Bighorn Basin Greater Sage-Grouse Project
2011 Summary Report

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Introduction
The decline of greater sage-grouse (*Centrocercus urophasianus*) distribution and population densities across western North America have lead conservation, research, and management objectives to focus efforts on understanding sage-grouse population dynamics across their range. Decreases in lek attendance since 2006 (Easterly 2009) in the Bighorn Basin Conservation Area of Wyoming sparked concern to investigate the demographic factors of this previously unstudied population.

Gregg et al. (1994, 2009) attributed declining abundance of sage-grouse to impaired productivity from excessive nest predation as well as reduced recruitment due to poor quality habitat. Previous studies have examined the relationship vegetation structure and habitat have on nest predation, chick survival, and nest placement (Gregg et al. 1994, 2009, Conover et al. 2010, Coates et al. 2008). Other studies have documented several species as predators of sage-grouse and their nests including the American badger (*Taxidea taxus*), golden eagle(*Aquila chrysaetos*), common raven (*Corvus corax*), black-billed magpie(*Pica pica*), coyote (*Canis latrans*), and other raptor species (Coates et al. 2008, Boyko et al. 2004). However, little research has been conducted on the direct effects of predation on adult sage-grouse survival and nest success.

Understanding direct and indirect predation effects on sage-grouse will provide managers and conservationists with additional information beyond habitat improvements that could enhance sage-grouse management. We are using the existing framework from predator removal efforts in accordance with wildlife damage management in Hot Springs and Park County to identify and measure predation effects on sage-grouse survival, nest success, and movement patterns. Here, we report on the first field season in which we collected baseline data to guide experimental design efforts that will be implemented in the second field season. In the first field season, we targeted two complexes within the Bighorn Basin to study sage-grouse predation effects: Oregon Basin (reference site in which no predator removal will happen) and Polecat Bench (treatment site in which WS predator removal program will occur in the second season).

Methods
Capture and Hen Monitoring:
Hens were captured via rocket nets from four leks (Fork in Road and Gravel Pit from Oregon Basin; Burn and Silver Tip from Polecat Bench) and fitted with VHF necklace style radio collars between 13 – 23 April2011. Hens were monitored for survival every 48-72 hours from the time of capture through the end of the brood rearing season (August). Exact locations were collected twice per week per bird from April – August to confirm nesting, monitor brood movements post-fledge, and track the onset of long distance migratory movements. Aerial searches were conducted if a collar was not located after seven days. Mortality signals were located and investigated by research personnel on the day of discovery to identify cause of death. Predators were identified by tracks, sign, carcass condition, trail camera photos, and necropsy analysis.

Hens were also captured via hoop net and spotlight techniques (Giesen et al. 1982) from areas of known use (VHF collared hen migration movements) and fitted with Argos satellite backpacks in late September. Argos packs were programmed to record up to seven locations per day, varying by season, which is then transmitted to researchers via email every three days.

Nest & Brood Monitoring:
Nests were visually confirmed after three consecutive locations of a hen in one area at which time infrared trail cameras were set 3-5m from an entrance to the nest. Scent minimizing precautions were taken when research personnel set cameras or changed memory cards. We continued to monitor hens through telemetry to confirm their location on nests and obtained visual confirmation when trail camera memory cards were changed every seven days. Cameras were left up until nests fledged, were predated, or abandoned. Cameras were left up an additional two weeks on three hens predated during the nesting season to monitor for post-mortem nest predation events. Clutch size was determined opportunistically if a hen was away from her nest, inadvertently flushed while maintaining cameras, or after hatching. All nests were categorized as successful (≥ 1 egg hatched) or unsuccessful. Nest predators were determined by tracks, scat, trail camera photos, and lab DNA analysis when necessary. Apparent nest success (Rebholz et al. 2009) was calculated for the entire population and each of the experimental areas independently including both first and second nesting attempts by hens.

We continued to monitor hens and collect two locations/bird/week during the brood season (July – August). Fledge dates were determined by telemetry, trail camera evidence, or calculated based on average incubation time of 27 days (Schroeder et al. 1999) from nest initiation dates. Counts of chicks were made opportunistically throughout the brood season culminating in a 35-day post fledge spotlight count. Chick survival was calculated as a percentage of chicks that survived to 35 days from initial brood fledge counts (determined from trail camera photos and hatched egg shells).

Terrestrial Predator Surveys:
Based on the average nesting distances from leks for collared hens scent station surveys were set up, centered at each lek in a 3x3 km grid-interval plot. Scent stations were set along roads, two-tracks, and game trails spaced 3 km from any other scent station. Each station consisted of a 1-meter circle of finely sifted dirt cleared of any vegetation. Stations were prepared and left pre-set for a minimum of four days prior to adding scent. Fatty-acid scent (FAS) was placed in a 6-inch hole placed at the center of the station and covered with a plug of dry grass on or after the fourth preset day. Scent stations were checked daily for 10 nights and visits were recorded to the species when possible. Scent stations were run from 15 June – 4 August at each of the three leks (Fork in Road, Gravel Pit, Burn (Polecat)) hens were captured. There were 19 scent stations at Fork in Road, 14 at Gravel Pit, and 18 at Burn (Polecat).

Camera trap surveys were established using the same grid-interval system as scent stations but set at different locations, at least 200 m from the nearest scent station, and run non-concurrently. Camera trap stations were set similarly to scent stations using roads, trails, and intersections throughout the survey area. Cameras were mounted between 2 - 5 m on custom rebar mounts and placed as discretely as possible in sagebrush and other vegetation to reduce visual obtrusiveness to animal movements. Camera surveys were conducted from 18 July – 19 August at each of the three leks (Fork in Road, Gravel Pit, Burn) hens were captured. There were 19 cameras placed at Fork in Road, 14 at Gravel Pit, and 15 at Burn. In addition, due to three hens nesting far outside the average nesting distance on Polecat a separate 4-camera station survey of the area those hens nested in was also conducted (Polecat-South).

Raptor Surveys:
Road transects were established within the study site grids used for scent and camera trap surveys. Two transects were established in both the Fork in Road and Burn sites, three transects in Gravel Pit, and one transect for the Polecat-South area. Road distance surveyed was 56 km for Fork in Road, 38 km for Gravel Pit, 55 km for Burn, and 11k m for Polecat-South. We ran transects twice between 13 July – 10 August at two

time intervals. Counts were generally made by one observer from a vehicle starting approximately one hour after sunrise (first time interval) or after 1100 (second, mid-day time interval). At each sighting, we stopped the vehicle and recorded the raptor species, activity (perched or flying), direction (compass bearing), distance (using rangefinders), and the major land use the raptor was occupying (Williams et al. 2000, Anderson et al. 1985, Andersen et al. 1979, Fuller et al. 1987).

Summary of Results

Twenty-five hens were captured in spring 2011; 10 birds were marked from the Polecat (treatment) complex and 15 birds were marked from the Oregon Basin (reference) complex (Table 1). A disproportionate number of juvenile (hens at first breeding season) were captured due to lateness of trapping initiation (7 adults, 18 juveniles). As of 1 October, nine hens were fitted with Argos satellite backpacks; three from Polecat Bench and six from Oregon Basin.

Table 1. Number and sex of captured sage-grouse by complex/lek caught during 2011 lekking season for VHF necklace collar deployments. Female grouse were aged into adult and juvenile (1st breeding season) age classes.

	Polecat		Oregon Basin	
	Burn	Silver Tip	Fork in Road	Gravel Pit
Males	14	8	8	5
Females				
Adult	4	0	0	3
Juvenile	5	1	9	3

We collected 649 locations on radio collared hens from April – August 2011. Average nest distances for lek complexes were 3.7 km on Oregon Basin and 9.6 km on Polecat Bench, with 4.3 km, 2.9 km, and 9.6 km average nest distances per lek for Fork in Road, Gravel Pit, and Burn, respectively. A summary of each bird captured including nesting history and fate as of 1 October 2011 can be found in Appendix A. Maps for individual grouse movement during the nest/brood season (April – August) for Oregon Basin and Polecat Bench can be found in Appendixes B, C, and D.

Nesting and Brood Fate:

We documented 22 hens as initiating nests between 28 April – 16 June for a total of 24 nests (Table 2), including two second nest attempts. Two hens were documented as re-nesting after predation of first nest attempts in Oregon Basin. We did not document any third nest attempts during 2011. Two hens died prior to nesting and we were unable to locate and track one hen (PCST 1) after capture to determine any nesting information. Apparent nest success was 33% for the population, 40% in Oregon Basin and 22% in Polecat Bench (Table 4). Fifty-four percent of nests documented in the population were predated, including second nest attempts. Individual area nest predation was 46% in Oregon Basin and 66% in Polecat Bench. Nest losses due to abandonment or hen mortalities during the nesting season accounted for 22% and 20% of nest failures in Oregon Basin and Polecat Bench, respectively.

Table 2. Summary of 2011 sage-grouse nest fate.

	Fledged	Predated	Partial Predated	Abandoned/Losses	Total
# Nests	8	9	2	5	24

We set trail cameras on 21 nests and documented 11 complete nest predations and two partial nest predations. Trail cameras captured one partial predation in Oregon Basin in which ravens visited a nest twice during the nesting season but the hen did not abandon the nest and successfully fledged five chicks from a clutch of six. The second partial predation occurred on Polecat Bench in which trail cameras captured a coyote visiting a nest after which the hen did not return (abandoned). We did not have a clutch size prior to the initial coyote visit, but the visit did instigate abandonment. None of the nests which were lost due to hen mortality during the nesting season were predated within three weeks post-mortem. However, by August all had been scavenged but no responsible species could be identified. The most common nest predators identified were coyotes. However, 5 nest predation events were categorized as unknown (Table 3) due to insufficient evidence (trail camera photos, eggs for lab analysis, or sign at the nest site) to indicate a predator. One nest loss occurred prior to trail camera placement at the nest site and no discernible sign could be identified. In two cases there were trail cameras at the nest but there were no photos of the predation event. We believe thick sage cover and camera placement at only entrance or exit are the reasons for the failure to document a predator and will modify this technique next year. One camera failed to take pictures after camouflaging material blocked the sensor, and one nest was not investigated after the hen moved off-nest within 1-2 days of visual confirmation of the nest.

Table 3. Sage-grouse nest predators for 2011 nest season.

	Coyote	Raven	Magpie	Bobcat	Unknown
# Nests	5*	2*	1	1	5

*includes partial predations
Note: magpie and bobcat predations contributed to same nest loss

Eight hens successfully fledged nests with mean clutch sizes of six and seven eggs for Oregon Basin and Polecat Bench, respectively. Hatch dates were from 31 May – 8 July. Chick survival to 35-days was 44% for Oregon Basin and 40% for Polecat Bench.

Hen Mortalities:
Eleven hen mortalities have occurred as of 1 October 2011. Sixty percent of collared hens on Oregon Basin suffered mortalities and 30% of hens on Polecat Bench (Table 4). Coyote (n = 4), golden eagle (n = 2), badger (n = 2), bodily trauma of undetermined origin (n = 1), and unknown predator (n = 2) were responsible for sage-grouse mortalities in Bighorn Basin. One hen also slipped her collar and is classified as ‘fate unknown.’ Of the mortalities documented, two hens died prior to nesting, four during the nesting period, and four after hens and broods had migrated out of brood and nesting areas.

Table 4. Summary of capture, nesting, and survival data for sage-grouse in two study sites in Bighorn Basin.

	Polecat	Oregon Basin
# radio-collared	10	15
# nests	9	15
nest successes	2	6**
nest predations	6	7**∫
nest loss/abandon	2*	3
bird mortalities	2	9
fate unknown	1	0
% nest success	22	40
% nest predations	66	46
% mortality	20	60

*one nest abandoned may also have been partially predated
**includes two second nest attempts
∫ includes a partial predation

Surveys:
We documented 172 visits to scent stations over 189 trap nights at Fork in Road (Table 5) with 31 predator visits and 25 lagomorph visits. Gravel Pit scent stations received 67 visits over 138 trap nights with 10 predator and nine lagomorph visits. Burn (Polecat) scent stations received 68 visits over 176 trap nights with 11 predator and nine lagomorph visits.

Table 5. Summary of scent station survey results from three sites in Bighorn Basin.

	# stations	# trap nights	predator visits	lagomorph visits	total visits
Oregon Basin					
Fork in Road	19	189	31	25	172
Gravel Pit	14	138	10	9	67
Polecat Bench					
Burn	18	176	11	9	68

We documented 391 visits to camera trap stations over 260 trap nights on Fork in Road with 17 predator visits and nine lagomorph visits (Table 6). Gravel Pit camera trap stations received 267 visits with 14 predator and 27 lagomorph visits. Polecat-South camera stations received 32 visits with two predator visits and five lagomorph visits, including a pygmy rabbit (*Brachylagus idahoensis*) far north of Fish & Wildlife historic and current distributions (FWS pygmy rabbit distribution map). We are still working through the photos from the Burn (Polecat) survey; tables will be updated with those data for the final 2011 analysis report but are currently listed as unknown.

Table 6. Summary of camera survey results from four sites in Bighorn Basin.

	# stations	# trap nights	#photos	predator visits	lagomorph visits	total visits
Oregon Basin						
Fork in Road	19	260	9348	17	9	391
Gravel Pit	14	182	5942	14	27	267
Polecat Bench						
Burn	15	Unknown	Unknown	Unknown	Unknown	Unknown
Polecat-South	4	46	1539	2	5	32

The most common predators detected at both scent and camera surveys were coyotes (Table 7), followed by red fox (*Vulpes vulpes*), and raccoon (*Procyon lotor*). Other terrestrial predators detected from surveys include bobcat (*Lynx rufus*), badger, striped skunk (*Mephitis mephitis*), and weasel (Mustelidae).

Table 7. Predator detections from scent station and camera surveys conducted on four sites in Bighorn Basin.

	Oregon Basin				Polecat Bench			
	Fork in Road		Gravel Pit		Burn		Polecat-South	
	Scent	Camera	Scent	Camera	Scent	Camera	Scent	Camera
Coyote	15	13	5	12	4	Unknown	-	0
Fox	8	4	0	2	1	Unknown	-	1
Bobcat	0	0	2	0	0	Unknown	-	0
Badger	0	0	0	0	3	Unknown	-	0
Raccoon	4	0	0	0	0	Unknown	-	0
Skunk	1	0	2	0	1	Unknown	-	1
Weasel	1	0	1	0	1	Unknown	-	0

We documented six raptor species in the two lek complexes surveyed (Table 8). Transects were pooled for tabulation, so detections do not reflect actual abundance of raptors in the study sites. Thirty-one raptors were detected in Fork in Road, 28 in Gravel Pit, 16 in Burn (Polecat), and 14 in Polecat-South. The most commonly detected raptor, American kestrel (*Falco sparverius*), is also the least likely to have any predation effects on sage-grouse, as their main prey base is composed of invertebrates, small mammals, and reptiles (Smallwood, 2002). More common predators of sage-grouse, red-tailed hawk (*Buteo jamaicensis*) and golden eagles, were detected at all but the Polecat-South site.

Table 8. Avian predator detections from road transect surveys conducted on four sites in Bighorn Basin.

		Oregon Basin		Polecat	
COMMON NAME	SCIENTIFIC NAME	Fork in Road	Gravel Pit	Burn	Polecat-South
Red-tailed Hawk	*Buteo jamaicensis*	1	5	2	0
Swainson's Hawk	*Buteo swainsoni*	1	0	0	0
Golden Eagle	*Aquila chrysaetos*	7	1	4	0
Northern Harrier	*Circus cyaneus*	0	6	3	0
American Kestrel	*Falco sparverius*	21	14	6	14
Prairie Falcon	*Falco sparverius*	1	2	0	0
# detections		31	28	16	14
# Surveys		4	6	4	4
Km Road		56	38	55	11

Future Plans

This report represents data collected during the first field season. Data analysis and additional work is needed over winter and throughout next season. The following outlines the direction of the study. In the second field season, we will expand our study to include two other sites for a total of four study sites. WS Operations will conduct predator removal of ravens and two of these study sites (treatment sites) with two others acting as control sites.

2011	
September - October	Argos backpack collar deployments on hens in 4 complexes
September – January	Weekly hen survival and location monitoring
2012	
December – February	Data analysis 2011 season
March 1, 2012	2011 Analysis report to stakeholders
January – March	Weekly hen survival monitoring (weather permitting), WS Operations predator removal for ravens begins (March)
mid March – April	Hen capture on leks to deploy remaining VHF & Argos collars to 4 complexes
April – July	Hen monitoring (survival, nest and brood fate)
May – August	Predator Surveys (scent station, camera trap, raptor road transects), WS Operations predator removal for ravens ends (August)
October	Preliminary Summary 2012 season
December	Data analysis (pre/post treatment)
2013	
March 1	Final Report and submission of at least 2 manuscripts to peer-reviewed journals

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Appendix A. VHF collared hen 2011 summary.

Bird ID	Complex	Lek	Capture Date	Age	Nested	Nest Fate	Predated	Predator	Renested	Nest Fate	Clutch Size	Brood Size Fledge	Brood Size 35-day	Post 35-day Counts	Bird Fate (10/1)	Mortality Cause
OBFR 1	OB	FR	4/15/2011	SY	no	-	-	-	-	-	-	-	-	-	Mort	Unknown[1]
OBFR 2	OB	FR	4/15/2011	SY	yes	Fledge	no	-	no	-	6	6	4	3[2]	Live	-
OBFR 3	OB	FR	4/15/2011	SY	yes	Fail	yes	coyote	no	-	5	-	-	-	Live	-
OBFR 4	OB	FR	4/15/2011	SY	yes	Fail	yes	Unk	no	-	Unk	-	-	-	Live	-
OBFR 5	OB	FR	4/15/2011	SY	yes	Fail	yes	coyote	no	-	4	-	-	-	Mort	Badger
OBFR 6	OB	FR	4/15/2011	SY	no	-	-	-	-	-	-	-	-	-	Mort	Unknown[1]
OBFR 7	OB	FR	4/16/2011	SY	yes	Fail	yes	Unk	yes	Fledge	4	4	0	1[3]	Live	-
OBFR 8	OB	FR	4/16/2011	SY	yes	Fledge	No	-	no	-	6	6	3	-	Live	-
OBFR 9	OB	FR	4/16/2011	SY	yes	Fail	No	-	no	-	7	-	-	-	Mort	Coyote
OBGP 1	OB	GP	4/15/2011	ASY	yes	Fail	yes	Raven	yes	Fail	6*	-	-	-	Mort[4]	Coyote
OBGP 2	OB	GP	4/15/2011	SY	yes	Fledge	partial	Raven	no	-	6	5	2	-	Mort	Coyote
OBGP 3	OB	GP	4/15/2011	SY	yes	Fledge	No	-	no	-	8	8	3	-	Live	-
OBGP 4	OB	GP	4/15/2011	SY	yes	Fail	yes	bobcat/magpie	no	-	7	-	-	-	Mort	Golden Eagle
OBGP 5	OB	GP	4/15/2011	SY	yes	Fail	No	-	no	-	8	-	-	-	Mort[5]	Coyote
OBGP 6	OB	GP	4/15/2011	ASY	yes	Fledge	No	-	no	-	7	7	0[6]	-	Mort	Badger
PCB 1	PC	PCB	4/13/2011	ASY	yes	Fail	yes	Unk[7]	no	-	Unk	-	-	-	Live	-
PCB 2	PC	PCB	4/13/2011	ASY	yes	Fail	no	-	no	-	1	-	-	-	Mort	Unknown[8]
PCB 3	PC	PCB	4/13/2011	SY	yes	Fail	yes	coyote	no	-	6	-	-	-	Mort	Golden Eagle
PCB 4	PC	PCB	4/13/2011	SY	yes	Fail	NC	Unk	no	-	Unk	-	-	-	Live	-
PCB 5	PC	PCB	4/13/2011	SY	yes	Fledge	no	-	no	-	6	5	3	-	Live	-
PCB 6	PC	PCB	4/13/2011	SY	yes	Fail	yes	Unk	no	-	Unk	-	-	-	Unk[9]	-
PCB 7	PC	PCB	4/23/2011	SY	yes	Fail	partial	coyote	no	-	6**	-	-	-	Live	-
PCB 8	PC	PCB	4/23/2011	ASY	yes	Fledge	no	-	no	-	8	5	NC	1[10]	Live	-
PCB 9	PC	PCB	4/23/2011	ASY	yes	Fail	yes	coyote	no	-	Unk	-	-	-	Live	-
PCST 1	PC	PCST	4/22/2011	SY	Unk	Unk	Unk	-	no	-	Unk	-	-	-	Live	-

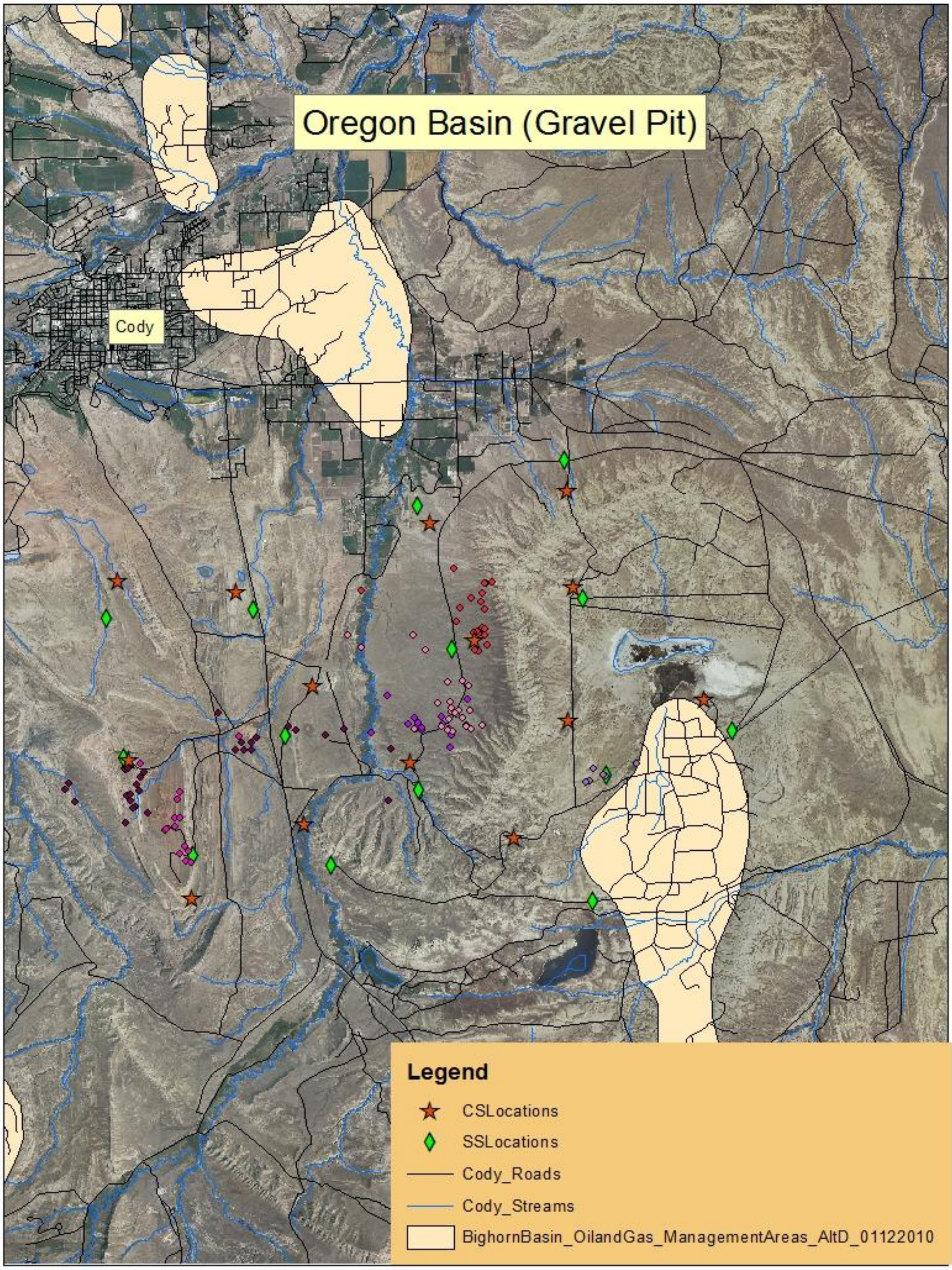
*lost six eggs each nesting attempt   Unk - unknown   NC - not completed

**number of eggs at nest post coyote visit and hen abandon

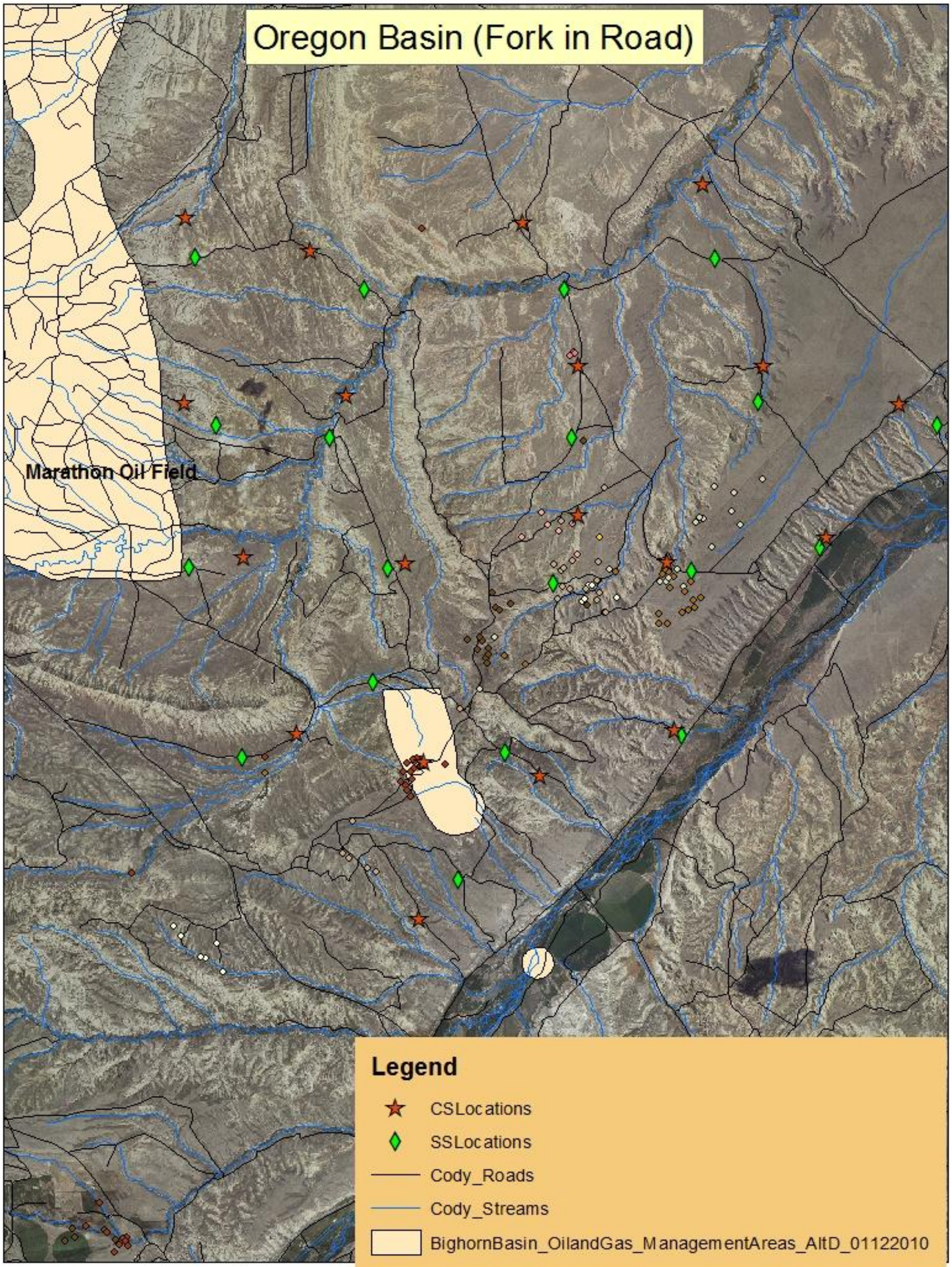
ASY - Adult, SY - yearling, HY - juvenile young of year

[1] likely golden eagle, died prior to nesting
[2] 3 chicks last seen with hen at 60 days
[3] 1 chick seen with hen at 53 days
[4] predated during second nesting attempt
[5] predated during nesting
[6] died prior to 35-day brood count
[7] likely raven nest predation
[8] died blunt head/chest trauma
[9] slipped collar
[10] 1 chick seen with hen at 54 days

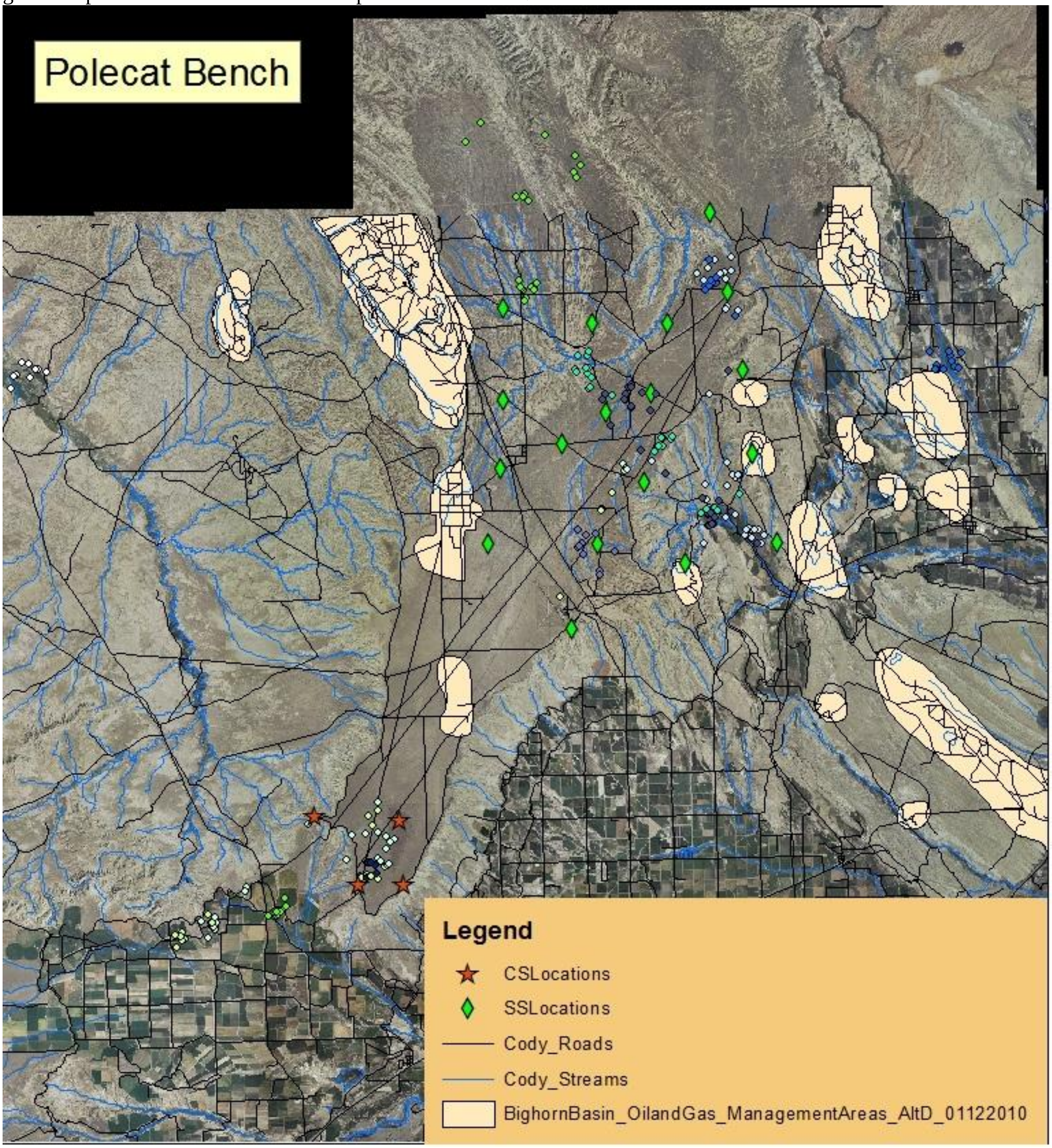
Appendix B. Locations of radio-collared hens (colored circles), scent stations (SS), and camera stations (CS) for sage-grouse captured from Gravel Pit in Oregon Basin.



Appendix C. Locations of radio-collared hens (colored circles), scent stations (SS), and camera stations (CS) for sage-grouse captured from Fork in Road in Oregon Basin.



Appendix D. Locations of radio-collared hens (colored circles), scent stations (SS), and camera stations (CS) for sage-grouse captured from Burn and Silver Tip on Polecat Bench.



Project Title: Cedar Mountain Targeted Predator Control to Benefit Mule Deer
Brief Description of Project: Radio Collar study to develop a program of targeted predator control for the Uinta County Predator board on key fawning rages for mule deer in the Uinta mule deer herd unit.
Submitted By / Affiliation: Jeff Short / Wyoming Game and Fish Department

The project area is located within Uinta and Sweetwater Counties in deer hunt area 132. This is within the Uinta mule deer herd unit and is commonly referred to as Cedar Mountain.

The Uinta/Cedar Mountain deer herd has not been able to recover from a severe population crash that occurred in the early 1990's. Manipulations of hunting season strategies alone have not improved overall herd numbers to our goals. Fawn recruitment continues to suffer and post season fawn ratios are not adequate to grow this herd to our objectives.

The project commenced with capture operations in December of 2010 and January of 2011. A total of 15 GPS collars and 10 VHF collars were affixed to adult mule deer does using helicopter drive netting and helicopter net gunning. Collars have been tracked since that time and will continue to be tracked until June of 2012.

This study will ultimately assist managers by locating the areas where targeted predator control efforts and habitat treatments can be implemented. It has been found that the most beneficial coyote control for mule deer is to target coyotes on fawning ranges. The majority of coyote predation on mule deer occurs in the first two months after parturition. This predation is usually by a select number of coyotes occupying specific fawning ranges. It is often intensified during times of low availability of alternate prey. This may be the case at the present time since rabbit populations are at a low point and deer in the area are experiencing low fawn recruitment. Coyote control done to benefit mule deer is far more effective if done in high intensity on specific fawning ranges right before, during and right after the fawning and done to specifically target coyotes active in those specific areas. To do this we need detailed information about what key areas mule deer does are utilizing for fawning ranges.

As we gather more data from these collars we will document critical habitat areas, especially fawning sites, used by mule deer in the Cedar Mountain area. Identification of critical habitats will allow the Department to recommend predator control efforts (conducted by Wildlife Services personnel) and habitat enhancement projects to the areas where it will have the most potential to improve mule deer numbers. The primary end goal of the project is to increase fawn:doe ratios and can be measured with trends in post season ratios.

ADMB budget expenditures

drive net stakes	$ 229.50
capture vests	$ 95.91
helicopter drive net capture	$ 3,816.25
helicopter net gunning capture	$ 7,600.00
preg test	$ 500.00
Radio Receivers	$ 1,760.00
June 2011 radio flights	$ 1,000.00
total	$ 15,001.66

Chemical Gonadectomy of the Coyote
WY Animal Damage Management Board
Fiscal Year Report August 2010 – July 2011

Dr. Donal Skinner, PI
Marjorie MacGregor, Graduate Research Assistant
University of Wyoming; Department of Zoology and Physiology

Background

Coyotes (*Canis latrans*) are predators of livestock, mainly domestic sheep (*Ovis aries*). Although sheep population in the United States has declined by 85% from 56.2 million in 1942, cattle production is increasing [1]. With this comes increased conflict between cattle producers and predating coyotes [2]. Research suggests that depredations are highest when coyotes have pups to provision. Till and Knowlton (1983) found that predation incidents decreased by 87.7% when pup litters were removed.

Bromley and Gese (2001) proposed surgical sterilization as a means of reducing sheep predation, as well as maintaining territory fidelity of breeding pairs, thus laying the groundwork for reproductive control of coyotes. During 1998, only 1 of 5 sterile coyote packs killed a single lamb whereas 3 of 6 intact (reproductive) packs killed a total of 11 lambs. Similarly, in 1999 sterile packs killed on average 0.38 lambs/week whereas intact packs killed an average of 2.95 lambs per week [3, 4]. There was no difference in territory fidelity between sterile and intact packs [4].

Additionally, controlling coyote reproduction may be beneficial for wildlife populations. It has been suggested that coyotes negatively impact bighorn sheep (*Ovis canadensis*) populations, especially lambs [5]. Coyote predation also impacts pronghorn antelope (*Antilocapra americana*) which has been suggested as contributing to current pronghorn population declines [6, 7]. In Colorado, pronghorn fawn survival rates were higher in areas with sterilized coyote home ranges versus non-sterilized coyote home ranges [7].

On the other hand, it has been suggested that elimination of coyotes in sage grouse areas is detrimental to this species, as it may allow predators of sage grouse to flourish [8]. Recent simulation models of coyote predation management have shown that reproductive control may have the greatest lasting impact on coyote management, assuming only impacts to reproduction [9]. We propose to investigate the effect of chronic exposure to a high dose, slow-release deslorelin implant on the reproductive axis of the male coyote as a means of chemical castration.

Specific Research Objectives

1. Determination of the relationship between GnRH agonist dose and duration of suppression of coyote reproduction.
2. Establishing specific pituitary changes induces by GnRH agonist.

Research Methodology

Three male coyotes were trapped by USDA/APHIS/WS Government Trappers (2 juveniles and 1 adult) and brought to the UW Coyote Facility in November. One additional adult male coyote was obtained from USDA/APHIS/WS Predator Research Facility in December. Coyotes were vaccinated, de-wormed and one coyote was treated for a moderate case of sarcoptic mange. All coyotes were allowed to acclimate until January. During the time, there was minimal contact with coyotes (cleaning, feeding and watering) and always by the same individual. Following the acclimation period, the following procedures and project actions were performed through July 2011 (Table 1):

Table 1*: Procedures and project actions performed through fiscal year 2010-2011*

Date	**Procedures and Project Actions**
1/21/11	Physical examination, blood draw from cephalic vein, electroejaculation and testicular measurements
2/2/11	Invited presentation – The Wildlife Society Student Chapter (*Chemical Gonadectomy of the Coyote*): University of Wyoming*
2/7/11	Invited graduate classroom workshop (*Coyote Reproduction and Management – Collaborative Approaches to Problem Solving*); University of Wyoming*
3/5/11	Research presentation at the AZA Contraceptive Advisory Group Board Meeting (*Chemical Gonadectomy of the Coyote*); St Louis Zoo, MO*
3/29/11	Invited 7th grade classroom program (*Coyote Reproduction, Management and Scientific Modeling*); Laramie, WY*
4/4/11	Physical examination, blood draw from cephalic vein, electroejaculation and testicular measurements
4/4/11	Test coyotes implanted with 47.0 mg Deslorelin (subQ)
5/11/11	Women in Science Workshops (*Coyote Reproduction and Management*): University of Wyoming*
5/13/11	Physical examination and cephalic vein blood draw
6/6/11	Physical examination, blood draw from cephalic vein, electroejaculation and testicular measurements
6/7/11	Total Testosterone Assay (plasma)
6/9/11	WY ADMB Board Meeting and Research Presentation
6/20/11	Submitted Field Day Bulletin (*Chemical Gonadectomy of the Coyote*) Agriculture Experimental Station; University of Wyoming*
7/13/11	Physical examination and cephalic vein blood draw (scheduled)

*WY Animal Damage Management Board cited as financial supporter

Budget

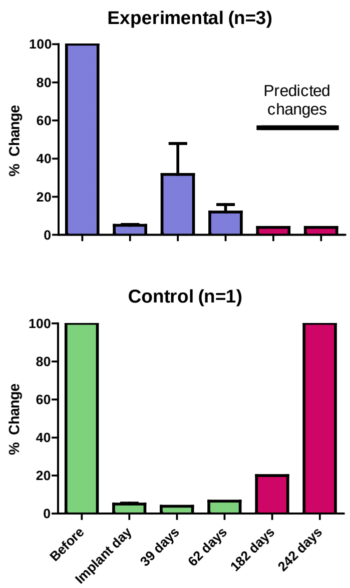
A detailed expense report for the WY Animal Damage Management Board grant for the *Chemical Gonadectomy of the Coyote* is detailed below (Table 2):

Table 2*: Itemized expenses accrued through fiscal year 2010-2011*

Item	Description	Amount ($)
PhD Student	Tuition, Fees, Salary, and Benefits	21562
Coyotes	USDA/APHIS/WS Trapping (November)	1000
Coyotes	USDA/APHIS/WS Coyote Care (10 pups)	750
Coyotes	Traveling health certificate	48
Drugs	Advantix flea and tick 20-55#, 6/pack	148.68
Drugs	Vaccines, distemper/parvo	122.5
Drugs	Fatal plus soln, 250ml	110
Drugs	Telazol, 5ml	200.25
Drugs	Rimadyl, 25mg, chewable	49.8
Drugs	Revolution, for mange trmt	93.18
Drugs	Revolution	93.18
Drugs	Amoxicillin 250mg, 100capsules	6.57
Drugs	Atipamazole (Anticedin) 10ml	128.4
Drugs	Yobine Injection	56.25
Drugs	Ketamine	37.66
Drugs	Xylazine (Rompin)	43.64
Drugs	Revolution Brown 20#	37.28
Food	Mazuri Exotic canine food	655.3
Supplies	Puralube, 1/8 oz.	10.8
Supplies	Sterile water, 10ml	6.8
Supplies	Needles, 20g, 1"	8.4
Supplies	Needles, 22g, 1"	12
Supplies	Catheters, asst, 12/pk	11.79
Supplies	Scale, digital	19.88
Supplies	Calculator	2.99
Supplies	Battery, for digital calipers	4.19
Supplies	Batteries, AAA	6.99
Supplies	Clock	3.97
Supplies	Catheters, assorted x 22", 12	23.58
Supplies	Catheters, 5 French x 22", 12	25.06
Supplies	Surgilube surgical lubricant	5.06
Supplies	Aquasonic 100, 1 liter	8.25
Supplies	Rectal probe and adaptor cord	205.7
Supplies	Live-Dead stain	16.99
Supplies	Caliper, carbon fiber, digital	22.22
Supplies	SentrySafe	44.88
UW	Overhead	303
Total		**25885.24**

Results

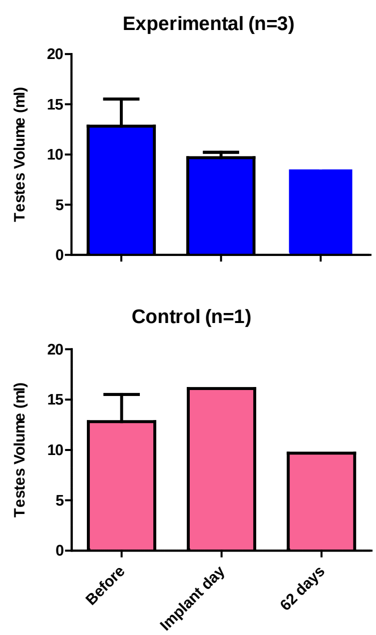
Total testosterone concentrations (relative to 100%) spiked 39 days after deslorelin implants in experimental coyotes (n=3) followed by a decrease at 62 days (see figure at left).



This anticipated testosterone spike occurs as an acute response to GnRH agonists. During this time, large surges of reproductive hormones (FSH and LH) present followed by the chronic stage in which production of hormones declines (10).

Continued suppression of testosterone is predicted for the upcoming breeding season. Coyotes are seasonal breeders with testosterone levels remaining low May – November then rising December – April. (11). A trend is apparent in the control coyote (n=1) with predicted testosterone levels returning to 100% the coming breeding season.

Testes volume (ml) in experimental coyotes is decreasing over time (see figure at right). Control group shows an increase followed by a decrease in testes volume. This data, however, represents one coyote. Whether this is indicative of individual level variation or a pattern remains to be determined.



Long-term predictions should show a relationship between testosterone concentrations and testes volume. In the near future, data analyzed from additional parameters (LH and FSH assays, sperm concentrations and GnRH challenges) will be used to support the specific research objectives. We anticipate richer data after completing one full breeding cycle with the coyotes.

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GREATER SAGE-GROUSE (*CENTROCERCUS UROPHASIANUS*) SELECT NEST-SITES AND BROOD-SITES AWAY FROM AVIAN PREDATORS

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ABSTRACT.—Greater Sage-Grouse (*Centrocercus urophasianus*; hereafter "sage-grouse") distribution and abundance in western North America has declined over the last century. Depredation of nests and predation of chicks are the most influential factors limiting sage-grouse productivity. We compared avian predator densities at sage-grouse nests and sage-grouse brood locations to random locations within available sage-grouse habitat. This comparison allowed us to assess the ability of sage-grouse to avoid avian predators during nesting and early brood-rearing. During 2008–2010, we conducted 10-min point-count surveys at 222 sage-grouse nests, 245 sage-grouse brood locations from 83 sage-grouse broods, and 498 random locations. We found that random locations had higher densities of avian predators relative to sage-grouse nest and brood locations. Sage-grouse nested in areas where there were lower densities of Common Ravens (*Corvus corax*), Black-billed Magpies (*Pica hudsonia*), Golden Eagles (*Aquila chrysaetos*), and *Buteo* hawks during nesting. Sage-grouse selected brood-rearing locations that had lower densities of Common Ravens, Black-billed Magpies, Golden Eagles, *Buteo* hawks, Northern Harriers (*Circus cyaneus*), and American Kestrels (*Falco sparverius*) than random locations. By selecting nest and brood-rearing locations with lower avian predator densities, sage-grouse may reduce the risk of nest depredation and predation on chicks and hens.

