Enacting Environmental Policy: A Bear of a Task

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Abstract

In 2014, Colorado Parks & Wildlife enacted a multi-pronged strategy with the intention of mitigating threats to the mule deer population. This species has declined in recent decades across the state of Colorado. Various public meetings provided input that predation and degraded habitat were some of the most important factors to mitigate. In 2016, CPW attempted to do just that with the Piceance Basin predator control study. In this study, black bears are included as a predator species to be removed from the designated area in order to determine if mule deer populations respond positively. This case's issues, however, are that the prior public meetings were overwhelmingly held in rural places, and garnered little input from urban residents. Coupling this issue with CPW's second strategy goal of mitigating developmental impacts has left it on the defense. This is because many residents, as expressed in meetings as well as my study, felt that energy development destroyed valuable mule deer habitat. Since the agency's research has suggested otherwise, my goal is not to dispute this but rather, question the lack of holistic research in the heavily developed predator control area. Most residents like black bears, and the effects of energy development on this species has not been explored. My paper has provided a solution that mediates some of the most contentious issues. It involves a newly proposed fund for predator research. By conducting a survey, I determined that public receptivity to additional wildlife funding exists and there are options to pursue it.

Preface

I have always loved being outdoors and learning about nature. I have also always loved finding connections between things and challenging myself to think creatively. When I heard about the Piceance Basin predator control plan, I couldn't stop researching the issue because it encompassed so many of my passions. It involved one of my favorite animals, black bears, and met at the confluence of public policy, ecology, and energy development. Understanding the case was a challenging pursuit, because it contained so many unique aspects. I was so fascinated with the details that I realized I didn't care how long the research would take. That was the day that ultimately led me to pursue this topic in a thesis.

I would like to thank my entire thesis committee, Dale Miller, Steve Vanderheiden, and Carol Wessman for guiding me throughout this experience. I never imagined that I would write a paper this important, or how challenging the process would be. Throughout this time, you've been incredibly, kind, patient, and supportive. Thank you for helping me accomplish something I never thought I could.

I would also like to thank the Undergraduate Research Opportunity Fund for providing me with my first grant. I learned so much about the process, and I am grateful for the opportunity to pursue my interests academically.

INTRODUCTION

Overview

Colorado Parks and Wildlife, which will be referred to by their acronym of CPW for the majority of this paper, are responsible for many things, including managing Colorado's wildlife. Due to the broad scope of their duties and the many factors that interact to affect their efficacy, the agency's decisions are rarely met with total support. This has become especially clear in recent years, as a particular case study grabbed the public's attention.

Enacted earlier this year, two predator culls in the Piceance Basin and Upper Arkansas River areas have spurred staunch opposition byf the general public. These culls were included as part of the 2014 Colorado West Slope Mule Deer Strategy in order to aid the recovery of ailing mule deer populations. In a broader sense, the 2014 plan's goals are to improve habitat quality, mitigate developmental impacts, alleviate the interference of highways on mule deer survival and migration, reduce the impacts of recreational activities, regulate the harvest of does, and maintain established techniques aimed at measuring deer populations in relation to disease (Colorado Parks & Wildlife 2014). This multi-pronged approach appears quite holistic in its address of the issues that are inhibiting the mule deer. However, it is my opinion that solutions such as the predator cull do not entirely address relevant ecological concepts or the opinions of the public to which the agency is responsible.

The predator control plans focus strictly on two apex predator species, black bears and mountain lions. For this thesis, I have decided to focus on the black bear aspect of the study. Mountain lions are charismatic megafauna, important to both the natural

ecosystem as well as the public. However, the majority of the conflict surrounding these studies seem to stem from a perceived lack of sound science. Mountain lions are part of the carnivorous family Felidae, so I am less inclined to believe that they are not contributing to mule deer declines, even if by a barely measurable amount. Black bears, on the other hand, exhibit entirely different behaviors and feeding habits. The decision to cull them to test the hypothesis of increased rates of predation raises more questions for me personally, and I do not believe my thesis can adequately cover the scope of both species.

Through this paper, my goal is not necessarily to refute the scientific research compiled by so many highly skilled biologists and wildlife managers working for and with CPW. However, I raise questions regarding the focus of the Piceance Basin predator control study. Its location and supporting research is in direct conflict with CPW's goal to mitigate developmental impacts. Energy companies are heavily involved in the area, and there has been basically no holistic research on their impacts on wildlife. While CPW found they are not contributing to mule deer declines, there has been no address of the predator species. Assuming that the eventual results of the Piceance Basin study prove predation is a substantial limiting factor on certain mule deer populations, I still fear that these studies may not address the root cause of the issue. Rather than focus on *how* the mule deer are declining through predation, it would be pertinent to study *why* the mule deer are declining through predation. Otherwise, the factors influencing increased predation rates will continue, and the problem will persist. If these root causes could be determined and addressed, a long term solution can potentially be found.

The method of maintaining ecosystem health that I am advocating for is best known as adaptive management. Adaptive management is comprised of four parts: learning, describing, predicting, and doing (Argent, 2009). The first stage involves learning about the system through observation and other monitoring efforts. The second utilizes graphics and simulations in order to visualize the system. Prediction estimates the merits of a potential solution. Doing involves carrying out management decisions. In addressing the mule deer decline, CPW did not assess, or learn, about the entire system. They studied the prey species of concern, but not the animals preying on them. The implementation of the Piceance Basin predator control study was a decision to determine if the ends justify the means. It is a study that overlooked influences that may confound their results, only to the detriment of predator species.

This thesis is a combination of analysis and critique of the established literature and policy, coupled with a novel public policy survey and recommendations to redirect wildlife management foci. My goal is to address the concerns of the general public from the dual perspectives of ecologically proven concepts as well as newly suggested public policy initiatives. This has led me to one research question in particular: What modifications could strengthen the goals of the 2014 Colorado mule deer strategy, in a manner that holistically addresses its ecology and public policy concerns? In order to answer this question, I conducted a survey and collected new data on a potential solution that could be employed.

Literature Review

Since the Piceance Basin predator control plan is an ongoing and unique case study, it was primarily informed by previous study efforts by CPW researchers in the area. The Piceance Basin is home to the largest migratory mule deer herd in Colorado, and provides ample opportunity for research efforts on this species. In a study on mule deer survival in the area, it was found that high mule deer densities were resulting in increased rates of mortality (White, Garrott, Bartmann, Carpenter, & Alldredge, 1987). This was primarily caused by starvation due to harsh conditions and inadequate winter forage. At the time, it was determined that reducing predators would not aid the mule deer population's survival. This was because mortality caused by predation was often compensatory to other factors, meaning predator removal would just result in the same number of deer dying, but through malnutrition instead (Bartmann, White, & Carpenter, 1992). The population declined into the early 1990s, and was reduced to just 1/3 of its previous density. This was most likely caused by the population surpassing the carrying capacity of the area and consuming all of its resources. Naturally, when a population has been reduced sufficiently in size, the stressed environment can recover and eventually support growing numbers again. This has not been the case in Colorado, however, where mule deer densities have generally continued to decline.

CPW compared the data gathered from White et al. in the 1980s to recent data collection efforts that began in 2008. After analyzing the equivalent of almost two decades of information, they found evidence to suggest that winter forage in the Piceance Basin is no longer a limiting factor on the population; winter fawn weights had increased by an average of almost 10 pounds, winter fawn survival had doubled to about 70%, and

starvation had been reduced from affecting one third of all fawns to less than 3% (CPW, n.d.). While this initial survival data seems promising, the issue lies in the information gleaned from mortalities. Although most fawns were no longer starving to death in the winter, this did not matter if predation rates still reduced the overall number of newborns that lived to *experience* the winter. According to CPW, December fawn counts have decreased from 79 fawns/100 does to just 49 fawns/100 does (n.d.). CPW also found that predation alone accounted for one in every two deaths of collared fawns and was contributing to an overall newborn survival rate of just 35-40%.

In addition to neonate fawn data collection in 2008, another CPW study was conducted to assess the effects of energy development on the Piceance Basin population. The location of this study was in the herd's overwinter and summer ranges, the same area in which the Piceance Basin study is taking place. Researchers determined that there were generally 0.2 well pads per square kilometer, with the density in different areas ranging from 0-6 per square kilometer (Northrup, Anderson, & Wittemyer, 2015). There were two kinds of pads: producing pads and drilling pads. Mule deer tended to avoid both, but in varying capacities. They exhibited strong avoidance of drilling pads both day and night, and maintained a distance of 600-1000 meters. They also avoided producing pads during the day by up to 600 meters, but not at night. This relates to the finding that they actually preferred cover during the day and open areas at night. The mule deer population exhibited behavioral changes in response to energy development in over half of their summer range during the day, and one quarter of it at night (Northrup, Anderson, & Wittemyer, 2015).

Since this study also found that mule deer in the area migrated quickly through it and with infrequent stops, there were questions of degraded habitat preventing them from lingering. However, this was dismissed with explanations of a threshold for behavioral changes. This implied that the mule deer population responded to the level of development occurring, and altered migration behavior accordingly. While high development areas interrupted many deer activities, areas with vegetation provided them with more optimal conditions to exhibit natural behaviors. This conclusion resulted in the CPW agency determining that habitat alterations due to energy development were not contributing to mule deer declines, which in turn, provided additional support for eventual predator control. Since this research was instrumental in the creation of the Piceance Basin study, it is important to discuss funding sources.

By way of the Colorado Open Records Act, Rico Moore of Boulder Weekly obtained CPW's mule deer energy research funding. In turn, I received the documents and analyzed their contents. They showed that beginning in 2007, oil and gas companies directly donated $1.6 million of the total $2.95 million. They also indirectly contributed an additional $1.19 million through Colorado's severance tax. When these amounts were combined, it revealed that the oil and gas industry had contributed a staggering 95% of funding to the study. While this information alone is not enough to state that the study was influenced by special interests nor is that my intention, these numbers should evoke questions. In order to maintain drilling operations, they would not want to be implicated in the decline of something so central to Colorado's identity. Although energy development negatively affected mule deer behaviors on half of their winter and summer range range, CPW did not imply that any further research was necessary. It is difficult to

believe that such impactful and ubiquitous regional development has not led to any noteworthy negative outcomes, or questions warranting further study. This is especially intriguing when Colorado's recent regulatory history of the industry is considered.

