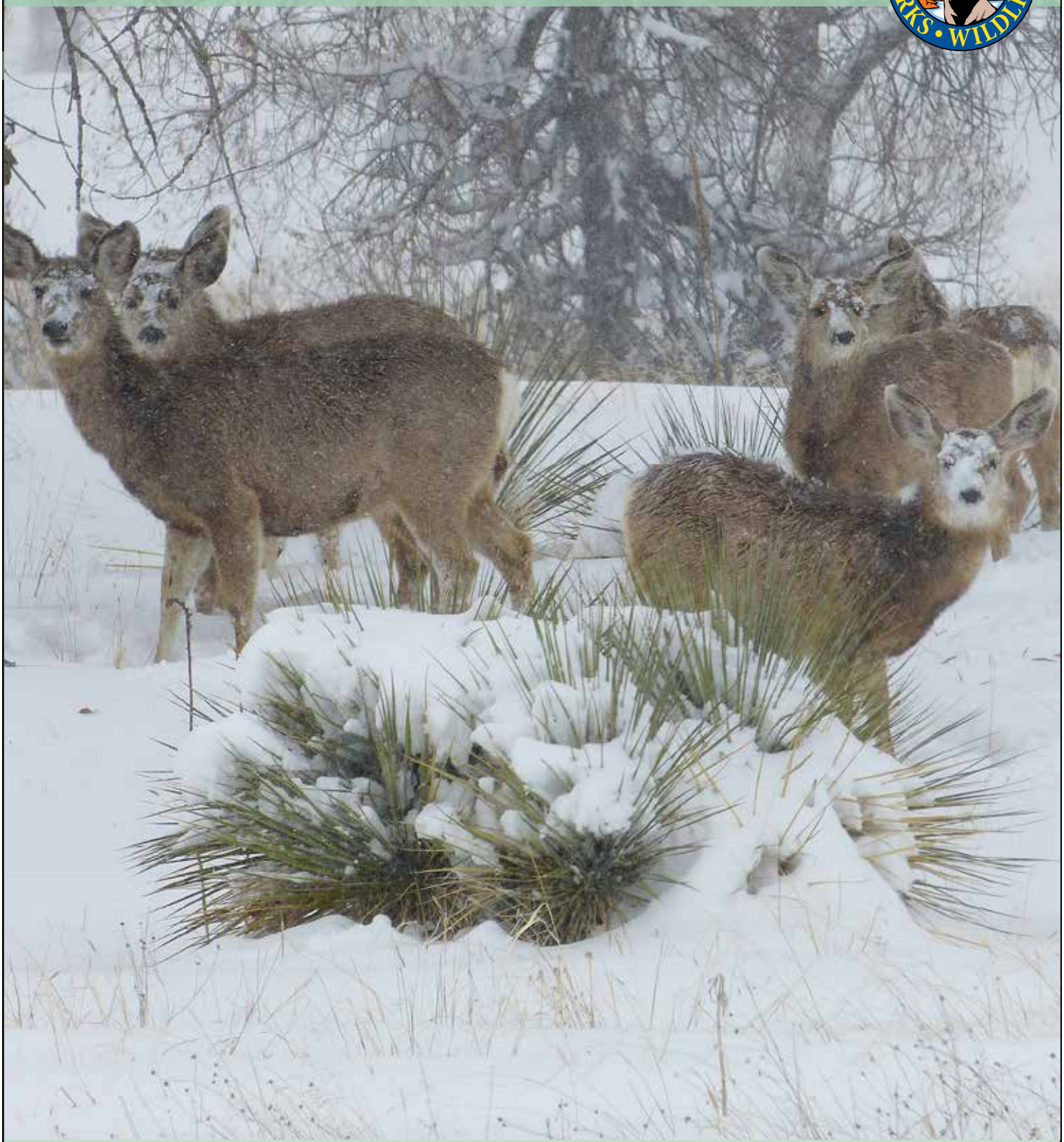
C O L O R A D O P A R K S & W I L D L I F E

2020 Status Report: Big Game Winter Range and Migration Corridors

STATE OF COLORADO • DEPARTMENT OF NATURAL RESOURCES



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List of Acronyms

BBMM . . . . . Brownian Bridge Movement Model

BLM . . . . . Bureau of Land Management

CDOT . . . . . Colorado Department of Transportation

CDOW . . . . . Colorado Division of Wildlife

COGCC . . . . . Colorado Oil and Gas Conservation Commission

CPW . . . . . Colorado Parks and Wildlife

CSFS . . . . . Colorado State Forest Service

CWHP . . . . . Colorado Wildlife Habitat Program

CWTA . . . . . Colorado Wildlife and Transportation Alliance

DAU . . . . . Data Analysis Unit

DOI . . . . . Department of Interior

DRMS. . . . . Colorado Department of Reclamation Mining and Safety

ESRI . . . . . Environmental Systems Research Institute

GIS . . . . . Geographic Information System

GMU . . . . . Game Management Unit

GOCO . . . . . Great Outdoors Colorado

GPS . . . . . Global Positioning System

HMP. . . . . Herd Management Plan

MDF . . . . . Mule Deer Foundation

List of Acronyms (cont.)