Key Words: brood-site selection, Greater Sage-Grouse, nest-site selection, Golden Eagle, Raven.

Greater Sage-Grouse (*Centrocercus urophasianus*: hereafter; "sage-grouse") abundance in western North America has declined over the last century (Gregg et al. 1994, Johnsgard 2002, Slater 2003, Connelly et al. 2004). These declines recently led the U.S. Fish and Wildlife Service

(2010) to conclude that sage-grouse are warranted for protection under the Endangered Species Act of 1973, but because threats were moderate in magnitude and did not occur across their range at an equal intensity, the listing was precluded in favor of other species under severe threat of extinction. Many factors have been attributed to this decline including habitat loss, habitat fragmentation, habitat degradation, and predation (Braun 1998, Schroeder et al. 2004).

Even in high quality sage-grouse habitat, most sage-grouse nests are lost to predators including Red Fox (*Vulpes vulpes*), American Badger (*Taxidea taxus*), Coyote (*Canis latrans*), Striped Skunk (*Mephitis mephitis*), Black-billed Magpie (*Pica hudsonia*; hereafter “magpie”), and Common Raven (*Corvus corax*; hereafter “raven;” Willis et al. 1993, Gregg et al. 1994, Holloran 1999, Connelly et al. 2004, Coates et al. 2008). High mortality rates on chicks have also been attributed to predators, especially during early brood-rearing (Aldridge 2005, Gregg and Crawford 2009, Guttery 2011). Avian predators may have significant impacts on sage-grouse nest success and chick survival, including ravens, magpies, Golden Eagles (*Aquila chrysaetos*), hawks (*Buteo* spp.), Northern Harriers (*Circus cyaneus*; hereafter “harrier”), and American Kestrels (*Falco sparverius*; hereafter “kestrel”; Schroeder et al. 1999, Schroeder and Baydack 2001).

In response to the risk of nest depredation, sage-grouse hide their nests from predators by placing their nests primarily in areas with sagebrush cover and greater visual obstruction (Connelly et al. 1994, Braun 1998, Holloran 1999). At the microhabitat scale, sage-grouse predominately choose nest sites concealed by vegetation cover (Connelly et al. 2004). Several studies have reported that sage-grouse select nest-sites based on a preference for different microhabitat characteristics including sagebrush density (Wallestad and Pyrah 1974, Connelly 2003), shrub height (Gregg et al. 1994), grass height (Gregg et al. 1994, Holloran et al. 2005), and grass cover (Kaczor 2008). Variability in reported nest-site selection among studies may indicate local differences in available microhabitat. However, consistent placement of nests in greater visual cover regardless of differences in local available habitat suggests that vertical (e.g., grass and shrub height) and horizontal cover (e.g., grass and shrub canopy cover), are important regardless of the type of vegetation cover that is available.

Sage-grouse select nest locations that hide their nests from visual predators but not olfactory predators (Conover et al. 2010). Conover et al. (2010) found that sage-grouse place nests in areas that have few updrafts, low turbulence, and slow wind speeds. Updrafts, high turbulence, and high wind speeds are climatic conditions that make it difficult for mammalian predators to use olfaction to locate nests (Conover 2007). These results coincide with results from other sage-grouse nest research that show sage-grouse’s preference for greater visual cover. Selection of nest-sites that conceal sage-grouse from visual predators but not olfactory predators may indicate that visual predators are a greater threat than olfactory predators to sage-grouse nests.

Sage-grouse broods also hide from avian predators through habitat selection and cryptic behavior. Recent studies focused on survival of radio-marked sage-grouse chicks have indicated that brood-rearing hens have greater success in locations with short sagebrush (Guttery 2011) and short grass (Aldridge 2005, Gregg and Crawford 2009, Guttery 2011). In contrast, Aldridge and Brigham (2002) found that sage-grouse brood hens select areas with greater percentages of sagebrush cover and taller grass heights when compared to random locations. Gregg and Crawford (2009) and Guttery (2011) assert that higher percent cover of low sagebrush and/or short grass provide adequate visual cover for sage-grouse chicks, which are cryptically colored and avoid detection by remaining motionless. Further, these studies have hypothesized that brood hens in low sagebrush and/or short grass may more easily detect an approaching predator.

Raven depredation on sage-grouse nests is a common occurrence in northeastern Nevada based on infrared video cameras set up at nest sites (Coates et al. 2008). Raven depredation of sage-grouse nests has been implicated as a potential factor limiting sage-grouse productivity in fragmented habitats (Batterson and Morse 1948, Willis et al. 1993, Gregg et al. 1994, Schroeder and Baydack 2001, Bui et al. 2010, Coates and Delehanty 2010). During the last century, densities of ravens have increased throughout the historic range of sage-grouse (Larsen and Dietrich 1970, Andrén 1992, Engel and Young 1992, Boarman et al. 1995, Boarman and Coe 2002). Ravens utilize human-provided resources, such as water, anthropogenic structures, road-kill, dead livestock, and garbage (Boarman 1993, Boarman et al. 1995).

Sage-grouse select nest sites at local (habitat directly around a nest) and landscape scales (Doherty et al. 2010). We hypothesized that at the landscape-scale, sage-grouse avoid nesting or raising their broods in areas where there are high densities of avian predators, specifically, ravens, magpies, Golden Eagles, hawks, and other raptors. The objective of our study was to test this hypothesis by comparing avian predator densities at sage-grouse nests and sage-grouse brood locations to random locations in available sage-grouse nesting and brood-rearing habitat.

METHODS

Study areas.—Our study was conducted in southwest and south-central Wyoming. We had 12 study sites, each 16 or 24 km in diameter (eight sites of 16-km diameter and four sites of 24-km diameter; Fig. 1). Most sage-grouse hens nest within 8-km of leks where they breed (Connelly et al. 2004). Thus, the study sites in southwest Wyoming were 16-km diameter and approximately centered around leks where hens were captured. Study sites in south-central

Wyoming were 24-km, because sage-grouse were captured at several nearby leks over a larger area. Five study sites were located in Lincoln County (16-km diameter each), two in Sweetwater County (one 16-km diameter and one 24-km diameter), two in Uinta County (both 16-km diameter), and three in Carbon County (24-km diameter each). Study sites were chosen to provide a representation of overall sage-grouse nesting habitat in southern Wyoming with a variety of land uses and topographic features. Elevation ranged from 1,950 m to 2,530 m among all study sites. Most of our study sites were federally owned and administered by the Bureau of Land Management (BLM) with a small percentage of private lands. Domestic sheep and cattle grazing were the dominant land uses in our study sites. All study sites had some energy development.

The landscape at all study sites was dominated by sagebrush (*Artemisia* spp.); Wyoming Big Sagebrush (*A. tridentata wyomingensis*) and Mountain Sagebrush (*A. t. vaseyana*) were the most common. Black Sagebrush (*A. nova*) and Dwarf Sagebrush (*A. arbuscula*) were found on exposed ridges. Other common shrub species in our study sites included: Antelope Bitterbrush (*Purshia tridentata*), Snowberry (*Symphoricarpos albus*), Chokecherry (*Prunus virginiana*), Alderleaf Mountain Mahogany (*Cercocarpus montanus*), Rabbit Brush (*Chrysothamnus* spp.), Greasewood (*Sarcobatus vermiculatus*), and Spiny Hopsage (*Grayia spinosa*). Isolated stands of juniper (*Juniperus* spp.) and Aspen (*Populus tremuloides*) were found at the higher elevations on north-facing hillsides.

Sage-grouse capture and monitoring.—We monitored sage-grouse hens during nesting and early brood-rearing in 2008-2010. Hens were captured, radio-collared, and released in April of each year. We captured hens at night using ATVs, spotlights, and hoop-nets **(**Giesen et al. 1982, Wakkinen 1992). Sage-grouse hens were fitted with 17.5-g or 22-g necklace radio collars

(Holohil Systems Ltd, RI-2D, Ontario, Canada or Advanced Telemetry Systems Inc, A4060, Isanti, Minnesota).

We located hens on a weekly basis with Communications Specialists (Communications Specialists, R-1000, Orange, California) receivers and 3-way Yagi antennas (Communications Specialists, Orange, California). Potential nests were identified with binoculars from >25 m away by circling a radio-marked hen until she was visually spotted under a shrub or determined to be under a few shrubs. Nests were verified by triangulating the hen under the same shrub from >50 m away or thoroughly searching the area of the potential nest when the hen was absent. We continued monitoring nests weekly until the nest hatched or failed. We assessed nest fate as successful or unsuccessful after a hen had left its nest. A successful nest was defined as having evidence that at least one egg hatched as determined by shell membrane condition (Wallestad and Pyrah 1974). We classified unsuccessful nests as abandoned (eggs not depredated or hatched) or depredated (at least one egg with evidence of depredation and no eggs hatched).

We located the broods of radio-marked hens with binoculars from >25 m away. Brood hens were identified by either visually detecting chicks or observing hen behavior that indicated the presence of a brood (e.g., hesitation to flush, feigning injury, or clucking).

Avian predator monitoring.**—**Between May and August of each year (sage-grouse nesting and brood-rearing season), we conducted point-count surveys at sage-grouse nests, sage-grouse brood locations, and random locations (hereafter; nest, brood, and random locations) within each study site to compare avian predator densities. We used standard distance sampling techniques, which entailed counting all corvids and raptors observed during point-counts and recording each avian predator's distance from the observer. We recorded distance as the distance from the observer to where an avian predator was first located; this minimized possible bias associated with avian predators being attracted to or flushed away from an observer. A 1500 m rangefinder (American Technologies Network Corp., RE-1500 m, San Francisco, California) was used to estimate distances directly when possible, or a 1500 m rangefinder and GPS were used by observers to validate visually estimated distances.

Random locations were selected in habitat considered to be available to sage-grouse for nesting within each study site. To restrict random locations to available nesting habitat, we used ArcMap version 9.2 (ESRI Inc., Redlands, California) to generate random locations only in sagebrush-dominated habitat, which was classified by the Northwest GAP landcover data from 2008. Random points were designated to be at least 1000 m apart; however, random selection of these points led to most random point-counts greater than 1750 m apart. We generated 12 random locations in each 16-km diameter study site and 18 random locations in each 24-km diameter study site per year (total n = 504). A new set of random locations was generated each year to avoid spatial autocorrelation; thus, random locations between years were independent.

Point-counts were 10 min in length, and we conducted point-count surveys during daylight hours on a weekly basis at each study site. Each point-count location was visited one to eight times with most locations visited greater than or equal to three occasions. We did not survey for avian predators in inclement weather (i.e., in precipitation or wind speeds greater than 32 km/h). We intermixed the sampling of nest, brood, and random point-counts within each study site, and each week we changed the time of day that we conducted individual point-counts within a study site (i.e., each individual point-count location regardless of type—nest, brood, or random—would be conducted at a different time of day each week). Nest and brood point-counts were performed after nests and broods were initially located; thus, nest point-counts were conducted in May and June and brood point-counts were conducted from mid-May to early-

August. We performed random point-counts throughout the nesting and early brood-rearing season (May to early-August).

To avoid disturbing an incubating hen, nest point-counts were conducted 100–200 m away from a sage-grouse nest but within a line-of-sight of that sage-grouse nest. We also performed brood point-counts 100–200 m away from a brood hen—estimated by triangulation—immediately before verifying that a radio-marked brood hen was still with chicks. This was intended to record avian predator densities before the observer disturbed any avian predators and to avoid flushing a brood hen when a predator was nearby. If the hen did not have chicks, the brood point-count was discarded.

Analyses.—We used DISTANCE 6.0 release 2 (Thomas et al. 2009) to estimate raven, magpie, Golden Eagle, Red-tailed Hawk (*Buteo jamaicensis*), Ferruginous Hawk (*Buteo regalis*), Swainson's Hawk (*Buteo swainsoni*), harrier, and kestrel densities for nest, brood, and random locations across all years and all study sites. Red-tailed Hawks, Ferruginous Hawks, and Swainson's Hawks were combined into a single group—*Buteo* hawks—for analyses. We fitted half-normal key detection functions with cosine, simple polynomial, and hermite polynomial adjustments. We did not consider point-count type (nest, brood, random) as a covariate for detection, because all point-counts were in sagebrush-dominated habitat (i.e., we did not expect any difference in detection at any point-count locations). We selected the appropriate key detection function and detection function adjustment for each avian predator species separately using Akaike's information criterion (AIC_c; Burnham and Anderson 2002; Table 1). We also used DISTANCE to estimate observer effective detection radius (EDR), which was described as the distance at which half the detections of a particular species were less than EDR; an EDR of

500 m for hawks indicates that 50% of the detected hawks were seen at less than or equal to 500 m by an observer.

In addition, we adjusted density estimates for survey effort (difference in visits per point-count location) and scaled our density estimates by the maximum number of visits per point-count location by dividing all estimates of density by eight within DISTANCE. Survey effort was accounted for in DISTANCE by dividing the total number of detected avian predators at each point-count location by that point-count's proportion of actual visits to maximum number of visits (e.g., the total number of Golden Eagles detected at point-count x = 3, visits to point-count x = 5, total visits possible = 8; thus, for DISTANCE analyses point-count x was given a golden eagle count of 3 / 0.625 = 4.8, which was then scaled appropriately in DISTANCE by dividing by 8; Thomas et al. 2009). Raven, magpie, Golden Eagle, and harrier detection distances were right truncated 5%; *Buteo* hawk detection distances for DISTANCE analyses were right truncated 7.5%; and kestrel detection distances were not right truncated.

We used 95% confidence intervals to compare raven, magpie, Golden Eagle, *Buteo* hawk, harrier, and kestrel densities separately at nest locations versus random locations and at brood locations versus random locations. Confidence intervals were generated empirically using density estimates and standard errors from DISTANCE. Furthermore, we estimated avian predator densities for random, nest, and brood locations at each of our study sites using DISTANCE. We used estimated avian predator densities at our study sites to compare avian predator densities at random versus nest locations and random versus brood locations with paired Student's *t*-tests (R 2.10.1; The R Foundation for Statistical Computing 2009).

RESULTS

We conducted 3,006 point-count surveys during 2008-2010 at 965 total point-count locations with 222 sage-grouse nest locations, 245 sage-grouse brood locations (with 83 separate broods), and 498 random locations. Ravens, magpies, Golden Eagles, Red-tailed Hawks, Ferruginous Hawks, Swainson's Hawks, harriers, and kestrels were the most commonly detected avian predators. We used point-count surveys to generate study-wide density estimates of multiple avian predators, including raven, magpie, Golden Eagle, *Buteo* hawk, harrier, and kestrel, in relation to sage-grouse nests, brood, and random locations. In addition, we used estimated densities at study sites to compare avian predator abundances between available habitat versus sage-grouse nests and available habitat versus sage-grouse brood locations. On the whole, sage-grouse selected nest and brood locations with lower densities of avian predators than random locations (Fig. 2, Tables 3 and 4).

EDR estimates ranged from 294 m for magpie to 1,006 m for Golden Eagles. EDR estimates showed that effective detection distances differed by avian predator species (Table 2). This verified the necessity of selecting detection functions for each avian predator species separately. All avian predator species had greater than 60–80 detections, that Buckland et al. (1993) suggested was necessary for reliable density estimates (Table 2).

Raven, magpie, Golden Eagle, and *Buteo* hawk densities were found to be significantly lower at sage-grouse nest locations than random locations (Fig. 2). These relationships were verified with paired Student's *t*-tests (Table 3). Harrier and kestrel densities were similar at sage-grouse nest locations and random locations (Fig. 2), which was also verified with paired Student's *t*-tests (Table 3).

Estimated densities of ravens, magpies, *Buteo* hawks, and kestrels were significantly lower at sage-grouse brood locations than random locations (Fig. 2). All estimated avian predator species had significantly lower densities at sage-grouse brood locations compared to random locations (Table 4).

Discussion

Although we estimated avian predator densities for nest, brood, and random locations across all years, we did not expect the pattern of sage-grouse avoidance of avian predators to differ among years. Our random locations were at different locations each year, which prevented autocorrelation of counts at random locations among years. By using point-counts instead of line-transects, we were able to estimate avian predator densities across available habitat while avoiding potential biases in estimating avian predator densities along roads, which are commonly used to conduct line-transects. Our method for generating random locations for point-counts was consistent with that of Bui et al. (2010) for raven point-counts in western Wyoming. However, we only surveyed random locations in habitat available to sage-grouse for nesting and brood-rearing, which allowed us to concentrate our effort into directly comparing avian predator densities in habitat that sage-grouse were using to potential sage-grouse habitat.

We found that sage-grouse nest and brood locations had lower densities of avian predators than habitat available to sage-grouse. Sage-grouse selected nest sites that were away from multiple avian predator species, including ravens, magpies, Golden Eagles, and *Buteo* hawks. Sage-grouse also selected early brood-rearing locations that had lower densities of ravens, magpies, Golden Eagles, *Buteo* hawks, harriers, and kestrels compared to available habitat. Our results indicate that sage-grouse are likely avoiding habitats with higher avian predator densities during nesting and brood-rearing.

Raven densities impact the nest success and nest-site selection of several prairie grouse species (Gregg et al. 1994, Manzer and Hannon 2005, Coates and Delehanty 2010). In southern

Alberta, sharp-tailed grouse (*Tympanuchus phasianellus*) had 8-times greater nest success in landscapes with less than three corvids/km^2 as opposed to landscapes with greater than or equal to three corvids/km^2 (Manzer and Hannon 2005). Sage-grouse nest success in northeastern Nevada was related to the number of ravens per 10-km transect with the odds of a nest failure increasing 7.4% with every additional raven (Coates and Delehanty 2010). Around Jackson and Pinedale, Wyoming, Bui et al. (2010) found that higher occupancy of ravens was correlated with failed sage-grouse nests. These studies suggest that high densities of ravens have significant impacts on sage-grouse nest success, which suggests why sage-grouse have a propensity to hide their nests from visual predators.

We found that sage-grouse located their nests and broods in areas with lower raven abundances compared to available sagebrush habitat. Interestingly in western Wyoming, Bui et al. (2010) found that sage-grouse nest and brood locations had significantly higher raven density estimates (1.0 ravens/km^2) compared to their ArcGIS predicted raven density estimates at those same locations (0.6 ravens/km^2), indicating that ravens were near sage-grouse nests and broods more than predicted by land cover metrics. They suggested that ravens may key in on sage-grouse nesting and brood-rearing areas. Bui et al. (2010) also found raven density around sage-grouse nesting and brood-rearing areas was marginally higher than raven densities in available sagebrush habitat (1.0 ravens/km^2 and 0.7 ravens/km^2, respectively); however, these results were not significantly different. In contrast, we found significantly lower raven densities at sage-grouse nest and brood locations (0.17 ravens/km^2 and 0.12 ravens/km^2, respectively) compared to available sagebrush habitat (0.29 ravens/km^2). The discrepancy between our results and Bui et al. (2010) may be a function of greater anthropogenic development and human activity in their study areas or differences between studies in sampling effort in available sagebrush habitat. Bui et al. (2010) sampled in available habitat twice per breeding season; whereas, we sampled an average of 4 times per breeding season at nests and in available habitat. Regardless, we agree with Bui et al. (2010) that as avian predators, especially ravens, increase in abundance in sage-grouse habitat, quality nesting and brood-rearing habitat will become more limited.

Magpies depredate sage-grouse nests (Holloran and Anderson 2003), and we found sage-grouse located nests and broods in areas with lower magpie densities. Intriguingly, we also found lower densities of magpies at sage-grouse brood locations. Although we could not find any study that verified magpies as potential chick predators, magpies are capable of consuming animals as large as sage-grouse chicks (Trost 1999). Magpies are known to be associated with riparian areas but also forage in sagebrush habitats (Trost 1999). Thus, sage-grouse avoidance of magpies during nesting may be related to sage-grouse avoidance of riparian areas within or adjacent to sagebrush habitat; however, sage-grouse are known to utilize riparian areas for foraging chicks (Connelly et al. 2004, Crawford et al. 2004). Our results indicate sage-grouse select habitat for brood rearing with lower abundances of magpies, even while balancing the need to utilize habitats, such as riparian habitats, that provide forage to meet the energetic requirements of chicks. Sage-grouse hens typically move broods to riparian areas after early-brood rearing (Crawford et al. 2004, Gregg and Crawford 2009), which likely corresponds with chicks being more mobile and less susceptible to predation by magpies.

In southwestern Wyoming, MacLaren et al. (1988) found that birds contributed to approximately 9% of the diet of nesting Golden Eagles, and sage-grouse was their primary avian prey. Danvir (2002) found that between November and May a northeastern Utah sage-grouse population was negatively correlated with wintering Golden Eagles (1985–2000), and 55% of radio-marked sage-grouse were killed by raptors, which he attributed mainly to Golden Eagles.

Golden Eagles have been suggested as the primary predator of adult sage-grouse (Schroeder et al. 1999, Schroeder and Baydack 2001, Mezquida et al. 2006). Thus, sage-grouse hens may avoid Golden Eagles year round. This constant avoidance of Golden Eagles likely spills over to selection of nest and brood locations. Nesting Red-tailed Hawks, Ferruginous Hawks, and Swainson's Hawks do not take significant numbers of sage-grouse (MacLaren 1988). Golden Eagles may be greater threats to sage-grouse than *Buteo* hawks; thus, it is possible that sage-grouse primarily avoid areas with high densities of Golden Eagles rather than *Buteo* hawks. Alternatively, sage-grouse may protect themselves from multiple avian predators through direct and indirect means. We found that sage-grouse avoided harriers and kestrels at brood locations but not nests. Harriers are known predators of sage-grouse adults and chicks (Schroeder et al. 1999, Schroder and Baydack 2001, Fletcher et al. 2003), and kestrels are known predators of sage-grouse chicks (Schroeder et al. 1999).

Sage-grouse preferentially select for greater visual concealment cover for nesting to hide from visual predators (Conover et al. 2010). Our results verify that sage-grouse treat visual predators as significant threats. This selection for hiding from and avoiding visual predators entails selection at multiple scales. At the local-scale, sage-grouse appear to be selecting for sites where they are visually concealed from avian predators (Connelly et al. 2004, Doherty et al. 2010). At landscape-scales, sage-grouse are selecting for areas where avian predators are less abundant. Sage-grouse selection of habitat at multiple scales achieves the same thing—reduced risk from avian predators.

Several studies have demonstrated that sage-grouse avoid habitat with man-made structures, such as oil and gas infrastructure (Aldridge 2005, Holloran 2005, Walker et al. 2007, Doherty 2008, Holloran et al. 2010) and power-lines (Braun 1998, Connelly et al. 2000, Aldridge and Boyce 2007, Naugle et al. 2011), all of which are potential perches for avian predators. In fact, Lammers and Collopy (2007) and Slater and Smith (2010) found that Golden Eagles, Red-tailed Hawks, Ferruginous Hawks, Swainson's Hawks, ravens, and kestrels utilized power lines and areas around power lines. Thus, sage-grouse may be avoiding man-made structures to avoid the avian predators they attract.

In addition to avoidance of tall structures, sage-grouse may avoid avian predators by avoiding habitats such as wetlands, conifers, and rough terrain. In northeastern Wyoming, Doherty et al. (2010) found that sage-grouse selected nesting habitat at an intermediate landscape-scale (100 m to 350 m) by selecting lower terrain roughness, percent conifer, percent grassland, and percent riparian, and greater density of sagebrush at the patch-scale.

Sage-grouse may avoid avian predators directly by watching them or indirectly by avoiding habitats such as wetlands or tall structures that might attract avian predators, or by both direct and indirect means. Arguments against indirect avoidance include the fact that our study sites had little riparian habitat and over half of our study sites had few anthropogenic structures. Yet, we found that sage-grouse avoided avian predators in all of our study sites. Perhaps sage-grouse avoid nesting and rearing broods in areas where they see raptors, but clearly more research needs to be done before conclusions can be drawn about the mechanisms behind sage-grouse avoidance of avian predators.

Increases in avian predator densities are likely to result in higher depredation rates on sage-grouse nests and reduced chick survival. Sage-grouse hens likely avoid avian predators for their own survival in addition to reducing depredation rates on their nests and chicks. Thus, the presence of greater abundances of avian predators, specifically corvids and raptors, may induce changes in sage-grouse behavior associated to habitat usage. Habitat that has high quality cover and forage may become functionally unavailable to sage-grouse when avian predator densities are at high levels. Regardless of the mechanisms behind sage-grouse hen selection of habitat with fewer avian predators, our results illustrate that sage-grouse were capable of avoiding areas with relatively higher densities of ravens, magpies, Golden Eagles, *Buteo* hawks, harriers, and kestrels compared to available sagebrush habitat.

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TABLE 1. Selection of half-normal detection function adjustments (cosine, simple polynomial, and hermite polynomial) that we used in DISTANCE to estimate avian predator densities, 2008–2010, southwestern and south-central, Wyoming, USA. We selected the best detection function adjustment with AIC for each avian predator species on species group (raven, magpie, Golden Eagle, *Buteo* hawk, harrier, and kestrel) individually.

Species	Adjustment	ΔAIC_c	AIC_c
Common Raven	Simple polynomial	0.00	8138.9
	Cosine	17.82	8156.6
	Hermite polynomial	68.68	8207.5
Black-billed Magpie	Cosine	0.00	1798.7
	Simple polynomial	2.28	1801.1
	Hermite polynomial	3.04	1801.7
Golden Eagle	Cosine	0.00	5876.9
	Simple polynomial	4.63	5881.6
	Hermite polynomial	24.73	5901.6
Buteo hawk	Cosine	0.00	3722.1
	Simple polynomial	18.97	3741.0
	Hermite polynomial	50.03	3771.9
Northern Harrier	Cosine	0.00	1399.1
	Simple polynomial	7.45	1406.4
	Hermite polynomial	22.01	1420.8
American Kestrel	Cosine	0.00	1667.0
	Simple polynomial	13.98	1680.7
	Hermite polynomial	32.36	1698.9

TABLE 2. Number of point-counts used in DISTANCE analyses, number of detections of avian predators, and estimated effective detection radii (EDR), 2008–2010, southwestern and south-central, Wyoming, USA.

Species	EDR	SE	detections	count locations
Common Raven	606.8	22.3	546	965
Black-billed Magpie	294.2	19.1	138	965
Golden Eagle	1006.3	42.7	376	965
Buteo hawk	439.1	26.0	242	965
Northern Harrier	318.4	26.3	100	965
American Kestrel	397.1	36.1	118	965

TABLE 3. Results of paired Student's *t*-tests comparing avian predator densities at random versus sage-grouse nests from 12 16-km or 24-km study sites, 2008–2010, southwestern and south-central, Wyoming, USA.

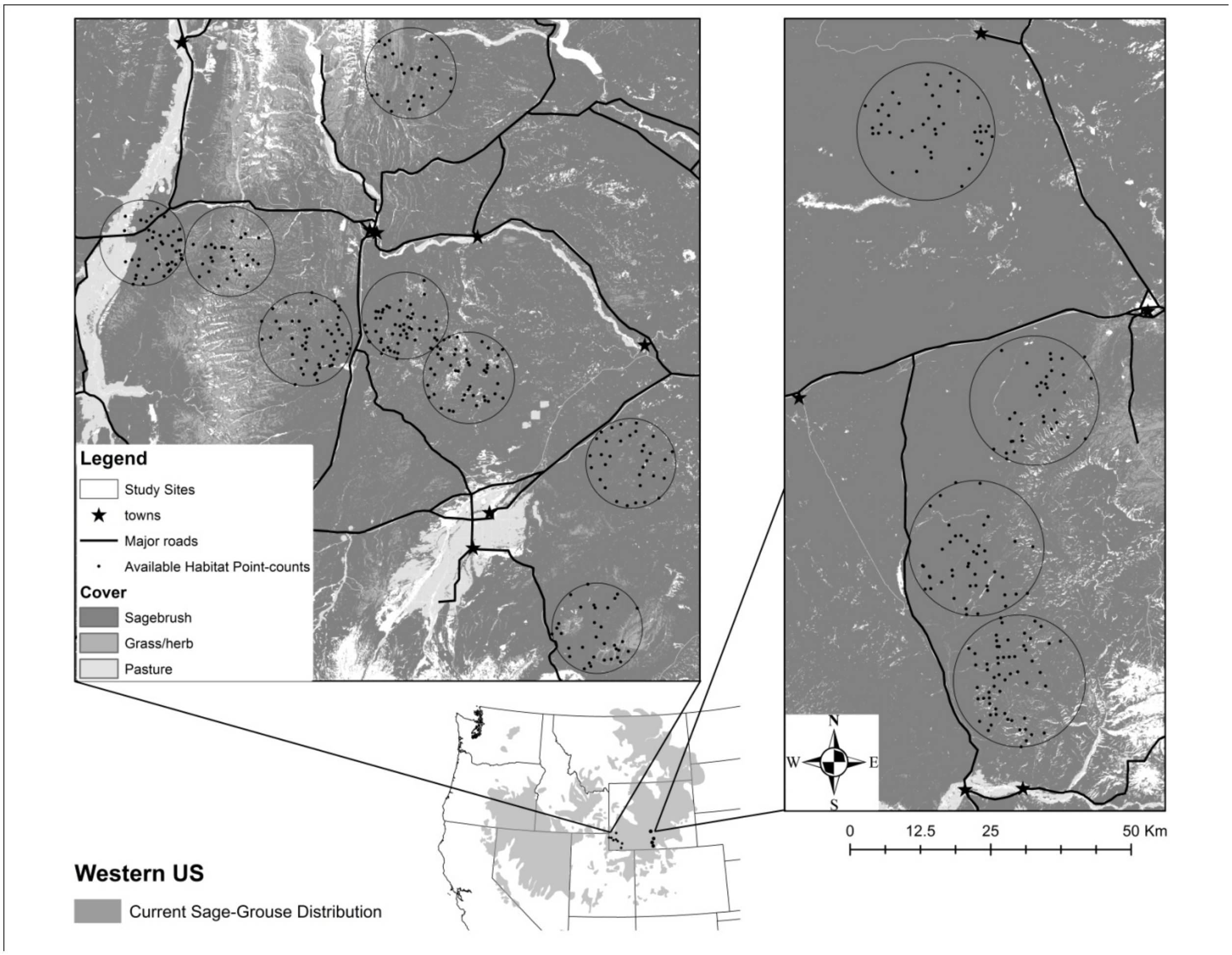
Avian predator species	Random		Nest			
	Mean	SE	Mean	SE	*t*	*P*
Common Raven	0.23	0.04	0.10	0.03	6.06	<0.0001
Black-billed Magpie	0.21	0.05	0.08	0.03	4.15	0.0016
Golden Eagle	0.06	0.01	0.03	0.01	3.30	0.0071
Buteo hawk	0.16	0.04	0.07	0.02	3.70	0.0035
Northern Harrier	0.10	0.01	0.10	0.03	0.45	0.6634
American Kestrel	0.10	0.02	0.09	0.02	0.34	0.7383

TABLE 4. Results of paired Student's *t*-tests comparing avian predator species densities at random versus sage-grouse brood locations from 12, 16-km or 24-km study sites, 2008–2010, southwestern and south-central, Wyoming, USA.

Avian predator species	Random		Nest			
	Mean	SE	Mean	SE	*t*	*P*
Common Raven	0.24	0.04	0.07	0.02	5.88	0.0002
Black-billed Magpie	0.16	0.05	0.06	0.04	2.87	0.0208
Golden Eagle	0.06	0.02	0.01	0.00	4.86	0.0007
Buteo hawk	0.15	0.05	0.03	0.01	5.21	0.0004
Northern Harrier	0.10	0.02	0.01	0.01	5.99	0.0001
American Kestrel	0.15	0.03	0.03	0.02	3.5	0.0067

Fig. 1. Study sites in southern Wyoming showing 12 study sites with 8, 16-km diameter and 4, 24-km diameter study sites, 2008–2010, southwestern and south-central, Wyoming, USA. Magnified sections correspond on left to southwest and on right to south-central Wyoming.

Fig. 2. Comparison of raven, magpie, Golden Eagle, *Buteo* hawk, harrier, and kestrel densities (per km^2) among sage-grouse nests, sage-grouse brood locations, and random locations. Densities were generated using radial point-count surveys and DISTANCE at sage-grouse nests, sage-grouse brood locations, and random locations from 2008 to 2010, southwestern and south-central, Wyoming, USA. Error bars are 95% confidence intervals.


Legend
Study Sites
towns
Major roads
Available Habitat Point-counts
Cover
Sagebrush
Grass/herb
Pasture
N
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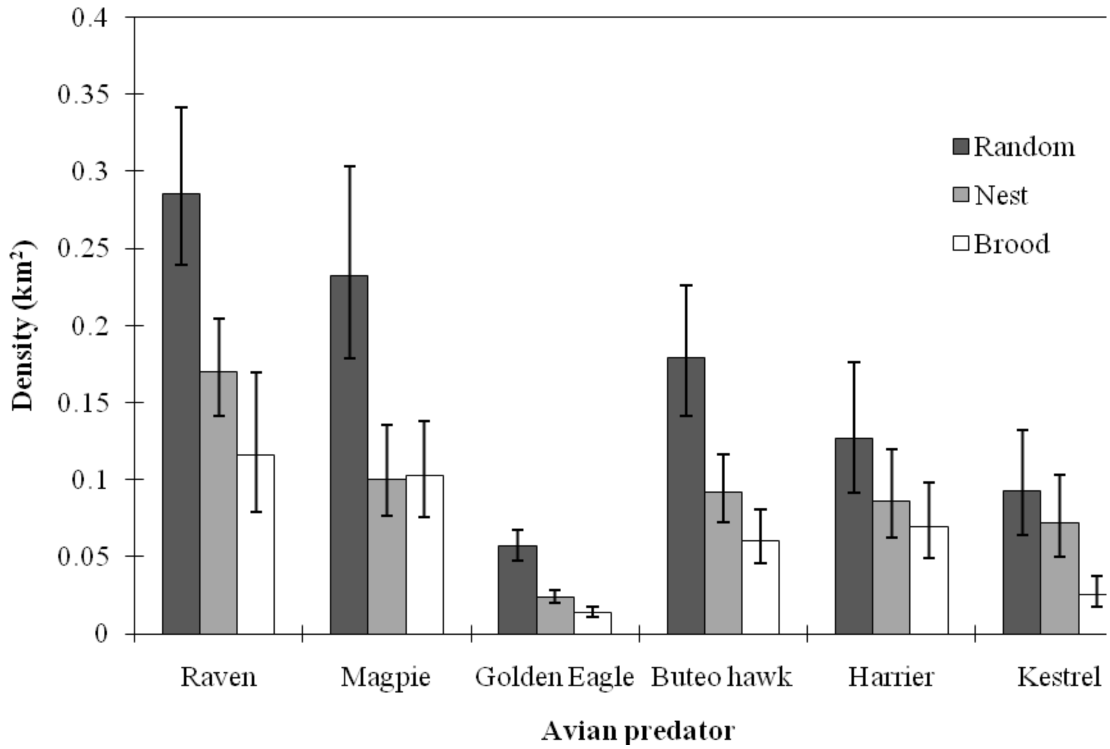
0
12.5
25
50 Km
Western US
Current Sage-Grouse Distribution



0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Density (km²)
Random
Nest
Brood
Raven
Magpie
Golden Eagle
Buteo hawk
Harrier
Kestrel
Avian predator

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4 June 2011

Co-Chairman Jason Fearneyhough and Co-Chairman Scott Talbott
Wyoming Animal Damage Management Board
2219 Carey Avenue
Cheyenne, Wyoming 82002

Dear Co-Chairmen Fearneyhough and Talbott,

The intent of this letter is to provide the Wyoming Animal Damage Management Board with an update for the "***Identification of mule deer seasonal ranges to maximize predator control benefits in the Platte Valley herd unit,"*** project. This project is part of a multi-facetted mule deer research project which began in July of 2010. The research is being conducted in joint by Wyoming Game and Fish Department, and the University of Wyoming's Cooperative Fish and Wildlife Research Unit. The primary funding source for this research is the Wyoming Game and Fish Department. During fiscal year 2011, the Wyoming Animal Damage Management Board granted $22,000, towards the capture and GPS radio-collaring of mule deer for this project, to delineate seasonal ranges in order to maximize any future predator control benefit.

In January of 2011, 70 mule deer were captured in the Platte Valley mule deer herd unit using a helicopter/net-gun capture technique. Each mule deer was fitted with a radio-collar (GPS collars on 50 does, VHF collars on 15 bucks and 5 does) and subsequently released. The 50 GPS radio-collars will record doe locations at 2 hour intervals until April of 2013, when the collars are programmed to drop off for collection. The data collected from the GPS radio-collars will allow managers to identify specific areas, and habitat types, selected by the does for fawning in the Platte Valley herd unit.

Currently the Platte Valley mule deer herd unit does not meet the criteria, as specified by Wyoming Game and Fish Commission Policy No. VII R, for the consideration of predator control projects to benefit mule deer. However, trend in both postseason fawn ratios (Figure 1.) and the herd unit population estimate (Figure 2.) indicate these are declining towards the Policy's criteria thresholds. If this mule deer herd unit meets the criteria for predator control in future years, managers will be able to use the fawning location data to design predator management projects specifically meant to increase fawn survival rates. Any subsequent predator control for the benefit of mule deer in the Platte Valley herd unit will also provide an economic and social benefit for the people of Wyoming.

Figure 1. 2000-2010 Post-season mule deer fawns per 100 does in the Platte Valley Herd Unit, Wyoming.

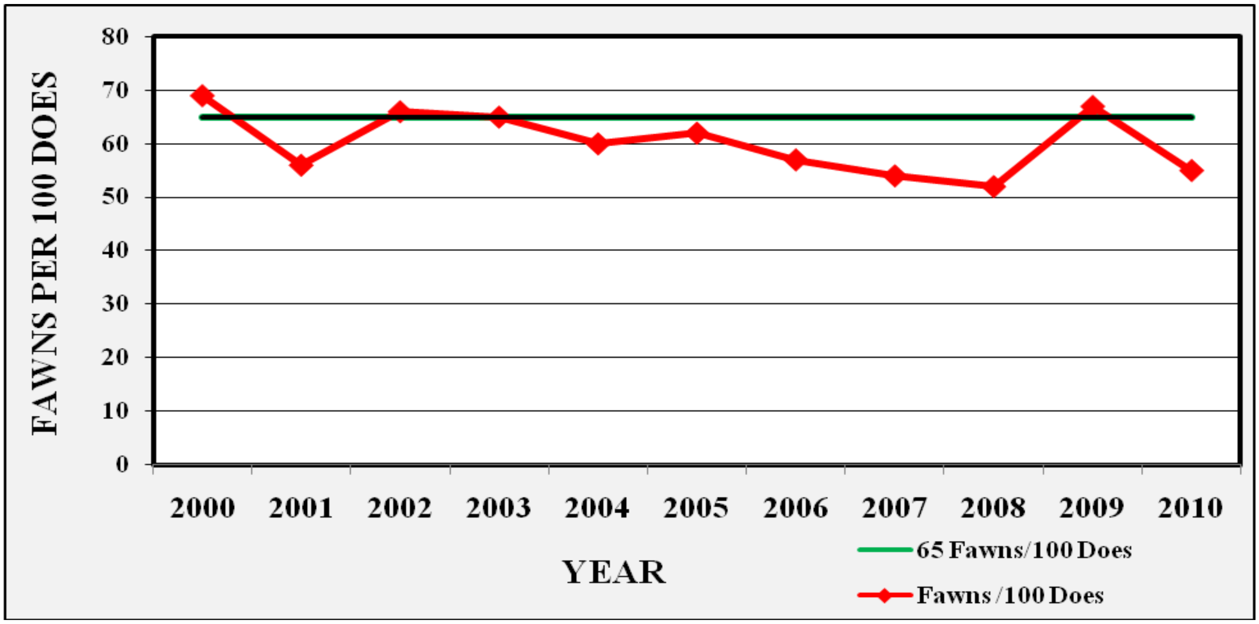
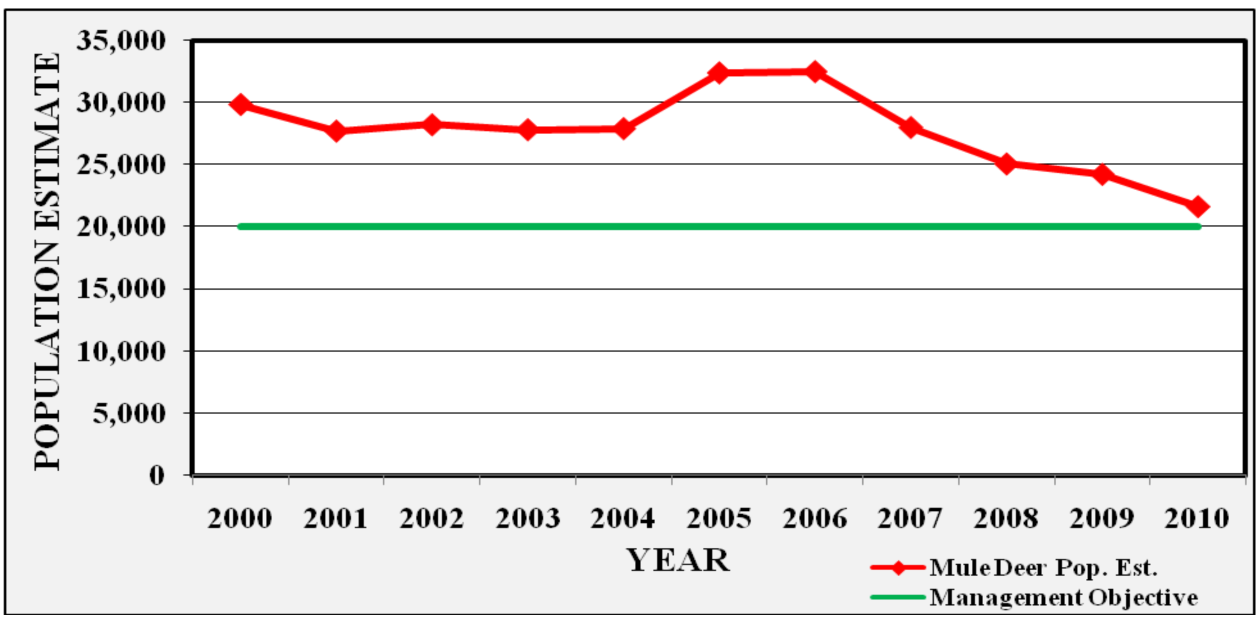


Figure 2. 2000-2010 post-season mule deer population estimates for the Platte Valley Herd Unit, Wyoming.



We thank the Wyoming Animal Damage Management Board for their financial support of this project. The Wyoming Animal Damage Management Board's contribution to this project will be recognized in future presentations and publications regarding the results of this important mule deer research.

Sincerely,

Will Schultz
Saratoga Wildlife Biologist

WS/ws

cc:

Dr. Matthew Kauffman
Bob Lanka
Bill Rudd
File

WYOMING GAME AND FISH DEPARTMENT

5400 Bishop Blvd. Cheyenne, WY 82006

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Web site: http://gf.state.wy.us

September 29, 2011

Kent Drake
Predator Management Coordinator
2219 Carey Ave
Cheyenne, WY 82002

Dear Kent:

Please consider this letter as the FY11 final report for the Wildlife Services/Wyoming Game and Fish Department (WGFD) contract dealing with trophy game animal damage investigation and mitigation and the Big Piney bear trap funding. The trophy game animal damage investigation and mitigation project has been one of the longest running projects supported by the Animal Damage Management Board (ADMB). This project continues to be based on the core concept that a high level of timely and professional damage evaluation services to livestock producer while ensuring human health and safety are the key to this project. It has been demonstrated that Department personnel working together with Wildlife Services personnel can respond to the needs of the public, especially the livestock industry, in a more effective and efficient manner. The project has proven valuable in the investigation and mitigation of damage efforts and compensation actions for claimants.

FY11 PROJECT FINAL REPORT
JULY 1, 2010- June 30, 2011

Project Title: Grizzly Bear/Black Bear/Mountain Lion/Wolves Livestock Depredation Prevention and Control

Brief Synopsis of Project: This is a project with ADMB to fund the Wyoming Game and Fish Department's contract with USDA-Wildlife Services up to a maximum of $25,000.00 for work to investigate and control damage caused by black bears, grizzly bears, mountain lions, and wolves. Work to control damage to livestock, bees, and beehives qualify for reimbursement.

Project Update: During FY11 USDA-Wildlife Services billed the WGFD for 135.3 hours of grizzly bear damage investigation and control for a total of $4,787.50, 229.5 hours of mountain lion damage investigation and control for a total of $8,032.50, and 270 hours of black bear damage investigation and control for a total of $9,398.00. Total hours charged during FY11 was 634.8 for a total monetary obligation of $22,218. There were no wolf damage investigations or control actions provided under this project.

Project Title: Big Piney Bear Trap

Brief Synopsis of project: This project was a benefit to the Wyoming Game and Fish Department, as well as livestock producers, and the citizens of Wyoming. The purchase of this new bear trap allowed Department personnel to address damage and nuisance bear conflicts in a more efficient and effective manner. It is anticipated that the trap will be used throughout the non-denning period each year and should have a functional life of over 20 years. Having this additional bear trap saved many man-hours.

Project Update: The funds ($5,000) provided by the ADMB have been used to purchase one new box style trap. With the increasing cost in steel, trap prices had increased from previous models. The trap will be used primarily in the Big Piney game warden district, but will also be available for use in the entire WGFD's Pinedale Region.