Historically, Colorado has been friendly to industries seeking to develop its natural resources. These companies have lawfully negotiated increases to well pad densities and have even been allowed to use some property taxes to excuse almost 90% of their severance taxes to the state (Davis, 2012). Recently though, shifting politics and constituencies as well as increased conflicts over land have led to a growing resistance to industry activities. Many groups are concerned with its environmental and health consequences. Since Colorado has an abundance of shale oil reserves, many groups have become concerned with the environmental and health consequences of extraction. They have cited grievances including groundwater contamination from drilling, inadequate disposal of wastewater, and poorly sealed pipes creating a buildup of greenhouse gases such as methane. In land disputes, ranchers with surface land rights have fought to keep energy companies with mineral rights from drilling. This has been contentious, and made energy companies a common enemy for the environmental and ranching groups that are usually at odds with one another. As the tension surrounding oil and gas development has increased, the state's government has attempted to address some of the issues.

The coupling of a democratic shift in Colorado's voting base and a growing environmental constituency has allowed the state to make important changes. Of those signed into law, one involved the authorizing agency on drilling operations, the Colorado Oil & Gas Commission. It was made to increase the size of its commission as well as include members with backgrounds in different biological concepts. A second law

mandated that oil and gas operations must be pursued in a manner that complements wildlife conservation efforts. Some urban cities like Longmont and Fort Collins had even voted to ban fracking locally (Layzer, 2016). Although they were struck down by the courts, these and other cities attempts to distance themselves from fracking are indicative of public attitudes toward it. The governmental environmental regulations provide state support that furthers the notion.

BACKGROUND AND CURRENT POLICY

This case spans so many fields of study that it is difficult to provide a concise summary of the relevant information. In the sections, that follow, I have instead attempted to organize them by such topics as general information about the study, its ecology, the extent and implications of energy development in the area, and the current public policy as well as proposed modifications, respectively. It is my intent to illustrate the subtle and blatant conflicts found in the connections amongst these topics that have been overlooked in creating the study, from its planning to implementation.

Predator Control Study Area

The Piceance Basin predator control research project is a currently ongoing study that aims to address black bear predation. The study areas lie across multiple Game Management Unit (GMU) boundaries. For the study, a winter range capture area has been outlined within GMU 22. The predator control area lies adjacent to it in the summer range area and straddles GMU's 22, 31, and 32. Slightly to the east, the area being used as a control covers portions of GMU's 23, 24, and and 33. Although the specific GMU's are not highlighted, CPW illustrated the location below in Figure 1 (see Appendix A).

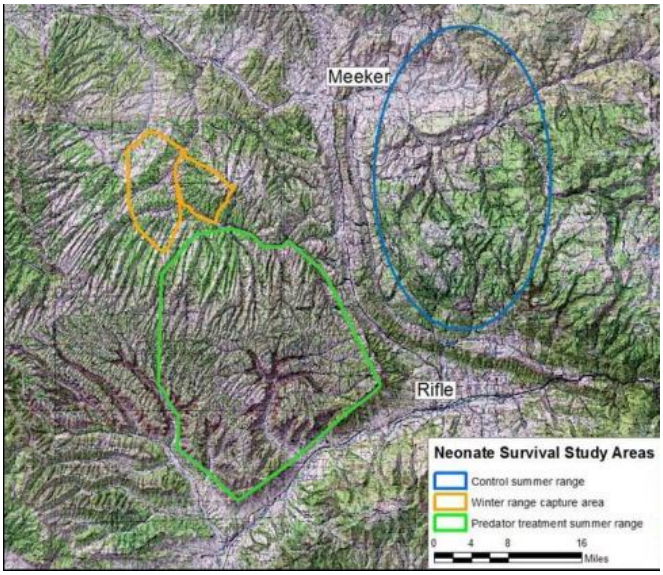

Figure 1. Predator removal efforts are to occur in the treatment area denoted by the green circle, while the control area is illustrated with the blue circle. *Courtesy of Colorado Parks & Wildlife Piceance Basin Predator Management Plan Overview (n.d.).*

The location that was selected is somewhat suspicious, because it calls for predator removal (treatment) in the same summer range that is dotted with hundreds of well pads. The control area that the results of these efforts will be compared to contains zero, as seen below (Figure 2, see Appendix A).

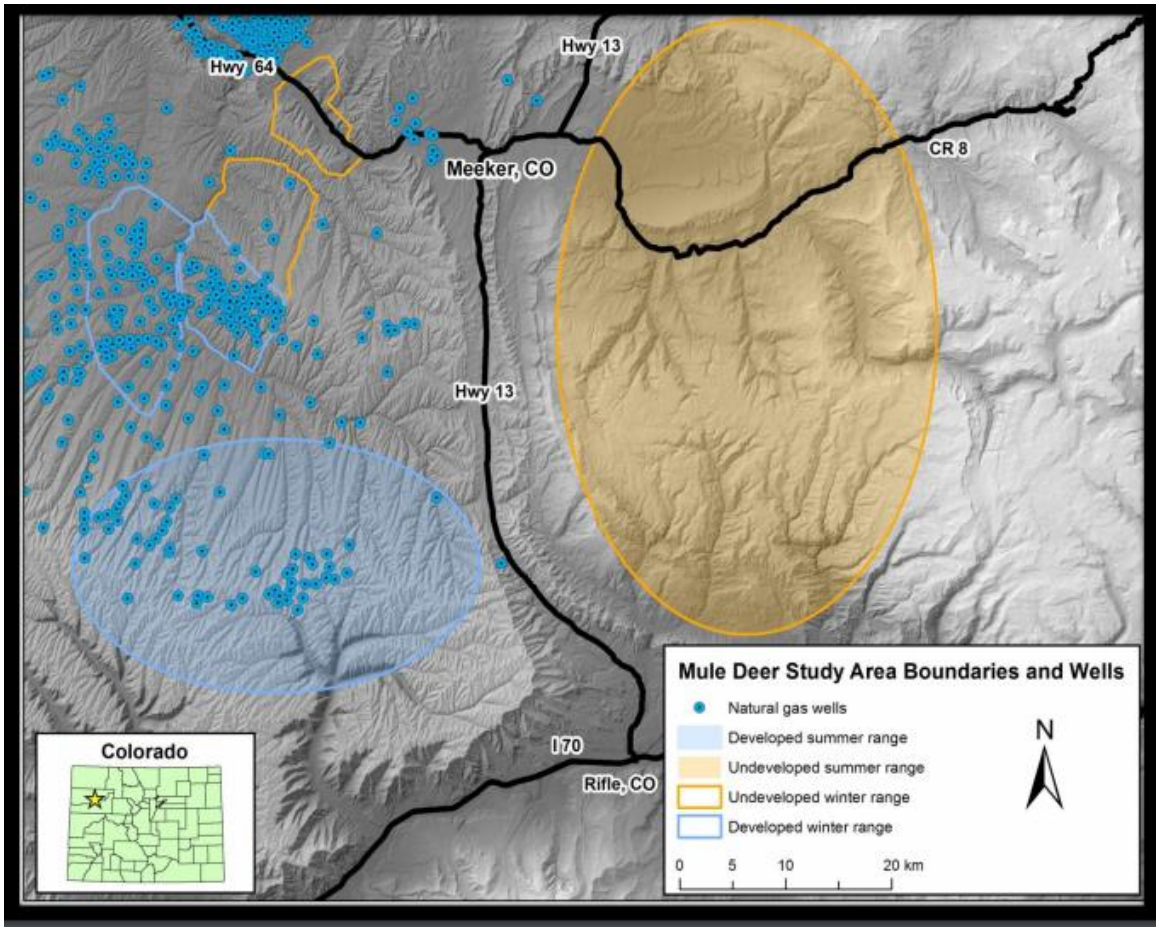

Figure 2. The confounding variable that confuses the predator control study is the vast number of well pads located in the treatment area, while they are absent in the control area. This is represented by the bue and orange circles, respectively. *Courtesy of Northrup, Anderson, and Wittemyer (2015).*

Even if energy development truly has not contributed to declines in the mule deer population, no research has been conducted on its effects on black bears. For the eventual results to be useful, confounding variables must be eliminated. The blatant differences in land use show that this has not been the case for predator control efforts.

According to CPW, black bears were responsible for 14% of neonate mule deer mortality from 2012-2015 (Colorado Parks & Wildlife, n.d.). Over the next three years, predator control efforts will remove 30-60 bears. This means annual removal targets are 10-20 bears. Assessments will be made as to whether newborn fawn survival increases in the spring, and further management strategies will then be discussed.

Black Bear Feeding Habits

The American black bear, *Ursus americanus,* is a predator species that is typically classified as an omnivore. This designation stems from feeding habits that have led to visible evolutionary adaptations in their teeth. Primarily, omnivorous bears show differences from carnivorous bears in their canines and molars (Sacco and Van Valkenburgh 2004). Their canines are blade shaped, which relates to the specific methods used to kill prey; rather than hold their prey in place, omnivorous bears are more likely to take shallow bites, albeit more numerously. Since they don't maintain contact with the prey while it is struggling, they are less likely to suffer damage to their teeth that would result in rounding.

The molars of omnivorous bears are enlarged when compared with carnivorous bears. Increased surface area allows for more efficient grinding action, which is critical when an animal eats a lot of vegetation. Since black bears are omnivorous, they fall somewhere in the middle in terms of overall vegetation consumption. Regional and geographic differences in black bear habitat across North America can further influence these amounts. For example, using scat analyses, two researchers determined the feeding habits of bears in Rocky Mountain National Park. They found that vegetative matter accounted for over half of the black bear's diet (Baldwin & Bender 2009). Animal matter as food mainly occurred through the consumption of insects, with vertebrate consumption accounting for less than 12% of their diets.

In Big Bend National Park in Texas, another study of scat analyses found that similar trends were exhibited. From early to late summer, plant matter increased in proportion from 77 to 86%, comprising a healthy majority of this species' diet (Hellgren

1993). In contrast, animal matter accounted for just 1/7 of their diet early in the season. Insects (mainly ants) and deer were the primary organisms that fulfilled this niche. It should also be noted that, unlike vegetative consumption, animal consumption decreased to 1/9 of the bear's diet from early to late summer.

Over the course of three years, feeding habits of black bears in Banff National Park were measured using similar scat analysis methods as the two previously named studies. Raine and Kansas (1990) found that ungulates made up just 6.4% of black bear diets, by volume of food items, at their greatest level in late May. Conversely, grass-like plants, horsetail, and dandelions were responsible for nearly 80% of their diet in the same time period.

In addition to scat analyses, researchers have increasingly been using stable isotope techniques in order to more accurately assess the feeding habits of different animals. Such methods are more accurate, as they measure the amount of food consumed that was fully incorporated into the animal's tissue at the atomic level. The buildup of nitrogen isotopes are measured to provide an estimate of meat intake, whereas carbon isotope levels can be used for analyses of plant consumption (Jacoby et al., 1999). In an extensive study, these stable isotopes were used to investigate the dietary meat:plant ratios of bears in western North America. Researchers determined that a sample of black bears from Colorado, New Mexico, and Arizona used meat to supplement about 40% of their diet (Jacoby et al., 1999). There is potential for this number to have been reached in error, however, as explained below.