NFWF . . . . . National Fish and Wildlife Foundation

NGOs . . . . . Non-governmental organizations

NRCS . . . . . Natural Resources Conservation Service

PUD . . . . . Planned Unit Development

PV . . . . . Photovoltaic

RESTORE . . . . . Restoration and Stewardship of Outdoor Resources and the Environment

RMEF . . . . . Rocky Mountain Elk Foundation

SAM . . . . . Species Activity Mapping

SCORP . . . . . Statewide Comprehensive Outdoor Recreation Plan

SLB . . . . . Colorado State Land Board

SO 3362 . . . . . Secretarial Order 3362

SUIT . . . . . Southern Ute Indian Tribe

USFS. . . . . United States Forest Service

VHF . . . . . Very High Frequency

WSMDS . . . . . West Slope Mule Deer Strategy

WSWPS . . . . . West Slope Wildlife Prioritization Study

WVC . . . . . Wildlife-vehicle collisions

USFWS. . . . . United Fish and Wildlife Service

USFWS-PFW . . . . United States Fish and Wildlife Service-Partners for Fish and Wildlife

Introduction

Purpose

Colorado Parks and Wildlife (CPW) manages wildlife for the use, benefit and enjoyment of the people of the state, in accordance with the CPW's Strategic Plan and direction from the Parks and Wildlife Commission and the Colorado Legislature. Colorado boasts a diversity of habitat types ranging from prairie grasslands to sagebrush plateaus, from pinyon-juniper woodlands to montane and subalpine forests, and semi-desert shrublands to alpine tundra. This diverse landscape is the primary reason that Colorado is home to some of the largest big game herds in North America, as well as to a growing human population. Colorado's majestic beauty and abundant natural resources continue to draw an increasing human population.

Colorado's wildlife resources require careful and increasingly intensive management to accommodate the many and varied public demands and growing impacts from people. CPW is actively working to balance the ever-increasing human presence on the landscape with conservation of our state's world-class natural resources.

On August 21, 2019, Governor Jared Polis directed both CPW and the Colorado Department of Transportation (CDOT) to work cooperatively to conserve Colorado's valuable big game resources through executive order D 2019 011: Conserving Colorado's Big Game Winter Range and Migration Corridors. This executive order directs CPW to compile a big game status report to guide both agencies, as well as our partners, to collectively improve the conservation of big game winter range and migration corridors.

The intent of this report is to provide a baseline of scientific information related to the following big game populations in Colorado: mule deer, elk, pronghorn, bighorn sheep and moose. CPW compiled the best available science on Colorado's big game populations, including: population status and trends, monitoring and inventory methods, seasonal habitats and migration corridors, and conservation threats and actions. This report also outlines current research and data gaps associated with Colorado's big game winter range and migration corridors. CPW concludes this report with recommendations on a path forward to conserve these valuable habitats and populations.

Background

Conservation of Colorado's big game herds and protection of habitat is of the highest priority for CPW. Big game populations across Colorado have been the topic of extensive scientific study for several decades. CPW has biologists and research staff dedicated to investigating specific wildlife management issues, and uses this data to inform wildlife management throughout the state.

In 2018, the Department of Interior (DOI) released Secretarial Order 3362: Improving Habitat Quality in Western Big Game Winter Range and Migration Corridors (SO 3362). SO 3362 directed appropriate bureaus in the DOI to work in partnership with Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, and Wyoming to improve big game winter range and migration corridors. As part of SO 3362, two funding opportunities emerged to provide support for western states to work on proactive habitat management and identification of big game migration corridors.

The DOI provides a grant to research big game movement patterns in priority landscapes. The second grant is from the National Fish and Wildlife Foundation (NFWF) to conduct proactive winter range habitat restoration projects. SO 3362 also directed the United States Fish and Wildlife Service-Partners for Wildlife (USFWS-PFW) program to allocate a portion of their funding toward big game winter range work on private lands in the focal western states.

Colorado has taken advantage of the SO 3362 grants in several ways. In 2018, CPW received funding ($272,000) to deploy Global Positioning System (GPS) collars in two landscapes in Colorado, North Park and San Juan (Figure 1). CDOT received funding ($317,734) to install wildlife fencing along U.S. Highway 160. In 2019, CPW received additional funding ($249,000) to deploy GPS collars to understand big game movement patterns in the South Park and the Front Range landscapes.

