PRESENTATION ABSTRACTS

Date: **Tuesday, Nov. 15, 2016**

Wyoming Chapter of the Wildlife Society

Session: Grassland and sagebrush environments: small mammals, raptors, and species interactions

Start Time	Title of Presentation	Presenter	Page #
3:00	Returning an endangered species home – a 35 year review of black-footed ferret conservation in Wyoming	Jesse Boulerice	1
3:15	Monitoring Wyoming's grassland Species of Greatest Conservation Need	Andrea Orabona	1
3:25	Balancing management priorities for grassland and sagebrush birds in the Thunder Basin National Grassland	Courtney Duchardt	2
3:40	Predator-prey interactions between mountain plover, burrowing owl, and swift fox on prairie dog colonies on Thunder Basin and Pawnee National Grasslands	Ryan Parker	2-3
3:55	Trapping protocol for difficult to detect small mammals	Kristina Harkins	3
4:10	Raptor rehabilitation in the Greater Yellowstone Ecosystem: common injuries, species diversity and the golden eagle rescue network	M. Warren & C. Adams	4
4:25	Golden eagle migration corridors and seasonal habitat selection in the Rocky Mountains and Western Great Plains	Bryan Bedrosian	4
4:40	Nighttime callback detections, nesting demographics, and habitat selection of great gray owls in western Wyoming	Katherine Gura	5
4:55	The influence of greater sage-grouse management on golden eagles in the Wyoming basin	Geoffrey Bedrosian	5-6
5:10	Using landscape scale estimates of relative electrocution risk to inform prioritization of retrofits: an example with golden eagles	Gary Williams	6
5:25	Wyoming Chapter of The Wildlife Society's Fellowship - Summer 2016 Experience	Jace Cussins	7

Society for Range Management - Wyoming Section

3:00	Bureau of Land Management	Tricia Hatle	None
3:15	U.S. Forest Service or National Park Service		None
3:30	Communicating the natural resources/range message to the public	Larry Butler	None
3:50	Keeping rangelands in your backyard	Mae Smith	None
4:10	Recovery of riparian habitat along Pete Creek in central Wyoming	Andy Warren	7
4:25	Restoration techniques to reduce commpetitive pressures on shrub species in a semi-arid system	Amy Jacobs	8
4:35	ESD Update	M. Patz & B. Christiansen	None
7:00	Complementing the showing of "*The Range Riders* ": Case study in low-stress herding for livestock - Large carnivore coexistence	Matt Barnes	8

PRESENTATION ABSTRACTS

Date: **Wednesday, Nov. 16, 2016**

Session: Ungulate behavior, nutrition, and management

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8:15	Adaptive management of winter elk feedgrounds in western Wyoming to reduce brucellosis prevalance in elk	Ben Wise	9-10
8:30	Investigating trends in elk habitat selection across time and burn severity	Travis Zaffarano	10
8:40	Linking climate and habitat to nutritional condition and recruitment in moose	Brett Jesmer	11
8:55	Quantifying greenscapes: spatialtemportal patterns of phenology shape green wave surfing in migratory mule deer	Ellen Aikens	11-12
9:10	Development and application of population genomic tools for conservation and management of Wyoming pronghorn	Melanie LaCava	12
9:25	The role of memory and past experience in shaping migratory behavior	Jerod Merkle	13
9:40	Risk-effects of a human-altered landscape: nutritional tradeoffs in behavior of mule deer	Samantha Dwinnell	13-14

Session: Mountain species and systems

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10:25	Basic information about mountainsnails	Lusha Tronstad	15
10:40	Seasonal resource selection by introduced mountain goats in the southwest Greater Yellowstone Area	Blake Lowrey	15-16
10:55	What to eat in a warming world: altering forage preferences may buffer climate stress	Embere Hall	16
11:10	The Greater Yellowstone sights and sounds archive: a new tool for wildlife researchers and educators	Nancy Bailey	17
11:25	The Greater Yellowstone Area Mountain ungulate research project	Robert Garrott	17-18
11:40	Multi-state wolverine monitoring and conservation	Nichole Bjornlie	18

PRESENTATION ABSTRACTS

Date: **Wednesday, Nov. 16, 2016**

Session: Sagebrush ecosystems and sage-grouse

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1:10	Microhabitat selection of brood-rearing sites by greater sage-grouse in Carbon county, Wyoming	Leslie Schreiber	19-20
1:20	Comparison of songbird population trends to sage-grouse lek trends: assessing sage-grouse core areas and umbrella species concept	Jonathan Dinkins	20
1:30	Beyond breeding habitat: comprehensive habitat requirements of a partial migrant	Aaron Pratt	21
1:45	Geophagy and movements of greater sage-grouse in the upper Green River drainage	Josh Hemenway	21
2:00	Using resilience and resistance concepts to develop a strategic approach for managing threats to sagebrush ecosystems, Gunnison sage-grouse, and greater sage-grouse in their eastern range	Tom Christiansen	22
2:15	Application of stable isotopes to reconstruct greater sage-grouse chick dietary history: diet selection and relative body condition	Kurt Smith	23
2:30	The non-target effects of sage-grouse habitat treatments on sagebrush-associated songbirds	Jason Carlisle	23-24
2:45	Evaluating efficacy of fence markers in reducing greater sage-grouse collisions	Taylor Gorman	24

Session: Freshwater environments and amphibians

Start Time	Title of Presentation	Presenter	Page #
3:20	Native freshwater mussel follow up investigations: filling survey gaps and exploring newly discovered populations	Oliver Wilmot	24-25
3:30	Fire, grazing and toads: vegetation management and Wyoming toads (Anaxyrus baxteri) recovery efforts	Melanie Murphy	25
3:45	Boreal toad habitat selection and survival in relation to grazing intensity and disease prevalence	Gabe Barrile	26
4:00	Enhancing detection of native Wyoming amphibians through environmental DNA and visual surveys	Andrew Gygli	26-27

Session: Influence of human disturbance and development on species

RETURNING AN ENDANGERED SPECIES HOME – A 35 YEAR REVIEW OF BLACK FOOTED FERRET CONSERVATION IN WYOMING

Jesse Boulerice

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This year marked the 35 year anniversary of the rediscovery of black-footed ferrets (*Mustela nigripes*) in Meeteetse, Wyoming, a fortuitous moment that irrefutably saved the species from extinction and initiated one of the most successful wildlife conservation stories in history. Since that time, Wyoming has been vitally linked to the recovery of the black-footed ferret as home to both the site of rediscovery as well as the first reintroduction site in the world at Shirley Basin. Over the past 26 years, regular monitoring of ferrets at the Shirley Basin reintroduction site suggested that the population is cyclic in nature likely linked to the status of prairie dogs (*Cynomys spp*.) on which ferrets rely. After the population appeared to be nearing carrying capacity between 2006-2010, monitoring in 2013-2015 indicated that ferrets experienced a population decline predicted to be the result of poor weather conditions and possibly disease outbreak. However, surveys conducted in 2016 suggested that the population in Shirley Basin may be recovering. In addition, 2016 welcomed a historical event in black-footed ferret recovery, as a second reintroduction site was established in Wyoming at Meeteetse, bringing ferrets back to the location that the species was originally rediscovered 35 years ago. The return of ferrets to Meeteetse, made possible by a multiagency collaboration, begins a new chapter for ferret conservation in Wyoming where efforts will be dedicated to ensuring the success of this population, thereby contributing to the ultimate goal of recovery of black-footed ferrets on a national-scale.

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MONITORING WYOMING'S GRASSLAND SPECIES OF GREATEST CONSERVATION NEED

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Four grassland-obligate species—Long-billed Curlew, Burrowing Owl, Upland Sandpiper, and Mountain Plover—are classified as Species of Greatest Conservation Need (SGCN) in Wyoming. However, they are not adequately monitored using existing methods, like the Breeding Bird Survey and Integrated Monitoring in Bird Conservation Regions programs, so require species-specific survey techniques instead. We received Wyoming Governor's Endangered Species Account funds to address the following objectives: 1) create new, permanent survey routes for grassland SGCN using preferred habitat associations, known distribution data, and availability of secondary public access roads; and 2) implement standardized, peer-reviewed, species-specific survey methods for long-term monitoring. We also addressed a Wyoming Game and Fish Department SGCN performance measure goal by using permanent personnel to assist the Wyoming Game and Fish Department Nongame Program with SGCN monitoring in Wyoming's grassland habitats. In 2013 and 2014, we established 80 new survey routes for grassland SGCN, as well as 10 routes for 4 species of secretive marsh birds, 2 of which are SGCN. We will present survey results from 2015, the inaugural year of our new SGCN monitoring program.

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BALANCING MANAGEMENT PRIORITIES FOR GRASSLAND AND SAGEBRUSH BIRDS IN THUNDER BASIN NATIONAL GRASSLAND

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Shifting management priorities have the potential to drastically alter landscapes over time. This problem is especially striking in heterogeneous, multi-use landscapes, such as the Thunder Basin National Grassland (TBNG) of northeastern Wyoming. The TBNG is situated along the boundary between the Great Plains and sagebrush steppe, and contains some of the largest remaining complexes of black-tailed prairie dog (*Cynomys ludovicianus*) colonies. This patchwork of vegetation types provides habitat for many imperiled species of shortgrass, mixed-grass, and sagebrush (*Artemisia* spp.) wildlife, while remaining an important resource for the ranching and energy industries. Further, there is specific conflict between shortgrass (i.e., prairie dog) and sagebrush management, as the region is a priority area both for greater sage-grouse (*Centrocercus urophasianus*) conservation and black-footed ferret (*Mustela nigripes*) reintroduction. More so than in more homogeneous landscapes, here it is especially crucial to strike a balance between management priorities that maintain populations of all focal wildlife species into the future. With this in mind, we initiated a study to determine how habitat features, and especially prairie dog colonies, influence avian communities in TBNG. In 2015 and 2016 we surveyed birds on transects within sagebrush habitat ("sagebrush," n=10), prairie dog colonies ("shortgrass," n=10), and across prairie dog colony edges ("edge," n=41). Over two years we observed over 60 bird species, including 14 Wyoming Species of Greatest Conservation Need. Ordinations of community data indicated distinct bird guilds occupying shortgrass, mixed-grass, and sagebrush habitats. These guilds were observed along a gradient from colony centers into adjacent sagebrush habitat. However, vegetation composition on colonies varied widely, and some interior colony edges were typified by moderate sagebrush cover. Preliminary results indicate that some prairie dog colonies can support sizeable populations of sagebrush birds, indicating that management conflict between these shortgrass and sagebrush habitats may not be as severe as previously thought.