In order to gauge bear diets, a herbivore baseline per ecosystem was used as a frame of reference. This is because in places where there was limited availability of meat

sources, bears exhibiting more herbivorous diets would, in theory, produce stable isotope signatures overlapping those of herbivores. In the case of the southwestern states, oak mast was a significant dietary input for bears. The mule deer and elk used for comparison in this sample did not eat nearly as much oak mast. This resulted in a baseline nitrogen isotope signature of 4.3%, nearly 3% lower than would have been produced by bears alone. If the higher consumption estimate of oak mast was used, it could have reduced the dietary meat proportion of the black bear's diet by half (Jacoby et al., 1999). This new estimate of 20% more closely resembles the results of previously mentioned studies about black bear food consumption. In Yellowstone National Park, meat consumption estimates were found to comprise 23% +/- 7% of black bear diets among both sexes (Fortin et al., 2013). Within this figure, ungulate consumption represented 5% +/- 7%.

As black bears generally maintain a plant heavy diet, the results of Colorado Parks and Wildlife's inquiry into the feeding habits of the bears in the study area are somewhat anomalous. According to their results, neonate fawns are suffering a ~50 percent mortality rate from predation, almost 1/3 of which has been in connection with predation by black bears. In contrast, of the studies cited above, only two estimates are near this figure, Rocky Mountain and Big Bend. In Rocky Mountain National Park, higher estimates of vertebrate consumption were expected because the high elevation of the park means that the growing season for plants is shorter and the lack of hard mast sources reduces forage of this niche (Baldwin & Bender, 2009). In Big Bend, all animal matter was grouped for their analysis. This prevented me from assessing what proportion of the bears' consumption was through ants, small mammals, and deer. However, the total estimate of animal consumption at its peak in the summer was still only 14%. This

shows that consumption of deer still falls below this estimate, and does not match CPW's findings.

Black Bear Ecology Implications

In analyzing CPW's results as well as these studies, I have come to two conclusions. Even under the assumption that CPW's finding of 14% predation by black bears is irrefutable, this is not necessarily indicative of over-predation. It is slightly above the rates seen at Rocky Mountain National Park, which were explained by habitat influences. In the case of the Piceance Basin, extensive energy development has altered the landscape. Habitat improvements were initiated and completed by CPW in 2013, and the site has undergone post-treatment monitoring since. CPW found excellent vegetation response rates beginning 3 and 4 years afterward. This was supported by increased mule deer conditions in overwinter periods (CPW, n.d.). This revegetation was primarily herbaceous materials, which makes sense, because hard mast takes many more years to repopulate and reach maturity. This is not alarming for mule deer, which receive the majority of their nutrition through forbs and grasses. They substitute their diet in the winter with browse materials, such as twigs and leaves from various shrubs.

Regarding black bears, however, it's possible that oil and gas development has affected their food sources more drastically. In terms of seasonal variations in their diets, grasses and other herbaceous species comprise the majority of their spring food sources. To supplement for the negligible nutritional content in these plants, though, the bears will generally increase their ant consumption through the summer. In the fall, bears were found to switch their focus to the consumption of juniper berries and acorns, amongst other berries and seeds (Raine & Kansas, 1990). Coincidentally, the summer range in the

Piceance Basin is composed of a sagebrush, pinyon pine, and Utah juniper shrubland complex. Other major plant species are Gambel oak and the Utah serviceberry (Bartmann, White, & Carpenter, 1992).

Juniper bushes are long-lived, but everything about their growth is slow, including when their berries ripen; on average, it takes two years for a juniper berry to reach maturity. Gambel oaks, for their part, produce the most acorns when their stem has grown to a diameter of 10-15 inches (Abella 2008). Both of these processes must be highly regulated for black bears to have a consistent food source, since they usually eat the previous season's berries. In the Piceance Basin, these hard mast plants have been destroyed by the implementation of well pads. Unlike grasses, they do not repopulate quickly. Even when they have become established, they do not produce berries and nuts for many years. The berries from these shrub species as well as others are crucial to black bear diets leading up to their winter torpor, but have been removed in many parts of the study area. Bears must already forage extensively in the fall, in order to ensure they have enough additional fat stores to survive the winter. With this information, it is reasonable to question the rates of predation by black bears that CPW measured. Returning to my former point about Rocky Mountain National Park, the same assumption can be made of the black bear population in the Piceance Basin. Reduced availability of important food sources such as juniper berries and acorns may have led the bear's to supplement their diets with increased consumption of mule deer. This is in line with CPW's observation that predation primarily occurs against neonate mule deer during the months of June-December. They are easy prey and have a higher concentration of energy and nutritional density in comparison to plants.

Black bear predation rates do not seem excessive when placed in the context of another Colorado study. However, if this population's natural rates of mule deer predation are expected to lie below 10%, as was indicated by other studies, then perhaps the quality and quantity of their food sources should be investigated by CPW. If these results are accurate, this change indicates that there are factors pushing the bears to rely more heavily on meat in their diets. Unless this issue is understood and resolved, the only way to prevent predation will be through continuous predator removal.

Predator-Prey Relationships

Throughout evolutionary history, it has been noted that, although their roles are antagonistic toward one another, direct predator-prey relationships are beneficial to the ecosystem as a whole. Ecological concepts such as trophic cascades and bottom up effects are the result of an alteration in ecosystem structure. Trophic cascades occur when animals located near the top of the food web, namely predators of some sort, are removed.

Depending on the state of the ecosystem, these efforts can be beneficial or negative. If an abundant predator population is suppressing the population growth of its prey to a detrimental level, some removal by humans seems warranted, but is not always necessary. Predator and prey species generally fluctuate predictably; as prey numbers increase, predators follow suit. When the predator population grows too large and decimates the prey population, it is, in turn, eventually reduced by density dependent regulation. These are abiotic factors such as disease and starvation from lack of resources that allow the species in lower levels to recover (Molles Jr., 2013). If too many animals are taken out of the system, however, it can result in prey populations rebounding too

much. In the same manner, they experience regulation through increased rates of mortality from degraded habitat. Natural systems are very dynamic, and these fluctuations are simply responses to change. The truth of ecological interactions is that no change can occur at one level or within one group without affecting others. These systems are complex, and human induced interruptions like the Piceance Basin predator cull must be made with thoughtful consideration.

Energy Development and Land Use Changes

The area in which the predator control plan is taking place becomes quite intriguing when its specific characteristics are analyzed. In the sections that follow, I will be exploring the features of the land that have piqued the interest of energy developers as well as the current makeup of land parcel ownership that reflects ongoing land use changes.

Land Ownership/Methodology

It has been well established that the Piceance Basin is a haven for energy development. The Green River Formation, which underlies this Colorado site as well as portions of Utah and Wyoming, contains the largest supply of oil shale in the world (Donnell 1961). Oil shale is a type of sedimentary rock that is comprised of large amounts of kerogen. When heated, kerogen is broken down to produce hydrocarbons, which in turn, are used to create fuels such as natural gas. As a whole, the Piceance Basin contains 1.525 trillion barrels of oil (USGS, 2009). In their assessment of the Mancos Shale, just one portion of the basin, the USGS also determined that the amount of natural gas available was 40 times higher than previously estimated. While this does not

necessarily mean it is all considered recoverable, the numbers are enticing for domestic energy production.

CPW has confirmed that the locations where the predator control studies are taking place occur primarily on energy company land (Colorado Parks and Wildlife, 2016). In order to determine the extent of this, I used ArcGis Pro to overlay the GMU's included in the Piceance Basin study with land ownership parcels from the following counties corresponding to the area: Rio Blanco, Mesa, and Garfield. From these overlays, I was able to alphabetically group the data based on ownership. To separate the parcels owned by energy companies, I initially searched for the names of well-known businesses such as Exxon Mobil, because of their publicized involvement in the industry. I also used the keywords 'oil,' 'gas,' 'petroleum,' and 'energy' as my search parameters, as a second means of identifying relevant companies. Once the largest companies had been identified, I sifted through the data once more, by searching the online business records of each company listed. Through this, I was able to identify energy companies that I had missed originally and compile an estimate that energy companies owned land in 23.56% of the study area, as illustrated in the map below (Figure 3, see Appendix A).