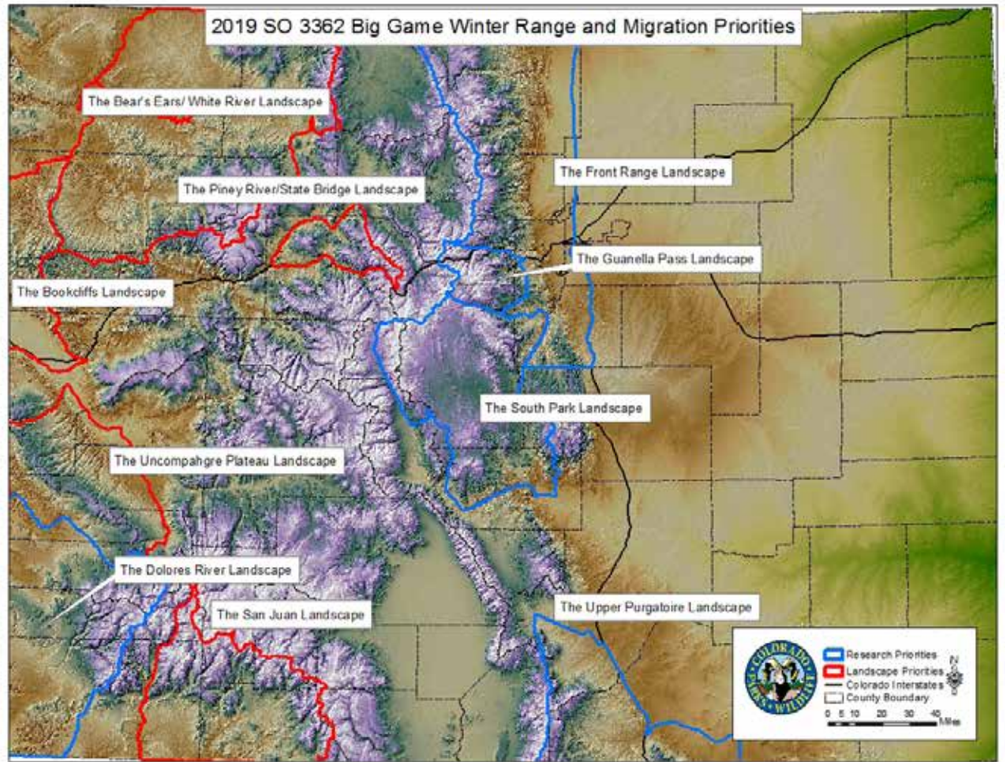

Figure 1. 2019 Colorado priority landscapes and research areas related to SO 3362.

Big Game Species Assessments

To manage big game populations, CPW uses a "management by objective" approach for each Data Analysis Unit (DAU). A DAU is the geographic area that represents the year-around range of a big game herd and delineates the seasonal ranges of a specific herd, while keeping interchange with adjacent herds to a minimum. A DAU includes the area where the majority of the animals in a herd complete their life cycle. Most DAUs are composed of multiple Game Management Units (GMUs), which are designed to distribute hunters within the DAU. In a few cases, only one GMU makes up a DAU.

Management of DAUs is guided by Herd Management Plans (HMPs), which contain target ranges for population size and herd composition for each population. The purpose of a HMP is to integrate CPW's management objectives with the concerns of other land management agencies and interested publics in determining how a big game herd in a specific geographic area (DAU) should be managed. CPW attempts to balance the biological capabilities of the herd and its habitat with public demand for wildlife recreational opportunities.

The primary metrics defined within each HMP are the desired population objective range within the DAU, and the desired sex ratio for that population (e.g., the number of males per 100 females). These numbers are referred to as the population objective and the sex ratio objective, respectively. CPW surveys big game populations in the winter, when snow concentrates animals at lower elevations. CPW conducts aerial post-hunt herd inventories for mule deer and elk to estimate sex ratios and age ratios (young/100 females.) These ratios are utilized, along with survival rates, to estimate population sizes and trends using population models. Post-hunt winter population estimates from 2018 are the most recent estimates available because 2019 post-hunt surveys are still being collected and processed

These objectives drive the process for setting numbers of hunting licenses based on harvest objectives in order to maintain the desired population size and herd composition. Each HMP is revised approximately every 10 years, while hunting license numbers are adjusted annually.

Mule Deer

Mule deer populations across the western states have shown declines on several occasions since CPW started monitoring their populations. In 1999, the Colorado Division of Wildlife (CDOW) submitted a report to the Colorado Legislature describing declines in mule deer populations, identifying issues and causes, and outlining proposed management actions to increase populations. Mule deer numbers declined most recently starting in 2007, not just in Colorado, but across all of the western United States. These mule deer population declines caused concerns within CPW and among Colorado's constituents with an interest in mule deer.

Nora Logue, CPW

Between 2007 and 2013, Colorado's estimated statewide deer population declined from roughly 600,000 deer to approximately 390,000 deer (Figure 2). Some herds have yet to recover from the severe winter of 2007-2008. Western Colorado has historically supported some of the largest mule deer herds in the state and across the western United States, such that these declines are of both statewide and regional significance. Deer populations fluctuate naturally in response to changing environmental conditions; however, the most recent (2007-2013) decline in the state's largest deer herds is atypical, leaving several mule deer herds well below their population objectives. Recognizing the need for additional action, CPW embarked on a comprehensive effort in 2013 to gather input from internal staff, researchers and the public to investigate the root cause of the most recent decline.

The product of this public process was the 2014 West Slope Mule Deer Strategy (WSMDS). The WSMDS identifies seven management priorities to address mule deer declines on the West Slope of Colorado.

- Landscape-scale habitat management to improve habitat quality
- Predator management where predation may be limiting deer survival
- Protection of habitat and mitigation of development impacts
- Reducing the impacts of highways on mule deer survival, movements and migration
- Reducing the impacts of human recreation on mule deer
- Regulation of doe harvest and providing youth hunting opportunity
- Maintaining a strong big game population and disease monitoring program and conducting applied research to improve management of deer populations

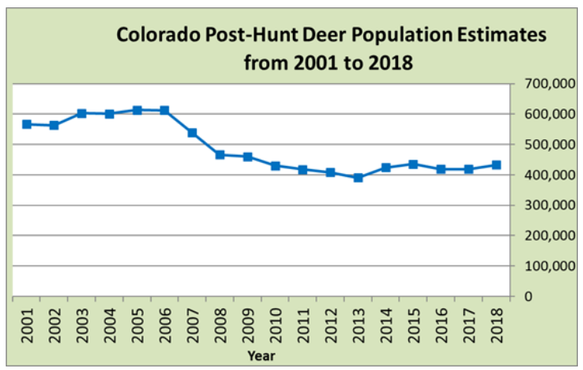

Figure 2. Colorado post-hunt deer population estimates from 2001 to 2018.