I would like to thank the ADMB for their continued support of WGFD projects. Feel free to contact me if need any additional information relating to these projects.

Sincerely,

Scott C. Edberg
Assistant Chief, Wildlife Division

SCE/sce

cc: Mark Bruscino, Trophy Game Supervisor
Kindra Brown, Administrative Assistant
Jennifer Doering, Fiscal Program Manager

Beth Orning-Tschampl
Utah State University
5230 Old Main Hill, Logan UT 84322
515-450-4852 (c) 435-797-0288 (fax)
b.orning.tschampl@aggiemail.usu.edu
Poster

MORTALITY, PREDATION, AND SPACE USE OF GREATER SAGE-GROUSE (*CENTROCERCUS UROPHASIANUS*) IN THE BIGHORN BASIN.

Orning-Tschampl, Elizabeth[1], Julie Young[2], Jim Pehringer[3].
[1]Department of Wildland Resources, Utah State University, 5230 Old Main Hill, Logan, UT 84322
[2]USDA-Wildlife Services, National Wildlife Research Center and Department of Wildland Resources, Utah State University, BNR 163, Logan, UT 84322-5295
[3]USDA-Wildlife Services, 3520 Cottonwood Avenue, Cody, Wyoming 82414

Reported decreases in greater sage-grouse (*Centrocercus urophasianus*) lek attendance since 2006 (WYGF 2009) in the Bighorn Basin Conservation Area of Wyoming sparked concern to investigate the demographic factors of this previously unstudied population. Understanding direct and indirect predation effects on sage-grouse will provide managers with additional information beyond habitat improvements that could enhance sage-grouse management. The objectives of this study are to provide baseline data on the type and impacts of predators on greater sage-grouse and their nests within the Bighorn Basin Conservation Area. We targeted two complexes within the Bighorn Basin to study sage-grouse predation effects: Oregon Basin (OB) and Polecat Bench (PB). Hens were captured via rocket nets from four leks, fitted with VHF radio collars, and monitored from April – August 2011 to document nesting, brood movements, and long-distance migrations. Infrared trail cameras were used to monitor and document nest predations. Terrestrial and avian predator surveys were conducted using scent stations, trail cameras, and road transects to obtain an index of predator abundance. We fitted vhf tags on 15 hens at OB; two were depredated before nesting and 13 were documented nesting. Ten hens were tagged from PB; 9 were documented nesting and one left the study area post-capture. Two of the 15 hens at OB attempted second nests after first nest failures. Six nests at OB and two nests at PB successfully fledged. Of the failed nests, nest predation was 67% in OB (n=9) and 57% (n=7) in PB. The other three nests failed at OB due to hen predation but the nests were never depredated. At PB, one female died before fledging but the nest was never depredated, one was not investigated in time to determine cause of nest failure, and one nest was abandoned once a coyote visited. Chick survival to 35 days was 44% at OB (n=25 chicks) and 3 of 5 chicks at PB from one of the two broods we were able to observe. Survival of vhf-tagged hens at the end of post-brooding season included six at OB and seven at PB, with one fate unknown (i.e., slipped collar). The data from 2011 are a baseline to compare the effect of predator removal treatment, to be applied in 2012, on sage-grouse ecology.

Park County Livestock Carcass Management Program

Tara Teaschner, Wyoming Game and Fish Department
Tara.Teaschner@wyo.gov

Summary

The Livestock Carcass Management program is a carcass retrieval service available to livestock producers or private landowners that have historically experienced a high number of human-bear conflicts (see Figure 6). On June 1, 2008, implementation of the Livestock Carcass Management program began in central and western Park County, Wyoming. The Wyoming Game and Fish Department developed and implemented the program with fiscal support from the Park County Predator Management District and Wyoming Animal Damage Management Board (ADMB).

The main purpose of this program is to minimize human-bear conflicts and increase human safety by removing carcasses that attract and hold grizzly bears in areas that are in close proximity to humans, ranch buildings, feed lots, or calving areas. This program serves as an alternative to disposing of livestock carcasses in traditional boneyards and provides producers with a cost effective means of managing a significant grizzly bear attractant. In addition to producers, the program also provides any livestock owner or small hobby farm owners a means of effectively removing grizzly bear attractants.

Used in conjunction with other methods of storing attractants (i.e. bear-resistant feed barrels/garbage cans, electric fencing), this program could have significant impact on the number of human-bear conflicts producers experience and may also aid in decreasing grizzly caused livestock depredations.

Program Description and Structure

The Livestock Carcass Management program is a domestic livestock carcass removal service available to livestock producers, hobby farm owners or any livestock owner who live in areas of Park County, Wyoming that have historically experienced a high number of human-bear conflicts (see Figure 6). The program is mirrored after an existing Carcass Management program that functions in the Blackfoot River Valley in west central Montana for the same purpose.

The Park County program utilizes an independent contractor that provides qualifying landowners with the carcass removal service on an on-call basis and is provided at no cost to the landowner. Frequency of service depends on landowner participation/need. The contractor receives calls directly from landowners and is expected to respond within a reasonable amount of time considering time of year and location of the carcass.

Carcasses are retrieved from private land as directed by the landowner's voluntary request and then transported to the Park County landfill. Pickup priority is given to those areas with the highest potential for human-bear conflicts, such as areas that are in close proximity to established carcass dumps or carcasses that are in close proximity to human development (i.e. houses, outbuilding, or corrals). General priority areas have been established within the qualifying zone in the event that resources and time are limited.

The carcass management program is intended to operate a minimum of five years as a pilot program in order to determine if the removal of carcasses will minimize human-bear conflicts in private agricultural settings.

Need

A preemptive approach to bear management is needed where human communities and bear populations overlap (See Figure 5). Managing bear attractants such as domestic carcasses in developed areas is likely to minimize the occurrence of human-bear conflicts, maximize human safety, and minimize management related bear mortality.

Park County, Wyoming experiences a higher number of human-bear conflicts than any other area in Wyoming or the Greater Yellowstone area. From 2005-2009, 403 human-bear conflicts occurred within Park County, an average of 80 conflicts each year. Eight-one percent of those conflicts involved grizzly bears and 19% involved black bears. Without preventive action, the trend in human-bear conflicts is expected to increase.

Progress

In May 2008, Randy Blackburn, an independent contractor, was awarded the Carcass Management program contract after participating in a formal bid process. The contractor is paid an hourly rate of $54.00 per hour for the service. Pickup service began June 1, 2008.

At this time, approximately 25 producers/landowners in the program area are participating. From June 1, 2008 to October 15, 2011, a total of 179 carcasses have been retrieved; 45 horses, 56 cows, 37 calves, 16 yearlings and 11 bulls in 152 independent retrieval trips (see Figure 1). The “other” category represents unusable portions of livestock carcasses after slaughter. Of the 179 carcasses retrieved, 43% (n=77) were retrieved from the South Fork of the Shoshone River area, 18% (n=23) from the Crandall/Sunlight area, 9% (n=17) from the North Cody/Clark area, 21% (n=37) from the North Fork of the Shoshone River area, and 14% (n=25) from areas west of Meeteetse (see Figure 2 and Figure 6).

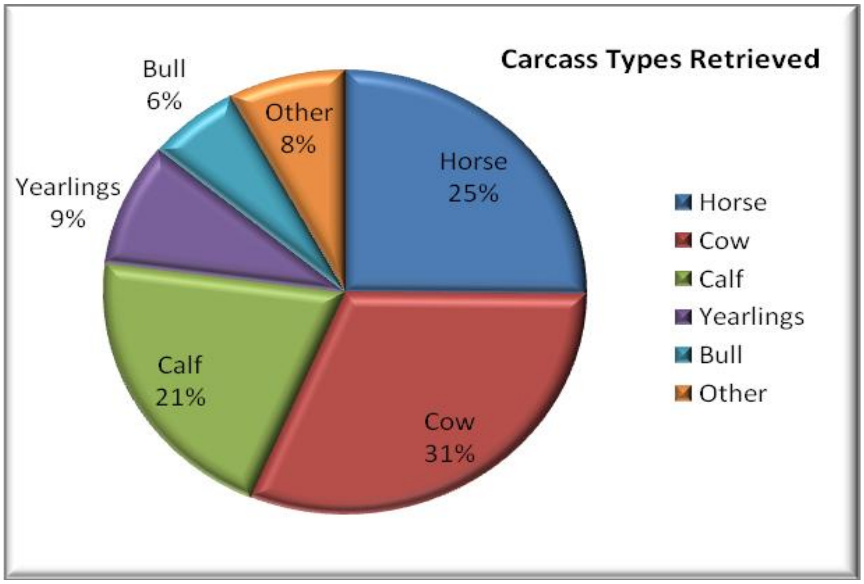

Figure 1. Carcass types retrieved from June 1, 2008 to October 15, 2011.

General Location	Number of Carcasses
South Fork of the Shoshone	77
North Fork of the Shoshone	37
Crandall/Sunlight Areas	23
Northeast Cody Area / Clark	17
Areas West of Meeteetse	25
Total	**179**

Figure 2: Number of carcasses retrieved from June 1, 2008 to October 15, 2011 in general locations within the program area.

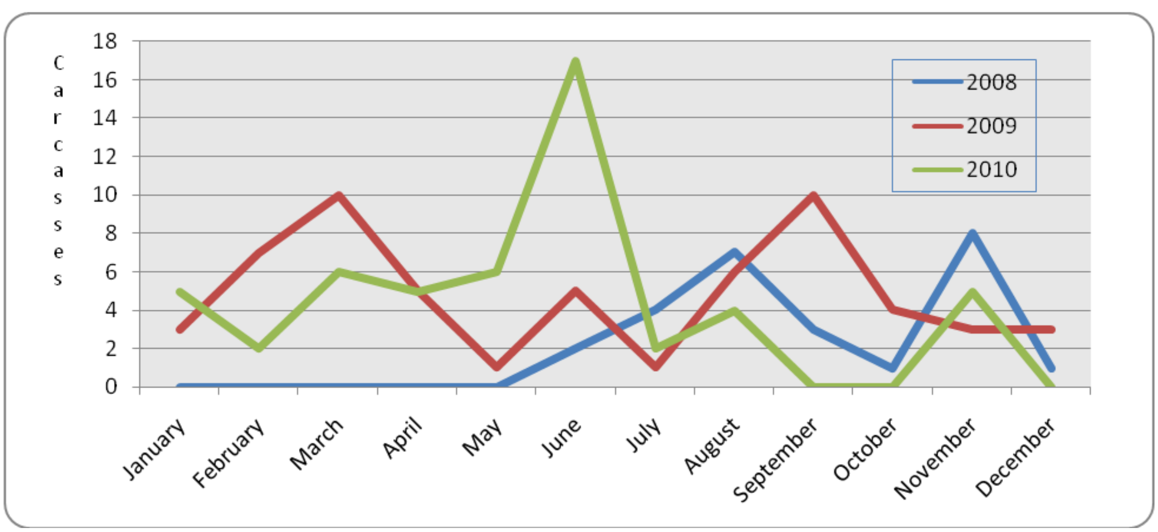

Figure 3: Number of carcasses retrieved per month from June 1, 2008 to December 15, 2010.

Cost Summary

The Animal Damage Management Board (ADMB) awarded the Park County Predator Management District a sum of $27,140.00 in January of 2008 to fund the Carcass Management program. The ADMB awarded the program $5,000 directly for the 2011 fiscal year in June 2010.

From June 1, 2008 to December 15, 2010, the Carcass Management program has utilized $28,868.00. Average annual cost is $8,700.00 and approximately $160.00 per carcass.

Funding Partner	**Contribution amount**
Park County Predator Management District	$ 27,140.00
Animal Damage Management Board (ADMB)	$ 5,000.00
Wyoming Game and Fish Department	In kind labor for program oversight and orchestration.
Big Horn Basin RC&D	In kind labor for assistance in identifying potential funding sources.

Figure 4: Funding partner and contribution amount for the Carcass Management program.

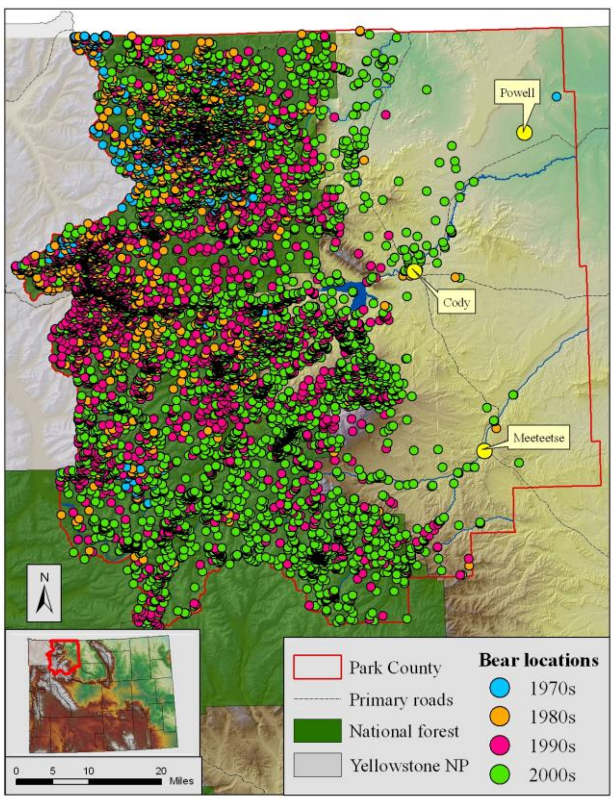

Figure 5: Documented grizzly bear and black bear locations in Park County from 1975 to 2009.

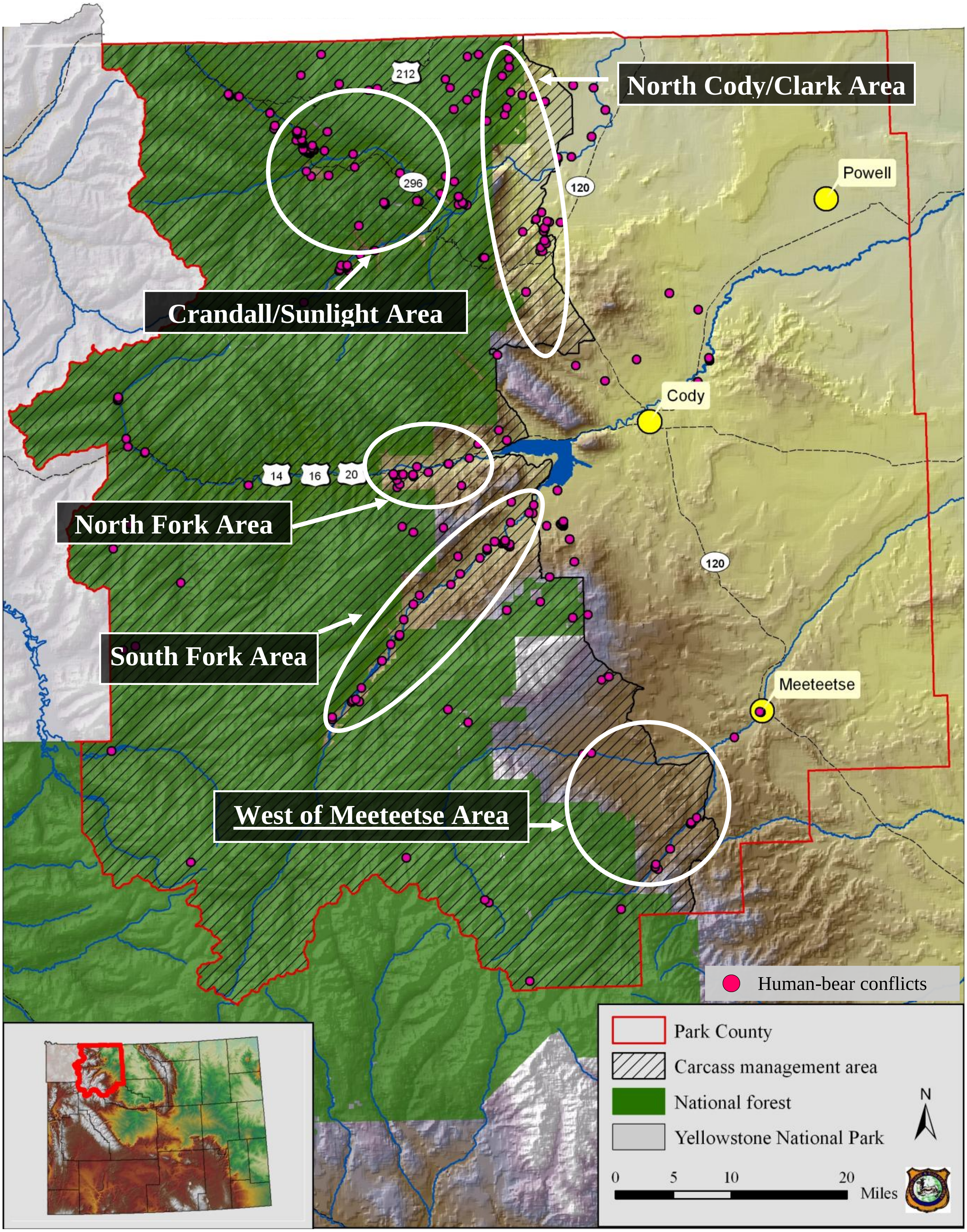

Figure 6: Carcass Management program area with human-bear conflict locations that have occurred from 2005-2009. Private landowners within the Carcass Management area have access to the carcass retrieval service for no fee. The qualifying area was determined based on historical locations of human-bear conflicts. General location areas were established for reporting purposes in order to protect the privacy of participating landowners.

To the University of Wyoming:

The members of the Committee approve the thesis of Abigail A. Nelson presented on 5/26/2011.

Matthew J. Kauffman, Chairperson

Ken Gerow, External Department Member

Steve Buskirk

Dan Doak

APPROVED:

Frank Rahel, Program Chair, Department of Zoology and Physiology.

B. Oliver Walter, College Dean

Nelson, Abigail A., Master of Science, M.S., Deparment of Zoology and Physiology, August 2011.

Human conflict is a unique and persistent driver of management and conservation of large mammalian carnivores. Understanding these conflicts in space and time can assist in appropriate decision-making as managers seek to balance the population viability of carnivore species with management that curbs carnivore impacts on human livelihoods. The patchy distribution of prey-rich habitat across landscapes influences abundance and movements of wolves; however, many ungulate populations are partially migratory, and it is unclear how wolves respond behaviorally to the seasonal movements of migratory versus nonmigratory prey. In this context, wolf selection for prey-rich habitat can influence seasonal encounter rates and thus depredation rates on domestic livestock. In this study, conducted in Northwest Wyoming, USA, we use three years of fine-scale wolf (n = 14) and elk (n = 70) movement information to evaluate the influence of elk distribution and other landscape features on wolf habitat selection and patterns of depredation on domestic livestock.

THE INFLUENCE OF MIGRATORY AND RESIDENT ELK MOVEMENTS ON SEASONAL WOLF HABITAT SELECTION AND DEPREDATION PATTERNS

By

Abigail A. Nelson

A thesis submitted to the Department of Zoology and Physiology

and the University of Wyoming

in partial fulfillment of the requirements

for the degree of

MASTER OF SCIENCE

in

ZOOLOGY AND PHYSIOLOGY

Laramie, Wyoming

August 2011

Acknowledgements

This project would not have been possible without the daily cooperation and support of many ranch managers and livestock producers in the Cody, Sunlight and Crandall areas. A particular thanks to Mark McArty of the Two Dot Ranch, and John and Eva Foos of the Sunlight Ranch, Wyatte Donald of Cayuse Ranch who entertained my questions and taught me much I did not know before this project. Thanks to the 7D Ranch, Chay Donnelly, and Chuck and Kerry Gunther for their cheerful provisioning of horses during the field season.

Many were responsible for wearing miles on their boots to safely find wolf kills: Angela Brennan, Brandon Covey, Sara Hansen, Emily Loufek, Scott Laursen, Toni Appleby, Rebecca Steinberg, Amanda Honhorst, Nate Payne, Sara Lykens, Erin Hurst, Jenny Grant, Ashlee Robinson, and Tim Metzler. Thanks to the extra effort put into data collection at depredation sites from Jim Pehringer, and Monty Nicholson (USDA Wildlife Services); Suzanna Woodruff (USFWS) for trapping expertise; and various forms of support from Andy Pils, Joe Hicks, and Lynette Otto (US Forest Service). The Yellowstone Wolf Project and YCR staff contributed different forms of support at various times throughout the project, including Doug Smith, Dan Stahler, Matt Metz, Rick McIntire, and Christie Hendrix. This project has greatly benefitted from many hours of safe piloting by Sky Aviation, Gallatin Aviation, Quicksilver Air, and Leading Edge Aviation, a particular thanks to Dave Stinson and Neil Cadwell.

Thanks to my advisor, Matt Kauffman, who allowed me independence in the field season, has always supported and inspired me to do the best work possible, and has put in a good effort to teach me to write. I am indebted to Doug McWhirter (and family) for support, inspiration, concentrated doses of wisdom, and guidance. I am grateful to Mike Jimenez, for giving both guidance and independence throughout the project, and for support, good humor, and insight into the realm of wolf management. Thanks to Chris Queen for local advice on wildlife topics and getting around the Absarokas; and to Mark Bruscino, for his support at key times. Thanks to my committee (Dan Doak, Steve Buskirk, Ken Gerow and Matthew Kauffman) for their comments and expertise that have improved these manuscripts. In particular, I would like to thank Arthur Middleton, who has an inspirational dedication to understanding this system and the animals in it, and whose unwavering support, confidence and friendship throughout has given a great amount of depth to this experience.

This research benefitted greatly from the support and assistance of staff of the Wyoming Cooperative Fish and Wildlife Research Unit, particularly Mandi Larson, and the staff, wardens and biologists in the Cody regional office of the Wyoming Game and Fish Department. Thanks to the throng of statisticians that helped at various points, in particular: Ken Gerow, David Legg, Jarrett Barber, and Ryan Neilson.

Thanks to my family who have always encouraged me to follow my ambitions, whether ordinary or not, and who have supported me throughout. I am grateful for my friends (near and far) who helped me maintain a high quality of life throughout graduate school.

Major funding for this research was provided by the Wyoming Animal Damage Management Board, the Wyoming Game and Fish Department, the Community Forestry and Environmental Research Partnership Fellowship, the Haub School Summer Research Grant and the UW Plummer Scholarship.

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CHAPTER 1: THE INFLUENCE OF MIGRATORY AND RESIDENT PREY ON THE SEASONAL HABITAT SELECTION OF WOLVES IN NORTHWEST WYOMING

ABSTRACT: Identifying ecological dynamics that drive human-wildlife conflicts can help manage and conserve wildlife populations. Although it is well known that the distribution and density of ungulate prey determines the distribution of terrestrial carnivores, many ungulate populations migrate seasonally, complicating our understanding of their influence on carnivore movements. There has been little empirical research that links carnivore distribution to large-scale movements of their prey. In this study, we use three years of fine-scale wolf (n = 14) and elk (n=70) movement information to evaluate the influence of elk distribution and other landscape features on wolf habitat selection in an area of chronic wolf-livestock conflicts in the northern Rocky Mountains, USA. We compared the seasonal habitat selection of wolves living in an area dominated by migratory elk with that of wolves living in a nearby area dominated by resident elk. Wolves occupying the migratory elk area faced large-scale seasonal shifts in elk distribution (migration = 40-55 km), whereas wolves occupying the resident elk area had year-round access to abundant prey. We used a generalized linear mixed model to compare relative probability of wolf use as a function of GIS-based habitat covariates in the migratory elk area and the resident elk area. Wolves in the resident elk area selected for elk-rich habitat in both summer and winter, but selection for elk was stronger in summer. Wolves in migratory elk areas did not vary their selection for elk-rich habitat summer to winter, indicating various strategies to cope with summer departure of elk. Wolves differed in their associations with roads. In winter months, wolves in the migratory elk area selected for roads, while wolves in the resident elk area

avoided roads. In summer, migratory elk area wolves were indifferent to roads, while wolves in resident elk areas strongly avoided roads, presumably due to a greater amount of traffic, and the location of dens. Although we observed differences in seasonal wolf habitat selection related to patterns of elk movement, our findings suggest that wolf avoidance of human activity plays an equally important role. Study findings can help managers anticipate the habitat use and establishment of wolf packs as they expand into areas with migratory or resident prey populations and varying levels of human activity.

INTRODUCTION

Understanding drivers of carnivore habitat selection as they relate to abundance and distribution of seasonal food resources may help predict variation in rates and locations of conflict. The density of large carnivore species that prey on ungulates is often determined by the abundance and distribution of prey (Carbone and Gittleman 2002), and thus prey distribution may mediate the spatial and temporal arrangement of conflicts between large carnivores and humans. These species require nuanced management because they can kill domestic livestock (Sillero-Zubiri and Laurenson 2001), compete with humans for ungulate prey (Reynolds and Tapper 1996), and range widely across landscapes that are increasingly human-dominated (Woodroffe and Ginsberg 1998, Brashares 2003, Treves and Karanth 2003). A remaining challenge is for ecologists and managers to understand how carnivores select habitat based on seasonal changes in distribution of migratory and non-migratory prey in ecosystems with varying levels of human use.

In many systems, the distribution of large ungulates changes seasonally due to annual migrations. Well known, long-distance migrants such as African wildebeest (*Connochaetes taurinus*) and barren-ground caribou (*Rangifer tarandus*) can move as far as 4,000 km, and species such as elk (*Cervus elaphus*), mule deer (*Odocoileus hemionus*), sheep (*Ovis canadensis*), pronghorn (*Antilocapra americana*), and bison (*Bison bison*) move 40-400 km (Berger 2004, Sawyer et al. 2005). Such movements are primarily driven by the seasonal availability of high-quality forage and may reduce the exposure of prey to denning predators (Fryxell and Sinclair 1988). The degree to which carnivores follow migrating prey is highly variable. Some carnivores do not move seasonally with preferred prey due to the need to attend young at a fixed den location (Fryxell and Sinclair 1988). In contrast, some spotted hyaenas in the Serengeti (*Crocuta crocuta;* Hofer and East 1993) and cougars (*Puma concolor*) in the Sierra Nevada Mountains (Pierce et al. 1999) follow seasonal prey movements by making 'commuting' trips or even fully migrating with their prey. The extent to which a carnivore tracks migrating prey has implications for migratory ungulates and carnivore populations, as their associated predation patterns may induce dramatic changes in partially migratory prey populations (Hebblewhite et al. 2006; Middleton et al. unpublished ms.).

In the Greater Yellowstone Ecosystem (GYE), gray wolves prey primarily on migratory elk and establish their territories on elk winter range (Smith et al. 2004). Outside of Yellowstone National Park (YNP), the low-elevation valleys where many ungulates winter are typically dominated by private land, much of which is used to graze livestock. Conflict between wolves and livestock can be locally chronic in these areas (Bangs et al. 2005). The coincidence of summer grazing and the departure of migratory elk (i.e., the 'replacement' of native with domestic prey) has been hypothesized as a driver of wolf-livestock conflict in the GYE (Garrott et al. 2005), but this notion has not been empirically evaluated. Migration is likely to play an important role in seasonal wolf habitat selection patterns, in as much as wolf distribution range-wide is tightly linked to the distribution (Messier 1984, Ballard et al. 1997), abundance (Massolo and Meriggi 1998, Potvin et al. 2005) and diversity (Ciucci et al. 2003) of prey, including prey that migrate. For example, Ballard et al. (1997) characterized 11% of study wolves in northwest Alaska as migratory, because they followed migratory caribou (*Rangifer tarandus*) herds. Depending on the extent to which they follow migratory prey, wolf territories can be considered static from season to season (Messier 1984, Ballard et al. 1997), partially migratory (Ballard et al. 1997), or fully migratory (Walton et al. 2001).

Dramatic reductions in the proportion of migrants to residents in partially migratory elk populations have recently been documented in the US (Middleton et al., unpublished ms.) and Canada (Hebblewhite et al. 2005, Hebblewhite et al.2006). The declining proportion of migrants in these populations has been caused partly by higher predation inside reserves where large carnivores are protected and recovering. As ungulate populations shift, the growing abundance of residents that remain year-round on low–elevation areas of mixed land-use (Hebblewhite et al. 2006; Middleton et al. *unpublished ms.*), may bring wolves into closer contact with domestic livestock and heighten conflict rates.

Wolves also alter their behavior to avoid the risk of human-related mortality while acquiring prey (Hebblewhite and Merrill 2008). Wolf avoidance of human disturbance is well-studied (Mladenoff et al. 1995, Potvin et al. 2005, Oakleaf et al. 2006) and mortality associated with humans has historically threatened large terrestrial carnivores (Woodroffe and Ginsberg

1998, Treves and Karanth 2003). For example, wolves in south-central Alaska use closed pipeline roads as travel corridors, but avoid oilfield access roads that have more traffic (Thurber et al. 1994). In Spain and Italy, wolves that live in disturbed areas are more active at night than day (Vila et al. 1995). And in Minnesota, wolves were found to select more strongly for cattle pastures at night, when human activity was low (Chavez and Gese 2006). The level of nocturnal activity among wolf populations also increases with anthropogenic food resources and road density (Theuerkauf 2009). The tradeoffs inherent in such foraging behaviors are perhaps best evaluated within the framework of predation risk (Whittington et al. 2005). Thus it is possible that wolves drawn into close contact with human activity by resident prey can adaptively balance their own risk of mortality with their need to forage. Such dynamic tradeoffs between food resources and risk complicate our understanding of wolf habitat selection.

In this study, we evaluated seasonal habitat selection of wolves whose winter territories encompass either migratory or resident elk subpopulations. Our study area in northwest Wyoming is typical of many landscapes in the western US where private ranches and public grazing allotments abut expansive wilderness areas. The wolf population we studied was characterized by high turnover rates due to lethal removals of problem wolves or packs by management agencies, often followed by re-establishment by dispersing wolves (see Musiani et al. 2005). In addition, the resident elk subpopulation is growing more numerous on front country ranchlands (Middleton et al. unpublished ms.), which are managed for both domestic livestock grazing and often only light harvest of elk herds focusing on trophy bulls. Understanding how wolf movements are influenced by shifting prey distribution in such mixed-use landscapes can aid in the effort to integrate the management of large carnivores, ungulates, and domestic livestock. We sought to evaluate the influence of elk distribution and human disturbance on seasonal wolf habitat selection by using fine-scale GPS movement data from four wolf packs over three years. We took a comparative approach, by contrasting the habitat selection in both summer and winter for a wolf pack living with year-round availability of resident elk and three wolf packs living with limited summer availability of migratory elk.

Study area

We studied wolf habitat use in the Absaroka Mountains of northwest Wyoming, including habitats just inside the eastern border of YNP and east to the town of Cody, Wyoming (Fig. 1.1). Land jurisdiction is primarily US Forest Service, with a mix of public, private and state land. The dominant vegetation types include alpine, subalpine, and montane meadows (≈ 40%), subalpine deciduous shrubland (20%), subalpine spruce-fir forests (13%), Douglas fir (*Pseudotsuga menziesii*) forests (11%), and sagebrush (*Artemesia)* steppe (6%). The elevation of the study area ranges from 1,738 to 3,734 m. The Clarks Fork and Cody elk herds consist of partially migratory elk. The migratory elk subpopulation winters in low-elevation valleys and migrates to the upper reaches of the Lamar River inside YNP during summer. These elk are preyed upon by three wolf packs (Sunlight, Beartooth and Hoodoo packs), and typically at least one additional pack in YNP during summer. The resident elk subpopulation occupies the Absaroka foothills year-round within 16 km of the town of Cody, WY, and is preyed upon by the Absaroka pack. During the years of 2007 – 2009, the study area encompassed the summer and winter range of approximately 4,000-5,000 elk in the Clarks Fork and Cody herds, 4,000 - 6,000 mule deer, 300-400 whitetail deer (*Odocoileus virginianus*), 200-300 pronghorn, and a small number of moose (*Alces alces*) (D.E.M., unpublished data). The study area contained three to five wolf packs each year, and grizzly bears, black bears (*Ursus americanus*), cougars and coyotes (*Canis latrans*) were also present. Several thousand head of cattle were grazed on public and private rangelands within the study area.

METHODS

Capture and collaring

We captured 14 wolves between 2007 and 2010 by aerial darting in winter (n = 12) and leghold trapping in summer (n = 2). Four wolves were captured in the resident elk area (Absaroka pack) and 10 wolves were captured in the migratory elk area (Sunlight pack: n=4, Hoodoo pack: n=3, Beartooth pack: n=3). Each wolf was immobilized with10 mg/kg Telozol for trapping efforts and 17 mg/ kg for helicopter capture (Kreeger and Arnemo 2007), delivered by a Cap-Chur Palmer dart gun; all wolves were fitted with GPS collars. Twelve wolves were fitted with Argos GPS collars (Model TGW-3580, Telonics Inc., Mesa AZ), programmed to acquire a fix once every three hours, and three wolves were fitted with remotely downloadable collars (4400s Lotek Wireless, Newmarket, Ontario) that recorded one fix every 20 minutes during the summer months only (July-October). Argos collars were deployed for one full year, and remote-downloadable collars were deployed for one to three months.

Adult female elk were captured via helicopter netgunning and fitted with GPS collars (Telonics TGW-3600) in January 2007 (n = 60) and 2008 (n = 10). Collars were programmed to record a fix every 3 hours on summer and winter range, and every 8 and 24 hours respectively for the duration of migratory periods of September – October and April – June. The elk collars were programmed to drop off after 3.25 years. All animal captures were conducted according to protocols approved by the University of Wyoming's Institutional Animal Care and Use Committee.

Habitat selection analysis

To estimate the influence of landscape variables on seasonal wolf habitat use we used the approach suggested by Marzluff et al. (2004), which uses kernel methods to translate point locations into a continuous estimate of intensity of use (i.e, the height of the kernel). We used each collared wolf in each season as the sampling unit, estimating a unique set of selection coefficients for each individual in each season. We characterized summer and winter seasons based on median elk migration dates of winter range departure and arrival for a subsample of elk collars that were retrieved in spring 2009 (n=9). Based on these criteria, we defined summer as May 27 – October 27 and winter as October 28 – May 26 in both migratory and resident elk areas.

For each wolf, we delineated the available habitat in summer and winter by creating a 99% volume contour from a fixed kernel density estimate (Hawth's Tools; Beyer et al. 2005). We used 80% of the optimum bandwidth as a smoothing factor for each dataset (Kie and Boroski 1996, Kie et al. 2002, 2010), which we calculated for each wolf's dataset using the Animal Space Use Tool (Horne and Garton 2007). The 99% volume contour with 80% optimum smoothing factor appeared to effectively represent habitat available to wolves for a third-order selection analysis (Buskirk and Millspaugh 2006).

We were primarily interested in how wolf habitat use was influenced by elk distribution, roads, distance to den, and other landscape features, including distance to forest edge, and elevation. We predicted that wolves in both resident and migratory elk areas would select strongly for elk, except for wolves in the migratory elk area in summer, when elk move to remote high-elevation habitat within YNP. All GIS covariates and response kernel rasters were created using a 100 m cell size. To estimate elk distribution, we created fixed kernel density estimates using location data from 80 elk within the study area for summer and winter. Elevation was described with a digital elevation model (DEM) obtained from the US Geological Survey (http://seamless.usgs.gov/). Wolves respond differently to roads that experience different levels of human use (Thurber et al. 1994), so we estimated a primary road layer consisting of any roads receiving daily traffic, year round. Road polylines (U.S. Detailed Streets, 2002) were edited using satellite imagery (NAIP Digital Ortho Photo Image 2007). We then created a distance to nearest road raster using the Spatial Analyst distance function (linear). We expected wolves to avoid roads less in winter when elk were concentrated at low elevations near road corridors, a pattern that has been observed elsewhere (Potvin et al. 2005). To relate wolf use to explanatory GIS variables, we created a sampling grid of 500m x 500m cells, created around regularly spaced center points that were clipped to the 99% volume contour for each wolf in each season. For each individual cell in the sampling grid, we estimated mean wolf utilization (height of the kernel) and the mean of each GIS covariate using Spatial Analyst zonal statistics tool (ArcMAP 2009). We then standardized values for each covariate per wolf.

Analyzing each individual wolf in each season separately, we modeled probability of use as a function of habitat variables using PROC GLIMMIX in SAS 9.2 (2009), with a log link, and a Gaussian error term. We modeled spatially correlated residuals using a spherical decay function as a random effect by wolf, thereby addressing the error in selection coefficient estimates that would otherwise be biased low (Marzluff et al. 2004). PROC GLIMMIX fit a unique sill and range value for each wolf (SAS Institute INC 2006) with no input parameters, consistent with the methods described by (Kleinschmidt et al. 2001). Using kernel methods to estimate habitat use as the continuous response variable provided better biological accuracy and fewer problems with convergence than did our earlier efforts modeling counts directly (see also Hebblewhite and Merrill 2008).

Mixed-effects modeling techniques have recently been used to estimate hierarchical responses (e.g., wolves and packs) and individual responses to habitat covariates (Hebblewhite and Merrill 2008). Because the wolves in our study varied widely in the degree of spatial correlation in their use patterns, and because we could not achieve model convergence in models that included all wolves and seasons, we estimated selection coefficients for each wolf separately in each season. This approach of modeling wolf habitat use provided a readily transparent means to characterize differential habitat associations of individual wolves. This approach yielded n=8 sets of selection coefficients in the migratory elk area and n=3 sets of selection coefficients in the resident elk area in each season. We sought to evaluate selection or avoidance for each habitat variable (i.e., whether coefficients were different from zero) and to determine if the strength or direction of selection differed between wolves in migrant or resident elk areas in each season, thereby using a functional data analysis approach (Zhao et al. 2004). To evaluate selection coefficients for migratory and resident elk areas in each season, we estimated bootstrapped confidence intervals by first randomly sampling with replacement from the wolves in each area, then drawing a bootstrap coefficient at random from a normal distribution using the selection coefficient as the mean and the variance estimate produced by GLIMMIX. Significant selection was determined by evaluating if 95% bootstrapped confidence intervals overlapped zero. To test for differences in the strength of selection between seasons and between migratory and resident elk areas, we conducted a similar bootstrap procedure, except that we used the bootstrapped differences and drew randomly from the distribution of normally distributed differences between selection coefficients of compared groups.

Because nocturnal and diurnal selection patterns often differ in wolves due to lower levels of human activity at night (Vila et al. 1995, Hebblewhite and Merrill 2008), we sought to examine the difference in distance to road between day and night locations. Because wolves exhibit more nocturnal activity near human development (Theuerkauf 2009), we expected wolves in our study area to be closer to roads during night time, and that the difference between day and night would be most pronounced during winter when prey aggregate near roads. We identified daylight hours by monthly averages calculated by mean sunrise and sunset times (http://aa.usno.navy.mil), and assigned each wolf location to day or night time periods. We then calculated an average distance to road measure during day and night, paired for each pack in each season, and tested for differences between day and night use of road habitat using a paired t-test.

RESULTS

Winter

Wolves in both resident and migratory elk areas showed significant selection for elk-rich habitat in winter (Fig. 1.2), supporting our predictions. In the migratory elk area, wolves showed stronger selection for elk (β_{MIG} = 0.0274) than those in the resident elk area (β_{RES} = 0.0085) although this difference was not significant (95% CIs were highly overlapping: Table 2; Fig. 1.3). As we expected, wolves in migratory elk areas were attracted to road habitat (β_{MIG} = -0.1861), however, contrary to our predictions, wolves in resident elk areas avoided roads in winter (β_{RES} = 0.0618, Table 1; Fig. 1.4).

Wolves in both areas showed significant selection for habitats close to the den (β_{MIG} = -0.4887, β_{RES} = -0.1950, Table 1) in winter, but such selection was stronger for wolves in the migratory elk area than in the resident elk area (Fig. 1.5, Table 2). This relationship could be driven by movements in the months of April – May when wolves tend to localize around the den (our winter time period ended May 27); inspection of wolf locations indicated that they spend time near their dens throughout winter. Wolves in the migratory elk area showed stronger selection for lower elevation habitats than did wolves living in resident elk areas (Table 2), likely due to the more rugged topography in the migratory elk area. In contrast with other studies (Bergman et al. 2006), forest edge habitat did not influence wolf habitat use patterns (Table 1).

Summer

In contrast with our prediction, wolves in the migratory elk area showed selection for elk-rich habitat in summer (β_{MIG} = 0.0152, Table 1) despite most elk migrating away from wolf den areas (Fig. 1.3). Wolves in the resident elk area selected more strongly for elk (β_{RES} = 0.0711) than wolves in the migratory elk areas, and their selection for elk was also stronger in summer than winter (Table 2; Fig. 1.4). In the migratory elk areas, wolves neither selected nor avoided roads in summer (β_{MIG} = 0.0092), while wolves consistently avoided roads in the resident elk area (β_{RES} = 0.1704, Table 1; Fig. 1.6). In the resident elk area, wolves selected for their dens more strongly in summer (β_{RES} = -0.4166) than winter (β_{RES} = -0.1950, Table 1). This pattern was different for wolves living in migratory elk areas, which showed similar levels of selection for habitats close to their den between seasons (Fig. 1.5). Although we expected wolves in the migratory elk areas to spend less time at the den compared with the resident elk area, there was no difference between areas in selection for den in summer (Table 2). Contrary to what we predicted, wolves in both prey areas selected lower elevation habitats than available, likely because they use high elevation habitat with elk but spend more time at moderate elevations. Wolves used habitat randomly with respect to forest edge habitat in summer (Table 1). Trips to high elevation summering elk likely caused this result, as wolves may spend more time at comparatively lower elevations close to the den. Several wolves in migratory elk areas took extraterritorial forays in summer in the direction of summering migratory elk (n = 3 animals, total 7 trips; Table 2), but wolves in the resident elk area did not exhibit this behavior .

Wolves living in both migratory and resident elk areas showed similar differences in their use of road habitat in day compared to night. As expected, pairing mean day and night locations within each pack and season, we found that wolves used habitat closer to roads at night compared to day. This effect differed between seasons, with an average 392 m (SE = 163, P=0.004) difference in winter and a 134 m difference in summer (SE = 37, P = 0.013; Fig. 1.7).

DISCUSSION

Wolf habitat selection patterns differed between adjacent areas that were dominated by migratory versus resident elk, affirming the importance of prey migration as a predictor of wolf movements. We predicted that wolves in the migratory elk area would not select for elk-rich habitat in summer, due to den-related movement constraints and availability of alternate prey;

however, both migratory and resident elk area wolves selected for elk in summer. While we expected wolves in the resident elk area to select for elk-rich habitat in summer, the difference in strength of selection for elk between summer and winter was much greater among wolves in the resident elk area, than the migratory elk area. Contrary to our main prediction, we also found that wolves living in the migratory elk area appear to adjust behaviorally throughout the summer to access elk distant from their den sites, by moving to rendezvous sites, accessing nearby resident elk, and taking extraterritorial forays towards summering migratory elk. In the resident elk area, the weaker selection for elk in winter was likely caused by wolf avoidance of human activity associated with the main north-south highway that bisects the elk winter range (Figs. 1.4 & 1.6). A county road also bisects the winter range of the migrant elk, but this road was not avoided by wolves (Fig. 1.2A), likely because the wintering elk were tightly associated with the valley bottom where the road is located. Wolf avoidance of roads appeared to have more significant impacts on disassociating wolf movements from elk-rich habitat than the 40-55 km seasonal prey migration. We also found that wolves in both areas use habitats close to human development more frequently during the night than the day (Vila et al. 1995, Chavez and Gese 2006). Such a strategy may allow wolves to access elk that aggregate in areas of high human activity (i.e., by using the cover of darkness to hunt). Although we found considerable variation between individuals and packs, likely constrained by age, sex and territoriality, our findings suggest that the migratory habits of elk can influence wolf habitat selection in predictable ways, and the variation among packs likely contributes to our understanding of how these effects may play out in different systems. These findings bear on several aspects of wolf ecology and management, particularly with respect to the expanding distribution of wolves, the changing migratory habitats of elk, and the continual progression of human development.

Variation in human activity

Wolves in the migratory and resident elk areas responded to human activity (e.g., roads and traffic) in disparate ways that appear to be related to the density and distribution of their prey and the intensity of human use. Wolves have often been observed to avoid areas with high road density (Mladenoff et al. 1995), except in cases where they might access prey- rich areas close to roads (Potvin et al. 2005), or use low-traffic roads for travel (Thurber et al. 1994). We found that in winter, wolves in the resident elk area failed to access the most elk-rich habitat immediately adjacent to a major highway (Fig. 1.2b), and wolf locations away from the road were consistent with known distributions of bull elk during winter (D.E.M., unpublished data). The high abundance of elk within the resident elk area pack's territory (Middleton et al. unpublished ms.) may have facilitated such a weak association between wolves and collared cow elk. In the migratory elk area, wolves showed significant selection for roads (and associated housing) that run through the core of their winter range. There exist few other habitats where wolves in migratory elk areas can predictably locate large groups of prey outside of these valley bottoms in winter. Despite differences in avoidance or selection of roads, all wolves used habitat closer to roads at night, and differences in nocturnal activity were strongest in winter when elk are close to roads (Fig. 1.7). These results confirm that 1) wolf use of human-dominated landscapes occurs to a greater degree when high prey density provides a strong incentive (Treves et al. 2004); and 2) where prey exist close to humans, wolves adjust by using a greater degree of nocturnal behavior (Theuerkauf 2009), which decays with distance to road (Hebblewhite and Merrill

2008). For example, (Hebblewhite and Merrill 2008) show wolf packs with home ranges farther from human development have a decreasing tendency for human-driven nocturnal activity, while our results suggest the same effect for wolves existing farther from roads in summer compared to winter (Fig. 1.6). Together, these findings indicate that wolves respond dynamically to human disturbance as they seek prey (Vila et al. 1995, Theuerkauf 2009), which might allow them to tolerate or even use areas with low levels of human development.