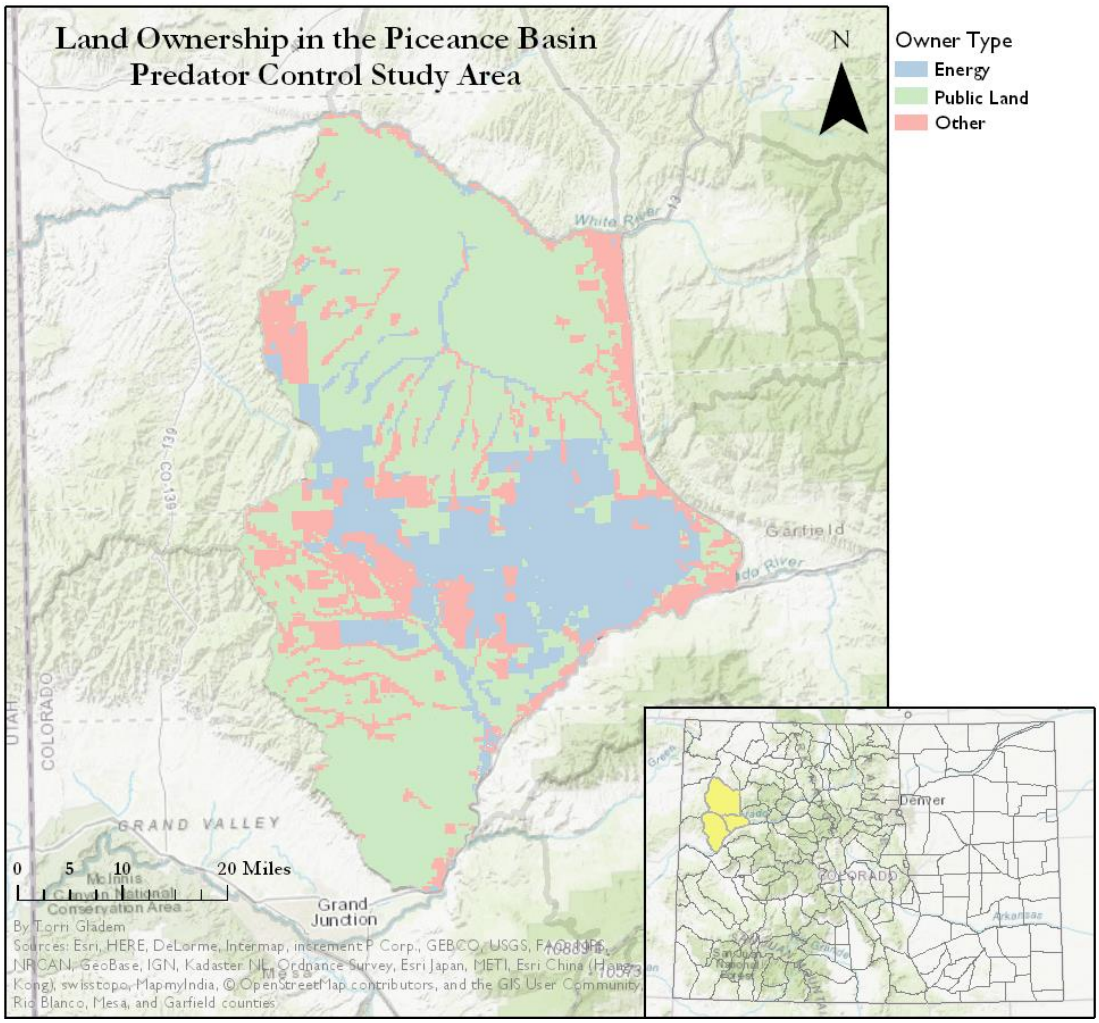

Figure 3. This map depicts the Piceance Basin predator control study area, and its various land ownership. The vast majority of land is owned by energy companies and the Bureau of Land Management.

The other two categories of land ownership I used to segment my map were 'public land' and 'other.' I felt it was important to categorize the parcels managed by the Bureau of Land Management (BLM) for multiple reasons. Primarily, I chose to highlight these parcels because it has been well-documented that BLM as an agency has suffered severely from regulatory capture in the past. This means that, although the bureau has been charged with managing public lands for the general public, their management strategies sometimes benefit smaller interest groups instead. The issue has historically been raised in connection with BLM's cattle grazing fees (Layzer, 2016). Spurred by the

Taylor Grazing Act of 1934, a portion of public lands, currently standing at 155 million acres, were reserved for grazing, initially at a price of $0.05 per animal unit month. Even this initial fee was well below the market value of the land, amounting to less than 33%. Since the implementation of the Taylor Grazing Act, however, the BLM has been incredibly unsuccessful in adjusting their grazing fees to reflect a more accurate cost; even in 2017, the fee had only been raised to $1.87, while the price for grazing on private lands was over $20 (Glaser and Moskowitz, 2015).

Grazing policy on federal lands has continued on this failing trajectory because of a vocal minority of constituents and their allies in federal departments and Congressional committees. This organized influence has thwarted reform for decades, and each failed attempt at change only strengthens the status quo. Previous administrative threats of dissolution, massive budget cuts, and actual restructuring of the agency in order to make it friendlier toward ranchers' interests have effectively crippled the BLM in regard to grazing (Layzer, 2016). Where this issue intersects with energy development is through the use of public lands for private interests and those implications.

As of 2015, BLM's records show the agency had leased about 32 million acres of public land to oil and gas development companies ("Total Number of Acres Under Lease as of the Last Day of the Fiscal Year," n.d.). This total was included in a table detailing the total number of acres under lease at the end of each fiscal year by state. I found that in the same year, 3.3 million of these acres under lease were located in Colorado. Through my own analysis of the data, I determined that from fiscal year 2003-2016, the average number of acres under lease in Colorado was 4,158,534 million. Using the same methods on BLM data regarding the total number of leases in effect, I found that in any given

year, Colorado has an average of 5,105 active oil and gas leases ("Total Number of Leases in Effect," n.d.). This lease information alone does not equate to regulatory capture by energy companies, and it is not my intention in this thesis to insinuate such claims. However, it does provide support for the notion that the BLM is open to, and actively endorses, consumptive uses of public lands through industries such as agriculture and energy. Both of these activities impact the wildlife in the area and actively degrade the landscape. I felt it was appropriate to note the public lands in the study area because they comprise 58.27% of it (Figure 3, see Appendix A). Although these lands are officially under the jurisdiction of the BLM, the activities that occur on them can represent entirely different interests. Using oil and gas data for Colorado from the BLM's records, I constructed a second ArcGis Pro map illustrating the leases that have been granted in the Piceance Basin from 2014-2017 (Figure 4, see Appendix A). This can be seen in the figure below.

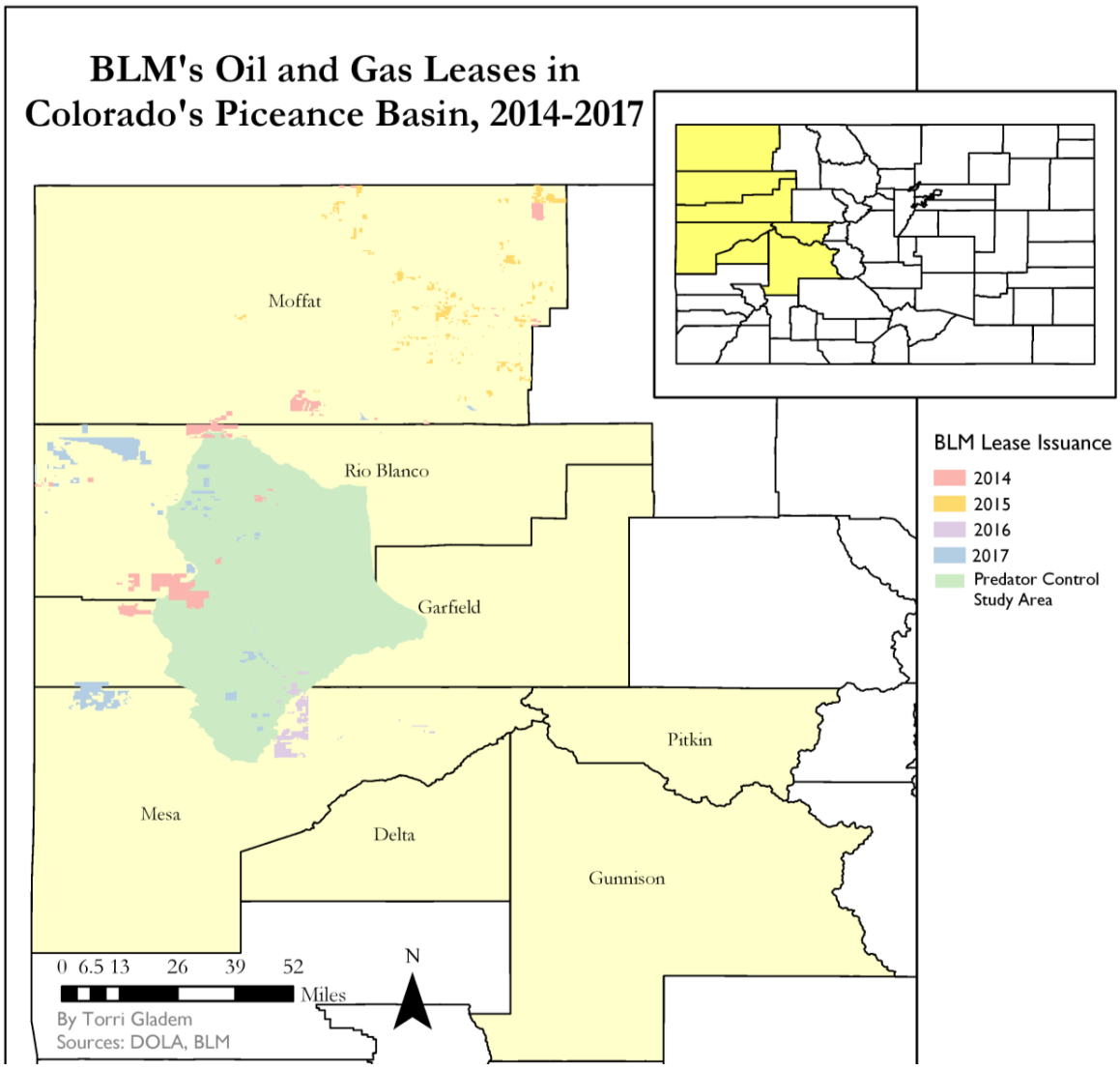

Figure 4. This map depicts the oil and gas leases granted by the BLM in the Piceance Basin from 2014-2017. Leases were granted in the eventual predator control study area every year, and sometimes multiple times in one year.

Colorado holds quarterly lease sales for land parcels available for oil and gas development. These parcels are located throughout the state. I found that lease sales in the Piceance Basin occurred every year of my analysis. In 2014 and 2017, energy companies were granted leases in multiple quarter periods. These leases have not just been granted in the Piceance Basin, but within the predator cull study area as well; the only year in which this did not occur was 2015. This illustrates that even though energy

companies only own land in a quarter of the study area, they have been granted control through leases in many other portions. The BLM issues two types of oil and gas leases, but both are established for an initial 10-year period that can later be extended, depending on levels of production (BLM, n.d.). The fact that this additional development is so prevalent in the study area is another example of contradictory goals laid out by CPW. The agency has stated in their strategy that they want to mitigate developmental impacts on mule deer, but to introduce a predator control study in an area where heavy development is ongoing and encouraged is a conflict. This is especially concerning when those effects on black bears and their responses have not been studied in depth.

The final category of my land ownership map, 'other', was used to group the companies and individual owners of parcels who did not represent energy development companies or the administering agencies of public land. These groups only comprised 18.17% of all ownership in the area.

Public Engagement and Comment Period

Prior to the creation of the predator control study, CPW did attempt to solicit the public's opinions about potential causes of the mule deer decline through 7 public meetings in 2014. They also employed a third party policy group, The Keystone Center, to assist at the meetings and to document the findings in a report. In order to notify the general public about the planned meetings, CPW used e-mail recruitment, a press release, and announcements in newspapers as well as theirs and The Keystone Center's, web sites. These efforts generated a total of 169 participants, spread amongst the cities in which the meetings were held: Craig, Durango, Eagle, Grand Junction, Gunnison,

Loveland, and Pueblo. Grand Junction boasted the most respondents by far, totaling 59. Gunnison and Eagle were second and third, with 27 and 26 respondents, respectively.

Participants were broken up into groups and instructed to discuss 10 management concerns that were pre-determined by CPW. They were as follows: "barriers to migration, competition with elk, disease, doe harvest and hunting demands, declining habitat quality, habitat loss, highway mortality, predation, recreational impacts, and weather" (The Keystone Center, June 2014, p. 6). Among most locations as well as trending statewide, predation was one of the top three concerns. Loss of habitat and habitat degradation were the other high ranking concerns listed. Among the causal factors for habitat issues, participants frequently cited development in all its forms-urban, commercial, and oil and gas.

