ADMB REPORT FOR GRANT EXPENDITURES

Wyoming Game and Fish Dept, ADMB-WS Large Carnivore-Livestock Depredation

As in past years, the Department received ADMB funding in FY16 and FY18 to fund Wildlife Services to alleviate black bear, grizzly bear, gray wolf and mountain lion depredation to livestock, bees and beehives throughout Wyoming. During FY16, R00419, the Department expended $22,956.10 of the allocated $25,000 and in FY18, R00615 expended $15,000 of the allocated $15,000.

HAUB SCHOOL OF ENVIRONMENT AND NATURAL RESOURCES

Deer-Elk Ecology Research Project

Coyote Update

June 2018

UW UNIVERSITY OF WYOMING

Purpose

In November 2015, the Deer-Elk Ecology Research Project commenced, with the overall goal to address questions regarding the opposite trajectories of two sympatric ungulates—mule deer and elk, in a high desert system—the Greater Little Mountain Area. Broadly, this project is investigating the nutritional relationships between mule deer and elk population dynamics, competitive interactions between mule deer and elk, habitat conditions, and climate to provide a mechanistic approach to monitoring and management of mule deer. A primary objective of the DEER Project is to evaluate nutritional underpinning of mule deer population dynamics in this system, thus neonate survival and recruitment was a primary focus of summer field work in 2016. From a single summer's worth of data, patterns have begun to arise. Most notably, relatively high levels of predation on neonates compared to other areas around the state. We collared a total of 55 fawns in 2016, and by the end of November 2016, we had a total of 40 fawns amounting to a 72 percent loss in five months. The largest proximal cause of mortality was predation (60 percent linked directly to predation), and coyotes accounted for at least 50 percent of the known predator mortalities. While preliminary, these data suggest that coyotes may play a role in regulating mule deer population dynamics, but the mechanisms driving coyote predation events are not well known.

Project Objectives

The overarching question of this proposed research is aimed at asking how the demography and behavioral ecology of coyotes affects their ability to regulate the abundance and fitness of sympatric large ungulates with differing life-history strategies (mule deer and elk), especially focused on neonate survival and recruitment. We intend for this work to examine neonate survival by understanding how mule deer and elk, both of which differ in body size and vulnerability to predation, respond to the presence and risk of predation from coyotes, and the effects of coyote predation on mule deer and elk population dynamics. To address these questions, we wanted to know what factors influence coyote predation events, and how the risk of coyote predation influences the behavior of female mule deer and elk during parturition.

Project Update

We currently have a total of 26 coyotes collared in the study area—13 males and 13 females. We have been able to achieve a fairly good spread of individuals throughout the entire study area. Generally speaking, the coyotes we have captured have been young (1-4 years old) with the exception of a few individuals that have been upwards of 6 years old. For instance, we captured a 6-year-old female coyote in April of 2017 that was pregnant with 2 pups at the time. On average, these coyotes have weighed around 25 pounds, although we have captured 2 male coyotes that weighed just over 40 pounds!

Sex	Number Captured	Average Weight (lbs)	Average Age (Years)
Male	13	29	4
Female	13	21	2

Average age and weight of male and female coyotes captured

6 year old female captured in April that was pregnant with 2 pups

Attaching GPS collar on young coyote

Where are the coyotes living?

Although we have not conducted any formal analyses, the GPS data from coyotes is interesting to look at. On average, our coyote home range looks to be about 56 square kilometers (about 21 square miles) which is what is typically reported in other areas in the West. There is, however, pretty large variation in individual coyote home range sizes with the largest spanning over 279 square kilometers (~100 square miles), and the smallest home range at 1.84 square kilometers (~0.5 square miles). Due to differences in when each animal was captured, we had to use GPS data from different time periods to estimate these home ranges. While they are not directly comparable, these home ranges allow us to look at general movement of each animal. The disparity among all of these home ranges is unknown at this point, but is likely in part due to some coyotes being residents and others transients that are searching for open territories.

Coyote Home Ranges in GLMA

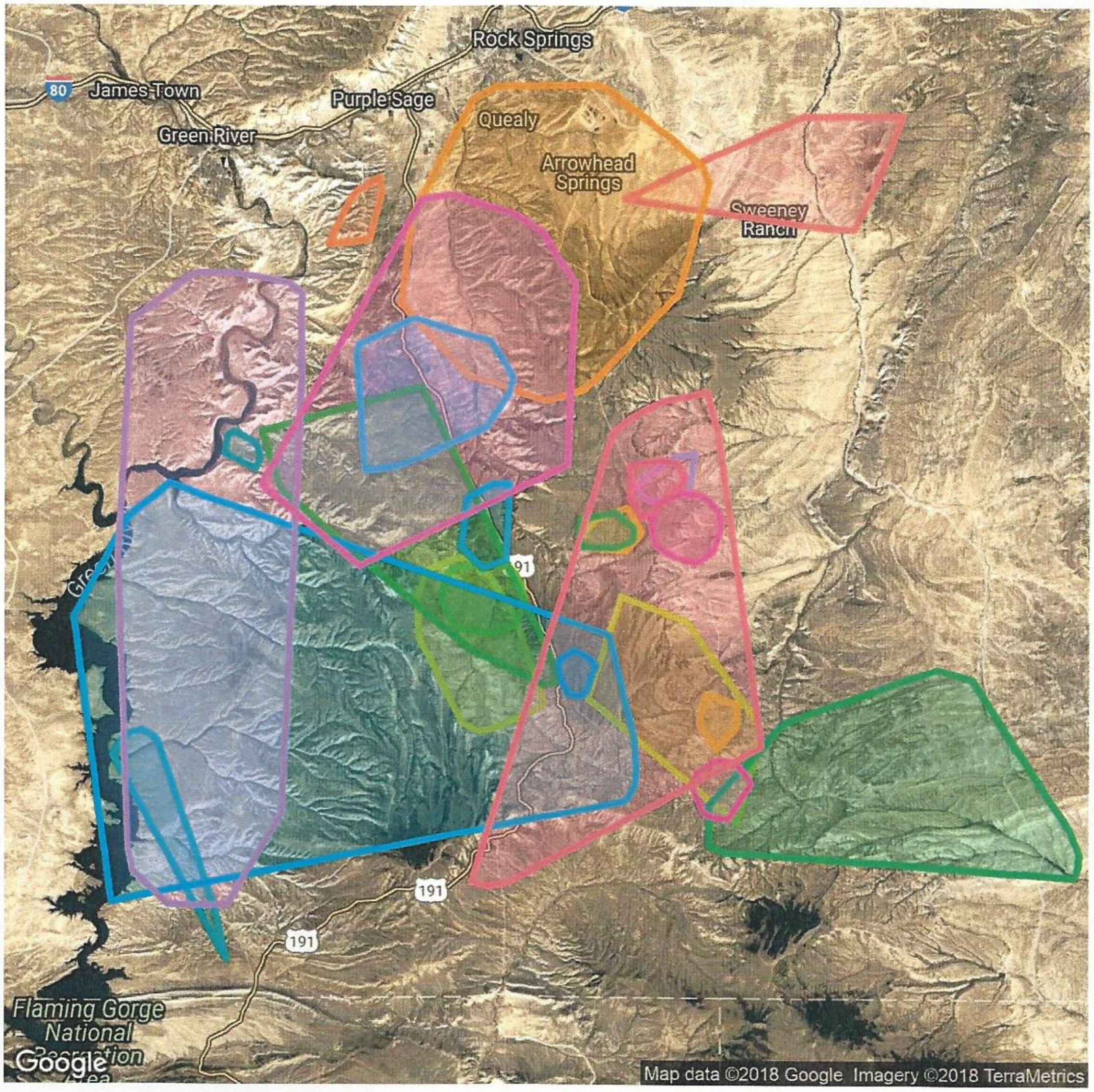


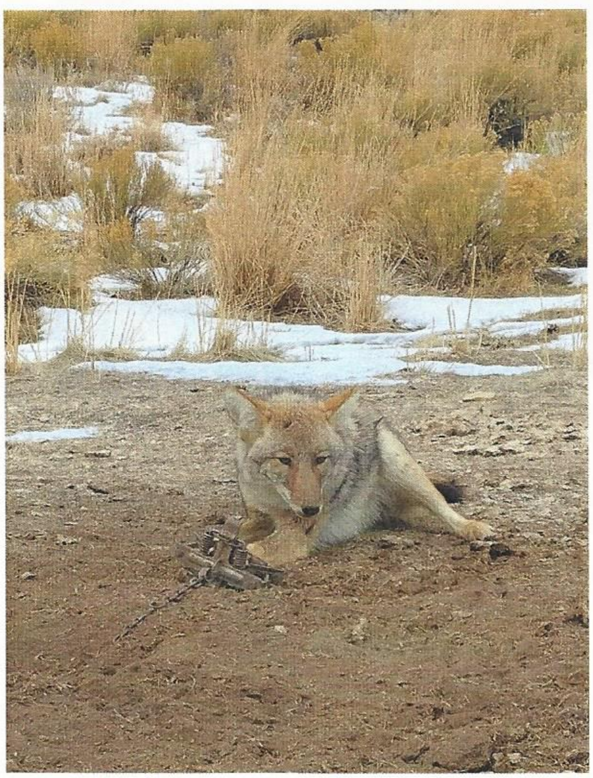
Figure 1. Home ranges for the 26 coyotes in the study area. Each color represents a unique individual

One interesting tidbit in looking at these home ranges, is that we likely have some individuals that are mated pairs. For instance, the smaller pink and purple circles (middle right) were a male and a female that were captured together. These types of information are important for us to understand when thinking about coyote predation during mule deer parturition, and social status is likely an important factor influencing levels of predation.

How are coyotes moving?

Coyotes are typically categorized as "coursing predators" meaning that they typically encounter their prey while travelling. In particular, coyotes typically travel linear features such as roads, trails, and powerlines in search of prey. Additionally, coyotes are typically known as opportunistic predators in that they prey on a variety of items, and don't necessarily specialize on any one item. They can be compared to something such as a Canada lynx for example, that feeds almost exclusively on snowshoe hare. The use of GPS collars on coyotes will allow us to understand how coyotes are moving on the landscape, and if they change their movements at all during mule deer parturition. In particular, we can look in more detail to see if coyotes are honing in on key mule deer parturition areas.

The coyotes collared for this study vary dramatically in their movements, and this is typically a function of age and social status. For example, we captured a 12 pound pup in January of 2018 that moved almost 13 miles in about three hours! She currently continues to bounce back and forth between Highway 430 and Pine Mountain. On the other hand, many coyotes do not move more than a few miles over a period of months—these are mostly pregnant female coyotes that have denned up for the season!



Pregnant female that has only moved about 2 miles in over a month

12 pound female pup that moved over 13 miles in 3 hours

Coyote Movement in GLMA

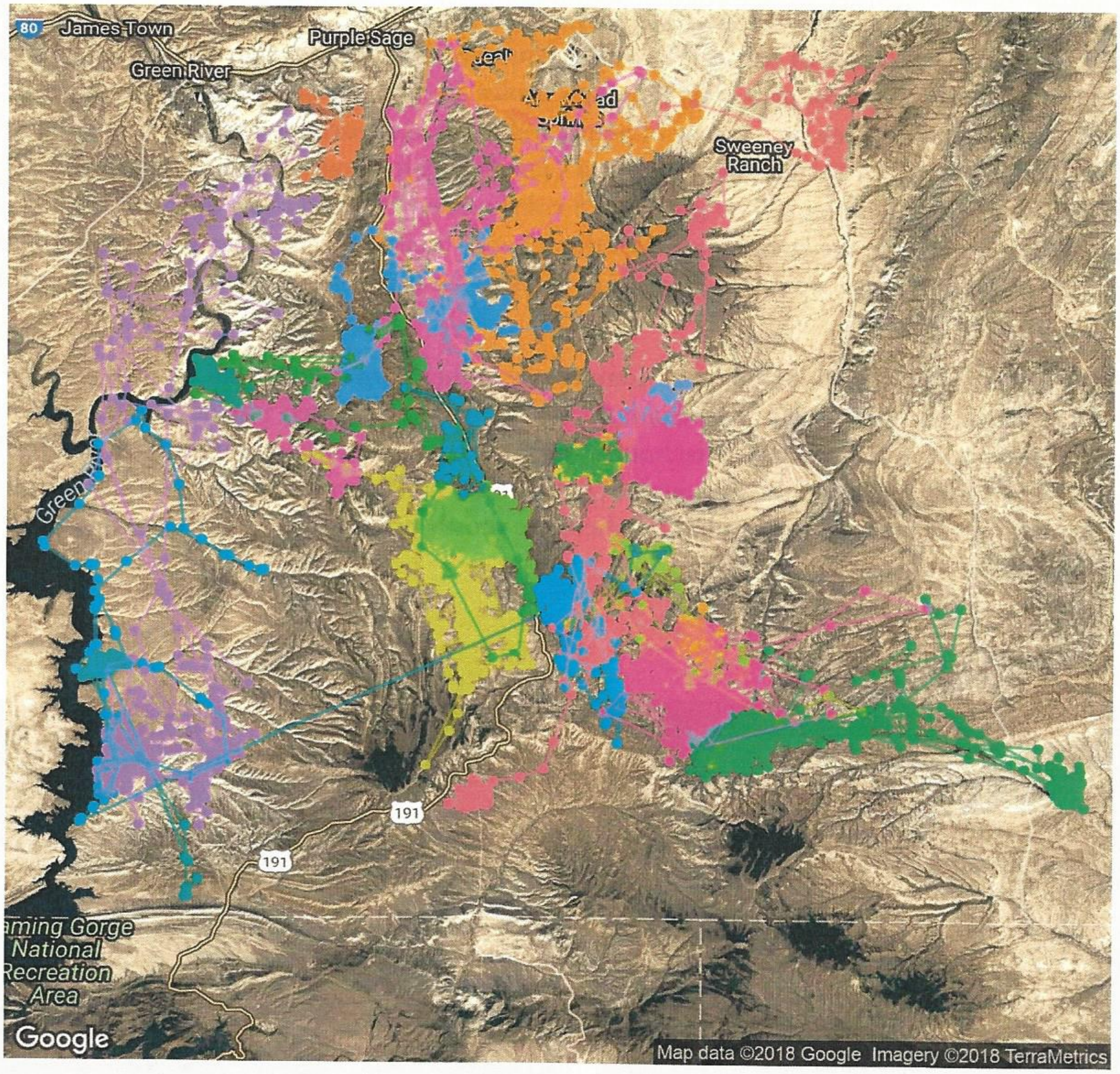


Figure 2. Movements of the 26 coyotes currently collared in the study area. Each color represents a unique individual. The green in the lower right is the 12 pound pup, and the purple in the middle is the pregnant female.

How are coyotes overlapping with female mule deer?

One of the primary objectives of this work is to understand how the risk of coyote predation to mule deer fawns influences the behavior of female mule deer. Specifically, we want to better understand if female mule deer select areas on the landscape that lower the risk of predation by coyotes, and if it actually works! We were able to achieve a sample of coyotes that overlap quite well with mule deer during parturition.

Coyote Home Ranges and Female Mule Deer Summer Locations

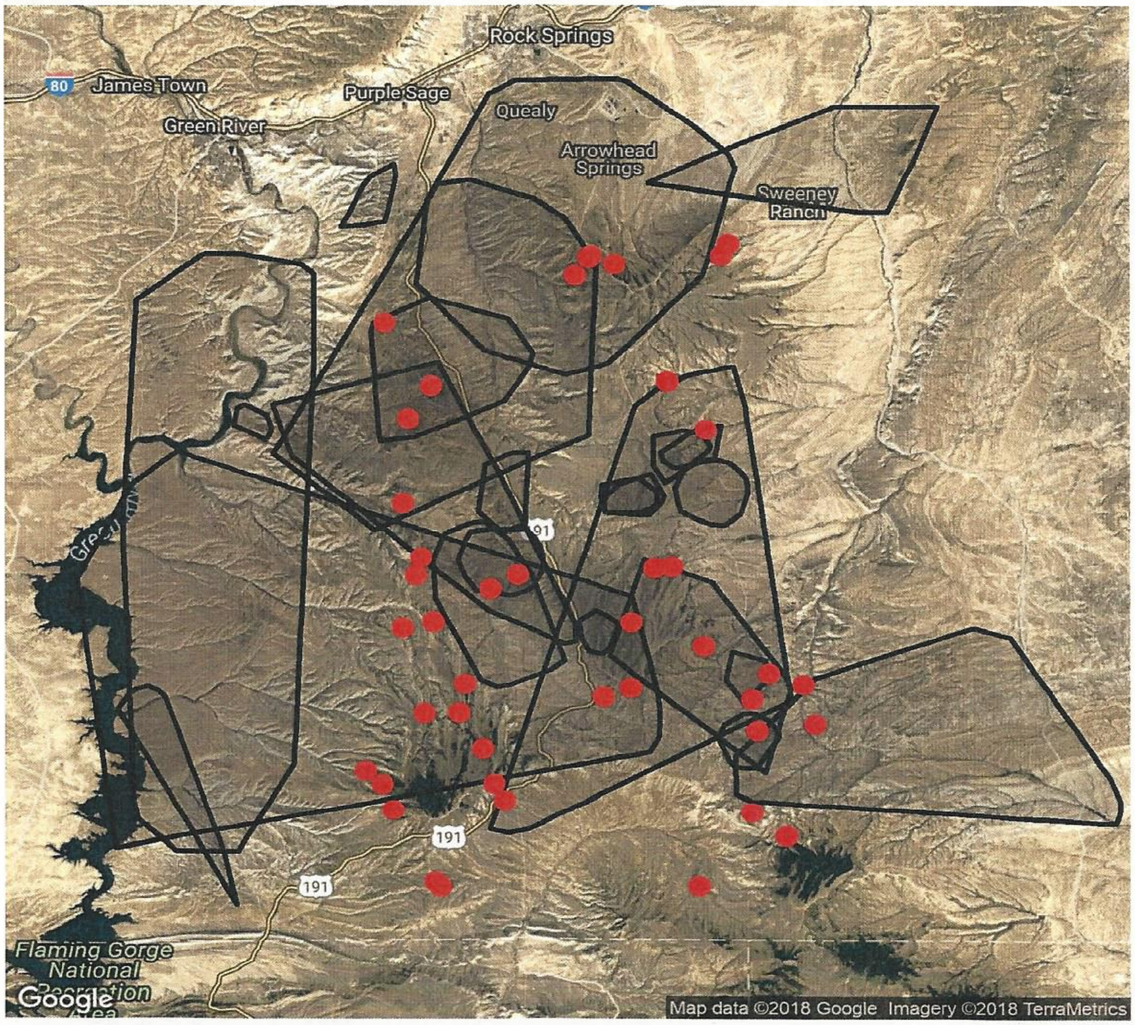


Figure 3. Home ranges of all 26 coyotes (black) with the located of female mule deer on June 15 (red).

Coyote Removal Efforts

Another important aspect of this work was to further understand the effectiveness of large scale coyote removal on bolstering mule deer fawn survival. To do so, we worked with USDA Wildlife Services to evaluate a removal-control study. Wildlife services removed coyotes from Aspen Mountain and Little Mountain around the first week of June. A total of 42 coyotes were removed in about a week long period. Regardless of this removal effort, we still saw fairly high levels of mortality within these removal areas. The level of coyote predation was slightly lower in 2017 versus 2016, however, we still witness about the same level of fawn mortality by the end of 2017.

Coyote Removal Areas and Fawn Mortality Locations

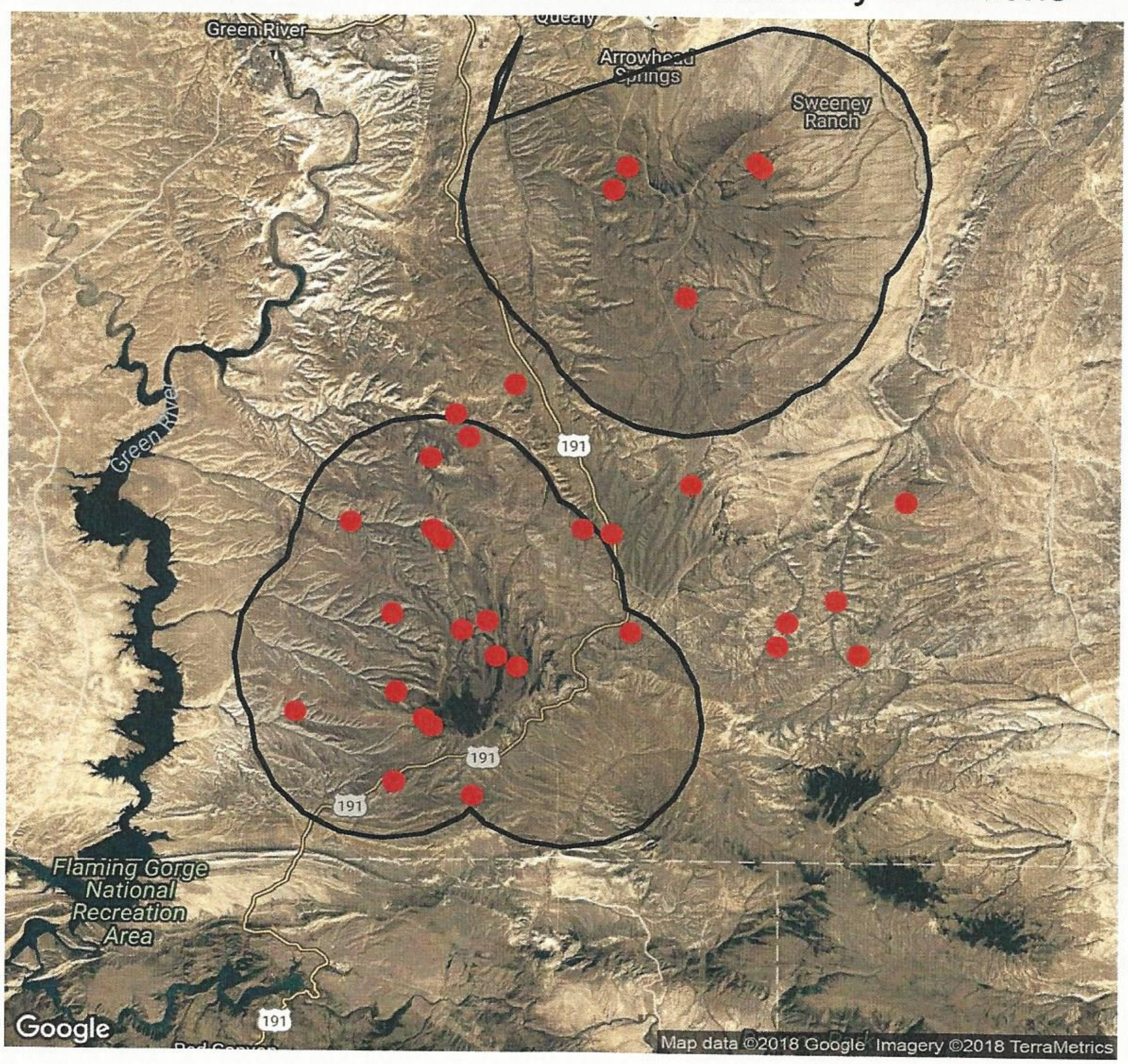


Figure 4. Coyote removal areas (black), and 2017 fawn mortality locations (red).

Future Directions

With finally a solid sample of radiocollared coyotes, along with our work on mule deer and elk in the same system, we are excited to soon begin the work to connecting all of the pieces to better understand the effects of predation risk by coyotes on female behavior and risk of predation to neonates during parturition. Stay tuned!

Thank You!

This project would not be possible without generous contributions and continued support from the Wyoming Game and Fish Department, Muley Fanatic Foundation Headquarters, the Southwest, Kemmerer, Flaming Gorge, Upper Green, and Casper Chapters of the Muley Fanatic Foundation, Wyoming Governor's Big Game License Coalition, Bureau of Land Management, Bowhunters of Wyoming, National Science Foundation, Wyoming Wildlife and Natural Resource Trust, Rocky Mountain Elk Foundation, and Animal Damage Management Board. A special thanks to those hunter-conservationists that have invested in the DEER Project through the grass-roots fundraising efforts led by the Muley Fanatic Foundation.

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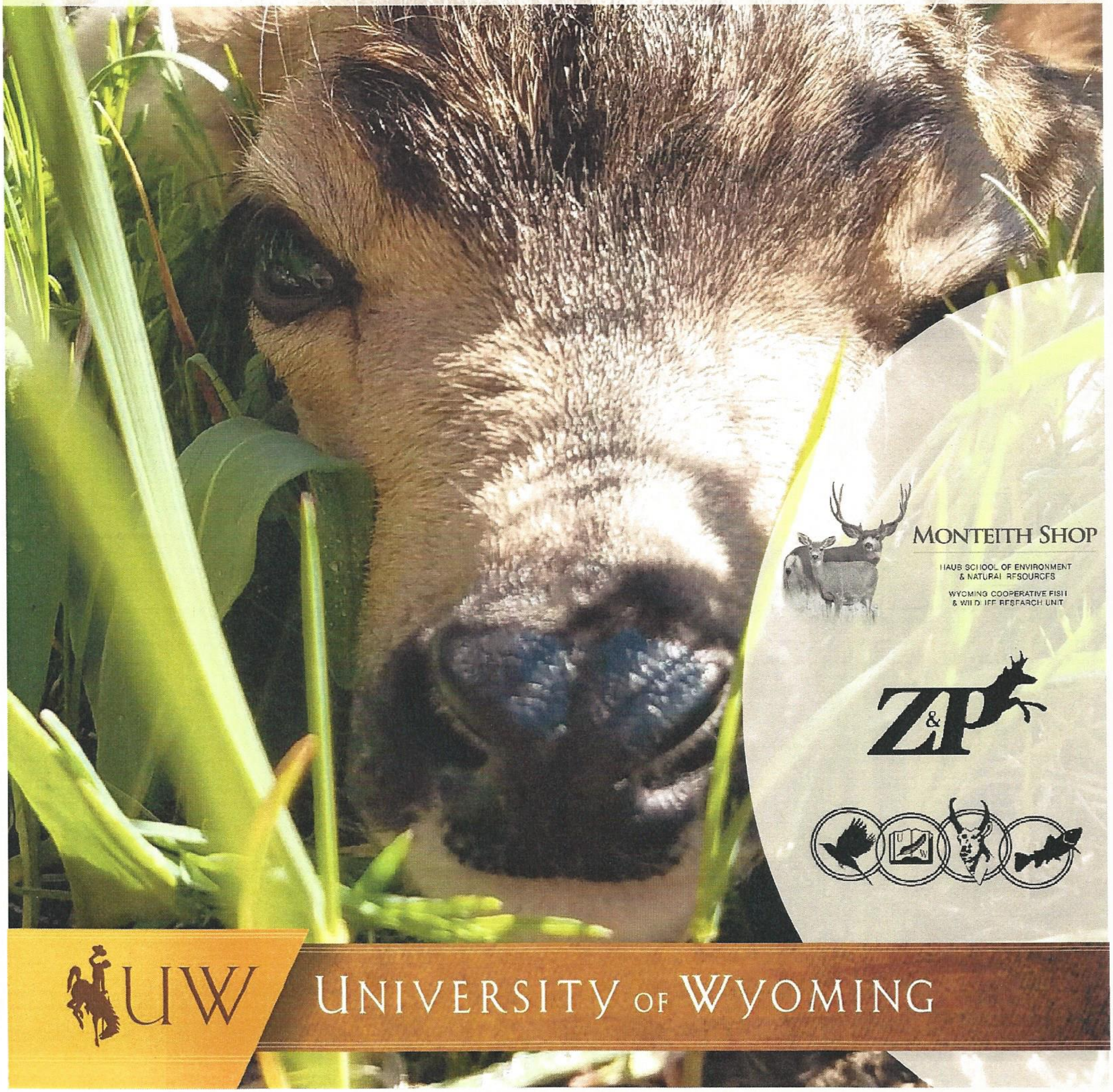
HAUB SCHOOL OF ENVIRONMENT AND NATURAL RESOURCES

Wyoming Range Mule Deer Project

Winter 2017-18 Update



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WYOMING RANGE MULE DEER PROJECT

Project Background

In recent decades, mule deer abundance throughout the West has struggled to reach historic numbers, and Wyoming is no exception to the nearly ubiquitous trend of population declines. In response to concerns of mule deer populations in Wyoming, in 2007, the Wyoming Game and Fish Commission adopted the *Wyoming Mule Deer Initiative* (MDI) with the intent to develop individual management plans for key populations. Of particular concern was the Wyoming Range mule deer population in western Wyoming—one of the largest mule deer herds in the state and a premier destination for mule deer hunting in the country. The Wyoming Range mule deer population has undergone dynamic changes in recent decades from a population high of >50,000 in the late 1980s, to a sustained population of ~30,000 during much of the last decade (Fig. 1). Consequently, the Wyoming Range mule deer population was identified as a top priority for the development of a management plan according to the MDI. The first of the population-specific management plans, the *Wyoming Range Mule Deer Initiative* (WRMDI), was finalized in 2011 following a collaborative public input process. To direct development of an effective management plan, it was recognized by the Mule Deer Working Group (2007) that the *"Success and implementation of these plans will depend upon our ability to identify limiting factors to mule deer populations and their habitats"*. Accordingly, the Wyoming Range Mule Deer Project was initiated 2013 to address the need for research in identifying the factors that regulate the Wyoming Range mule deer population.