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PREDATOR-PREY INTERACTIONS BETWEEN MOUNTAIN PLOVER, BURROWING OWL, AND SWIFT FOX ON PRAIRIE DOG COLONIES ON THUNDER BASIN AND PAWNEE NATIONAL GRASSLANDS

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Short-grass prairies across the Northern Great Plains are an ecologically diverse landscape dependent on disturbances such as grazing caused by prairie dogs (*Cynomys sp.*) and domestic cattle (*Bos taurus*), as well as fire. Mountain Plover (*Charadrius montanus*), Burrowing Owl (*Athene cunicularia*), and Swift Fox (*Vulpes velox*) are

species of conservation concern that rely on these processes for breeding habitat and prey requirements. Literature provides support for their individual dependence on disturbed short-grass prairies, however, important interactions between the species remains unclear. Here we examine a case where predator-prey dynamics offer an insight into multi-species interactions on a disturbed landscape. Survey data was collected by the Forest Service over a 7-year span (2010-2016) on Thunder Basin National Grassland (TBNG) in Wyoming and a 27-year span (1990-2016) on Pawnee National Grassland (PNG) in Colorado. After overlaying the data from each, a pattern emerges between plovers, owls, and foxes at the population level. Plovers and foxes remain common and owls sparse on TBNG, whereas plovers and foxes are sparse and owls common on PNG. We hypothesize that there is a correlation at the population level for the three species in this potential predator-prey relationship. For example, a positive correlation may occur when plover numbers increase because fox numbers will also increase. This sets the stage for a proposed multi-species occupancy model combining detection/non-detection data from plovers, owls, and foxes, using a subset of black-tailed prairie dog (*Cynomys ludovicianus*) colonies on TBNG and PNG as our sample frame. Continued research aims to offer multi-species management recommendations important for land-management agencies, and provide opportunities for further research on prairie ecosystems at a species-interaction level.

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TRAPPING PROTOCOL FOR DIFFICULT TO DETECT SMALL MAMMALS

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Many species of small mammals are considered rare largely because they are difficult to detect on the landscape. Such species will therefore require specific survey methods to optimize their detection. Most studies for small mammals follow a similar protocol that includes trapping a relatively small area with Sherman live traps and using a peanut-butter-oat mix for bait. As part of a larger study focused on delineation of the distribution of rare pocket mice (*Perognathus spp*.) across Wyoming, we tested a new protocol designed to maximize the capture success of pocket mice. We also determined trap and bait preferences of different small mammal species. We used three trap types: Sherman, Havahart, and Longworth traps set at 25 m intervals along four transects of 20 stations each. We baited each station with one of three different bait types in an alternate fashion: peanut butter and oat mix, three-way horse feed with molasses, and roasted bird seed. We found that capture probability was highest in Havaharts for 21 species of pocket mice (Perognathus spp. and Chaetodipus spp.), Ord's kangaroo rats (*Dipodomys ordii*), deer mice (*Perognathus maniculatus*), harvest mice (*Reithrodontomys spp*.), northern grasshopper mice (*Onchomys leucogaster*), least chipmunks (*Tamias minimus*), thirteen-lined ground squirrel (*Ictidomys tridecemlineatus*) and voles (*Microtus spp*. and *Lemmiscus curtatus*) except bushy-tailed woodrats (*Neotoma cinerea*) which were more readily caught in Sherman traps. Bait preference significantly varied by species with pocket mice exhibiting preference for bird seed. These results can be used to produce species-specific capture protocols for future studies.

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RAPTOR REHABILITATION IN THE GREATER YELLOWSTONE ECOSYSTEM: COMMON INJURIES, SPECIES DIVERSITY AND THE GOLDEN EAGLE RESCUE NETWORK

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Anthropocentric caused injuries continues to be a significant cause of mortality for raptors in the southern Greater Yellowstone Ecosystem. Since 1997, we have been admitting injured raptors from Idaho and Wyoming to Teton Raptor Center for rehabilitation, care, and release. Admissions have continually risen each year, with a total of 130 raptors admitted in 2015 and 118 in 2016, to-date. We have admitted 24 species of raptors over the past 6 years. The leading causes of injury have been car strikes, window strikes and illegal shooting. Continuing conservation and education efforts within and surrounding the GYE are needed to help abate and reduce these injuries in raptors. We will report on injury rates, species admitted, success rates for care and release, and opportunities to reduce raptor injuries. Further, to help facilitate care of Golden Eagles from across Wyoming, we have recently created the Golden Eagle Rescue Network, including detailed instructions for first responders, veterinarians, agency personnel, and a volunteer transport network. We will report on the status of the Golden Eagle Rescue Network and provide instructions on its use and how to get involved.

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GOLDEN EAGLE MIGRATION CORRIDORS AND SEASONAL HABITAT SELECTION IN THE ROCKY MOUNTAINS AND WESTERN GREAT PLAINS

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Golden Eagles (*Aquila chrysaetos*) have been receiving increased attention in the western United States due to an increase in anthropogenic population threats, including wind and other industrial energy developments. Conservation of Golden Eagles hinges on knowledge of threats within breeding ranges, migratory corridors, and over-wintering areas. Understanding threats along migration corridors can be difficult due to the short temporal use of migration paths and because pathways can often be dispersed across the landscape. Further, movements and habitat use of non-breeding and sub-adult eagles are often overlooked due to wide-ranging behaviors. We used GPS satellite tracking data from 40 Golden Eagles across three studies and created individual dynamic Brownian Bridge Movement Models (dBBMM) to estimate key migration routes and bottlenecks for migratory Golden Eagles wintering or passing through Montana and Wyoming, with an emphasis on the Rocky Mountain Front. We also combined data from an additional 30 Golden Eagles that are a part of a fourth study across USFWS Region 6 to summarize seasonal movement metrics and create use/availability Resource Selection Function models for sub-adult Golden Eagles across the Wyoming Basin, Northwest Great Plains and High Plains Level III ecoregions. These models can be used for assessing future developments and conservation measures for Golden Eagles in Wyoming and the surrounding areas.

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NIGHTTIME CALLBACK DETECTIONS, NESTING DEMOGRAPHICS, AND HABITAT SELECTION OF GREAT GRAY OWLS IN WESTERN WYOMING

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The Great Gray Owl (*Strix nebulosa*) is a Wyoming State Species of Greatest Conservation Need and are among the least studied raptors in the USA due to their secretive nature and typically low breeding densities. Generally occurring in boreal forests, these habitats are at increasing risk due to wildlife, harvest, insect infestations, and disease outbreaks; all of which may be exacerbated in the future by climate change. As part of a large-scale, multi-year study, we have been investigating survey techniques, demographics, movements and habitat use of Great Gray Owls in western Wyoming from 2013-2016. We have surveyed a total of 1,478 unique locations across 2013-2015 using nighttime callback techniques. Resulting from night surveys we found a total of 37 active Great Gray Owl nests across years, with average production of 1.50, 1.56, and 1.83, and 1.67 fledglings/nest in 2013-16, respectively. Nest success was high and generally consistent among years (73-78%) but there was fluctuation in nest initiation rates and nest failures were correlated with pocket gopher (*Thomomys talpoides*) abundance. We also outfitted 35 owls with VHF and/or GPS transmitters and tracked individuals year-round. We investigated breeding season home range (1 March – 31 August) characteristics for adult owls and winter ranges for all owls (breeders and sub-adults). We found that owls generally shifted winter ranges to lower elevation in the riparian corridors as opposed to higher altitude, boreal forests during the breeding season. We also created predictive resource selection models in the southern Greater Yellowstone Ecosystem for breeding season home ranges of adult owls to help inform future conservation and management.

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THE INFLUENCE OF GREATER SAGE-GROUSE MANAGEMENT ON GOLDEN EAGLES IN THE WYOMING BASIN

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Greater Sage-Grouse (*Centrocercus urophasianus*) have been the focus of an unparalleled amount of conservation attention across the western U.S., and landscape-scale conservation strategies are currently underway to protect Greater Sage-Grouse across vast areas (~310,000 km^2). Greater Sage-Grouse are thought to be an umbrella species, meaning that management actions for Greater Sage-Grouse can benefit a host of other species. Golden Eagles (*Aquila chrysaetos*) inhabit much of the sagebrush steppe where Greater Sage-Grouse occur and are also a species of conservation interest in the West. Because there may be substantial overlap between important habitat for Greater Sage-Grouse and Golden Eagles, and because both species face similar threats in parts of their range, there is an opportunity for Golden Eagles to benefit from Greater Sage-Grouse management. Our objective was to determine the amount of overlap between areas managed for Greater Sage-Grouse and seasonal habitats of Golden Eagles in the Wyoming Basin ecoregion (portions of Wyoming, Colorado, Idaho, and Utah). We

calculated the amount of spatial overlap between habitats protected by federally designated Priority Areas of Conservation (PACs) for Greater Sage-Grouse and relative habitat suitability models for Golden Eagles during the winter and breeding seasons using GIS. We found that Greater Sage-Grouse PACs in the Wyoming Basin contained 47.20% of Golden Eagle winter habitat and 44.58% of Golden Eagle breeding habitat. Management actions on PACs may benefit Golden Eagles by preserving habitat and prey resources that may otherwise be lost without proactive management. Our work provides a spatially explicit framework for identifying areas where Golden Eagle conservation may be augmented by efforts to protect Greater Sage-Grouse, as well as areas where high quality Golden Eagle habitats could potentially be at risk if development and land-use impacts shift to areas outside of Greater Sage-Grouse PACs.