In terms of issues that CPW could control most easily, the results were somewhat telling. Many of the participants ranked predation as one of the primary limiting factors on mule deer for CPW to address. Other top concerns were doe harvest and hunting strain on the population, as well as declining habitat quality. In terms of issues participants felt CPW could least effectively mitigate, weather, disease, and habitat loss ranked in the top three. Participants also noted that in attempting to address any of these issues, their connections to one another would present additional issues. For example, predators are also affected by habitat loss, and as it advances, they are pressed into an increasingly small area with prey species such as mule deer.

The information gleaned from the general public's comments at these initial meetings was eventually used to help advise some of the management strategies adopted in the 2014 Colorado West Slope Mule Deer Strategy. In an additional public meeting

called the Statewide Summit, the draft of this document was made available for participants to provide input before the final strategy was released. To their credit, CPW employed even more outreach methods to attract people to this meeting. They used the same methods as they had previously, and also utilized radio stations to run stories on the event. The Statewide Summit was held in Glenwood Springs and attendants from the general public totaled 58. Of these participants, 31% of them had previously attended one of the seven public meetings that were held (The Keystone Center, August 2014). The goal of this meeting was to assess the strengths and weaknesses of the strategy. Participants were pleased that the plan was inclusive and addressed a variety of threats to the mule deer. A large proportion were concerned, however, that the strategy as a whole would be difficult to implement without conflicts as well as to fund. With these concerns noted, the Colorado West Slope Mule Deer Strategy was finalized and implemented in November 2014.

Shifting Public Perceptions

One of the things born out of the Colorado West Slope Mule Deer Strategy was the Piceance Basin predator control study plan. Two years after the first public meetings on mule deer, in August of 2016, a public meeting regarding this new topic was convened. The meeting was held in Rifle and boasted 37 attendees. According to the Piceance Basin Predator Control Plan, the public comments were widely supportive and out of 37 participants, there were only 6 opposed to the plan. However, the Meridian Institute's Summary of Public Comments from a meeting in September of 2016 exhibited a clear shift: 22 out of 28 public speakers voiced their discontent (Colorado Parks &

Wildlife, November 2016). A key point about this meeting was that it was held in Denver, the first urban city to be included as a host for one of these gatherings.

Following the public meetings, CPW has endured a torrent of backlash. For one, prominent biologists at Colorado State University penned a blunt letter to the CPW commissioners that was relayed to the public by the Denver Post. They stated that CPW's predator control plans contradicted sound wildlife policies as well as their own prior studies. The environmental group Wild Earth Guardians even began a lawsuit against CPW, citing amongst their reasoning 6,500 comments opposed to the plans (Associated Press, 2017). After weeks of coverage, a poll conducted by the Denver Post revealed that 87% of respondents were not supportive of the management strategy (2016). Although predator species are charismatic and incite strong emotions in the public, this highly negative response should be viewed skeptically, but not ignored.

Predator Control Study Critiques and Modified Solution

Now that I have outlined the information necessary to understanding this case, I am devoting the following sections to explaining the issues with it that I encountered in my research. I will also be describing a potential solution that might better rectify the desires of the public with CPW's management decisions.

Sampling Bias

The initial meetings CPW held about the mule deer strategy were numerous and the public's responses indicated predation was a leading issue that should be prioritized. For the number of meetings that were held, however, there was a very low response rate. The meetings were also primarily held in more rural and industrial production type cities. Over the course of the last three years of meetings, only the one held in Denver

represented an urban populace. While CPW is not required to hold public meetings nor to follow the suggestions of the public, they made an effort in this case. They struck short, however, by ignoring urban centers. Communities along the Front Range represent values and interests that are just as important as rural communities' perspectives, and should be represented. If a greater proportion of this constituency had been included in the meetings, the top concerns for mule deer decline might have been ranked differently. In turn, this may have resulted in an entirely different approach of issues in the mule deer strategy document.

Funding Issues

As it stands currently, funds from state park visitation fees cannot be used for wildlife management. This is due to constraints imposed by state and federal laws, whereby the Colorado parks budget must remain separate from the wildlife management budget and expenditures. I believe that this setup is outdated for two agencies that have merged in all other senses, especially since it ignores one of the top reasons people visit state parks: the wildlife. State parks are some of the best expanses of land available for people normally removed by nature to visit and connect with it. If the wildlife populations are declining, our parks will also decline as a result. When visitors begin to stop experiencing the wild beauty that is massive elk and deer herds or rare sightings of lynx and other charismatic megafauna, they will be less inclined to visit overall. In order to maintain budgets, it is imperative that we preserve these things that make our parks so unique. Although this is undoubtedly one of the reasons for the mule deer strategy to be adopted in the first place, participants at the Statewide Summit also mentioned overwhelming concerns that it would be difficult to fund effectively (The Keystone

Center, August 2014). With this reasoning in mind, I have chosen to ignore current constraints on CPW's separate budgets for my suggested solution. For the agency to succeed in its management strategies, changes will have to be made legislatively. If there is a vocal and receptive public, these could realistically be made in the future.

Proposed Solution: Reasons and Merits

Here I am proposing that while the 2014 Colorado West Slope Mule Deer Strategy was wide-reaching in each of its goals, the details of each goal were somewhat muddled and unexplored. Without addressing these particulars, I feel that the strategy as a whole will not be as successful as it could be. This is particularly true in the case of the predator control study. To reiterate, the treatment area for the study contains massive amounts of drilling wells while the control area contains zero. This presents a conflict of interest, as one of the strategy's goals along with predator control is to mitigate developmental impacts. To focus predator removal efforts in an area heavily developed by energy interests is to skew results. Sound results could only be maintained in the predator control study area's current setup if there was thorough data proving that drilling pads have not limited black bear's food sources. Until then, we do not know if changes to the availability of herbaceous materials has forced them to actively pursue more available sources such as mule deer. Due to the lack of research in this area, it's currently impossible to determine what factors have altered their behavior to such a degree. Therefore, it is my opinion that these are confounding factors, which must be addressed first to enforce the relevancy of the study. Otherwise, the resulting scientific insights will be informed on potentially false premises. This will prevent us from being able to

accurately say that culling predators is the best solution, and will only affect change in the short term to the detriment of these animals.

In addition to finding a potential solution that addresses the ecological issues with the predator control study, I wanted to devise a solution that respected the general public's attitudes about predator species. In a study conducted by Messmer, Brunson, Reiter, and Hewitt, public perceptions on this topic were measured by way of surveying over 500 participants and found to be generally positive (1999). A majority of participants agreed with the sentiment that they enjoyed knowing predator species such as black bears existed in North America. The majority also disagreed to varying amounts that predator reduction was necessary to mitigate predator issues. The researchers also found that nearly 100% of participants found predators to be an essential part of nature (Messmer et al., 1999). Coupling this with the overwhelming dissent to the plans CPW announced, I determined that a viable modification to the current study plan would be to conduct an observational study of strictly the black bears in the area. This would provide answers as to why the black bear population's feeding habits have shifted, without decreasing their numbers based on inadequate data. It would also avoid the pitfalls of translocation attempts. Translocation accomplishes the same goal of the current study, meaning that the bears are removed from the Piceance Basin and the deer population is monitored. The problem with the method is that it is expensive, time consuming, and not always successful (Miller, Ralls, Reading, & Scott, 1999). In contrast, an observational study would not remove the bears, but it is the least expensive monitoring option and would provide valuable data. This data could even be used in the future to support

predator removal efforts if they are truly warranted. The study would have produced the valuable information needed to accurately assess that, unlike the current setup.

In order to fund such a study, I am proposing a two-tiered optional licensing and pass system. Hunters and anglers are already some of the most familiar members of the public to wildlife issues, and their license sales contribute nearly 80% of the funds used to manage Colorado's wildlife (CPW, August 2017). Regarding state parks passes, CPW's Fact Sheet revealed that the parks have attracted over 13.5 million visitors annually (2017). Half of these visitors have been Coloradan residents, and therefore, important stakeholders. Since fishing licenses, hunting licenses, and state parks passes are currently priced on a staggered scale, my two-tiered pricing system would incorporate this factor. The lower tier would represent fishing and hunting licenses as well as state parks passes at the prices they are currently: $26, $34-49 (with the exception of moose licenses, which are $254), and $70, respectively. The more expensive tier would represent the same items at a price increase of $10, $15, and $20, respectively, so as not to price out any outdoorsmen through a flat rate. This option would be completely voluntary upon purchase, and all additional proceeds from it would be funneled into a predator specific conservation fund. This would allow concerned stakeholders to contribute to such a cause, without forcing uninterested parties to do so and potentially alienate them.

To determine the viability of this solution, I conducted a survey of the general public, a copy of which can be found in Appendix B. Within my survey, I also analyzed the perceptions of the general public regarding the predator control case study as it currently stands. As I mentioned briefly before, the vast majority of public meetings held

about mule deer and predator control occurred in rural areas, and did not attract very many participants. I determined if there are any connections between a person's place of residence and their subsequent perspectives about the current wildlife management strategy. In this way, I found to what extent the plan reflects the attitudes of Coloradans as a whole as well as their receptivity to my modifications.

With the relevant literature in mind, it is my hypothesis that the majority of the general public will have positive feelings about black bears, and subsequently, negative feelings about the predator control study. I also believe presenting them with details of the energy development in the area will make the majority of respondents question some details of CPW's wildlife management. It is my assumption that this will, in turn, lead them to feel more supportive of my proposed solution. The fact that my solution is optional as well will hopefully be an attractive point.

METHODS

Overview

In order to gather information on the general public's knowledge of my topic, I felt that distributing a survey was the appropriate method to follow. Since it involved human subjects, this survey was approved by the Institutional Review Board. The survey was heavily targeted toward more prominent stakeholders such as outdoorsmen because it was more likely that they contributed to CPW's funding. In turn, this meant that their responses to questions suggesting changing CPW's funding scheme to more holistically address the issues in this case study would hold more weight. In addition, many of the most active community members initially concerned with this case study consider themselves outdoorsmen. By targeting people with this characteristic, I wanted to ensure

that my results could be more closely compared to the data that influenced this case study. I used the Qualtrics platform to create and distribute my survey, a copy of which can be found in Appendix B. I prefaced the questions with a concise summary of the relevant background information, under the assumption that the general public would not be familiar with the details of this case.