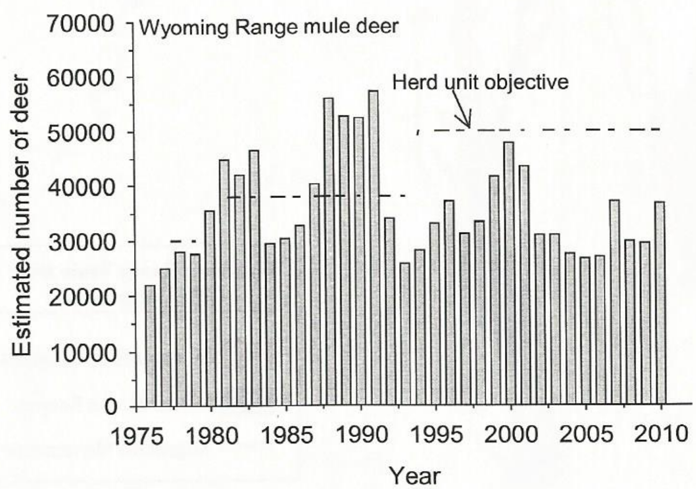


Figure 1. Estimated population size of the Wyoming Range mule deer herd relative to herd unit objective, 1976-2010.

The overarching goal of the Wyoming Range Mule Deer Project is to investigate the nutritional relationships among habitat conditions, climate, and behavior to understand how these factors interact to regulate population performance. We initiated the project in March 2013 with the capture of 70 adult, female mule deer on two discrete winter ranges for migratory, Wyoming Range mule deer (Fig. 2). In summer 2015, we initiated Phase II of the Wyoming Range Mule

Deer Project that focuses on survival and cause-specific mortality of neonate mule deer. Since the initiation of the project, we have tracked and monitored the survival, behaviors, reproduction, and habitat conditions of 202 adult female and 195 juvenile mule deer of the Wyoming Range. This update highlights some of our many discoveries on mule deer ecology since the initiation of the project.

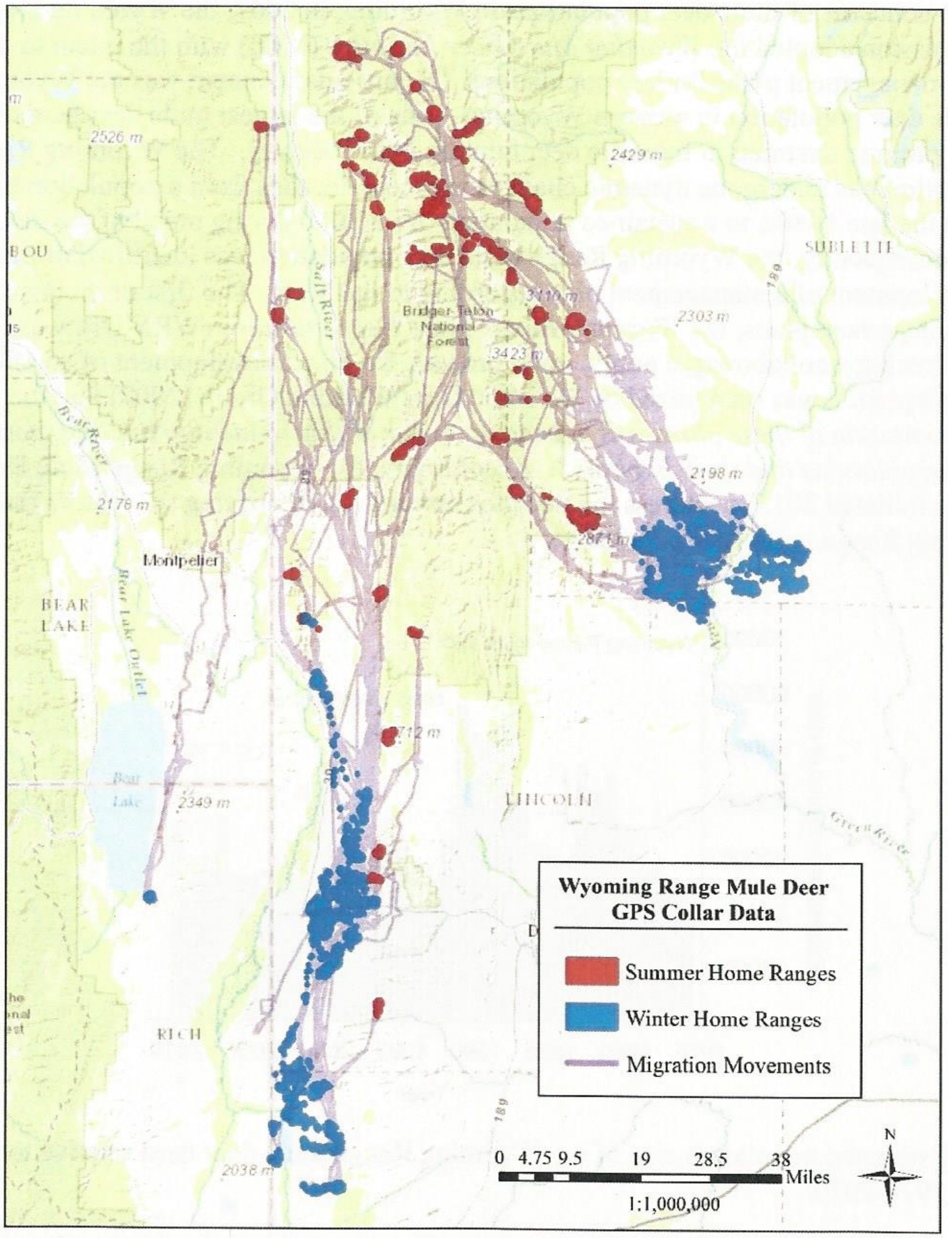


Figure 2. Winter and summer home ranges (based on 95% Kernel Utilization Distribution of GPS collar data) as well as migration movements of Wyoming Range mule deer.

A Nutritional Ecology Framework: Linking the Individual to the Population

Using a nutritional ecology framework, we aim to evaluate how conditions of all seasonal ranges mule deer encounter throughout the year—ranges used during summer, winter, and migration—affect individual animals. Using this unique approach, we can develop a comprehensive understanding of how the connections individual mule deer have with their environments influences population dynamics.

Mule Deer Capture

Since March 2013, we have captured and recaptured 202 adult, female mule deer. Upon each capture, in addition to fitting each animal with a GPS collar, we collect a suite of data on individual animals including age, nutritional condition, morphometry, and pregnancy. Animals are recaptured each spring (in March) and autumn (in December) to monitor longitudinal changes in nutritional condition and reproduction. In doing this, we can link various life-history characteristics with behaviors and habitat conditions of individual animals.

Nutritional Condition

At each capture event, we use ultrasonography to measure fat reserves (i.e., % body fat). By recapturing collared mule deer and measuring body fat each autumn and spring, we are able to track changes in nutritional condition between summer and winter seasons.

Although most animals lost fat in the winter and gained fat in the summer, the rate at which fat reserves increased or decreased varied widely among individual animals (Fig. 3). A suite of factors can influence fat dynamics between winter and summer seasons, but availability of food on seasonal ranges and number of fawns a female raises have the greatest effect on fat dynamics.

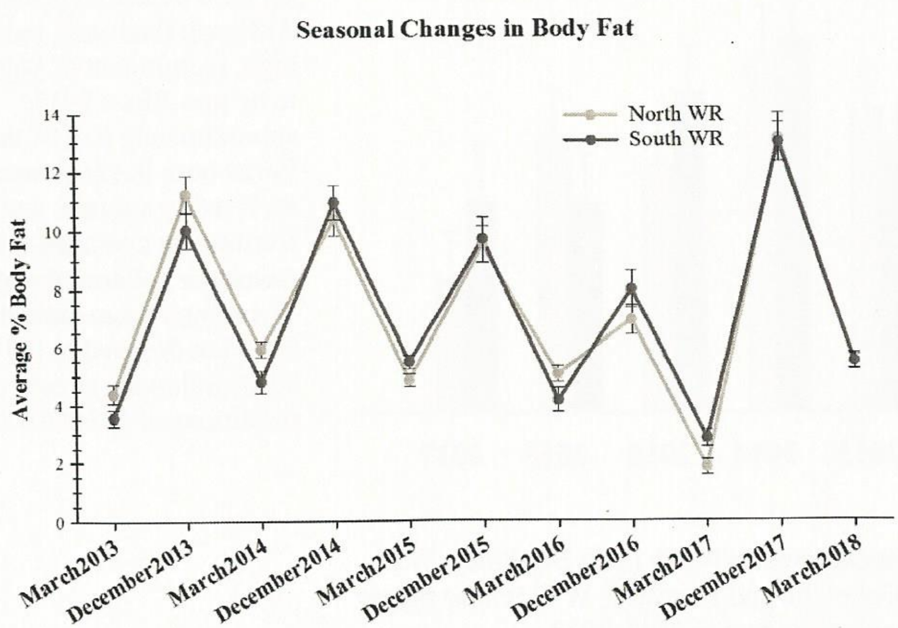


Figure 3. Average % body fat of adult, female mule deer on North (near Big Piney, WY) and South (near Cokeville and Evanston, WY) winter ranges for Wyoming Range mule deer.

Reproduction

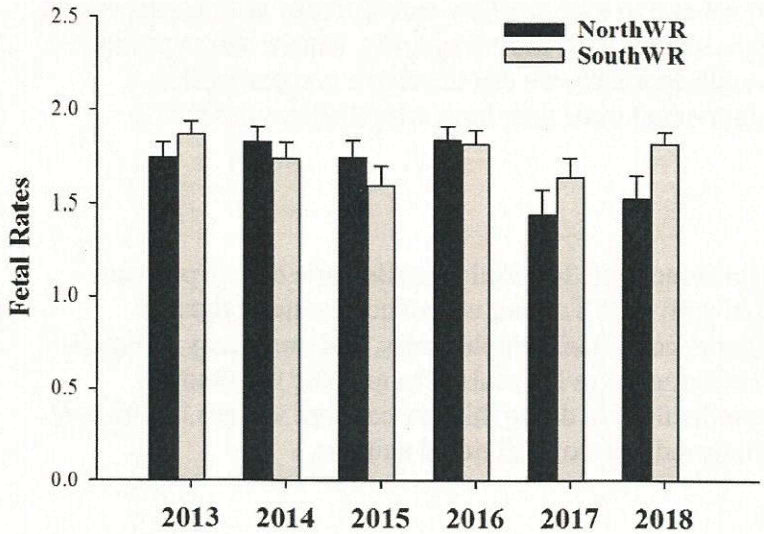


Figure 4. Fetal rates (average number of fetuses per pregnant animal) on North (near Big Piney, WY) and South (near Cokeville and Evanston, WY) winter ranges for Wyoming Range mule deer in 2013-2018.

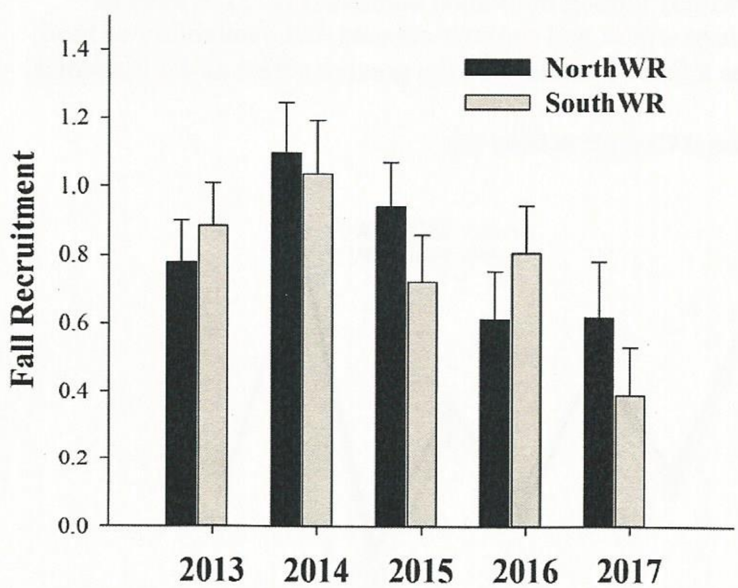


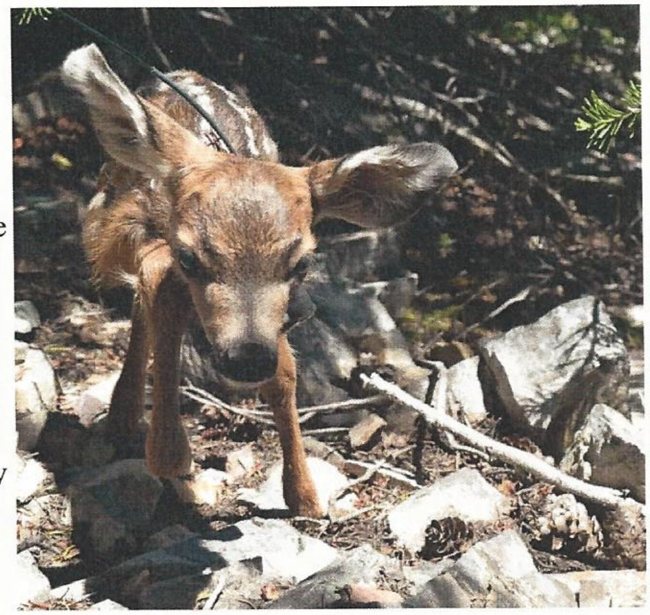
Figure 5. Recruitment rates on North (near Big Piney, WY) and South (near Cokeville and Evanston, WY) winter ranges for Wyoming Range mule deer in 2013-2017.

Reproductive success of individual animals greatly influences population dynamics; therefore, we closely monitor pregnancy and recruitment of young for each of our study animals. We use ultrasonography to monitor pregnancy rates of our study animals during spring capture events. Each autumn, as animals arrive to winter range, we evaluate fall recruitment using on-the-ground observations of the number of fawns at heel of our collared adults.

Pregnancy rates among mule deer of the Wyoming Range were typically high and ranged between 90-99%. Furthermore, most animals were pregnant with twins each year resulting in relatively high fetal rates (average number of fetuses per pregnant animal was 1.71 ± 0.03 across years; Fig. 4). Although fetal rates tended to be high, recruitment of young tended to be low. Since 2013, approximately half of the potential fawns born in early summer survived to autumn, and fall recruitment averaged 0.83 ± 0.05 fawns per collared female for Wyoming Range mule deer 2013-2016 but dropped to 0.51 ± 0.11 in 2017, following severe winter conditions of 2016/2017 (Fig. 5).

Disentangling the Relative Role of Predation, Habitat, Climate, and Disease on Fawn Survival

Fawn Capture



In March 2015, we initiated Phase II of the Wyoming Range Mule Deer Project by recapturing collared deer and deploying a vaginal implant transmitter (VIT) in pregnant females. VITs were used to indicate where and when birth occurred. Once birth events were identified, we captured and collared fawns born to our collared females as well as fawns that were found opportunistically throughout the Wyoming Range. Since 2015, we have successfully tracked 194 fawns and have been continually monitoring their survival.

	2015	2016	2017
Number of Fawns Tracked	58	70	67
Median Birthdate	June 10	June 13	June 17
Summer Mortality	45%	56%	52%
Winter Mortality	10%	44%	7%
Total Mortality	55%	100%	NA

Cause-Specific Mortality of Fawns

To evaluate cause-specific mortality of fawns, we tracked daily survival of all fawns captured 2015 – 2017. When a mortality was detected, we immediately investigated the event to ensure an accurate assessment of the cause of mortality. There was a breadth of various causes for fawn mortality including predation, disease, malnutrition, drowning, hypothermia, vehicle-collision, and just being caught in vegetation. The proportion of fawns that died because of the aforementioned causes varied from year to year (Fig. 7).

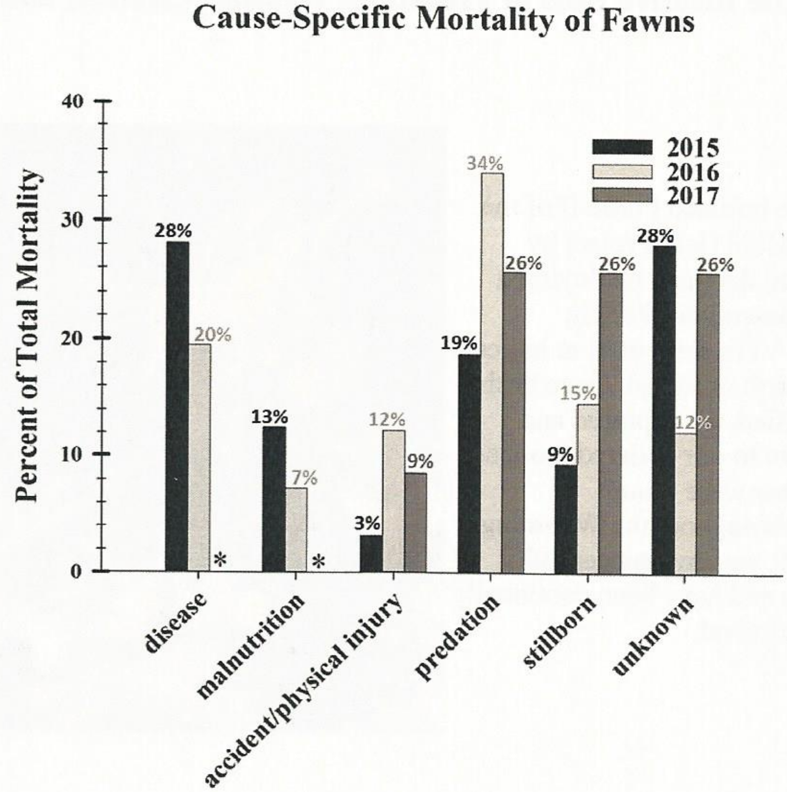
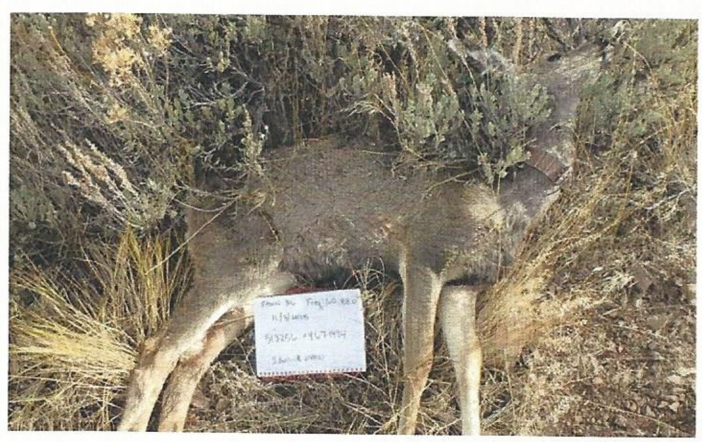


Figure 7. The relative occurrences of various causes of mortality for mule deer fawns of the Wyoming Range in 2015-2017. Asterisks indicate lab results from 2017 that are still pending.



In 2015, disease was the leading cause of death and accounted for 28% of all mortalities. The most prevalent disease adenovirus hemorrhagic disease (AHD). AHD is a viral disease that can cause internal hemorrhaging and pulmonary edema. Although AHD was detected in mule deer populations before, it was not previously known to be a major mortality factor in Wyoming. Nevertheless, the discovery of AHD in the Wyoming Range mule deer population has been motivation for further research into the epidemiology of AHD. We are still awaiting necropsy results from the Wyoming State Vet Lab from samples collected from fawn mortalities in 2017; therefore, the relative influence of various causes of mortality—specifically, disease and malnutrition—on fawn mortality is still pending. Regardless, 26% of mortalities in 2017 were because fawns were stillborn. Currently, this ties with predation as the leading cause of death for fawns in 2017.

Habitat and Maternal Conditions

The condition of a female and the habitat conditions she experiences in the summer may be very important in predicting and understanding fawn survival—especially in understanding the influence of malnutrition and disease on fawn survival. Therefore, we are coupling data on summer habitat conditions with information on maternal condition (i.e., nutritional condition) to evaluate how it influences fawn survival.

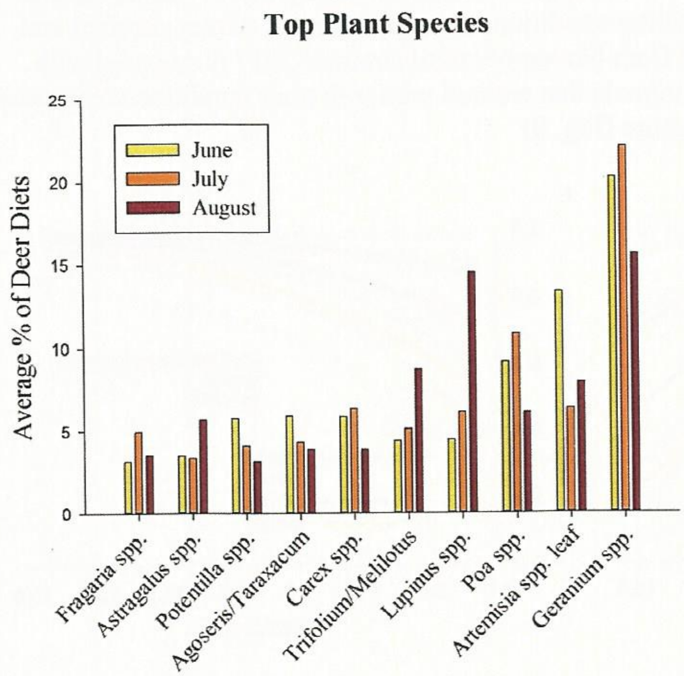
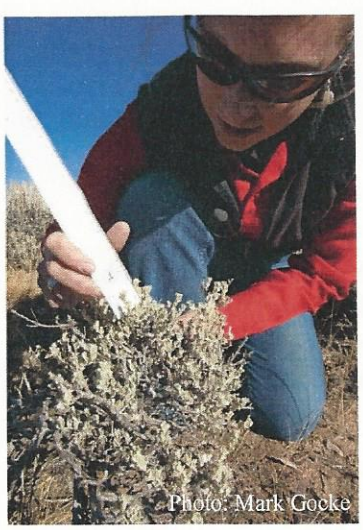
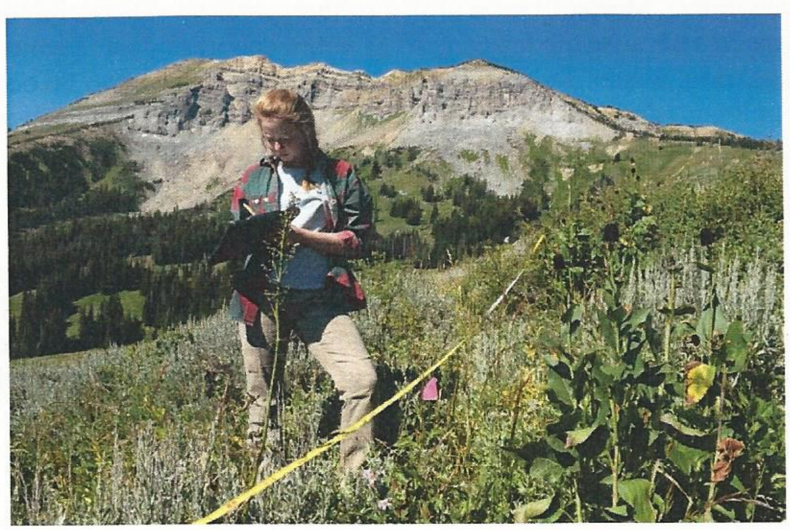


Figure 8. The top ten plant genera within diets (according to the average % of diets comprised of each plant genera) of Wyoming Range mule deer. Diet composition was evaluated in June, July, and August of 2013 and 2014.

Since 2013, we have evaluated the quality and availability of plants within the diets of Wyoming Range mule deer during summer. To assess mule deer diets, we collected fecal samples from summer home ranges of collared deer and used microhistology to identify plant species within their diets (Fig. 8) in summer 2013 and 2014. Based on frequency of plants within mule deer diets, we then collected plant clippings that we analyzed for quality (e.g., crude protein and digestibility). We are now coupling data on diet quality with forage availability by quantifying the abundance of key forage species at known locations of collared mule deer throughout the summer.





Effects of Winter Severity on Survival and Reproduction

Adult Winter Survival

Winter of 2016/2017 proved to be a tough on mule deer. Conditions on winter ranges for Wyoming Range mule deer were severe with snowpack levels exceeding 200% and numerous days of sub-zero weather. These harsh winter conditions strongly affected winter survival and only 63% of our collared adults survived from November until summer 2017 (compared with >90% in years past). Older animals and animals that entered winter in poor condition were more susceptible to succumbing to winter exposure (Fig. 9).

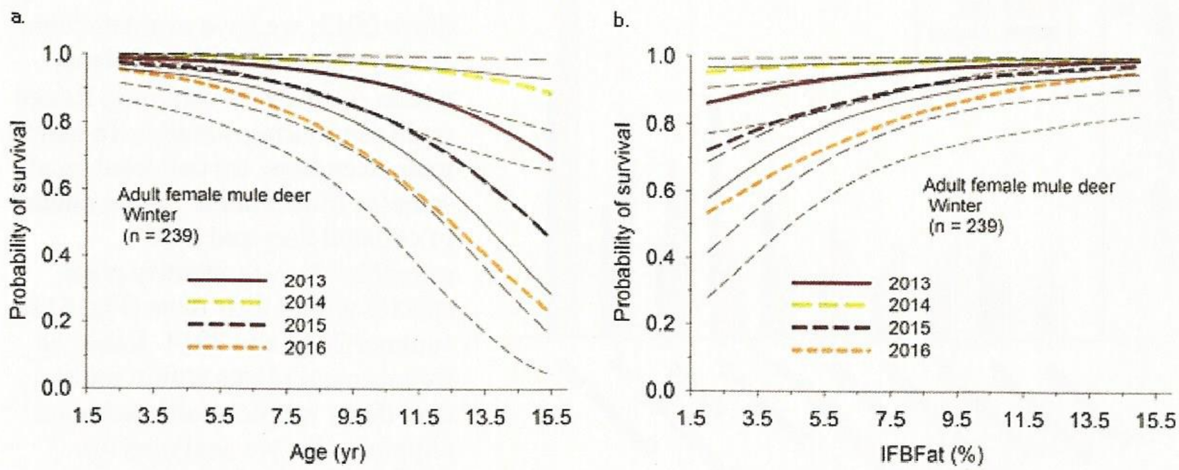


Figure 9. The effects of age (a) and December body fat (IFBFat %; b) on the probability of survival overwinter. Probability of survival decreased as animals aged and as the % body fat (IFBFat %) in December decreased.