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USING LANDSCAPE-SCALE ESTIMATES OF RELATIVE ELECTROCUTION RISK TO INFORM PRIORITIZATION OF RETROFITS: AN EXAMPLE WITH GOLDEN EAGLES

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Electrocution continues to be a significant source of mortality for Golden Eagles despite decades of retrofitting efforts. This is perhaps not surprising due to the enormous number of power poles in the United States (> 115 million and increasing) and the high cost of retrofitting (often > $1,000/pole). Given this situation, it is critically important to retrofit the riskiest poles first. Landscape-scale models of Golden Eagle habitat and electrocution hazard can be used to develop retrofitting prioritization schemes that focus on high risk areas first and result in fewer electrocutions over time. Here, we demonstrate such an approach by overlaying landscape-scale models of Golden Eagle breeding and winter habitat (i.e., estimates of exposure) with a landscape-scale model of electrocution hazard to identify priority areas for retrofits. Our assumption was that electrocution risk would be greater where high quality habitat (i.e., higher potential for exposure) overlaps areas of high electrocution hazard. To evaluate this prediction, we compared the locations Golden Eagle 282 electrocution records from the service area of a utility in northeastern Wyoming to our mapped predictions of relative electrocution risk. Preliminary analyses indicated mortality rates were approximately 2.5 times higher in areas classified as high electrocution risk when compared to the average across the landscape. These results demonstrate the utility of combining landscape-scale estimates of exposure and hazard to prioritize retrofitting. Such tools could prove to be particularly useful for utilities that lack formal retrofitting plans.

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THE WYOMING CHAPTER OF THE WILDLIFE SOCIETY'S 2016 FELLOWSHIP EXPERIENCE

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The mission of the Wyoming Chapter of The Wildlife Society's Fellowship's program is to develop and mentor future wildlife professionals. Now in its fifth year, this program allows the selected Fellow to explore multiple career opportunities as he/she travels, networks, assists, learns, and interacts with the public around Wyoming. As the 2016 Fellow, I had just completed my junior year as an undergraduate in the wildlife program at The University of Wyoming, where I also serve as the President of the Wyoming Student Chapter. This three-month position enabled me to shadow seventeen different wildlife organizations including federal agencies, state agencies, universities, NGOs, and consultants. This exposure helped me to not only understand the structure of organizations involved in managing Wyoming's wildlife, but also some of the hot topics in wildlife management. Shadowing passionate and enthusiastic wildlife professionals was motivating, providing me a unique opportunity to learn about their educational background and how they worked different positions to arrive at their current job. Seeing both the educational background and the practical use in the field, made for an impressionable experience to guide me as I develop a meaningful career in the wildlife field.

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RECOVERY OF RIPARIAN HABITAT ALONG PETE CREEK IN CENTRAL WYOMING BETWEEN 1982 AND 2015, FOLLOWING CHANGES IN LIVESTOCK GRAZING AND THE RETURN OF BEAVER

Andy Warren, Supervisory Rangeland Management Specialist, Thomas Powell, GIS Specialist, Clayton Bolton, Rangeland Management Specialist, USDI-BLM, Rawlins, WY 82301

Pete Creek flows off the north slope of Ferris Mountain into the Sweetwater River within the North Platte River drainage, with approximately three miles of perennial channel located on BLM-administered public land upstream of privately owned irrigated hay meadows. Livestock grazing has occurred since the Sun Family settled nearby in 1872, and photos from the early 1980s depict the impacts of summer-long cattle grazing and loss of beaver within this ecosystem. Through the development of pasture fencing and additional water sources, grazing by cattle was changed in the late 1980's to a short duration, primarily fall use period. Photographs show the improvement over time in riparian habitat, including reduction in channel width, improved bank cover, and expansion of woody plants, particularly willows. In addition, monitoring by the WGFD – Casper Fish Division, has also shown an increase in the numbers and pounds per stream mile of brook trout. As the riparian habitat improved, beaver also returned to this area, and since 2000 have increased water storage and spreading through their dam-building activities. Recent comparison of aerial photography between 1982 and 2015 also confirm a much broader improvement in riparian habitat across the entire floodplain. The art of riparian management was still in its' infancy in the 1980's, however, the knowledge gained from Pete Creek and other sites across the West, demonstrate the success of BLM's multiple-use concept in supporting livestock grazing in conjunction with managing for wildlife, fisheries, watershed, and recreation values.

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RESTORATION TECHNIQUES TO REDUCE COMPETITIVE PRESSURES ON FOUNDATION SHRUB SPECIES IN A SEMI-ARID SYSTEM

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Efforts to restore burned Wyoming big sagebrush (*Artemisia tridentata* ssp. *wyomingensis* Beetle & A.W. Young) populations are frequently unsuccessful due to the inability of sagebrush seedlings to compete with established grasses, which are not killed by fire. Current best management practices used to curb competition typically include seeding of native perennial grasses and use of herbicides. The objective of my study focuses on the efficacy of mechanical suppression of grasses competing with planted sagebrush seedlings using various mulch treatment types. My study site is located in a burned Wyoming big sagebrush landscape in Converse County, Wyoming. Approximately 10,900 container grown Wyoming big sagebrush were transplanted into 115 plots (95 m2). Each plot was planted exclusively using one of five mulch treatments with 95 seedlings per plot. Transplants were planted in uniform rows with 2 m separation between each. The objective of my research is to quantify the effects of different mulch treatments on improving sagebrush transplant survivorship, fitness, and above ground growth. Preliminary results indicate that treatment types have a significant effect on survivorship and an even more significant effect on crown volume (up to 400%). Research methodology and results will be expanded upon at time of presentation.

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LOW-STRESS HERDING FOR LIVESTOCK – LARGE CARNIVORE COEXISTENCE: A CASE STUDY

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Grazing management strategies such as rotational grazing and low-stress herding may promote coexistence with potential predators by taking advantage of grazing animals' primary anti-predator behavior, aggregation into fewer, larger groups, or ideally a single large and mobile herd. The Wind River Ranger District, near the southeastern edge of Greater Yellowstone's established grizzly and wolf populations, has the highest conflict level on the Shoshone National Forest. On the Union Pass Allotment, permittees had been having depredations every year for several years. The two permittees, the USFS range staff, and a conservationist agreed to test a strategy of low-stress herding to combine two herds, follow an existing grazing plan of rotation through mostly unfenced subunits, and hypothetically to reduce vulnerability to predation. The permittees had previously struggled to implement the grazing plan. We agreed to invest in the permittees themselves rather than hire an outside range rider. Over a three-year period (2014-2016) we hosted low-stress livestock handling consultants for three, once-a-year workshops emphasizing herding and range management applications (the latter two co-hosted with the Dubois-Crowheart Conservation District). The permittees have partially adopted low-stress methods, and have been partially successful: one herd has mostly stayed together; the other herd has tended to be in fewer groups than in previous years, and more of that herd has been with the first herd (a modest increase in group size). The herds have not yet been fully able to follow a scheduled rotation without fences. They have had no confirmed depredations in the three seasons since the project began, but have lost some calves each year to unknown causes, which may include predation. Low-stress herding appears to be an important tool for reducing vulnerability to predation, and thus for coexistence. This project is featured in the documentary film, *The Range Riders*, which will be shown.

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INFLUENCE OF THE BARK BEETLE EPIDEMIC ON ELK AND HUNTER RESOURCE SELECTION AND INTERACTIONS

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For large ungulates, factors such as nutrition, energetics, and hiding and thermal cover all influence resource selection. For nearly two decades, the forests of the Rocky Mountains (USA) have been experiencing a bark beetle epidemic of severity and duration that has not been seen in over a 100 years. Between northern Colorado and southern Wyoming, the mountain pine beetle (*Dendoctronus ponderosae*) alone has caused mortalities in over 1.5 million hectares of lodgepole pine (*Pinus contorta*) forest. As the epidemic changes the structure and characteristics of the forest, the ungulates that inhabit these areas may alter their resource selection patterns to adapt to changing habitats. Moreover, ungulate distributional shifts may also lead to changes in the hunting patterns of humans, which are the primary predator of adult ungulates in affected forests. We are evaluating how the resource selection of elk (*Cervus elaphus*) is being influenced by the bark beetle epidemic in the Sierra Madre Mountains of southcentral Wyoming. By employing global positioning system (GPS) technology to document the movements of elk, we are quantifying how elk move about a forest with increased downed trees and understory vegetation and a potential reduction of thermal and hiding cover. Specifically, we will use a satellite-derived land classification to develop resource selection functions for elk to examine resource selection during various stages of beetle-killed forests. In addition, we are coupling our analysis of elk resource selection with an analysis of how beetle kill is influencing hunter movements and interactions with elk. This work is done through voluntary monitoring of hunter movement paths during the fall hunting season. Our work will provide novel insights into how the bark beetle epidemic will influence elk resource selection and hunter effort, and this information will inform wildlife and land management decisions regarding ungulates and hunting in beetle-killed forests.