Survey Distribution

Using social media, my survey was distributed to prominent groups such as the Alpine Club at CU and the Hiking Club at CU. While current members to the campus groups are almost all college students and would skew my results, the members of the Facebook groups are not limited by this. Online, the Alpine Club page boasts a community of 2,755 members, including past and present students of CU Boulder, as well as general residents of Colorado. The Hiking Club's Facebook page is currently supported by 814 members, and assisted me in my survey outreach efforts by adding to my potential sample size. Most of the people in these groups are interested in multiple outdoor pursuits, and make great use of the state's public lands and resources. Therefore, they represented the target demographic I wanted to address, and I felt they would provide me with a more accurate measure of concerned stakeholder's opinions.

Analysis of Results

Once the survey responses had been collected and organized, it was my intention to determine how well my sample represented the Coloradan population as a whole. In order to do this, I constructed a code in Rstudio for a binomial proportion confidence interval. The notation and guidance for this can be found in Appendix C. I chose this statistical analysis because it provides a range of values within which the true value for

the population lies. I chose a confidence level of 95%, meaning that I am 95% certain the interval calculated contains the true mean for the population. This test was useful for my survey data because it provided an estimate of the general public's opinions by way of a small sampling.

RESULTS

My survey generated 96 responses total. Since I was primarily concerned with Coloradan stakeholders, however, I filtered out responses from non-residents. This left me with 75 responses to fully analyze. Overall, I received responses from 27 towns or cities, summarized in Figure 5 below.

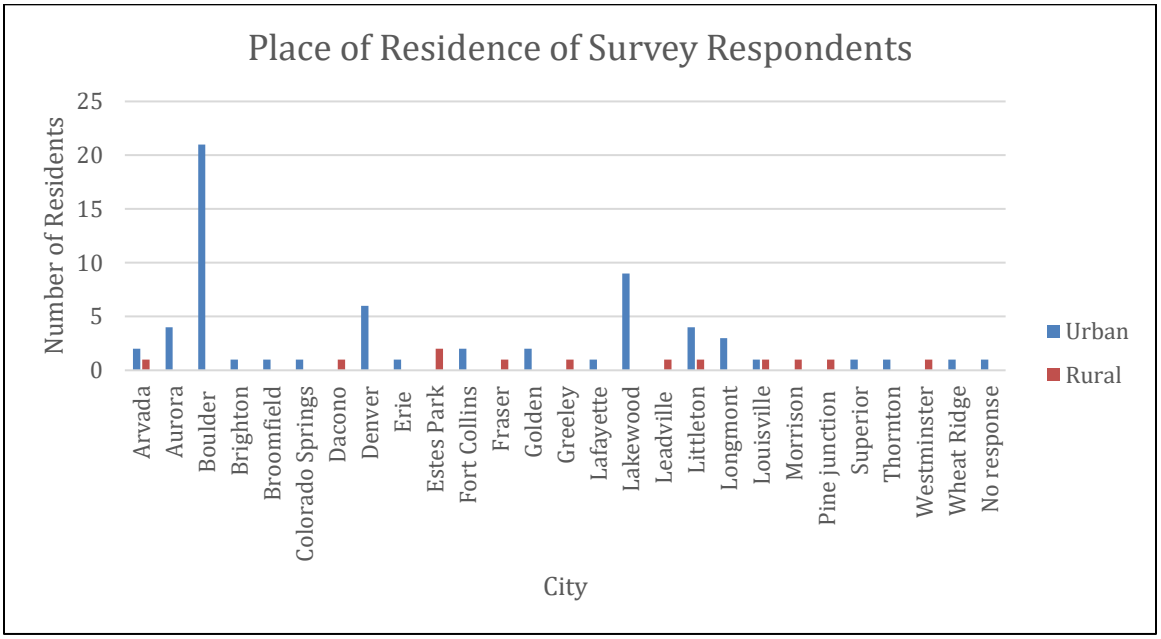

Figure 5. When participants' information was categorized by place of residence, it was clear that respondents to this survey typically resided in urban areas along the Front Range. Boulder, Denver, and Lakewood accounted for 48% of the responses. Amongst the remaining responses, a diverse group of 24 cities was represented in varying capacities.

Since 84%, or 63 out of 75, of my participants classified their place of residence as 'urban,' I chose to focus my analysis on the resulting answers from this overwhelming majority. This is not to say that the answers I received from 'rural' residents were not

telling; they still helped me determine some of the general trends of my data. However, they could not be used to estimate a true representation of the rural population of Colorado's opinions because my sample size was too small to create valuable confidence intervals. Along with this, a portion of my participants left answers blank as the survey progressed. To prevent this from skewing my results, I discarded all of the 'No responses' as I analyzed each question individually. This left me with slightly different sample totals for some questions, which are summarized below in Table 1, alongside other relevant results.

Table 1. Summary of survey results for urban participants. A confidence interval was calculated for each question response, and provides a range of values that contain the true proportion of those in the Coloradan public who share the same view with a confidence level of 95%.

Question	Choices	Number of Responses	Mean	95% Confidence Interval
Were you aware of the predator control plans before today?	Yes	9	14	7-25
	No	54	86	75-93
How did you initially hear about the predator control plans?	Colorado Parks & Wildlife	2	22	3-60
	News and media coverage	5	56	21-86
	Friends and family	2	22	3-60
What is your opinion of the predator control plans?	Positive	8	14	6-25
	Neutral (No opinion)	26	44	31-58
	Negative	25	42	30-56
How do you feel about the amount of research that has been conducted on predator species?	There is substantial research on predator species	3	5	1-14
	There is adequate research on predator species, but more should be conducted to better our understanding	36	61	47-73
	There is not nearly enough research on predator species	20	34	22-47
Have you ever bought a (CO state) hunting license, fishing license, or season pass for Colorado's state parks?	Yes	32	54	41-67
	No	27	46	33-59
How often would you estimate that you have bought one of these licenses or passes?	>1 per year	3	10	2-26
	1 every year	18	58	39-75
	1 every two years	4	13	4-30
	1 every three years	2	6	0.8-21
	1 every four years	1	3	0.08-17
	1 every five years or more	3	10	2-26
How do you feel about predator species in Colorado, specifically black bears?	Positively	35	61	48-74
	Neutral	21	37	24-51
	Negatively	1	2	0.04-9
Consider this scenario: There is a two-tiered pricing system regarding the licenses and passes mentioned above…How would you feel about having the option to contribute to such a fund in this way?	Positively-I would support a two-tiered system	45	80	68-90
	Neutral-I have no opinion on a two-tiered system	9	16	8-28
	Negatively-I would not support a two-tiered system	2	4	0.4-12
Would you personally be inclined to support predator research by choosing to buy the more expensive license or pass?	Yes	24	43	30-57
	Maybe	22	39	26-53
	No	10	18	9-30
Agree/disagree with the following statement: State wildlife policy has emphasized oil and gas development over wildlife management.	Strongly agree	11	20	10-32
	Agree	19	34	22-48
	Neither agree nor disagree	16	29	17-42
	Disagree	5	9	3-20
	Strongly disagree	5	9	3-20

The general trend was that my survey results reflected my initial assumptions. As suspected, almost none of the participants had heard of the predator control plans previously. Of the nine respondents who did, five of them received their information through friends and family. The remaining four were split equally in regard to having heard of the plans through news and media coverage or the CPW agency themselves. My question about the public meetings as well as its follow-up had to be omitted due to a lack of responses. Almost no one had been aware of the public meetings; in fact, only one participant had previously heard of them.

The most important results from my survey were that most participants felt negatively or neutral about the predator control plans. In contrast, a majority of respondents felt positively about black bears. A strong majority, 80%, was supportive of an optional two-tiered pricing system. Results were split almost equally amongst participants who did or did not buy a hunting/fishing licenses or season pass, but of those who did, the vast majority bought one every year. Of these 18 respondents, 8 would personally support building a predator research fund, 7 potentially would, and only 3 would not. This translated to a median estimate that 44% of the general population could be expected to support the proposal, with a 95% confidence interval of 22-69%. While 44% is a promising proportion, the large interval makes the true value harder to assume. 30 out of 51 respondents either agreed or strongly agreed that wildlife management has been overlooked in favor of energy development. Most of the remaining participants felt neutrally, and very few, 18%, disagreed.

In depth analyses of my results were limited due to low response rates to certain questions and answer choices. This issue was more pronounced when I tried to pair question responses, because it usually involved an analysis of less than 10 people. This would provide confidence intervals spanning nearly the entire range from 0-100. Such results lack relevant or useful information, and warrant further analysis of a large sample size.

DISCUSSION

My results reflect the perspectives of the public that was largely left out of the decision making process which led to the Piceance Basin predator cull. This group was urban residents. The majority of them did not know about the predator control plans prior to my study, nor did they know about the public meetings held on the issue. As it stands, CPW held public meetings inviting input in primarily rural areas that were located far from the communities on the Front Range. While they attempted to inform the public and invite participation, the locations they chose effectively cut those unwilling or unable to travel three hours out of the process.

The meetings resulted in concerns that predators were a primary cause of mule deer decline. Habitat degradation from energy development was another leading thought. This resulted in the implementation of the 2014 Colorado West Slope Mule Deer Strategy, where the Piceance Basin predator control study was announced. It was enacted without any prior research on potential causes of increased predation, which my survey respondents indicated prioritized energy development interests. Their attitude also reflected that a comfortable majority of the general population can be assumed to feel positively about predators, since 61% percent responded affirmatively. This resulted in a

confidence interval estimating the true sentiments of the general population to lie between 48-74%. Although the range of this interval is large, the interesting piece is where the ranges lies. One half to three quarters of the general population feeling positively about black bears implies a majority. This majority is crucial to implementing a new strategy for wildlife management that involves black bear conservation.

As expected, a large proportion of my respondents felt negatively or neutral about the predator control plans, while very few felt positively. This trend underpinned the gap that seems to span between CPW's goals and the general public's opinions. In order to assess the viability of my solution meant to mitigate this, I found that about 54% of people could be expected to buy a hunting/fishing license or season pass annually. In turn, the likelihood of these same individuals supporting my two-tiered fee system through their own purchases was about 58%, with an estimate that the true value for the population lies within the interval of 39-75%. While I would have liked to see a more obvious majority, these results show that there is receptivity to a predator research fund. There are also people willing to contribute to it. Further research with a larger sample size would be required to understand the true extent of this, but these results are hopeful.