Fawn Winter Survival

Winter conditions tend to have the greatest effect on survival of fawns, and this winter was no exception. We observed 100% mortality of the fawns we collared in summer 2016 (44% died overwinter). Mortality rates of that caliber can have substantial repercussions on population dynamics because the majority of an entire cohort of deer is gone. Although these numbers are staggering, winter die-offs, as the one observed this winter, do occasionally occur and populations do eventually rebound. We have now found ourselves with a unique opportunity to evaluate how mule deer populations rebound from harsh winters.

Nutritional Condition

Nutritional condition in March 2017, measured as % body fat, was the lowest we have observed in our research (2.3% in 2017 compared with 4.0–5.3% in 2013–2016; Fig. 10). Although it is rare to see animals in this poor of condition, it was surely a product of deep snow restricting access to forage and heightened energy expenditures associated with locomotion in deep snow and thermoregulation in plummeting temperatures.

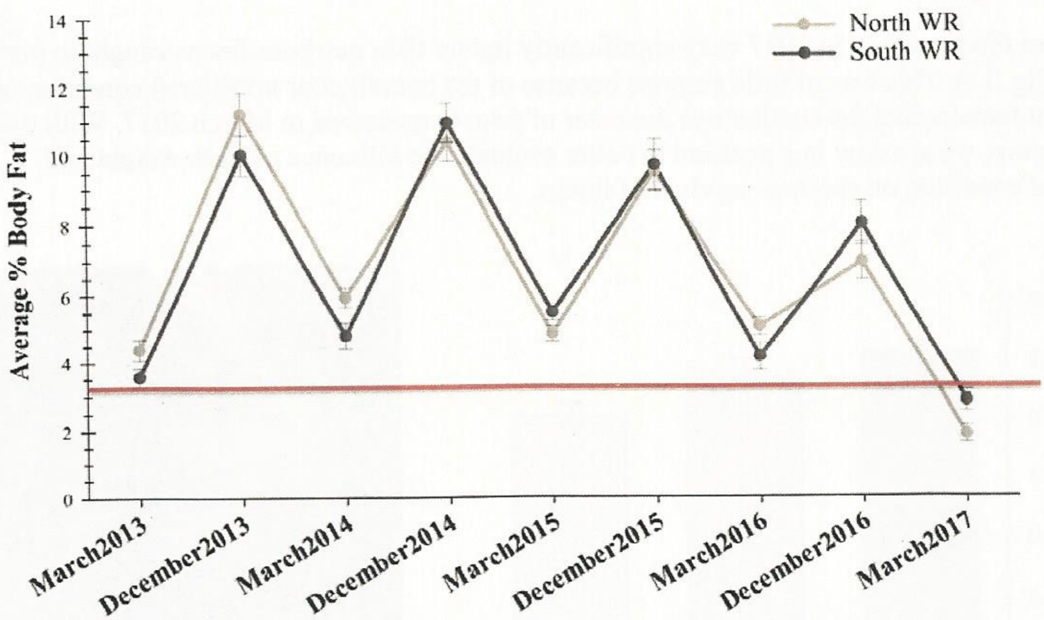


Figure 10. Average % body fat of adult, female mule deer on North (near Big Piney,WY) and South (near Cokeville and Evanston, WY) winter ranges for Wyoming Range mule deer in March 2013 – March 2017. Following the sever winter conditions of 2017, animals were in the worst nutritional condition recorded since the beginning of our research in 2013.

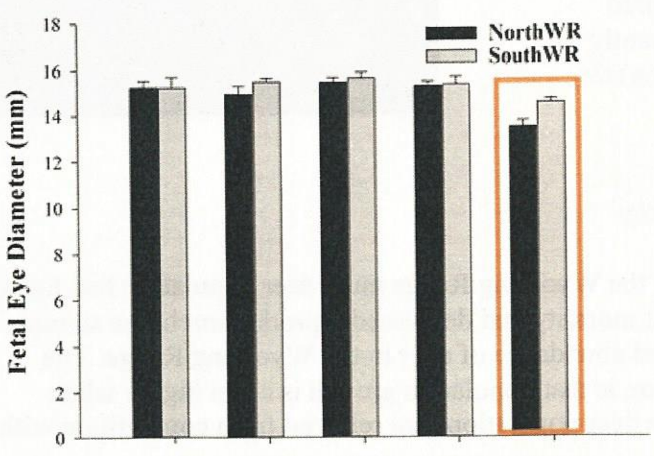


Figure 11. Average fetal eye diameter measured in March of each year. Fetal eye diameter was significantly smaller in March 2017 compared with any other year.

Pregnancy

Despite extremely poor nutritional condition of animals in March 2017, fetal rates among winter ranges were comparable to the preceding 4 years (Fig. 4) and pregnancy rates remained high. Interestingly, average eye diameter of fetuses was lower in March 2017 (14.0 ± 0.18) than in previous years (15.3 ± 0.11; Fig. 11). Fetal eye diameter is a measure of fetal development and is often used to estimate the timing of birth.

Carryover Effects

Newborn fawns caught in 2017 were significantly lighter than newborn fawns caught in previous years (Fig. 12). This was of little surprise because of the overall poor nutritional condition of pregnant females and the smaller eye diameter of fetuses measured in March 2017. With this information, we are now in a position to better evaluate the influence of birth weight and maternal condition on summer survival of fawns.

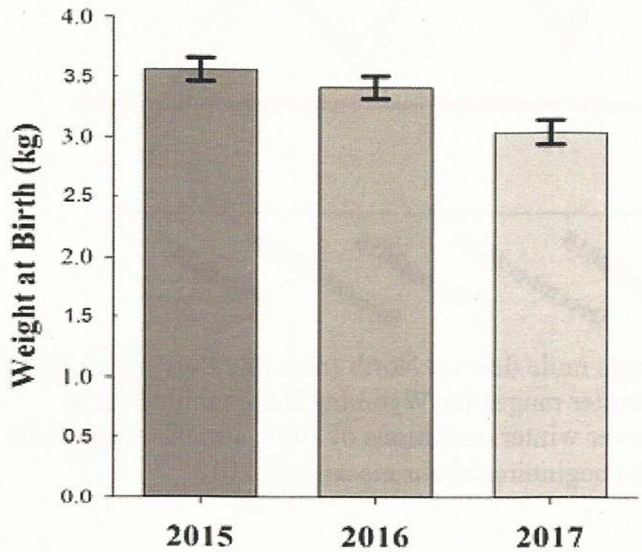
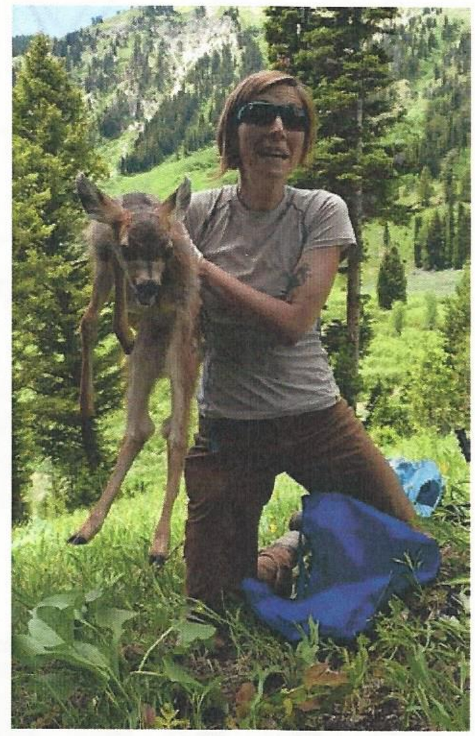


Figure 12. Average weight of fawns captured <48hours from birth. Fawns were significantly lighter in 2017 compared with the previous two years.



Population Benefits of Reduced Deer Density

Following the severe winter of 2016/2017, the Wyoming Range mule deer population had found itself in an interesting place. The high adult morality and depressed reproduction in the summer following undoubtedly resulted in decreased abundance of deer in the Wyoming Range. The silver lining to the decrease in the population is that population growth is often higher when abundance is low (Fig. 13). This is because deer populations are relieved from competition with other deer.

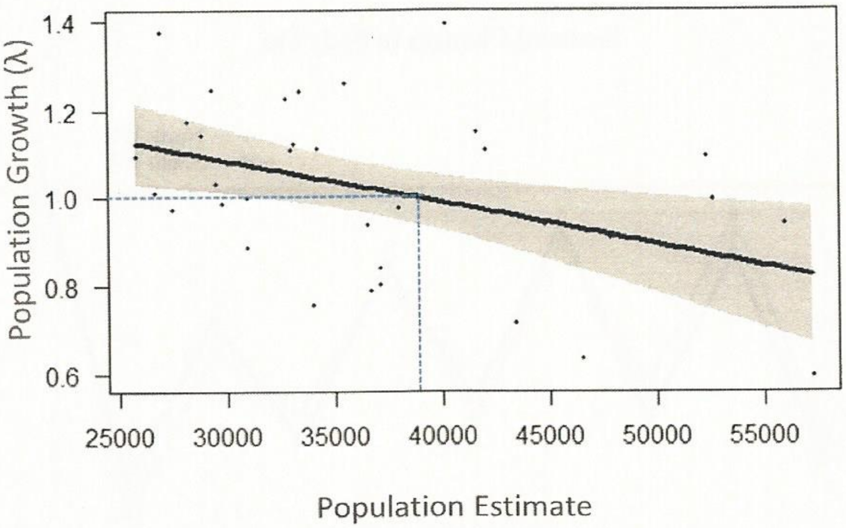


Figure 13. The relationship between population growth (λ) and estimated population abundance of Wyoming Range mule deer. As population abundance decreases, the growth rate (λ) of that population increases.

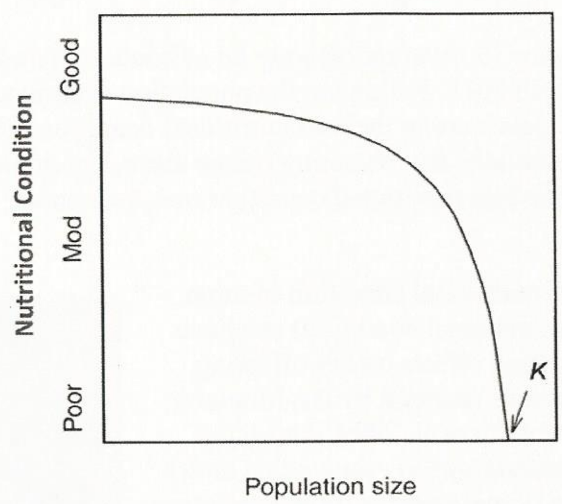


Figure 14. The relationship between population size and nutritional condition of ungulate populations. As population size increases and approaches carrying capacity (*K*), the overall nutritional condition of that population decreases (Kie et al. 2003).

As deer density decreases, per capita food increases. Consequently, populations at low abundance, relative to the carrying capacity (*K*) of their landscape, tend to be in overall better nutritional condition because each individual has access to more food (Fig. 14). Conversely, deer populations that are at or near carrying capacity tend to be in overall worse nutritional condition because deer are competing with other deer for food. Some of these trends were reflected in our longitudinal data of trends in fat dynamics since 2013 (Fig. 15).

Seasonal Changes in Body Fat

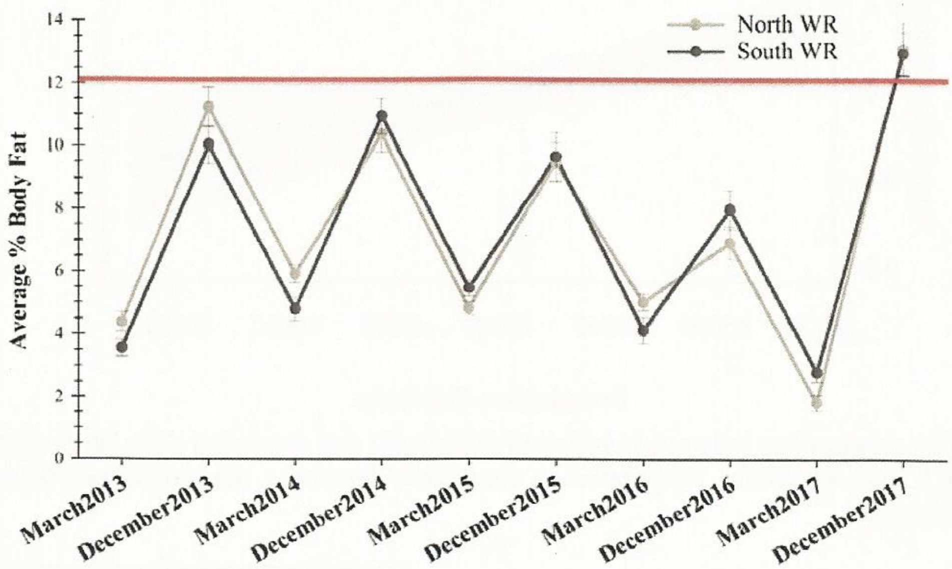


Figure 15. Average % body fat of adult, female Wyoming Range mule deer in March 2013 – March 2017. Following the population decline after the severe winter conditions of 2016/2017, animals were in the best nutritional condition recorded since our research began in March 2013. Essentially, the Wyoming Range mule deer population went from the worst nutritional condition to the best nutritional condition over a summer.

The nutritional condition of mom (i.e., maternal condition) can have life-long effects on her offspring. Previous research by Dr. Monteith (Monteith et al. 2009, *Journal of Mammalogy*) has shown that antler size of male deer is influenced more by maternal condition than genetics. Dr. Monteith, along with colleagues, observed that male fawns born to mothers in good maternal condition grew to be larger deer that exceeded the size of their fathers. Considering these research findings, Wyoming Range mule deer that can exploit their high nutritional condition (relative to previous years) observed in December 2017 may be better poised in allocating stored fat to fetal development and provisioning of young that are born in spring/early summer 2018. The summer of 2018 will be telling for the propensity for population growth and potential for large male deer in years to come.

A Positive Outlook for the Future

Overall survival throughout winter 2017/2018 was high (100% of collared adults and 93% of collared fawns survived), and in March 2018, we recaptured all surviving adult deer and their female offspring. Average % body fat in March 2018 was slightly higher than the overall average over the 6 years of our research (average of 5.46 ± 0.20% in March 2018 compared with overall study average of 4.46 ± 0.10% in March 2013-2018; Figure 3). Also, as would be expected for this population of mule deer, pregnancy rates and fetal rates were comparable to previous observations—94% of animals were pregnant and most were pregnant with twins (fetal rate was 1.68 ± 0.07, which is similar to the average throughout the study; figure 4).

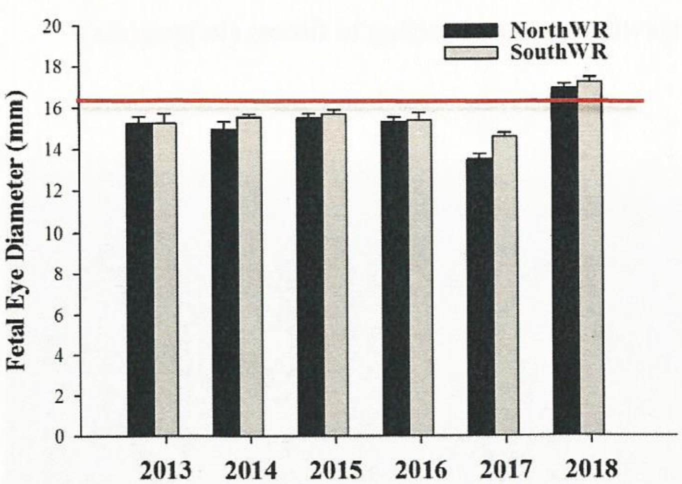


Figure 16. Average fetal eye diameter (mm) measured in March 2013-2018. Fetal eye diameter was significantly higher in 2018

Although nutritional condition and pregnancy in March 2018 were not significantly greater than what has been observed previously, we did observe notable differences in investment in reproduction throughout winter 2017/2018. More specifically, fetuses were significantly larger in March 2018 than in previous years (fetal eye diameter of 17.08 ± 0.16mm compared with a study average of 15.40 ± 0.09; figure 16), and fetuses were 22% larger in March 2018 than in March 2017. This increased investment in fetal development may be a direct result from the high fat stores that Wyoming Range mule deer had coming into the winter. We are excited to see how such investment in fetal development influences timing of birth and the size of young born in May and June.

Spring Migration Ecology of Mule Deer

At the largest spatial scale, migration is recognized as a strategy that allows migrants to exploit high-quality resources available on one seasonal range, while avoiding resource deficiencies on the other. Much less is known, however, about the fine scale movement behaviors that animals make during migration. This portion of the Wyoming Range Mule Deer Project aims to understand the importance of food resources available during migration, and how the habitat quality of migratory routes influences survival and reproduction of migratory mule deer in the Wyoming Range.

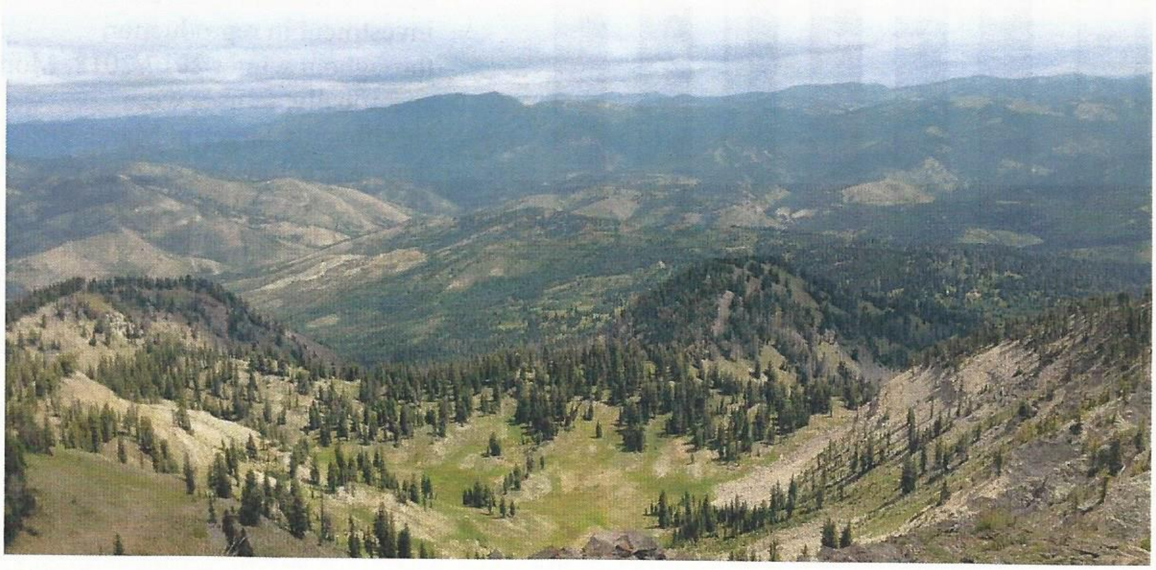
Spring migration is a critical time for migrants, in which they must recover from harsh winter conditions and prepare for upcoming reproductive costs. It is hypothesized that movement from low elevation winter ranges to high elevation summer ranges, allows migrants to extend the amount of time they are exposed to young, highly palatable forage. Following a wave of newly emergent, high-quality forage along elevational gradients, is known as "surfing the green wave". This project will investigate the role of the migration route as critical habitat, with the aim to better understand the importance of migration as well as to inform management strategies to protect migration in the Wyoming Range and beyond.

Project Objectives

1. Test the green wave hypothesis in migratory mule deer and explore the source of individual variability in green-wave surfing (Completed, see below).

2. Investigate the influence of drought on green-wave surfing (In progress).

3. Understand the relative importance of green-wave surfing to fitness (In progress).



Testing the Green Wave Hypothesis

Deer should select plants that are at intermediate growth stages (i.e. not too old or not too young) because plants which are greening up are both easy to digest and available in large enough quantities to maximize energetic gains. If deer surf a wave of plant green-up, then the timing of their movements during spring migration should be perfectly matched with the timing of peak green-up in plants. When we tested this prediction, this is indeed what we found (Figure 1). We noticed, however, that there was a lot of variability in the green-wave surfing ability of individuals. To further investigate the source of this difference in green-wave surfing we considered how the progression of the green-wave across individual routes may differ. We found that some routes had long, easy to follow gradients in plant green-up, while other routes had short, rapid and difficult to follow gradients in plant green-up. Together this difference in the amount of time when green-up was available along a migration route (i.e. the green-up duration) and the gradient of green-up from winter range to summer range (i.e. the order of green-up), which we refer to as the "greenscape", largely explained the differences in green-wave surfing across individual deer using different migration routes.

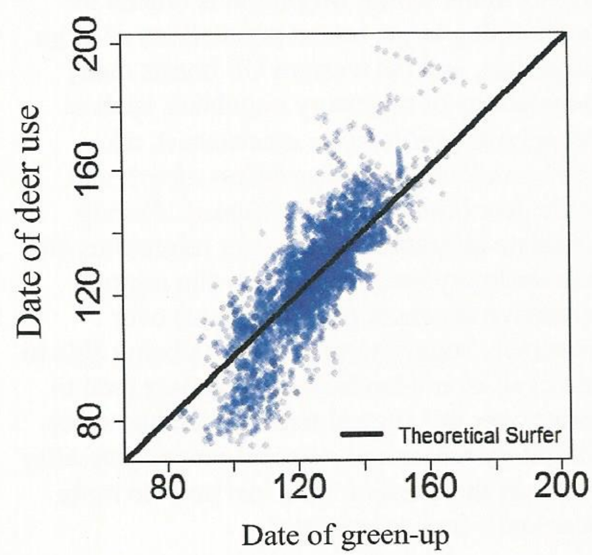


Figure 16. Evidence for green-wave surfing by mule deer in the Wyoming Range. The black line represents the theoretical prediction of a perfect match between the date of green-up and the date of deer use. Data points fall close to this line, suggesting that in general deer are surfing the green wave.

What have we learned?

- Green wave surfing is key to the foraging benefit of migration.
- The migration route provides critical habitat.
- Timing is key, thus activities that may alter the ability of deer to exploit the green wave should be avoided or minimized during the spring migration period.
- The greenscape (i.e. the duration and order of green-up along a migration route) determines the quality of a route.

This research is published! For more information, see:

Aikens, E.O., M. J. Kauffman, J. A. Merkle, S. P. H. Dwinnell, G. L. Fralick, and K. L. Monteith. 2017. The greenscape shapes surfing of resource waves in a large migratory herbivore. *Ecology Letters* 20:741-750.

The Rose Petal Project

While seasonal migration occurs in diverse animals and habitats, large ungulate migrations are some of the most spectacular wildlife events in the world. Migration is crucial to maintaining large, robust populations of large ungulates, and the western US boasts many populations of migratory ungulates, such as pronghorn (*Antilocapra americana*), elk (*Cervus elaphus*), moose (*Alces alces*), and mule deer (*Odocoileus hemionus*). Among ungulate migrations, mule deer migrations are extraordinary because animals can migrate extensive distances (up to 260 km) over extremely rugged terrain. Despite being able to travel all over a landscape, mule deer tend to move over this rugged terrain using the same migratory routes and seasonal ranges year after year, yet the question remains: how do mule deer know how to migrate?

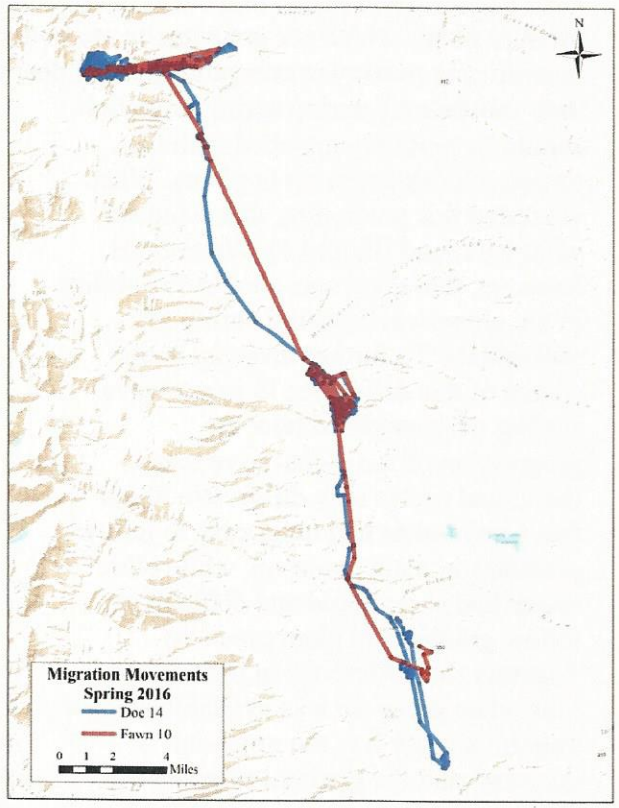
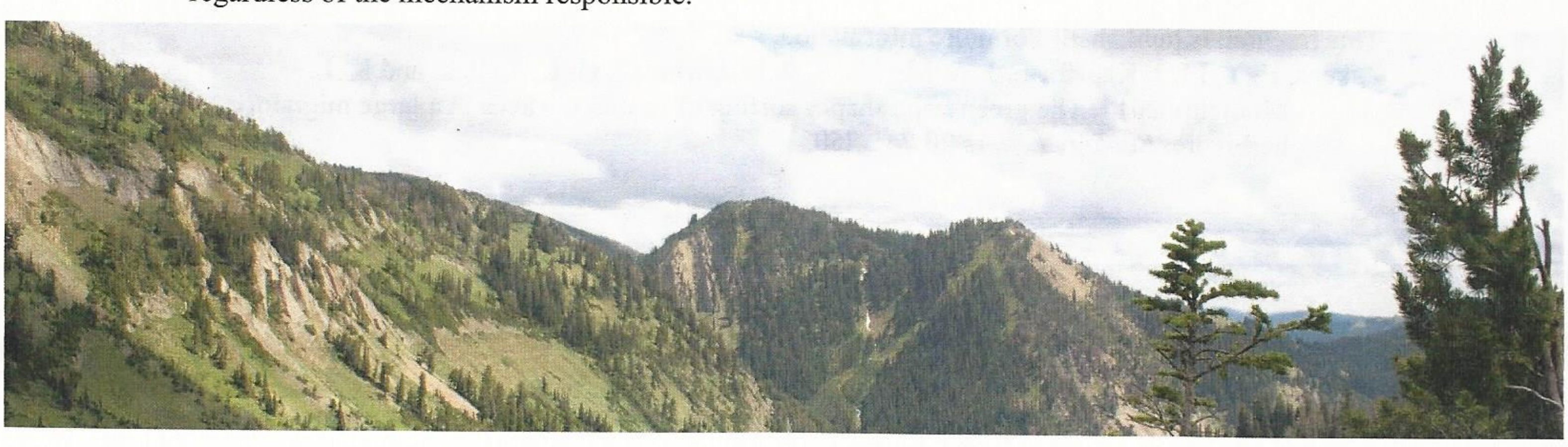


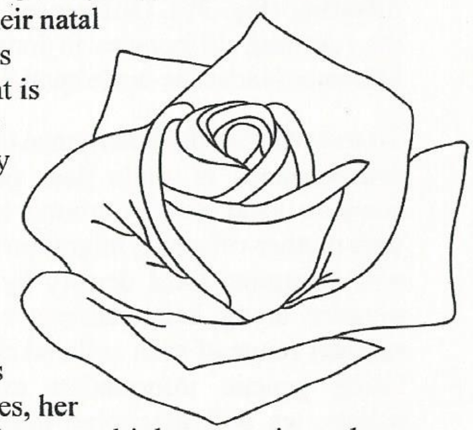
Fig 17. Paired migratory movements of mother (blue) and daughter (red) mule deer in Wyoming, USA. The migration paths of mother and daughter overlap considerably, and warrant investigation of the role of cultural inheritance in shaping migratory behaviors.
Credit: S. Dwinnell.