CPW has been implementing these priorities as outlined by the WSMDS since its adoption in 2014. CPW continues to work closely with hunters, landowners, community leaders and partner agencies to identify major areas of impacts to deer herds in Colorado, using the WSMDS to help guide management decisions. Together with stakeholders, CPW is working to sustain and increase mule deer populations in western Colorado and, in turn, increase hunting, viewing and wildlife-related recreational opportunities.

Populations

The current statewide post-hunt deer population estimate is 433,000, which is well below the population objective range of 500,000-560,000 mule deer. In 2018, 23 of 54 (43%) deer herds are below their population objective ranges (Figure 2).

Population performance varies considerably throughout the state due to diverse habitat types, environmental conditions, disease, and human impacts. While some deer herds are performing well and population sizes and license numbers are stable or increasing (east of Interstate 25), there remains an overall decline across collective mule deer herds in Colorado. Many deer herds west of Interstate 25 are well below objective (Figure 3).

Wayne D. Lewis , CPW

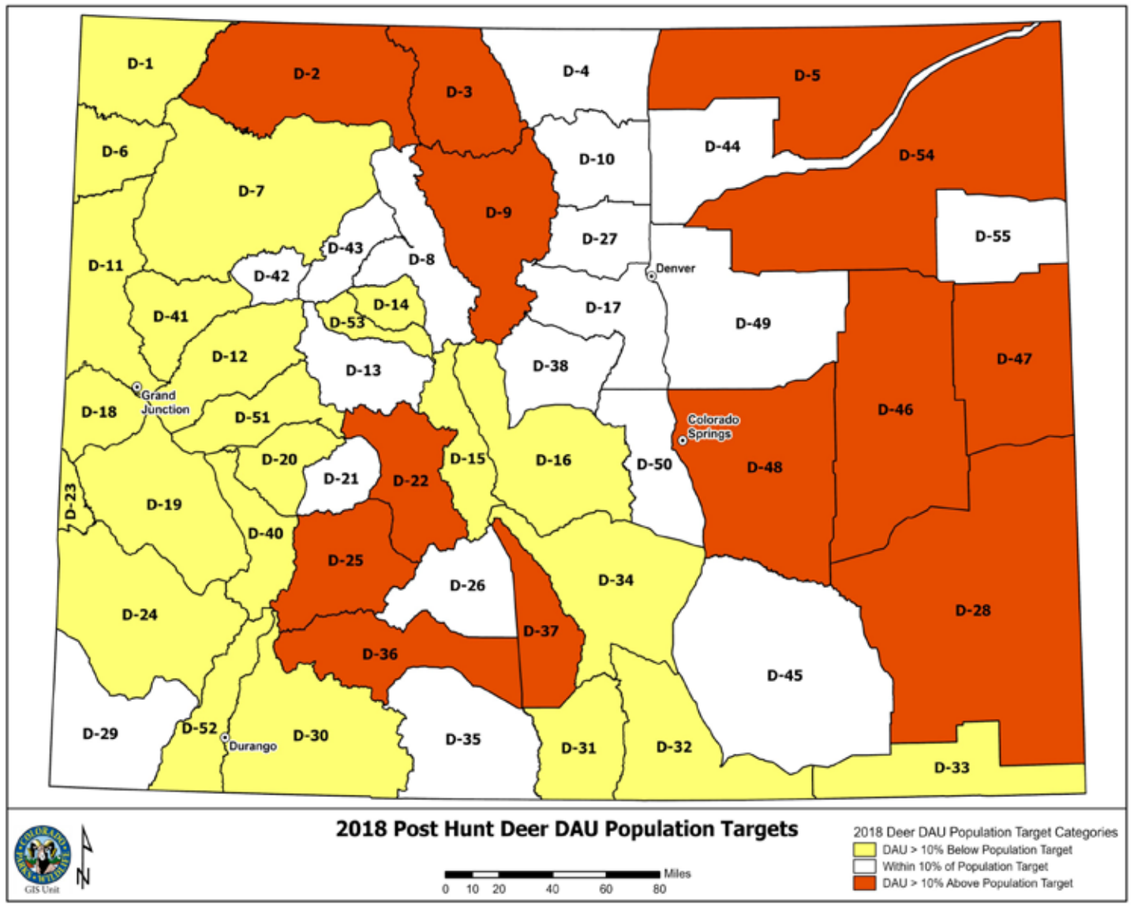

Figure 3. Colorado 2018 post-hunt deer DAU population objectives.

Monitoring and Inventory

CPW intensively monitors annual adult doe survival and winter fawn survival in five mule deer herds (White River D-7, Middle Park D-9, Cripple Creek D-16, Uncompahgre D-19, and Gunnison Basin D-21, D-22, D-25). CPW also monitors buck survival in two of these herds, White River and Middle Park. CPW annually monitors over 1,000 VHF radio-collared mule deer throughout Colorado. Survival rates from these sentinel herds are used as a parameter in deer models to estimate populations. Survival rates within the monitored herds vary by DAU. Survival in D-9 (Middle Park) is well above average, D-7 (White River) is somewhat below average, and the other three monitoring areas fall within the long-term average.