Wolves in the resident elk area appear to have a distinct advantage in selecting for elk-rich habitat while avoiding roads on a year- round basis (Fig. 1.8a, b). However, wolves living in the migratory elk area both select for elk and avoid roads to a greater extent only in summer (Fig. 1.8b). Presumably these tradeoffs between avoiding humans and the associated risk of mortality while acquiring food (Whittington et al. 2005) would cause wolves in the resident elk area to have greater fitness than wolves in the migratory elk area (Messier 1984). Ultimately, however, given immigration, high quality habitat patches with growing available resident elk will likely result in continued high densities of wolves via turnover and reestablishment (Musiani et al. 2005) despite mortality. Of even greater consequence to population dynamics in this system is whether or not wolves are involved with livestock depredations and then undergo subsequent lethal removal. However, our wolf habitat selection results indicate wolves will continue to be attracted to these landscapes with resident elk.

Do wolves follow migratory prey?

In migratory elk areas, we expected wolf selection for elk to weaken once elk completed their spring migration (Garrott et al. 2005). However, the strength of wolf selection for elk in the migratory elk area did not differ between seasons (Table 2), despite considerable change in the seasonal distribution of migratory elk (Figs. 1.3A & 1.4A). This result would suggest that some individual wolves may follow migratory prey (Table 3); however, wolves appear to use four discernible strategies in summer to cope with seasonal shifts in prey availability. First, some wolves in the migratory elk area did not alter their distribution seasonally and showed weak or negative selection for elk, which could have been afforded given availability of alternate prey, similar to Northwest Alaska described by Ballard et al. (1997). In this system, predation data that we have collected indicate that wolves may be able to hunt sufficiently by using local deer as an alternate prey source, killing about 50% each of deer and elk in summer months (A. Nelson, Chapter 2). Second, the Sunlight pack, which occupies a migratory elk territory adjacent to the resident elk area, killed elk in the periphery of the nearby resident elk herd during the summer months (A. Nelson, Chapter 2). Third, some animals made extraterritorial forays towards the summer range of the migratory elk (n = 3 animals, 7 total trips), behavior typical of wolves considered to be partially migratory (Ballard et al. 1997). And fourth, the Hoodoo and Sunlight packs appeared to shift their rendezvous sites closer to the elk summer range – for the Hoodoo pack in the direction of summering migratory elk, and for the Sunlight pack close to summering resident elk. These data suggest that while wolves may spatially respond to the shifts in density of their preferred prey, encountering other alternate prey and having nearby resident elk may buffer them from more extreme fitness costs that wolves denning in areas with a single migratory prey species experience (Frame et al. 2009). In Southwest Quebec, Canada, wolves living in low prey areas had higher adult and pup mortality compared to those living in high prey areas (Messier 1984), and wolves had larger litters in habitats with high levels of ungulate biomass (Boertje and Stephenson 1992). Our results, and the results of others, suggest there are distinct rewards to accessing prey-rich habitat despite the costs of travel. Further study would be required, however, to assess the threshold distance at which such advantages outweigh the cost of traveling long distances.

Whether or not wolves follow migrating elk is mediated by the constraints placed on wolves as they regularly deliver food to young at den and rendezvous sites throughout the summer months (Thurston 2002). Consistent with our expectations, wolves in the resident elk area spent more time near their den during summer (Table 2, Fig. 1.5). The ability of wolves living in the resident elk area to tend their young at the den while accessing abundant prey may confer fitness benefits, similar to higher rates of pup survival observed in wolf packs that denned close to caribou migration routes in Alaska (Frame et al. 2009). Wolves in the Yellowstone area establish dens in late winter (Thurston 2002) when migratory elk remain densely aggregated on low-elevation winter ranges. Thus, in other systems, when prey migrate away during summer, wolves may be forced to travel long distances from the den to locate prey (Walton et al. 2001), whereas wolves with resident prey can access an abundance of prey close to their den (Fig. 1.3b). Such a pattern, whereby migratory elk departure for high-elevation summer range decouples wolves from the distribution of elk in summer, has been hypothesized to occur in much of the GYE (Garrott et al. 2005). However, our observations indicate strategies wolves may use to cope with this dilemma. One strategy that may explain why wolf selection for elk remained positive after elk dispersed from winter range is moving centers of activity or rendezvous sites closer to summering groups of elk. We documented in one of three packs in the migratory area show this behavior: the Hoodoo pack ceased activity at their natal den after July 23rd, presumably moving to a rendezvous site 5.5 km closer to summering migratory elk. Indeed, wolves can move their pups to rendezvous sites that are within 1- 8 km from the den as summer progresses (Mech and Boitani 2003), distances which may be related to seasonal changes in distribution of prey (Packard 2003). For example, Scott and Shackleton (1982) found that wolves moved to rendezvous sites in the direction of the seasonal range of black tailed deer (*Odocoileus hemionus columbianus*). This type of shift in homesite location likely explains some selection for elk during the summer. In Alaska, where wolves are generally non-territorial in the season preceding whelping, they select their dens close to tree line to maximize the time they can hunt migratory caribou (Heard and Williams 1992). In our study area, however, wolves are strongly territorial during winter months preceding den selection and may have limited flexibility in selecting natal den sites. There has been a lack of consensus about whether large carnivores can effectively follow the migrations of their prey. Our work suggests that wolves use several different behavioral strategies to cope with seasonal fluctuations in the distribution of their prey.

MANAGEMENT IMPLICATIONS

Migratory prey, resident prey and livestock depredations

In the resident elk area, our results suggest that encounters between wolves and livestock may be more frequent in pastures where elk and cattle comingle and relatively uncommon in pastures that are close to roads and human activity, during the day. Although we did not directly measure the depredation rates of wolves on cattle, our findings are consistent with prior studies in the northern Rocky Mountains that found elk density in pastures increases the risk of wolf-cattle conflicts (Bradley and Pletscher 2005). For livestock producers and wildlife managers, separation of wildlife (in this case elk) and livestock is a topic of increasing management importance for disease concerns; however, our results suggest that there may be additional benefits to maintaining separation to decrease livestock predator encounters. Additionally, such knowledge of the timing of cattle and elk comingling could be used to increase the level of attention (i.e., range riders) that ranchers provide their cattle during key times of the summer. However, these options can be expensive and at times may require much effort with limited success. An alternative management consideration may be the augmentation of efforts to reduce the density of elk that comingle with these livestock, which has proven complicated when ranch owners or managers are averse to allowing high levels of hunter access (Haggerty and Travis 2006). Several agencies in the region are attempting to address this issue through improved partnerships and hunter access programs.

In migratory elk areas, our study yielded two findings that could help predict wolf-livestock encounters in areas with migratory prey and low human density. Wolves in both prey areas selected for elk-rich habitat in winter (despite its close proximity to people) and habitat close to their natal den year round (Fig. 1.2a). Thus, livestock that graze in areas of low human density among wintering elk may encounter wolves commonly, especially at night. In our study area, livestock in the migratory elk area generally spend winters elsewhere, and do not overlap with wintering elk during the most vulnerable period of calving. However, in other parts of the GYE, producers calve in winter months among wintering elk, and this may partially explain winter and spring depredations that happen in these areas. Dens and rendezvous sites are known to be hotspots for conflicts with cattle (Oakleaf et al. 2003, Bradley and Pletscher 2005), and our results support the likelihood of increased wolf-cattle encounters around dens irrespective of the migratory behavior of prey. Because den selection is known to be related to predictable, aggregated food sources (Ciucci and Mech 1992), and appears to be related to wintering elk in our system, knowledge of prey distribution may assist in predicting where wolves den and hunt on the landscape, zones which may be high risk for conflict once cattle are turned out. Most producers are not afforded the flexibility of altering pasture use patterns due to consideration of grass phenology and the peak of poisonous plants among other restrictions. However, if necessary to use pastures with elk or close to dens, it may prove beneficial to do so when calves are older and less vulnerable.

Human-induced predation refugia for elk populations

Wolf pack avoidance of human activity - and specifically, roads - may translate to fitness benefits for the resident elk subpopulation we studied. Wolves are a primary predator of adult elk in the GYE (Smith et al. 2004), an important secondary predator of elk calves (National Research Council 1997, Barber-Meyer et al. 2008), and their predation pressure can influence lifetime reproductive contribution in ungulates (Kjellander et al. 2004). Thus, wolves' avoidance of human activity may effectively generate refuge areas for prey. In Banff National Park, elk prospered in and around the townsite of Banff, which was avoided by wolves (Hebblewhite and Merrill 2007). A similar pattern has been observed elsewhere in the Madison valley of YNP, where White et al. (2009) suggested that elk have begun to favor areas of high visitor traffic in winter following wolf establishment (White et al. 2009). In our study, resident elk that cross a two-lane highway (i.e., WY Highway 120) experience very low levels of exposure to wolves, which is likely caused by wolf avoidance of the highway. Recent changes in the demography of migratory and resident elk support the notion that resident elk are benefiting from lower rates of predation (Middleton et al. unpublished ms.). It is likely this is especially significant with respect to calf production; wolves are a predator of elk calves in YNP (Barber-Meyer et al. 2008, Metz et al. 2011 *in press*). The resident subpopulation currently experiences calf: cow ratios around 40 per 100, whereas the migratory subpopulation has declined to calf ratios of 15 per 100 cows, although poor summer habitat quality is also an important contributing factor (Middleton et. al. unpublished ms.). As carnivore populations are restored to the Rocky Mountain West, human-induced refugia may become an increasingly important driver of demographic differences among prey populations living along a gradient of human development.

Growing resident front country populations of elk

There is growing tension in the northern Rockies between the interests of producing cattle and harboring wildlife populations on private and public rangelands (Haggerty and Travis 2006), and thus a growing need for integrative wildlife and domestic species management. A key finding of our study, that wolf selection for elk is likely to draw wolves into close contact with cattle operations, highlights these challenges. Livestock loss due to the co-occurrence of wolves, elk, and cattle on private and public lands (Bradley and Pletscher 2005) can reduce the tolerance for living with carnivores (Bangs et al. 2005). In turn, lethal removal of wolves associated with domestic sheep and cattle influences wolf demography throughout the Northern Rocky Mountain region, as it is the most common cause of death for wolves outside protected areas (Smith et al. 2010). These consequences of comingling among elk, cattle and wolves are likely to become particularly acute if the ratio of migratory to resident prey continues to diminish in the region, providing “attractive sinks” to wolves outside of wilderness areas into the agricultural matrix (Hebblewhite and Merrill 2008). However management actions play out, our results suggest areas of congregating prey populations will remain important attractants to the fine-scale habitat use patterns of wolves. Some management options exist that seek to prevent elk and cattle from comingling. In the Paradise Valley of Montana just outside of YNP, Montana Fish, Wildlife and Parks employs an elk herder to keep elk and cattle separate during the winter season when elk are driven down onto low elevation ranchlands, mainly for disease reasons. Treves (2009) suggested managers increase hunter access and potentially reduce the spatial overlap of wolves and cattle by displacing wolves with hunters and reducing elk populations in these areas through hunter harvest. Managing wolves into the future is likely to require creative solutions such as these and others involving knowledge of prey demography and movements that can sustain wolf populations while reducing wolf-livestock conflicts.

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Table 1.1. Selection coefficients averaged among collared wolves for summer and winter models in the migratory (n = 10 wolves) and resident (n = 4 wolves) elk areas. Confidence intervals are bootstrapped among individual wolf coefficients and significance ($P < 0.05$) denoted by bold text.

	WINTER MODEL						SUMMER MODEL					
	Migratory area			Resident area			Migratory area			Resident area		
	β mig	95%Cl-mig		β res	95%Cl-res		β mig	95% Cl-mig		β res	95%Cl-res	
elk[Ψ†]	**0.0274**	0.0029	0.0573	**0.0085**	0.0006	0.0179	**0.0152**	0.0025	0.0283	**0.0711**	0.0522	0.0906
road [Ψ† Φ ί]	**-0.1861**	-0.2659	-0.1156	**0.0618**	0.0310	0.0933	0.0092	-0.085	0.1204	**0.1704**	0.1372	0.2052
forest edge	0.0007	-0.003	0.0053	-0.0019	-0.0043	0.0004	0.0002	-0.002	0.0029	-0.0025	-0.0082	0.0026
elevation[Φ]	**-0.0424**	-0.06	-0.027	-0.007	-0.0145	0.0024	**-0.0296**	-0.0459	-0.0134	**-0.0334**	-0.0573	-0.0103
den[† Φ]	**-0.4887**	-0.735	-0.29	**-0.195**	-0.3101	-0.091	**-0.422**	-0.6753	-0.2075	**-0.4166**	-0.4838	-0.3572

Ψ = Selection coefficients different between migratory and resident elk areas in summer.
† = Selection coefficients in the resident elk area are different in summer and winter.
Φ = Selection coefficients different between resident and migratory elk areas in winter.
Ί = Selection coefficients different are different between summer and winter in the migratory elk area.

Table 1.2. Wolves in study area that took extraterritorial forays lived in the migratory elk area and generally travelled long distances towards migratory prey**.** This table does not include dispersal resulting in death (n = 2). Forays typically began either at a den or rendezvous (RV) site.

Wolf ID	Age	Start	End	Start	Destination	Dist. (km	Num. days
608M	3	6/17/2007	6/24/2007	den	YNP: Specimin ridge	155.8	7
608M	3	10/11/2007	10/14/2007	RV	YNP: Cache cr.	65.3	3
608M	3	10/21/2007	10/23/2007	RV	Republic cr.	55.1	2
664M	4	7/4/2008	7/15/2008	den	YNP:Lamar x Soda Butte cr.	231.4	11
664M	4	7/17/2008	8/2/2008	den	YNP: Hellroaring	444.8	16
673F	1.5	10/15/2008	10/28/2008	Crandall cr.	YNP: Jasper bench	158.4	13
697M	2	4/17/2009	4/27/2009	den	YNP: Lamar	83.7	10
					Average	170.6	8.9

Figure 1.1. Study area map showing the year-round distribution of wolf study packs using areas with migratory and resident elk in northwest Wyoming. Year-round elk locations from GPS collars are indicated for migratory (black dots) and resident (white dots) subpopulations. The three wolf packs living in the migratory elk area (white 95% use contour, Sunlight, Hoodoo, and Beartooth packs) overlap slightly with one another and the one wolf pack (Absaroka) living in the resident elk area (black 95%use contour).

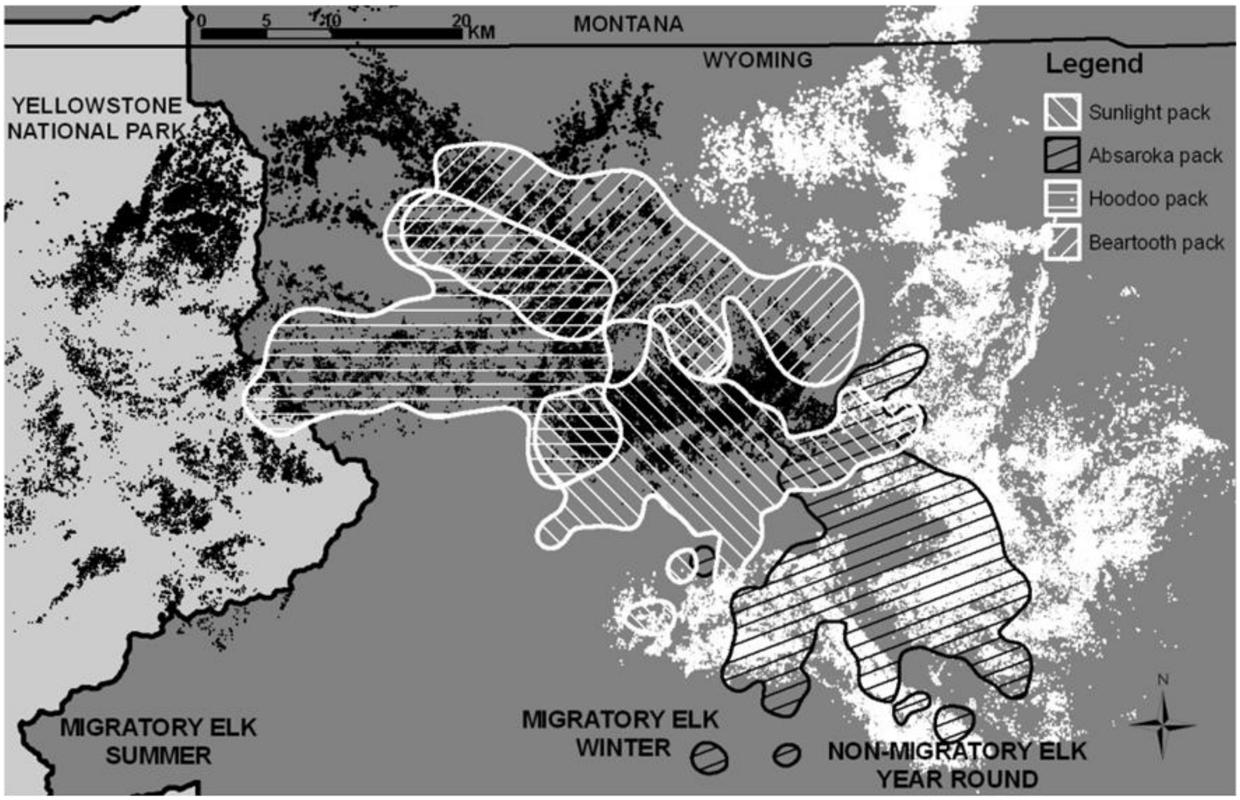


Figure 1. 2. Locations of wolf packs living in the migratory elk area (Panel A) are strongly associated with the wintering elk (60% kernel contour), whereas wolf packs living in resident elk area (panel B) are weakly associated with resident elk that winter near a major highway.

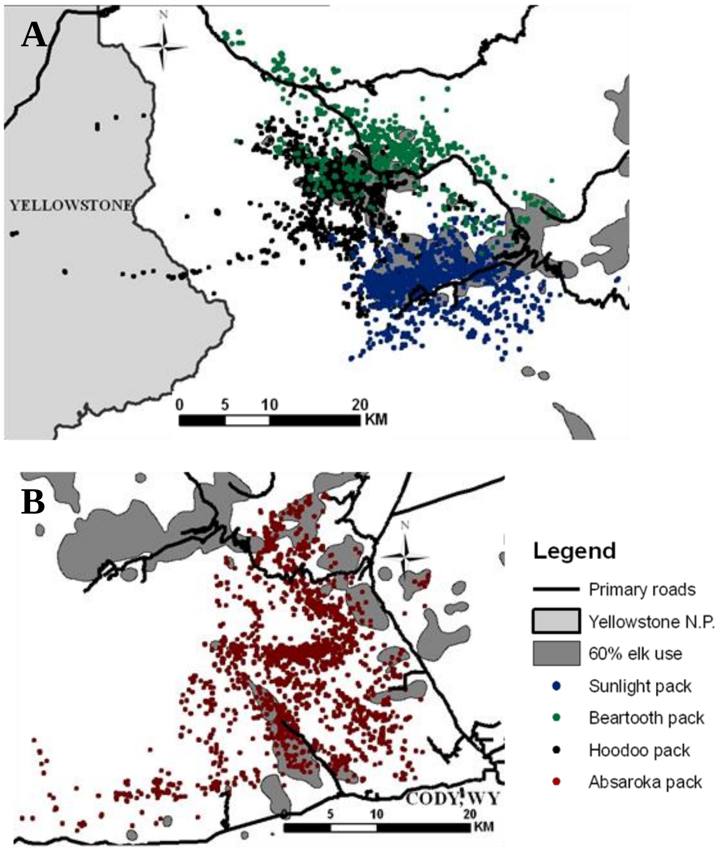


Figure 1.3. Wolves are associated with elk- rich habitat across areas, but the strength of association is mediated by seasonal migratory patterns of elk. Individual wolf selection coefficients for elk density with the population means (hollow circle) and bootstrapped confidence intervals for wolves living in the migratory and resident areas in winter (panel A) and summer (panel B). Packs using the migratory elk area included Hoodoo (X), Beartooth (diamond), and Sunlight (triangle) packs, with the Absaroka pack (square) using the resident area.

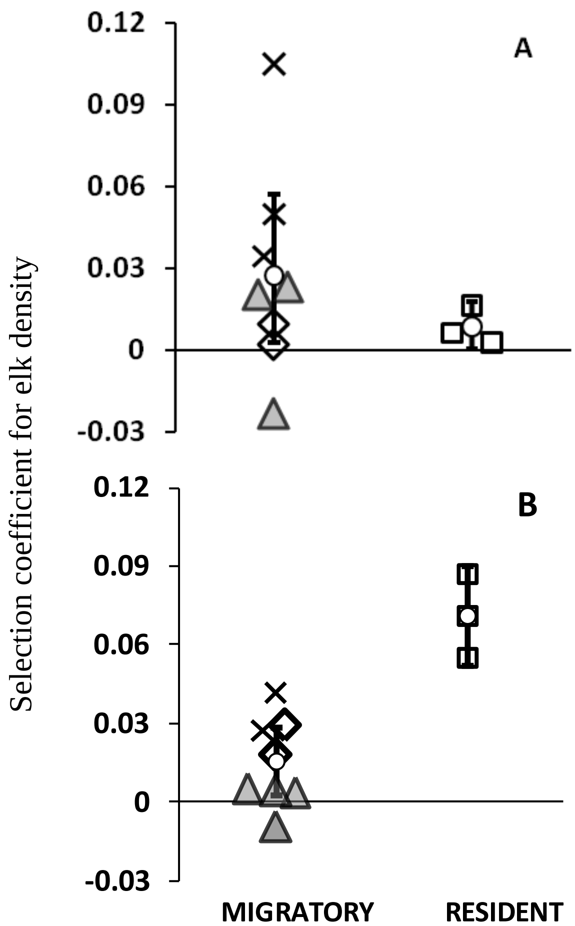


Figure 1.4. Locations of wolf packs living in the migratory elk area (Panel A) access some areas of summering migratory and resident elk (60% kernel contour), whereas wolf packs living in resident elk area (panel B) are strongly associated with resident elk on summer range.

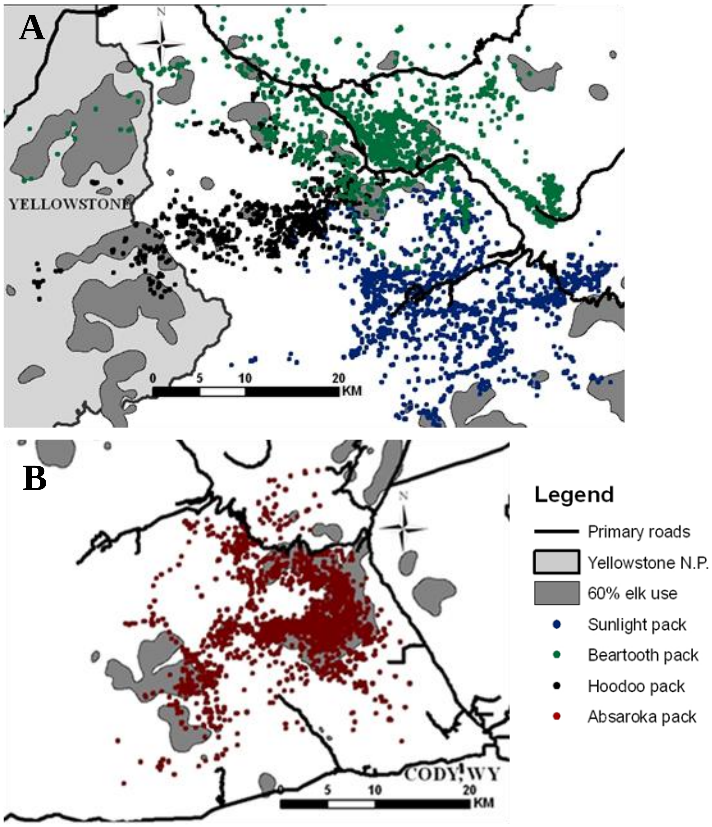


Figure 1.5. Individual wolf selection coefficients for proximity to natal den are different in winter between wolves living in migratory and resident elk areas (A); and between summer (B) and winter (A) for resident elk area wolves. The population means (hollow circle) and bootstrapped confidence intervals shown for wolves living in the migratory and resident elk areas. Negative selection coefficient indicates selection for feature, and positive coefficient indicates avoidance. Packs using the migratory prey area included Hoodoo (X), Beartooth (diamond), and Sunlight (triangle) packs, with the Absaroka pack (square) using the resident area.

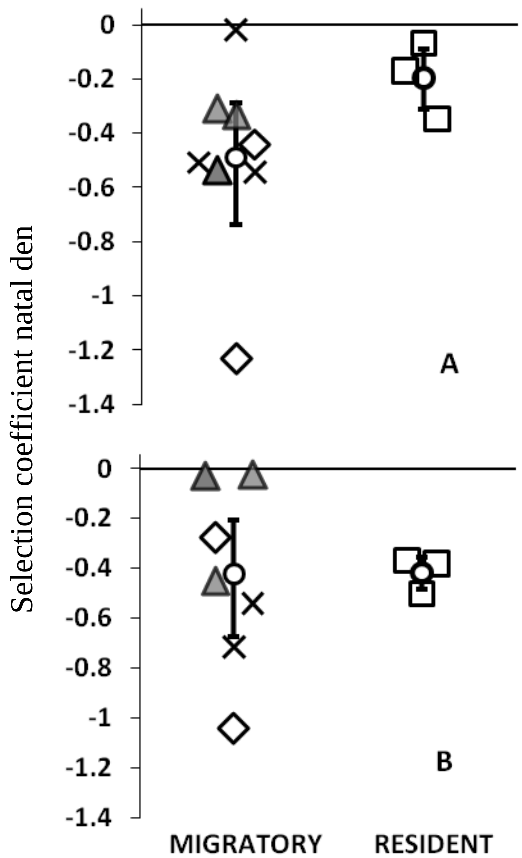


Figure 1.6. Wolf selection for habitat close to roads varied by season and by area. Individual wolf selection coefficients for open roads with the population means (hollow circle) and bootstrapped confidence intervals for wolves living in the migratory and resident areas in winter (panel A) and summer (panel B). Negative selection coefficient indicates selection for feature, and positive coefficient indicates avoidance. Packs using the migratory prey area included Hoodoo (X), Beartooth (diamond), and Sunlight (triangle) packs, with the Absaroka pack (square) using the resident area.

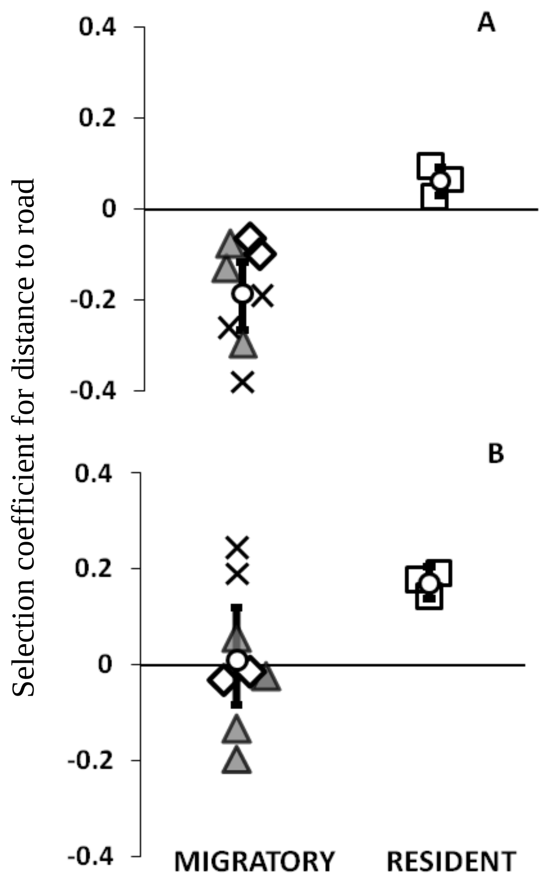


Figure 1.7. Wolves used landscapes closer to roads at night than during the day. Mean differences of day vs. night paired locations by pack are shown by open circles (n = four packs and 14 individual wolves).

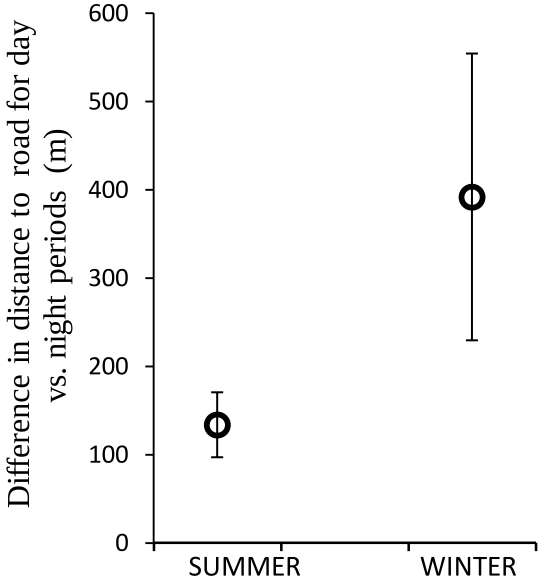
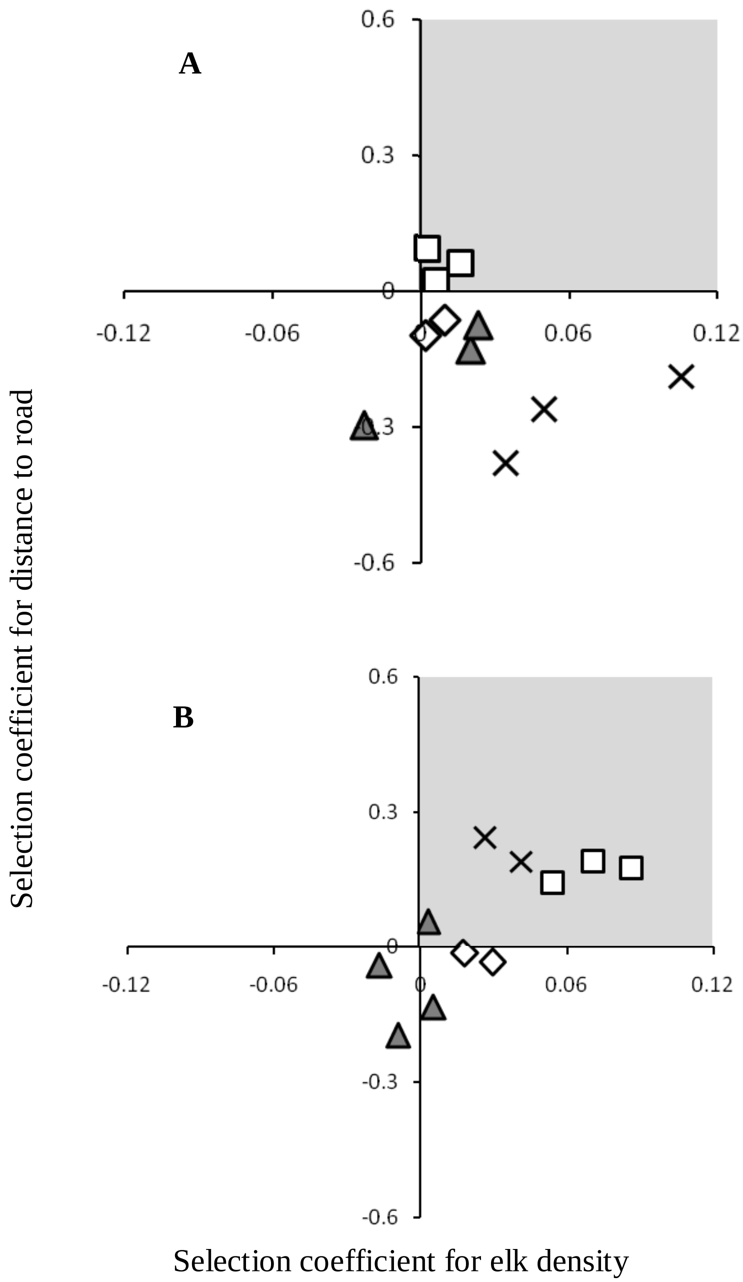


Figure 1.8. Individual wolves varied in the strength of selection for elk and their avoidance of roads. Wolves living in the resident elk area were able to select for elk and avoid roads (square marker; shaded quadrant in upper right) in both winter (panel A) and summer (panel B). Wolves in the migratory elk area, which included the Hoodoo (X), Sunlight (triangle) and Beartooth (diamond) packs, appeared to tradeoff these two resources to some degree, especially in winter when migratory elk move to low-elevation valleys close to human settlements. Positive coefficients for roads indicate avoidance.



CHAPTER 2: LANDSCAPE PATTERNS OF WOLF DEPREDATIONS OF CATTLE IN NORTHWEST WYOMING: A COMPARISION BETWEEN AREAS WITH MIGRATORY AND RESIDENT ELK

ABSTRACT: As large carnivores recover in many wilderness areas, wildlife management agencies must seek ways to minimize private property damage while maintaining viable populations, and the success of these efforts can influence public tolerance for carnivores. Although much is known about carnivore-livestock conflicts, our knowledge of what drives these processes in the Northern Rocky Mountains is still emerging amid the dynamic conditions of recovering predator populations (gray wolves [*Canis lupus*] and grizzly bears [*Ursus arctos horribilis*]), declining elk productivity, and the re-distribution of migratory and resident elk subpopulations. There has been little research to date that examines the influence of fine-scale elk distribution and movements on patterns of livestock depredation. In this study, we analyze four years of cattle depredation data, two years of summer and fall wolf predation data (n = 4 wolves), and three years of elk movement data (n = 70 elk) to assess the influence of migratory and resident prey on the location and occurrence of wolf depredations on cattle. Wolves living in migratory elk areas face low densities of their preferred prey in summer, when elk depart for higher elevations inside Yellowstone National Park (YNP), while wolves living in the resident elk area have access to abundant elk year-round. Wolves living in both areas have the potential to interact with several thousand head of cattle. We used logistic regression to compare the relative influence of landscape features on the risk of livestock depredation in the migratory and resident elk areas. We also evaluated the role of migration and native prey availability on wolf diet by comparing the composition of wolf kills in the migratory and resident elk areas. Wolf-

killed cattle were associated with areas that increased encounter rates between wolves and livestock, and these areas were different for cattle living in the migratory elk area and the resident elk area. Depredation sites in the resident elk area were associated with habitats closer to roads and with high elk density, while depredation sites in the migratory elk area were associated with dens, streams, and open habitat away from the forest edge. Our findings indicate that knowledge of ungulate distributions and migration patterns can help understand and predict hotspots of wolf conflict with livestock.

INTRODUCTION

Understanding the factors that drive patterns of wolf depredation of livestock is important to reduce and manage conflicts. Large carnivores inhabit vast homeranges, bringing them into contact with human settlements where they can cause conflicts (Woodroffe and Ginsberg 1998). Wolf-cattle conflicts are associated with a number of landscape features, such as prey distribution, den and rendezvous sites, and forest cover (Dorrance 1982, Oakleaf et al. 2003, Bradley and Pletscher 2005), but a general understanding has yet to emerge. In the Northern Rockies, wolf packs occupy a variety of land-use types, including National Parks, wilderness areas, and private or agricultural land (Oakleaf et al. 2006). Although depredations by wolves represent only a small percentage of livestock losses in the western US (Bangs et al. 2005), they tend to be locally chronic, with some producers carrying a high proportion of re-occurring losses (Mech et al. 2000). Tolerance is often promoted through methods like financial compensation to producers and lethal control of problem wolves (Mech 1995). Often the removal of depredating packs is a temporary solution, however, as it generally results in recolonization by dispersing individuals in subsequent years (Musiani et al. 2005). A better understanding of the landscape attributes that influence wolf-livestock conflicts may enhance the ability of wildlife managers to maintain target levels of wolf numbers while minimizing livestock losses.

The distribution and abundance of native prey is a critical factor influencing where wolves kill livestock on the landscape. Prior studies have found surprisingly divergent patterns, with either a positive or negative influence of prey density on livestock depredation by wolves (Gunson 1983, Treves et al. 2004). A study in Montana and Idaho found that elk presence was a strong predictor of whether or not pastures had cattle depredations (Bradley and Pletscher 2005), and a 25-year study from Wisconsin and Minnesota found that wolves killed cattle more often in townships with higher deer (*Odocoileus virginianus*) densities (Treves et al. 2004). These studies suggest that as wolves seek out native prey, they may learn to hunt cattle (Harper et al. 2005), or kill them incidentally (Treves et al. 2004) where cattle and native prey comingle. We refer to this hypothesis, wherein wolves are strongly attracted to – and tend to kill livestock that co-occur with – the distribution of their native prey, as the Prey Tracking Hypothesis.

Additional considerations in the context of changing native prey distribution are needed to understand the implications of the Prey Tracking Hypothesis. Throughout the range of wolves, the migratory patterns of elk, a primary prey species, are shifting in ways that favors resident (i.e., non-migratory) herds (Hebblewhite et al. 2006). There are several causes for these changes, including increased predation on migrants (Hebblewhite et al. 2006), drought on high-elevation range of migrants (Middleton et al. unpublished ms.), and a low level of hunting pressure and predation on residents that occupy private land refuges (Haggerty and Travis 2006, Hebblewhite et al. 2006). Prior work that we have conducted has shown that patterns of elk migration, especially their summer distribution, influence seasonal wolf habitat selection and may alter wolf travel patterns and encounters with livestock (A. Nelson, Chapter 1.). Despite the importance of elk migration to patterns of wolf habitat selection, little empirical work has examined whether such seasonal dynamics of elk density also influence patterns of cattle depredation on the landscape. As some elk populations shift to favor resident subpopulations existing alongside cattle in mixed-use landscapes (Middleton et al., unpublished ms.), it has been hypothesized that wolf distribution may track such shifts in native prey (Garrott et al. 2005) and lead to more wolf cattle conflicts where elk and cattle comingle. Reconciling whether such changes in ungulate migration will exacerbate or dampen livestock depredations by wolves hinges on understanding the degree to which native prey distribution influences wolf hunting of livestock.

In contrast, wolves also kill cattle when native prey are scarce, a pattern likely caused by declines in native prey availability. In systems with multiple ungulates, declines in preferred prey can result in diet shifts reflective of a change in relative prey abundance, or true prey switching, where preference changes (Garrott et al. 2007). A synthesis of 15 studies conducted in southern Europe found that when prey abundance declines, wolves tend to include a greater amount of livestock as the main component of their diet (Meriggi and Lovari 1996). In an extreme example of this pattern, a study in northern Italy found that wolves preyed almost exclusively on domestic goats when native prey abundance was low (Vos 2000). Regarding seasonal changes in native prey, Garrott et al. (2005) hypothesized that the departure of wolves preferred prey (elk) during summer when cattle grazing begins, may explain some patterns of depredations. In these situations, wolves shift to hunting livestock when native prey become scarce, with the amount of livestock in the diet mediated by availability of alternate prey. We refer to this as the Prey Scarcity Hypothesis.

The manner in which wolves respond to scarcity of native prey is varied and may include: following groups of migrating prey (Forbes and Theberge 1996), using local alternate native prey (Ballard et al. 1997), or killing livestock (Meriggi and Lovari 1996). In Alaska, the degree to which wolves extended their search distance to follow migratory prey depended on the annual availability of alternate prey (Ballard et al. 1997). In northwest Montana, wolves responded to diminishing elk numbers by switching to deer, apparently because hunting wintering deer was more predictable and profitable than dispersed groups of elk (Kunkel et al. 2004). Some studies have shown that depredations occur on ranches with larger groups of cattle (Mech et al. 2000), perhaps due to a high degree of predictability in locating groups of cattle compared to hunting dispersed native prey. In addition to changes in availability, vulnerability of native prey also can shift seasonally (Smith et al. 2004). On the Northern Range of YNP, wolves increased their use of deer from 7% of the diet in May to 14% of the diet in June and July (Metz 2011). However, whether this diet shift is driven by changes in elk and deer vulnerability or availability is unclear. The relative availability and vulnerability of prey species are two key factors that influence shifts in prey selection (Garrott et al. 2007). These factors would predict that with seasonal shifts in prey availability, the extent to which wolves seasonally rely on domestic livestock – or other native alternate prey - may increase, as described by the Prey Scarcity Hypothesis.

Patterns of wolf encounters and kills of native ungulate prey may also inform where wolves kill livestock. There is some debate regarding whether native prey are most vulnerable where wolves travel (Bergman et al. 2006) or where landscape features increase wolf capture success (see Hebblewhite et al. 2005). Kauffman et al. (2007) suggested that landscape attributes mediate the outcome of interactions between wolves and elk, causing elk to be more vulnerable in areas where wolves can best target and capture them. Similarly, Hebblewhite et al. (2005) suggested that topography and openness facilitated wolf-elk encounters, whereas low elevation pine stands increased the likelihood of a successful kill once an encounter had occurred. Because of domestication, antipredator behaviors are generally not as strong in cattle compared to wild prey (Linnell et al. 1999, Muhly et al. 2009), perhaps increasing the importance of factors that influence wolf-cattle encounters alone. The post-encounter success rate of wolves killing elk and bison in Yellowstone is quite low, approximately 21% and 7% respectively (Smith et al. 2000). While this difference is likely due to both prey abundance and ease of killing, we hypothesize that encounters with cattle likely have a greater potential to lead to a successful kill due to diminished antipredator behaviors (Linnell et al. 1999) and the ability of wolves to kill novel or weak prey when the incentive exists (Smith et al. 2000).

Many studies have now revealed the factors that influence vulnerability of native prey to wolf predation (Kunkel et al. 1999, Smith et al. 2004, Gude et al. 2006, Kauffman et al. 2007, Hebblewhite and Merrill 2009). Similar quantitative evaluations of how landscape attributes influence high-risk areas for livestock depredations have been conducted, though at larger scales, and without fine-scale native prey distribution data (Treves et al. 2004; Edge et al. 2011; Treves et al. 2011). In addition to native prey distribution, landscape factors also play a role in the habitats where wolves tend to kill cattle. For example, in Wisconsin, livestock kills occurred in open areas (Treves et al. 2011) and wolf-livestock conflicts have been positively associated with other attributes such as den or rendezvous areas (Bradley and Pletscher 2005), forest cover and remote areas (Dorrance 1982; Bjorge 1983), calving locations, and dead livestock (Fritts 1982). Indeed, an influence of landscape features may account for the difficulty in generalizing the influence of native prey distribution across systems.

We have been studying the interactions among wolves, native prey, and livestock in an area of chronic wolf-livestock conflict in the Greater Yellowstone Ecosystem, where wolf packs generally hunt either resident or migratory populations of elk, their primary prey. We sought to evaluate two predictions that follow from the Prey Tracking Hypothesis. If wolves are strongly associated with native prey during the grazing season, 1) elk distribution should predict wolf depredations of cattle; and 2) depredation rates should increase during time periods when elk and cattle comingle. We also used the comparison of wolves hunting migrant vs. resident elk as a means of evaluating aspects of the Prey Scarcity Hypothesis. First, we sought to evaluate whether the spring migration of elk forced wolves to shift to hunting alternative prey during summer compared to the hunting patterns of wolves in resident elk areas. Next, we asked whether the inclusion of deer in the summer diets of wolves in migratory elk areas mediated their consumption of livestock. We tracked four GPS-collared wolves to identify the location and timing of livestock depredations and prey selection in areas where elk where are migratory or resident. Clarifying how native prey influence where wolves cause chronic livestock conflicts may enhance our understanding of regional control-driven population dynamics (Smith et al. 2010) involving depredating and non-depredating wolf packs.

Study area

Our study area was located in the Absaroka Mountains of northwest Wyoming and consists of habitats just inside the eastern border of YNP, and east to the town of Cody, Wyoming (Fig. 2.1). Land jurisdiction is primarily USDA National Forest Service, with a mix of public, private and state land. The eastern front of the Absaroka Mountains is characterized by rugged topography, prominent rocky peaks, and a patchwork of forest and grasslands. The dominant vegetation types include alpine, subalpine, and montane meadows (≈ 40%), subalpine deciduous shrubland (20%), subalpine spruce-fir forests (13%), Douglas fir (*Pseudotsuga menziesii*) forests (11%), and sagebrush (*Artemesia)* steppe (6%). The average elevation of the study area was 2,404 m and ranged from 1,738 to 3,734 m. The migratory elk subpopulation wintered in low-elevation valleys formed by Sunlight and Crandall Creeks and the Clark's Fork of the Yellowstone River, and summered in the upper reaches of the Lamar River inside YNP. These elk were preyed upon by the Sunlight, Beartooth and Hoodoo packs. The resident elk herd moved only short distances seasonally, occupying overlapping summer and winter ranges in the Absaroka foothills within 10 miles of the town of Cody, WY; they were preyed upon by the Absaroka pack. During the years of 2007 – 2009, the study area encompassed the summer and winter range of approximately 3,500 elk in the Clarks Fork and Cody herds, 4,000 - 6,000 mule deer (*Odocoileus hemionus)*, 300-400 whitetail deer (*Odocoileus virginianus*), 200-300 pronghorn (*Antilocapra americana)*, and a small number of moose (*Alces alces*) (D.E.M., unpublished data). The study area contained three to five wolf packs in a given year, and grizzly bear (*Ursus arctos horribilis)*, black bear (*Ursus americanus*), cougar (*Puma concolor*) and coyote (*Canis latrans*) were also present. Public and private rangelands support several thousand head of cattle that spatially overlap with at least part of the range of all four wolf packs we studied.