Ungulates may know how to migrate if information on migratory traits (e.g., timing to initiate migration, rate of movement, migration path, seasonal range characteristics) is passed down from parent to offspring. Two potential mechanism could facilitate this transmission from parent to offspring: genetic inheritance and cultural inheritance. While genetics may underpin migratory traits in some bird species, whether genetics underpin ungulate migration remains to be discovered. Additionally, migratory traits may be passed from mother to offspring if offspring migrate alongside and learn the behaviors of the mother – in other words, through cultural inheritance. Depending on the mechanism responsible for determining the transmission of migratory traits, we may need to alter our management strategies to ensure robust deer populations. Before we can understand these mechanisms, however, we need to test an overlooked assumption: that migration is passed from generation to generation at all, regardless of the mechanism responsible.



In mule deer, managers and scientists currently assume that mothers migrate with their newborn offspring from summer range to winter range, and return with their offspring to summer range the following spring (Fig. 1). The transmission of migratory traits (through either genetic or cultural inheritance) could allow parents to pass information about already successful or familiar habitats and routes to their offspring. While scientists have largely overlooked the transmission of migratory behaviors from parent to offspring, studying whether information is transmitted across generations has huge ramifications for understanding the ontogeny – or development – of migratory behaviors.

In addition to being fascinating, understanding the ontogeny of migration could change how we manage populations of migratory mule deer and other migratory ungulates. Because the females in many species of ungulates do not disperse far from their natal range, clusters of closely related females will form when mothers successfully raise offspring. This behavior of spatial arrangement is deemed the *rose petal hypothesis*, and results in clusters of mule deer families while they are on summer range. Passing migratory behaviors from parent to offspring could have population-level consequences if inherited behaviors constrain the habitat which family lineages can access. For example, if a mother mule deer transmits information about high-quality habitat to her daughter, that daughter may be more successful at having and raising offspring of her own. Alternatively, if a mother transmits information that leads her daughter to low-quality seasonal ranges, her daughter may have lower reproductive success. When combined over multiple generations, the inheritance of migratory traits of differing quality could produce differences in the sizes of these roses – potentially creating areas analogous to mule deer "hot spots" (robust rose) or "dead zones" (dilapidated rose). Identifying the migratory traits that result in these so-called "hot spots" could provide managers with information about which individuals, management areas, or behaviors to prioritize.



Are migratory traits transmitted from mother to daughter?

We aim to identify whether migratory traits are transmitted from generation to generation in mule deer. We expect that if migratory traits are transmitted, offspring will display migratory traits (e.g., migration timing, rate of movement, migration route, and quality of seasonal ranges) resembling their mothers (Fig. 2a).

To test whether migratory traits are transmitted, we will compare migration characteristics among and between mother-daughter pairs of Wyoming Range mule deer fitted with GPS collars. We began collaring efforts in 2016, and expect to collar approximately 50 mother-daughter pairs by the end of the project. We will use a suite of analyses including movement coordinate index, linear regression, and utilization distribution overlap index to quantify similarities between mother-offspring migratory traits.

What are the population consequences of transmitting migratory traits?

If migratory traits are transmitted, lineages may be constrained in the habitat they can occupy, such that transmission of certain combinations of migratory traits will lead to differential reproduction and local density. We expect founding mothers that inherit access to advantageous habitat will successfully raise more offspring over their lifetime, while mothers that inherit access to low-quality habitat will raise fewer offspring (Fig. 2b). Differences in reproduction, and the resulting differences in local density, may then influence landscape-scale spatial distribution.

To test whether the inheritance of migration traits has consequences of mule deer populations, we will compare local density around each collared female with mother-offspring migration trait similarities. We will determine local density by searching for fecal samples along belt transects centered around the summer range of each collared mother-daughter pair. Using genetic information extracted from fecal pellets, we will determine individual identification and genetic relatedness to the collared female. We will then test whether similarities in migration traits between mother and offspring influence local density.

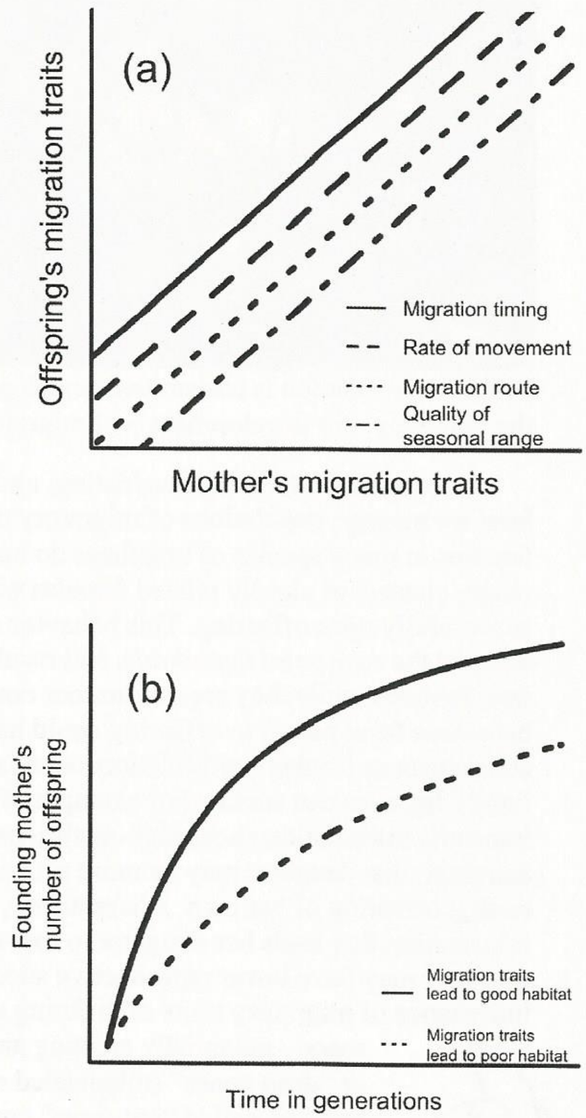


Fig. 18. Predictions associated with the cultural inheritance hypothesis (a) and the population consequences hypothesis (b).

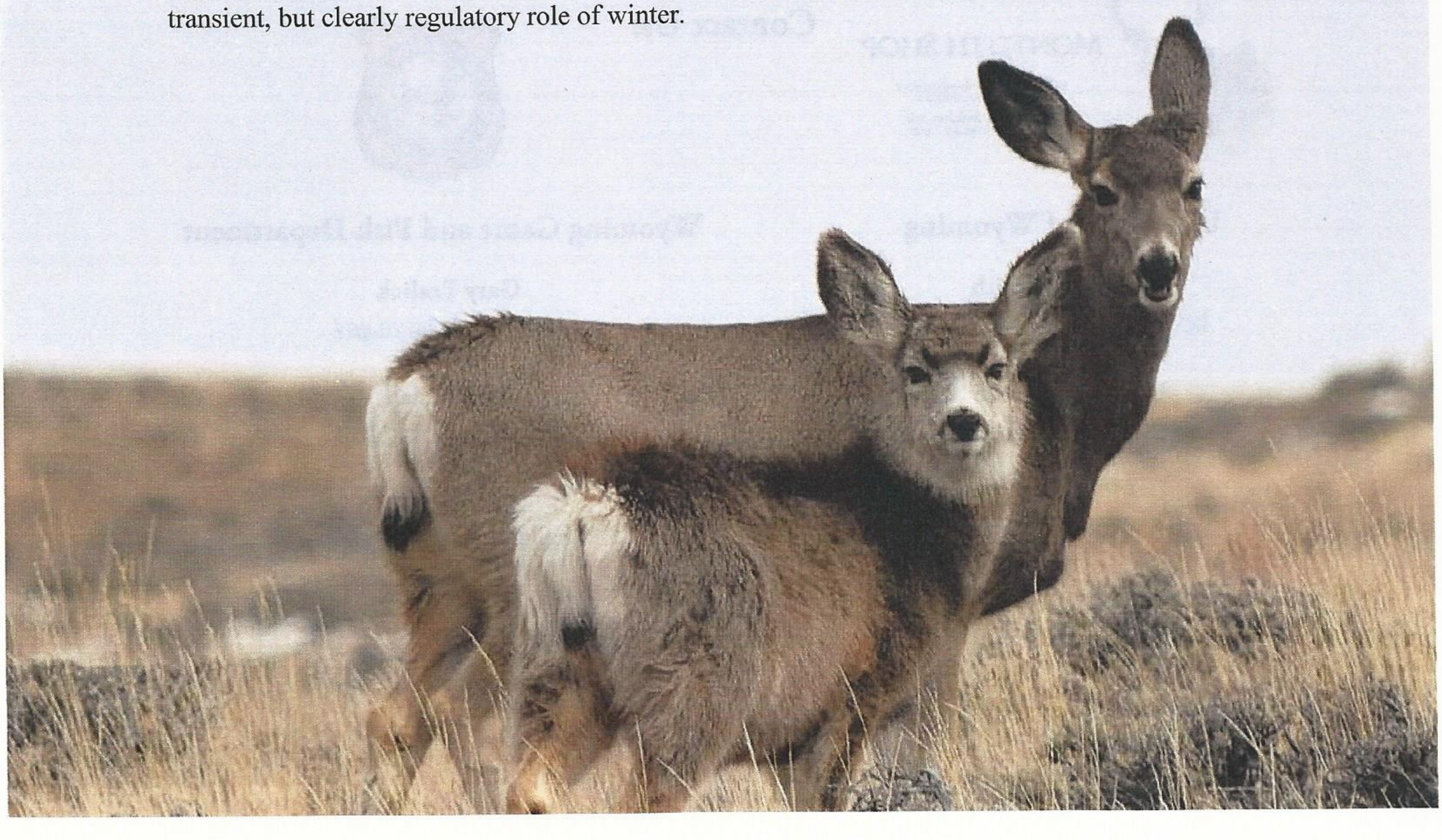
Management implications

Despite the importance of migration to many ungulate species, anthropogenic change is rapidly altering landscapes and, consequently, migratory behaviors. Halting or altering migratory behaviors could impact ungulate population trajectories by rendering segments of seasonal habitats unused, ultimately constraining species abundance, occupancy, and distribution. Because migration strategies developed under past conditions, properly managing ungulates in a rapidly changing world relies on characterizing the factors shaping migratory traits and the subsequent population ramifications.

Future Directions

The effects of the 2016-17 winter has been distressing, but we now are uniquely poised to document the long-term effects severe winters and understand the factors that will influence population recovery from the devastating losses. We have been extremely fortunate to have been conducting research on this herd, not only through the course of this harsh winter, but for several years prior, which will yield the data to address questions associated with how severe winters may affect mule deer herds throughout the state. With dramatic reductions in density, forage resources available per individual should be bolstered and thus, nutritional condition, reproductive success, and survival may well all respond very favorably. Nevertheless, with lower deer density compared with recent decades, the role of predators in this population also may change in either positive or negative ways. The marked decline of the Wyoming Range deer population following the 1992-93 winter, and the near absence of any substantial recovery thereafter, also begs the question to what extent recovery will occur given historic patterns. Regardless, the overwhelming management desire is for recovery, and our aim is to document recovery and the mechanisms that underpin it.

The overall goal of our continued work in the Wyoming Range will be to build on our understanding of the nutritional and population ecology of this herd to document the carryover effects of the severe winter of 2016-17, and how and to what extent the population will rebound from the dramatic reduction in abundance. As before, our overall approach will continue to mesh data on nutritional condition, habitat condition, and population performance to understand factors regulating Wyoming Range mule deer and the ability of the current habitat to support mule deer—with now a distinct reduction in density, habitat and density-dependent feedbacks onto the population should illuminate ever more so than previously. Our approach will allow us to continue to elucidate the relative roles of habitat, nutrition, predation, and disease on the regulation of deer in western WY, and fully grasp the magnitude and extent of the effects of the transient, but clearly regulatory role of winter.



Partners

The Wyoming Range Deer Project is a collaborative partnership in inception, development, operations, and funding. Without all the active partners, this work would not be possible. Funds have been provided by the Wyoming Game and Fish Department, Wyoming Game and Fish Commission, Wyoming Wildlife and Natural Resource Trust, Muley Fanatic Foundation, Bureau of Land Management, Knobloch Family Foundation, U.S. Geological Survey, National Science Foundation, Wyoming Governor's Big Game License Coalition, Boone and Crockett Club, Animal Damage Management Board, Ridgeline Energy Atlantic Power, Bowhunters of Wyoming, and the Wyoming Outfitters and Guides Association. Special thanks to the Wyoming Game and Fish Department, Bureau of Land Management, and Wyoming State Veterinary Lab for assistance with logistics, lab analyses, and fieldwork. Also, thanks to the Cokeville Meadows National Wildlife Refuge and U.S. Forest Service for providing field housing.

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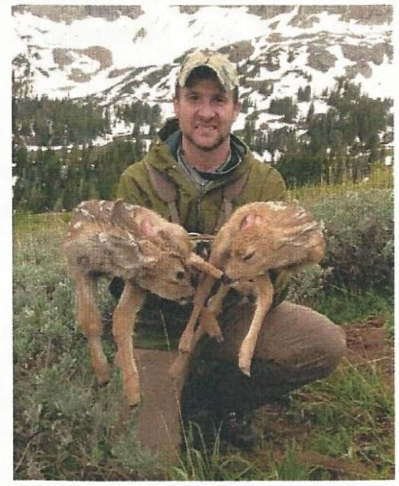
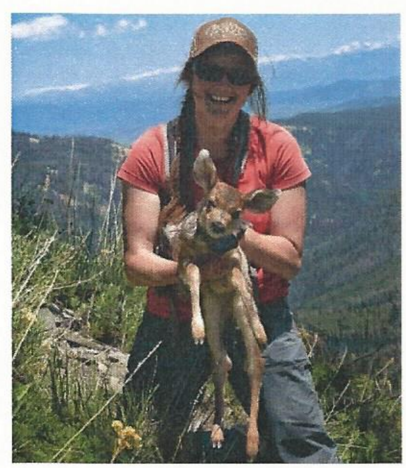


Kevin Monteith is an Assistant Professor of the Haub School of Environment and Natural Resources and the Wyoming Cooperative Fish and Wildlife Research Unit, Department of Zoology and Physiology at the University of Wyoming. After receiving his BSc and MSc in Wildlife and Fisheries Sciences from South Dakota State University, he went on to obtain his PhD in Biology from Idaho State University in 2011. Kevin's research program is focused on integrating nutritional ecology with intensive field studies of large ungulates to elucidate the mechanisms that underpin behavior, growth, reproductive allocation, predator-prey dynamics, and ultimately, the factors affecting population growth. Kevin and his graduate students are currently conducting research on most of Wyoming's large ungulates; topics are centered on establishing a protocol for habitat-based, sustainable management of ungulate populations, while investigating the effects of predation, habitat alteration, climate change, migration tactics, and novel disturbance.

Ellen Aikens

Ellen is a PhD candidate in the Program in Ecology at the University of Wyoming. Ellen is fascinated by animal movement, especially migration. Ellen plans to pursue a career in research, with a focus on the interface between fundamental research and applied conservation and management. Before coming to Wyoming, Ellen worked at the Smithsonian Conservation Biology Institute's GIS lab, where she analyzed remote sensing and GPS telemetry data for conservation research projects across the globe. Ellen is a recipient of the National Science Foundation Graduate Research Fellowship and the Berry Fellowship. Ellen earned her bachelor's degree in Biology and Environmental Studies from Ursinus College.

Samantha Dwinnell

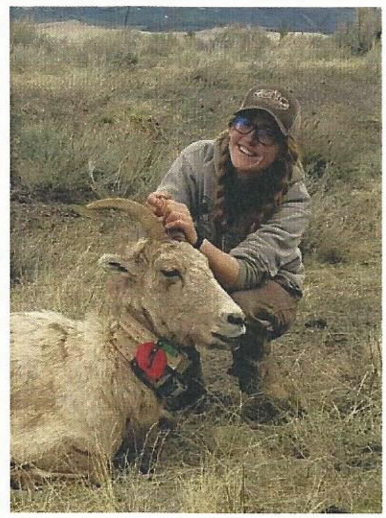


Samantha Dwinnell is a Research Scientist with the Haub School of Environment and Natural Resources. Samantha is the first student to miraculously graduate (May 2017) with a MSc from the Monteith Shop. Immediately following her defense that was made successful through bribery, she foolishly convinced Dr. Monteith to hire her as a Research Scientist to manage the Wyoming Range Mule Deer Project. Samantha's graduate research was focused on the nutritional relationships among mule deer behavior, forage, and human disturbance. Currently, her research is focused on disentangling the relative influence of various factors that affect fawn survival. Although Samantha is most interested in research aimed at informing management and conservation of wildlife, she also dedicates research efforts into finding ways to mountain bike and ski without her boss knowing.

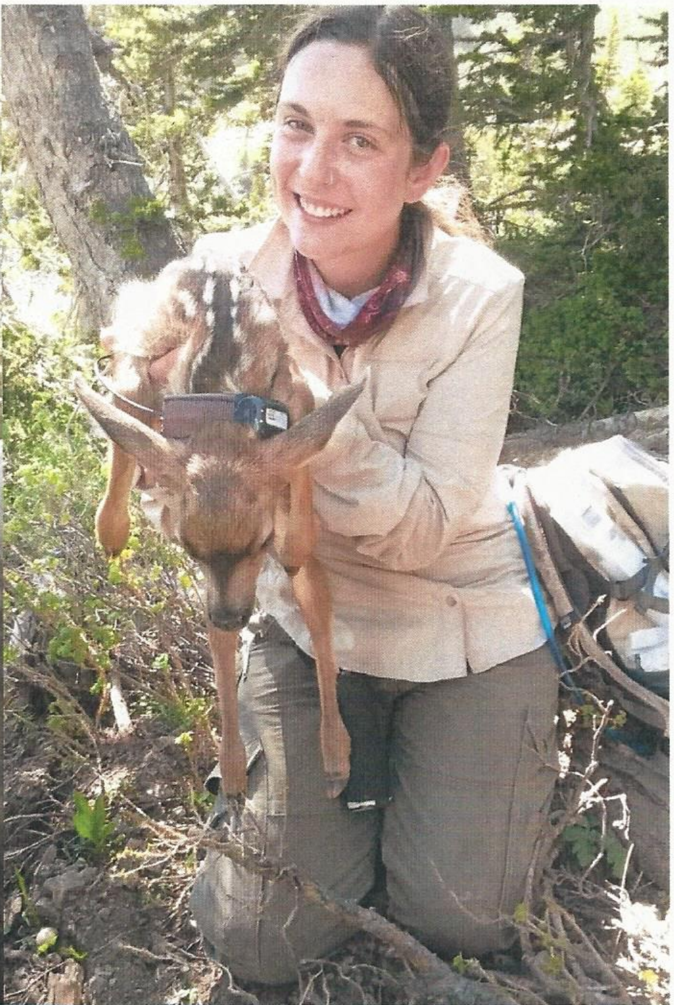
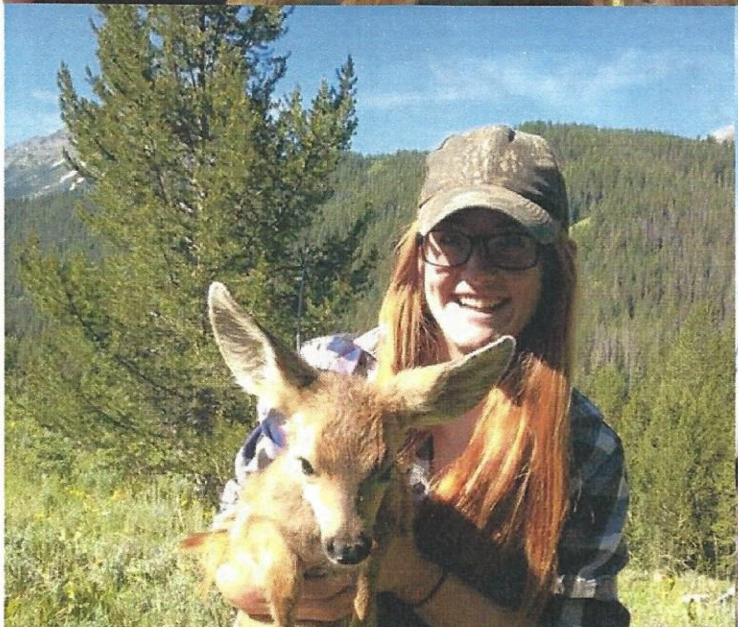
Rhiannon Jakopak

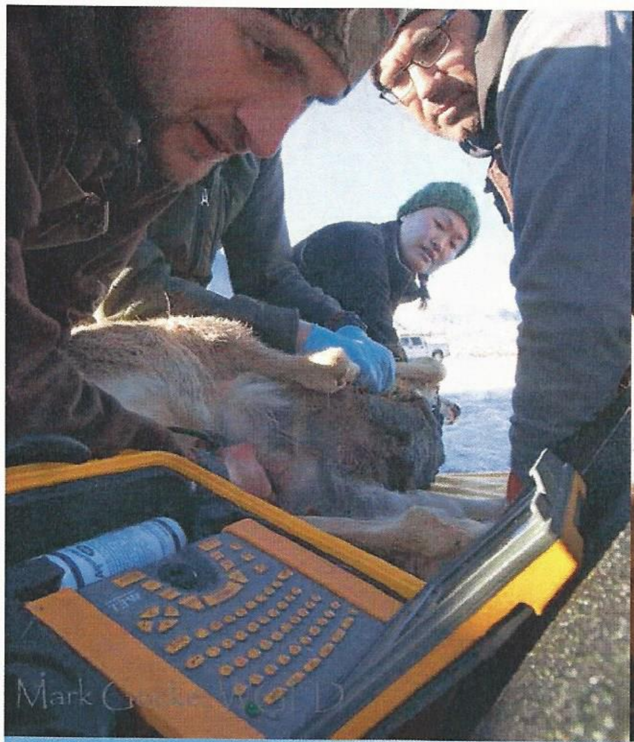
Rhiannon is currently a master's student in the Cooperative Fish and Wildlife Research Unit at the University of Wyoming. She received dual bachelor's degrees in Wildlife and Fisheries Biology and Management and Religious Studies at the University of Wyoming in 2016. She is broadly interested in population ecology and mammalogy, and more specifically interested in the processes regulating the distribution of species. Her master's project seeks to identify the factors which influence the development of migration and the subsequent population consequences.

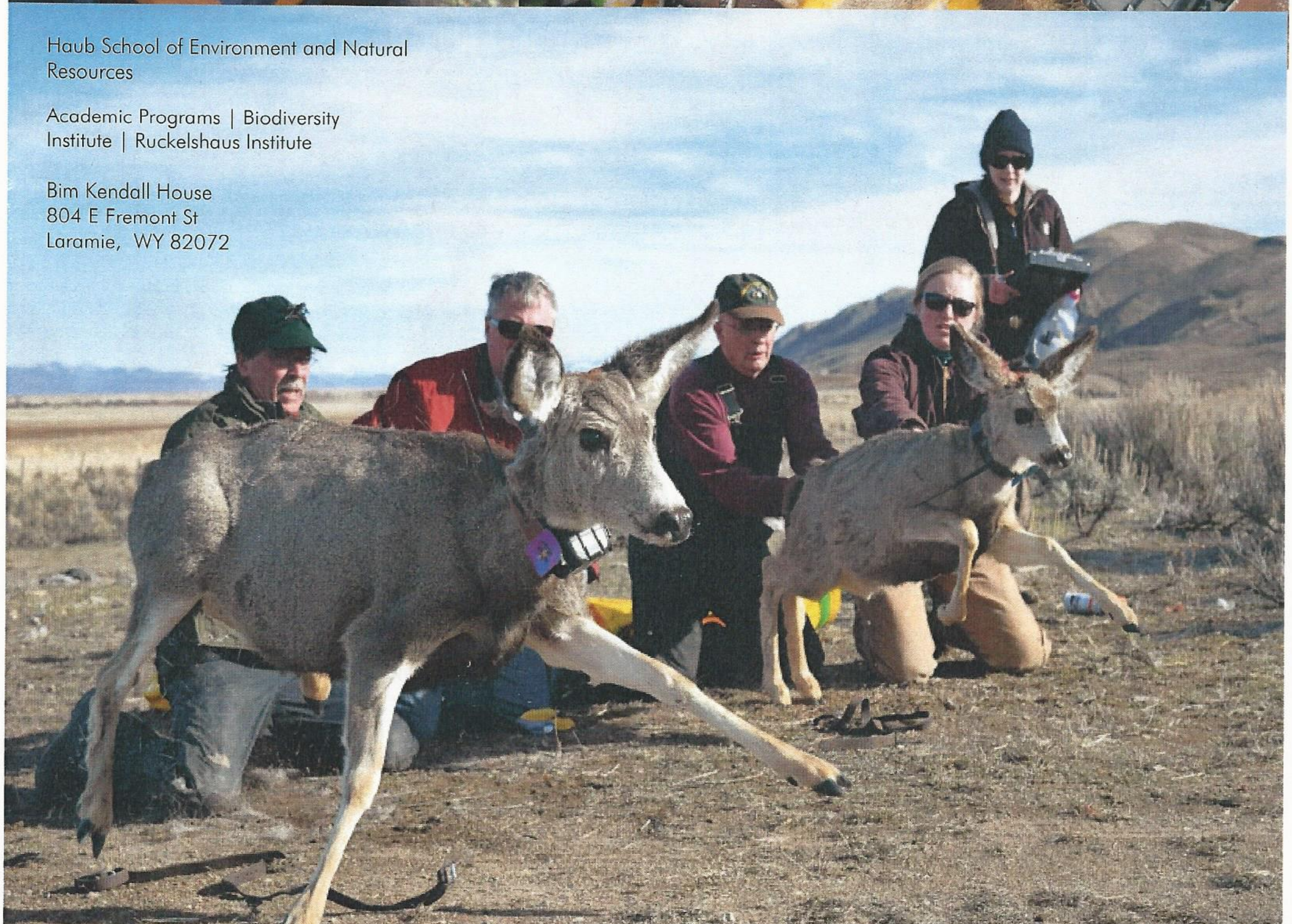
Tayler LaSharr



Tayler LaSharr is a MSc student in the Cooperative Fish and Wildlife Research Unit. Tayler grew up in Phoenix, AZ and attended the University of Arizona where she obtained a BSc in Natural Resources with an emphasis in Conservation Biology and a minor in Chemistry in May of 2015. During her time at the University of Arizona, she studied life history tradeoffs in Western and Mountain Bluebirds and the effects of aggression in closely related species on habitat and range dynamics. In the summer of 2015, she began work in the Wyoming Cooperative Fish and Wildlife Research Unit as a technician on a fawn survival study of mule deer in the Wyoming Range. In the fall of 2015, she began work on her own research, which focuses on understanding the effects of harvest on horn size of mountain sheep. Following the completion of her MSc work in the spring of 2018, she will transition to a PhD working on a component of the Wyoming Range Mule Deer Project assessing population recovery following a severe winter.