Vik Schendel, CPW

The current average sex ratio objective for deer herds statewide is 30 bucks/100 does. During the post-hunt herd inventories in 2018, CPW staff classified 71,000 deer and observed an average sex ratio of 35 bucks/100 does and age ratio of 59 fawns/100 does (Figure 4). The ratio of fawns per 100 does is an index of annual fawn production and survival, which is an indicator of the "fitness" of an individual herd. Fawn/doe ratios in many of Colorado's deer herds have been declining since the early 1970's.

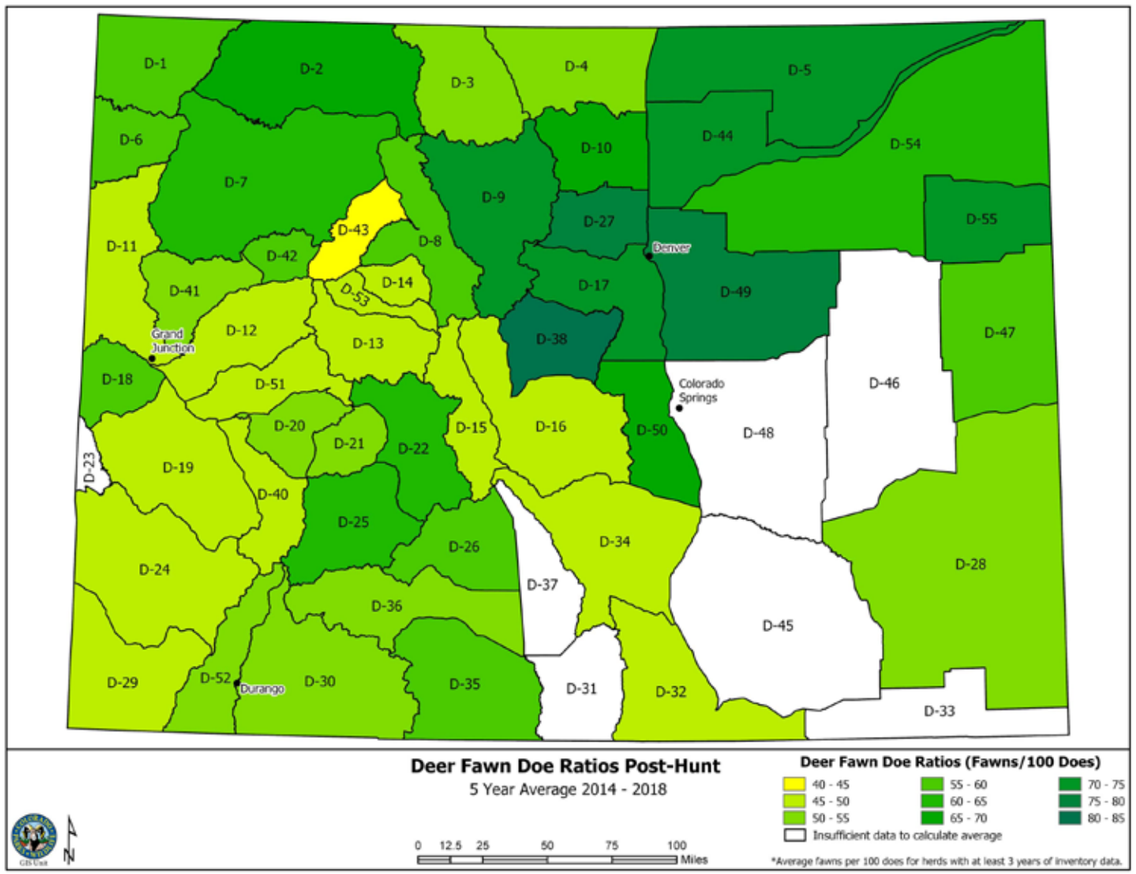

Figure 4. Colorado 2018 post-hunt deer fawn/doe ratios.

Elk

Populations

Colorado's statewide elk population, the largest in the United States, most recently peaked in 2001 at 305,000 animals. The statewide 2018 post-hunt population objective range is 233,000-282,000. The 2018 post-hunt estimate was 287,000, up slightly from 282,000 in 2017 (Figure 5). CPW utilizes season structure and hunter harvest, specifically antlerless harvest, to maintain or achieve population herd objectives. CPW has intentionally reduced elk populations to achieve population objectives. Reductions in antlerless licenses are anticipated as elk populations reach objectives or as population objectives increase.

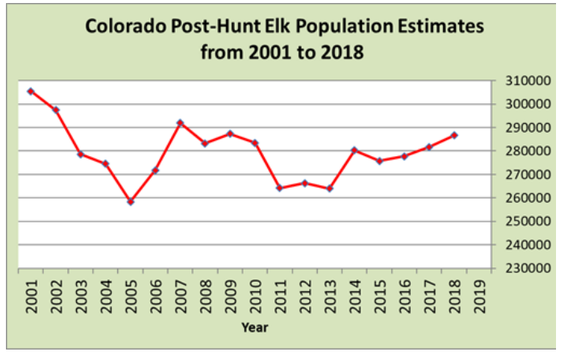

Figure 5. Colorado post-hunt elk population estimates from 2001 to 2018.