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ADAPTIVE MANAGEMENT OF WINTER ELK FEEDGROUNDS IN WESTERN WYOMING TO REDUCE BRUCELLOSIS PREVALENCE IN ELK

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Brucellosis is of large economic and management concern in the Greater Yellowstone Ecosystem where infected elk and bison comprise the last nidus of *Brucella abortus* in the United States. Wyoming Game and Fish Department (WGFD) management of brucellosis has traditionally focused on temporal and spatial separation of elk (*Cervus elaphus*) and cattle (*Bos taurus*) primarily through operation of 22 winter feedgrounds. Feedgrounds reduce elk damage to stored crops and private lands as well as the risk of disease spill over from elk to cattle while

concomitantly perpetuating brucellosis infections among elk by densely aggregating animals during the transmission period. However, separation efforts have been fallible, as recent brucellosis infections in Wyoming cattle during 2004, 2008 and 2015 were linked to feedground elk. Intensive research of brucellosis in feedground elk was conducted during 2006-2015. Major results indicated that 1) most important transmission events on feedgrounds occurred on feedlines, 2) brucellosis seroprevalence in elk attending feedgrounds is positively correlated with mean feeding end-date, and 3) elk density during calving season may increase with number of days spent on supplemental feed. Findings from this research lead the WGFD to develop the Target Feedground Project, an adaptive strategy incorporating feeding management manipulations to reduce risk of brucellosis transmission among elk on 8 'Target Feedgrounds'. The first objective is to reduce elk densities while on feedgrounds by using Low-Density feeding. The second objective is to reduce duration of high elk concentration by manipulating end-feeding season date through systematic reductions in hay rations in late-winter/early-spring, with the goal of ending an average of 3-4 weeks earlier than long-term means. Advantages of this project, if successful, include a sustainable reduction of brucellosis in elk and associated decreased risk to cattle, lower elk feeding costs, and continued operation of feedgrounds to minimize elk-cattle commingling, elk damage.

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INVESTIGATING TRENDS IN ELK HABITAT SELECTION ACROSS TIME AND BURN SEVERITY

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Controlled burns and natural wildfires are increasingly being used as management tools to improve big game habitat in many states throughout the intermountain West. Many studies evaluating the nutritional quality of forage species after fire events suggest that an increase in forage quality is beneficial to large ungulates and the subsequent flush of nutritious forage is the mechanism underlying increased selection for burned habitats by elk. However, the duration of increased forage quality and consequent habitat preference due to fire events is poorly understood. The 2011 Red Rock Fire, which burned over 9,000 acres in the Gros Ventre watershed in the Bridger-Teton National Forest of western Wyoming, was managed for resource benefit and burned in a mosaic pattern of various severities. This fire event presents a unique opportunity to investigate trends in the habitat selection of elk with regards to both temporal components and burn severity across the landscape. With the availability of GPS location data for elk before and after the occurrence of this wildfire, as well as several years of nutritional quality data for numerous forage vegetation species, we aim to determine if strength in habitat selection by elk is influenced by time, burn severity, and nutritional quality of forage. Preliminary findings suggest preferential selection for burned areas, with varying strengths of selection across the burn severity spectrum. Duration of preferential selection occurred for three years post-fire, followed by a decrease in selection – similar to findings in nutritional content of many forage species sampled. Coupling both habitat selection and forage quality, we aim to disentangle some of the mechanisms underlying selection for burned habitat during those initial years. This research will increase our understanding of fire ecology in montane forests, and help direct future habitat improvement procedures in which prescribed burning is the primary tool for landscape change.

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LINKING CLIMATE AND HABITAT TO NUTRITIONAL CONDITION AND RECRUITMENT IN MOOSE

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A major goal in population ecology is to understand factors underlying density-dependent and density-independent shifts in demography. Life-history theory predicts that nutritional reserves of large herbivores should be allocated to reproduction in a state-dependent manner because survival is highly conserved. Consequently, the effects of climate and density on reproductive success are often mediated through nutrition. Recruitment rates in many moose (*Alces alces*) populations across the Intermountain West are declining, even in areas lacking large carnivores, which suggests bottom-up limitation. From 2011–2014, we measured habitat condition via an index of willow (*Salix spp*.) condition, autumn nutritional condition of harvested animals using a kidney fat index, recruitment of young from aerial surveys, and climate using remotely sensed data across eight moose populations. We evaluated models describing both trends in recruitment and annual recruitment rates. Willow condition and kidney fat predicted trend in recruitment, but prediction of annual recruitment required additional climatic data. Populations with declining recruitment were more sensitive to warming and drying, indicating that habitat quality and nutritional condition buffer against unfavorable climatic conditions. Our work demonstrates that life-history theory provides a useful framework through which reproductive effort of large herbivores can be linked to shifts in nutritional condition stemming from habitat and climatic conditions. Thus, monitoring habitat and nutritional condition of large herbivores should allow managers to preempt - and thus proactively manage - prolonged declines in recruitment.

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Quantifying Greenscapes: Spatiotemporal Patterns of Phenology Shape Green Wave Surfing in Migratory Mule Deer

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Animals live in environments with resources that change in space and time. In landscapes with resource waves - pulses of ephemeral resources that progress along spatiotemporal gradients – mobile consumers should enhance energy gains by moving in response to resources. The Green Wave Hypothesis (GWH) posits that migration

manifests in response to resource waves, and predicts that animals should synchronize their movements with the propagation of resources along those waves. For many ungulates, green waves of nutritious forage progress along elevational or latitudinal gradients in spring. We evaluated if 1) mule deer (*Odocoileus hemionus*) track waves of nutritious forage during migration, and 2) develop and test three hypotheses to explain variability in tracking among individuals. Although variable across individuals, mule deer tracked changing resource quality during migration. Characteristics of the "greenscape" or quality of the resource wave, which we defined by the order, rate, and duration of green-up, was the primary factor affecting tracking ability (greenscape hypothesis). Resource tracking was not influenced by the condition (state-dependent hypothesis) or age (learning hypothesis) of the animal. Our work demonstrates that the spatiotemporal configuration of resources – and not the age or physiological state of the animal – was critical in shaping the movement and presumed energy gains of individuals. By linking movement and spatial ecology to quantify greenscapes, our work highlights an often overlooked but critical component shaping the movement of migratory species. Moreover, given the importance of the greenscape to successful surfing, knowledge about the greenscape can inform efforts to prioritize conservation and enhancement of routes to sustain long-distance migration.

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DEVELOPMENT AND APPLICATION OF POPULATION GENOMIC TOOLS FOR CONSERVATION AND MANAGEMENT OF WYOMING PRONGHORN

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Anthropogenic landscape alterations have resulted in widespread population declines and reduced connectivity for many wildlife species. It is critical to characterize and maintain genetic diversity and gene flow for these affected species, especially those that require large, contiguous landscapes for dispersal and seasonal movements, such as pronghorn (*Antilocapra americana*). Pronghorn once inhabited North American prairies in the tens of millions; however, overharvest and habitat destruction led to estimates as low as 13,000 individuals worldwide by 1915, with only 2,000 in Wyoming. Though pronghorn have gradually recovered over the past century, populations continue to experience considerable fluctuations in size throughout the species' range. Today, pronghorn populations are threatened by habitat loss and human-constructed barriers to seasonal movements and dispersal (e.g., highways, fencing). Research implicating the negative impacts of these threats is growing, but genetic research for this species remains limited. To assess how historic population declines and current anthropogenic stressors affect Wyoming pronghorn, we are determining current levels of genetic diversity and genetic structure for populations across the state. We are developing thousands of single nucleotide polymorphism (SNP) loci using double digest restriction-site associated DNA (ddRAD) sequencing. Ultimately, we aim to delineate genetic population units, identify natural and anthropogenic barriers to gene flow, and pinpoint essential corridors for dispersal. I present preliminary ddRAD data and analyses of genetic diversity and population structure for Wyoming pronghorn. This research establishes critical baseline genomic data useful for future research and management of this species that is a valued natural resource for wildlife viewing, tourism and hunting.

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THE ROLE OF MEMORY AND PAST EXPERIENCE IN SHAPING MIGRATORY BEHAVIOR

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Previous experiences strongly influence animal behavior. Although much work has focused on spatial memory in home-ranging species, many large ungulates are migratory, and the role of memory in assisting animals to navigate over large landscapes is largely unknown. Our objectives were to examine the role of memory in migratory decisions, and test whether previous knowledge of a landscape facilitates successful exploitation of high quality forage. Using GPS collared mule deer (*Odocoileus hemionus*) in western Wyoming, we developed movement models during spring migration and tested whether deer selected previously used habitat patches while taking into account other indices of forage quality. Additionally, using bighorn sheep (*Ovis canadensis*) GPS collar data from across Wyoming, we tested whether individuals with a history of occurrence on native range could track green-up dynamics better than their translocated counterparts. Although deer selected habitat patches on south facing ridges and at their peak in forage quality, the distance a habitat patch was to an individual's previous migration route was by far the best predictor of movement (10 times the effect size of the next most important variable). Thus, memory emerges as a key driver of the chosen migration route apart from decision cues associated with habitat or phenology. Bighorn sheep with previous knowledge of their range were able to exploit spring green-up better than their translocated counterparts, with the timing of their movements being matched 5.6±2.2 days closer to temporal peaks in forage quality. Our results suggest that mule deer have strong spatial memory and they employ it to efficiently navigate over long-distance migrations. Further, remembering past experience allows individuals to efficiently exploit gradients of vegetation quality during green-up. We discuss implications of these findings for how to conserve migratory routes of species with strong fidelity and for successfully reintroducing animals into new, and thus novel, landscapes.

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RISK-EFFECTS OF A HUMAN-ALTERED LANDSCAPE: NUTRITIONAL TRADEOFFS IN BEHAVIOR OF MULE DEER

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Behavioral responses to perceived risk can create tradeoffs between obtaining forage and avoiding risk of predation that may modify nutritional dynamics of ungulates; however, a landscape may not require the presence of predators to prompt risk-sensitive foraging. Human disturbance may be a novel form of perceived risk similar to predation, and affect how ungulates use available habitats. Behavioral responses to human disturbance are known to affect population performance, but the proximate mechanisms that underpin those effects are poorly understood. We hypothesized that the integrative relationship between risk-sensitive behavior and nutritional condition is the mechanism by which human disturbance affects ungulate populations. We measured use of available browse on the landscape and linked individual behaviors and seasonal changes in nutritional condition of 148 female mule deer (*Odocoileus hemionus*) equipped with GPS collars to habitat conditions across three winter ranges that vary in intensity of human disturbance from energy development. Use of available browse was affected by proximity to energy development and annual production of browse (R2 = 0.23; *p*-value = < 0.0001). Although use decreased with proximity to development (1.2% decrease with each 100 meters closer to development), an interaction between distance to development and annual production of browse revealed that the effect of development was less when production was high. Furthermore, deer exposed to high levels of human disturbance increased movement rates, which in turn, had a negative but weak effect on nutritional condition (*p*-value = 0.053). Our results are evidence that mule deer on winter ranges with exposure to human disturbance alter behavior in a way that may have a negative effect on nutritional condition. Understanding these mechanisms by which human disturbance can affect wildlife populations is a prerequisite to making conservation and management decisions for ungulate populations where increases in human disturbance occur.