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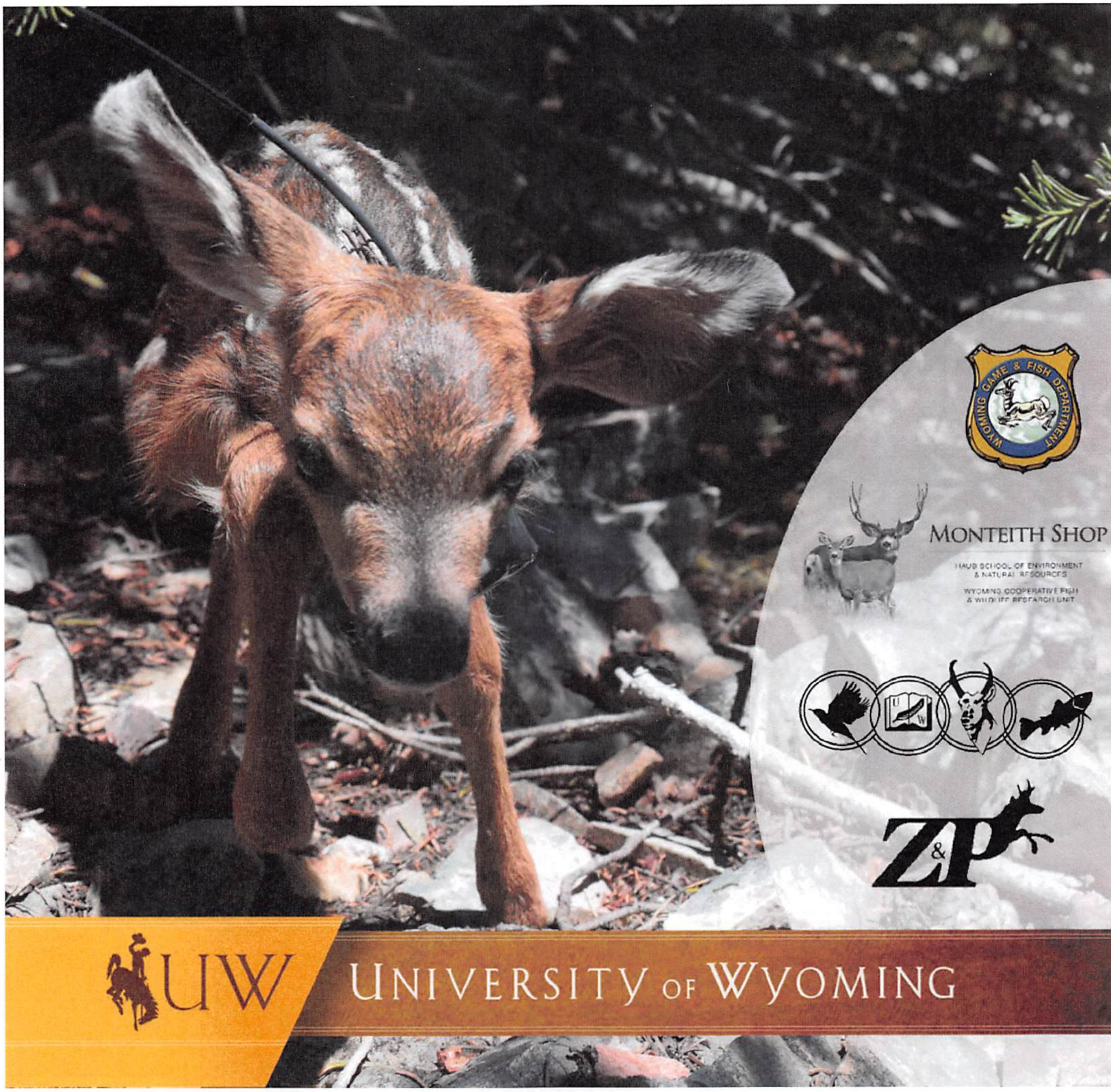
HAUB SCHOOL OF ENVIRONMENT AND NATURAL RESOURCES

Wyoming Range Mule Deer Project

Summer 2017 Update



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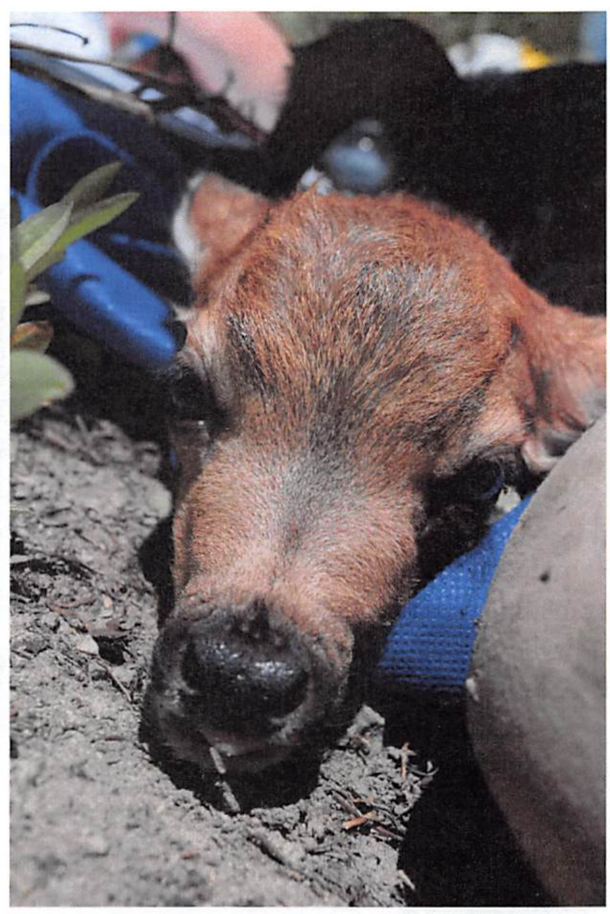
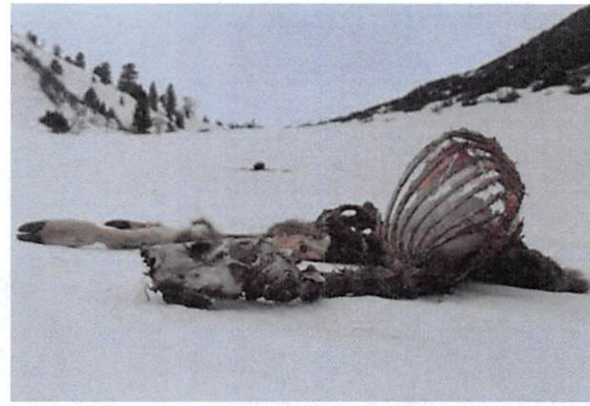
PROJECT BACKGROUND

The Wyoming Range Mule Deer Project was initiated in March 2013. The overarching goal of the project is to investigate the nutritional relationships among habitat conditions, climate, and behavior to understand how these factors interact to regulate population performance. Since the initiation of the project, we have tracked and monitored the survival, behaviors, reproduction, and habitat conditions of 164 female, adult mule deer of the Wyoming Range. In March 2015, we expanded our research efforts to include evaluation of survival and cause-specific mortality of fawns belonging to our collared mule deer. This component of the project is aimed at unraveling the relative contributions of habitat, maternal nutrition, and predation on survival of young mule deer—a study that is the first of it's kind in Wyoming. This update will report on some of our accomplishments and preliminary findings of adult survival and reproduction and will highlight the breadth of factors that contribute to fawn mortality in western Wyoming. So far, our research has gleaned invaluable insight into what regulates population performance of this iconic population, and we aim to further refine our understanding of the factors that affect the population with continued, robust data collection on various aspects of mule deer ecology, including nutrition and habitat contributions, predation, migration, reproduction, and survival.



WINTER 2016/2017

Adult Survival



This last winter of 2016/2017 proved to be a tough one for mule deer. Conditions on winter ranges for Wyoming Range mule deer were severe with snowpack levels exceeding 200% and numerous days of sub-zero weather. These harsh winter conditions strongly affected winter survival and only 63% of our collared adults survived from November until summer 2017 (compared with >90% in years past). Older animals and animals that entered winter in poor condition were more susceptible to succumbing to winter exposure (Figure 1).

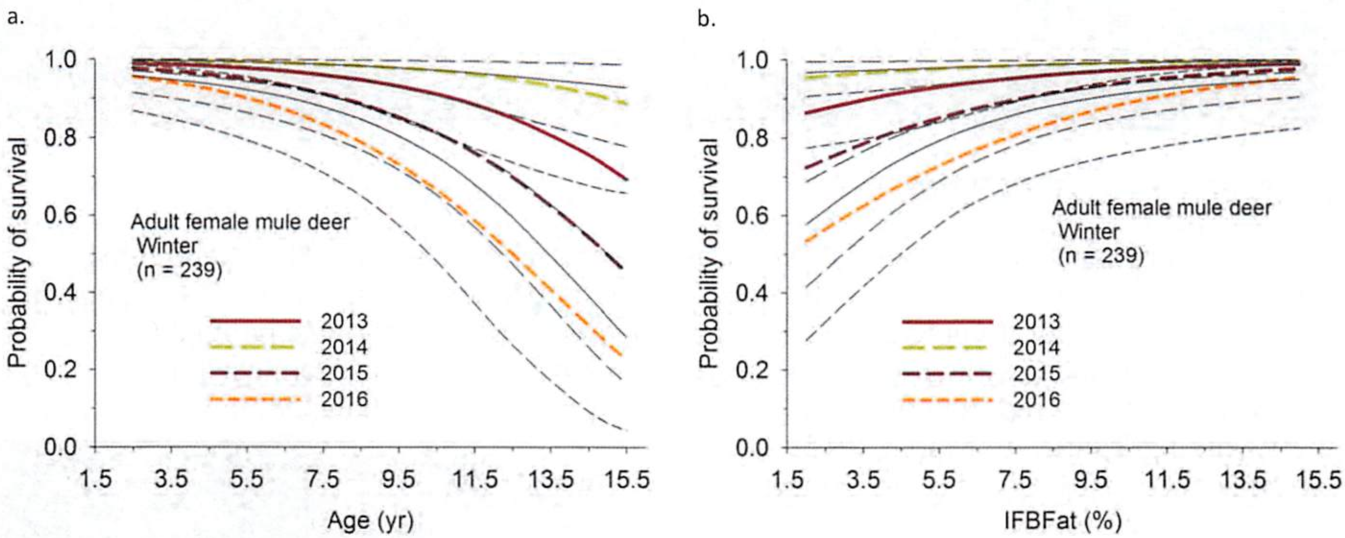


Figure 1. The effects of age (a) and December body fat (IFBFat %; b) on the probability of survival overwinter. Probability of survival decreases as animals get older and as the % body fat (IFBFat %) in December decreases.

Fawn Survival

Winter conditions tend to have the greatest effect on survival of fawns and this winter was no exception. We observed 100% mortality of the fawns we collared in summer 2016 and had survived to the beginning of winter. Mortality rates of that caliber can have substantial repercussions on population dynamics because the majority of an entire cohort of deer is gone. Although these numbers are staggering, winter die-offs like the one observed this winter do occasionally occur and populations do eventually rebound. We have now found ourselves with a unique opportunity to evaluate how mule deer populations rebound from harsh winters.

We retrieved all remains of mortalities of collared fawns. Whole carcasses were submitted to the Wyoming State Veterinary Lab and WGFD Wildlife Health Laboratory for necropsy.

MARCH 2017 ADULT CAPTURES

Since March 2013, we have recaptured collared mule deer as they enter winter ranges in December and before they leave winter ranges in March. This has allowed us to track changes in nutritional condition and reproductive status of animals.

We use ultrasonography to measure % body fat and evaluate pregnancy of collared mule deer.

Nutritional Condition

Nutritional condition in March 2017, measured as % body fat, was the lowest we have observed in our research (averaging 1.8% ± 0.25; Figure 2). Although it is rare to see animals in this poor of condition, it was expected given the severity of the winter.

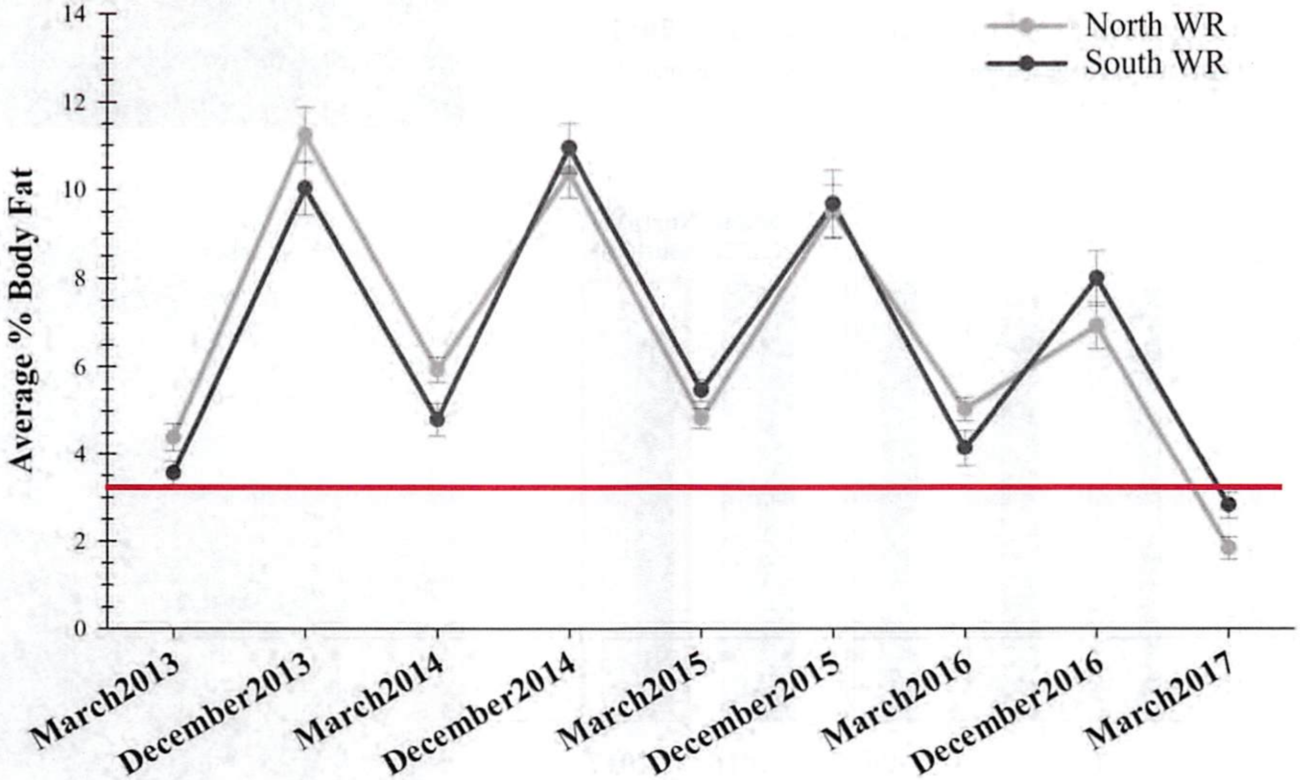


Figure 2. Average % body fat of adult, female mule deer on North (near Big Piney,WY) and South (near Cokeville and Evanston, WY) winter ranges for Wyoming Range mule deer. Deer were in significantly poorer shape in March 2017 than any other year.

Pregnancy

Despite extremely poor nutritional condition of animals this March, fetal rates among winter ranges were comparable to the preceding 4 years (Figure 3) and pregnancy rates remained high. Interestingly, average eye diameter of fetuses was lower in March 2017 (14.0 ± 0.18) than in previous years (15.3 ± 0.11; Figure 4). Fetal eye diameter is a measure of fetal development and is often used to estimate the timing of birth.

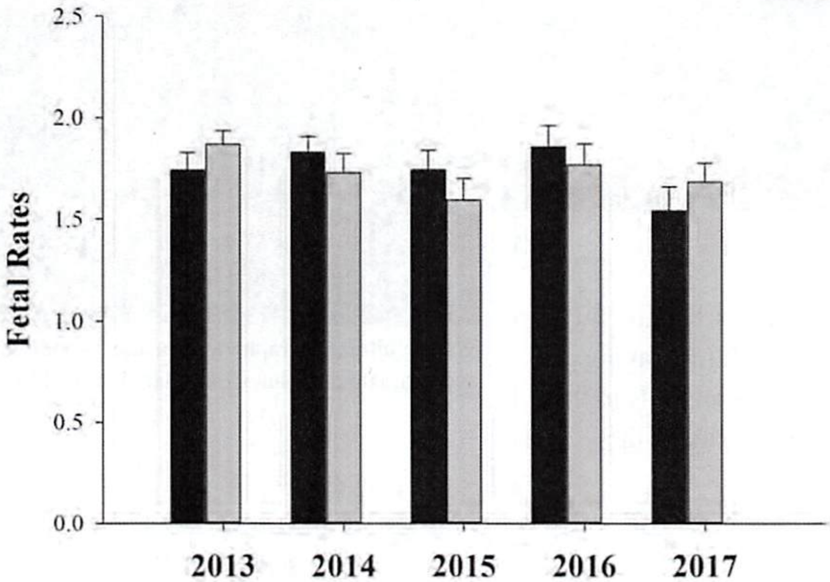
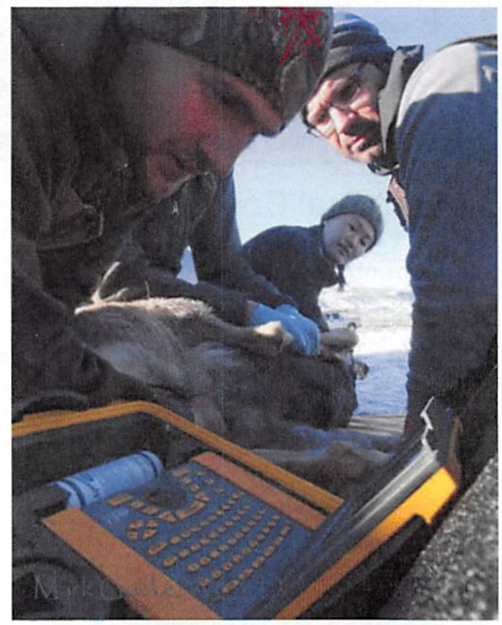


Figure 3. Fetal rates (average number of fetuses per pregnant animal) did not differ among years—despite severe winter conditions.



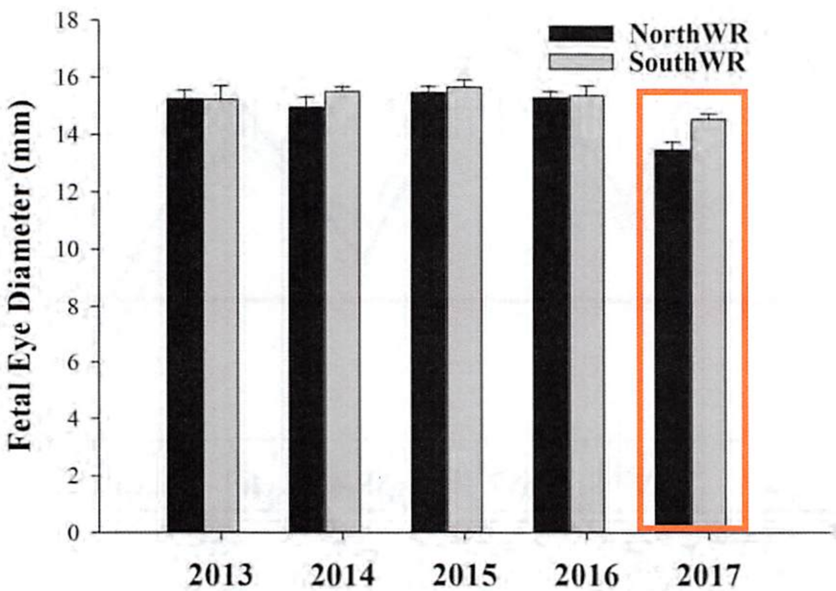


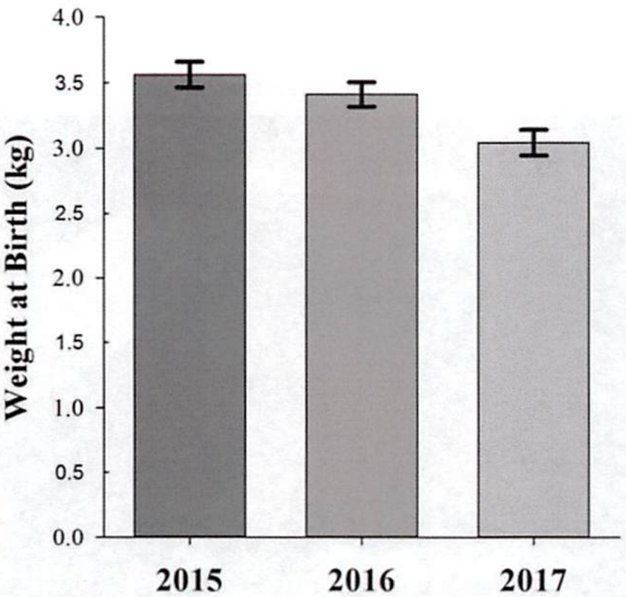
Figure 4. Average fetal eye diameter measured in March of each year. Fetal eye diameter was significantly smaller in March 2017 compared with any other year.

FAWN SURVIVAL

Fawn Capture and Collaring

Since March 2015, we have been capturing and collaring fawns of our collared adults to evaluate what factor most influence fawn survival. Fawns are located using a vaginal implanted transmitter (VIT) deployed in pregnant females that is expelled at birth. Once fawns are located, we then capture, radio-collare, and collecte a suite physical data (e.g., body weight). We then monitored daily survival of collared fawns. Over the three summers, we have tracked the survival of 194 mule deer fawns throughout the Wyoming Range.

	2015	2016	2017 - So Far
Number of Fawns Tracked	58	70	66
Summer Mortality	45%	56%	44%
Median Birthdate	June 10	June 13	June 16
Average Weight at Birth	3.56 (± 0.098)	3.41 (±0.093)	3.04 (±0.099)



Newborn fawns caught in 2017 were significantly lighter than newborn fawns caught in previous years (Figure 5). This was of little surprise because of the overall poor nutritional condition of pregnant females and the smaller eye diameter of fetuses measured in March 2017. With this information, we are now in a position to better evaluate the influence of birth weight and maternal condition on summer survival of fawns.

Figure 5. Average weight of fawns captured <48hours from birth. Fawns were significantly lighter in 2017 compared with the previous two years.

Cause-Specific Mortality of Fawns

To evaluate cause-specific mortality of fawns, we track daily survival of all fawns captured over the course of the summer. When a mortality is detected, we immediately investigate the event to ensure an accurate assessment of the cause of mortality. There is a breadth of various causes for fawn mortality including predation, disease, malnutrition, drowning, hypothermia, vehicle-collision, and just getting caught up in vegetation. The proportion of fawns that die because of the aforementioned causes varies from year to year (Figure 6).

So far, in summer 2017, 30% of mortalities were because fawns were stillborn. Currently, this is leading cause of death for fawns in 2017, but that will inevitably change as the summer progresses and more fawns die of other causes such as disease and predation.

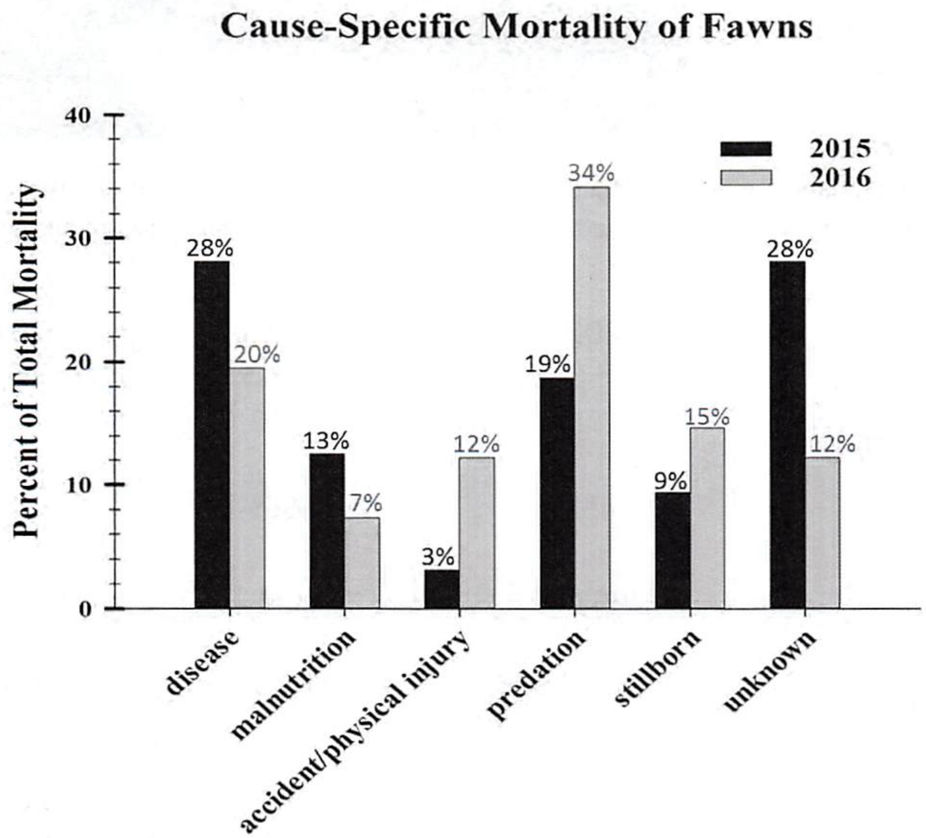


Figure 6. The relative occurrences of various causes of mortality for mule deer fawns.

Habitat and Maternal Conditions

The condition of a female and the habitat conditions she experiences in the summer may be very important in predicting and understanding fawn survival – especially in understanding the influence of malnutrition and disease on fawn survival. Therefore, we are evaluating forage and habitat conditions within summer home ranges of collared deer. Specifically, we are measuring habitat structure and forage availability of known locations of use by collared adults that gave birth to fawns. We will then couple these data with information on maternal condition (i.e., nutritional condition) and evaluate the influence on fawn survival.

FUTURE RESEARCH EFFORTS

Throughout summer and winter of 2017, we will continue our research efforts aimed at elucidating the relative influence of predation, climate, and habitat conditions on fawn survival in the Wyoming Range. The severe winter conditions of 2017 will provide us with a unique opportunity to evaluate how severe winter weather may influence the ability of females to subsequently rear young, and thus, provide valuable insight into the factors that regulate population growth and examine the prospects for recovery of this cherished herd.