Hunters and outfitters have increasingly expressed concerns that elk populations are becoming too low in some herds, despite the fact that 22 of 42 (52%) of the elk herds are above their current population objective ranges (Figure 6). Based on feedback from the public, CPW gives serious consideration to raising population objectives in herds as HMPs are updated. The agency must balance requests from hunters with landowner concerns about damage to their properties or crops, land management agencies concerns regarding habitat conditions, and preferences identified by local communities. Hunter experience helps to inform the upper and lower social thresholds for elk population size in many herds, which benefits herd management planning efforts.

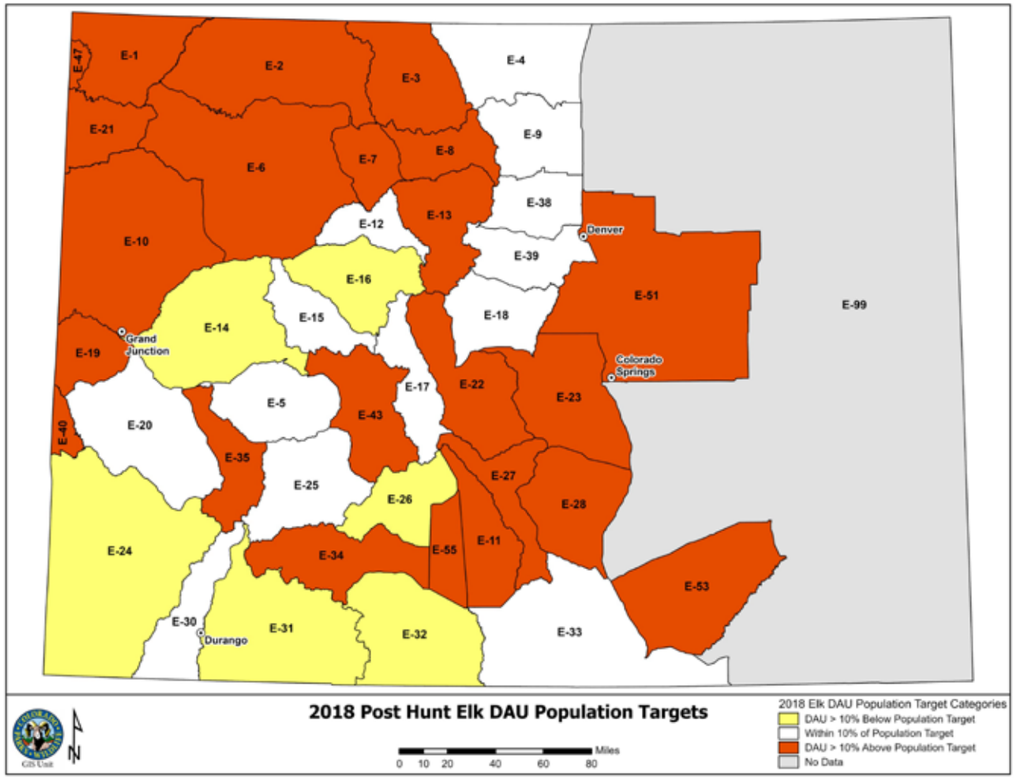

Figure 6. Colorado 2018 post-hunt elk population objectives.