METHODS

Capture and collaring

To determine the identity, location, and timing of wolf predation events, we tracked GPS collared wolves. We captured four wolves using leghold traps in the summers of 2007 (n=2) and 2008 (n=2). One wolf was captured in the resident elk area (Absaroka pack) and three wolves were captured in the migratory elk area, with one wolf each in the Sunlight, Crandall, and

Beartooth packs. Each wolf was immobilized with 10 mg/kg Telazol during trapping efforts and 17 mg/kg Telazol/ Kg during helicopter capture (Kreeger and Arnemo 2007). Telazol was delivered by a Cap-Chur Palmer dart gun. Wolves were fitted with remotely downloadable collars (4400s, Lotek Wireless, Newmarket, Ontario) that recorded one fix every 20 minutes during the summer months (July-October) to generate data to locate kill sites. Collars were deployed for durations of 1- 3 months. Adult female elk were captured via helicopter netgunning and fitted with GPS collars (Telonics TGW-3600) in January 2007 (n = 60) and 2008 (n = 10). Elk collars were programmed to record a fix every 3 hours on summer and winter range, and every 8 and 24 hours respectively for migration periods of September – October and April – June. The collars were programmed to drop off after 3.25 years. All animal captures were conducted in compliance with protocols approved by the University of Wyoming's Institutional Animal Care and Use Committee.

Locating and identifying wolf kills

We located wolf-killed native ungulate and cattle carcasses using cluster searching methods (Anderson and Lindzey 2003, Sand et al. 2005) from July 1 – October 26, which included the seasonal peak in depredations by Wyoming wolves that occurs in August (Jimenez et al. 2011). We remotely downloaded GPS data from collared wolves every 7-10 days on foot or from aircraft. Distinct clusters of locations were identified in GIS (ArcMAP 9.2) and searched by field crews. Clusters, which were defined as being within 100 m of at least two other points, identified all areas where wolves spent > 40 minutes within a 100 m radius. We visited 96% of 594 clusters within an average of 8.6 days (± 5.2 SD) after wolves left the site.

Most clusters associated with a den or rendezvous site were searched after the wolves left the area. The majority of cattle kills were recorded through agency depredation records (n=39) from 2007 - 2010, a small proportion of which were also located through cluster searching methods (n=3).

Searching techniques described here are similar to those described in (Metz et al. *in press*). We searched a radius of 35 m around each individual location within a cluster (Webb et al. 2008), and we conducted a final search that included a 30-40 m buffer around the perimeter of the cluster. We searched individual clusters for an average of 34 minutes (± 28 SD). Once a carcass was located, the approximate date of death was estimated and cross-checked with the date of first GPS location at the site. The scene was assessed for signs of predation (e.g., broken vegetation, blood splatter), and the remains of the carcass were assessed for hemorrhaging consistent with a wolf attack or other forms of predation (Bjorge and Gunson 1983, Clucas 2005). We categorized each carcass as: unknown cause of death, possible wolf kill, probable wolf kill, definite wolf kill, or other. Presence of bears and other scavengers was documented. To ensure documentation of multiple carcasses if appropriate, we searched all locations within clusters in this manner regardless of whether we located a carcass or not. We identified and catalogued prey by species, approximate age (yearling, young of year, or adult) and sex. Livestock kills were confirmed by USDA Wildlife Services or Wyoming Game and Fish Department personnel according to similar protocols developed for agency purposes.

Analyzing factors influencing wolf kill locations

We were primarily interested in the influence of elk distribution on wolf-killed cattle, but we also sought to evaluate the influence of distance to stream, distance to road, distance to forest edge and distance to den on the locations of cattle kills. We derived GIS covariate rasters (100 m cell size) to index these landscape attributes across the study area. To index elk distribution, we created a fixed kernel density estimate using location data from 80 elk GPS collars within the study area for summer months based on the median date of elk migration in the migratory elk area (May 27th). To investigate the proximity of cattle kills to streams, we used a high resolution NHD stream polyline layer (National Hydrology Dataset 1999) to develop a raster that served as an index for proximity to stream, using the Spatial Analyst linear distance tool. We were interested in location of cattle kills in relation to human activity, so as a proxy for human development, we estimated a primary road layer. For this layer, we edited polylines from U.S. Detailed Streets (2002) using satellite imagery (NAIP Digital Ortho Photo Image 2007) to include all roads receiving daily traffic, year-round. Roads were ultimately characterized as a raster of linear distance to the nearest road using the Spatial Analyst distance function. Similarly, we created a distance to den raster, including known natal dens for each of the study packs. We did not include rendezvous sites in the analysis because association of pups to GPS collared wolves was not always clear.

Cattle depredation analysis

We used a resource selection function (RSF) with a use vs. availability design (Manley et al. 2002) to evaluate the factors that influence cattle kill sites in migratory vs. resident elk areas. The domain of availability was defined as cattle pastures where depredations had the potential to occur, which included all pastures where wolves were known (via GPS collar data) or suspected (from sightings) to occur during May – October in the resident and migratory elk areas (Fig.

2.2). Used locations consisted of confirmed, probable, or definite wolf-killed cattle locations found through GPS clusters in addition to carcasses found by ranchers and state and federal agency personnel. We classified kills as either occurring in the migratory or resident elk area, using a dividing line consistent with the WGFD elk herd unit. Available points were randomly placed (20 per used location) in the study area with a 200 m buffer within which the GIS covariates were averaged. There were a few occasions where wolves in the migratory elk area travelled east to make kills in the resident elk area. In this case we classified these kills as belonging to the resident elk area. We suspect that because most of the cattle depredations were obtained through the reports of ranchers and agency personnel, these locations were likely biased towards open areas and roads, although we had no means to correct for this. Thus, this is a potential unaccounted for bias in our analysis. We used separate logistic regression (Minitab Inc, State College, PA) analyses in migratory and resident elk areas to evaluate the influence of habitat coefficients on kill-site locations.

Timing of kills and prey selection

We sought to test the prediction from the Prey Tracking Hypothesis that the rate of cattle kills increased over the course of summer due to increased comingling of cattle and elk, which is known to occur in the resident area. We assessed the frequency of depredations occurring within two week intervals throughout the summer with a 4-year depredation dataset (2007-2010). We regressed the number of kills occurring against these ordered time periods throughout the summer. Because of small sample size and the lethal removal of problem wolves soon after they began killing cattle, we view this analysis as largely descriptive. We did not have a large enough sample of kills to evaluate temporal trends separately for each area.

To identify differences in composition of wolf-killed prey species between wolves in migratory and resident elk areas, we compared the frequency of wild ungulate prey identified through cluster searching. We sought to evaluate differences between wolves in migrant and resident areas that might result from wolves living in migratory elk areas switching to alternate prey, or following elk migration. The available prey included cattle, mule deer, moose, white tailed deer and elk, along with pronghorn and bison for wolves that took extraterritorial forays into YNP (see A. Nelson, Chapter 1.). Because most prey remains were elk and deer, we conducted a binomial proportion test to evaluate differences in the proportion of deer and elk in the diets of wolves from each area.

RESULTS

Cattle kill resource selection function

Landscape attributes associated with 20 cattle kills in the migratory area and 19 cattle kills in the resident area support the Prey Tracking Hypothesis, as cattle depredations in resident areas were positively associated with elk-rich habitat ($Z = 3.18$, $P = 0.001$). Depredations in this area also occurred closer to roads than what was available ($Z = -2.61$, $P = 0.009$), which was contrary to our predicted results. There was no relationship between resident cattle kills and the remaining landscape variables (Table 1). In the migratory area, landscape attributes played a stronger role, with kills occurring close to the den ($Z = -2.36$, $P = 0.018$) and streams ($Z = -2.66$, $P=0.008$) and farther from the forest edge ($Z = 2.47$, $P = 0.014$). In contrast to the resident area, elk distribution in the migratory elk area did not influence the location of cattle depredations (Table 1).

Timing of kills and prey selection

The number of cattle kills in combined resident and migratory areas showed a modest increase over the course of the summer ($F_{1,9}$ = 11.8, P = 0.009, r^2 = 54.6; Fig. 2.4). Binomial proportion analysis indicated differences in the composition of wild ungulate prey between wolves living in migratory and resident area (Z = -3.22, P = 0.001; Fig. 2.5), suggesting the use of deer as alternative prey by wolves in the migratory elk area. Wild ungulate composition of kills made by wolves living in resident elk areas was 92% (11/12) elk and 8% (1/12) deer, while wolves in migratory areas consumed equal proportions of elk (50%; 12/24) and deer (50%; 12/24). In the migratory area, results show that of all kills found at clusters, 3% were domestic cattle, suggesting that wolves do not rely heavily on domestic cattle as an alternate prey resource when elk migrate away during the grazing season. The radio collared wolf in the resident elk area dispersed late August 2007, and although we discovered depredations through rancher and agency reports from the Absaroka pack following dispersal, we did not locate any cattle kills at GPS cluster sites prior to dispersal.

DISCUSSION

We found that depredations on cattle were strongly associated with elk density in the resident elk area but not in the migratory elk area. We expected that landscape attributes would influence cattle depredations in both areas as they do for native ungulates; however, they had a stronger influence on cattle kills in the migratory area. The timing of depredations in both areas showed a tendency for the frequency of cattle depredations to increase over the course of the summer. Although based on a small number of kills, this finding appears consistent with pasture rotations that bring cattle to higher elevation where they comingle with elk (in the resident area), or in some instances, closer to den locations as summer progresses (in the migratory area). These two findings in the resident elk area indicate that the close spatial association between wolves and elk appears to influence the incidence of cattle depredations and provides support for the Prey Tracking Hypothesis. Although we did not have enough cattle kill data to test the Prey Scarcity Hypothesis, we did find support for the importance of alternative prey in the migratory elk area. Prey composition of wolf kills in the migratory elk area suggests that wolves still prey on elk, but also shift to hunting deer when elk densities became seasonally low. The availability of deer as alternative prey may have influenced the tendency of migratory wolves to kill cattle in a somewhat incidental manner, as encountered close to dens, in the open, and close to streams. Although our sample size is small, the few cattle kills located in the migratory elk area (10% of killed animals at GPS clusters) support the notion of incidental cattle predation. Overall, these finding suggest the seasonal variability in native prey distribution can mediate the location and occurrence of livestock depredations, indicating an increasing importance of co-managing livestock, wolves, and growing resident elk populations.

Consistent with the observation that wolves have higher encounter rates with large elk groups (Hebblewhite and Pletscher 2002), we found, in the resident area, that they tend to kill cattle in locations with high elk density. The strong association between wolves and elk (A. Nelson, Chapter 1.) seems to provide a benefit to cattle when they are nearby, but not comingling with elk. Cattle in our system are grazed within reach of wolves (less than 1 mile) for much of the grazing season. Wolves killed relatively few cattle in pastures separate from elk, yet depredations tended to increase when cattle were moved into higher elevation elk-rich habitat (Fig. 2.3C). Wolf predation of elk was also tightly associated with elk distribution in the resident elk area (Fig. 2.3A). Gude et al. (2006) suggested that areas where predation occurs are different from areas of frequent wolf presence. Although we did not test this directly, spatial patterns of native ungulate kills overlapped with livestock depredation locations, suggesting that areas of high predation, or "hunting zones" (e.g., Gude et al. 2006), could carry over from native prey to livestock (Fig. 2.3A & 2.3C). These results are also consistent with studies conducted at a larger scale that found that elk abundance in pastures increases the likelihood of wolf depredations (Bradley and Pletscher 2005). In the migratory area, elk only occur in small diffuse pockets in summer, which did not influence the location of cattle kills, suggesting that threshold levels of elk density that facilitate increased encounter rates with livestock may exist.

In the resident elk area, we expected elk density and landscape attributes to influence the location of cattle kills, but only elk density and proximity to roads were important. By contrast, landscape attributes had a stronger influence on the location of cattle kills in the migratory areas. These findings suggest that in the absence of strong wolf association with native prey, other attributes that influence encounter rates between wolves and cattle become important drivers. Wolves in Idaho that had high spatial overlap with cattle also had higher rates of depredation (Oakleaf et al. 2003), which supports the importance of encounter rates between wolves and cattle. This differs from Kauffman et al. (2007) who suggested that when wolves are hunting native prey, landscape attributes influence the ability of wolves to successfully kill their prey after the initial encounter, e.g., by hindering prey escape (Hebblewhite et al. 2005). Due to dampened anti-predator behavior (Linnell et al. 1999, Muhly et al. 2009), domestic livestock may be highly vulnerable where they encounter wolves. Although we do not have rates of capture success for wolf-cattle encounters, we suspect that it is higher than the success rate of wolves that encounter elk, which has been estimated at ≈ 21% (Smith et al. 2000).

Most landscape attributes associated with cattle kill sites were consistent with the mechanism of increased rates of encounter between wolves and cattle. Kills in the migratory areas were associated with dens, which are seasonal centers of activity for wolves (Mech 1970). This is clearly a factor that increases encounters between wolves and cattle and was also found by Bradley and Pletscher (2005) to increase likelihood of cattle depredations in Montana and Idaho. The lack of any association between kills and dens in the resident area may be a function of these dens being somewhat equally spaced throughout the available habitat. Cattle kills in the migratory elk area were associated with habitat distant from forest edge. Some studies have shown that depredations are more common in forested areas (Fritts 1982, Gunson 1983) or near forest edge (Treves et al. 2004). However, cattle depredations have also been associated with open habitats in some systems such as Wisconsin which may be due to either wolves tracking their native prey (Treves wt al. 2011) or the visual attractant of cattle congregating in large groups in open areas (Oakleaf et al. 2003). A caveat to this finding, however, is that our method of collecting depredation reports includes a likely bias towards open areas, as 36 of 39 cattle kills were derived exclusively from human reporting; only a few kills (n=3) were also located through GPS cluster searches. These three kills, however, were located in open areas as well. Our finding of depredations close to streams also supports the importance of wolf-cattle encounters, because cattle tend to use riparian habitat close to a consistent water source (Yeo et al. 1993, Oakleaf et al. 2003) and wolves often travel along easiest travel routes (Kunkel and Pletscher 2001), which was also evident in our study area on trails along steep drainages. Our results support the notion that landscape attributes that facilitate predator-prey encounters may have the strongest influence on the spatial patterns of wolf-livestock kills.

We found that wolves selected deer as an alternate prey resource when elk became scarce due to seasonal migration (Fig. 2.5). Prey switching can occur in response to changing availability or vulnerability of preferred prey (Garrott et al. 2007). Although we cannot confirm true switching, wolves appear to respond to declines in abundance of elk by killing a greater proportion of deer than was found during winter in YNP studies (96% elk; Smith et al. 2004) and in the resident elk area we studied (Fig. 2.5). Morehouse (2010) suggested that cattle may replace ungulates as a prey source during the summer grazing season, although the role of wolf prey selection is unclear. For example, elk were the predominant prey item in scats (42.6%; Morehouse 2010) during the non-grazing season, while cattle were the dominant prey item in scats (58.9%; Morehouse (2010)) during the grazing season. While some studies have found that low abundance of native prey is associated with more frequent cattle depredations (Gunson 1983, Meriggi and Lovari 1996), our findings suggests that availability of deer as alternative prey may reduce wolf depredation on cattle. An important caveat, however, is that we studied an effectively managed wolf population whereby lethal removal slowed or stopped the behavior of wolves that killed cattle once they were detected. This management appeared to yield remaining wolves that relied predominantly on deer and elk in the migratory area. We note that prey selection is known to change throughout the summer and by individual (Metz et al. *in press*), indicating that a larger sample of wolves followed over a longer time frame might reveal predation patterns different than those we have reported.

Depredations of cattle within our study area occurred at an increasing rate throughout the summer, and not at all during the winter and spring months. These findings are consistent with some other areas in the GYE, and may be driven by changes in prey vulnerability and pasture rotations that bring cattle close to elk groups or wolf dens. In British Columbia, the highest frequency of cattle depredations occurred in July and August (Tompa 1983), and in Minnesota, wolf depredation of sheep and turkeys typically peaks in August, presumably due to the increased food needs of pups. In YNP, wolf consumption of vulnerable neonate ungulates declines after the start of July, and biomass consumption reaches a year-round low (Metz et al. *in press*). Changing vulnerability of prey may have influenced patterns in the migratory area, but we did not have an adequate sample size to evaluate the timing of depredations between the migratory and resident areas (Fig. 2.4). Cattle tend to move up in elevation in resident areas as the summer progresses; such pastures have high elk numbers (A. Nelson, Chapter 1) and are remote from human activity. Both remoteness and the presence of elk have been associated with wolf depredations (Dorrance 1982, Bradley and Pletscher 2005). Some research has suggested moving cattle closer to human settlements in late summer (Dorrance 1982), but this is likely not possible for most ranchers in our study area due to concerns with optimizing phenology of grasses and the timing of the emergence of poisonous plants.

MANAGEMENT IMPLICATIONS

Our research suggests that as resident elk subpopulations grow and migratory subpopulations decline, the redistribution of ungulate biomass towards front country multiple-use landscapes is likely to increase wolf depredation rates, wolf lethal removal, and potentially influence regional wolf population dynamics (Garrott et al. 2005). Growing resident elk populations increasingly exist year-round on private land that is often characterized by restricted hunting access and livestock grazing. We found that the strong association of wolves with resident elk during summer (A. Nelson, Chapter 1) appears also to elevate depredation rates when cattle are allowed to comingle with elk late summer. However, while wolves have abundant, easily accessible prey, it is possible that strong associations with native prey groups may take pressure off nearby cattle that are not comingling with elk. On these multiple-use landscapes, wolves typically encounter cattle at some point alongside elk, and wolves that chronically kill livestock can be lethally removed (Jimenez et al. 2010). It is unclear whether changing patterns of elk distribution and migratory patterns will slow pack re-establishment following control actions in areas with declining migratory prey (see Musiani et al. 2005), or create an attractant for wolf establishment in areas with abundant resident prey.

Study findings may also be relevant to several aspects of wolf management as wolves are now considered recovered and jurisdiction is shifting from federal to state management. Wolf harvest is an important management tool for delisted wolf populations under the state plans for Montana, Wyoming and Idaho. Creating harvest quotas that accurately reflect current wolf population numbers prior to the start of the harvest will be necessary to maintain minimum wolf numbers, as states may manage closer to the minimum population sizes than has been allowed under federal management. Our research shows that depredations and subsequent lethal removal may often peak in September and October, after harvest quotas have been established for most areas. The timing of the most severe periods of livestock conflicts in areas such as those we studied often warrant entire pack removals, which, in combination with a pre-established harvest quotas may drive populations to below desired levels. This suggests a need for management agencies to establish an overall mortality objective for the year within which they can flexibly adjust harvest quotas during or immediately prior to the season opening, depending on the extent of livestock- related lethal removal, or find other creative means to reconcile managed harvest with lethal removal of problem packs. Additionally, human activity, such as that generated by a hunting season, may temporarily displace wolves (Treves 2009) and elk following livestock conflict, which could prove useful in the early fall when depredation rates appear to increase in our study area. Our results suggest that when managing for ungulate harvest and cattle production across large rangelands, managed separation of cattle and elk will likely decrease conflicts with wolves and livestock. Though such notions may currently seem impractical, they may become more important as the distributions of elk, both migrant and resident, and wolves continue to change.

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Table 2.1. Landscape attributes and resource selection function coefficients that influence the location of wolf-killed cattle in areas where elk are resident (n = 19 kills) or migratory (n = 20). Significant variables are in bold.

	RESIDENT AREA				MIGRATORY AREA			
Predictor	Coef	SE	Z	P value	Coef	SE	Z	P value
den	-0.01	0.01	-1.45	0.148	-0.03	0.02	-2.36	**0.018**
roads	-0.04	0.02	-2.59	**0.010**	0.00	0.02	0.18	0.859
forest	-0.11	0.07	-1.49	0.137	0.67	0.27	2.47	**0.014**
elk	1634.67	513.63	3.18	**0.001**	-6099.13	4578.04	-1.33	0.183
stream	-0.17	0.22	-0.75	0.453	-0.95	0.36	-2.66	**0.008**

Figure 2.1 Study area located in northwestern Wyoming, including the eastern boundary of Yellowstone National Park. Summer movements (July 1 – October 22) of four GPS-collared wolves where cluster searches were conducted are shown. Wolf packs occupying migratory elk areas are shown in green, red and blue (Beartooth, Crandall, and Sunlight packs respectively), and the resident Absaroka pack is shown in black. Core summer use areas for migratory (grey stipple polygon) and resident elk (grey polygon) are also shown, which were derived from 50% use contours of fixed kernel density estimates. Crandall pack male 664M took two extraterritorial forays, 11 and 16 days in length, before killing a beef calf in the resident elk area (see Table 2, Chapter 1).

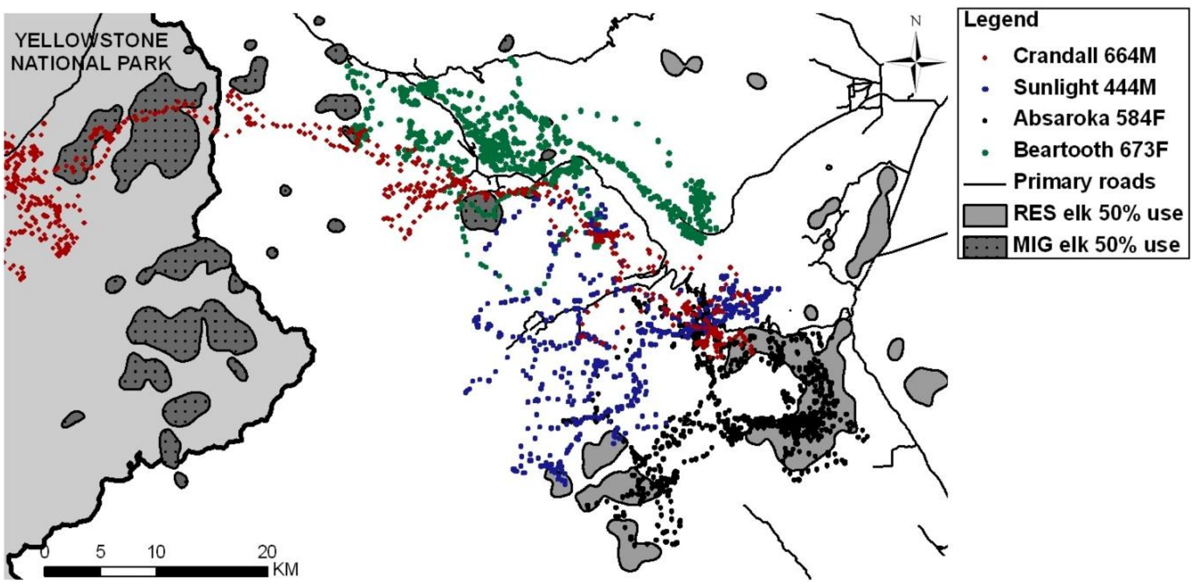


Figure 2.2. Pastures that were considered available for wolves to kill cattle in resident (blue outline) and migratory (red outline) prey areas. Cattle depredation locations (black triangles) were positively associated with areas of core summer elk use (grey polygons) in the resident elk areas, but showed no association with elk density in the migratory elk area.

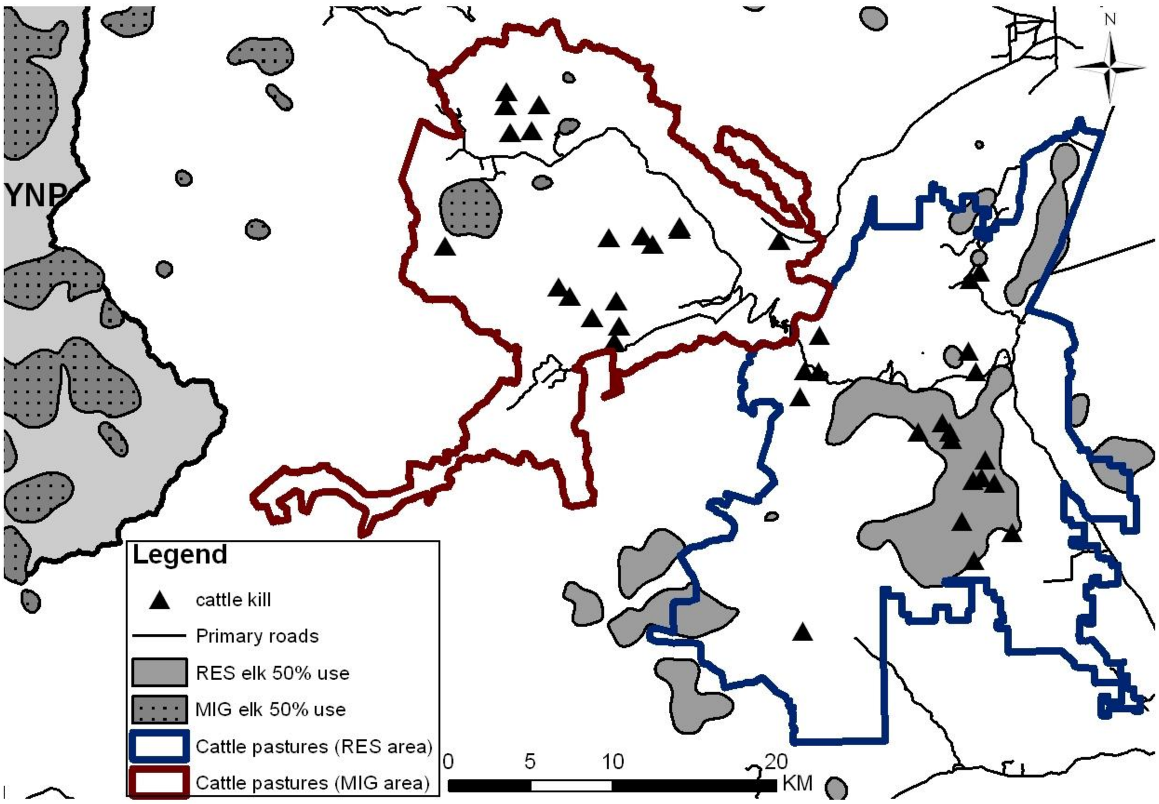


Figure 2.3. (A) Wolf movements (black dots) were closely associated with resident elk density (striped polygon) throughout summer, and they tended to kill ungulates (July – mid-August; blue circles) in areas with large elk groups. (B) In early summer (May 1 – August 15), there were few cattle depredations (red circles) and they occurred somewhat randomly with respect to elk distribution. (C) In late summer (August 15 – October 31), wolves tended to kill more cattle (red dots) as pasture rotations brought cattle to comingle with elk (C).

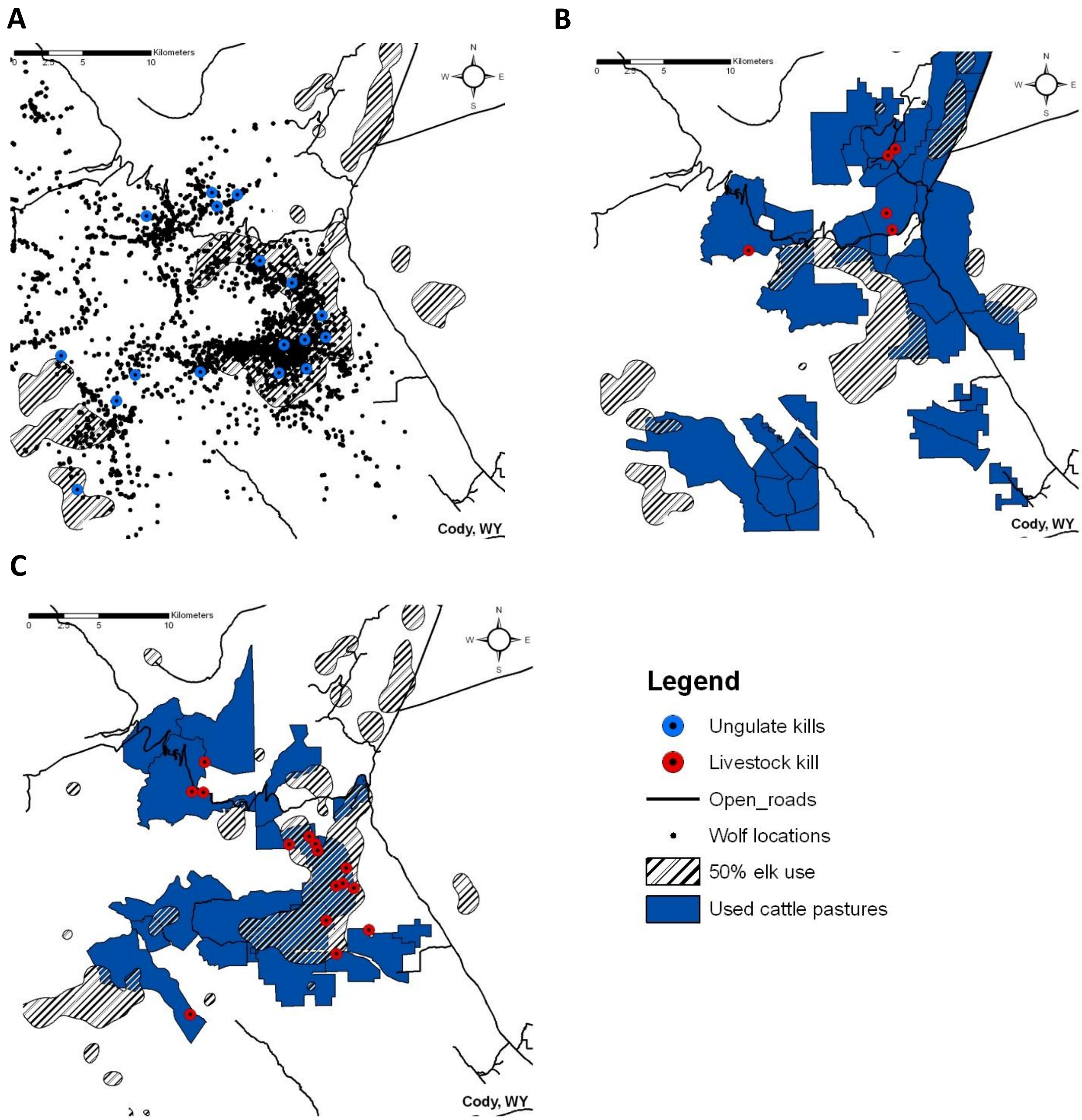


Figure 2.4 The number of cattle depredations (per two-week intervals) increased over the summer period (2007-2010). Due to small sample size, depredations from both resident (black) and migratory (white) elk areas were combined. Considerable variability between years existed, however the timing of depredation appears to be consistent with increased comingling of elk and cattle in late summer.

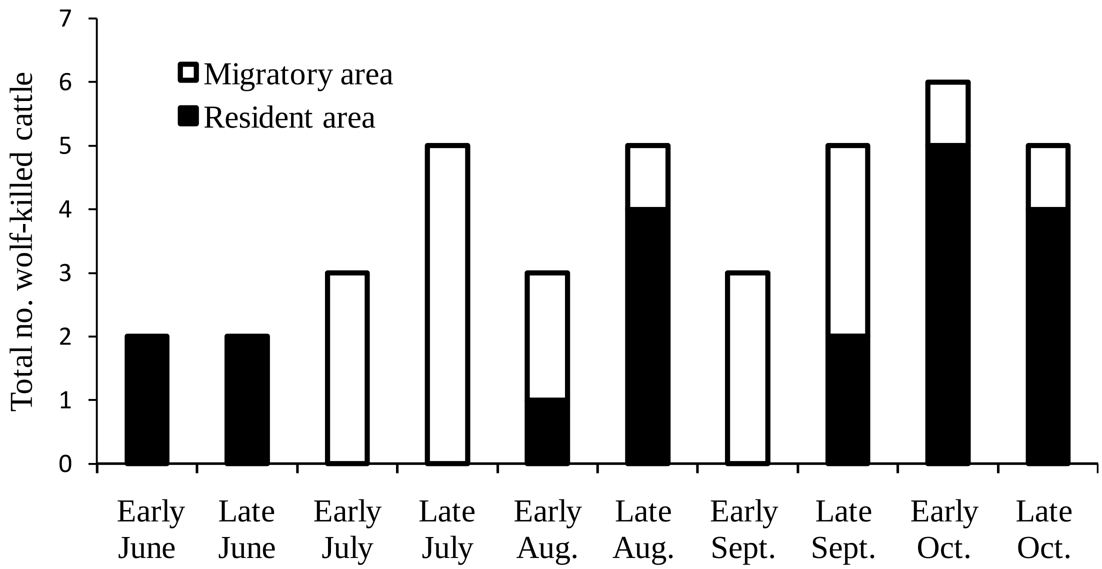
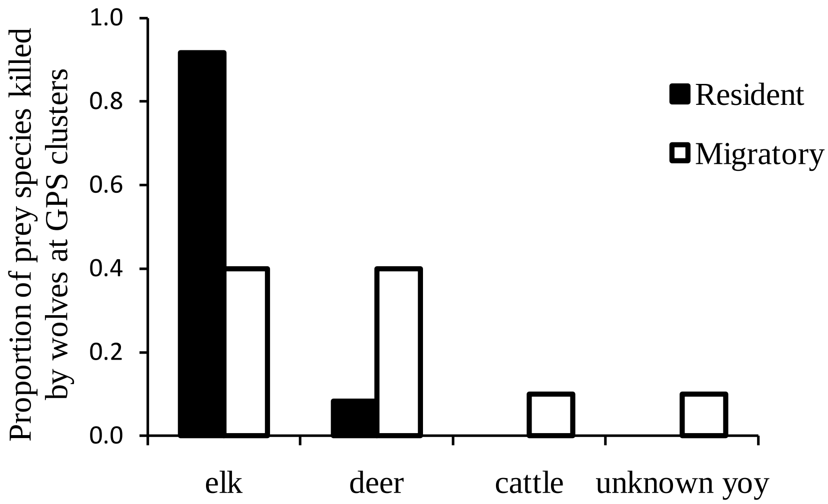


Figure 2.5. Proportion of ungulate prey species killed by wolves at GPS clusters for wolves living in resident (black; n = 12 kills) and migratory (white; n = 30 kills) prey areas. Young of year (yoy) refers to deer fawn or elk calf remains that were present with signs of predation but too inconclusive to determine species.



Appendix A. Wolves fitted with GPS collars used for this research. ID numbers given by management authority (USFWS).

GPS collared wolves that contributed to research

ID	Color	Age	Breeder?	Pack	Area	Chapter	Collar start	Collar end	Fate
584F	Black	3	N	Absaroka	Res.	1,2	7/1/2007	8/22/2007	Dispersal, unknown mort.
585F	Grey	2	Unk.	Absaroka	Res.	1	1/26/2007	12/27/2007	Dropped collar
683F	Black	3	Y	Absaroka	Res.	1	1/10/2009	1/3/2010	Collar replaced
583M	Grey	4	Unk.	Absaroka	Res.	1	1/26/2007	3/8/2007	Intraspecific mort.
608M	Black	3	Unk.	Beartooth	Mig.	1	3/6/2007	11/2/2007	Dropped collar
673F	Black	1	N	Beartooth	Mig.	1,2	8/4/2008	10/27/2008	Dropped collar
717F	Black	3	Y	Beartooth	Mig.	1	2/24/2009	6/22/2009	Collar replaced
664M	Black	3	Unk.	Crandall	Mig.	2	7/1/2008	8/10/2008	Lethal removal
525F	Black	5	Y	Hoodoo	Mig.	1	1/12/2009	1/1/2010	Collar replaced
681M	Black	4	Y	Hoodoo	Mig.	1	1/12/2009	11/30/2009	Dropped collar
697M	Black	1	N	Hoodoo	Mig.	1	1/12/2009	12/29/2009	Dispersal, intraspec. mort.
444M	Black	7	Unk.	Sunlight	Mig.	1,2	7/20/2007	8/27/2007	Collar malfunction
581M	Black	3	Unk.	Sunlight	Mig.	1	1/26/2007	1/15/2008	Dropped collar
582M	Black	3	Unk.	Sunlight	Mig.	1	1/26/2007	8/20/2007	Dropped collar
649F	Black	1.5	N	Sunlight	Mig.	1	2/19/2008	9/20/2008	Dropped collar

Transferring successful Old World livestock protection dog traditions to areas of large carnivore occupancy in the United States (Livestock Protection Dog International Research Project Report)

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Project summary

As a follow-up to our paper published in *Sheep & Goat Research Journal*[1] in February 2010, Jim and Cat Urbigkit traveled to three Old World regions (Spain, Bulgaria, and Turkey) in October 2010 to conduct intensive interviews with livestock producers about the use of livestock protection dogs (LPDs) in areas of large carnivore occupancy. We were able to see wolf-fighting breeds actually in use in large carnivore country, with both migratory and stationary livestock herds.

The interviews yielded baseline information about how specific LPD breeds are used with varied livestock operations, the benefits and problems associated with their use, and husbandry and management practices that have been shown to be successful. It also resulted in contact information for potential import of pups from working LPD parents into the United States. The project also yielded an increase of knowledge about one important tool to assist in increasing the survivability of existing LPDs in the United States: anti-wolf spiked collars. We photographed dozens of the collars used in the Old World, interviewed producers in each country about their use, and purchased six collars to use as prototypes in the United States. Information on spiked collars will soon be submitted for publication in a scientific journal.

Since returning from the trip, we've also undertaken an ambitious information dissemination campaign, which will continue in the months and years ahead. Articles about the project have appeared in the *Wyoming Livestock Roundup, American Sheep Industry News, Casper Star-Tribune, Billings Gazette, Pinedale Roundup*, Pinedale Online, Steve Bodio's nature blog, and *Western Ag Reporter*, among other online news sites. We've presented our findings at the Wyoming Stock Growers Association and American Sheep Industry conventions, as well as in smaller sessions such as one in Jackson Hole, Wyoming involving natural resource agency/conflict personnel. We also maintain a notebook of news clips, articles, and email that we'd be glad to share with the board if needed.

Cat Urbigkit's presentation at the American Sheep Industry conference in Reno, Nevada, drew the interest of USDA Wildlife Services Director William Clay. After a private meeting to discuss the matter, Clay has instructed his staff to develop a project budget aimed at importing and breeding LPDs more suited to challenging wolves for distribution to western ranches.

Next steps: The Urbigkits plan publication of two other major works to conclude their involvement in this project: publication of a scientific paper on the use of spiked collars; and publication of an article on husbandry practices of

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[1] Urbigkit, C, and J. Urbigkit, 2010. "A Review: The Use of Livestock Protection Dogs in Association with Large Carnivores in the Rocky Mountains." *Sheep and Goat Research Journal*: Vol. 25.

livestock producers in the Old World. In addition, the Urbigkits are glad to entertain invitations to speak about LPDs to any groups expressing an interest.

Background/A note on EU livestock programs

The government program for livestock grazing in the European Union member nations of Spain and Bulgaria:

• The government will count all your sheep, and take individual blood samples and provide you with subsidy per head per year. Producers using livestock protection dogs receive a higher subsidy.

• All sheep and goats must ingest a stomach bolus that contains a microchip. This program is mandatory, but free. Cattle must have an electronic coded eartag containing all its genetic and health information.

• Cattle are bled for brucellosis twice a year, with blood samples taken from the shoulder. Only animals that test positive are slaughtered, but remainder of herd must be retested every three months.

• You are required to have a disposal service to pick up every dead animal – the government will pay 60 percent of the cost, but because it knows how many sheep you have, you have to account for all your sheep at the end of the year.

• All of your dogs have to be micro-chipped (E80/$115USD– paid for by the producer) and have annual rabies vaccine. Local veterinarians will have “field days” in rural areas for everyone to meet up and get their dogs taken care of.

• Producers are not allowed firearms.

Why does this system work? Because the government, and society in general, have acknowledged their interest in maintaining livestock grazing and agricultural production. Some of the areas in the countries we visited suffer from the “ghost village” syndrome in which all the inhabitants have left rural lifestyles, leaving uninhabited areas that were once thriving agricultural communities.

In Spain we saw mountainsides covered with thick heather – a travesty. This is because grazing had been reduced or eliminated over the years, a situation some EU nations are attempting to reverse.

Herders are with the sheep at all times, but not to protect the sheep from predators. It’s to keep the sheep out of grain fields because there are few fences. When the herder needs lunch, the 200 or so sheep are turned into a pen for resting and siesta before going back out to graze again. We also saw herders with burros and cattle as well, again for the same reason. More cattle were kept in fenced areas, but most of the areas were unfenced.

Other important items:

• None of the countries we visited have large visible wild ungulate populations for wolves to prey on, like we are so accustomed to in western Wyoming. Where there are higher game populations, there are higher densities of wolves.

• Agricultural systems in Europe are much less efficient than similar systems in the United States. We found that to our liking, since the result is more people involved in, and employed by, agriculture.

• Much of the livestock production systems we observed were small subsistence operations. Local diets relied heavily on locally produced foods, including much milk and cheese products from sheep and goat production.

• The average citizen throughout the regions we visited were more familiar with food production and livestock grazing than most Americans. Most citizens had family members recently involved in agricultural production – parents or grandparents. Society seems to be more aware of pastoral lifestyles.

• There are few fenced rangelands for grazing, so most livestock herds (regardless of species) are nearly constantly accompanied by human herders. Much of the herding is done on foot, not on horseback.

• We saw few herding dogs in use in any country we visited.

• The command to the LPDs meaning "go to the sheep" was used throughout Spain and Bulgaria, but not Turkey. We've never heard such a command used on a ranch in the United States.

Spain (Spanish mastiff livestock protection dogs)
Spain was one of three emphasis areas on our research trip sponsored by the Wyoming Wool Growers Association and funded by the Wyoming Animal Damage Management board. We wanted to see working guardian dogs that are aggressive enough to be effective against wolves while not being aggressive to humans. We struck gold in the working Spanish mastiffs we encountered. The dogs we met had been proven against wolves, and we unintentionally provided the ultimate test of their human aggression (a story shared below).

First a little background. We were fortunate enough to have two wolf biologists as our guides in central Spain – including one whose job it was to ensure distribution of mastiffs to producers in wolf country, especially into areas where the wolf population was expanding. These two, Yolanda Cortés and Juan Carlos Blanco[2], organized all our interviews with producers, and got us to wherever we needed to be. We doubt our trip would have been so successful without their insights and assistance. Yolanda and Juan Carlos are freelance biologists, mostly working for the Spanish Minister of the Environment, but also working for regional governments on wolf research projects.

Ranches, farms, and estates are called "exploitations" in Spain, which we noted with some humor. The mastiffs are not called livestock guardian dogs, protection dogs, or simply dogs, but instead are always referred to as mastiffs. To the Spanish producer (sheep, goat or cattle) there is simply no other animal comparable to the mastiff. It should also be noted that producers are very specific about these being Spanish mastiffs, because other breeds sharing the mastiff name are not the same.

Most of the grazing areas we visited are unfenced, so the herder must stay with the herd in order to keep the animals from entering grain/cereal fields in the area. The herder stays with the herd until he's ready to eat lunch about 2 p.m. At that time, the herd is placed into a centrally located pen, which in some cases has been reinforced with electrical wire to keep wolves out. The herder goes away for lunch, and comes back to let the sheep back out after a few hours. The sheep continue to graze, with the herder alongside, until it's nearly dark and they are most often penned again. Larger herds (we saw one with about 1,000 head of sheep and 11 mastiffs) are not night-penned, but stay out with their mastiffs. The herders are almost always the owners of the animals and the ranch (I believe we

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only saw one exception to that). We also saw herders with burros and cattle as well, again for the same reason. More cattle were kept in fenced areas, but most of the areas were unfenced.

The Spanish mastiffs are massive, and most producers allowed us to pet and handle their dogs. The dogs were very tolerant, but quickly went back to work. We met dogs that had actively fought wolves, including one female who was still healing up from a battle a few months prior, as well as a big male dog who had killed a wolf. Okay, so they work against wolves, and they seemed not to be human aggressive, but were they really no danger to humans? We were soon to find out.

The Iberian wolf population is located in the connected region of northeastern Portugal and northwestern Spain. This portion of Spain has long been home to a wolf population, but the region south of the Duero River was recently recolonized by the species. Spain is home to about 2,000 wolves.

Juan Carlos Blanco & Yolanda Cortés provided the following information about the wolves living in agricultural areas of Spain (from a Conservation Biology conference in Hungary in 2006):

> "Since 1970 wolves have been increasing in Spain and expanding into areas with highly modified agricultural landscapes. From 1997 to 2005 we have radio-collared 16 wolves in a population established in an agricultural habitat where wild ungulates are almost absent. Wolf density, assessed by radio-tracking and simulated howling to detect different packs, was 2.4-3.0 wolves/100 km^2. Wolves expanded their range during the study period. Seventy five percent of the diet biomass, studied by the analysis of 603 scats, was made up of livestock carrion, very abundant during most of the study period. Wolves lived in packs, which averaged 9-10 individuals during the autumn but the percentage of solitary wolves was higher than in most other studies.
>
> "The average home range of radio-collared wolves ranged between 150 and 200 km^2. Both resident and transient wolves crossed 4-lane, fenced highways using bridges built for vehicles, but where deterred by a barrier formed by the river Duero and a transport corridor. We conclude that these carrion-eating, adaptable wolves keep the same social and ecological behaviour as other wolves studied in natural and semi- natural areas of North-America and Europe."

Cortés estimates it costs 200 Euros ($267 USD) per year to purchase and maintain a mastiff. The criteria for enrollment in the program to receive free mastiff pups included:

1. the producer had to have suffered wolf attacks;
2. ranch located inside wolf distribution area; and
3. rancher had to be willing to cooperate with program.