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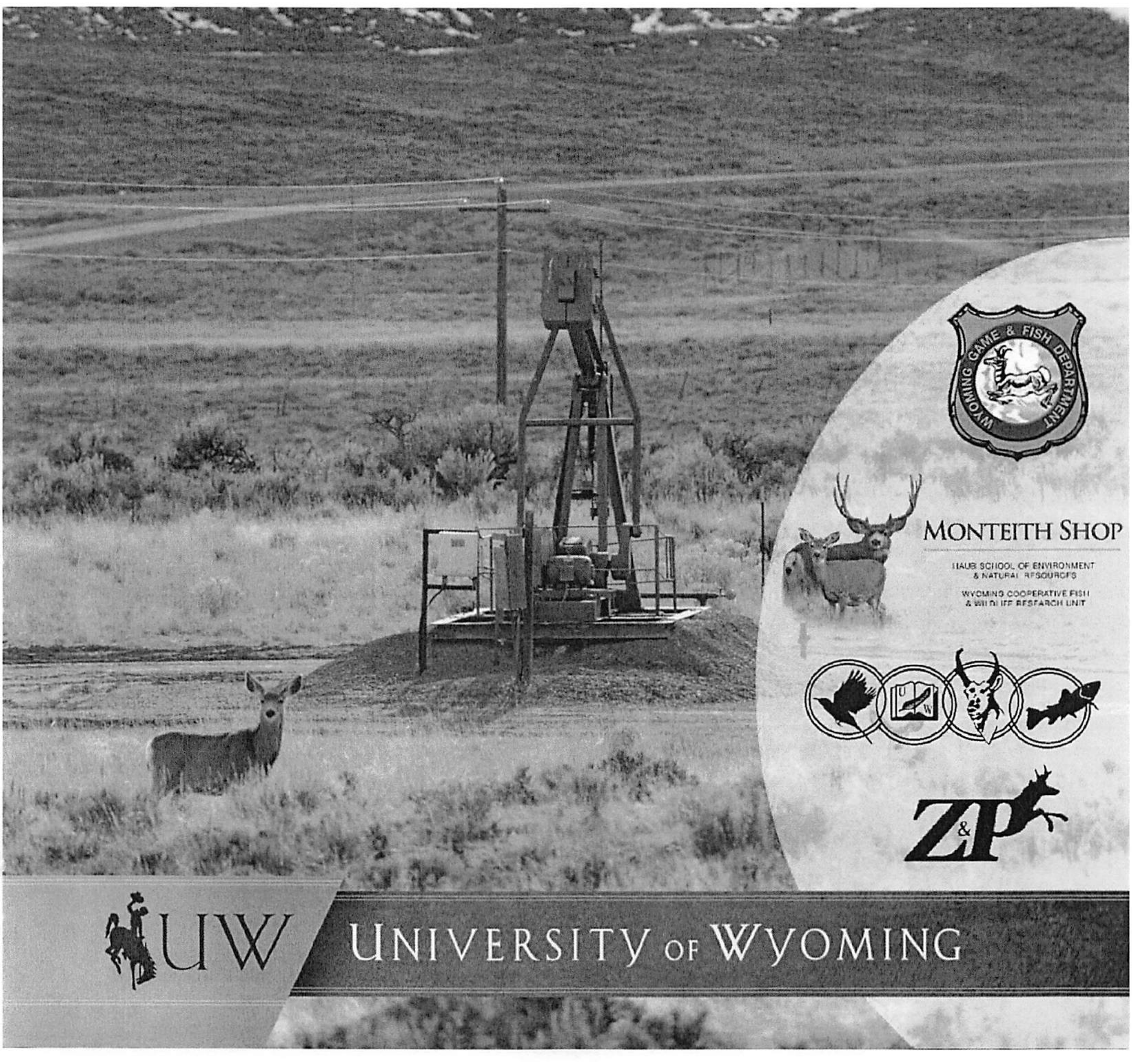
HAUB SCHOOL OF ENVIRONMENT AND NATURAL RESOURCES

Wyoming Range Mule Deer Project

A Brief Report:

Effects of Energy Development on Behavior and Forage Use of Mule Deer



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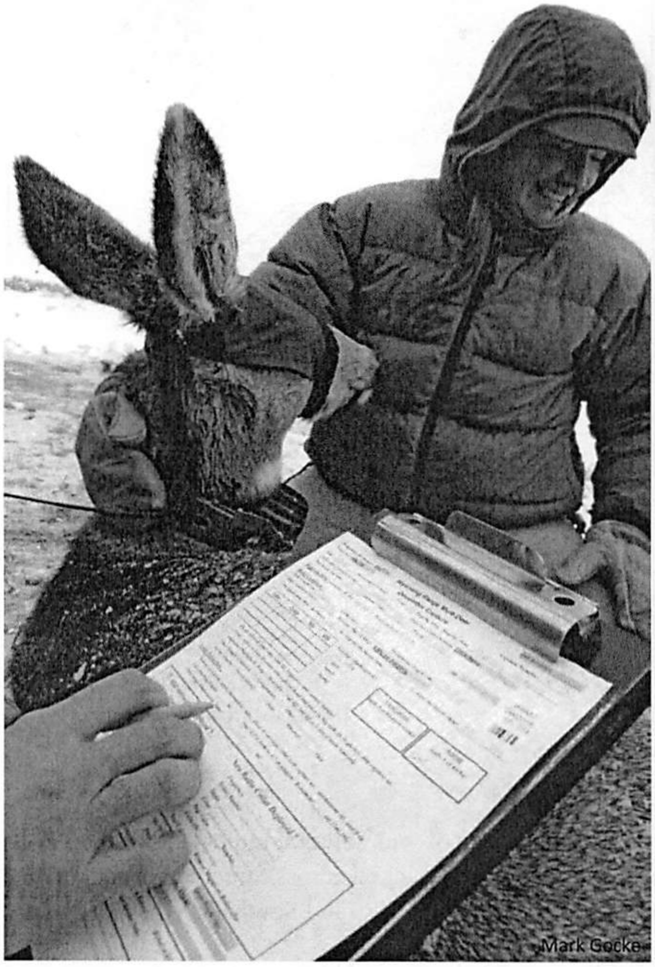
PROJECT BACKGROUND



The Wyoming Range Mule Deer Project was initiated in March 2013. The overarching goal of the project is to investigate the nutritional relationships among habitat conditions, climate, and behavior to understand how these factors interact to regulate population performance. Since the initiation of the project, we have tracked and monitored the survival, behaviors, reproduction, and habitat conditions of 164 adult female mule deer of the Wyoming Range. Although our research is evaluating conditions of all seasonal ranges mule deer encounter throughout the year (i.e., ranges used during summer, winter, and migration), the focus of this brief report will be on our research aimed at evaluating the nutritional relationships among behavior, habitat, and human disturbance of mule deer on winter ranges.

Energy development occurs to varying degrees across winter ranges for many Wyoming Range mule deer, and the effects of the ensuing human disturbance is a concern for wildlife managers, landscape conservationists, and members of the energy industry. Between 2013 and 2015, many of our research efforts were aimed at understanding how behavioral responses to human disturbance associated with energy development affect the way mule deer use available forage on winter ranges. We coupled GPS collar data with on-the-ground measurements of forage use across three winter ranges in western Wyoming that ranged in a gradient of intensity of energy development. This brief report highlights some of our findings that have enhanced our understanding of the effects of human disturbance on mule deer populations.

RESEARCH APPROACH

A Nutritional Ecology Framework

We used a unique approach in our research in that we evaluated the factors that regulate populations through a nutritional ecology framework. We linked behaviors of individuals to the habitats they use. Doing so allowed for a comprehensive understanding of the connections mule deer have with the landscapes they encounter.

Evaluating Mule Deer Behavior

In March 2013, we captured and GPS collared 95 mule deer across three winter ranges that varied in a gradient of intensity of human disturbance resulting from energy development (Fig. 1). Winter ranges included the Pinedale Anticline Project Area (PAPA), winter range near Big Piney and LaBarge (NorthWR), and winter range near Cokeville and Evanston (SouthWR). Using GPS collar data and behavioral observations from the ground, we evaluated behaviors in habitat selection, movement, and feeding behavior of collared animals on each winter range.

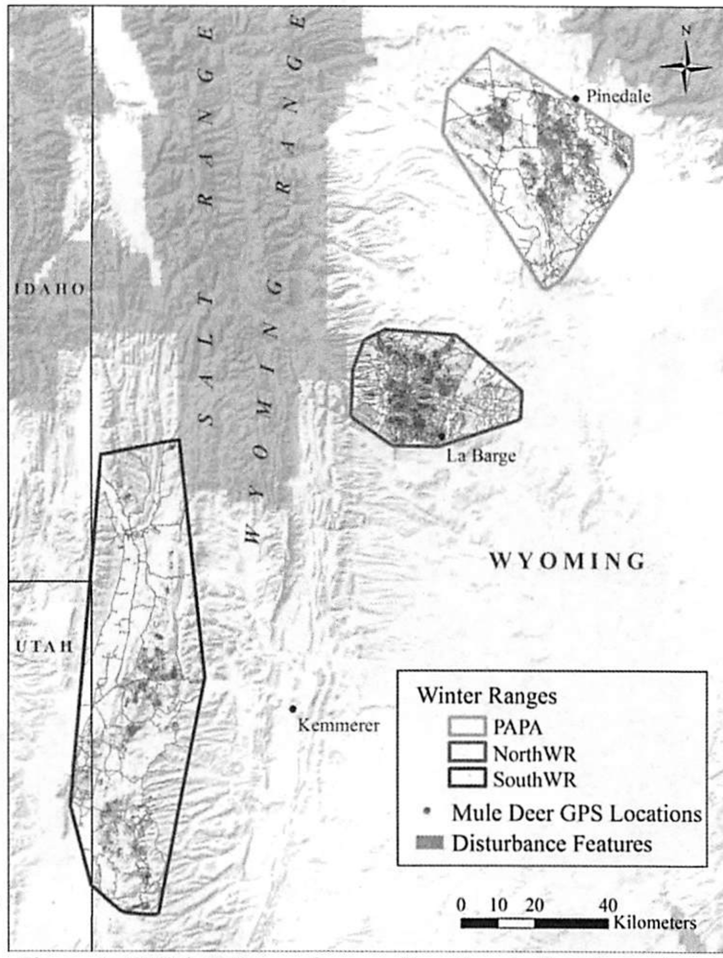
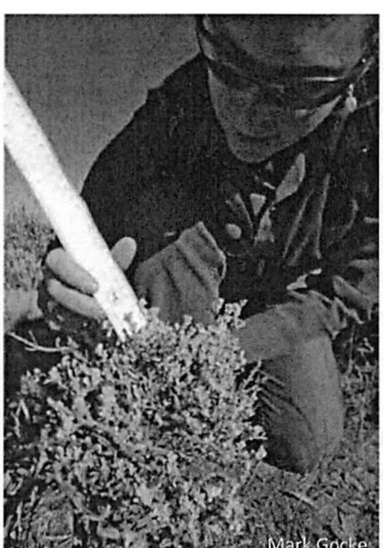


Figure 1. GPS locations of our collared mule deer in western Wyoming. Animals were tracked across three winter ranges for mule deer (PAPA, NorthWR, and SouthWR) that varied in intensity of energy development.

Quantifying Use of Available Forage

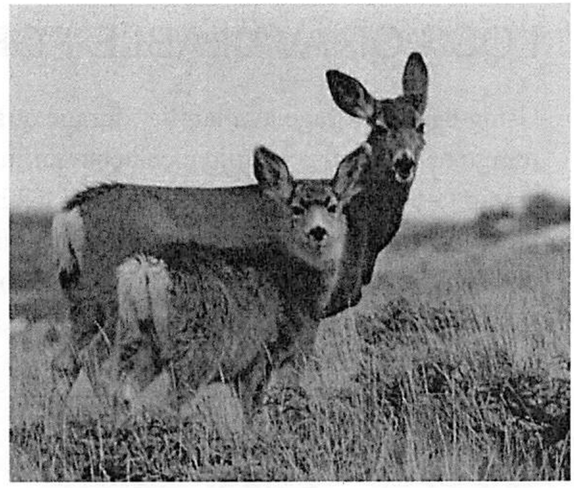


Habitat Biologist, Jill Randall, measuring annual leader growth of sagebrush at one of our forage transects in the autumn.

In the spring, we measured use of forage by counting the number of sagebrush leaders that were consumed overwinter.

We established 150 forage transects across all three winter ranges to quantify annual availability and use of forage. Each autumn, before animals arrived to winter range, we measured forage availability by measuring annual leader growth of sagebrush (i.e., sagebrush production). In the spring, after animals left winter range for summer range, we returned to those same forage transects and measured how many leaders of sagebrush were consumed throughout the winter. At each transect, we also evaluated the quality of forage (e.g., % crude protein, digestibility, and presence of toxins), topographical features, climate (e.g., snow water equivalent), and proximity to energy development.

BEHAVIORAL REPONSES



Using GPS collar data and behavioral observations, we evaluated how mule deer respond behaviorally to human disturbance resulting from energy development on winter ranges. Overall, mule deer avoided human disturbance across multiple behavioral scales (Fig. 2). Furthermore, when near human disturbance, mule deer were increasing their movements and spending more time in vigilant behavior (which means less time for feeding). These behavioral responses of avoidance compromised the ability of mule deer to use forage that was available to them. Consequently, use of available forage was less near human disturbance compared with use of available forage away from human disturbance (Fig. 3). This left food unused near human disturbance that would have otherwise been consumed in its absence.

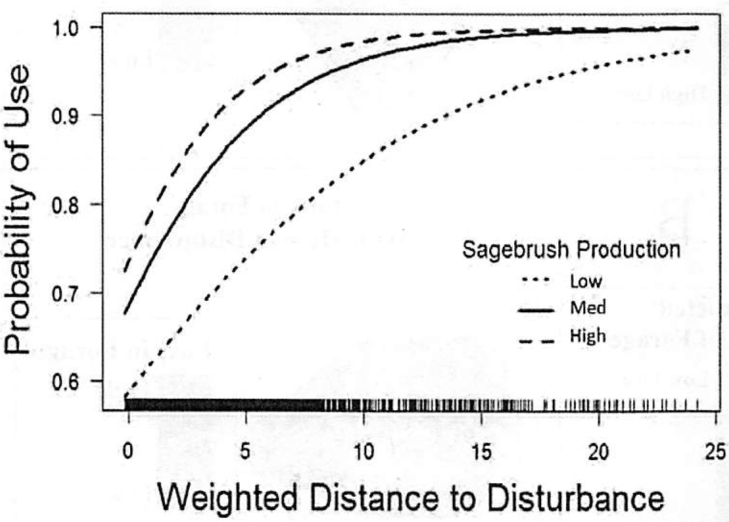


Figure 2. Behavior in habitat selection resulting from our analyses of resource selection functions revealed that animals were avoiding habitats near human disturbance and the probability of use decreased closer to disturbance. Furthermore, when sagebrush production (average annual leader growth) was low, avoidance of habitats near disturbance was even greater. The weighted distance to disturbance was created to capture intensity of energy development and was created by multiplying the distance of the nearest road by the distance to the nearest well pad. The influence of the weighted distance to disturbance on probability of use was non-linear; thus, a quadratic transformation was applied to these data. Units of the x-axis are the transformed, weighted distance to disturbance with the values centered on zero.

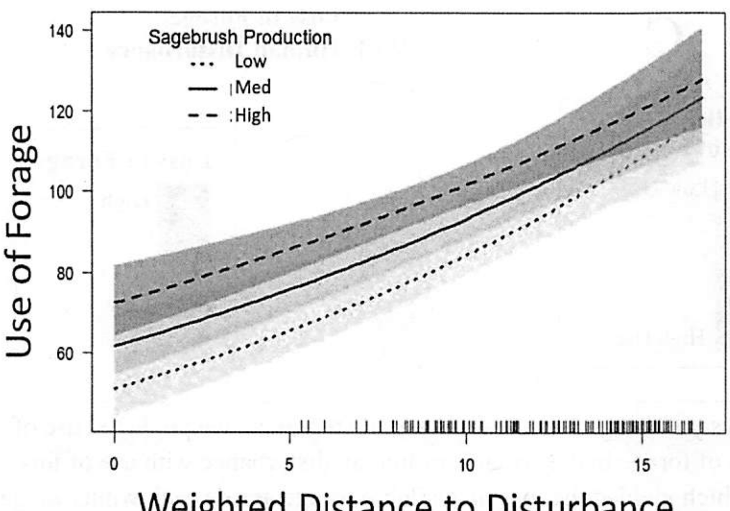


Figure 3. Analyses of data collected from our forage transects revealed that animals were not using available forage near disturbance and use of forage decreased closer to disturbance. Furthermore, when sagebrush production (average annual leader growth) was low, use near disturbance was even less (dotted line). The weighted distance to disturbance was also used for these analyses. The influence of the weighted distance to disturbance on use of forage was non-linear; thus, a natural log transformation was applied to these data. The gray-blue bands represent 95% confidence bands for the weighted distance to disturbance coefficient. Units of the x-axis are the natural log transformation of the weighted distance to disturbance. Units of the y-axis are the number of leaders consumed at a transect.

LOSS OF AVAILABLE FORAGE

Using data on forage availability, forage quality, and use of forage, we quantified the loss of available forage resulting from avoidance behavior in response to human disturbance. First, we quantified the amount of forage lost because of direct habitat loss (i.e., development of well pads and roadways) and then quantified the loss of forage resulting from avoidance behavior (i.e., indirect habitat loss). Through this comparison, with every 1% of forage lost to direct habitat loss, there was an additional 4.6% loss of forage resulting from behavioral avoidance across all winter ranges (Fig. 4). These results revealed the multiplicative effects of human disturbance on the loss of forage for mule deer on winter ranges.

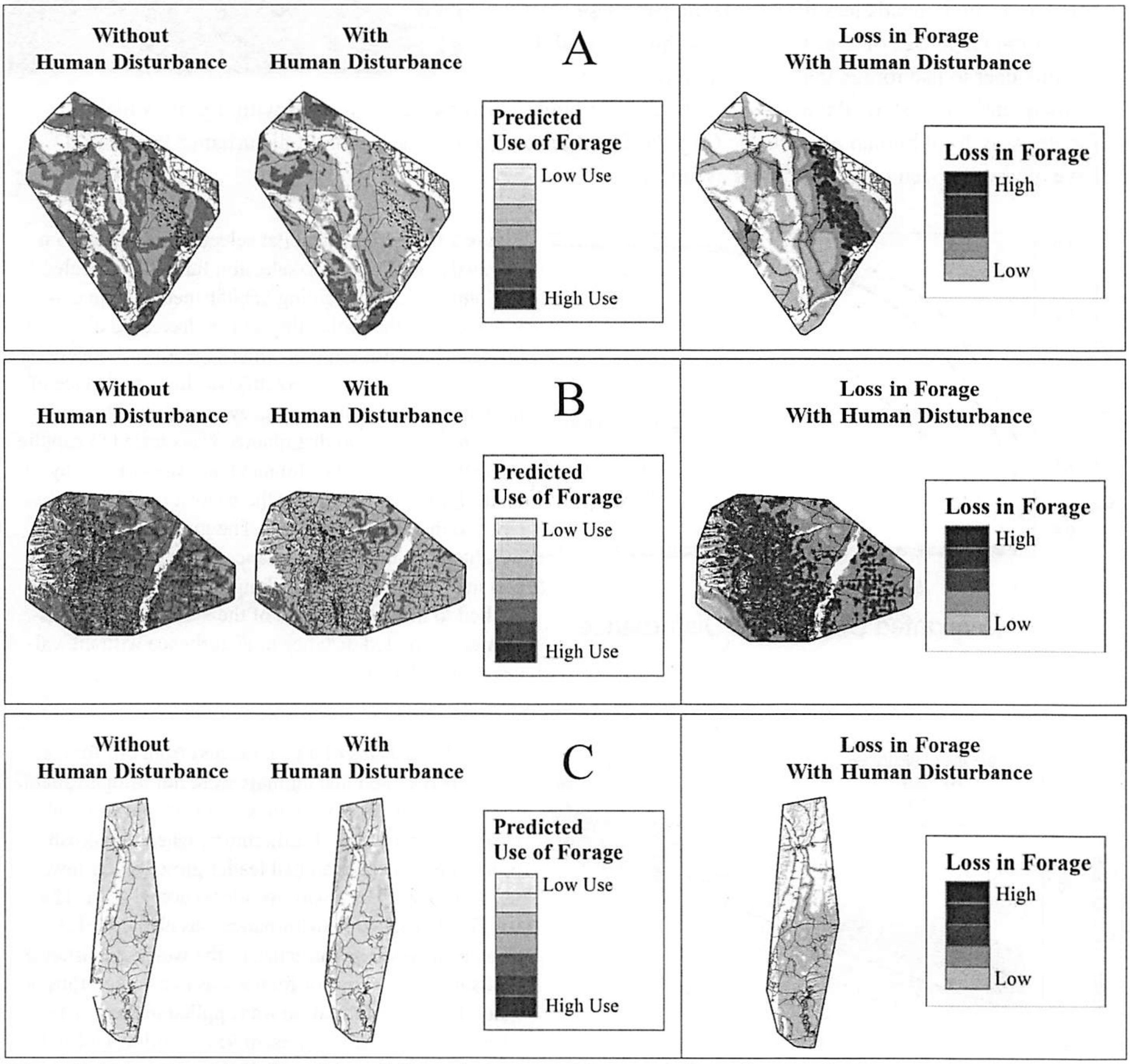


Figure 3. Using the statistical model used for analyzing use of forage relative to human disturbance, we predicted use of forage across winter ranges. We compared predicted use of forage in the absence of human disturbance with use of forage with human disturbance present on the landscape, which yielded the loss in available forage across each winter range as depicted in each panel: A—PAPA, B—NorthWR, and C—SouthWR.

MANAGEMENT IMPLICATIONS

Planning for Future Development

To meet demands for energy resources, development of infrastructure for oil and gas extraction will continue to occur in Wyoming. Inevitably, development will be proposed on critical ranges for wildlife, including crucial winter ranges for mule deer. Our research provides wildlife managers and industrial planners with realistic expectations for the effects of energy development on mule deer, because we now have the tools to quantify losses in foraging habitats and the ensuing effects on the carrying capacity of winter ranges. Our research can be used to guide decision makers in finding the balance between extracting the energy resources we need and sustaining the wildlife populations we value.

Hypothetical Scenarios of Development

A common concern among managers and planners is the relative effects that various configurations of energy development may have on wildlife populations. Using the data and models used in analyzing forage loss resulting from avoidance behavior on the three winter ranges we studied, we constructed hypothetical scenarios of various configurations of energy development (Fig. 5) to evaluate how it may affect the overall loss of available forage on winter ranges where development may occur.

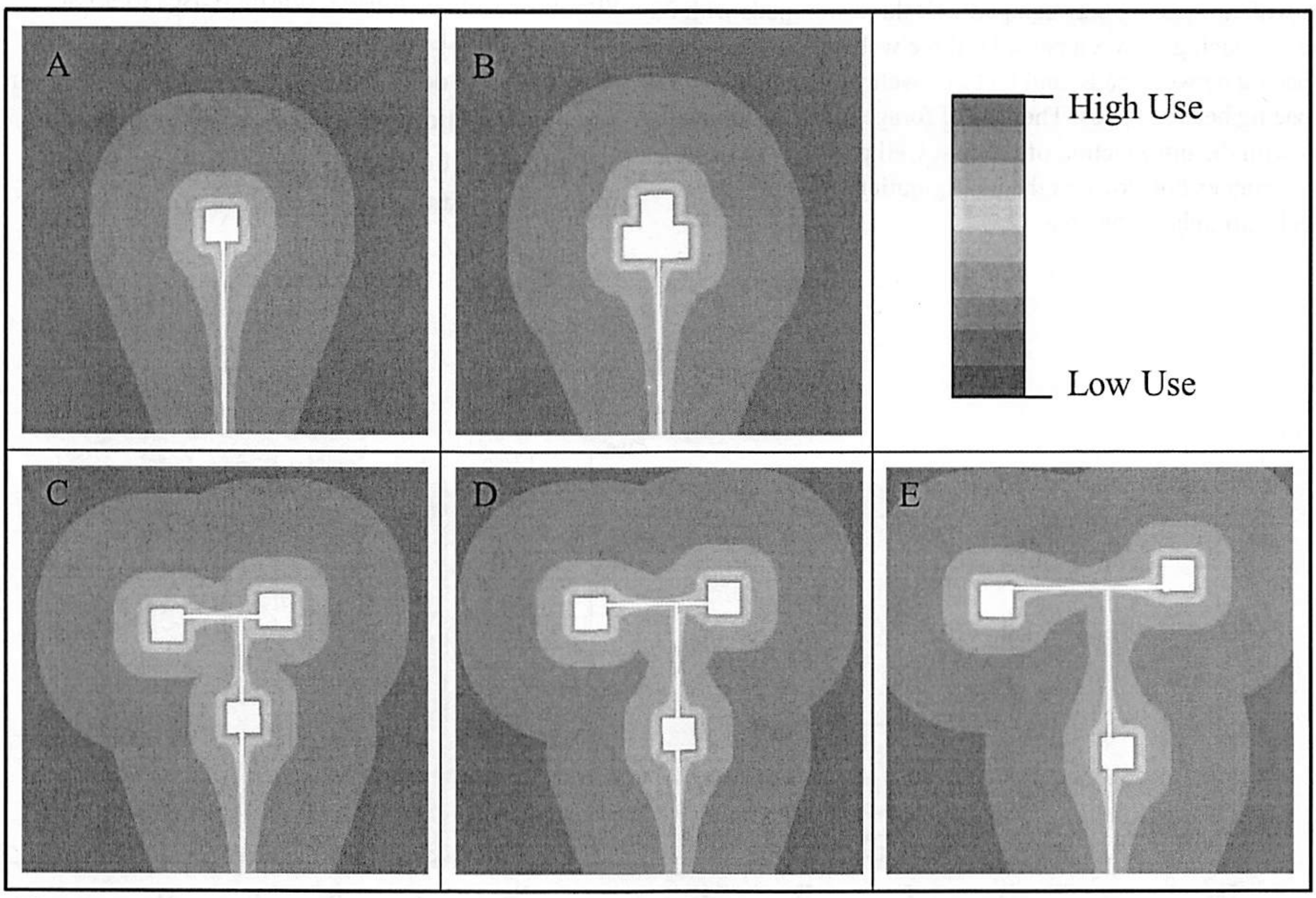


Figure 5. Four scenarios of various well pad configurations including roadways and the effect each scenario has on use of forage. Each scenario is configured as follows: A) one well pad, B) three well pads with no spacing between pads, C) three well pads with 20 acres of spacing between pads, D) three well pads with 40 acres of spacing between pads, and E) three well pads with 80 acres of spacing between pads. Each well pad is 3.7 acres (the average size of a well pad). Scenarios were constructed within an area of one square mile.

Effects of Development Configurations on Use of Forage

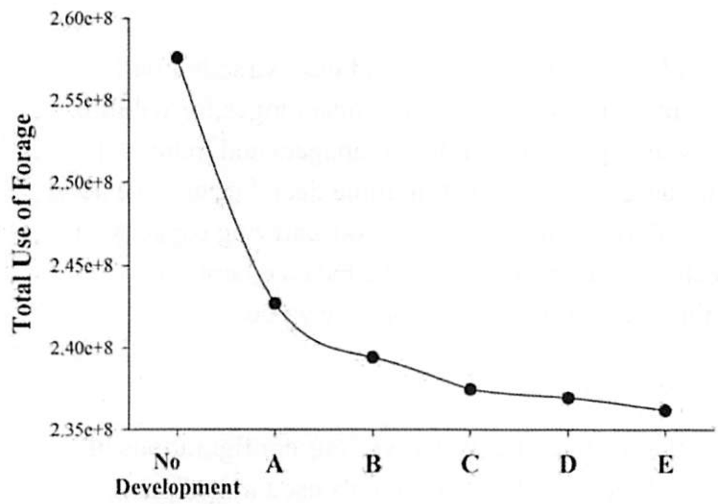


Figure 6. The total use of forage (number of sagebrush leaders consumed within a 1 sq. mile area) under each scenario of varying development configurations: A) one well pad, B) three well pads with no spacing between pads, C) three well pads with 20 acres of spacing between pads, D) three well pads with 40 acres of spacing between pads, and E) three well pads with 80 acres of spacing between pads. The loss of forage increases dramatically with the introduction of the first well pad and the rate of loss continues but slows as the configuration of well pads spreads throughout the area.

Results from our analysis of forage loss under varying hypothetical scenarios of energy development configurations demonstrate that minimizing direct habitat loss (i.e., introducing the least amount of infrastructure to an undisturbed area) has the least effect on loss of forage (Fig. 6). Overall, the more broadly distributed well pads are from one another, (e.g., scenario D at 80 acres) the greater loss in use of forage. Indirect habitat loss resulting from avoidance behavior is maintained under all scenarios but as direct habitat loss increases with the need for more roadway infrastructure under scenarios where well pads a spread out, the overall loss in forage increases (Fig. 7). Furthermore, the area of influence—the area of reduced forage—exceeds 80% of the total area under all scenarios, but increases to 93% when well pads are broadly distributed (Fig. 8). This exercise demonstrates the practical use of our research in guiding future planning of energy development with an eye toward mitigating effects of human disturbance on wildlife populations.