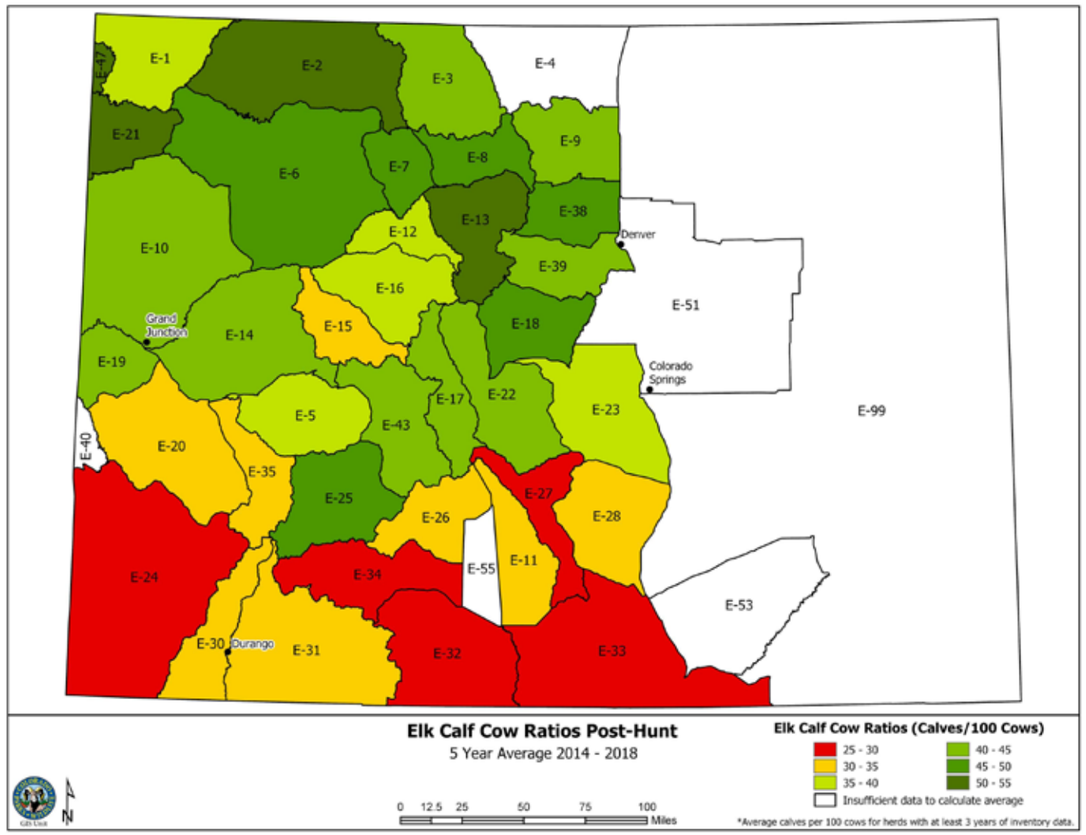

Figure 7. Colorado 2018 post-hunt elk calf/cow ratios.

Wayne D. Lewis, CPW

Monitoring and Inventory

During 2018 post-hunt herd inventories, CPW staff classified 96,000 elk and observed a statewide average sex ratio of 23 bulls/100 cows. Calf/cow ratios are an index of annual calf production and survival to mid-winter, which is an indicator of the "fitness" of the herd. During post-hunt surveys over the past decade, CPW has observed a decline in calf/cow ratios in several DAUs in the southern portion of the state (Figure 7). Consequently, the number of antlerless elk licenses available to hunters has decreased in these DAUs, which ultimately reduces hunting opportunity. In comparison, the average calf/cow ratios in Northwest region are 47 calves/100 cows, and the Northeast Region is 41 calves/100. Historically, northern Colorado has had higher calf ratios. Further research and management adjustments are necessary to address the ongoing low calf production in several herds.

Pronghorn

Populations

Colorado's statewide post-hunt pronghorn population objective range is 68,000 – 78,000, which is divided among 30 herds across the state (Figure 8 and Figure 9). The 2018 statewide post-hunt pronghorn population estimate is 79,000, down from the record high of 86,000 in 2017 (Figure 8). Thirteen of 29 (45%) pronghorn herds are above their population objective range (Figure 9). Approximately half of the state's pronghorn herds reside in the Southeast Region, where the greatest number of licenses are available. Licenses are issued to provide the maximum opportunity for hunters without negatively affecting success rates or exceeding landowner tolerance for pronghorn hunters.

Vik Schendel , CPW

Monitoring and Inventory

During pre-hunt herd surveys in 2018, CPW staff classified 16,000 pronghorn. The average observed pre-hunt sex ratio was 49 bucks/100 does, down from 51 bucks/100 does in 2017. The average observed pre-hunt fawn/doe ratio was 43 fawns/100 does, much lower than the 57 fawns/100 does in the previous year. Drier range conditions may be contributing to a reduction in the fawn/doe ratio.

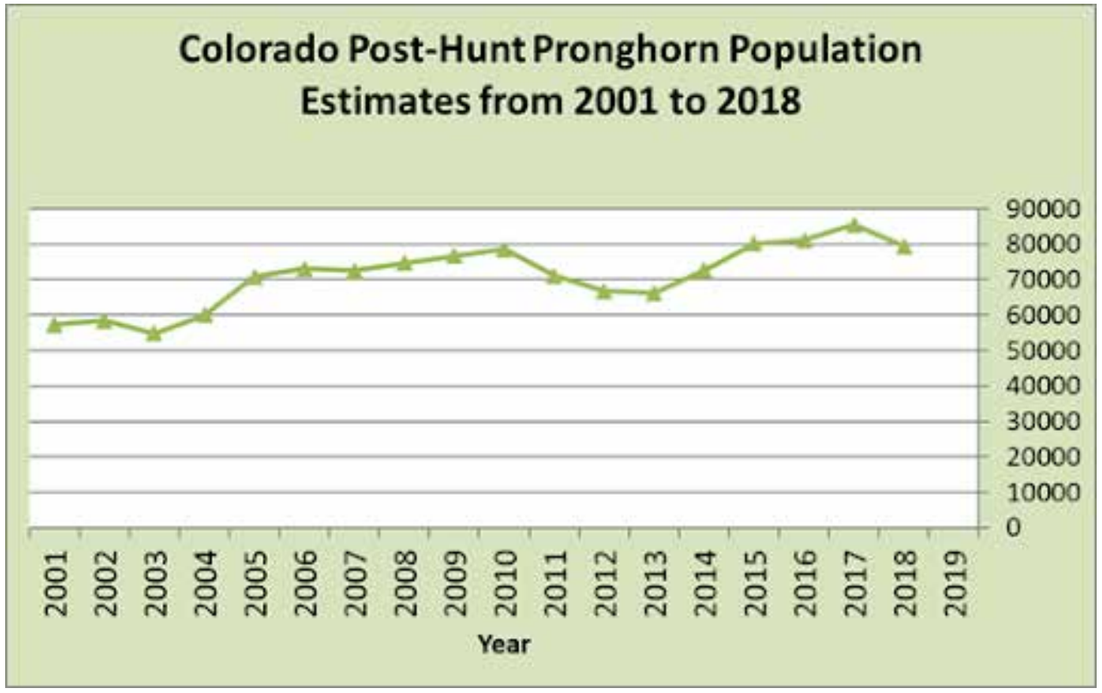

Figure 8. Colorado post-hunt pronghorn population estimate from 2001-2018.