Ranchers are compensated for damages caused by wolves in the Castilla-Leon region. In the 1970s, wolves were located north of the Duero River, but as the population increased and recovered in that region, protections were eased. In southern Spain, there are a few smaller scattered populations of wolves where wolves are still protected. Wolves are hunted north of the Duero River, but not south of the river, where wolves are protected both under Spanish and European law. When wolves attack livestock south of the river, a team confirms the kill and provides documentation for compensation. Ranchers pay 0.3 Euros per head per year (about 40 cents per year) for insurance on their animals, and compensation is provided by the regional government for damages, up to the first 200 Euros. The insurance company pays for damages higher than that amount.

In Europe, livestock production is subsidized by the European Union. Every farmer in Spain receives 30 Euros ($40 USD) per head to raise sheep, and this amount is paid by the European Union.
"Without subsidies, livestock grazing in Europe is not sustainable," Cortés said. "Society pays the farmers to maintain livestock grazing."
Consumers pay 15 Euros ($20 USD) per kilo (2.2 kilos per pound) for lamb meat in their local grocery stores.
(In contrast, in the United States, producers pay to graze on public land, and compensation may or may not be provided for damages, and if so, not by the federal government).

"In Europe, many habitats and many species depend on agricultural areas," Cortés said. These areas are very important to keep animals from extinction. The EU is also concerned about abandonment of rural areas.
"That's one of the reasons the EU is paying to maintain agriculture in many areas," she said. There are no pristine landscapes in Europe, both the wolf biologists noted.

In every village in Spain, pits were in place for all farmers from the area to bring their dead animals, and these pits were the main food source for wolves. But now the burial of carcasses is not allowed. Since 2002, when the cattle disease Bovine spongiform encephalopathy issue arose in Europe, rules were put in place dead animals must be inspected and hauled away by a disposal company, where the carcasses are burned. One producer, Francisco, told us he pays 1,000 Euros ($1,337 USD) per year as a flat fee for the disposal service (this is a subsidized service also). If he didn't pay this contract amount, he would have to pay 11 Euros ($15 USD) per dead animal.

The new policy resulted in a 70-80 percent decline in the food supply for endangered vultures, so the European Union had to relax regulations in some areas so that pits could be created that are only accessible to avian predators. The disappearance of carcass pits had a negative effect on wolves as well.

Most of the livestock producers we met in central Spain did not have spiked collars (called carlancas in Spain) on their dogs, although Yolanda said carlanca use is predominantly a practice of northern Spain. In higher wolf density areas, or with longer recent history of wolves, carlanca use is more common.

We met our guides in central Spain, in a wide open, rolling landscape that reminded us of eastern Idaho's potato country. It's this area that wolves are recolonizing, hiding in the cover of remnant forests, moving down draws and gullies to hunt. We spent our time in Spain in the Castilla-Leon region, and near Guadalajara in the Castilla La Mancha region, basing out of Segovia, Spain.

"Cattle spend the whole day alone in the mountains, and mastiffs are their only protection," Cortés said, noting that cattle are the most common livestock in northern Spain.

The Spanish wolves weigh from 65 to 99 pounds., with the average weight about 77 pounds. Wolf packs normally include five to seven wolves per pack, primarily eating deer, wild boar, and carrion.

"The wolves and the wildlife here have been shot at for centuries – that's why the wildlife in Europe are much more shy than in America. All the animals are shy," Cortés said. "The wolves are completely nocturnal. The wolves don't howl during the day – they are very shy. In many parts, they don't even howl, not even during the night. They completely avoid humans." Even radio-collared packs with known territories fail to respond to howls from biologists tracking them, a common survey method for wolves in America that simply doesn't work in Spain.

Firearm use is tightly regulated in Spain, and as one producer told us, he is not allowed to shoot at either a wolf or a stray dog attacking his sheep. He must call a ranger to shoot the offending animal.

Cortés is the author of a small handbook for farmers detailing proper training/health care of LPDs. She noted: "Farmers who have not had dogs do not know how to train the dogs. The project not only gave the dogs for free, but also helped teach the farmer to train the dog. I think that's very, very important."
The guide, written in Spanish, has been presented to USDA Wildlife Services for translation and use in the United States.[3]

[3] Julie Young, Supervisory Research Wildlife Biologist, USDA Wildlife Services National Wildlife Research Center, Logan UT. Juliie.k.young@aphis.usda.gov. Telephone (435) 797-1348.

Cortés said: "You must put the pups together with cows, in a close place for 4-6 weeks more or less to create the social bond. It's more important to create the bond with cattle than with sheep. You must be more careful with cattle, but the process is the same."
Cortés noted that producers need to find a balance between not handling a dog at all and handling the dog just a little bit.
"You need to help him get used to a certain degree of handling," she said.
The owner of the dog must handle the dog so it is used to a certain degree of handling, petting and grooming it frequently, and providing food, but that's all, she said. She also noted that while the dogs are in the mountains with their flocks in the summer, pups are sometimes stolen.

Mastiffs don't like bicycles very much, Cortés said, adding that negative encounters occur on occasion, but not very often. Mountain grazing areas are also high recreational use areas.
Farmers in lowlands see the dogs every day, but only every few days in mountains in summer. "That's why it's so important to avoid that aggressive behavior," she said.

Cortés reported that there have been a few cases of sheep herds attacked by wolves in the past, with these herds becoming afraid of dark-colored dogs. The program replaced the dark-colored dogs with light-colored or white mastiffs to get the herds to accept the dogs. Dark brown and black dogs reminded the sheep of wolves. It was reported that the program had to remove dark mastiffs from farms in two cases and replaced them with white mastiffs.

For the most part, the mastiffs are much larger than the wolves, and barking is usually enough to deter wolves from protected flocks. The wolves then turn to unprotected flocks as prey.

Noting that some LPD researchers believe that actual physical encounters between LPDs and predators are rare, Jim Urbigkit asked Cortés, "Do the dogs fight the wolves here?" Cortés laughed in response to the question, stating: "Oh yeah. It's not frequent, but they do."

In the Northern Rockies, as migratory sheep flocks move, most depredations occur within the first few days of moving onto new range, as the dogs work to clear out predators and establish their possession of the canid niche. Cortés said they have found both mastiffs that have been killed by wolves, and wolves that have been killed by mastiffs. Most of the dead mastiffs were female mastiffs entering wolf rendezvous sites.

Mastiffs used for guarding livestock must be from livestock breeders, not just mastiff breeders, Cortés warned, adding that it is unacceptable for the dogs to have human aggression. It was also pointed out on numerous occasions that the presence of a set of double back dewclaws is a characteristic of purebred Spanish mastiffs.

We did not find any mastiffs with docked ears or tails in Spain. With mandatory microchips and rabies vaccinations, local veterinarians host annual "field days" where they drive out to central rural locations to meet producers and see to their veterinary needs.

Cortés and Blanco were Spain's representatives in the European Commission's four-year, five-country LIFE COEX program to reduce conflicts between livestock and large carnivores. The program paid for placement of high-quality LPDs, and installation of electric fences, as well as other mitigation and education measures. In Spain, compensation for large carnivore damages were linked to the use of damage prevention measures (such as electric fences and mastiff LPDs).

Goya

Goya is a milk sheep producer in the Segovia area of the Castilla-Leon region of central Spain who had frequent incidents of wolves attacking his sheep at night while the sheep were in the field. The situation had become such that Goya was spending the nights out in the field with his sheep in order to protect them. The COEX program donated an electric fence to be used for night penning his sheep. As soon as the five-wire fence was erected to reinforce an existing pen, the attacks stopped. Cortés reported that the COEX program donated 30 electric fences to Spanish producers in three years, and in that time, the number of attacks declined to only three, with one dead sheep. The fences were determined to be highly effective in reducing the number of attacks by 98 percent and in reducing the number of livestock killed or injured by 99 percent.

Goya has had mastiffs for five years, since wolves arrived in his area, and after wolves attacked his flock, killing 20-25 sheep. Goya expressed no preference for male mastiffs or female mastiffs, but noted normally males are more territorial, and usually defend territories much more.

Goya said the number of dogs recommended is dependent upon the size of the area where the livestock is grazed: 1,000 sheep in an enclosure is different than 1,000 sheep on the mountain.

Cortés said that most ranches include 800 to 1,000 sheep, many of them with only two or three mastiffs. She noted that there is less threat of predation in Spain than in Northern Rockies with coyotes, so it's logical American producers may need a higher number of dogs, especially in range flocks.

Goya had an aggressive mastiff, but it was not a pure mastiff. He had to kill the dog because of the conflicts with humans.
Cortés recommended, "Completely avoid aggressive dogs in the field." The dogs should be eliminated, culled from the program.

Although Spanish mastiffs have shorter hair than some other LPD breeds, they also have thick undercoats. Goya said the mastiffs are content in winter temperatures, even in mountains.

Training is very important, Goya said, recommending producers be very strict with pups during training. He noted the importance of constantly controlling the dog – if the dog goes away, it is important to call him back and teach him to go to the sheep.
"The dogs must stay with the sheep – they must always stay with the livestock," Goya said.

Goya's lambs are sold at about 20 days of age, at a weight of 10-12 kilos (22-26.4 pounds). His ewes lamb all year long, with ewes producing lambs three times in two years. Most lambing occurs indoors, and the dogs are not allowed to eat the afterbirth.

Goya's dogs are affectionate with the sheep, licking their faces and demonstrating affection. Scavengers present include other dogs near inhabited areas, ravens, crows, kites, and raptors.

When asked if she believed that wolves are attracted by dogs (perhaps because of competition or the potential for breeding), Cortés said, "I think that's nonsense." Cortés pointed out that it is easier to find a female dog than a female wolf, but the cases of wolf trying to breed dogs are low. She said wolves may approach dogs either when wolves are at very low densities, or in response to a female dog's heat cycle.

Goya strongly recommended that western livestock producers try Spanish mastiff dogs. "The instinct of the mastiff for protecting livestock is very strong," he said. "The most important thing is that you have the control over the dog, the dog must learn that you control the situation, you must teach them to stay with livestock and you must teach him that you are the one who rules."
Goya recognized the problems for range producers in establishing this type of relationship with the dogs, suggesting it was easier in a farm-flock or stationary type of situation.

When we approached Goya's farm in the car, a mastiff dog ran up to the car barking. This dog was part of a small flock of sheep that were passing by Goya's farm at the same time that we arrived.
Goya would not allow his dogs to approach cars. If his dog behaved in this fashion, he would go to the dog and reprimand it for such behavior. If the dog were allowed to proceed with such behavior, Goya noted, it may become bolder and bolder, and may eventually show aggression toward a human.
The dogs from the passing sheep herd and Goya's farm were not overly aggressive in their interaction, although Goya said sometimes more aggression is exhibited. The dogs quickly establish and avoid each other's territories. Some farmers encourage their dogs to challenge other dogs they meet in trailing or grazing.

Goya recommended to never let the dog abandon the herd while grazing, and never let the dog come back to the stable when it should be with the herd. Goya believes that in a situation like that in the Northern Rockies, having lots of predators will keep the dogs alert.

Goya also had a herding dog. Also, Goya's 11-month old male mastiff that we photographed would not allow us to handle his front feet and legs, something we've noticed with other wolf-wrestling LPD breeds.

Goya said the most important things for the producer to remember are:
1. The dog must learn that you are the owner and the one who controls the situations;
2. The dog must stay with the livestock all the time; and
3. Avoid encouraging aggressive behavior with other dogs.

Rufino

Rufino runs about 200 head of Israeli milk sheep in the Castilla-Leon region – an area that contains 50-60 percent of the wolf population in Spain, with a relatively low human density. It's a beautiful countryside, thick with Spanish lavender (which smells like lavender, but looks like sagebrush). In this area, sheep are always accompanied by people because they graze near grain fields where there are no fences, a common scenario in Spain.

The sheep graze during the day, penned at mid-day so the herder can have lunch, before being freed for afternoon grazing. The sheep are night-penned and are guarded by at least three livestock protection dogs that roam outside the pen. The pen has been reinforced with 5-wire electrical fence.

Rufino has always used livestock protection dogs in the past, but in the last five years has switched to breeding pure Spanish mastiffs. He uses mastiffs as a prevention measure, and reports he has had no problems with wolves since acquiring the dogs.

Rufino said his dogs are not aggressive to humans in the field, but do become more aggressive when located at his stables. Although Rufino uses herding dogs, he reports no conflict between his mastiffs and the herding dogs. For the most part, the mastiffs get along, but sometimes they have conflict over guarding duties, Rufino reported. The pups are born in the stable, and are kept there with their mother until about two months old.

As we talked, Rufino penned his sheep, and one young livestock guardian dog kept Cat busy, keeping between Cat and the herd. None of Rufino's guardian dogs showed aggression to us, although they barked as we approached. The dogs maintained their bodies between us and the herd.

Rufino reported he'd never had his dogs bite or behave too aggressively to humans.

Francisco

This meat sheep producer runs 1,500 head of sheep of the native Spanish Castellena breed. We saw one intact male mastiff that was very shy to us strangers. This male also had a naturally docked tail.

We were told Francisco had two castrated males out with the herd. They had been castrated to prevent them from roaming. He recommends three to four mastiffs per 1,000 head of sheep. He uses four dogs all summer long with 900 head of sheep. With 700 head in a flock, he'll use three dogs.

His herd lambs outside, but then he brings the newborns into a large barn for their first four or five days of age. Francisco sells slaughter-ready lambs at 10 kilos, at 21 days of age. Last year he was required to submit blood samples from 100 percent of his sheep herd, and this year, he had to provide samples from 75 percent of the herd – a percentage that he expects to decline in future years, with more occasional monitoring of his herd by governmental officials.

Francisco reports no problems with dog aggression against humans. His dogs are more aggressive towards humans near the stables, and not out in the field. He's used mastiffs for about five years. He had one attack before acquiring good mastiffs, but since using "good" mastiffs, no attacks. Good mastiffs means purebreds from other working producers. He lambs twice in one year, and one the next. Most of his herd give birth to twins in February through April (because it's the natural season), so less lambs out of season.

"Mastiffs are very, very useful for not just wolves, but stray dogs," he said.
If he sees a dog attacking a sheep, he has to call a ranger to shoot the dog. He is not allowed to shoot at either stray dogs or wolves.

Carlos

Carlos is the foreman at Caserio De La Torre, a large range operation. We arrived at the Caserio De La Torre to learn that a pack of wolves lives on the ranch, attacking the livestock herds constantly. This ranch reminds me of the beautiful rolling range country of central California. The introduction of mastiffs resulted in major declines in attacks, although some do still occur.

Cortés explained that the mastiff guarding behavior generally is to chase the predator away from protected livestock, but after a few hundred meters, the dog should stop and return to the herd. She said producers should avoid chase behavior in their mastiffs.

Carlos explained that a wolf had jumped over an 8-foot tall wire-topped rock wall during the night and killed a ewe in a pen at the ranch, as we later went out to observe and confirm. The carcass had been left in place, since a ranger planned to use it as bait for shooting the wolf should it return during the night.

Ranch losses:
In 2010 included 12 calves and 8 sheep;
In 2009, 24 calves;
In 2008, 11 calves; and
In 2007, 27 calves.

It was in 2007 that the ranch was presented with three mastiffs, but the dogs had been bonded to sheep and not cattle. Carlos came to the ranch in early 2009 and brought his own mastiffs with him. As we talked, we learned he was in the process of liquidating the ranch's 300 sheep (unrelated to wolf issue), and converting entirely to a 500-cow production outfit, with five adult mastiffs and two pups for protection. The ranch breeds Avilena cattle, a native Iberian breed that is known for its bravery. The breed produces high quality beef.

Carlos showed us photos of wolves approaching his cattle, only to be confronted and chased off by his mastiffs.

Carlos also showed us his bonding pen containing yearling cattle and two young mastiff pups. The pups were allowed constant access to the cattle in a building, but could escape into their own pen for protection if needed.

Carlos began using the carlanca collars after wolves tried to kill his mastiffs. Four months prior to our visit, the shepherd arrived to find the adult pair of mastiffs "had been beaten by wolves." It was nearly two weeks later before they found the dead wolf in the pasture, proof that the dogs hadn't lost the battle.

Wolf attacks occur year-round, but late summer and fall is most common, Cortés said, which Carlos confirmed, when the wolf pups are getting bigger and starting to hunt with the parents more.

It is very common for mastiff owners to practice severe culling of pups in Spain, usually only saving one or two pups from any litter. In recognition of this, Cortés went to specific breeders and asked them not to kill their upcoming pups so they could be used in the distribution program in central Spain.

Ideal number of dogs with free ranging cattle is dependent upon the terrain in which the herd grazes in addition to the size of the herd, according to Carlos. He prefers to have at least four dogs with 300 head of sheep.

The cattle are always available for wolves, since they are always out in pastures.

Carlos reported no problems ("no, never") with aggression towards people, even with the presence of a public road and recreation area within the grazing range. "Mastiffs are selected to confront predators, not people," Cortés said.
He reported that leashed dogs accompanying recreationalists are not a problem, but unleashed dogs are, since the mastiffs will confront them. Hunting dogs are also a problem, since wild boars are hunted in drives, and the hunting dogs will be lost on the range. Dogs that come into the herd are killed by mastiffs – the fate of two hunting dogs in Carlos's herd.

Cortés cautioned that LPDs that show untoward aggression need to be trained to reinforce that such behavior is unacceptable. Carlos recommended producers focus on bonding their pups, begin their education early, and correct undesirable behavior from the beginning.

Carlos recommended that iron collars be worn in summer, and switching to leather in winter (since the leather collars will sweat in summer). He cautioned that the dogs sometimes try to scratch their heads when the collars are first fitted, and are injured that way. Carlos recommends the collars be placed on the dogs year-round.

Carlos, who is going into the mastiff breeding business, would be interested in exporting dogs to the United States.

Mastiffs are tough and hardy, with no skin or hair problems. No color selection is practiced in working LPDs, although show breeders select for uniform coloration. Cortés said her program paid 450 Euros (about $600 USD) per pup to get the best working dogs.

Guadalajara, Spain

Juan Carlos Blanco guided us to livestock producers in the Guadalajara area east of Madrid, in the Castilla la Mancha region. There are few bears in northern Spain, but not in Central Spain, so the major predator of interest there is the wolf.

“Wolves are new to this area – breeding packs were first documented here five years ago,” he said, so many producers are now learning how to use these dogs.

“Some producers don’t like carlancas because the dogs fight. They can be injured by the carlancas,” Blanco said. He noted that female mastiffs are very territorial and competitive. While some view competition among the dogs as a problem, he said, “Some say it’s nice too.” The female dogs will spread themselves out around a herd to avoid each other.

The average number of wolves in the local wolf pack he studied in 2010 is 10 wolves. Blanco said that a research program radio collared 70 wolves, and there were 10 known deaths of those wolves. None were killed by other wolves, but one was killed by a mastiff in a cattle pasture, and the remainder were human kills (both hunting and illegal killing).

A mastiff was killed by wolves on a large ranch where 2,000 sheep and 300 cows are raised, along with 12 adult mastiffs. The sheep spend nights alone in the field with mastiffs, and wolves are around all the time.

Blanco said that good mastiffs stay with sheep and the biggest problem posed is when a female dog enters her heat cycle.

The livestock herder must be sure all sheep are together, or two groups with mastiffs in both herds, before he goes home for the night. Wolves kill some sheep from time to time, but not many, he said.

October/November through January/February is the wolf-hunting season, with a 140-wolf quota in the Castilla de Leon region, according to Blanco. In wolf damage areas, additional wolf control is authorized. There are 149 known wolf packs in the same region, and wolf hunting is concentrated in wolf damage areas.

Many wolves are killed by cars, but at least 50 percent of wolf mortality is due to illegal hunting (according to a 10-year old survey), Blanco noted.

In northern Spain, wolves never disappeared, and neither did the mastiffs used to guard against them. Because of this long tradition, the mastiffs protecting the herds became simply part of the landscape. In the Basque country, wolves arrived within the last 20 years, and dogs were brought in, in response. Trouble with tourists resulted, he said. People in agricultural areas of Spain know that they have to be careful around livestock, so society is more familiar and accepting of mastiff dogs.

In Spain, there is now a working branch and a show branch of mastiffs, Blanco said. It’s important that livestock producers only use dogs from the working lineages.

The Griffon vulture is common in Spain. The European Union forbids livestock carcasses being left in the field. Since this policy has been enacted, the vultures are now attacking lambs and calves at birthing time, Blanco said. This is a new problem, and initially, biologists denied such activity was taking place, but livestock producers were able to record the incidents with their cell phone cameras. Researchers soon learned that near-starvation had forced vultures to switch to live prey.

The importance of using mastiffs was underscored by recent livestock depredations in the region. As we drove near El Pico De Lobo mountain, we learned the day prior that wolves had killed six sheep on the other side of the mountain. A month prior, wolves killed 60 sheep of a herd of 150 that had been left unprotected, Blanco said.

Juan

Juan Arenar is a very important and influential livestock producer from the village Cantalojas. His operation consists of 2,000 sheep and 300 cows. His lambs are sold at 20 days of age, for 60 Euros each.

There is a local pack of wolves that keeps Juan’s sheep flock surrounded at all times. His sheep graze on rangelands governed by communal/ancestral grazing rights, administered by local towns. The sheep are herded during the day, or checked by a herder a few times a day. The dogs are fed in the mornings, and herd is checked late in the day to be sure they are guarded and in a good area for bedding.

The herd grazes a “natural area” or “natural park.” The Beech Forest Park Tejera Negra was set aside as a Natural Site of National Interest in the 1970s to protect the beech forest in the southern portion of the Iberian peninsula. Our visit to Juan Arena’s rangeland was filmed by a Spanish public television crew for a special on wolves and livestock protection dogs.

When the dogs are two months old, they are placed with sheep for seven months more for an intensive bonding process. Some pups will try to play with the sheep and will wound them. When this happens, Juan Arenar advises that the pups be placed with male sheep (bucks/rams) for a month so they will learn to behave, since the rams will not tolerate such behavior. He noted such chase behavior happens with yearling pups.
But pups that are gentle with sheep can go out onto the range with sheep when they are six months old.

Just one dog on his range was wearing a carlanca, although he told us he prefers for his dogs to wear carlancas. There were several dogs limping because they had been fighting over a female in heat.

One female dog was wearing a bell. I asked why and learned that she was pregnant. She would have pups out in the grazing area, and the bell will allow the herder to track her and check her pups.

His dogs come to the approach of the truck every day for food. It's a typical sheepherder truck, dented and dirty, a bag of meat scraps and bones in the back.
"They protect the sheep in exchange for food," Blanco explained of the relationship between the herder and his mastiffs.

When a sheep dies, the dogs protect the carcass, but there are many vultures in the area, and they work very fast, Blanco explained.

Juan's herd lambs inside a barn. Juan said he has used the mastiffs for more than 10 years, and trades other livestock producers for dogs when needed. He believes the dogs have improved his sheep's behavior, making them "more compact" or better at flocking.

The only health problem identified with this breed is hip dysplasia, although it was reported that dogs with this condition are from heavily inbred lines, not working dog lineages. Another occasional health issue reported is that the stubble on cereal fields will rub their back dewclaws, causing chafing.

Juan Avenar reported that some of the dogs will run after wolves, while others will not, during the day. At night, he reported, the dogs stay with the herd.

When a litter of pups is born, there are usually 5-8 pups, but only three or four at most are saved. He said he always selects for double back dewclaws because this is a sign of pure mastiff.

One of his problems with dogs is that hunters kill them, a problem we heard repeatedly in both Spain and Bulgaria.

We saw a mastiff in Juan's barn that had been attacked by wolves in August. She had been very sick afterwards, and it was October and she was still recovering.

Any sheep that wander off on their own, or in small groups, will immediately be killed by wolves, Juan reported. For example, one group of 20 sheep was released without mastiffs and was promptly killed.

Paulino

Paulino is a goat producer who uses six mastiffs with his main herd of 448 goats. His herd mostly kids in his barn, but sometimes out in the fields. He sells market kids at 10 kilos (about 30 days of age) for E56/$80USD. Paulino's herds grazed on acorns.

Paulino's first ordeal with wolves was only three years ago, when a wolf pack moved into the area. There were at least two wolves involved, but the exact number isn't known. Many of the livestock producers didn't believe there were wolves in the area, and few precautions were taken. Paulino had two mastiffs at that time – a very pregnant female, and a 10-month old pup, so his goats were not well guarded. The wolves killed 51 goats in one night. After that depredation incident, Paulino purchased several more mastiff dogs and has not suffered any major losses since then.

Paulino often locks his goats in the barn or a pen at night, but some nights the goats stay out with their mastiffs. He factually noted that any goat left out without a mastiff will be killed by wolves. "The goats must be protected," he said.

Paulino has a second herd of 60 goats that are protected by one mastiff. We also saw 60 black cows with a mastiff just outside his village.

Our last livestock producer visit one afternoon was to Paulino's second herd, consisting of 60 mother goats that were out grazing, away from their penned kids. Paulino reported there was one mastiff dog with this bunch that he thought we would like to see. We arrived at the pen in the evening, and the mother goats were nowhere to be found. We walked through thick brush covering the mountainside, trying to find the herd, but couldn't even hear their bells. Paulino decided to drop down into the canyon below in attempt to find the herd and place the mothers back with their kids for the night in the safety of the 8-foot tall wire pen, so we were to wait.

As it started to get dark, and we could hear the goat bells coming in the distance, we (wolf researcher Juan Carlos Blanco, Jim, and Cat) walked back to the kid pen, opened the gates to let the goats in, and stepped back out of the way. We realized that if the goats tried to approach the pen and saw strange figures in the darkness, they would never enter the pen. So Jim and Cat stood very still next to Paulino's vehicle, while Juan Carlos stood on the other side. The goats began coming to the pen, but they approached from both sides, so Jim sat down on the ground so he couldn't be seen. Afraid to move, Cat just stood frozen in place.

Suddenly a large mastiff male approached the pen with the front of the herd, so the goats began to enter. The male stuck his nose to the ground and wheeled around looking in Cat's direction. Cat warned Jim so he could get up off the ground, and began softly telling the massive dog what a "good puppy" he was. The dog barked loudly at Cat and came directly for her, but when he approached close, he simply sniffed her hands, which she quickly used to pet and praise him. He raked Cat's hands with his teeth, and then passed behind the vehicle to meet Juan Carlos. Cat could hear Juan Carlos talk to the dog before the dog continued his circle to meet Jim. The dog raked Jim's hands with his teeth as well, but did not bite.

That was a miracle. We had created the worst disaster scenario in which we were fully prepared to be attacked by a guardian dog, yet the dog did not bite anyone, and only showed mild aggression. He was very nervous, and although Paulino was talking to us, as we approached the goat pen, the dog continued to rake our hands with his teeth, taking our hands into his mouth in attempt to redirect our attention from the goats to him. Understanding his body language and what he was attempting, we walked away from the pen. This increased the dog's comfort level and he went inside the pen to his goat herd, with we strangers safely locked out.

It was too dark to get a photo, but this was a typical massive mastiff, only one year and two months old. Paulino's mastiffs were not friendly mastiffs like others we had met, and did not want to be touched by strangers. This is probably a reflection of Paulino's belief that the dogs should not be petted while they are being bonded to livestock as pups. His largest and most valuable mastiff, Leon, was always nearby, but lurked in the brush where we could never even fully see him. Leon was the only dog wearing a spiked leather collar as a defense against wolves. The collars are often reserved for the best dogs.

We were extremely impressed with the working Spanish mastiffs we met in Spain, and recommend that livestock producers in wolf country in the United States try this breed. Their effectiveness against large carnivores, without human aggression, is highly desirable. We hope to gain support for bringing pups from working lineages in Spain to the Northern Rockies. Wolf biologist Cortés would be a logical contact for such a project, and could bring both the dogs and the knowledge of their husbandry to share with us in the United States.

Paulino uses the same bonding process as most producers in America, placing the pups in a pen of kid goats to bond for their first two or three months of life. Little training is undertaken, although if a pup chews on the ears of a kid, he spanks the pup with a newspaper.

"They should always be with the goats, and with the other dogs," he said. "Even when the pups are young, if they are with older dogs, this is enough to train them."

Paulino breeds and raises pups, giving excess pups to other producers. Paulino said he does not castrate his dogs, with his interpreter stating, "He thinks that they suffer a lot." "The goats are the family of the dogs," Paulino said through his interpreter. "They believe they are."

Paulino does not pet or play with the pups, and if they approach him for affection, he rejects them. Paulino advises that producers avoid strong links with the dogs, fearing that the dogs will leave the goats and attempt to follow the herder. He does pet his dogs enough so that he can catch them for veterinary care. When asked about whether dogs that aren't socialized to humans may be more aggressive to humans later, Paulino explained that from one litter of pups all raised together, only one in the litter became aggressive as an adult.

Although the goats and mastiffs share expressions of affection, the mother goats will also attack the dogs during kidding if they feel their kids are being threatened. One dog is very protective of any lame or sick goats that tend to follow behind the herd, and this dog will push the slow goats with its head to hurry them along.

Paulino feeds the mastiffs once or twice a day, using kibble and bread mixed with fat. Because the goats will compete with the dogs for food, he supervises the feeding to reduce conflict.

Like his goats, Paulino's dogs were a mixture of colors, and Paulino admitted to having a preference for white dogs since he can see them better from a distance.

Paulino is very happy with his mastiffs, and recommends that American producers in wolf country try the breed. Although he leaves his goats alone on the mountain with the dogs at times, Paulino fears the wolf pack will return.

When asked about mastiff aggression toward humans, Paulino said he has seen his dogs bark at people in a threatening manner, but never bite anyone. Paulino also reported that on occasion his mastiffs have conflicts with his herding dog, but attributed that to the smaller dog's insistence that it is the top dog.

Bulgaria

We were fortunate to meet up with Atila[4] and Sider Sedefchev, and Elena Tsingarska, soon after arriving in Sofia, Bulgaria, for an interview and interesting conversation about large carnivores and LPDs before we began our journey into the countryside. We arranged to hire Atila for the week as our driver and guide, and would conclude our week's tour at Sider's farm near Kresna. In addition to the farm, which focuses on conservation of native breeds of livestock and livestock protection dogs, Sider and wife Elena Tsingarska (a wolf researcher), and Atila are the founders and operators of the Large Carnivore Conservation Center, an educational facility complete with two captive wolves and a European brown bear, in addition to the livestock and dogs. Elena is Bulgaria's primary wolf researcher, a job she's held since 1997. The Sedefchevs are noted experts on the native Karakachan LPD.

Atila and Sider wrote: "We decided that conservation of the Karakachan dog in its original type and working abilities was impossible without the conservation of the habitat where the breed is formed. This meant conservation of predators, livestock, pastures and pastoral traditions: conservation of the unique symbiosis between all these elements.

"We started with projects for the prevention of harm to livestock by predators. We have been using Karakachan dogs as a conservation measure for the protection of large carnivore species.

"For Bulgaria this was pioneering work. We unite the conservation of a guardian and a predator, because evolutionarily they developed together. Survival of the guardian depends on the survival of the predator and vice versa."

We also had the pleasure of spending an evening with Dr. Atanas Vuchkov, a professor in Agrarian University-Plovdiv and a member of managing body of the International Karakachan dog Association (IKDA), and Venelin Dinchev, chairman of the IKDA.

Sider reports that the Karakachan LPD works well with sheep, goats, and cattle in protecting against attack by wolves, bears, and golden jackals. Bulgaria has some of the highest large carnivore densities of any country in Europe, with about 1,200 wolves and 600 bears. A European brown bear recently killed a woman out picking mushrooms.

A program to distribute Karakachan pups to livestock producers in regions of the Balkans that are inhabited by large carnivores has reportedly resulted in an 80-percent decrease in depredations. Much of the livestock grazing in southern Bulgaria involves common flocks, in which the livestock is gathered together from all the people in a village and are grazed together. Sider reports, "In one

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flock, numbering 1,200 animals, where sheep were gathered from 114 different owners, we gave four dogs. Later the shepherd of this flock produced many puppies and kept four of them for himself**.** "
The contract for participation in the program requires the producer to give Karakachan pups from future litters to other producers.

From our observation, herding of animals is mostly done on foot. In much of southern and central Bulgaria, the landscape is generally too steep and rugged for horseback-based herding.

In a 2005 article in Carnivore Damage Prevention News, Sider explained: "The *Karakachan Dog* is strictly territorial. It accepts the flock as its territory, wherever it is. Being close to the flock, they become visible aggressive. If a stranger tries to catch an animal from the herd this person can be exposed to serious aggression. However, when a flock is passing through a village the dogs walk calmly without paying attention to people. But I do not remember a case of a person being bitten by project *Karakachan Dog* guarding livestock."

"There is another reason for the lack of accidents. Namely, the tradition of guarding livestock with big, aggressive dogs has always existed in Bulgaria. Everyone knows about them and people simply avoid the flocks so conflicts don't occur. Also there are dogs, which do not express aggressiveness towards people, but in same time are excellent guards against predators. The trends are in breeding dogs that are less aggressive towards people."

"These livestock guarding dog has always been the only effective traditional protection against predators. It is a key factor in solving the predator/man conflict and consequently saving large carnivores."

We found the dogs to be extremely athletic, and learned they are very effective against bears. The dog pack works together to move danger away from the herd. We found aggression varied in the dogs we met. Most Karakachans are used in high recreation areas, and have little conflict with humans. But we also met one breeder specializing in human-aggressive LPDs because of livestock theft.

Bulgaria has been part of the EU for three years. The EU pays a subsidy per head, plus per hectare, for livestock grazing, at a stocking rate of six sheep per hectare. If the producer uses LPDs, the subsidy is higher. They are paid for grazing in the national forest, national parks, and municipal lands.

Taxes for goats are ten times higher than grazing for sheep. Goats are viewed as bad, or "evil," and are forbidden from mountain grazing.

All of the thick, brushy mountainsides we observed was once open country (within the last 100 years), because herders would set fire to it when they left for the season. The Bulgarian sheep herd has been reduced from 10 million sheep to 1.5 million sheep.

Because of all the moisture and fog associated with the Balkans, producers use bells on many of their animals in order to find them. We saw and heard bells on LPDs, goats, sheep, and cattle. The mountains are alive with the soft ringing of bells.

Atila maintains that the LPDs must like challenge to be effective guardians in large carnivore country. He reports no problems with wildlife and the dogs, since shepherds won't tolerate dogs that chase.
Both Atila and Sider are offended by comments from some researchers suggesting that LPDs think that they are sheep.

"The dog is brave and has instinct, or not," according to Sider.

We also learned that in some European countries, it is illegal to dock dog tails or ears, or remove dewclaws from a dog. Bulgaria also has a law requiring LPDs to wear a 30cm-long stick attached to the collar of their dogs. This stick, called a spavachka, is to hang to the elbow joint of the dog. Sider explained that spavachka is supposed to act as a hindrance to prevent the dog from running after game animals, and a LPD without one can legally be shot. Shepherds despise the law and feel it hinders the dog's ability to work. They have devised numerous spavachkas that comply with law, but do little to hinder the dog's movement.

In our interviews, one herder commented that he felt he could not graze livestock without his LPDs. He noted that wolves were the same color as the trees and were too difficult to see.

Daniela

Sheep and goat producer Daniela Chakarova of Progled, Bulgaria has used Karakachans for more than 20 years. In the winter, her herd is located on the mountainsides outside the ski resort village of Chepelare and near Progled (we went to both places) in the Rhodope Mountains. The herd grazes in the summer in Hadzhiitza and Karamanitza mountain pastures. She uses seven dogs with 300 sheep, with three or four extra dogs available.

Tradition is to raise only two pups per litter, but since there is an effort being made to distribute Karakachans and more dogs are needed, the culling program has been softened.

Daniela told us that having one ear docked is the sign of a working LPD.
She does not fence her sheep, but does use night pens. Sheep are lambed out on the mountain.

Daniela said Karakachans “are very clever.” The dogs avoid direct conflicts with bears, instead making the bears run away from the herd. The dogs are very athletic, and move very quickly.

Daniela uses iron spiked collars on her dogs, and said she’s still using them because of Bulgarian tradition. Daniela said her dogs generally don’t fight amongst each other, unless a female is in heat.

Most problems are with brown bears that come into the villages, Daniela said, while most wolf attacks involve more than one wolf.
“That’s why we prefer to have young dogs,” she said, pointing out that old dogs go out after the wolves, and the young dogs stay back and bark.

In one case, she had 20 goats, 10 of which were killed by wolves in one night. The mayor of the town demanded she chain all her dogs after the wolf killed the goats, so a bear came in and killed one of her pups as well.

Daniela said she would not be able to continue in the sheep and goat business without her guardian dogs. Some dogs patrol within the herd, others outside the herd.

If a dog is missing, that means she is missing sheep, Daniela said.

She cuts up carcasses to feed to dogs. Also feeds a mixture of wheat, corn mix in boiled water, sometimes adds milk to it – it’s called kakamucka. She also puts whey into dog food, every day.

Her dogs give birth in the wild, with the livestock. Just the dog’s owners touch the pups, while feeding the female, so they will have the ability to catch and handle the pups later on. They become bonded to the flocks and to the shepherd only.

The dogs tend to keep their distance from people, but may attack people if they come too close. If you stand quietly and do not enter the herd, you’ll be fine, she said.
While we were on the mountain amid Daniela’s herd, a man from a nearby village came near the herd while picking berries, and the dogs did not behave aggressively toward the man.

Younger dogs don’t go out away from the flock. Pups go out with herd for the first time when they are two months old. It’s good to have littermates together in a herd, so there won’t be conflicts later on as adults, she said.

At one year old, the pups will defend the herd, but will have little experience, Daniela said. After they are three years old, the dogs are perfect guardians. She said the dogs live to 15 years (a few cases of 20/21 years old).

She teaches certain commands to the dogs, including “go to herd” and “stop attack” using the same base word (“Off-sta” = sheep).

She prefers her dogs to have double back dewclaws, black mouths, and she also has a preference for big pups. She advises the use of white dogs in a dark herd so they can be seen as they move in the fog. She likes a contrast in colorations, and doesn’t like dogs that are completely white or completely black.

Dimitar & Georgi

We met up with the father and son team of Dimitar & Georgi Varshilov who are owners of a herd of sheep we found eating thistles in a field in a populated area near Plovdiv. This outfit had a lot of dogs, and 800 sheep that are managed as four herds, with three or four dogs used in each group in the summer on the highlands. While the dogs are in the lowlands during the winter months they are chained or tethered. We visited two of their four herds.

The primary predators of concern are bears and wolves. This producer has used livestock protection dogs for 40 years.

The ewes give birth to two, three or four lambs – Ill de France and East Friesian dairy sheep. This producer places colorful beaded collars on his sheep “for beauty.”

Bears pose less of a problem to this herd, according to the men. Bears don’t care about sheep because they are being fed at bear feeding stations. With big dogs, there are no bears.

“The dogs know the bears,” Dimitar said.

The Varshilovs noted that the Karakachans mark their territory, so the more dogs marking the territory, the better. Dimitar noted that wolves and dogs share some of the same behaviors, such as the dogs marking the same territory as the wolves. The wolves learn and do not challenge the dogs.

“So the wolves, when they see the dogs are serious, they go on,” he said.

Occasionally there are problems with wolves. One year, a wolf grabbed a sheep around the neck, but did not kill it, while there was only one young dog with that herd providing protection. The family has had no losses on high pastures in the last six years, even though wolves are present.

The Varshilovs have not had dogs killed or injured by wolves. They breed their own dogs, keeping five or six pups if it’s a really good litter. The dogs bond with the sheep, lick the lambs, and show affection. The dogs will lick and clean injuries on a sheep as well. Pups move with the herds from a very young age, and pups that are born on the mountain with the herd learn from older dogs. The herders seem to believe that pups born out with the sheep, and moving with the movement of the herd, lack health issues like hip dysplaysia.

They reported the maximum size of their male dogs is 45 kilos (99 pounds), for a 1 ½ year-old male.

The herd is sometimes night penned, and in bad weather the herd is kept inside, but in good weather, the herd stays out with the dogs.
Some dogs stay inside the flock, while others patrol outside, and the dogs load into trucks alongside their sheep.

When asked if they have a problem with shyness in their dogs, the Varshilovs said the dogs have some contact with the herders because they must have some control.
"They prefer a more soft dog, because they are easier to handle," their interpreter explained.

The dogs respond to tourists approaching too closely by barking. They go out 15-20 meters from the flock and bark. Motorcycle or bicyclists have been chased, and one of their dogs bit the tire of a motorcycle.

This family has a color preference, preferring black and white dogs, saying that they are more visible in the herd.

Their dogs fight occasionally, but it's over females in heat.

The family has used spiked collars in the past.

Although this producer does not dock his dog's ears because the men personally do not like it, they cautioned that if the dogs are fighting often (either with each other or with wolves) the ears are the weak spot. They do not castrate dogs either – they did this to one dog once, because the dog wasn't staying with the herd.
The dogs are fed every day, usually bones and the trachea of cattle from a slaughter house/rendering plant. Sometimes they feed meat with porridge, and out-of-date sausage or kovbasa.

Their dogs are trained to the "return to sheep" command. They perform regular vaccination of pups, but now there is a new program where producers must go to the vet to get prescriptions to get vaccines, a program disliked by producers.

They do have problems with young dogs getting killed on roads.

Miroslav

Miroslav Marinov is of Zmeyovo village, near Stara Zagora, Bulgaria. He owns the Volcan Karakachan kennel, and raises 450 head of Zakar sheep, the local sheep breed of southeastern Bulgaria. His herd grazes in winter near Zmeyevo in Sredna Gora Mountain, and in summer, in Central Balkan National Park.

A veterinarian by trade, he has recently achieved some musical success. As his wealth increased, he purchased a farm and livestock 15 years ago, so that he could have these dogs. First he bred goats on his farm, but switched to sheep.

Because of past problems with human thievery, Miroslav selects for human aggressive dogs. His training involves chaining the dogs out, and having a stranger with a stick attack the dogs as if they were to be beaten. The dogs lunge forward, trying to attack the stranger with the stick.
Five or six “softer” dogs are allowed out with the herd during the day, but the “harder” dogs are unleashed at night.

His dogs sometimes fight, but in principle have a strong pack hierarchy. Sometimes the dogs fight for dominance, or for food, and females. The dogs will keep all intruders out of the herd, but must show submission to the flock.

His dogs will challenge and fight dogs from other flocks, but in subsequent meetings, will not let the dogs within 100 meters of his herd. He said the bigger dogs get in the fights, not the smaller ones. The dogs launch very fast attacks, which he said is important when facing bears.

He does have problems with tourists and hikers.
“It is a problem because hikers are not trained how to deal with dogs,” he said. One hiker was bitten on the butt by one of his dogs, so he presented the hiker with the gift of a puppy to make it up to him. The dogs also chase motorcyclists.

Miroslav said wolves prefer donkey meat to sheep. Wolves and jackals are his major predators. In the last 10 years, he has had only one goat killed in the lowlands by three wolves. The goats were guarded by only one dog at the time.

Miroslav reports that his dogs have deterred six bear attacks that he knows.
One herd guarded by 8 dogs had 25 sheep killed by wolves.
One herd had 14 sheep killed by wolves. The herder used lights and a pistol to make noise to keep the wolves away. He eventually gave up this pasture and got better guardian dogs.
One night he left two dogs with the herd, and 8 wolves attacked. Some of the wolves lured the dogs from the herd, while others moved in to attack. The flock separated into three groups, and some were attacked on necks, others on the shoulders. This mountain pasture is within the Central Balkans National Park.

Castrated dogs have only about 70 percent of their working ability, he said, adding that it was better to have 70 percent of a dog than zero.
“It’s rare to castrate a dog,” he said, adding that castration causes the problem of more fighting between the sexes (males and females fighting each other).
“It is better to have fertile dogs, to protection your lineage,” he said.

He does not docked tails, stating that curled tails are very visible in the herd. He prefers lighter-colored dogs, and prefers lots of white so he can see the dogs at night. He said his sheep, which have encountered wolves, do not like dark-colored dogs. He uses a German Shepherd as a herding dog.

This producer said the dogs are "absolutely trustworthy" around his family members. He advised the less human contact, the better, although puppies are encouraged to learn its flock and its owner.
Miroslav said the dogs have to have human contact in order for the herder to be able to manage the dogs. Dogs must know the livestock first, then the owner.

One of Miroslav's dogs that we saw was a seven-year old female that had her leg broken in a fight with a bear three months prior.

Most of his pups are born out, and they try to time whelping so pups are born in the winter months so the pups can be with the lambs.

Sheep spend nights inside buildings, with their guardian dogs, while the shepherd sleeps in the village. The dogs keep new shepherds from entering the buildings as well.

When it comes to chasing predators, Miroslav said some dogs chase long distances (as far as one kilometer), while others are short-distanced. In principle, the older dogs with more experience stay closer to the flock, and the young dogs chase farther. He said the more dogs guarding the herd, the farther the chase will go, and less dogs stay closer.
The dogs must be brave enough to attack the bear, and not just bay it like a hunting dog.

The size of the dog isn't as important, Miroslav said, since the group works together as a pack when danger approaches. He selects dog behaviors for his herds – some will stay on front, others in back, outside, inside herd. He said this is important because when sheep are trailing, wolves will try to kill from behind. He selects dogs that work as a team.

He sometimes purchases dogs, then chains them so that the dogs can see each other. He then brings the dog to the herd and others on a leash. He said it's similar to introducing a new sheep to the herd.

Miroslav said the best guardian dog is a female. We saw a 14-year old male dog on his farm, again indicating the rather long lives of this breed.

His dogs wear generic collars (without spikes) and spavachkas. He selects for double back dewclaws.