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Fire History and Regeneration Dynamics of Low-Elevation Douglas Fir Forests in the Grand Teton Area

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Fire history research provides critical information on fire regimes, historic range of variation of wildfires, and fire-climate relationships. Whereas detailed fire history information exists for Yellowstone National Park, topographic, vegetative, and geologic differences between the Yellowstone area and the Jackson Hole area imply significant fire regime differences between the two locations. Our prior fire history work in the Grand Teton Area supported widespread stand-replacing fires in the latter half of the 1800's, especially in lodgepole pine dominated forests. In this study, we seek to better understand wildfire frequency and severity as well as regeneration dynamics in both north- and south-facing, low-elevation Douglas fir dominated forests (the driest widespread forest type in this area). We randomly sampled paired plots in north- and south-facing Douglas fir dominated forests below 7,500 feet in elevation. In each plot we extracted tree cores, fire scars (if present), and forest structure data from four subplots. Altogether, in the summer of 2015, we sampled 51 plots, collected 2,244 tree cores and 75 fire scars.

Forest structure, tree growth rates, and average forest age was significantly different in north- versus south-facing slopes; with north-facing forests showing higher tree density, slower tree growth, and older average tree ages. Fire frequency was highly variable in the Douglas fir forest type (point return intervals ranged from 26 years to over 100 years) and did not significantly differ by slope aspect. Whereas fire frequency did not differ between aspects, fire severity often did. On south facing slopes more trees survived fire events and stand replacing fires were less common than on north-facing slopes. Regeneration dynamics also differed between aspects, with south-facing forests showing a longer time lag in tree regeneration after a fire event. The differences in Douglas fir forest structure and fire effects between north- and south-facing slopes observed in this study may give us a window

into how the forests and habitat of the Greater Yellowstone Ecosystem may respond to climate warming – self-organizing to become more similar to south facing forests, with reduced tree densities and an increased ability to resist mortality from wildfire.

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BASIC INFORMATION ABOUT MOUNTAINSNAILS

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Mountainsnails (*Oreohelix* spp.) are the largest land snails in Wyoming and the current taxonomy describes several endemic species. These snails are widely distributed in the mountainous areas of our state. Three species have been petitioned for Endangered Species Act listing in Wyoming; however, we lack basic information about these snails. I studied a population of *Oreohexlis subrudis* in the Snowy Mountains over five years to estimate life span, growth, mortality, movement and predation. I marked nearly 300 individuals since 2011 using unique snail polish markings and bee tags. Over that time, ~10% have died (2% due to predators). Mountainsnails moved about ~1 meter annually, but I measured snails moving up to 15 meters. Growth rates were highest for the youngest snails, but snails appear to grow throughout their life. I have recaptured individuals that were originally marked in 2011 indicating that mountainsnails can live 5 years. I will continue to monitor the population so that managers have basic life history information with which to base management discussion on.

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SEASONAL RESOURCE SELECTION BY INTRODUCED MOUNTAIN GOATS IN THE SOUTHWEST GREATER YELLOWSTONE AREA

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Introduced mountain goats (*Oreamnos americanus*) and native bighorn sheep (*Ovis canadensis*) inhabit high-elevation, mountainous terrain in the Greater Yellowstone Area (GYA). Mountain goats have been expanding their range in GYA since their initial introductions in the 1940's, prompting concern that competition and disease transfer could negatively impact native bighorn sheep. We constructed summer and winter resource selection models using GPS data collected during 2011-2014 from 18 (14 female, 4 male) allopatric mountain goats in the Snake River Range of the southwest GYA. We used a mixed-model approach and evaluated landscape and environmental covariates at multiple spatial grains within four related suites. Mountain goat resource selection was grain dependent in both seasons. In summer, mountain goats largely selected rugged and steep areas at high elevations and avoided high solar radiation, canopy cover, and time-integrated NDVI. In winter, mountain goats selected lower elevations characterized by steep and rugged slopes on warm aspects and avoided areas with high canopy cover, NDVI amplitude, and snow water equivalent. Slope was the dominant predictor of habitat use in

both seasons, although mountain goats selected for steeper slopes in winter than in summer. Regional extrapolations depicted suitable mountain goat habitat in the Snake River, Teton, Gros Ventre, Wyoming and Salt Ranges centered around steep and rugged areas. Winter range was generally characterized by the steepest slopes within a more broadly distributed and generally less steep summer range. Further research should examine the spatial and temporal overlap of sympatric populations to further our understanding of resource selection dynamics and the potential for introduced mountain goats to alter bighorn sheep behavioral processes.

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WHAT TO EAT IN A WARMING WORLD: ALTERING FORAGE PREFERENCES MAY BUFFER CLIMATE STRESS

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Contemporary climate change affects nearly all biomes, causing shifts in animal distributions, resource availability, and species persistence. Changes in resource selection may allow individuals to offset climatic stress, thereby providing a mechanism for persistence amidst warming conditions. The extent to which individuals buffer stress by changing resource preferences, however, is an open question. We addressed whether individuals compensated for temperature-related reductions in foraging time by altering forage preferences, using the American pika (*Ochotona princeps*) as a model organism. We tested two hypotheses: 1) Forage-quality Hypothesis: Individuals exposed to temperature extremes should select higher quality vegetation; and 2) Forage-efficiency Hypothesis: Individuals exposed to temperature extremes should select vegetation that is most available. We examined forage preference at 5 sites exposed to either chronic heat stress (> 1 month during which below-talus temperatures exceeded 16°C; 3 sites) or neutral conditions (2 sites). At each pika territory we quantified the composition and quality (% moisture, % nitrogen, and fiber content) of available and cached vegetation, and deployed a network of temperature sensors to measure *in situ* conditions. Pikas cached plants that were higher in nitrogen and moisture, compared to available vegetation, and avoided vegetation with high fiber composition. Individuals exposed to more extreme daytime temperatures showed stronger selection for high-nitrogen vegetation, suggesting support for the Forage-quality Hypothesis. By shifting resource-selection patterns, temperature-limited animals may be able to buffer some of the negative effects associated with rapidly warming environments. As climate change continues to manifest, efforts to understand changing animal-habitat relationships will be enhanced by considering both resource availability and the capacity of organisms to modify selection dynamics.

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THE GREATER YELLOWSTONE SIGHTS AND SOUNDS ARCHIVE: A NEW TOOL FOR WILDLIFE RESEARCHERS AND EDUCATORS

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The Draper Natural History Museum at the Buffalo Bill Center of the West has been acquiring and cataloging video recordings of wildlife, landscapes, and personal interviews with land and wildlife managers and the general public in the Greater Yellowstone region since 2000. The collection is maintained as the Greater Yellowstone Sights and Sounds Archive (Archive) and represents a novel approach and resource for monitoring wildlife occurrence and behavior, environmental change, and human perceptions and attitudes about wildlife through time. Some samples of Archive materials are available to view online through the Center's McCracken Research Library, and all materials in the Archive are available to researchers and educators on request. The Archive is curated like a scientific specimen collection, including data fields for location and date of collection, collector, and other pertinent information. Although still in its infancy, the Archive can be accessed to illustrate animal behaviors, landscape characteristics, and human experiences and perceptions about wildlife and the environment. It also provides a video record of environmental change, such as bark beetle kill, wildfire, and human-induced alteration of Greater Yellowstone landscapes, and important issues, such as grizzly bear management. For example, materials from the Archive have been used by CBS *60 Minutes* for a report on bears in Wapiti, Wyoming by the Draper Museum and U. S. Forest Service to create a five-part series of "Bear Aware" instructional videos that have enjoyed wide use in museum exhibits and outreach programs. We are continuing to build and catalog the Archive and welcome partnerships and well-documented video donations to expand the content and access to this valuable collection.

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THE GREATER YELLOWSTONE AREA MOUNTAIN UNGULATE RESEARCH PROJECT

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The Greater Yellowstone Area (GYA) encompasses one of the core ranges for Rocky Mountain bighorn sheep in North America. Conservation efforts have restored bighorn sheep after the era of exploitation, however many areas of the GYA, including both National Parks, support only small patchily distributed bighorn sheep populations. While mountain goats were not present in the GYA at the time of European settlement, there has been a

progressive increase in the abundance and distribution of non-native mountain goats since they were introduced into mountain ranges in Montana and Idaho during the mid-20th century. Despite their iconic status among the public and natural resource agencies, these mountain ungulates have received comparatively little scientific attention and all natural resource agencies within the GYA have an interest in improving ecological understanding of both species. Over the past 8 years a broad coalition of agencies and organizations has combined their expertise and resources to support the GYA Mountain Ungulate Project. Our strong partnerships have allowed us to capture, sample, and instrument bighorn sheep and mountain goats throughout the GYA in order to better understand seasonal movements, habitat use, migration patterns and corridors, and patterns of mortality and survival. In addition, biological sampling of captured animals is providing insight into variation in pregnancy and body condition among herds occupying diverse ecological settings, as well as presence and prevalence of important pathogens that are known to cause epizootics. To date, >300 animals have been captured, sampled, and radio collared. This presentation will provide an overview of this integrated research initiative, summarize some of the accomplishments to date, and provide some of the initial insights we are gaining on various aspects of bighorn sheep and mountain goat ecology in the GYA.