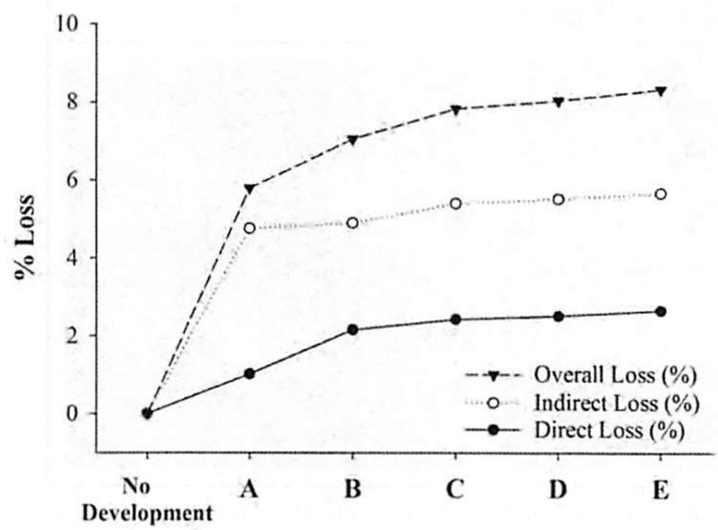


Figure 7. The percent of forage lost to direct habitat loss and indirect habitat loss resulting from avoidance behavior under each scenario of development configurations.

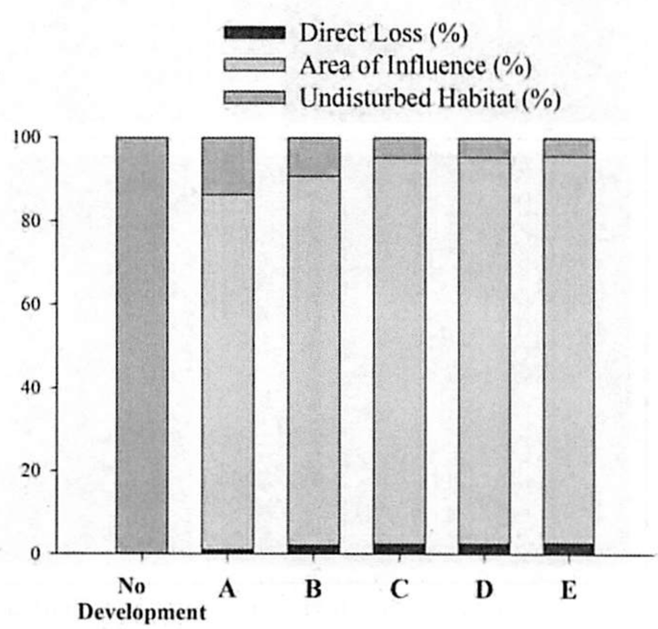
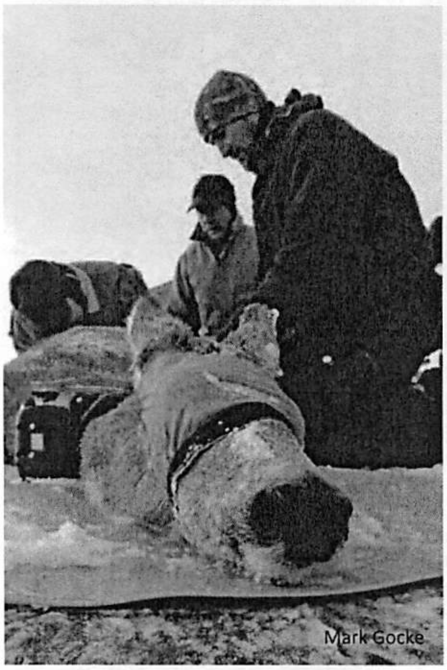


Figure 8. The percent of the area that is influenced by disturbance through a reduced use of forage under each scenario of development configurations.

FUTURE RESEARCH EFFORTS

Throughout summer and winter of 2017, we will continue our research in evaluating the relative influence of various factors that regulate mule deer in the Wyoming Range. The main focus of our future research efforts will be aimed at elucidating the relative influence of predation, climate, and habitat conditions on survival and recruitment of young. Most of this work will be focused on summer ranges; however, we will continue other research in migration ecology and habitat conditions on winter ranges. For example, we will continue monitoring sagebrush production (i.e., measuring annual leader growth at forage transects) and quality through this upcoming winter. Continuing our rigorous research across all seasonal ranges for Wyoming Range mule deer will enhance our understanding of the ecology of this population and will only advance our ability to effectively manage and conserve this cherished herd.



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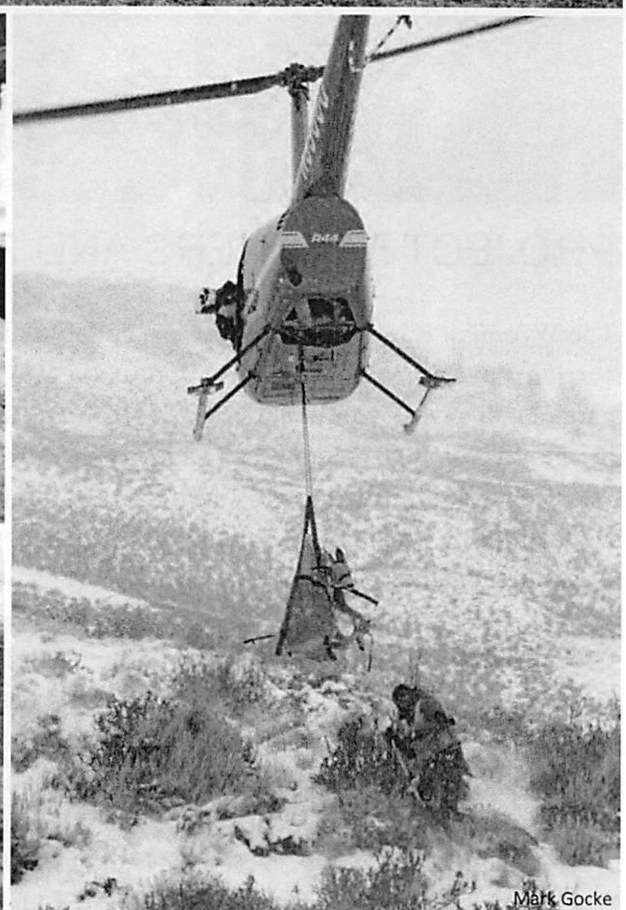

Mark Gocke

Wyoming Range Mule Deer Project: A Brief Update on Population Trends Winter 2017

Winter ranges for mule deer in the Wyoming Range have experienced exceptional winter weather in 2017. With snowpack levels at ~200% of normal and numerous days of sub-zero weather, this winter has tested the resilience of wildlife populations in western Wyoming. Although winter conditions similar to 2017 occasionally occur, it has been many years since we have experienced conditions as severe. Performance of mule deer populations can be affected strongly by winter severity and population declines often occur immediately following severe winters—a trend that has been documented repeatedly throughout the western North America. Fortunately, severe winters do not lead to the demise of mule deer, and populations tend to have the propensity to bounce back. Our research at the University of Wyoming in collaboration with Wyoming Game and Fish Department has documented some interesting (and unfortunately, expected) trends in survival, recruitment, and pregnancy following severe winter conditions for Wyoming Range mule deer. Here, we briefly highlight some of our more marked trends observed in winter 2017 as of mid-March.

Survival—Adults

Before 2017, adult survival for Wyoming Range mule deer was relatively high with an annual survival rate of 92%, and age was the number one factor affecting overwinter survival. Conversely, the severe winter conditions of 2017 have led to only 75% of our marked animals surviving through mid-March. As was expected, adult mortality this winter affected old animals in particular (average age at mortality was 9.7 ± 0.62), with all mortalities being of individuals older than 6 years.

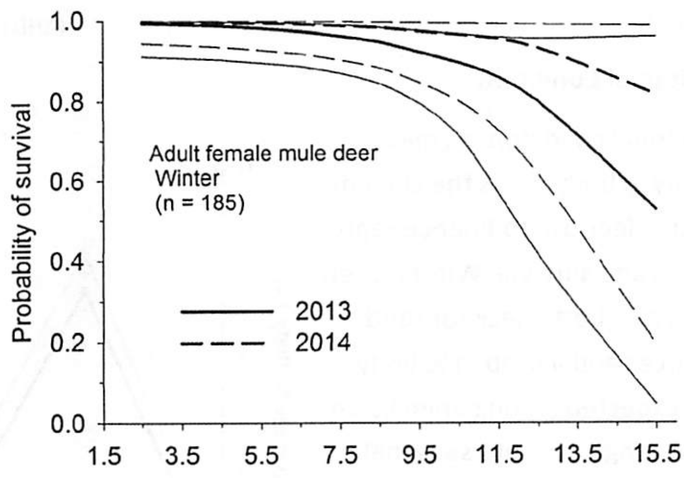
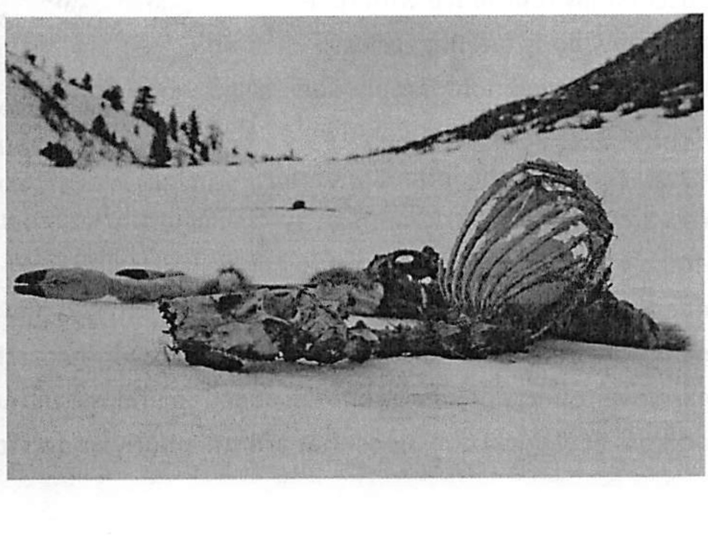
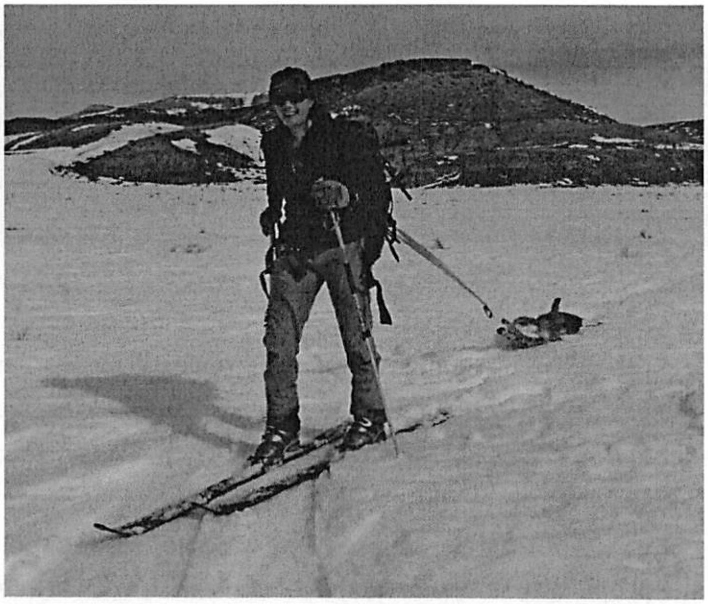


Figure 1: Probability of adult survival throughout the winters of 2013 and 2014. As age of the animal increased, the probability of survival decreased.



Survival—Fawns

Annual fawn survival for most mule deer populations is often lower than adult survival, and it is not uncommon for less than half of the fawns born in June to make it through their first year of life. In the first year of our research evaluating survival of fawns, 45% of fawns born in summer 2015 survived until June 2016; only 17% of annual mortalities occurred during winter. Unfortunately, survival of fawns born in summer 2016 tells a much different story. As of March 5, 2017, only one of the 70 fawns we tracked was still alive— **which equates to a 99% mortality of fawns.** Although fawns tend to be especially susceptible to the effects of winter severity, the winter of 2017 has resulted in an almost entire loss of the cohort of fawns born during the past summer.



We retrieved all remains of mortalities of collared fawns. Whole carcasses were submitted to the Wyoming State Veterinary Lab and WGFD Wildlife Health Laboratory for necropsy and to assess the influence of diseases such as adenovirus hemorrhagic disease (AHD) on winter mortalities.

Nutritional Condition

Nutritional condition, as measured by % body fat, is the currency mule deer use to finance reproduction and survival. Winter often serves as a bottleneck for food resources and a drop in % body fat is expected among animals on winter range. Despite seasonal fluctuations in nutritional condition, unlike many other ungulate species, mule deer still manage to successfully reproduce with relatively low body fat. Regardless, nutritional condition of mule deer in March 2017 was the worst we have seen since the initiation of our research in March 2013 with an average of 1.8% (± 0.25) body fat for deer on winter ranges near Big Piney (i.e., NorthWR) and 2.8% (± 0.30) body fat for deer on winter ranges near Cokeville and Evanston (i.e., SouthWR). Our research this following summer will help us understand the carryover effects of winter on reproduction and recruitment when conditions are severe and will allow us to address ecological questions that are still poorly understood.

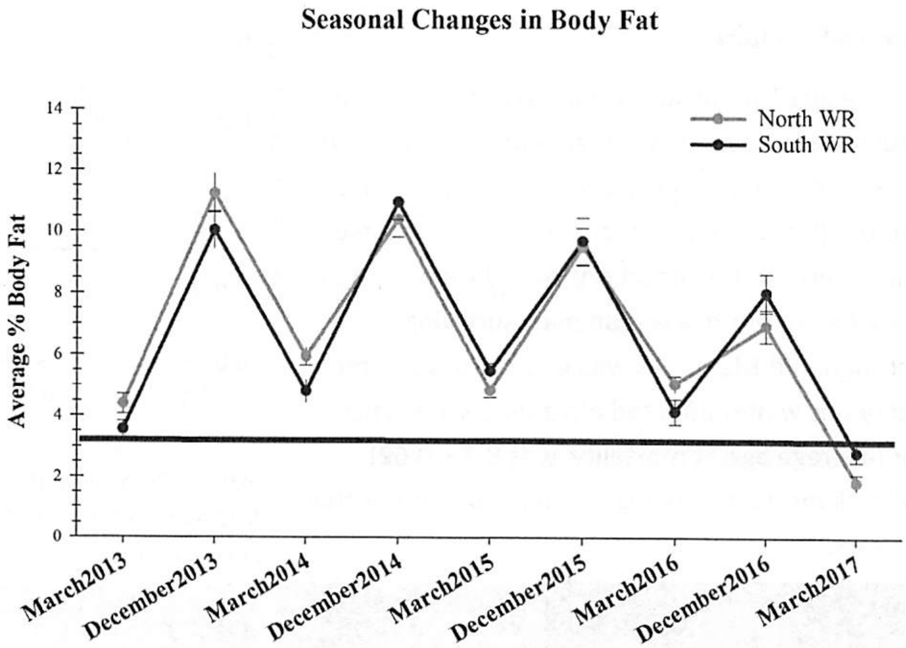


Figure 2: Seasonal changes in percent body fat of mule deer captured as they enter (in December) and leave (in March) winter ranges in the Wyoming Range. The red line marks the lowest average % body fat observed in mule deer of the Wyoming Range prior to March 2017. Note that March 2017 is the worst condition we have observed for the duration of our study.

Pregnancy and Fetal Growth

Pregnancy and fetal rates (number of fetuses per animal) among mule deer tends to be high among populations, and most adults are pregnant with twins. Since March 2013, fetal rates averaged about 1.7. Despite extremely poor nutritional condition of animals this March, fetal rates among winter ranges were 1.6 in 2017—comparable to the preceding 4 years. As also reported in other work, pregnancy rates among mule deer tend to vary little among years (regardless of weather conditions). Interestingly, average eye diameter of fetuses was lower in March 2017 (14.0 ± 0.18) than in previous years (15.3 ± 0.11). A lowered average in fetal eye diameter may indicate suppressed fetal growth coinciding with the significant decrease in % body fat of animals in March 2017. Our subsequent research this summer will help us better understand the ability of animals to successfully provision the resources needed for rearing young following severe winter conditions on winter ranges.

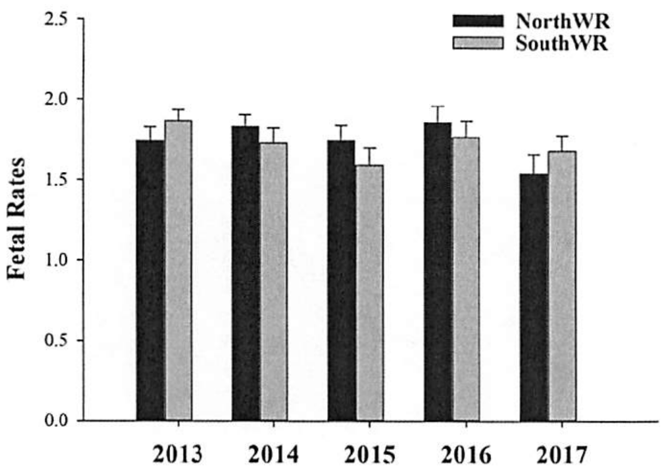


Figure 3: Fetal rates of Wyoming Range mule deer on NorthWR and SouthWR winter ranges. Although most animals had low % body fat in winter 2017, fetal rates in March 2017 did not significantly differ from previous years.

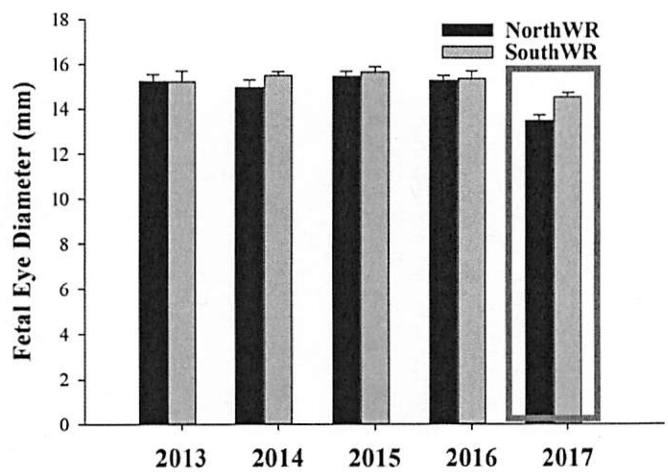


Figure 4: Fetal eye diameter of Wyoming Range mule deer on NorthWR and SouthWR winter ranges. Fetal eye diameter in 2017 (outlined in red) was lower than what was observed in previous years potentially indicating suppressed fetal growth over winter.

Future Research Efforts

Throughout summer 2017, we will continue our research efforts aimed at elucidating the relative influence of predation, climate, and habitat conditions on fawn survival in the Wyoming Range. The severe winter conditions of 2017 will provide us with a unique opportunity to evaluate how severe winter weather may influence the ability of females to subsequently rear young, and thus, provide valuable insight into the factors that regulate population growth and examine the prospects for recovery of this cherished herd.

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Photo: Mark Thonhoff

HAUB SCHOOL OF ENVIRONMENT AND NATURAL RESOURCES

NUTRITIONAL DYNAMICS AND INTERACTIONS WITH DISEASE IN BIGHORN SHEEP

FALL 2017 UPDATE

UW UNIVERSITY OF WYOMING

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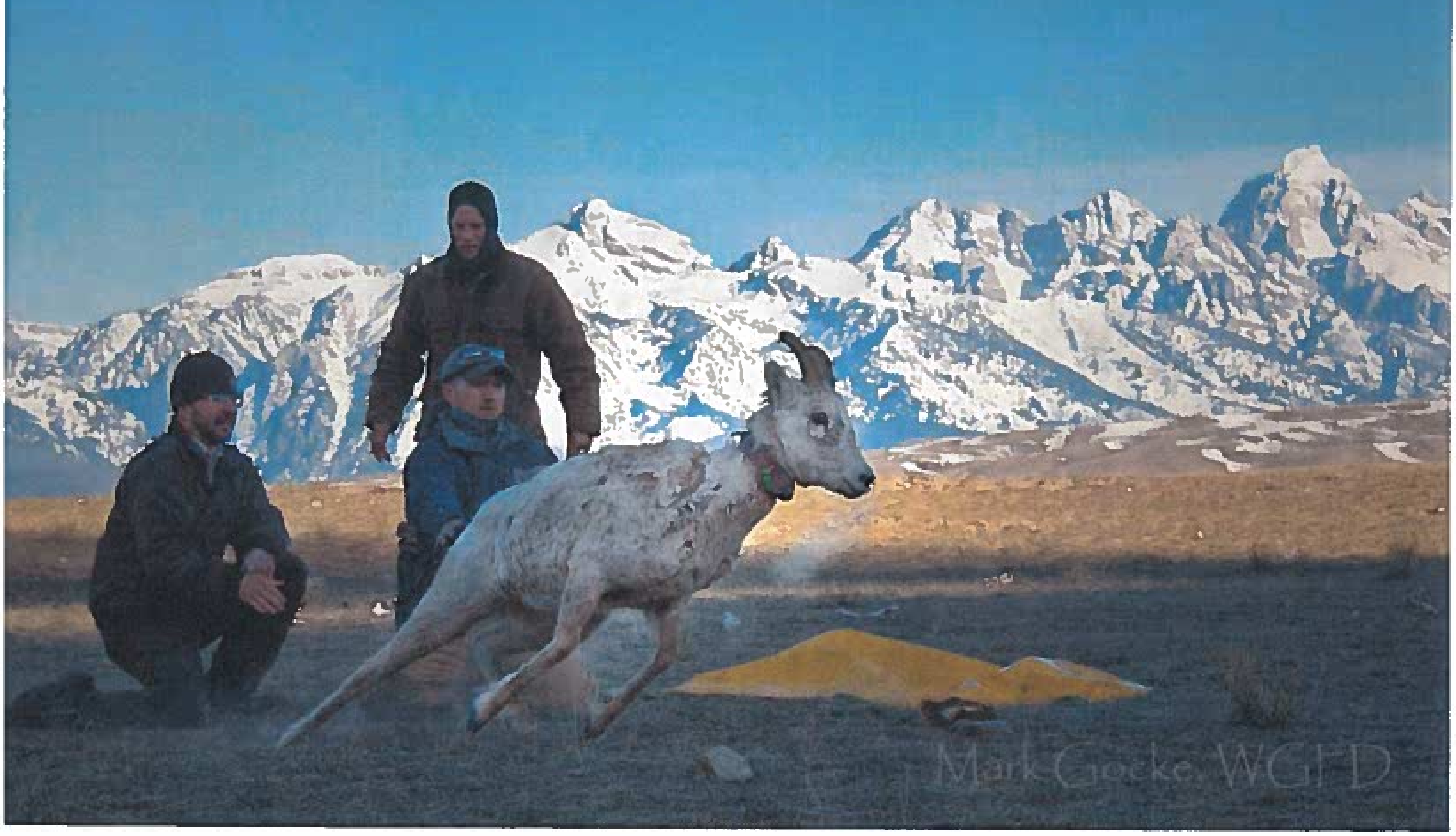
INTERACTIONS OF EPIZOOTIC PNEUMONIA & NUTRITION IN BIGHORN SHEEP

The entrance of epizootic pneumonia to bighorn sheep populations muddles the already complicated processes underlying population dynamics, and is often the culprit for massive crashes of sheep populations. Although pneumonia caused by bacterial respiratory pathogens is known to be the underlying driver of massive mortality events, the frequency and intensity of dieoffs are inconsistent, and infections are not always manifested in disease. Therefore, dieoffs may be dependent upon certain ecological or environmental conditions—the understanding of which could yield management alternatives to help reduce the frequency of outbreaks. Identifying how disease, nutrition, and population densities interact is critical in developing management options for and improving our understanding of pneumonia in bighorn sheep.

In Wyoming, the Statewide Bighorn Sheep Disease Surveillance Program, led by the Wyoming Game and Fish Department, has documented many bacterial pathogens in herds across the state. While some herds continue to do well, others have undergone repeated pneumonia outbreaks and recoveries, and others have never recovered from dieoffs. By adding long-term research on bacterial pathogens, nutritional condition, survival, pregnancy, and lamb recruitment in female bighorn sheep from three herds over time to the ongoing Disease Surveillance Program, we can work to disentangle the relative roles of each of those components on crashes and recoveries of bighorn sheep populations throughout the state.



BIGHORN SHEEP CAPTURES & DISEASE SAMPLING

Starting in March 2015, the Haub School of Environment and Natural Resources, Wyoming Cooperative Fish and Wildlife Research Unit, and the Wyoming Game and Fish Department, in collaboration with the US Fish and Wildlife Service, the Shoshone and Arapaho Tribes of the Wind River Indian Reservation, and the National Elk Refuge captured adult female bighorn sheep in the Jackson, Cody, and Whiskey herds of northwest Wyoming. Each December and March thereafter, our objective was to recapture those same adult females to monitor how their recruitment status, disease status, nutritional condition and reproduction status varies seasonally. Adult females were captured via helicopter netgunning (Jackson and Whiskey herds) and ground darting (Cody herd). Each subsequent winter and spring, we have attempted to recapture those females. In the spring of 2017, we also included the Temple Peak herd and captured 11 animals from that population.

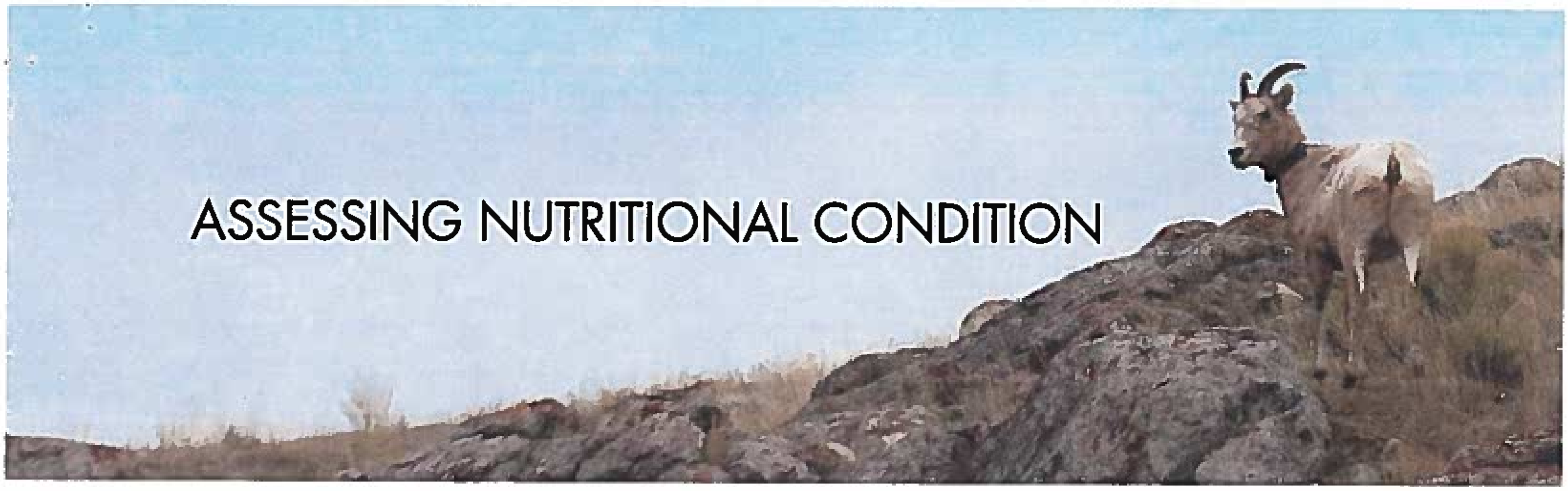
During captures, numerous disease-related samples are collected from each animal including nasal and tonsil swabs, feces, and blood following protocols established through the Statewide Bighorn Sheep Disease Surveillance Program. Samples are currently being analyzed by the Wildlife Disease laboratory to identify respiratory pathogens and macro-, and micro-nutrient levels. Future work will seek to assess whether previous experiences of individual animals affect their probability of becoming infected, becoming symptomatic, and their subsequent effects on vital rates. Results from these analyses are forthcoming.