His dogs do fight, and he had one dog killed by other dogs.

His farm is a former state farm, as was evident by the stone water troughs that were 50 or 60 years old.

He feeds the dogs a grain porridge while the dogs are on mountain pastures, and in the lowlands, he often feeds kibble because it is lighter and easier. He often feeds cuttings from the butcher as well.

He keeps more dogs than necessary to his operation to avoid a crisis situation if dogs are killed or die.
"It is better to feed dogs than wolves," he said.
He thinks six dogs on five wolves would do okay. He finds bear fur in the mornings when the dogs have encountered marauding bears.

His kennel produces four to six litters of pups a year, breeding in the October through January season. His females come in heat once or twice a year. He does not cull any pups because he cannot select the best dogs at birth.

His predator problems are not seasonal. In every case, when he removes dogs, there has been a problem. The peak of wolf attacks on his herds occurs in mid-August and in the autumn when wolf pups are learning to hunt.

In the national park where he grazes his herds, tourists are deemed more important than grazing, and there are conflicts.

Sider

Sider's Karakachan sheep herd grazes in Pirin National Park in the Pirin Mountains, and in winter, around Vlahi village. Sider's flock of native sheep totals 448 head, and he pens the herd at night in a pen made of bushes. They also have an enclosure on the mountain, but if the pen is muddy, the sheep are left out at night. The herd lambs outside in January and February, with the dogs cleaning up the afterbirth. If a sheep dies out on the mountain, the wolves will clean up the carrion. The dogs will eat the dead sheep if it is cut up for them.

Sider reported the dogs have no major health issues, although one female died of cancer, which he said is more common in breeding stations than on working farms in the countryside.

Pups are raised with the flock. Sider said that having more male LPDs is better than having more females because there will be less fighting. Sider said bonded pairs stay together, and older pups help care for younger pups.

Most Karakachans die from being poisoned or shot, but otherwise can have rather long lives. He's had two dogs live 15 years, and one lived to be 18 or 19, but the average is six or seven years for these working dogs. He has had 13 working Karakachans dogs killed by hunters in 10 years. The situation is dire enough that his herders carry an antidote to poison in their backpacks so they are prepared to provide care to poisoned LPDs.

Puppies can be effective guardians, even as young as four- to six-months old, Sider said.
“They can be effective too, because they can see, they can smell, they can give signals to the other dogs,” he said. But a dog aged 1 ½ years “ is very effective.” “I think the best dog is a three- to five-year old dog,” Sider said, calling them prime guardians at that point.

When asked how far the dogs will pursue when encountering wolves, Sider said it varies, but sometimes the dogs will run 20 minutes non-stop through the forest, going far if there are other dogs remaining with the herd.
Sider also noted that Karakachans are rarely found in the middle of their herd, instead preferring to surround the herd.

Sider does not castrate any of his dogs, saying that castrated dogs become lazy. “Old shepherds really like castrated dogs because they are not problematic,” Sider said, because the males do not fight and pursue females.
He brings the females to the farm for breeding because the males will fight over the females on the mountain.

Sider maintains there are important characteristics of male and female Karakachans, including that the females bond more closely, but are not as good at attacks. He maintains that the presence of females improves the male’s performance. He said two females with four males is a good combination.

Sider does not cull pups from litters. Although he doesn’t cull for color, he likes black dogs with white neck collars, and he likes a third color as well.
“In the forest, the spotted dog is more visible, during the day or during the night,” he said. Most of the pups are born at the farm, but if born out, he follows the female to find the pups. At 20 to 40 days of age, they start feeding them food.

He tries to limit the amount of contact the pups have with humans, but this does not apply to the shepherds. There are many people around – volunteers, people coming to visit and see the large carnivore center, tourists on the mountain. Limiting the pup’s contact with others is aimed at keeping them from following visitors and bonding with strangers. Sider touches them and bonds with them instead. Sider doesn’t want every visitor touching the pups. When the pups do something bad, he kicks them. He doesn’t want the pups to go with the nice stranger instead of him. It’s part of training for the pups.

Sider believes he could train his dogs to be human aggressive, but that isn’t what he wants because of the human encounters the dogs will have in the forest. He noted the genetic lineages of his dogs do not include a base of human aggression.

Sider noted that when it comes to Karakachans, size really doesn't matter because the dogs are very easy moving and quick in their actions.

Sider also noted that the dogs can look at people and judge a person's intentions. His dogs will react differently to new volunteers than to strangers coming from the village.

Sider recommends about five dogs per 200 goats, and trains his dogs to a variety of commands. He uses the "go to sheep" command, and he trains his dogs to a signal for when to look aggressive, and what direction to run.

The sheep and goats don't like each other much, Sider said, so they are kept in separate flocks with their own dogs.

The dogs will chase game, so need to be kept busy.

Sider said it is tradition to dock one ear, but it's not a tradition he's followed. Traditional docking of one ear is done to assist in hearing, he said.

He feeds porridge every day, and feeds twice a day on the mountain because of the energy required by the dogs. He also cuts up carcasses to feeds to the dogs.

Sider recommended that if the dogs are working well together, use the anti-wolf collars as great protection for the dogs. But if there is conflict among the group of dogs, the collars will cause additional problems for the producer. Once a new dog finds its place in the pack (after the hierarchy fighting is over) he places iron collars on the dogs.
He said to put the collars on the three bravest dogs in the flock because these will be the dogs to immediately challenge the wolves. This strategy provides a better possibility for the dogs to survive the initial attack while the other dogs are coming to join in.

Sider wasn't currently using spiked collars, but has used them in the past, and will again in the future. Dogs have interpack strife and iron collars can result in broken teeth. He reported the collars do not cause problems in heavy brush, or getting snagged.
"They can use this," and "the more experience they have, they know how to use them."
"Our best dog would use his, he was a professional fighter. He liked to fight but was very intelligent."
He had some broken teeth, Sider said, "he was so good."
"He was just like human, you could speak with him," Sider said in admiration of his dog.

Most of the dogs do not fight to the death, although a few will. Sider had a pack of five dogs he could walk with, free, and not cause problems. He also had this one dog that loved to fight, “he was fighting to kill them, not to fight” and killed numerous dogs. This was a dog he had purchased as an adult, not one he had raised.

Sider admitted that his dogs have bitten people. His dogs will attack if people try to cross through the flock. There are many tourists around, as many as 100 people at once. The people must be taught to go around the herds, he emphasized, because the dogs must be allowed to do their jobs.

The predator encountered most is by Sider’s herds are wolves – most encounters are two or three wolves, often from 3-5 wolves in a pack in the area.
“There were years when I lost a lot of goats because of the goatkeeper,” he said, because the goats were scattering, causing a few cases of predation.
“Once the wolves killed a young goat in front of me. I saw the wolf for a second, but it was too late,” Sider said. “That same year, our dogs managed to kill a wolf. Some year, maybe four years ago, they killed another wolf, mainly when they were alone.”

He was losing 15 or more sheep a year to wolves in the past. One year, he had three sheep killed by wolves, while the dogs were distracted by a female in heat. In one year, seven young horses and three cows were killed by wolves in 10 days. The male wolf was eventually killed. The horses and cows were free-ranging, without guardians.

“With the sheep, almost nothing in these 10 years,” Sider said, “because the sheep stay always together. And I have always better dogs with the sheep.”

The reason his losses are low are because the sheep flock well when paired with good guardian dogs, Sider said. The dogs help to keep the sheep together.

He did give a Karakachan to a cow herder, and the dogs bonded to the cattle. There are some cases of people using these dogs with cattle, but since cattle are used mostly in the lowlands, not so much. Now that there is a subsidy for grazing in the highlands, and for using livestock protection dogs, he expects more people to try it.

Dogs will sometimes bite the sheep in dispute over food, Sider said. Sometimes there is injury, but it’s not a big problem. The sheep learn not to bother the dog food.

When a sheep or goat dies, Sider cuts up the carcasses to feed to his dogs, adding that his dogs will guard a dead sheep and await the herder.

His dogs have been injured by large predators, including a female dog that was slapped across the face and scalped by a bear.

He does not believe wolves are attracted to his dogs in any manner, including female dogs in heat.

Sider said from his experience, wolf packs will select the least-protected herd or flock to attack. So if his herds are guarded by Karakachan LPDs, and his neighbor’s herd is not, it will be the neighbor who suffers.

In Bulgaria, back dewclaws are know as “wolf fingers” because of the gripping power of the dew claws. (Even though wolves don’t have back dewclaws.) In Turkey, they are called the “wolf killers.”

Sider’s program breeds and sells Karakachans and he’s happy to ship to the United States, as he’s done in the past.

Karakachans are effective in guarding herds from both wolves and bears, but have varied levels of human aggression. We recommend further research on the potential use of this breed in large-carnivore country of the United States, but wouldn’t hesitate to recommend producers in grizzly bear range give this breed a try. LPDs should be selected from working lineages without human aggression.

Turkey:

We flew into Izmir, on the Mediterranean coast, meeting our guide for the week, Guvener Isik[5] ("Isik"), and spending the night in a private home along the shoreline. The next morning, we rented a car for the week and headed for our first stop, Denizli.

Turkey is huge landmass, with many people involved in agriculture. There are few fences, so livestock must be herded. There is a substantial wild boar population, which many livestock producers view as a much bigger threat to their livelihoods than wolves. We saw and heard bells on sheep, goats, and dogs. We saw beautiful collars placed on sheep "for beauty."

The Turkish wolf population is estimated to be about 5,000 to 7,000, and wolves are considered an unprotected pest species. There are no established quotas for wolf hunting, or set hunting season, so wolves can be taken much as we do coyotes.

Isik told us that villagers believe that the behavior of wolves has changed over the years, and now the wolves don't howl, or don't form big packs very often. Most packs are usually only two to four animals.

Isik told us that wolves do breed LPDs on occasion, and we heard local stories about it. One village in eastern Turkey is known for its wolf crosses, although we did not travel there because it wasn't part of our area of inquiry. We also heard a story of a shepherd who captured a wolf pup and raised it with his herd at least until it was four years old. We heard this story repeated by several different people. Other wolves in Turkey are known to prey on dogs as a food source.

We saw tethered LPDs and learned that they are set free at night, to guard a cattle dairy from a nearby gypsy encampment. We found that generally, dogs that are tethered during the day are more dangerous to humans.

Dog fighting/wrestling is still popular in parts of Turkey, and those who raise big LPDs often meet up for competition between their dogs and those from other villages.

The Kangal is now the national dog of Turkey, leading to show-dog syndrome, where some of the top dogs are called Kangals but have little guardian instinct, and breeders are expected to be paid high dollar for pups. Soon after we arrived in the country, we realized there are several different ideas about what constitutes a "Kangal," so we stopped using that breed name. We learned that there is a wide variety of large shepherd dogs in Turkey, and some are given regional names. We call them, collectively, Turkish shepherd dogs.

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[5] Guvener Isik, isik34@hotmail.com

We met Turkish LPDs that are proven fighting dogs, as well as excellent guardians. It can be very difficult to legally export the dogs, but we don't believe it to be impossible.

LPDs in Turkey must guard against jackals, wolves, leopards and wild boars. We did not learn of any human aggression or livestock aggression in street dogs, village dogs, etc., although they are found throughout the country. The Turkish government does not kill stray dogs, but catches and neuters strays before turning them back out for the citizens to take care of.

Throughout Turkey, we saw large shepherd dogs everywhere. Some were fighting dogs, good herd guardians, village dogs, and street dogs. They are large and look like LPDs, even if they aren't in the business of guarding livestock. They occupy the canid niche, serving as a deterrent to wolves.

One evening, we entered a mountain camp where the LPDs live with the cattle on the mountain full time. We also saw villages where cattle are penned at night, and let out to graze the highlands during the day, their LPDs constantly at their side.

Kayis

In the village of Seyit, outside of Denizli, in southwestern Turkey, we met up with Ibrahim Kayış at his home, and then traveled with him out to his fields to meet his sheep herd that was being tended to by his brother Musa and father Hasan. Their 400-head herd produces both meat and milk, and they've raised livestock protection dogs all their lives.

They lamb out in the fields, and the dogs clean up the afterbirth. They have lots of wolves in the area, in addition to jackals, but no bears in this region of the country.

When they don't need the pups, they cull. The presence of back dewclaws on the dogs varies.

They crop ears when the pups are a few days old. Ibrahim doesn't like the looks of hanging ears, so that's why he crops. His father, Hasan said: "It looks nice, but the main reason apart from that, different dogs of different herds attack each other, and they damage each other, plus the wolf does the same thing, grabs the ear and damages the ear. With the wolf, he has no chance, with those ears."

They don't crop the tail because they believe the tail adds balance to the dog, and allows them to cover their faces when it's cold.

The dogs are fed yal – a grain-based porridge, in addition to wild boar, which is cut up and fed to them, as are dead sheep. Ibrahim said, "Just because you feed him a dead sheep doesn't mean that he'll eat a live sheep."

They had 17 wolves in one pack recently, and the pack was seen crossing the road. They recently shot two jackals in the village, although they don't regularly kill jackals since jackals will eat wild boar piglets. Big wolf packs used to be more common (a generation ago), but then declined, now are making somewhat of a comeback in this region of Turkey, according to Ibrahim.

They recently found a wolf dead in the water, and showed us a photo of it. They tried to save the wolf, but realized it was dead.

"If you have good dogs, the dogs will take care of the wolves," Ibrahim said. "The poor thing died," he said. "If you trust your dogs, they can handle them." We were told that herders wouldn't shoot a wolf because that would be an admission their LPDs weren't good enough.

The Kayis's haven't had any recent losses to wolves, and they keep three or four dogs with 400 sheep. They said this combination will take care of the wolves, but there will be some lambs lost. The sheep are penned at night.

As for spiked collars, Ibrahim said they are necessary to give the dogs a chance against wolves. He noted that different dogs from different flocks will attack each other, and wolves do the same thing. Hasan said that if the dog is wearing a collar, the wolf cannot grab the dog around the throat or the back of the neck. The dog knows how to hit it – the wolf, he said. "As they get older, they know the use of it {the collar}, and they start actively using it."

"In Konya, they say the same thing," Isik said, that experienced dogs actively use their collars in battle. The dogs wear the collars all the time, Hasan said, and the dogs sometimes fight each other and inflict damage on each other with the collars.

Ibrahim suggested the reason so many American livestock protection dogs are getting killed by wolves is that their genetics may be getting diluted, or getting softer genes passed, or by crossed with other lineages, with not enough desire.

Talking about his dogs, Hasan: "The males are very dominant –the way they howl tells the coming dogs to stay away, by the tone of their voice, not their approach. But some dogs, they want to challenge it, so they come in anyway." Their dogs do not allow other dogs to breed their females.

Hasan: "The wolf also knows the mighty dog. The wolf can feel that these dogs are dangerous, so it does not approach. It's the same, with the dog and the wolf – the voice tells the wolf its strength."

They feed the dogs well so that they are able to challenge wolves. The best thing to feed the dogs is yal, the men said. Before dog wrestling events, yal is the only thing that is fed. These are not the carnivores, we were told. Something is different in their metabolism, they just utilize that bread. “They are like bearish animals,” Isik said, adding that overfeeding can result in hip and bone problems.

Yes, these dogs can be aggressive to humans, and several people have climbed trees to get away from their dogs, the men said. They alleged that it depends on the people – that the dogs will chase and attack gypsies.

People in Turkey will try to steal sheep, we were told, so the dogs need to be aggressive to humans at times. The dogs independently judge the human and its activities, and respond in the manner it feels appropriate. In Turkey, if a dog bites a person, there is no real recourse for the human.

The day before our visit, two flocks crossed paths, and the neighboring sheep herder stopped and petted one of the Kayis’s dogs. All was well with that, but then one of the neighbor’s sheep joined the Kayis’s flock, and when the neighboring herder attempted to grab his sheep back from the Kayis’s herd, he was grabbed on the buttock by the very dog he had just petted. The herder did not say anything bad about the situation, realizing he should have known that’s what would happen.

“The people need to be educated, instead of changing the dog, people need to change.” Isik said. “These dogs have a job to do and they do it.”

“The man should be wiser,” Isik said. “If your dog has no aggression, how is it going to guard your sheep?” Isik asked.

They test their dogs all the time, Ibrahim said, and he sells dogs with a guarantee that the buyer won’t have livestock losses.

“The wolves in this area are the size of the dogs, and sometimes larger,” Isik interpreted for Ibrahim.

The pups are handled, but not petted by adults. The children play with them, but not adults. Too much touching makes the dogs too soft.

“It makes them soft.” Muslims also view the dogs as unclean, so that’s an added reason.

The dogs do work together. When danger approaches, one stays in the herd, while the others surround the flock. The dogs are affectionate with the sheep, and do not kill the family’s chickens, which range freely around the dogs. A magpie that was bothering the chickens didn’t have the same fate though, being shot by one of the men. The magpies look the same as those in Wyoming, but have a different call.

We watched a cell phone video of two of the Kayis's dogs killing a 450-pound wild boar.

We were told a typical wolf encounter goes like this: the pack sends one wolf in first, to check around the dogs, and if the dogs aren't too aggressive, the wolves attack. Some of the encounters with wolves take place over long distances and times. Sometimes the dogs will go for two or three miles in chase. The chasers are the wolf killers – sometimes not returning for three days.

None of their dogs have been killed by wolves in the last 45 years, we were told. We also saw photos of a wolf that was killed by one of their dogs.

One of their dogs lived to be 13 years old, but the average is seven years. Apparently the dogs live longer lives in cold climates, shorter lives in hotter climates.

The Kayis dogs are huge – not less than 80cm at the shoulder, and one was 86 cm at shoulder. These are long-distance dogs, traveling six months of the year, so their paws can get worn and bleed.

Isparta goat herder

We met a goat herder along the roadside near Isparta (southwestern Turkey) and stopped to talk. His dogs were native of the Anatolian region. Four of this dogs had fought with two wolves and ran the wolves off after the wolves had killed four goats.

He feeds his dogs yal and he reported that they have no human aggression.

Zaizihni

In southeastern Anatolia, we met a cattleman in a village, Zaizihni Kovulmaz. The village grazes over 100 cattle and one or two dogs with the herd, in addition to a herd of 400 Mandak sheep. The herders have very close contact with their herd members throughout the day.

This region has a four-month winter where the cattle are free outside the village. All villages in this area of the country have chickens and guardian dogs on the streets, but they are losing their people and their herds. We were told they need young people, especially young women/wives, because all the younger people are moving to the cities.

They feed yal to their dogs, dock some ears, and feed dead animals to the dogs as well.

As we drove across the country, we regularly saw dead dogs, (large livestock protection dogs or shepherds) that had been killed by vehicle collisions. The number of men, dogs, and cattle are getting smaller, we were told. Zaizihni pointed out they have hot and cold running water in his village, electricity, and all their food is organic, but yet they are still losing people.

The village sheep are penned at night in rock barns with windows. The windows allow for airflow, but wolves occasionally use them to gain entrance and kill sheep.

Ali

Ali Keskin is a goat producer who lives near the village Selcen. When we visited he was trying to figure out why one of his goat's was suffering from paralysis. Ali uses three dogs with 250 goats.

Ali has a two-and-a-half-year old unmanageable dog that had pulled down two people from tractors, and killed a wolf that came into his barn a month prior. Because the dog works against wolves, it was still alive, but Ali was willing to offer him for sale to us. The dog was obviously very dangerous.

Ali does not pet, socialize, or train his dogs in any way. The dogs are only fed yal.

Ali docks his dog's ears because the dogs fight with wolves. He said docking minimizes the damage done to the dog, and because "A dog with ears cannot hear."

Ali doesn't like to use spiked collars in brushy country because the collars can get stuck, he said.

Wolves have killed some of his dogs in the past. Now that wolves are congregating in bigger packs, he has constant wolf problems.

Kultu

Father and son Hayuk and Ilhan Kultu are Anatolian Turkmen and sheep producers. They had four sheep killed by wolves, so they brought in a new bitch – a wolf-proven bitch. Their dogs have been injured in fights with wolves, without loss of sheep. They also have a dog that wrestled a bear. They recommend eight dogs with 1,000 sheep, or three or four dogs with 500 sheep.

The dogs fight between themselves, the men reported. These dogs can kill badgers, they said, and not many animals can. They feed the dogs yal and biscuits made like a ball from yal.

They said in 2010, every flock in their region had losses from wolves, with four or five sheep lost from each flock, and flock sizes varying from 500 to 1,000. They also noted that wolf behavior is changing, that the wolves are more shy and sneaky.

All their dogs wear spiked collars except for when around the village so the dogs aren't given an unfair advantage with village dogs (so they wear spiked collars for eight months of the year). The iron collars are too cold, so felt lining is used to line collars.

The collars are used "to provide protection from wolves."

"A smart dog knows how to use its spiked collar," Hatuk said.

He said the size of the dog doesn't matter, it's all about the heart. But his bear-killer dog was a very big dog. Big dogs are not good for rocky areas, they said, adding that they select for hard, compact paws.

They dock their dog's ears, but not tails. They recommend always cropping the ears, with no exception, because when the dogs have conflicts with wolves, they lose their ears. In summertime, they don't crop the ears, so when those dogs grow up, they get in conflicts with wolves and get their ears ripped.

Some of their dogs have naturally cropped tails, not from their active cropping. They do not castrate or neuter. They prefer dogs with back dewclaws.

Their dogs are allowed to eat on carcasses once they open them up, and the dogs are also allowed to eat afterbirth.

A good dog manages the rest of the dogs, and the lead dogs are usually bitches, they reported. In pursuit of wolves, they don't like their dogs to go too far.

They recommended we use felt underneath the iron collars, and suggested we continue the Turk tradition of painting the collars, and adding bells to the collars.

These people don't like dogs called Kangals – they like the LPDs called Central Anatolians.

Memet

Memet is a cattleman in a small Yoruk village called Sarkikaraaagac. He raises small native cattle (40-42 inches at shoulder) that he says are more economical than larger breeds.

Memet told us his area was "infested" by wolves. If the cattle are related and have close bonds, they do well. If not, the wolves may snatch calves, he said. The cows will bunch into a circle to protect the calves, and normally wolves are unable to breach the circle to make a kill. He said that some of the cows will also defend their livestock protection dogs. There is a very close cooperation between the animals, Memet said.

He only feeds yal, and boils it for the dogs.

He crops one ear to promote good hearing. His herds graze within Cedar National Park, where goats are forbidden.

Village shepherds had recently met and decided not to use spiked collars because village dogs have been killed in conflicts with LPDs wearing the collars.

We heard the sound of a shotgun being fired while we were at the cattle camp on the mountain late one evening. We were told they were shooting to keep the wolves away.

In the cattleman's village, we were told that they are losing ancient traditions, including the use of spiked collars. But because there are lots of wolves, and with more dogs, there is more fighting. The village has both cattle and sheep herds with herders.

They harvest apples and cherries in and around the village. They don't shoot wolves because the wolves control the wild boar piglet population. They lost one calf last year, and a neighboring herd lost one just prior to their visit. Herders come down to the camp or village at night, but the dogs stay on the mountain with the cattle herds.

<u>The Turkish countryside</u>

We purchased two plain iron dog collars at a blacksmith shop in Ilgin, outside the city of Konya.

We spent a night at a dive in Konya, and purchased iron collars in a shop there. The streets were busy, with men selling hot, fresh bagels from trays on their heads, and others delivering trays of hot tea to various businesses and groups of people. In this extremely conservative part of the country, women are fully covered from head to toe, and we saw no mixed groups of people. The men eat lunch in the restaurants first, the women later.

There are no livestock trailers – either they are shipped on the hoof, or in trucks. We learned that human theft of livestock is always a consideration and a risk.

In Anatolia, there is a 3,000-foot elevation, and sugar beets are grown there. Everywhere we went, we saw people involved in agriculture, herding sheep, goats, and cattle on foot, harvesting apples, beets, lettuce, cabbage, peppers, and olives. We saw tractors constantly on the roads, as well as farm wagons, burros, horse-drawn carts, and tethered and free shepherd dogs, many wearing spiked collars. In the Cappadocia region, we saw the beautiful rock walls with the caves and homes built in (near Avanos) and prettily painted farm wagons in that region. I found the inland city of Kayseri to be surprising and beautiful.

We saw lots of gypsy camps throughout Turkey and Bulgaria. Isik commented, “Gypsies are like pigeons – they are everywhere.”

Our travels took us around the base of Mount Demirkazk, and wound through the highlands adjacent to the Taurus Mountains. At that time, there was no YouTube allowed in Turkey. We sat in our hotel room watching the censored version of Desperado, where they even blurred the vision of a woman smoking. We saw concrete snow fences, and pay “WC”s (waste closets). All the school children we saw were wearing uniforms.

We encountered a few Kurdish herders, and even ended up in the Kurdish conflict zone. The “Jandarma” or military police were everywhere with guns at the ready, snipers visible on the hillsides, and armored personnel carriers on the streets near Kurecik. I loved the Kurdish villages and the countryside where they are located, but we weren’t allowed to linger or loiter. There were fighter jets – including American jets – flying overhead.

We talked with one family, and had breakfast with them, who had moved to the village 130 years ago from the Caucasian Mountains.

The food we ate in people’s homes was truly delicious: garbanzo bean soup, honey combs, tomatoes, coddled cream, cheeses, fresh breads, hot, soft hard-boiled eggs, and fresh flatbreads. At restaurants, I quickly became addicted to flatbread pides, with eggplant being especially good. Jim ate lamb in many varieties.

We stopped at a roadside stand near Yarvas, and ate the most delicious apricot-wrapped-almonds.

We found large parts of the highland range available for grazing, but abandoned. We saw what are called “yellow houses of death” – large complexes designed to move herders into to get them away from their free lifestyle.

In Mus, we found bootlegged copies of banned movies – order one for $2 and wait for it to be burned for you in popular stores.

The villages from Mus to about half-way to Ezurim have manure piles (stockpiled for winter fuel) and reminded me of the Mongolian steppe. Village life in this area was similar to that of Mongolia as well.

In this country where not everyone owns a car, there are people on the streets and roads, hitchhiking and selling things. This also makes for lively streets and markets, with streets packed with people instead of cars.

Towns and parks call herders with cattle or sheep to come and graze their properties so there is no major cost for maintenance or grooming of the landscape.

Northern Anatolia is where we began to see large, long-haired livestock protection dogs. We also saw lots of mixed herds of livestock, with most combinations being sheep and goats, and goats and cattle.

All villages here have chickens and guardian dogs on the streets, but they are losing their people and their herds. We were told they need young people, young women/wives.

We saw a few hawks, eagles and storks, and huge flocks of black crows in eastern Turkey. There were huge flocks of domestic turkeys as well, some both herded and guarded by dogs.

Isik told us that sometimes nomad dogs are fed once a week. The dogs also eat sheep and goat manure, but love donkey manure also. The dogs also clean up human feces, which is another reason whey they are viewed as unclean and should not be touched.

Rock water fountains were installed in various regions of the countryside as good deeds, required by the Muslim religion. We saw nomads with thousands of head of sheep near Karaakocan, and admired the old rock night pens we saw on the range.

The road from Ankara to Istanbul reminded us of the Bighorn Mountains of Wyoming. We saw few fences, but did see chain-link fences near Ankara and Istanbul, in the area before the tunnel under the mountain. When coming out the other side of the tunnel (the western side) it’s like the Pacific Northwest.

The Marriott Asia hotel in Istanbul, sitting on the Marmara seashore, has extremely high security – from the guarded gates that serve its entrance (where they check your trunk for luggage), to the metal detectors that are located in the doorway, and baggage screening in the entryway, and the guards everywhere, including in the lobby. After three weeks on the road and in somewhat primitive conditions, our one night in such luxury was wonderful. We flew out the next morning for America, and learned of a bombing that took place a few blocks away the next weekend. Our initial security check at the Istanbul airport involved both airport security and police, as they inspected our spiked, anti-wolf collars. They quickly saw what they were, and sent us through, leaving the sharp objects in our checked luggage. Cat was searched, but women in burkas were not, and neither was Jim.

Portugal (Transmontano Mastiffs)

When we departed the United States, we initially traveled to Portugal, hoping to learn about the Transmontano Mastiffs we'd read about in that country. It took considerable planning for us to get from Porto, Portugal to a small home/hotel inside Montesinho Natural Park, the heart of northern Portugal's wolf country. Our timing was bad, with herds already returned to home pastures for the fall and winter, and the expert we had hoped to meet was unavailable.

Walking the streets and roads of the natural park, we met up with our first guardian dogs, of two native breeds. There is a program in place to distribute the Transmontano mastiff to cattle and sheep grazers in the park to protect their herds from wolf depredation. The park maintains a registry of mastiff litters and makes these dogs available to producers. Since the program's inception in 1994, the result has been a decrease in depredations on both sheep and cattle.

The Transmontano mastiff originated in a pastoral livestock system where stock are grazed in uncultivated areas away from villages, with the continuous presence of wolves leading to its functional body structure of massiveness with long head and limbs, which enable it to travel with the herds. Ninety-five percent of the northern Transmontano dog population is reportedly still used to protect extensive sheep flocks from wolf predation. An aggressive program to reduce wolf predation on sheep and cattle herds in Portugal's Montesinho Natural Park was begun in 1994, placing Transmontano Mastiff LPD pups with herdsmen. Transmontano mastiffs are quite reserved and docile, while not being highly aggressive. Work is being done to gain international recognition for this breed.

We also encountered a few Estrela mountain livestock protection dogs. The Estrela is probably the most widespread native breed of dog in Portugal. A traditional dog used to guard sheep high in the mountains, because of its beauty, the breed is widespread and often used as pets. It was interesting to see both dog breeds, and it was notable that we heard concern about the working lineages of these dogs being overtaken by the pet/show lines.

One evening while we were in Portugal we shared a very pleasant dinner conversation with a couple from France (the husband was a native of Belgium, while the wife was from England). Two of their adult children became vegetarians, while their father is an avid carnivore.

In France, beef is produced for the local market. The eartag in each calf contains records of its date of birth and source of origin, and remains with the calf its entire life. The calf remains with its mother for nine months, before it is weaned and fattened, and sent to slaughter. When the meat is purchased from the local grocery store, the farm producer's name is listed on the package of meat. So if a consumer likes that meat, they can continuously buy from that producer. The beef is processed locally, and they know that producer.

That couple is very proud of the cattle their local producer raises. When there are issues (resource management or political) that would impact the livestock producer, that producer has support from the local people who eat his beef, in resolving any resource dispute. This is in stark contrast to the situation in America. The consumer in America rarely knows the producer whose livelihood depends on the consumption of his product.

Final Recommendations

• An English translation of Spanish mastiff manual should be made available to livestock producers in the United States.

• Spiked collars should be manufactured and distributed to livestock producers using LPDs in areas where wolves are present. Along with distribution of the collars should be distribution of information about their proper use.

• There should be a government program developed to establish effective wolf-fighting dogs on ranches in the United States. This would probably entail contracting with Old World experts to bring pups to the U.S., and host training sessions on LPD husbandry.[6]

• APHIS specialists should be sent to Bulgaria to investigate the potential use of Karakachans in U.S.[7]

• Livestock producers should be actively encouraged to use LPDs, and the dogs should be used toward filling the canid niche in agricultural areas of rural Wyoming.[8]

• Both the general public and natural resource and land management agencies should be better educated about the value of LPDs, their use as a management tool, and proper human behavior around these animals.

• There is a gap in knowledge about LPDs killed by wolves in the Northern Rockies. Further investigation into the details of all such incidents should reveal the sex, age, number of animals involved, and further details that will shed light on the potential reason for the conflicts.

• More detail is also needed concerning LPD aggression toward humans. Details should be revealed and compiled from confirmed conflicts in the United States, including breeds involved, sex and age, and the socialization process of the dog's rearing.

• We encourage the continued research and discovery of Old World LPD breeds and traditions in large carnivore country, and transfer of knowledge from the Old World to the agricultural community in the United States. Breeds and traditions associated in need of further examination include (but not limited to) the Central Asian Ovcharka and the Shar Planinetz or Sarplaninac of Macedonia.

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[6] Yolanda Cortés of Spain is immensely qualified and experienced for such an undertaking.

[7] Michael Marlow, USDA Wildlife Services Resource Management Specialist based in Fort Collins, Colorado would be a logical contact for this. His contact information is Michael.c.marlow@aphis.usda.gov and telephone is (970) 494-7456.

[8] Interested producers wanting more information/to try Old World breeds more suited to challenging wolves:
Mickey Thoman, 38622 Wyoming 372, Kemmerer WY 83101
Jody Bagley, 1146 Highway 238, Auburn WY 83111
Dave Neves, Box 108, Emblem WY 82422
John Espy, 906 13th Rawlins, WY 82301
Pete Arambel, Box 636, Rock Springs WY 82902

Trip & financial summary:
We traveled a full three weeks in foreign countries in October 2010, and as we pledged, visited three different regions with large carnivore populations and active livestock grazing. We arrived in Europe on the very day the U.S. State Department issued a warning to American travelers about increased terrorism activity in Europe, so we were careful in all our travels to stay away from concentrations of people (except in airports where it couldn't be avoided). That was easy enough to do, since we were there for livestock operations, not tourism. The last day of our international travel was spent in Istanbul, Turkey, and a week later, a suicide-bomber killed himself and about a dozen other people (mostly police) at a popular historic square in that city. We even entered the Kurdish conflict zone in Turkey one tense afternoon. We managed to get stuck in a farmer's field in Spain, and were subject to regular and random police stops in Turkey.

We began the journey in Portugal, but unfortunately we were unable to make contact with enough experts/shepherds to be able to fairly assess the effectiveness of their native livestock protection dogs (although we did encounter a few of the dogs). Striking out in Portugal, our contacts in Spain urged us to hurry there, and we did so, where our guides were two freelance wolf biologists who work with ranchers on a daily basis. One of our guides, Yolanda Cortes, was in charge of placing livestock protection dogs with livestock producers in wolf country. These were very knowledgeable people we managed to hire away from their regular duties to set up interviews with producers for us, drive us to those interviews, and then serve as our interpreters. We had four days of very packed schedules, arriving back to our hotel at nearly 11 p.m. every night. We learned a great deal about Spanish mastiff dogs in wolf country.

Next we traveled to Bulgaria, where Cat became ill for a few days. Once she recovered, we traveled with our guide, Atila, one of a family of three who run sheep and work on large carnivore recovery in the Balkans. Another family member is a wolf biologist, and the third family member is the shepherd who tends to the sheep. They also operate a large carnivore education center, complete with captive wolves and bear, and showcase the use of Karakachan livestock protection dogs in order for all species to co-exist in the region. The bear population is dense in this region, and the dogs do an amazing job keeping the bears out of the herd. We again had a grueling schedule of back-to-back interviews and travel to see different livestock operations.

Our last week of travel was spent in Turkey, with Isik Guvernor, an expert on the shepherd dogs of Turkey who also runs a goat creamery. We saw a wide variety of large protection dogs throughout our travels in Turkey, and were struck at how the dogs are everywhere – in villages, along roads, with livestock – in essence filling the large canine niche. Where the dogs are, the wolves cannot be.

Here's how our draft budget numbers for travel compared to the actual trip:

	Budget	Actual
Flights:	$8,640	$5,747.60
Per diem:	$8,765	$9,134.00
Hired:	$3,500	$4,573.12
Total:	$20,905	$19,454.72

Now an explanation:
<u>Flights:</u> Our travel agent is a genius, so that's why flights were less.
<u>Per diem:</u> is based on the per diem schedule below, and the rates were based on 1 ½ people per day, since Jim and Cat shared motel rooms. As it ended up, we also paid for all food and accommodations for our guides, as well as purchased the fuel for rental cars. A few times we were able to stay with families, and our paid accommodations ranged from some nasty dives, to comfortable, and even one five-star hotel on our last night of the trip in Istanbul (found a deal on the Internet, so had to do it!).

Per diem Rates (using US gov rates):

SLC x 2 days ($228 total)	$456
Portugal x 2 days (288)	$576
Spain x 4 days (625)	$2,500
Bulgaria x 6 days ($371)	$2,226
Turkey x 8 days ($422)	$3,376
TOTAL:	$9,134

<u>Hired:</u> While we were pretty close on estimating what it would cost to hire guides, we underestimated the cost of car rental and other transportation costs (taxis, public transport systems) that we had to use because we were in such remote regions.

Portugal:
Taxis/public bus to Spain $150
Total Portugal: *$150*

Spain:
Taxi/airport $50.
Guide $350
Total Spain: *$400.*

Bulgaria:
Taxi/airport x 2 $70
Guide $420
Rental car $727.21
Total Bulgaria: *$1,217.21*

Turkey:
Taxi/airport $40.00

Guide $1,650
Rental car $1,115.91
Total Turkey: $2,805.91

Total hired services: $4,573.12

Additional expenditures:
Misc expenditures not budgeted:
The Urbigkits spent an additional $620.42 for items not in the original travel budget, including:

$215 to purchase six spiked anti-wolf collars in Turkey;
$40 for Visa permits to enter Turkey, the only country with such a requirement;
$60 for a toll road permit to enter Istanbul;
$92.42 on travel guide books & maps;
$213 on gifts for the people interviewed on our travels (multi-tools & books for shepherds, toy cars for children, and Wyoming pins for women).

In addition, although we had proposed (and budgeted) to attend the Wyoming Wool Growers Association/Wyoming Stock Growers Association joint convention on December 14, 2010, the two organizations did not meet jointly. Cat did a presentation to the WSGA convention in Casper as planned, but was unable to present at the WWGA meeting, which was held jointly with the Idaho wool growers. Instead, Bryce Reece managed to get Cat an invitation to speak at the American Sheep Industry convention in Nevada, so she spent an additional $473 at attend that session (Hotel $224, registration $100, plane tickets $149).

The Urbigkits and Wyoming Wool Growers Association in-kind contributions to this project were as budgeted ($14,000 and $2,500, respectively).

LPD management practices

	Producer	Species	Back dewclaws	Crop ears	Crop tails	Neuter	Feed	Carcass	Afterbirth	Collars
Spain										
	Goya	sheep	yes/double	no	no	n/a	kibble	yes	no	no
	Rufino	sheep	yes/double	no	no	no	kibble/bread	no	no	no
	Francisco	sheep	yes/double	no	no*	yes	sheep pellets/bread	yes	no	no
	Carlos	cattle	yes/double	no	no	no	kibble	no	yes	yes
	Juan	cattle/sheep	yes/double	no	no*	no	kibble/meat	no	no	yes
	Paulino	goats	yes/double	no	no*	no	kibble/bread	no	no	yes
Bulgaria										
	Georgi	sheep	no	no	no*	no	meat/yal	no	yes	yes
	Daniela	goats/sheep	yes/double	no	no	no	meat/yal	yes	yes	yes
	Miroslav	sheep	yes/double	no	no	no	meat/yal/kibble	yes	yes	yes
	Sider	sheep/goats	yes/double	no	no	no	meat/yal	yes	yes	no
Turkey										
	Kayis	sheep	yes	yes	no	no	yal/wild boar	no	yes	yes
	Isparta	goats	yes	yes	no	no	yal	yes	yes	no
	Ali	goats	yes	yes	no	no	yal	yes	yes	yes
	Kultu	sheep	yes	yes	no*	no	yal	yes	yes	yes
	Memet	cattle	yes	yes	no	no	yal	yes	yes	no

* some occur naturally

yal is a grain-based porridge cooked by herders

Producers in Spain used spiked collars made of leather, while those in Bulgaria and Turkey used iron.

Wyoming Ag In the Classroom
Grant Review for
Animal Damage Management Board
September 2011

Wyoming Ag In the Classroom (WAIC) is very grateful for the continued support from the Animal Damage Management Board. The grant money of $3500.00 was well spent in developing, printing and distribution of the 2010 *Country to Classroom* as well as facilitating the annual Rendezvous, now known as the Wyoming Ag and Natural Resource Science Institute.

The 2010 *Country to Classroom* was distributed to educators and agriculture organizations across the state. Approximately 16,000 copies were distributed to schools and organizations with 5,000 copies requested by other educators; 2,000 copies utilized for administrative use, and the remaining 2,000 copies utilized in WAIC teacher trainings, events and workshops. A total of 25,000 copies are printed with a PDF version available for download from the WAIC website. Two pages highlighted predator management and focused on raccoons.

The 2011 Institute was a great success and the Hulett community was very welcoming. Twenty teachers from across the state attended to gain a greater understanding of agriculture and natural resources. The institute focused on providing teachers with tools and curriculum to utilize in implementing the concepts into their classrooms. The class was well diversified with teachers from all across the state and expertise ranging from elementary to high school and after school programs. There was a predator management workshop. WAIC also brought in a guest speaker, a local rancher, to discuss the challenges of predator management.

In addition to this report there is a copy of the 2010 *Country to Classroom*, Institute Agenda and total financial cost for both the publication and Institute. Grant money was spent on postage and printing expensive for the publication and for the Institute, materials and travel. Please contact Jessie Dafoe at 307-421-4341 or at jberry@wyomingagclassroom.org with any additional questions. Thank you again for your support.