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MULTI-STATE WOLVERINE MONITORING AND CONSERVATION

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Wolverines (*Gulo gulo*) have a circumpolar distribution that historically extended to California and New Mexico. Since 1920, wolverines have recolonized portions of their former range, although extent of recolonization is unknown. Concerns about the vulnerability to climate change led to a petition to list the species in 2000, and a federal court ruling recently remanded the 2014 not warranted finding. In 2015, Idaho, Montana, Washington, and Wyoming, with support of the Western Association of Fish and Wildlife Agencies, initiated the Western States Wolverine Conservation Project to assess current distribution and identify conservation actions. That year, the Wyoming Game and Fish Department (Department) funded a project to develop and evaluate techniques to detect wolverines and estimate occupancy. From a survey of 18 grid cells, we estimated occupancy at 62.9% (95% CI: 36.2 to 83.7) and probability of detection at 32.1% (95% CI: 12.8 to 57.5), giving a high probability of detection over the 5-month sampling period (0.86). Based on ventral pelage, ≥3 wolverines were detected during the effort. In 2016, using protocols developed by the cooperating states and others, the Department completed the first of a 2-year effort to sample the western mountains in Wyoming; we detected ≥2 wolverines at 3 of 25 grid cells. This winter, the Department and cooperating states will complete surveys at 180 grid cells throughout wolverine habitat in the 4-state area. Results will be used to refine and identify gaps in distribution, establish a baseline for future monitoring, collect genetic samples, and elucidate population connectivity.

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SHORT-TERM VEGETATION RESPONSE TO MOWING AND HERBICIDE TREATMENTS IN WYOMING BIG SAGEBRUSH

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Wyoming big sagebrush (*Artemisia tridentata wyomingensis*) has been historically treated through chemical application, mechanical treatments, and prescribed burning to increase the amount and quality of herbaceous forage available to wildlife and livestock. Treatments are often intended to rejuvenate sagebrush stands by killing older sagebrush plants to promote growth of younger sagebrush plants and increase resources for herbaceous production. We evaluated the vegetation response of mowing and herbicide treatments in Wyoming big sagebrush habitats in central Wyoming as part of a larger study to evaluate how sagebrush treatments influence habitat selection and demographic parameters of greater sage-grouse (*Centrocercus urophasianus*). Mowing and Spike® 20P treatments were applied in the winter and spring of 2014, respectively. We installed exclosures to exclude livestock from treated and paired untreated sagebrush. Shrub characteristics, grass height, herbaceous canopy cover, and ground cover were evaluated at treated and untreated sagebrush in 24 exclosures that excluded livestock grazing and at 100 treated and untreated areas where livestock grazing occurred from 2014 to 2016. Vegetation characteristics were estimated along two perpendicular 30-m transects centered at each location and followed protocols similar to those used to evaluate sage-grouse microhabitat selection. As expected, treatments resulted in a reduction in sagebrush cover and height; however, herbaceous understory response was variable and often mimicked untreated reference locations in both grazed and un-grazed locations. Our results corroborate other studies that suggest treating Wyoming big sagebrush communities does not often result in short-term increases in herbaceous understories important for greater sage-grouse breeding habitats.

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MICROHABITAT SELECTION OF BROOD-REARING SITES BY GREATER SAGE-GROUSE IN CARBON COUNTY, WYOMING

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Declines in Greater Sage-Grouse (*Centrocercus urophasianus*, hereafter sage-grouse) populations could be attributed to low chick survival, which may be influenced by the availability of food and cover at sites used by females rearing broods. We monitored brood-rearing female sage-grouse equipped with solar Argos Global Positioning System Platform Transmitter Terminals from 2011 to 2013 to assess microhabitat selection by broods in Carbon County, Wyoming. We measured vegetation and arthropod characteristics at diurnal sites used by broods (n = 42 in 2011, n = 31 in 2012, n = 32 in 2013) and at 3 paired-random sites associated with each used site (n = 315), located 50 m, 250 m, and 500 m from the used site. We fit conditional logistic models within an information-theoretic framework to identify vegetation and arthropod characteristics associated with microsite

selection of brood-rearing sites. Sage-grouse selected brood-rearing sites with greater visual obstruction (0–45.7 cm in height), higher numbers of arthropods in the order Diptera, and lower numbers of arthropods in the order Coleoptera. There was an interaction effect between the number of arthropods in the order Hymenoptera and the canopy cover of broad-leaf forbs; the relative probability of selection increased with increasing number of Hymenoptera when there was low cover (<20%) of broad-leaf forbs, but decreased with increasing number of Hymenoptera when there was high broad-leaf forb cover (>20%). We also found a quadratic relationship between selection of brood-rearing sites and total vegetation canopy cover; the relative probability of selection increased until approximately 75% cover and then decreased with increasing cover. Sage-grouse rearing broods selected a diverse array of vegetation types, but greatest use occurred within mesic communities. Our results could be used to identify vegetation communities with high relative probabilities of use by sage-grouse rearing broods, which will help guide management decisions.

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COMPARISON OF SONGBIRD POPULATION TRENDS TO SAGE-GROUSE LEK TRENDS: ASSESSING SAGE-GROUSE CORE AREAS AND UMBRELLA SPECIES CONCEPT

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Conservation strategies including the umbrella species concept promote the potential of multiple species benefitting from protection of large areas necessary for one species continued viability, such as Wyoming's Sage-grouse Core Area Policy. Greater sage-grouse (*Centrocercus urophasianus*; hereafter: sage-grouse) have been identified as an umbrella species for many other sagebrush-obligates including songbirds. Sagebrush-obligate songbirds and sage-grouse have undergone population declines throughout the western United States attributed to similar habitat issues. To assess the umbrella species concept and conservation benefit of the Core Area Policy, we compared trends of sagebrush-obligate songbirds from the Breeding Bird Survey and sage-grouse leks, 1996–2013, to evaluate if their trends were similar. We compared trends within and outside of Core Areas in the Powder River Basin and Wyoming Basins, Wyoming. Trends of sagebrush-obligate songbirds were generally not similar to sage-grouse (within or outside of Core Areas). In Wyoming, sage-grouse trends declined more outside of Core Areas. Even though differential trends of sage-grouse within and outside of Core Areas were likely a relic of historically higher habitat quality within Core Areas, our results indicated Core Areas were successful at maintaining higher sage-grouse trends compared to areas not protected under the Core Area Policy. While Core Areas were well placed for sage-grouse, sagebrush-obligate songbird trends did not follow the same pattern. This suggests that protection of only the best remaining sage-grouse habitat may not be a suitable conservation strategy for other sagebrush-obligate birds, and undermines the utility of the umbrella species concept as an effective universal approach to conservation.

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BEYOND BREEDING HABITAT: COMPREHENSIVE HABITAT REQUIREMENTS OF A PARTIAL MIGRANT

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Effective conservation and management of landscapes for target species is dependent on identifying and locating habitat requirements. This is frequently attempted by predicting the relative probability of selection of resource units (raster pixels) with a resource selection function based on habitat characteristics. Traditionally, conservation strategies have focused on breeding habitat as priority areas because of its importance for reproductive activities. However, effectively conserving habitat for one season may not capture the habitat needs for a species on an annual basis. This is particularly true for species that occupy large landscapes and exhibit partial-migratory behavior, such as greater sage-grouse (*Centrocercus urophasianus*). Sage-grouse have distinct breeding, summer, and winter seasonal habitat requirements and often exhibit interseasonal transitions between seasonal ranges. Our objective was to evaluate how well conserving breeding habitat would conserve the annual habitat requirements for sage-grouse in landscapes where seasonal habitats were more (Central Wyoming) and less (Bighorn Basin) spatially intermixed. Analyses were dependent on study area-specific observations from 52 GPS-equipped female grouse in Central Wyoming and 81 GPS-equipped female grouse in the Bighorn Basin from 2011–2015. First, we developed resource selection functions using generalized estimating equations and predicted relative probability of selection for each study area for the 3 seasons and 3 transitional periods. Second, we calculated correlations between different seasonal habitat predictions to suggest how well habitat conservation for one season would affect conservation of other seasons. Third, we incorporated a biologically meaningful method to calculate a comprehensive conservation priority metric that accounted for seasonal habitat selection, timing of presence on seasonal ranges, contribution of seasons to vital demographic rates, population size, and amounts of available habitat. We will present results on how effectively different conservation strategies would capture the comprehensive annual requirements of a partial migrant in 2 contrasting landscapes.

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GEOPHAGY AND MOVEMENTS OF GREATER SAGE-GROUSE IN THE UPPER GREEN RIVER DRAINAGE

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Greater Sage-grouse (*Centrocercus urophasianus*) select winter range on a variety of factors including many habitat characteristics. One potential habitat factor that has not been adequately investigated for sage-grouse is the influence of geophagy locations on winter habitat selection. Geophagy, or the act of purposefully ingesting soil, is a newly observed regular behavior seen in the wintering populations of Greater Sage-grouse in the Upper Green River Drainage. We coupled several projects to better document geophagy of sage-grouse in the region. We gathered >50,000 GPS locations from 52 Greater Sage-grouse from 2014-2016 to document seasonal movement to winter ranges and to identify potential geophagy locations. As the first step in a multi-faceted study, we collected soil samples at 24 confirmed geophagy sites, 24 paired samples within 100m of the sites, and 30 random locations to investigate soil and mineral composition. We also documented seasonal migrations to these areas and movements to geophagy locations. We will describe geophagy site characteristics, seasonal movements, and how geophagy may affect winter range selection of Greater Sage-grouse in western Wyoming.