CPW has many programs for different aspects of conservation and research, but none of them are specifically focused on predators. Since research is lacking on them in general, an idea supported by 61% of my respondents, a two-tiered pricing system is a potential option. It would give the public greater control over the wildlife that they already support heavily through their recreational activities. It would also give CPW a chance to show that they have looked at all of the impacts from energy development, a sentiment that should be supported by a Coloradan public that has grown increasingly

concerned with the environmental implications of such activities. If CPW pursued predator research before enacting drastic management experiments, they might determine new information that leads to predator success *along with* mule deer. If habitat degradation were found to be a limiting factor on predator species, attempts to address this may solve the biotic issues with mule deer decline. Such research is only possible with the proper funding, however. I cannot conclusively say that my solution is the best or even the most feasible, but it demonstrates a need for research as well as an option for garnering the resources necessary to conduct it. It is a talking point that could lead to improvements in the future.

CONCLUSIONS AND RECOMMENDATIONS

Public policy is a huge task to undertake, and not something CPW is required to make integral to their agency. Their previous efforts to include the public in meetings and decision-making processes about wildlife has shown that they are committed to making an attempt. In order to include a broader group of participants, they should hold future public meetings in a variety of locations, both urban and rural. It would be pertinent for the agency to also entertain new wildlife management strategies. My paper has shown that there is a dichotomy between the Piceance Basin predator control plan's objectives and the feelings of a large constituency. This same constituency expressed interest in creating a predator specific research fund through a two-tiered pass system. While more data is necessary to discern what the true support of the Coloradan population is, this result shows that there is, at the very least, receptivity to the idea. In future research, it would be interesting to determine what the opinions and perspectives of out of state residents are. While they do not make use of Colorado's resources to the same extent as

residents, they are still valuable stakeholders. They contribute funds to non-resident licenses and passes, and also have a vested interest in our wildlife. If this group was also supportive of changes to the fee system in order to support more holistic research, funding may be viable. It would also be interesting to look at other aspects of funding, because there may be available solutions unique from my proposal, but that accomplish similar goals.

My solution was an attempt to provide a more palatable answer to the vast number of people who feel the Piceance Basin predator control study was not planned or implemented properly. It works to reconcile impacts from energy development companies and the general attitudes of the urban constituency that was mostly removed from public meetings about the mule deer issue. While it is by no means perfect, it has the potential to provide CPW with a new wildlife fund, determined by the public. This public would be able to showcase their support through their own choices of funding predator research, which gives them a more tangible role in the fate of the wildlife that is considered a resource for all. In a similar sense, CPW would benefit from receiving the funds to present holistic, well-researched information before enacting management experiments. This solution would allow them to pursue true ecosystem health through adaptive management, in a way that is only becoming more necessary as developmental impacts are ongoing and increasing.

Although the mule deer strategy as a whole was implemented in 2014 and the Piceance Basin predator control study began this year and is set to run through 2019, this information provides an option for the future. The insights gained from observational predator research could be used to affect long-term positive change in the mule deer

population, rather than short-term reactionary change. It could also mitigate current conflicts that make the strategy's goals less effective, and truly align CPW's goals with their studies and actions.

APPENDICES
Appendix A: Maps

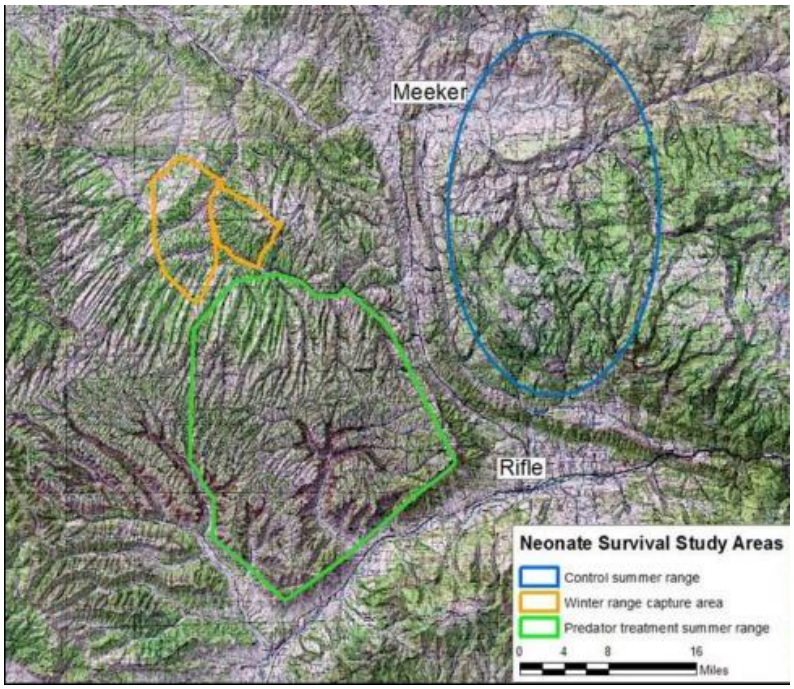

Figure 1. Predator removal efforts are to occur in the treatment area denoted by the green circle, while the control area is illustrated with the blue circle. *Courtesy of Colorado Parks & Wildlife Piceance Basin Predator Management Plan Overview (n.d.).*

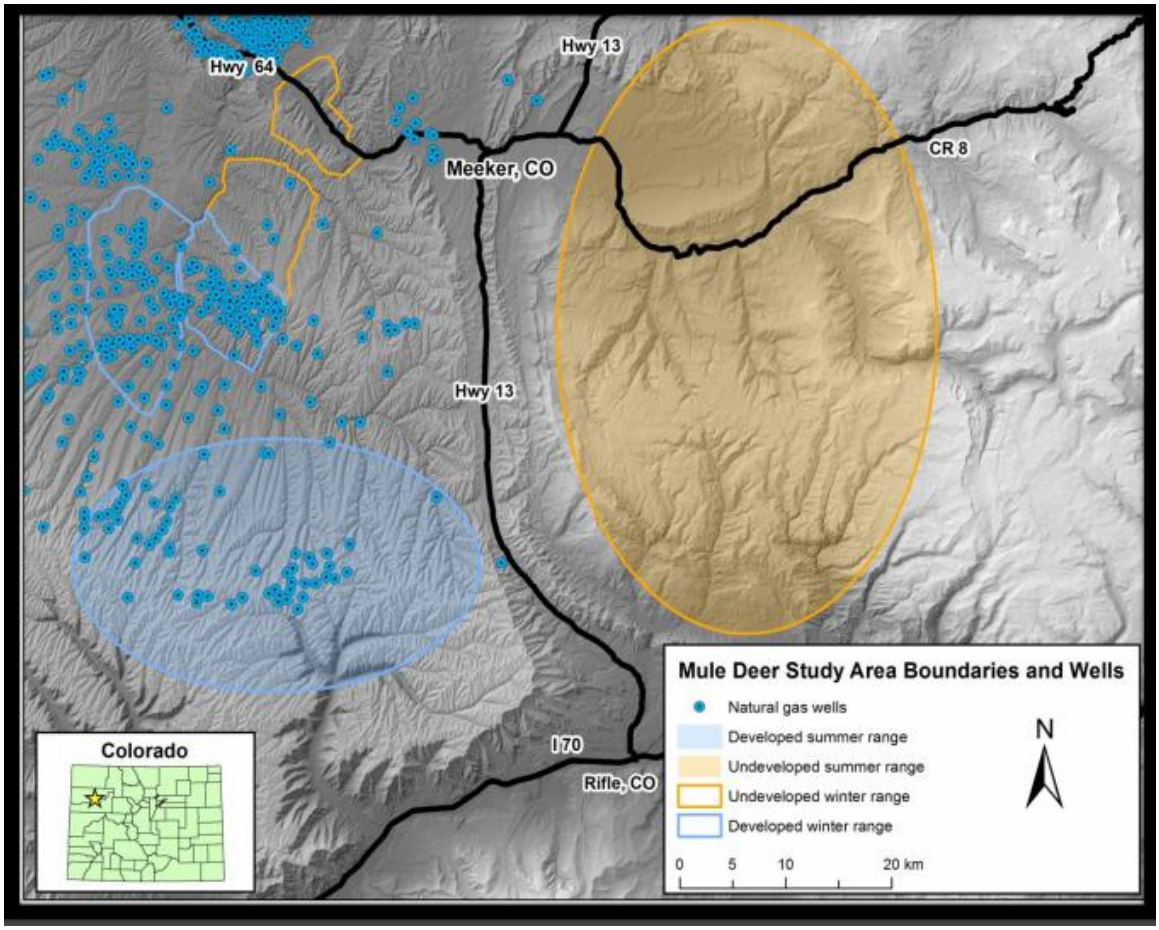

Figure 2. The confounding variable that confuses the predator control study is the vast number of well pads located in the treatment area, while they are absent in the control area This is represented by the blue and orange shaded circles, respectively. *Courtesy of Northrup, Anderson, and Wittemyer (2015).*