2:43 PM
09/28/11
Accrual Basis

Wyoming Agriculture in the Classroom
Transaction Detail By Account
January through December 2011

Type	Date	Num	Name	Memo	Class	Clr	Split	Amount	Balance
40050 · Awards									
Bill	9/14/2011	5361JB	First Bankcard	v5031	Rendezv...		20000 · Accou...	127.00	127.00
Total 40050 · Awards								127.00	127.00
41115 · Material									
Bill	7/12/2011		Jessie Berry-	v5028	Rendezv...		20000 · Accou...	228.56	228.56
Bill	7/12/2011	5361	First Bankcard	v5026	Rendezv...		20000 · Accou...	72.96	301.52
Bill	7/12/2011	5361	First Bankcard	v5026	Rendezv...		20000 · Accou...	27.01	328.53
Bill	7/12/2011	5361	First Bankcard	v5026	Rendezv...		20000 · Accou...	285.61	614.14
Bill	9/14/2011	5361JB	First Bankcard	v5031	Rendezv...		20000 · Accou...	50.37	664.51
Bill	9/14/2011	5361JB	First Bankcard	v5037	Rendezv...		20000 · Accou...	127.92	792.43
Bill	9/14/2011	5361JB	First Bankcard	v5037	Rendezv...		20000 · Accou...	68.80	861.23
Total 41115 · Material								861.23	861.23
41300 · Office Photocopies									
Bill	2/25/2011	1/31/...	Wyoming Departme...		Rendezv...		20000 · Accou...	0.58	0.58
Total 41300 · Office Photocopies								0.58	0.58
41600 · Travel									
Bill	2/2/2011	1231...	Wyoming Departme...	v2209	Rendezv...		20000 · Accou...	11.33	11.33
Bill	5/16/2011		First Bankcard	v5015	Rendezv...		20000 · Accou...	4.50	15.83
Bill	6/1/2011		Jessie Berry-	v5013 mileage	Rendezv...		20000 · Accou...	328.95	344.78
Bill	6/21/2011		First Bankcard	v5015	Rendezv...		20000 · Accou...	91.79	436.57
Bill	6/21/2011		First Bankcard	v5015	Rendezv...		20000 · Accou...	4.99	441.56
Bill	6/21/2011		First Bankcard	v5023	Rendezv...		20000 · Accou...	83.16	524.72
Bill	7/12/2011		Jessie Berry-	v5024 summ...	Rendezv...		20000 · Accou...	344.25	868.97
Bill	7/12/2011		Jessie Berry-	v5024	Rendezv...		20000 · Accou...	183.60	1,052.57
Bill	7/12/2011	5361	First Bankcard	v5027	Rendezv...		20000 · Accou...	3,859.47	4,912.04
Bill	7/12/2011	5361	First Bankcard	lm jb 7/12-ne...	Rendezv...		20000 · Accou...	260.70	5,172.74
Total 41600 · Travel								5,172.74	5,172.74
46900 · Meals									
Bill	5/16/2011		First Bankcard	5361	Rendezv...		20000 · Accou...	10.59	10.59
Bill	6/21/2011		First Bankcard	v5015	Rendezv...		20000 · Accou...	37.74	48.33
Bill	6/21/2011		First Bankcard	v5015	Rendezv...		20000 · Accou...	25.67	74.00
Bill	7/12/2011	5361	First Bankcard	v5026	Rendezv...		20000 · Accou...	220.87	294.87
Bill	7/12/2011	5361	First Bankcard	v5026	Rendezv...		20000 · Accou...	553.98	848.85
Bill	7/12/2011	5361	First Bankcard	v5026	Rendezv...		20000 · Accou...	101.76	950.61
Total 46900 · Meals								950.61	950.61
TOTAL								**7,112.16**	**7,112.16**

2:40 PM

09/28/11

Accrual Basis

Wyoming Agriculture in the Classroom
Transaction Detail By Account
January through December 2010

Type	Date	Num	Name	Memo	Class	Clr	Split	Amount	Balance
41400 · Office Supplies									
Bill	11/16/2010	1031...	Wyoming Departme...		Country t...		20000 · Accou...	79.76	79.76
Total 41400 · Office Supplies								79.76	79.76
41450 · Postage									
Bill	1/15/2010		FIA Card Services		Country t...		20000 · Accou...	38.07	38.07
Bill	3/16/2010	3489	FIA Card Services		Country t...		20000 · Accou...	2.58	40.65
Bill	8/18/2010		FIA Card Services		Country t...		20000 · Accou...	2.44	43.09
Bill	9/21/2010	3489	FIA Card Services		Country t...		20000 · Accou...	1.05	44.14
Check	12/1/2010	1257	Douglas Budget	v2218	Country t...		12050 · Ameri...	4,513.20	4,557.34
Total 41450 · Postage								4,557.34	4,557.34
41460 · Printing Expense									
Bill	8/18/2010	898	Douglas Budget		Country t...		20000 · Accou...	900.00	900.00
Bill	10/7/2010	898	Douglas Budget		Country t...		20000 · Accou...	1,350.00	2,250.00
Bill	12/2/2010	C2C ...	Douglas Budget	printing v2222	Country t...		20000 · Accou...	4,801.00	7,051.00
Bill	12/2/2010	C2C ...	Douglas Budget	typsetting v2...	Country t...		20000 · Accou...	3,150.00	10,201.00
Total 41460 · Printing Expense								10,201.00	10,201.00
41600 · Travel									
Bill	11/16/2010	0930...	Wyoming Departme...	meet waic bo...	Country t...		20000 · Accou...	36.90	36.90
Total 41600 · Travel								36.90	36.90
TOTAL								**14,875.00**	**14,875.00**

WY Ag & Natural Resource Science Institute
Course Syllabus
June 13-15, 2010
Devils Tower, Wyoming

a) **Course**: University of Wyoming - NASC 5959

b) **Title:** WY Ag & Natural Resource Science Institute 2011

c) **Credits:** Two (3.0) UW Graduate Credits
   i) Credit does not count toward a degree program.
   ii) UW credit is $50/credit

d) **Prerequisites:**
   i) Complete WAIC registration form (download www.wyomingagclassroom.org)
   ii) UW Registration Form & Payment Received

e) **University Course Instructor**:

Teresa Brown
P.O. Box 23
Devils Tower, WY 82714
Phone: 307-290-1954
brownta@crook1.com

f) **Class Location**: Devils Tower, Wyoming

g) **Course Description**

This course provides teachers the opportunity to experience, internalize and take agriculture and natural resource lessons back to their classrooms. The institute will begin at the Hulett School of Vocational Training with focus on the activities of the school including a canula cow, genetics and the school's log furniture business. Teachers will travel to an agriculture supply store and ranch that exhibits and demonstrates different sectors of the agriculture industry. Sawmills and the forestry industry will be another focus of the institute and provide lessons to take back to each classroom. Other ranches and tours are scheduled for the institute as well as a chance to see and understand the workings of Devils Tower. The tours and specialized expertise of local businessmen will enhance the understanding and ability to relate back to the classroom an understanding of the agriculture and natural resources in the northeast corner of Wyoming.

h) **Method of Instruction**
   i) A forum for informal discussion, hands-on activities, field trips, and networking.

i) **Educational Goal and Learning Objectives**

1. EG: Workshop participants will experience Wyoming agriculture and natural resources.

    i. *LO1: Participants will recognize the value of Wyoming agriculture and natural resources in daily living.*
    ii. *LO2: Participants will make a personal connection between production and product.*
    iii. *LO3: Participants will integrate and relate Wyoming agriculture and natural resources to existing lessons and activities.*

2. EG: Workshop participants will engage in and complete hands-on activities and lessons pertaining to Wyoming agriculture and natural resources.

    i. *LO1: Participants will observe and repeat several activities important to Wyoming agriculture and natural resources.*
    ii. *LO2: Participants will associate agriculture and natural resource industries or products with activities completed.*
    iii. *LO3: Participants will be able to combine activities with existing classroom curricula.*

3. EG: Workshop participants will be able to apply "experience-based" lessons on Wyoming agriculture and natural resources in their classrooms.

    i. *LO1: Participants will repeat activities in their classroom.*
    ii. *LO2: Participants will share Wyoming agriculture and natural resource "experience-based" learning with the students and peers in their local area.*
    iii. *LO3: Participants will be able to connect WY State Education Standards to "real world" issues dealing with Wyoming Agriculture and natural resources.*

j) **Supplies**
   i) Willing Attitude
   ii) Open mind
   iii) All necessary items will be provided

k) **Class Size**
   i) 40 Maximum

l) **Course Length**
   i) 28.00 Hours

(1) 00.50 Pre-Survey
(2) 25.00 Hands-on workshop
(3) 00.50 Post-Survey
(4) 02.00 Resource Composition Piece

m) **Assessment**
- i) Pre/Post Survey
- ii) Self-Evaluation
- iii) Participant evaluation of course
- iv) Completion of Resource Composition Piece

n) **Course Requirements**
- i) Students are **required to attend and participate** in all sessions and discussions. Handouts and other printed materials will be provided.
- ii) Participants are expected to ride provided transportation and arrive at scheduled locations in a timely manner.
- iii) Participants are expected to dress and act appropriately. Activity materials will be provided. ***Participants are responsible for wearing appropriate clothing and shoes, providing any personal items or medications, and notifying WAIC of any allergies or special needs.***
- iv) Participants will sign a form releasing all participating sponsors and cooperative organizations of any medical liability. Participants are responsible for their own personal needs and are attending on a voluntary basis.
- v) ***Post Course: Participants will submit a written composition detailing 5-10 resource organizations or individuals available in their location with an overview of how that resource might benefit their classroom.***
  - *(1) All reviews must be submitted electronically via email to jberry@wyomngagclassroom.org by midnight* ***Monday, August 2, 2011.***
    - *(a) 8.5 x 11" paper with 1" margins, at least 12 pt. font, and 1.5 line spacing.*
    - *(b) Cover page will include: Participant name, course title, and date.*
    - *(c) Instructor must receive written composition by designated date to receive an "S" for the course.*

o) **Grades And Evaluation**
- i) This course is offered for an S/U only. In order to receive an "S" grade, students must complete the course requirements described above.
- ii) Complete University of Wyoming Outreach Evaluation
- iii) Complete Wyoming Agriculture in the Classroom course Evaluation Form

Wyoming Agriculture In the Classroom
Wyoming Ag & Natural Resource Science Institute
Devils Tower, Wyoming
June 13-15, 2011

COURSE OUTLINE:

<u>Sunday, June 12, 2011</u>

Registrants check into hotel

Best Western Devils Tower Inn
229 Highway 24,
Hulett, Wyoming 82720
Phone: 307/467-5747 | Fax: 307/467-5765

<u>Monday, June 13, 2011</u>

Best Western Devils Tower Inn
6:00-8:00 Continental Breakfast

8:00-9:00 Registration/ Meet and Greet - Hotel Meeting Room

9:00-9:30 Welcome and Code of the West presentation

9:30-9:45 Walk to Hulett School Vocational Training Facility

9:45-11:45 Video Presentation – Jim Pannell, Vocational Ag Teacher
"Placing a Cannula in a Cow for Nutrition & Digestion Studies"

Canula Cow - Jim Pannell, Vocational Ag Teacher

Microscope Viewing

Genetics – Teresa Brown & Jim Pannell

Devils Tower Log Furniture

11:45-12:30 Lunch – "R Deli"

Beth Marlatt 4th Grade Authors (bookmark winners- Angel)

12:30-12:45 Load Buses/Travel to Tower Valley Ag – Chip Nei man

12:45-1:15 Tower Valley Ag Supply (Feed Store) - Chip Neiman
"Diversification in Ag"

1:15-1:30 Load buses/Travel to JH Ranch

1:30-3:00 JH Ranch - Chip Neiman
Pivot
Crop Rotation
Balance Rations
Futures/Marketing – Board Game
Production Ag
Beef Operation
Grain Management
Fertilizer

3:00-3:15 Load Buses/Travel to Neiman Sawmill

3:15-5:15 Neiman Sawmill / Mills Sawmill
How money follows timber
Tree cookies
Forest thinning lesson

5:15-5:30 Load Buses/Travel to Hulett School Vocational Training Facility

5:30-6:00 "Portable Saw Mill" – Todd Hickman, Woods teacher

6:30-8:30 Dinner - Golf Course
"Women In Timber" – Linda T. & Dena Neiman Mills

Tuesday, June 14, 2011

6:00-7:45 Continental Breakfast – Best Western Devils Tower Inn (ag/ranch lesson)

8:30-10:45 Neiman 77 Ranch - Ryan Neiman & Jim Pannell
Beef Production Selection/Sonogram from Veterinarian
Trait Selection
Genetics

10:45-11:00 Load Buses/Travel to KOA

11:00 – 11:45 Predator Management - JW and Thea Nuckolls
Predator Prey Box

11:45-12:30 Lunch – KOA with Predator Management Workshop

12:30-12:45 Load buses/Travel to Driskill Campstool Ranch

12:45-5:30 Driskill Campstool Ranch – Ogden & Zanny Driskill
Group 1 – Water
Group 2 – Soil
Group 3 - Noxious Weeds

5:30-5:45 Load Buses/Travel to Best Western Devils Tower Inn

5:45-6:30 Personal Time

6:30-6:45 Load Buses/Travel to Jess Driskill home

6:45-8:45 Dinner - Jess Driskill Home (instruction)

Wednesday, June 15, 2011

6:00-7:45 Continental Breakfast – Best Western Devils Tower Inn (instruction)

7:45-8:30 Load buses/Travel to Devils Tower

8:30-11:30 Devils Tower

11:30-Noon Load Buses/Travel to Best Western Devils Tower Inn

12:00-1:00 Lunch (implementation in the classroom instruction)

1:00-2:00 Surveys/ Wrap up

GREATER SAGE-GROUSE (*CENTROCERCUS UROPHASIANUS*) SELECT NEST-SITES AND BROOD-SITES AWAY FROM AVIAN PREDATORS

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ABSTRACT.—Greater Sage-Grouse (*Centrocercus urophasianus*; hereafter "sage-grouse") distribution and abundance in western North America has declined over the last century. Depredation of nests and predation of chicks are the most influential factors limiting sage-grouse productivity. We compared avian predator densities at sage-grouse nests and sage-grouse brood locations to random locations within available sage-grouse habitat. This comparison allowed us to assess the ability of sage-grouse to avoid avian predators during nesting and early brood-rearing. During 2008–2010, we conducted 10-min point-count surveys at 222 sage-grouse nests, 245 sage-grouse brood locations from 83 sage-grouse broods, and 498 random locations. We found that random locations had higher densities of avian predators relative to sage-grouse nest and brood locations. Sage-grouse nested in areas where there were lower densities of Common Ravens (*Corvus corax*), Black-billed Magpies (*Pica hudsonia*), Golden Eagles (*Aquila chrysaetos*), and *Buteo* hawks during nesting. Sage-grouse selected brood-rearing locations that had lower densities of Common Ravens, Black-billed Magpies, Golden Eagles, *Buteo* hawks, Northern Harriers (*Circus cyaneus*), and American Kestrels (*Falco sparverius*) than random locations. By selecting nest and brood-rearing locations with lower avian predator densities, sage-grouse may reduce the risk of nest depredation and predation on chicks and hens.

Key Words: brood-site selection, Greater Sage-Grouse, nest-site selection, Golden Eagle, Raven.

Greater Sage-Grouse (*Centrocercus urophasianus*: hereafter; "sage-grouse") abundance in western North America has declined over the last century (Gregg et al. 1994, Johnsgard 2002, Slater 2003, Connelly et al. 2004). These declines recently led the U.S. Fish and Wildlife Service

(2010) to conclude that sage-grouse are warranted for protection under the Endangered Species Act of 1973, but because threats were moderate in magnitude and did not occur across their range at an equal intensity, the listing was precluded in favor of other species under severe threat of extinction. Many factors have been attributed to this decline including habitat loss, habitat fragmentation, habitat degradation, and predation (Braun 1998, Schroeder et al. 2004).

Even in high quality sage-grouse habitat, most sage-grouse nests are lost to predators including Red Fox (*Vulpes vulpes*), American Badger (*Taxidea taxus*), Coyote (*Canis latrans*), Striped Skunk (*Mephitis mephitis*), Black-billed Magpie (*Pica hudsonia*; hereafter “magpie”), and Common Raven (*Corvus corax*; hereafter “raven;” Willis et al. 1993, Gregg et al. 1994, Holloran 1999, Connelly et al. 2004, Coates et al. 2008). High mortality rates on chicks have also been attributed to predators, especially during early brood-rearing (Aldridge 2005, Gregg and Crawford 2009, Guttery 2011). Avian predators may have significant impacts on sage-grouse nest success and chick survival, including ravens, magpies, Golden Eagles (*Aquila chrysaetos*), hawks (*Buteo* spp.), Northern Harriers (*Circus cyaneus*; hereafter “harrier”), and American Kestrels (*Falco sparverius*; hereafter “kestrel”; Schroeder et al. 1999, Schroeder and Baydack 2001).

In response to the risk of nest depredation, sage-grouse hide their nests from predators by placing their nests primarily in areas with sagebrush cover and greater visual obstruction (Connelly et al. 1994, Braun 1998, Holloran 1999). At the microhabitat scale, sage-grouse predominately choose nest sites concealed by vegetation cover (Connelly et al. 2004). Several studies have reported that sage-grouse select nest-sites based on a preference for different microhabitat characteristics including sagebrush density (Wallestad and Pyrah 1974, Connelly 2003), shrub height (Gregg et al. 1994), grass height (Gregg et al. 1994, Holloran et al. 2005), and grass cover (Kaczor 2008). Variability in reported nest-site selection among studies may indicate local differences in available microhabitat. However, consistent placement of nests in greater visual cover regardless of differences in local available habitat suggests that vertical (e.g., grass and shrub height) and horizontal cover (e.g., grass and shrub canopy cover), are important regardless of the type of vegetation cover that is available.

Sage-grouse select nest locations that hide their nests from visual predators but not olfactory predators (Conover et al. 2010). Conover et al. (2010) found that sage-grouse place nests in areas that have few updrafts, low turbulence, and slow wind speeds. Updrafts, high turbulence, and high wind speeds are climatic conditions that make it difficult for mammalian predators to use olfaction to locate nests (Conover 2007). These results coincide with results from other sage-grouse nest research that show sage-grouse's preference for greater visual cover. Selection of nest-sites that conceal sage-grouse from visual predators but not olfactory predators may indicate that visual predators are a greater threat than olfactory predators to sage-grouse nests.

Sage-grouse broods also hide from avian predators through habitat selection and cryptic behavior. Recent studies focused on survival of radio-marked sage-grouse chicks have indicated that brood-rearing hens have greater success in locations with short sagebrush (Guttery 2011) and short grass (Aldridge 2005, Gregg and Crawford 2009, Guttery 2011). In contrast, Aldridge and Brigham (2002) found that sage-grouse brood hens select areas with greater percentages of sagebrush cover and taller grass heights when compared to random locations. Gregg and Crawford (2009) and Guttery (2011) assert that higher percent cover of low sagebrush and/or short grass provide adequate visual cover for sage-grouse chicks, which are cryptically colored and avoid detection by remaining motionless. Further, these studies have hypothesized that brood hens in low sagebrush and/or short grass may more easily detect an approaching predator.

Raven depredation on sage-grouse nests is a common occurrence in northeastern Nevada based on infrared video cameras set up at nest sites (Coates et al. 2008). Raven depredation of sage-grouse nests has been implicated as a potential factor limiting sage-grouse productivity in fragmented habitats (Batterson and Morse 1948, Willis et al. 1993, Gregg et al. 1994, Schroeder and Baydack 2001, Bui et al. 2010, Coates and Delehanty 2010). During the last century, densities of ravens have increased throughout the historic range of sage-grouse (Larsen and Dietrich 1970, Andrén 1992, Engel and Young 1992, Boarman et al. 1995, Boarman and Coe 2002). Ravens utilize human-provided resources, such as water, anthropogenic structures, road-kill, dead livestock, and garbage (Boarman 1993, Boarman et al. 1995).

Sage-grouse select nest sites at local (habitat directly around a nest) and landscape scales (Doherty et al. 2010). We hypothesized that at the landscape-scale, sage-grouse avoid nesting or raising their broods in areas where there are high densities of avian predators, specifically, ravens, magpies, Golden Eagles, hawks, and other raptors. The objective of our study was to test this hypothesis by comparing avian predator densities at sage-grouse nests and sage-grouse brood locations to random locations in available sage-grouse nesting and brood-rearing habitat.

METHODS

Study areas.—Our study was conducted in southwest and south-central Wyoming. We had 12 study sites, each 16 or 24 km in diameter (eight sites of 16-km diameter and four sites of 24-km diameter; Fig. 1). Most sage-grouse hens nest within 8-km of leks where they breed (Connelly et al. 2004). Thus, the study sites in southwest Wyoming were 16-km diameter and approximately centered around leks where hens were captured. Study sites in south-central

Wyoming were 24-km, because sage-grouse were captured at several nearby leks over a larger area. Five study sites were located in Lincoln County (16-km diameter each), two in Sweetwater County (one 16-km diameter and one 24-km diameter), two in Uinta County (both 16-km diameter), and three in Carbon County (24-km diameter each). Study sites were chosen to provide a representation of overall sage-grouse nesting habitat in southern Wyoming with a variety of land uses and topographic features. Elevation ranged from 1,950 m to 2,530 m among all study sites. Most of our study sites were federally owned and administered by the Bureau of Land Management (BLM) with a small percentage of private lands. Domestic sheep and cattle grazing were the dominant land uses in our study sites. All study sites had some energy development.

The landscape at all study sites was dominated by sagebrush (*Artemisia* spp.); Wyoming Big Sagebrush (*A. tridentata wyomingensis*) and Mountain Sagebrush (*A. t. vaseyana*) were the most common. Black Sagebrush (*A. nova*) and Dwarf Sagebrush (*A. arbuscula*) were found on exposed ridges. Other common shrub species in our study sites included: Antelope Bitterbrush (*Purshia tridentata*), Snowberry (*Symphoricarpos albus*), Chokecherry (*Prunus virginiana*), Alderleaf Mountain Mahogany (*Cercocarpus montanus*), Rabbit Brush (*Chrysothamnus* spp.), Greasewood (*Sarcobatus vermiculatus*), and Spiny Hopsage (*Grayia spinosa*). Isolated stands of juniper (*Juniperus* spp.) and Aspen (*Populus tremuloides*) were found at the higher elevations on north-facing hillsides.

Sage-grouse capture and monitoring.—We monitored sage-grouse hens during nesting and early brood-rearing in 2008-2010. Hens were captured, radio-collared, and released in April of each year. We captured hens at night using ATVs, spotlights, and hoop-nets **(**Giesen et al. 1982, Wakkinen 1992). Sage-grouse hens were fitted with 17.5-g or 22-g necklace radio collars

(Holohil Systems Ltd, RI-2D, Ontario, Canada or Advanced Telemetry Systems Inc, A4060, Isanti, Minnesota).

We located hens on a weekly basis with Communications Specialists (Communications Specialists, R-1000, Orange, California) receivers and 3-way Yagi antennas (Communications Specialists, Orange, California). Potential nests were identified with binoculars from >25 m away by circling a radio-marked hen until she was visually spotted under a shrub or determined to be under a few shrubs. Nests were verified by triangulating the hen under the same shrub from >50 m away or thoroughly searching the area of the potential nest when the hen was absent. We continued monitoring nests weekly until the nest hatched or failed. We assessed nest fate as successful or unsuccessful after a hen had left its nest. A successful nest was defined as having evidence that at least one egg hatched as determined by shell membrane condition (Wallestad and Pyrah 1974). We classified unsuccessful nests as abandoned (eggs not depredated or hatched) or depredated (at least one egg with evidence of depredation and no eggs hatched).

We located the broods of radio-marked hens with binoculars from >25 m away. Brood hens were identified by either visually detecting chicks or observing hen behavior that indicated the presence of a brood (e.g., hesitation to flush, feigning injury, or clucking).

Avian predator monitoring.—Between May and August of each year (sage-grouse nesting and brood-rearing season), we conducted point-count surveys at sage-grouse nests, sage-grouse brood locations, and random locations (hereafter; nest, brood, and random locations) within each study site to compare avian predator densities. We used standard distance sampling techniques, which entailed counting all corvids and raptors observed during point-counts and recording each avian predator's distance from the observer. We recorded distance as the distance from the observer to where an avian predator was first located; this minimized possible bias associated with avian predators being attracted to or flushed away from an observer. A 1500 m rangefinder (American Technologies Network Corp., RE-1500 m, San Francisco, California) was used to estimate distances directly when possible, or a 1500 m rangefinder and GPS were used by observers to validate visually estimated distances.

Random locations were selected in habitat considered to be available to sage-grouse for nesting within each study site. To restrict random locations to available nesting habitat, we used ArcMap version 9.2 (ESRI Inc., Redlands, California) to generate random locations only in sagebrush-dominated habitat, which was classified by the Northwest GAP landcover data from 2008. Random points were designated to be at least 1000 m apart; however, random selection of these points led to most random point-counts greater than 1750 m apart. We generated 12 random locations in each 16-km diameter study site and 18 random locations in each 24-km diameter study site per year (total n = 504). A new set of random locations was generated each year to avoid spatial autocorrelation; thus, random locations between years were independent.

Point-counts were 10 min in length, and we conducted point-count surveys during daylight hours on a weekly basis at each study site. Each point-count location was visited one to eight times with most locations visited greater than or equal to three occasions. We did not survey for avian predators in inclement weather (i.e., in precipitation or wind speeds greater than 32 km/h). We intermixed the sampling of nest, brood, and random point-counts within each study site, and each week we changed the time of day that we conducted individual point-counts within a study site (i.e., each individual point-count location regardless of type—nest, brood, or random—would be conducted at a different time of day each week). Nest and brood point-counts were performed after nests and broods were initially located; thus, nest point-counts were conducted in May and June and brood point-counts were conducted from mid-May to early-

August. We performed random point-counts throughout the nesting and early brood-rearing season (May to early-August).

To avoid disturbing an incubating hen, nest point-counts were conducted 100–200 m away from a sage-grouse nest but within a line-of-sight of that sage-grouse nest. We also performed brood point-counts 100–200 m away from a brood hen—estimated by triangulation—immediately before verifying that a radio-marked brood hen was still with chicks. This was intended to record avian predator densities before the observer disturbed any avian predators and to avoid flushing a brood hen when a predator was nearby. If the hen did not have chicks, the brood point-count was discarded.

Analyses.—We used DISTANCE 6.0 release 2 (Thomas et al. 2009) to estimate raven, magpie, Golden Eagle, Red-tailed Hawk (*Buteo jamaicensis*), Ferruginous Hawk (*Buteo regalis*), Swainson's Hawk (*Buteo swainsoni*), harrier, and kestrel densities for nest, brood, and random locations across all years and all study sites. Red-tailed Hawks, Ferruginous Hawks, and Swainson's Hawks were combined into a single group—*Buteo* hawks—for analyses. We fitted half-normal key detection functions with cosine, simple polynomial, and hermite polynomial adjustments. We did not consider point-count type (nest, brood, random) as a covariate for detection, because all point-counts were in sagebrush-dominated habitat (i.e., we did not expect any difference in detection at any point-count locations). We selected the appropriate key detection function and detection function adjustment for each avian predator species separately using Akaike's information criterion (AIC_c; Burnham and Anderson 2002; Table 1). We also used DISTANCE to estimate observer effective detection radius (EDR), which was described as the distance at which half the detections of a particular species were less than EDR; an EDR of

500 m for hawks indicates that 50% of the detected hawks were seen at less than or equal to 500 m by an observer.

In addition, we adjusted density estimates for survey effort (difference in visits per point-count location) and scaled our density estimates by the maximum number of visits per point-count location by dividing all estimates of density by eight within DISTANCE. Survey effort was accounted for in DISTANCE by dividing the total number of detected avian predators at each point-count location by that point-count's proportion of actual visits to maximum number of visits (e.g., the total number of Golden Eagles detected at point-count x = 3, visits to point-count x = 5, total visits possible = 8; thus, for DISTANCE analyses point-count x was given a golden eagle count of 3 / 0.625 = 4.8, which was then scaled appropriately in DISTANCE by dividing by 8; Thomas et al. 2009). Raven, magpie, Golden Eagle, and harrier detection distances were right truncated 5%; *Buteo* hawk detection distances for DISTANCE analyses were right truncated 7.5%; and kestrel detection distances were not right truncated.

We used 95% confidence intervals to compare raven, magpie, Golden Eagle, *Buteo* hawk, harrier, and kestrel densities separately at nest locations versus random locations and at brood locations versus random locations. Confidence intervals were generated empirically using density estimates and standard errors from DISTANCE. Furthermore, we estimated avian predator densities for random, nest, and brood locations at each of our study sites using DISTANCE. We used estimated avian predator densities at our study sites to compare avian predator densities at random versus nest locations and random versus brood locations with paired Student's *t*-tests (R 2.10.1; The R Foundation for Statistical Computing 2009).

RESULTS

We conducted 3,006 point-count surveys during 2008-2010 at 965 total point-count locations with 222 sage-grouse nest locations, 245 sage-grouse brood locations (with 83 separate broods), and 498 random locations. Ravens, magpies, Golden Eagles, Red-tailed Hawks, Ferruginous Hawks, Swainson's Hawks, harriers, and kestrels were the most commonly detected avian predators. We used point-count surveys to generate study-wide density estimates of multiple avian predators, including raven, magpie, Golden Eagle, *Buteo* hawk, harrier, and kestrel, in relation to sage-grouse nests, brood, and random locations. In addition, we used estimated densities at study sites to compare avian predator abundances between available habitat versus sage-grouse nests and available habitat versus sage-grouse brood locations. On the whole, sage-grouse selected nest and brood locations with lower densities of avian predators than random locations (Fig. 2, Tables 3 and 4).

EDR estimates ranged from 294 m for magpie to 1,006 m for Golden Eagles. EDR estimates showed that effective detection distances differed by avian predator species (Table 2). This verified the necessity of selecting detection functions for each avian predator species separately. All avian predator species had greater than 60–80 detections, that Buckland et al. (1993) suggested was necessary for reliable density estimates (Table 2).

Raven, magpie, Golden Eagle, and *Buteo* hawk densities were found to be significantly lower at sage-grouse nest locations than random locations (Fig. 2). These relationships were verified with paired Student's *t*-tests (Table 3). Harrier and kestrel densities were similar at sage-grouse nest locations and random locations (Fig. 2), which was also verified with paired Student's *t*-tests (Table 3).

Estimated densities of ravens, magpies, *Buteo* hawks, and kestrels were significantly lower at sage-grouse brood locations than random locations (Fig. 2). All estimated avian predator species had significantly lower densities at sage-grouse brood locations compared to random locations (Table 4).

Discussion

Although we estimated avian predator densities for nest, brood, and random locations across all years, we did not expect the pattern of sage-grouse avoidance of avian predators to differ among years. Our random locations were at different locations each year, which prevented autocorrelation of counts at random locations among years. By using point-counts instead of line-transects, we were able to estimate avian predator densities across available habitat while avoiding potential biases in estimating avian predator densities along roads, which are commonly used to conduct line-transects. Our method for generating random locations for point-counts was consistent with that of Bui et al. (2010) for raven point-counts in western Wyoming. However, we only surveyed random locations in habitat available to sage-grouse for nesting and brood-rearing, which allowed us to concentrate our effort into directly comparing avian predator densities in habitat that sage-grouse were using to potential sage-grouse habitat.

We found that sage-grouse nest and brood locations had lower densities of avian predators than habitat available to sage-grouse. Sage-grouse selected nest sites that were away from multiple avian predator species, including ravens, magpies, Golden Eagles, and *Buteo* hawks. Sage-grouse also selected early brood-rearing locations that had lower densities of ravens, magpies, Golden Eagles, *Buteo* hawks, harriers, and kestrels compared to available habitat. Our results indicate that sage-grouse are likely avoiding habitats with higher avian predator densities during nesting and brood-rearing.

Raven densities impact the nest success and nest-site selection of several prairie grouse species (Gregg et al. 1994, Manzer and Hannon 2005, Coates and Delehanty 2010). In southern

Alberta, sharp-tailed grouse (*Tympanuchus phasianellus*) had 8-times greater nest success in landscapes with less than three corvids/km^2 as opposed to landscapes with greater than or equal to three corvids/km^2 (Manzer and Hannon 2005). Sage-grouse nest success in northeastern Nevada was related to the number of ravens per 10-km transect with the odds of a nest failure increasing 7.4% with every additional raven (Coates and Delehanty 2010). Around Jackson and Pinedale, Wyoming, Bui et al. (2010) found that higher occupancy of ravens was correlated with failed sage-grouse nests. These studies suggest that high densities of ravens have significant impacts on sage-grouse nest success, which suggests why sage-grouse have a propensity to hide their nests from visual predators.

We found that sage-grouse located their nests and broods in areas with lower raven abundances compared to available sagebrush habitat. Interestingly in western Wyoming, Bui et al. (2010) found that sage-grouse nest and brood locations had significantly higher raven density estimates (1.0 ravens/km^2) compared to their ArcGIS predicted raven density estimates at those same locations (0.6 ravens/km^2), indicating that ravens were near sage-grouse nests and broods more than predicted by land cover metrics. They suggested that ravens may key in on sage-grouse nesting and brood-rearing areas. Bui et al. (2010) also found raven density around sage-grouse nesting and brood-rearing areas was marginally higher than raven densities in available sagebrush habitat (1.0 ravens/km^2 and 0.7 ravens/km^2, respectively); however, these results were not significantly different. In contrast, we found significantly lower raven densities at sage-grouse nest and brood locations (0.17 ravens/km^2 and 0.12 ravens/km^2, respectively) compared to available sagebrush habitat (0.29 ravens/km^2). The discrepancy between our results and Bui et al. (2010) may be a function of greater anthropogenic development and human activity in their study areas or differences between studies in sampling effort in available sagebrush habitat. Bui et al. (2010) sampled in available habitat twice per breeding season; whereas, we sampled an average of 4 times per breeding season at nests and in available habitat. Regardless, we agree with Bui et al. (2010) that as avian predators, especially ravens, increase in abundance in sage-grouse habitat, quality nesting and brood-rearing habitat will become more limited.

Magpies depredate sage-grouse nests (Holloran and Anderson 2003), and we found sage-grouse located nests and broods in areas with lower magpie densities. Intriguingly, we also found lower densities of magpies at sage-grouse brood locations. Although we could not find any study that verified magpies as potential chick predators, magpies are capable of consuming animals as large as sage-grouse chicks (Trost 1999). Magpies are known to be associated with riparian areas but also forage in sagebrush habitats (Trost 1999). Thus, sage-grouse avoidance of magpies during nesting may be related to sage-grouse avoidance of riparian areas within or adjacent to sagebrush habitat; however, sage-grouse are known to utilize riparian areas for foraging chicks (Connelly et al. 2004, Crawford et al. 2004). Our results indicate sage-grouse select habitat for brood rearing with lower abundances of magpies, even while balancing the need to utilize habitats, such as riparian habitats, that provide forage to meet the energetic requirements of chicks. Sage-grouse hens typically move broods to riparian areas after early-brood rearing (Crawford et al. 2004, Gregg and Crawford 2009), which likely corresponds with chicks being more mobile and less susceptible to predation by magpies.

In southwestern Wyoming, MacLaren et al. (1988) found that birds contributed to approximately 9% of the diet of nesting Golden Eagles, and sage-grouse was their primary avian prey. Danvir (2002) found that between November and May a northeastern Utah sage-grouse population was negatively correlated with wintering Golden Eagles (1985–2000), and 55% of radio-marked sage-grouse were killed by raptors, which he attributed mainly to Golden Eagles.

Golden Eagles have been suggested as the primary predator of adult sage-grouse (Schroeder et al. 1999, Schroeder and Baydack 2001, Mezquida et al. 2006). Thus, sage-grouse hens may avoid Golden Eagles year round. This constant avoidance of Golden Eagles likely spills over to selection of nest and brood locations. Nesting Red-tailed Hawks, Ferruginous Hawks, and Swainson's Hawks do not take significant numbers of sage-grouse (MacLaren 1988). Golden Eagles may be greater threats to sage-grouse than *Buteo* hawks; thus, it is possible that sage-grouse primarily avoid areas with high densities of Golden Eagles rather than *Buteo* hawks. Alternatively, sage-grouse may protect themselves from multiple avian predators through direct and indirect means. We found that sage-grouse avoided harriers and kestrels at brood locations but not nests. Harriers are known predators of sage-grouse adults and chicks (Schroeder et al. 1999, Schroder and Baydack 2001, Fletcher et al. 2003), and kestrels are known predators of sage-grouse chicks (Schroeder et al. 1999).

Sage-grouse preferentially select for greater visual concealment cover for nesting to hide from visual predators (Conover et al. 2010). Our results verify that sage-grouse treat visual predators as significant threats. This selection for hiding from and avoiding visual predators entails selection at multiple scales. At the local-scale, sage-grouse appear to be selecting for sites where they are visually concealed from avian predators (Connelly et al. 2004, Doherty et al. 2010). At landscape-scales, sage-grouse are selecting for areas where avian predators are less abundant. Sage-grouse selection of habitat at multiple scales achieves the same thing—reduced risk from avian predators.

Several studies have demonstrated that sage-grouse avoid habitat with man-made structures, such as oil and gas infrastructure (Aldridge 2005, Holloran 2005, Walker et al. 2007, Doherty 2008, Holloran et al. 2010) and power-lines (Braun 1998, Connelly et al. 2000, Aldridge and Boyce 2007, Naugle et al. 2011), all of which are potential perches for avian predators. In fact, Lammers and Collopy (2007) and Slater and Smith (2010) found that Golden Eagles, Red-tailed Hawks, Ferruginous Hawks, Swainson's Hawks, ravens, and kestrels utilized power lines and areas around power lines. Thus, sage-grouse may be avoiding man-made structures to avoid the avian predators they attract.

In addition to avoidance of tall structures, sage-grouse may avoid avian predators by avoiding habitats such as wetlands, conifers, and rough terrain. In northeastern Wyoming, Doherty et al. (2010) found that sage-grouse selected nesting habitat at an intermediate landscape-scale (100 m to 350 m) by selecting lower terrain roughness, percent conifer, percent grassland, and percent riparian, and greater density of sagebrush at the patch-scale.

Sage-grouse may avoid avian predators directly by watching them or indirectly by avoiding habitats such as wetlands or tall structures that might attract avian predators, or by both direct and indirect means. Arguments against indirect avoidance include the fact that our study sites had little riparian habitat and over half of our study sites had few anthropogenic structures. Yet, we found that sage-grouse avoided avian predators in all of our study sites. Perhaps sage-grouse avoid nesting and rearing broods in areas where they see raptors, but clearly more research needs to be done before conclusions can be drawn about the mechanisms behind sage-grouse avoidance of avian predators.

Increases in avian predator densities are likely to result in higher depredation rates on sage-grouse nests and reduced chick survival. Sage-grouse hens likely avoid avian predators for their own survival in addition to reducing depredation rates on their nests and chicks. Thus, the presence of greater abundances of avian predators, specifically corvids and raptors, may induce changes in sage-grouse behavior associated to habitat usage. Habitat that has high quality cover and forage may become functionally unavailable to sage-grouse when avian predator densities are at high levels. Regardless of the mechanisms behind sage-grouse hen selection of habitat with fewer avian predators, our results illustrate that sage-grouse were capable of avoiding areas with relatively higher densities of ravens, magpies, Golden Eagles, *Buteo* hawks, harriers, and kestrels compared to available sagebrush habitat.

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TABLE 1. Selection of half-normal detection function adjustments (cosine, simple polynomial, and hermite polynomial) that we used in DISTANCE to estimate avian predator densities, 2008–2010, southwestern and south-central, Wyoming, USA. We selected the best detection function adjustment with AIC for each avian predator species on species group (raven, magpie, Golden Eagle, *Buteo* hawk, harrier, and kestrel) individually.

Species	Adjustment	ΔAIC_c	AIC_c
Common Raven	Simple polynomial	0.00	8138.9
	Cosine	17.82	8156.6
	Hermite polynomial	68.68	8207.5
Black-billed Magpie	Cosine	0.00	1798.7
	Simple polynomial	2.28	1801.1
	Hermite polynomial	3.04	1801.7
Golden Eagle	Cosine	0.00	5876.9
	Simple polynomial	4.63	5881.6
	Hermite polynomial	24.73	5901.6
Buteo hawk	Cosine	0.00	3722.1
	Simple polynomial	18.97	3741.0
	Hermite polynomial	50.03	3771.9
Northern Harrier	Cosine	0.00	1399.1
	Simple polynomial	7.45	1406.4
	Hermite polynomial	22.01	1420.8
American Kestrel	Cosine	0.00	1667.0
	Simple polynomial	13.98	1680.7
	Hermite polynomial	32.36	1698.9

TABLE 2. Number of point-counts used in DISTANCE analyses, number of detections of avian predators, and estimated effective detection radii (EDR), 2008–2010, southwestern and south-central, Wyoming, USA.

Species	EDR	SE	detections	count locations
Common Raven	606.8	22.3	546	965
Black-billed Magpie	294.2	19.1	138	965
Golden Eagle	1006.3	42.7	376	965
Buteo hawk	439.1	26.0	242	965
Northern Harrier	318.4	26.3	100	965
American Kestrel	397.1	36.1	118	965

TABLE 3. Results of paired Student's *t*-tests comparing avian predator densities at random versus sage-grouse nests from 12 16-km or 24-km study sites, 2008–2010, southwestern and south-central, Wyoming, USA.

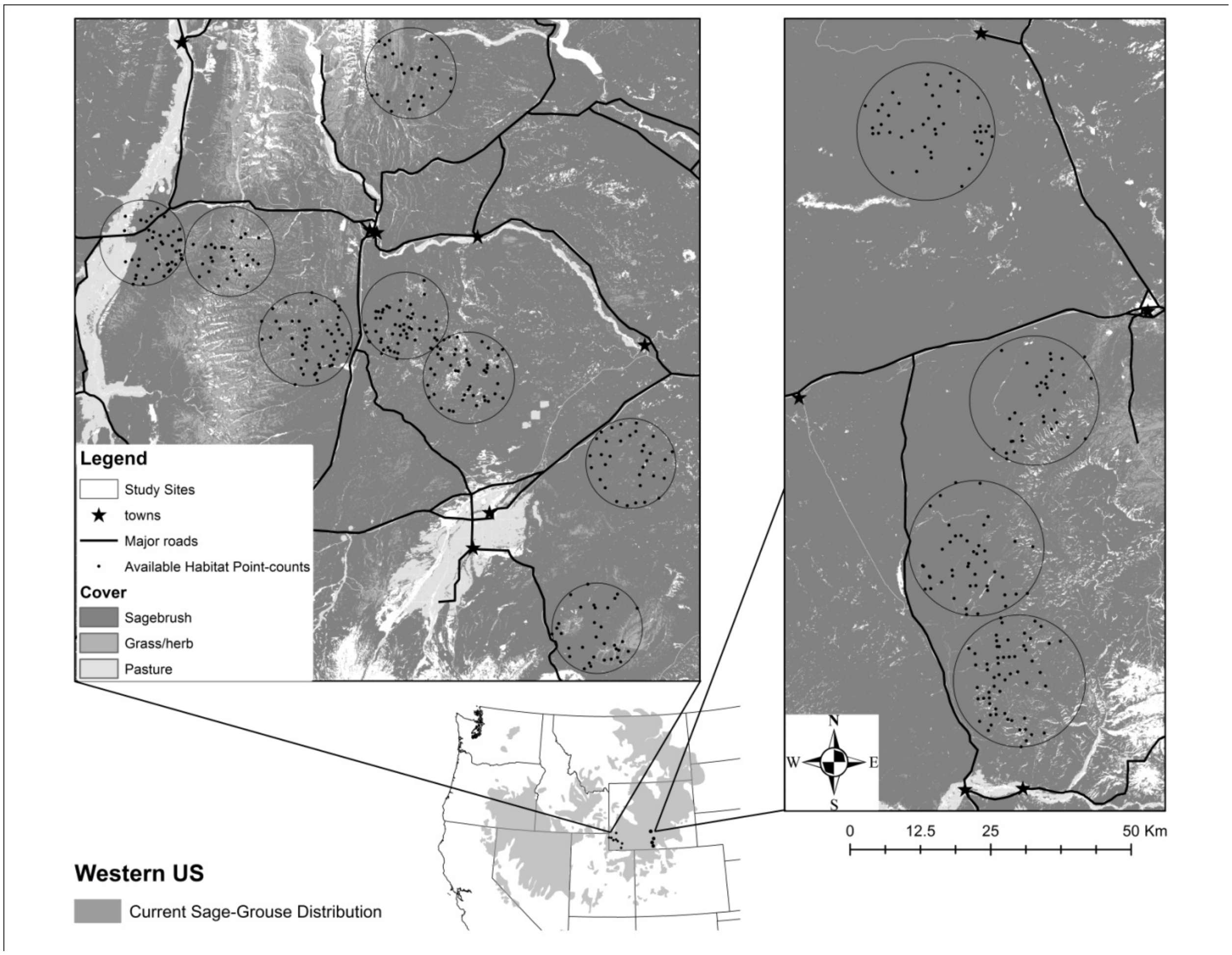
Avian predator species	Random		Nest			
	Mean	SE	Mean	SE	*t*	*P*
Common Raven	0.23	0.04	0.10	0.03	6.06	<0.0001
Black-billed Magpie	0.21	0.05	0.08	0.03	4.15	0.0016
Golden Eagle	0.06	0.01	0.03	0.01	3.30	0.0071
Buteo hawk	0.16	0.04	0.07	0.02	3.70	0.0035
Northern Harrier	0.10	0.01	0.10	0.03	0.45	0.6634
American Kestrel	0.10	0.02	0.09	0.02	0.34	0.7383

TABLE 4. Results of paired Student's *t*-tests comparing avian predator species densities at random versus sage-grouse brood locations from 12, 16-km or 24-km study sites, 2008–2010, southwestern and south-central, Wyoming, USA.

Avian predator species	Random		Nest			
	Mean	SE	Mean	SE	*t*	*P*
Common Raven	0.24	0.04	0.07	0.02	5.88	0.0002
Black-billed Magpie	0.16	0.05	0.06	0.04	2.87	0.0208
Golden Eagle	0.06	0.02	0.01	0.00	4.86	0.0007
Buteo hawk	0.15	0.05	0.03	0.01	5.21	0.0004
Northern Harrier	0.10	0.02	0.01	0.01	5.99	0.0001
American Kestrel	0.15	0.03	0.03	0.02	3.5	0.0067

Fig. 1. Study sites in southern Wyoming showing 12 study sites with 8, 16-km diameter and 4, 24-km diameter study sites, 2008–2010, southwestern and south-central, Wyoming, USA. Magnified sections correspond on left to southwest and on right to south-central Wyoming.

Fig. 2. Comparison of raven, magpie, Golden Eagle, *Buteo* hawk, harrier, and kestrel densities (per km^2) among sage-grouse nests, sage-grouse brood locations, and random locations. Densities were generated using radial point-count surveys and DISTANCE at sage-grouse nests, sage-grouse brood locations, and random locations from 2008 to 2010, southwestern and south-central, Wyoming, USA. Error bars are 95% confidence intervals.


Legend
Study Sites
towns
Major roads
Available Habitat Point-counts
Cover
Sagebrush
Grass/herb
Pasture
Western US
Current Sage-Grouse Distribution
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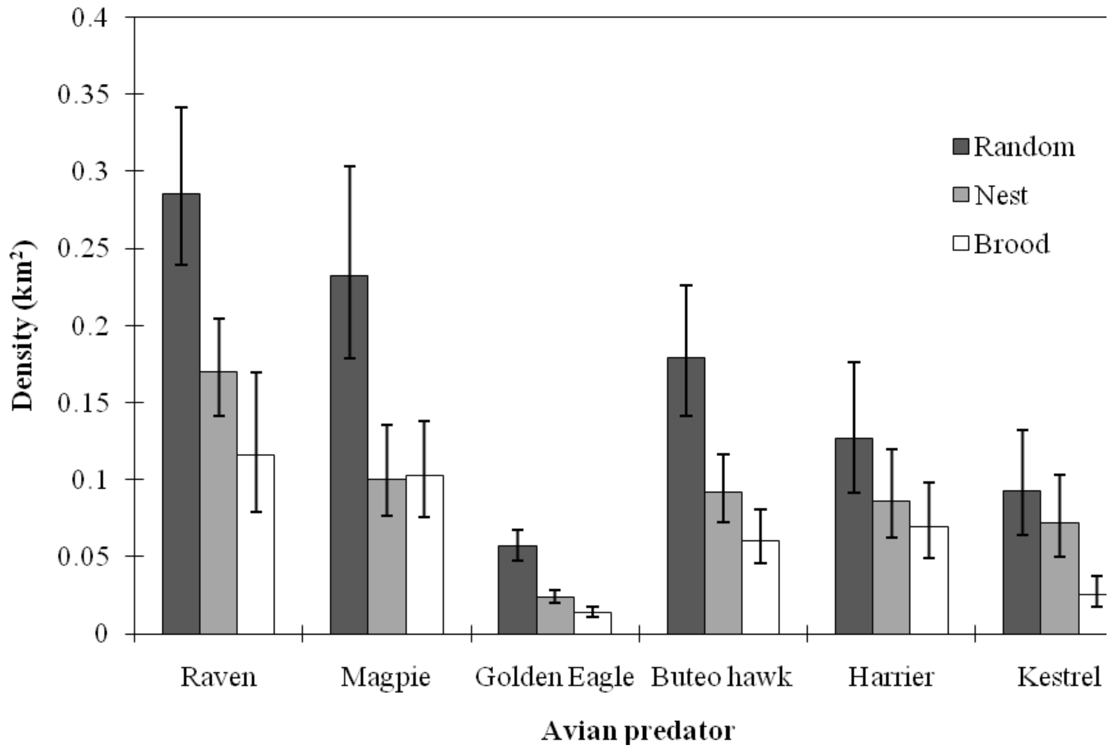
0.4
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0.3
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Density (km²)
Random
Nest
Brood
Raven
Magpie
Golden Eagle
Buteo hawk
Harrier
Kestrel
Avian predator