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USING RESILIENCE AND RESISTANCE CONCEPTS TO DEVELOP A STRATEGIC APPROACH FOR MANAGING THREATS TO SAGEBRUSH ECOSYSTEMS, GUNNISON SAGE-GROUSE, AND GREATER SAGE-GROUSE IN THEIR EASTERN RANGE

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Persistent ecosystem and anthropogenic disturbances and stressors are threatening sustainability of sagebrush ecosystems in the western US, and managers and policy makers are seeking strategic, holistic approaches for species conservation and ecosystem restoration. Recent research indicates that an understanding of ecosystem resilience to disturbance and resistance to nonnative invasive species can be used to prioritize management activities across large landscapes and determine the most appropriate actions at project scales. An interagency WAFWA working group has linked this understanding with breeding habitat probabilities for greater and Gunnison sage-grouse, and developed a habitat decision matrix for assisting land managers in best allocating resources. This approach was incorporated into the Subregional Greater Sage-grouse EISs and served as the basis of a BLM Fire and Invasives Assessment Tool which was used to prioritize sage-grouse habitat for targeted management activities in the Great Basin. Recently a similar approach has been developed for the eastern range of greater sage-grouse and Gunnison sage-grouse – the Sagebrush Management Resilience and Resistance Tool. A 2015 Implementation Plan for DOI Secretarial Order 3336 – Rangeland Fire Prevention, Management and Restoration - provides necessary guidance to ensure application of this approach.

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APPLICATION OF STABLE ISOTOPES TO RECONSTRUCT GREATER SAGE-GROUSE CHICK DIETARY HISTORY: DIET SELECTION AND RELATIVE BODY CONDITION

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Survival of chick greater sage-grouse (*Centrocercus urophasianus*) has compelling implications for persistence of sage-grouse populations. Nutritional demand during this life stage is high and availability of insects and forbs consumed by chicks is correlated with growth, body condition, and subsequent survival. Because chicks in the best body condition are likely to have higher survival, the abundance of forbs and insects in diets producing chicks in the best condition provides important insights about the effects of diet on chick survival. We evaluated multiple objectives about chick sage-grouse diet selection from spring 2013 to 2015 and body condition in south-central and north-central Wyoming. To determine diet availability we collected insect and forb samples at brood-rearing and random locations. To quantify chick diets we compared the ratio of naturally occurring isotopes ($\delta^{15}N$, $\delta^{13}C$) in feathers from captured chicks (n = 153) to establish the relative contribution of forbs and insects in diets from hatch to week 5 post-hatch. To obtain body condition measurements we weighed chicks and measured their wing chord length to correlate with isotopic ratios. The relationship between chick diet selection and isotopic composition of feathers allowed us to 1) investigate diet selection relative to diet availability at brood locations, 2) understand brood site selection in relation to diet availability, and 3) assess the relationship between diet composition and chick body condition. A measure of body condition in relation to chick diets provided a means to assess the relative value of foods across an array of sagebrush habitats for sage-grouse as well as better understanding how management practices intended to improve sage-grouse habitats influence diet availability.

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NON-TARGET EFFECTS OF SAGE-GROUSE HABITAT TREATMENTS ON SAGEBRUSH-ASSOCIATED SONGBIRDS

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Greater Sage-Grouse are considered an umbrella species, meaning that management actions taken for sage-grouse are expected to benefit other species. The removal of sagebrush (through mowing, herbicide application, etc.) is commonly prescribed to improve sage-grouse habitat by encouraging the growth of herbaceous, understory plants. Sagebrush-associated songbirds rely on sagebrush shrubs for nesting, foraging, and singing perches; therefore, sagebrush-associated songbirds may be particularly susceptible to management prescriptions that remove large numbers of shrubs. We conducted a before-after-control-impact study to assess the effects of sage-grouse habitat treatments on songbirds breeding in sagebrush habitats near Sweetwater Station, WY. Our study spanned 2013-15 and included a comprehensive set of surveys to estimate the abundance, nest-site selection, nestling condition, nest survival, and fledgling habitat selection for songbirds in areas that experienced

either a mowing or herbicide treatment, or were untreated reference areas. Treatment effects varied by the species and metric examined. For example, Brewer's Sparrows (a shrub-nesting sagebrush-obligate species) were more abundant post-treatment (relative to pre-treatment) in areas that experienced some mowing; however, they were displaced from nesting directly within the mowing footprint. Brewer's Sparrow fledglings avoided mowed areas in favor of adjacent, untreated areas. Vesper Sparrows (a ground-nesting generalist species) nested closer to mowed areas post-treatment, and Vesper Sparrow nestlings reared in areas that experienced some mowing had better body condition relative to reference nestlings. In sum, the non-target effects of habitat treatments for sage-grouse were complex and varied by species and life stage examined. Our results will aid managers in weighing the potential costs to non-target species incurred by habitat treatments for sage-grouse.

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EVALUATING EFFICACY OF FENCE MARKERS IN REDUCING GREATER SAGE-GROUSE COLLISIONS

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Greater sage-grouse populations have declined substantially over the last several decades. Concurrently, the density of fences and other anthropogenic structures has increased dramatically in sagebrush habitats, with potential negative impacts on sage-grouse. Markers have been applied to fences to reduce sage-grouse collisions with fencing, yet there is little empirical evidence on their efficacy as well as how fencing characteristics and surrounding landscape characteristics influence the probability of collisions. We developed a multi-scale occupancy model to estimate the probabilities of sage-grouse fence collisions and evaluate factors influencing those probabilities in Wyoming, 2014-2015. We found strong evidence for lower collision probabilities at fences with wood posts, taller surrounding vegetation, and those farther from leks. We also found substantial evidence for the ability of markers to reduce collision probabilities. Our study provides further evidence for the efficacy of fence markers at reducing collisions, identifies landscape- and local-level factors which influence collision rates, and provides land owners and managers with recommendations for efficiently deploying markers to reduce collisions.

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NATIVE FRESHWATER MUSSEL FOLLOW UP INVESTIGATIONS: FILLING SURVEY GAPS AND EXPLORING NEWLY DISCOVERED POPULATIONS

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Freshwater mussels are declining worldwide due to impacts from invasive species, polluting aquatic ecosystems, reorganizing fish faunas, overharvesting, damming streams and channelizing waterways. Seven mussel species are known to inhabit rivers and lakes of Wyoming, although little is known about these populations. Currently, none

of the freshwater mussels in Wyoming are threatened, but six species are endangered in surrounding states. Thus, understanding the status of Wyoming species and monitoring their populations is critical to avoid similar declines and their consequent management crises in the near future. Our objectives are: 1) fill major gaps among statewide native mussel surveys, 2) investigate newly discovered populations of mussels, and 3) update previously reported population assessments. We employed a variety of techniques for mussel surveys (snorkeling, view buckets, polarized sunglasses) and would often use a combination of these methods to optimize detection. We recorded the total time sampled and the number of surveyors to calculate the overall person-hours and catch per unit effort (CPUE, number of live mussels per person-hour). We measured the total length (TL, mm) of all live mussels to give a relative population age structure then returned the mussels to their approximate location. If we measured a large range of sizes, especially the presence of small individuals, we confirmed that recruitment was occurring as TL is relative to age. In addition, we measured environmental variables (i.e. seston, water temperature, dissolved oxygen, pH) at each site to help interpret the mussel observations. We discovered Western Pearlshell mussels (*Margaritifera falcata*) on new sections of the Bear River, Green River and Fisherman Creek, a tributary of the Hoback River. We also found Cylindrical Papershell mussels (*Anodontoides ferrusacianus*) in Lodgepole Creek and Muddy Creek, tributaries of the South Platte River. Recruitment was verified in the mussel populations located in Muddy Creek and Fisherman Creek.

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FIRE, GRAZING AND TOADS: VEGETATION MANAGEMENT AND WYOMING TOAD (*ANAXYRUS BAXTERI*) RECOVERY EFFORTS

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The Wyoming Toad is a narrow-range endemic to the Laramie Plain that after rapid enigmatic decline became functionally extinct in the wild. Habitat alteration and disease are two potential explanations for Wyoming toad extirpation. Shallow, warm waters and riparian areas with vegetative openings may facilitate growth and limit disease. Historically, the Laramie Plain had ungulate grazing and fire as primary disturbances which could maintain these habitats. However, the primary reintroduction site (Mortenson Lake National Wildlife Refuge) is prone to thick bulrush. Vegetation manipulation experiments (2013, 2014) suggest that mid-height vegetation produces the largest sized juvenile toads, conditions more likely with grazing and/or fire. To test the effects of vegetation treatments on Wyoming toads, we raised recently metamorphosed Wyoming toads in vegetation treated with either prescribed fire or cattle grazing (2015, 2016). We found that toads raised in areas treated with fire had greater length and mass than toads raised in untreated vegetation. Toads in vegetation treated with cattle grazing tended to be lighter than toads in vegetation that was not grazed. Finally, we use observations of Wyoming toads from throughout the Laramie Plain to assess range reductions in the current landscape. We found that available habitat for the Wyoming toad has declined by ~40%. These results indicate that habitat restoration (potentially through fire and/or grazing) may be necessary to meet Wyoming toad recovery goals.

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BOREAL TOAD HABITAT SELECTION AND SURVIVAL IN RELATION TO GRAZING INTENSITY AND DISEASE PREVALENCE

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In recent decades, many amphibian populations have declined worldwide. Human-induced habitat disturbance and alteration have been cited as a dominate causes, which can interact with other stressors such as climate change and disease. In the majority of cases, however, mechanisms underlying declines are considered enigmatic; therefore, developing a better understanding of the individual and interactive factors threatening amphibians will be critical to prevent further population declines and species extinctions. To investigate the possible effects of multiple stressors on amphibians, we will assess how livestock grazing individually and in conjunction with disease may affect boreal toad (*Anaxyrus boreas*) movement, habitat selection, and survival in the Bridger-Teton National Forest in western Wyoming. In the summer months of 2015 and 2016, we used radio-telemetry to study the movements and habitat use of 110 adult boreal toads across sites varying in grazing intensity. Additionally, we swabbed individuals for disease and inserted passive integrated transponder (PIT) tags into 602 adult toads. We will analyze habitat selection at the micro- and macro-scales by comparing sites used by radio-tracked toads with paired and randomly selected sites. In 2017, we will continue conducting recapture surveys to evaluate toad survival rates. We will also test swab samples for *Batrachochytrium dendrobatidis* (*Bd*) to evaluate disease status of boreal toads across several drainages. Findings from this study will provide valuable information to several agencies working to improve management of toad populations in Wyoming. More broadly, by assessing how multiple stressors may interact to influence amphibian behavior, ecology, and habitat quality, our study design may provide a framework for future research evaluating causative factors in amphibian declines.