A bighorn sheep from the Jackson herd with visible symptoms of *Ecthyma contagiosum* in the spring of 2016.

In addition to disease testing, we measured nutritional condition using a combination of ultrasonography and body condition scoring based on standardized methods developed for bighorn sheep for each captured animal. Nutritional condition of an animal is a product of its environment and therefore, represents the energetic gains and deficits experienced by an animal, as well as the nutritional reserves it carries into the upcoming season. Assessing nutritional condition of an animal is a critical step in understanding how disease, the environment, pregnancy and recruitment interact to affect bighorn sheep populations throughout the state.

We also estimate age using a combination of toothwear and replacement patterns, and by counting horn annuli. Age data are critical to understanding behavior, nutritional condition, reproductive performance, and disease exposure of individuals

ASSESSING NUTRITIONAL CONDITION



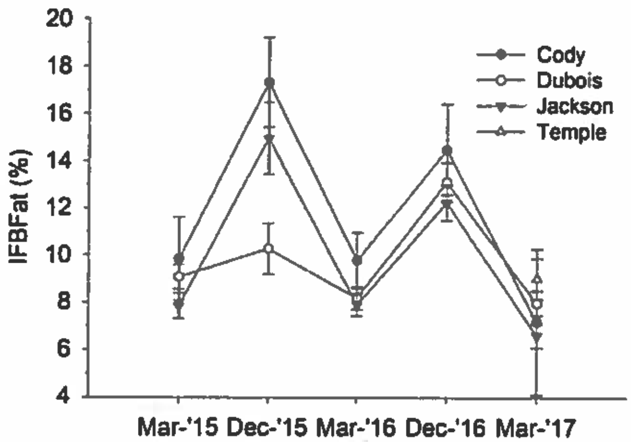


Figure 1. Ingesta-free body fat (%±SE) of adult female bighorn sheep from March 2015 to March 2017 in the Cody, Dubois, Jackson and Temple Peak herds.

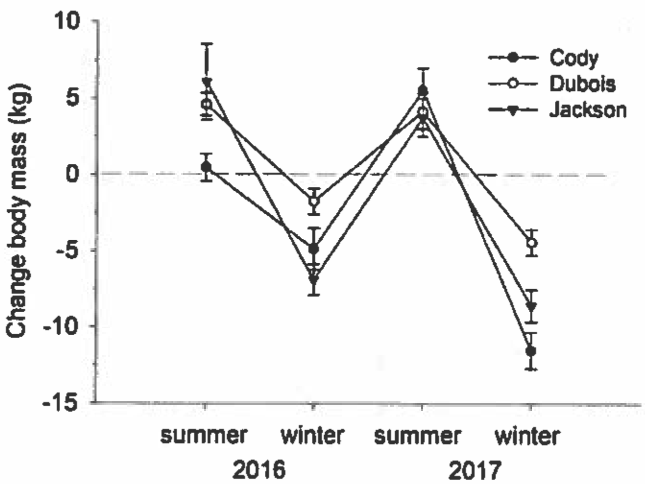


Figure 2. Change in body mass (%±SE) of adult female bighorn sheep between summer and winter in 2016 and 2017 in the Cody, Dubois and Jackson herds.

As of the summer of 2017, some of the most interesting results stem from nutritional dynamics across the different populations. The Dubois herd appears to be nutritionally limited on their summer ranges, while experiencing adequate winter conditions. Conversely, the Jackson herd appears to have robust summer ranges, but experience poorer conditions when on winter ranges than the Dubois herd. Finally, the Cody winter and summer ranges appear to fall somewhere in between those in Dubois and Jackson.

REPRODUCTION AND RECRUITMENT

Each spring, we determine pregnancy status of captured females, and if a female is pregnant, measure the eye diameter of her fetus. Size of eye diameters allows us to estimate growth of a fetus and predict parturition dates of the mother. Interestingly, pregnancy rate of the Dubois herd has remained relatively constant across the three years of this study, while pregnancy rate of the Cody herd has steadily declined and pregnancy rate of the Jackson herd first increased slightly in 2016 and then dropped substantially in 2017.

Each fall, we conduct recruitment surveys in all three populations to determine which females successfully raised offspring through the summer. During winter captures, we also assess lactation status of females, which can provide additional evidence of recruitment (if a female is still lactating), or if she lost her offspring earlier in the summer or fall (if she is no longer lactating). Lactation rates and thus, lamb recruitment was particularly poor for sheep in Dubois during summer 2016.

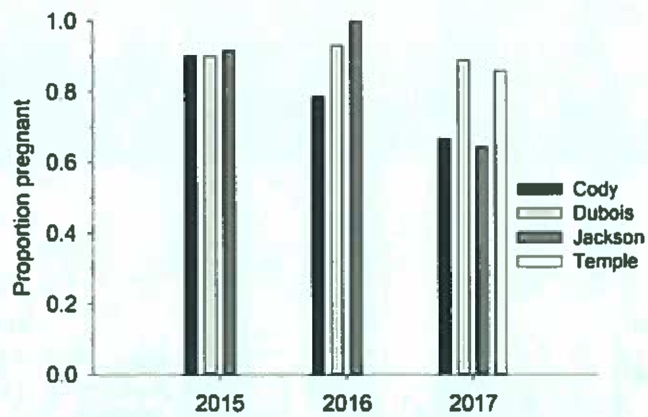
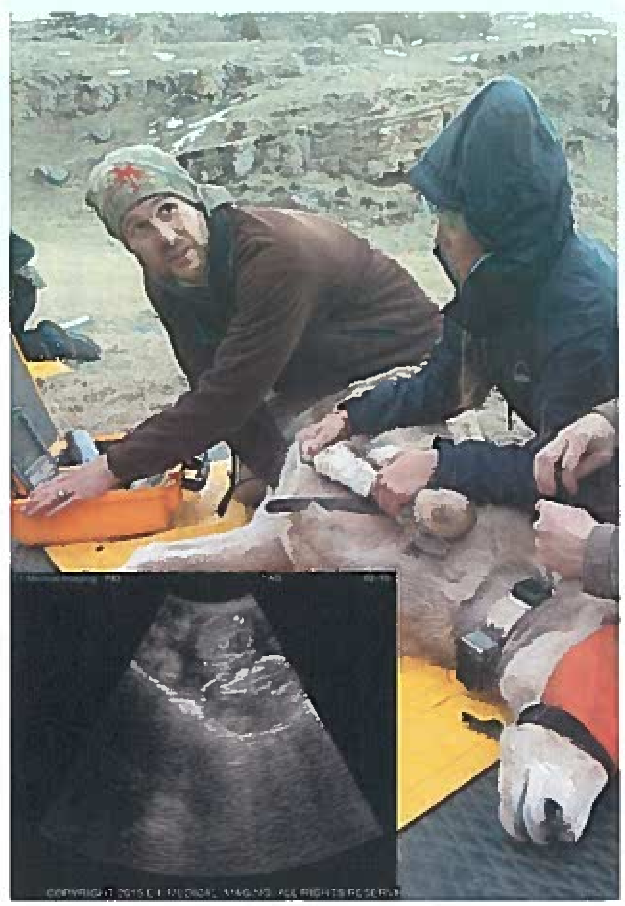


Figure 3. Proportion of pregnant adult female bighorn sheep in March 2015 -2017 in the Cody, Dubois, Jackson and Temple Peak herds of northwest Wyoming.



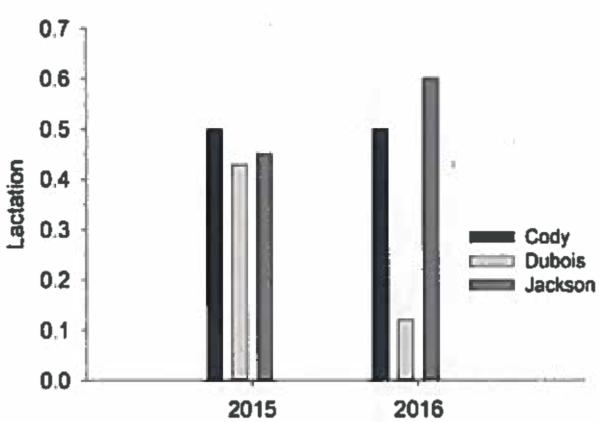


Figure 4. Proportion of adult female bighorn sheep that were lactating in December 2015 and 2016 in the Cody, Dubois, and Jackson herds of northwest Wyoming.

DISENTANGLING THE INTERACTION OF DISEASE AND THE ENVIRONMENT ON BIGHORN SHEEP POPULATIONS

Piecing together how nutrition, disease, and vital rates of populations interact to influence the overall health and success of a herd is paramount in effective management of bighorn sheep populations. Our work thus far has demonstrated that nutrition is an important part of the equation when attempting to understand how population characteristics influence crashes and recoveries of bighorn sheep populations and may play one of the most important roles in regulating populations of bighorn sheep.

Although efforts are still underway to process and analyze current data, a few meaningful and yet, intriguing patterns have emerged. First, through the longitudinal study design, which includes recaptures in both winter and spring, we have identified differences in the seasonal ranges of the three herds. This is especially important in Dubois, where summer ranges appear to be lacking in nutritional quality and potentially influencing recruitment of offspring, despite a relatively high and constant rate of pregnancy. In 2016, recruitment in the Dubois herd was surprisingly low and the costs of lactation (when females did successfully recruit young) was much higher in Dubois than in the other two ranges, providing further evidence that there are differences in the summer ranges among the three populations that influence performance and the condition that a female enters winter in.

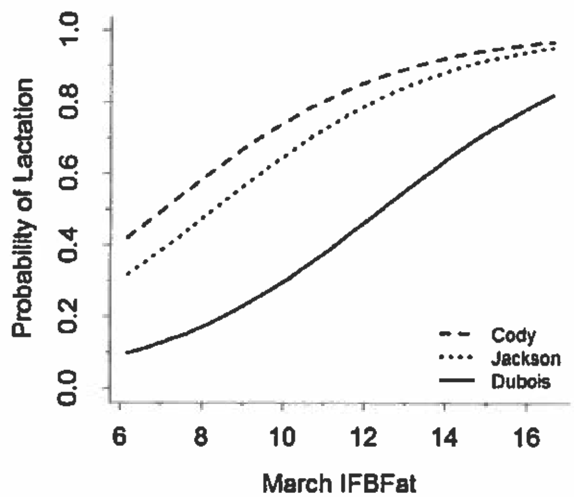
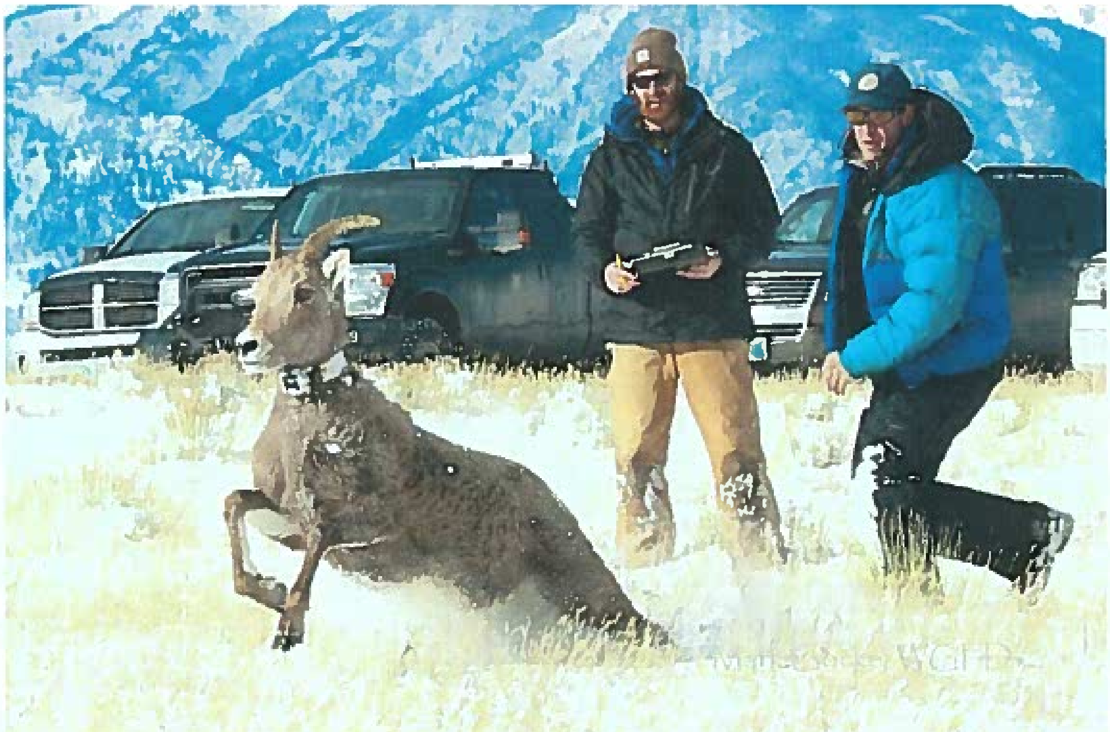


Figure 5. Probability that a female bighorn sheep was lactating (and therefore likely recruited offspring) in fall based on her ingesta-free body fat in spring for the Cody, Jackson, and Dubois herds.



We also observed a decline in the nutritional condition (in both autumn and spring) of females in the Jackson herd through time, which is linked to a decline in pregnancy rates of that population over the past three years. That corresponding change in both nutritional condition and pregnancy could be evidence of the Jackson herd reaching nutritional carrying capacity and thus, could indicate that a potential dieoff may be imminent. Finally, despite some differences across the three ranges, we found that seasonal nutritional condition is linked strongly to pregnancy, recruitment of young and seasonal change in condition of bighorn sheep in northwestern Wyoming.

Understanding how nutrition, disease, survival, pregnancy, and lamb recruitment in female bighorn sheep from these three herds interact to influence population dynamics is critical in developing management plans to maintain healthy populations of one of our most cherished ungulate species in Wyoming.

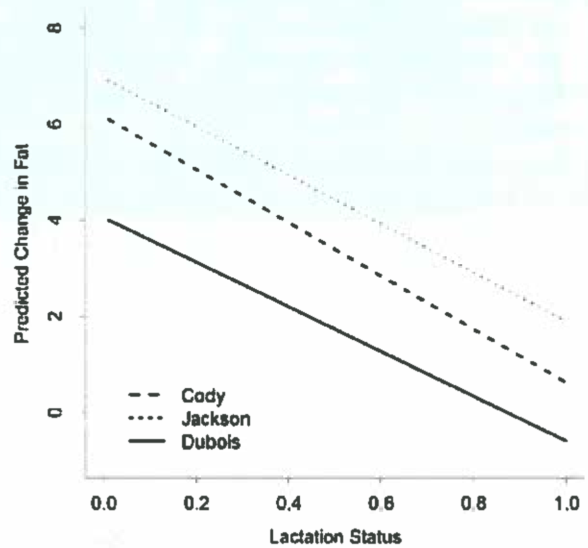
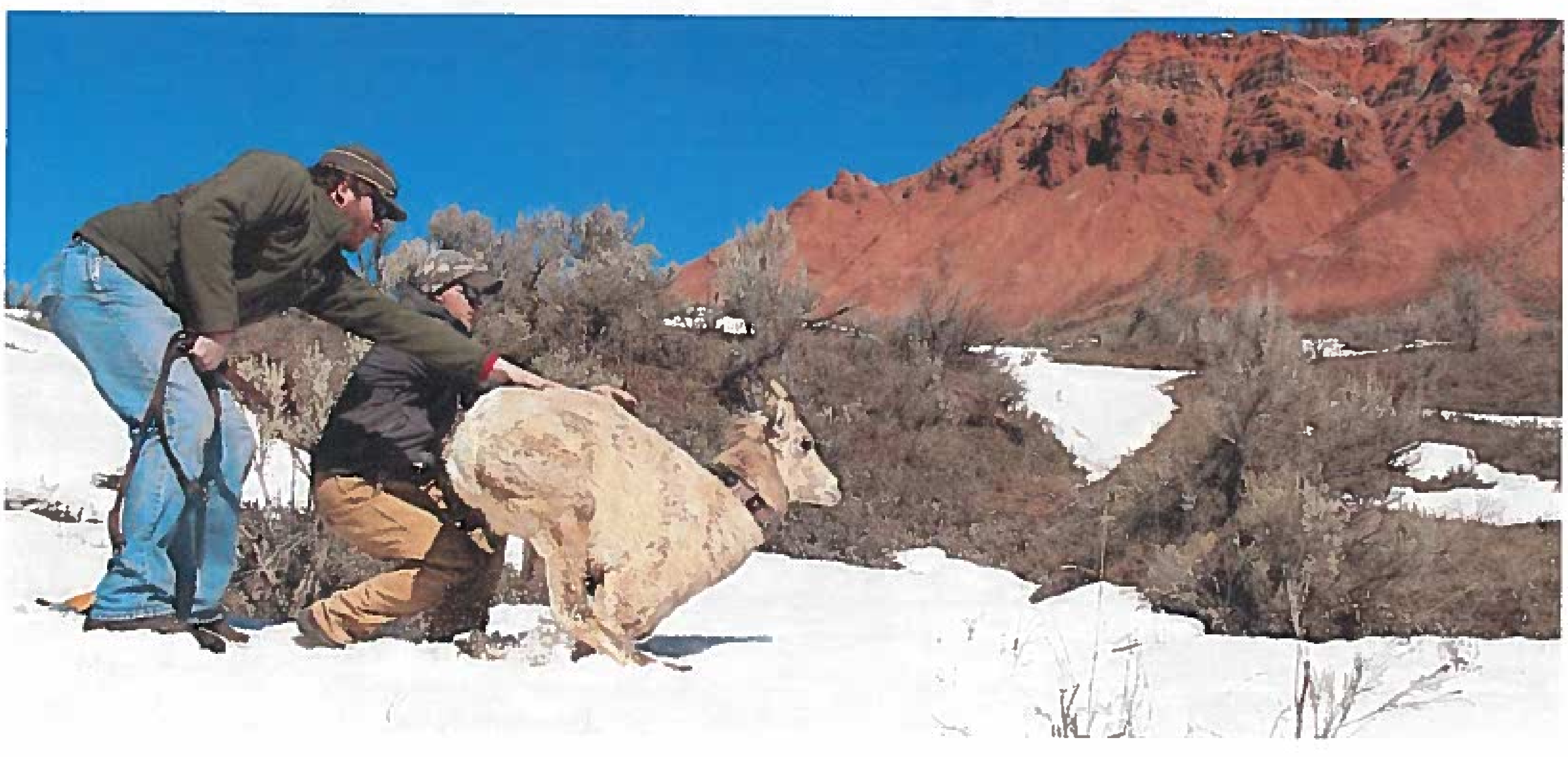


Figure 6. Predicted change in fat over summer of female bighorn sheep based on lactation status, weight in spring, IFBFat in spring, age, and pregnancy status in spring, for the Cody, Jackson and Dubois herds.

LOOKING FORWARD

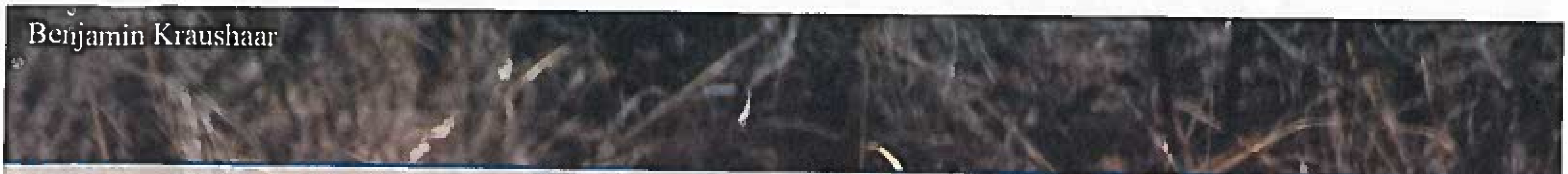
Our efforts over the past three years of captures and monitoring of bighorn sheep in northwest Wyoming marks what we hope to be the first step in exploring the disease-nutrition interface in bighorn sheep, and to develop an understanding of the range limits (i.e., nutritional carrying capacity) of our sheep populations in northwest Wyoming. With time, our goal is to piece together each female's history to describe how she interacts with her environment, understand her success to survive and reproduce or lack thereof, and how she fits within the population in which she resides. By piecing together the histories of each female we monitor, we hope to add an important piece to the puzzle of the complex interactions of environment, disease, and dynamics of our cherished bighorn sheep populations.

Given evidence to date of factors currently affecting sheep in northwest WY, our hope is to continue recapturing and monitoring sheep in the Jackson, Cody, and Dubois herds until the winter of 2020, while digging deeper into quantifying summer nutrition and measuring survival of young. To monitor the reproductive efforts of these populations more closely, our goal is to capture and collar neonate bighorn sheep in the Dubois and Jackson herds in the summers of 2019 and 2020, monitor their survival, and identify causes of mortality. Furthermore, we hope to gain a better understanding of the nutritional contributions of summer range through diet analysis and vegetation assessment on the summer ranges of both the Dubois and Jackson herds.



It has become clear that the fundamental components underlying any large ungulate population (e.g., habitat quality and quantity, and density dependent interactions) remain operational, even in the presence of disease. Our work to date has demonstrated that indeed, infected populations are not divorced from fundamental nutritional dynamics and instead, suggests that nutrition may well be a key explanatory factor, along with disease, of the disparity in performance across sheep herds in northwest Wyoming.

Through this work, we have the opportunity to more effectively manage bighorn sheep and their habitat through science, potentially demonstrate the value of offering additional hunting opportunity if doing so may mitigate the effects of pneumonia, and demonstrate the value of hunting as a conservation and management tool. Moreover, implicit with our continued work is calibrating models of animal-indicated nutritional carrying capacity for Wyoming sheep, which will increase the toolset for managers to understand how habitat, density, and extrinsic factors such as predation or perhaps disease are regulating these and other populations of bighorn sheep.



THANK YOU!

This project would not be possible without the financial and logistical support of our research partners. Funding has been provided by the Wyoming Wildlife/Livestock Disease Research Partnership and the Wyoming Governor's Big Game License Coalition. We thank the Shoshone and Arapaho tribes for access to lands on the Wind River Indian Reservation, and to the US Fish and Wildlife Service for access to the National Elk Refuge for capture and research. We also thank the numerous folks who took time out of their busy schedules to assist with captures. Thanks to M. Gocke and B. Kraushaar for photographs contained herein.

WYOMING GOVERNOR'S BIG GAME LICENSE COALITION WGBGLC

Wyoming Wildlife/Livestock Disease Research Partnership

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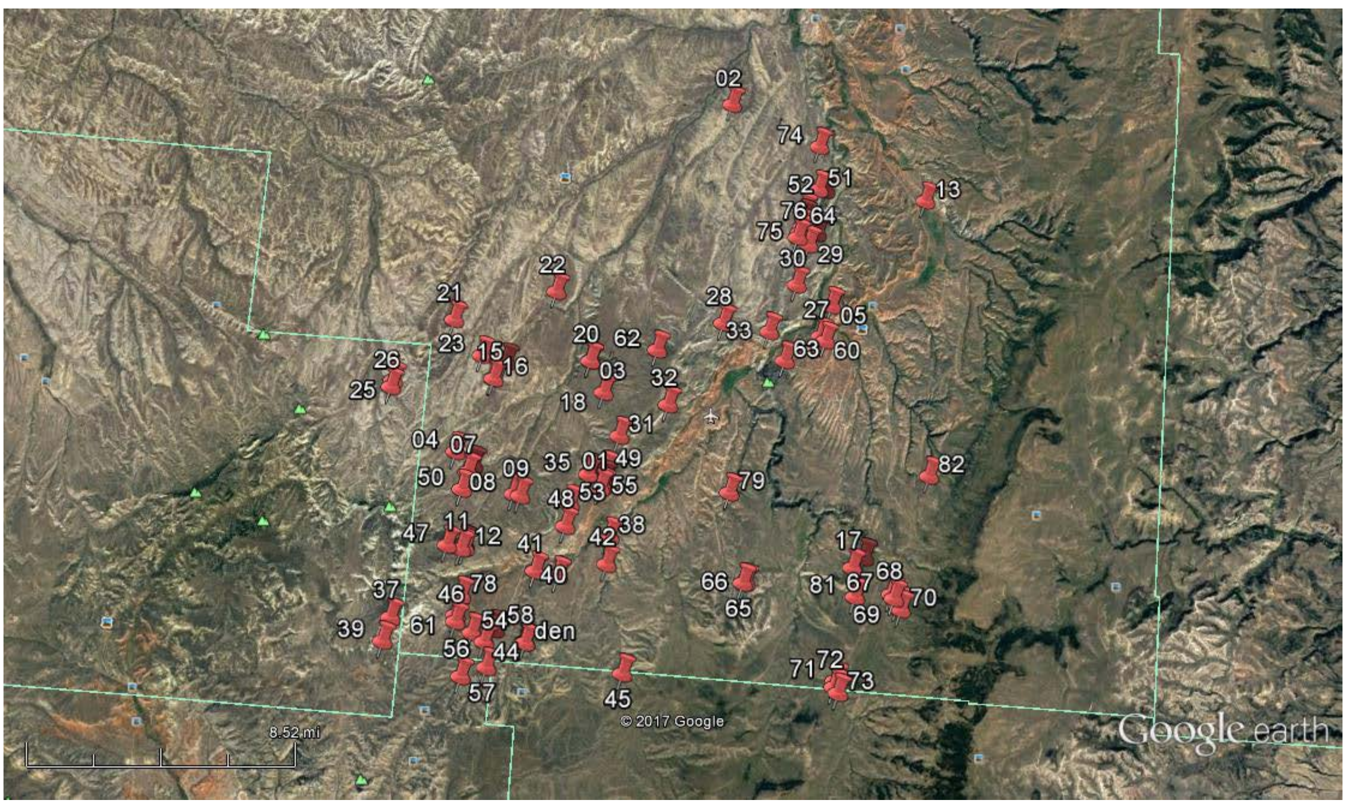
Southwest Bighorns Mule Deer Fawn Recruitment Project, 2017 (1st year of project)

Completed By:
Michael Burrell, USDA APHIS Wildlife Services
Bart Kroger, Wyoming Game and Fish Department

The spring of 2017 is the first season of coyote removal in a three-year project, (if ADMB funding allows) to increase mule deer fawn ratios in the southwest Bighorn Mountains. Coyote removal work was initiated on 3/1/17 and continued until 6/27/17 by Wildlife Services.

There was $10,000 received from the ADMB for this project. These funds were spent on 9.7 hours of helicopter time ($6,630) and 18 hours ($3,000) of fixed-wing time. Additionally, another 216 hours were spent on the ground conducting operational work by 4 different Wildlife Service employees.

The project area comprises of 80,000 acres of State, BLM, and private land. Roughly, 58% public and 42% private land in the upper Nowood Basin. There were a total of 82 coyotes removed: Helicopter: 36; Fixed Wing: 23; Ground Operations: 23.



Aerial image of locations of 82 coyotes removed in the 2017 spring season in upper Nowood.

Wyoming Game and Fish biologists intend to observe and analyze doe:fawn ratios this fall and in the upcoming two seasons to evaluate the effectiveness of the coyote removal project on fawn recruitment. In June of 2017, ADMB once again funded this project another $10,000 for the 2018 spring season. We intend to operate similar to how we did this season.