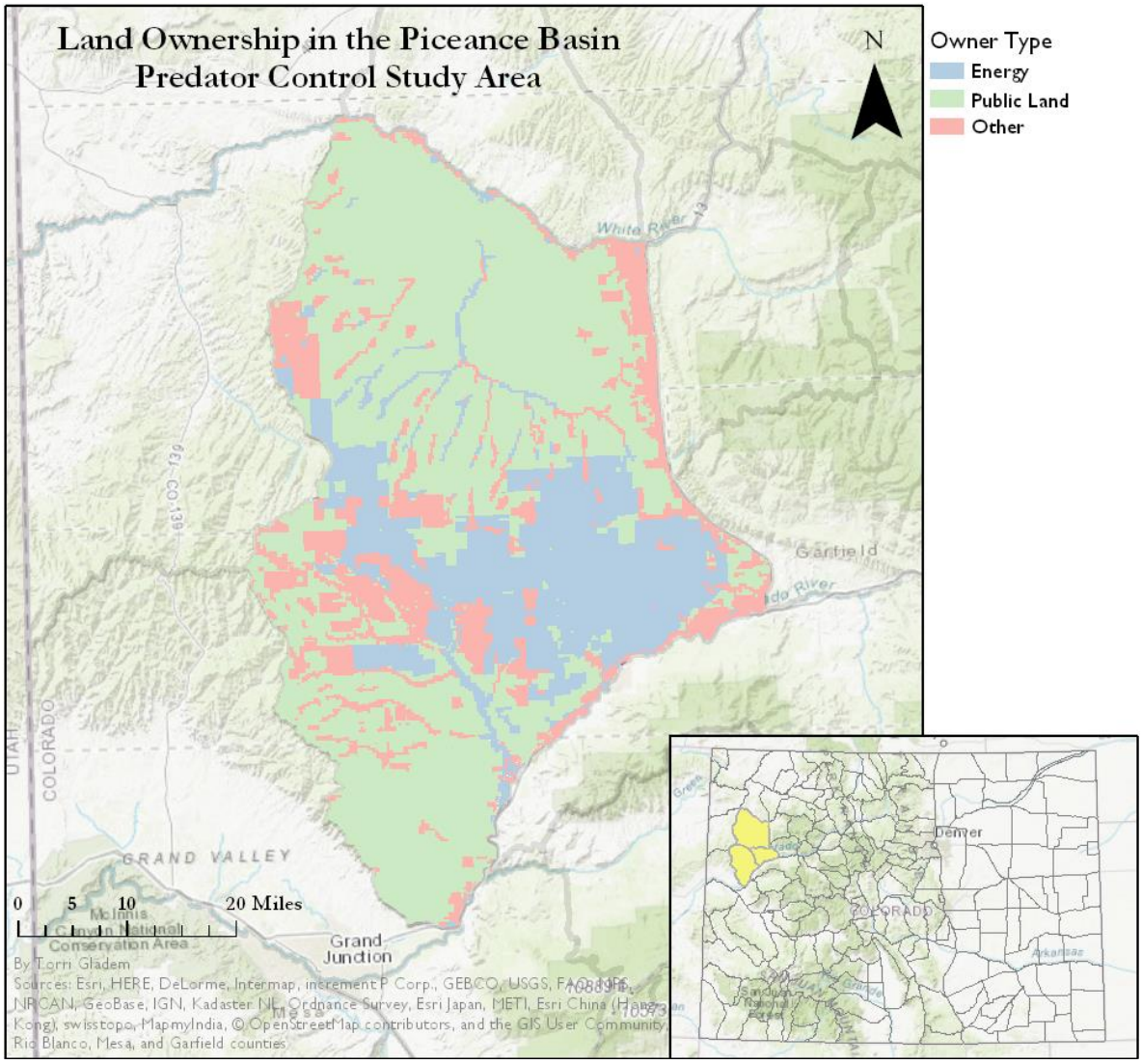

Figure 3. This map depicts the Piceance Basin predator control study area, and its various land ownership. The vast majority of land is owned by energy companies and the Bureau of Land Management.

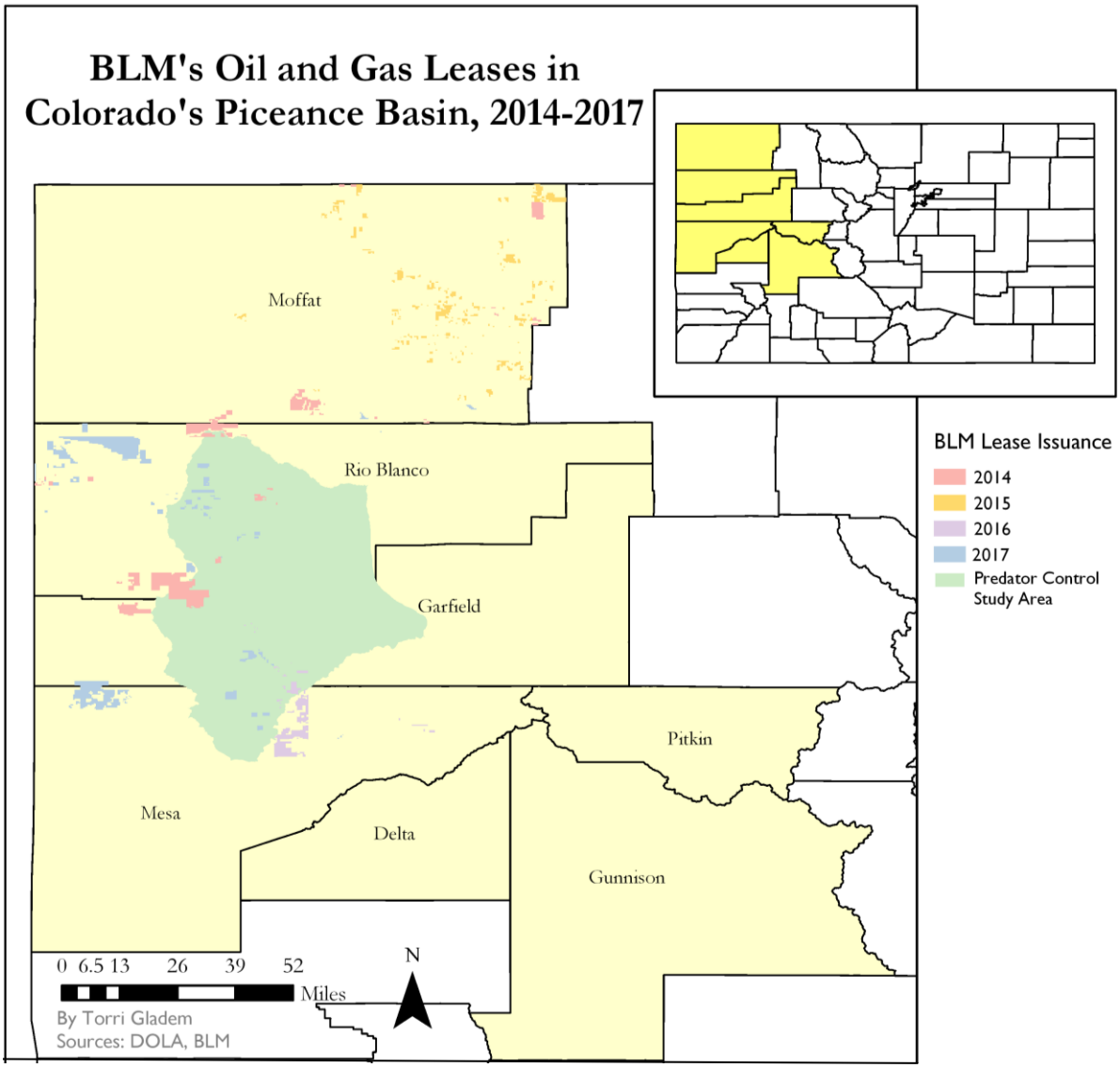

Figure 4. This map depicts the oil and gas leases granted by the BLM in the Piceance Basin from 2014-2017. Leases were granted in the eventual predator control study area every year, and sometimes multiple times in one year.

Appendix B: Survey

Introduction/Background: This research is being conducted in an effort to address and better understand the viewpoints of key stakeholders regarding a Colorado Parks & Wildlife management strategy. This survey will take approximately 5 minutes to complete and does not require any personal information to be disclosed. Thank you for participating!

Please read the following background information before beginning the survey: The Piceance Basin predator cull is a wildlife management strategy implemented in 2017 by Colorado Parks & Wildlife (CPW). This plan was enacted as part of the larger effort to aid declining mule deer populations, known as the 2014 Colorado West Slope Mule Deer Strategy. In public meetings held by CPW prior to this decision, participants consistently identified predation, habitat loss, and habitat degradation as the top three most threatening factors for mule deer population recovery. In an effort to address these concerns, another important goal of the 2014 strategy is to mitigate developmental impacts on mule deer. However, the area in which the predator cull study is taking place consists of lands largely owned by energy development companies. These companies are actively drilling and developing in the Piceance Basin because it contains massive reserves of oil shale and natural gas.

While there is an expanding body of research on the responses of mule deer to land use changes in the area, similar information as it relates to predator species is less available. Generally, this is because such species exist in smaller numbers, are solitary for much of the year, and quite elusive by nature. Previously conducted research has found energy development to negatively impact mule deer, but in a personal study, CPW biologists suggested the deer population in question is not limited by habitat changes. Therefore, they've hypothesized that the herd's numbers are limited by increased predation instead. Specifically as it relates to black bears, the predator control plan concerns the culling of up to 25 bears annually for 3 years. This is expected to limit predation rates, but will not address other activities occurring in the Piceance Basin.

Questions:

Q1. I understand that this survey does not utilize any personal information and consent to participate.

Yes

No

Q2. Are you a current resident of Colorado?

Yes

No

Q3. Which word most accurately describes the area in which you live?

Rural

Urban

Q4. What city/town do you live in?

_____

Q5. Were you aware of the predator control plans before today?

Yes

No

If you answered 'No' to Question 5, you may skip ahead to Question 7.

Q6. How did you initially hear about the predator control plans?

Colorado Parks & Wildlife

News and media coverage

Friends and family

Q7. Did you know about any of the public meetings that Colorado Parks and Wildlife held inviting input on the mule deer issue?"

Yes

No

If you answered 'No' to Question 7, you may skip ahead to Question 9.

Q8. Complete the following statement: I would have been more likely to attend one of the public meetings if

It was held closer to my residence

I was included on an e-mail list that updated me with relevant CPW topics

If the issue/study area was in my city/town

I would not attend

Q9. What is your opinion of the predator control plans?

Positive

Neutral (No opinion)

Negative

Q10. How do you feel about the amount of research that has been conducted on predator species?

There is substantial research on predator species

There is adequate research, but more should be conducted to better our understanding

There is not nearly enough research on predator species

Q11. Have you ever bought a (CO state) hunting license, fishing license, or season pass for Colorado's state parks?

Yes

No

If you answered 'No' to Question 11, you may skip ahead to Question 13.

Q12. How often would you estimate that you have bought one of these licenses or passes?

>1 per year

1 per year

1 every two years

1 every three years

1 every four years

1 every five years or more

Q13. How do you feel about predator species in Colorado, specifically black bears?

Positively

Neutral

Negatively

Q14. Consider this scenario: There is a two-tiered pricing system regarding the licenses and passes mentioned above. The lower tier would represent licenses and passes at the

same prices they are currently. The higher tiered option would represent a reasonable increase in price ($10 for fishing, $15 for hunting, and $20 for season passes) , but all of the additional proceeds would support building a new predator species research fund. How would you feel about having the option to contribute to such a fund in this way?

Positively-I would support a two-tiered system
Neutral-I have no opinion on a two-tiered system
Negatively-I would not support a two-tiered system

Q15. Would you personally be inclined to support predator research by choosing to buy the more expensive license or pass?

Yes
Maybe
No

Q16. Agree/disagree with the following statement: State wildlife policy has emphasized oil and gas development over wildlife management.

Strongly agree
Agree
Neither agree nor disagree
Disagree
Strongly disagree

Appendix C: Code

```
#Change this if you want to look at another type of question
nms <- c("    yes",
         "neutral",
           "     no")
#Enter num yes, num neutral, num no
resp <- c(x, y, z)

for(i in 1:3){
   print(stringr::str_c(nms[i], ": Mean = ",
                        round(resp[i] / sum(resp), digits = 5),
                        "     95% CI: ",
                        paste(round(binom.test(resp[i], sum(resp))$conf.int,
                                    digits = 5), collapse = " - ")))
}
```

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