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ENHANCING DETECTION OF NATIVE WYOMING AMPHIBIANS THROUGH ENVIRONMENTAL DNA AND VISUAL SURVEYS

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Long-term monitoring of amphibian populations is an essential management need as amphibian biodiversity is declining more rapidly than other vertebrate taxa. On the Medicine Bow-Routt National Forest, three of five of the species are state Species of Concern or Greatest Conservation Need, due in part to a lack of quality data. Data for rare, cryptic, or difficult to identify species are susceptible to imperfect detection (false negatives and/or false positives). Imperfect detection can confound accurate presence/absence surveys for target species and lead to inaccurate and imprecise estimates of occupancy, predicted species distributions, and potentially misinform

management actions. We aimed to improve our ability to effectively survey and monitor amphibians by maximizing species specific detectability estimates by incorporating multiple survey methods in an occupancy modeling framework. Over two seasons we surveyed sites contained within wetland catchments (2015=20 catchments; 2016=15) across the Medicine Bow-Routt. In two surveys per visit and two visits per catchment per year, we performed 384 visual encounter (VES) and 466 environmental (eDNA). We collected eDNA samples and VES simultaneously to ensure survey cohesion. We then used quantitative real-time PCR to determine species presence based on eDNA surveys. After correcting for environmental factors influencing the probability of detecting each species in an occupancy modelling framework, we determined the optimal combination of VES and eDNA methods to maximize each species' detection probabilities. The benefit for each species will vary with its abundance and behavior and greatly enhance our ability to accurately detect amphibians and potentially other aquatic organisms.

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IS A MESOPREDATOR RELEASE UNDERLYING INCREASED SONGBIRD NEST PREDATION NEAR NATURAL GAS DEVELOPMENT?

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Understanding the mechanisms underlying avian responses to human-induced habitat change is a rare but critical endeavor for conservation and management. Energy development has become a major source of anthropogenic habitat alteration globally. In the western US, the majority of development is occurring within sagebrush dominated landscapes. Previous research in western Wyoming demonstrated decreased nest survival of the three sagebrush-obligate songbird species (Brewer's sparrow, sagebrush sparrow and sage thrasher) with increased surrounding habitat loss due to natural gas development. This decreased nest success was primarily due to predation, with three quarters of observed depredation events attributed to rodents. Here, we tested the hypothesis that rodents may experience a release from predation risk near energy development due to reduced numbers of their avian (e.g., raptors) and terrestrial predators (e.g., canids and badgers), thereby increasing local rodent abundance. We simultaneously measured songbird nest survival, rodent abundance, apex predator activity and perceived predation risk across a gradient of energy development, and did not find support for the mesopredator release hypothesis. Instead we observed increased activity of apex predators and perceived predation risk around energy development, suggesting that apex predators may actually be drawn to development sites to take advantage of rodent food resources. The rejection of this hypothesis is a key step towards understanding the drivers of nest survival in this system and how human-induced habitat change can influence species of concern.

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GOLDEN EAGLE REPRODUCTION IN RELATION TO ENERGY DEVELOPMENT AND LANDSCAPE COMPOSITION IN THE BIGHORN BASIN

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Increased energy development, off-road recreation, invasive species, exurban sprawl, climate change, and other factors are dramatically transforming landscapes in the western U.S. The golden eagle (*Aquila chrysaetos*) is a revered cultural icon, an apex predator, and a federally protected species occupying a variety of open and semi-open habitats in the western U. S., ranging from warm deserts to alpine tundra. While some reports suggest golden eagles may be declining in at least some regions of North America, other reports indicate general stability of the golden eagle population in the western U.S. Golden eagles nest through much of northwestern Wyoming and the Greater Yellowstone Ecosystem (GYE), but information on reproductive rates and population dynamics in this region is scant. In 2009 we began developing an inventory of nesting territories and documenting reproductive rates of golden eagles nesting in the northwestern corner of the Bighorn Basin, a multiple use, mixed shrub-steppe environment along the eastern margin of the GYE. Annual nesting success and reproductive rates have fluctuated dramatically during the study period, related closely to fluctuating cottontail (*Sylvilagus* spp.) abundance. Through the use of multivariate discriminant function analysis, we have been able to demonstrate that reproduction is significantly related to a complex suite of landscape features and human activity. We found that nesting territories producing a high number of total fledglings during the study period are located greater distances from energy well pads and include fewer well-used, unpaved roads and motorized trails than nesting territories producing a low number of total fledglings. This effect is less pronounced during years of high cottontail abundance. Our results suggest opportunities for mitigating potential negative effects of energy development and moderate human motorized activity on reproduction.

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EVALUATING THE INFLUENCE OF DEVELOPMENT ON MULE DEER MIGRATION AND PHENOLOGY TRACKING

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Increasingly we are understanding that migration corridors are key habitats for migratory mule deer (*Odocoileus hemionus*), where they spend time foraging to regain energy stores along the route. As migration routes become constrained by development and human disturbance, a common response is for migrating animals to increase rate of movement, reduce stopover use, and occasionally detour around established routes. Thus, alterations to the behavior of animals during migration has the potential to modify their ability to track changing plant phenology across the landscape, also known as "surfing the green wave". We used GPS movement data to evaluate the influence of development on the ability of mule deer to track phenology in southwestern Wyoming.

We analyzed data collected from three study areas characterized by different development types: energy (*n* = 163 deer), residential (*n* = 121), and dispersed rural (*n* = 108). We sought to test whether development influenced green wave surfing. To evaluate the ability of deer to track phenology, we calculated several metrics, including Instantaneous Rate of Greenup (IRG; a phenology-based measure of forage quality) and Days from Peak green up (DFP) for each animal, for each year of available data. In general, across study areas and years, deer showed a strong tendency to surf the green wave, as evidenced by a correlation between the date a location was occupied by a deer and the date of peak IRG. We used regression analysis to evaluate whether intense development along a route reduced the ability of deer to optimally surf. This work helps to understand how development influences not just the behavior of animals, but also the functionality of the route and the foraging benefits migratory animals derive from surfing.

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EFFECTS OF ROADS ON DEER MIGRATION AND MOVEMENT CORRIDORS IN WYOMING

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Wyoming is home to some of the longest distance and most intact ungulate migration routes in North America. Along these migration routes, however, animals face numerous challenges as they come into contact with human development. Roads present one of the most significant barriers to ungulate movements. Roads cause both stress and mortalities for ungulates and in some cases pose a complete barrier —truncating migration corridors and access to seasonal ranges. As human development and traffic volumes increase, it is important to understand and mitigate the effects of roads on ungulate movements. We used carcass and collision records to identify the areas in Wyoming where deer are most likely to get hit by vehicles. We then analyzed the ecological and road characteristics associated with high deer-vehicle collision (DVC) rates. Collisions were strongly associated with high traffic volumes and speed limits, deer migration and winter-use habitat, irrigated agriculture, and wetlands. In many cases, multiple risk factors intersect to create distinct "hotspots" of DVCs. We then examined the spatial and temporal patterns of DVCs in relation to known deer migration routes and winter-use areas, defined using Brownian bridge movement modeling on 310 GPS-collared mule deer from seven distinct herds. This allowed us to identify where, and during which seasons, deer migration routes and movements are most impacted by roads. Using these results, we are able to suggest condition-specific measures to reduce DVC and improve deer habitat connectivity for each area where deer movements are threatened by roads. These results also illustrate how low-cost carcass data can be used to prioritize landscape connectivity and DVC mitigation efforts. Our approach enables transportation and wildlife managers to prioritize mitigations to maximize their cost-effectiveness, and ultimately to improve habitat connectivity for wildlife, as well as human safety, in this region.

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MORTALITY RISK FOR PRONGHORN IN THE RED DESERT IN THE FACE OF ENVIRONMENTAL AND ANTHROPOGENIC CHANGE

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Pronghorn (*Antilocapra americana*) are an iconic species, occupying the open, flat grasslands and sagebrush habitats of western North America. In Wyoming, this species is deeply engrained in the state's culture, and it is a common sentiment that there are more pronghorn in the state than people, however, people outnumber pronghorn in the state by approximately 180,000. Wyoming pronghorn populations have declined statewide by nearly 30% in less than a decade. Over the same time, similar declines have been reported in the Red Desert of south-central Wyoming, where drops in herd size range from 15−35%. During this decline, the Red Desert region has experienced changes in environmental conditions, with droughts becoming increasingly frequent and severe. In addition, portions of the area have been developed for natural gas and coalbed methane extraction. To better understand the effects of such environmental and anthropogenic change on pronghorn, we monitored 124 adult female pronghorn across four study areas, each with differing levels of resource extraction intensity, between November 2013 and February 2016. Over the course of our study, we observed 31 deaths, with a Kaplan-Meier survival estimate of 63.3% (95% CI: 55.1−71.5). We also used the Cox proportional hazards model to identify covariates contributing to the weekly risk of death for pronghorn. Covariates were related to environmental conditions such as precipitation levels, anthropogenic conditions such as oil and gas well density, and intrinsic factors like body condition. Our results enhance knowledge of pronghorn demographic responses to increasing climatic variability and anthropogenic disturbance. Given that greater than 50% of all pronghorn occur in Wyoming, it is crucial that we improve our ability to untangle and understand the influence of environmental change and resource extraction on pronghorn populations in the state to guide management and mitigation.

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