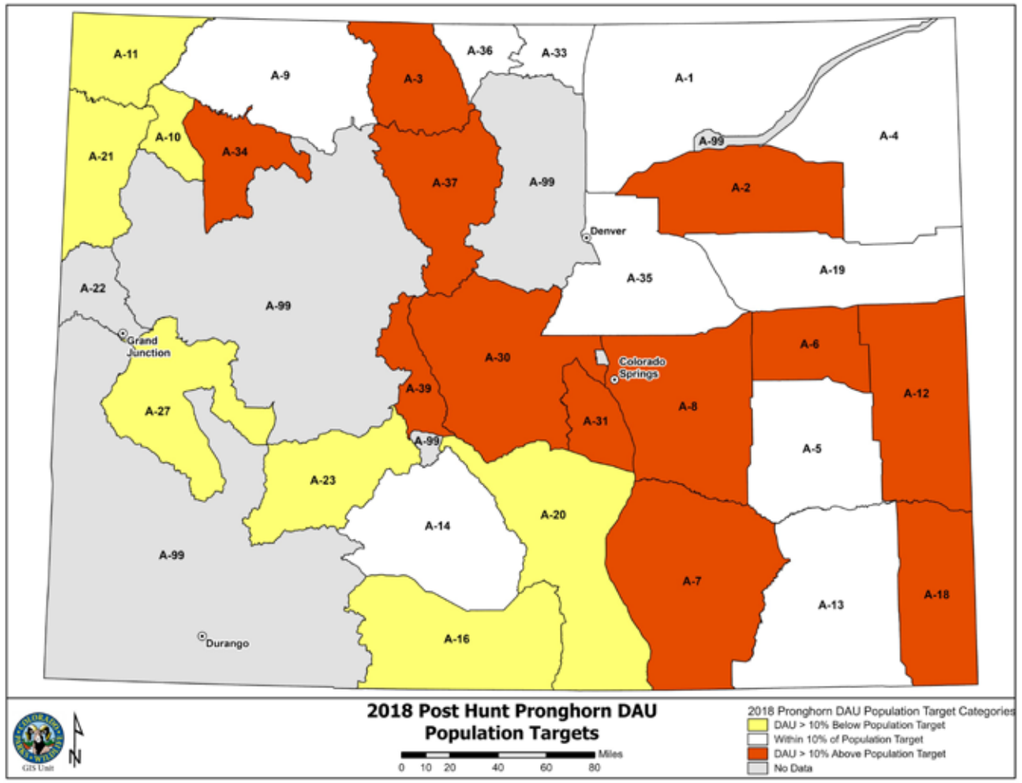

Figure 9. Colorado 2018 post-hunt pronghorn population objectives.

Bighorn Sheep (Rocky Mountain and Desert)

Populations

The 2019 post-hunt estimate for Rocky Mountain bighorn sheep populations is 6,940 (Figure 10). Rocky Mountain bighorn sheep hunting opportunities are divided into 39 different DAUs (Figure 12). There are approximately 550 desert bighorn sheep in 2 DAUs in Colorado (Figure 11).

It is difficult to estimate how many wild sheep were present in Colorado in pre-settlement times. Journals of explorers indicate great numbers of sheep in both the mountainous areas and along the Front Range of Colorado. Since the late 1800's the general trend of wild sheep populations in Colorado and throughout the west has been downward. Historical statewide estimates of 7,230 bighorn sheep in 1915, 3,200 in 1958 and 2,200 in 1970 reflect this trend. However, there were an estimated 6,045 bighorns in Colorado in 1988, and in 2007 there were an estimated 7,040 bighorn sheep statewide (George et al. 2009). One reason for the increase in Colorado's bighorn sheep population is a longstanding effort to trap and translocate wild sheep to establish new populations or supplement existing populations. Based on available records,

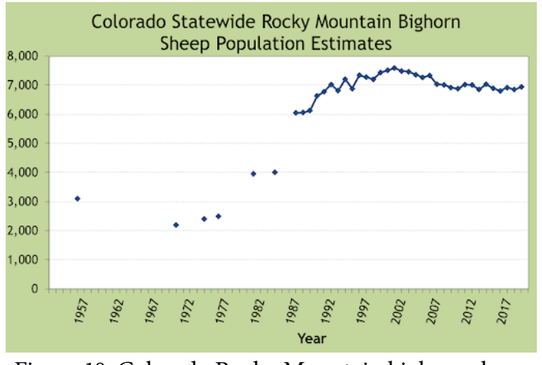

Figure 10. Colorado Rocky Mountain bighorn sheep population estimates from 1987-2019.

only 18 of the Rocky Mountain bighorn sheep herds existing in 2007 have not been established or supplemented by translocations since 1945. All of the desert bighorn sheep herds in Colorado have resulted from translocations (George et al. 2009).

Disease has often been implicated in periodic "all-age" die-offs and sustained bouts of poor lamb survival in Colorado bighorns. The causes of these early die-offs are hard to verify retrospectively, but contact with domestic livestock that led to the introduction of exotic diseases and parasites seems the most logical explanation (George et al. 2009).

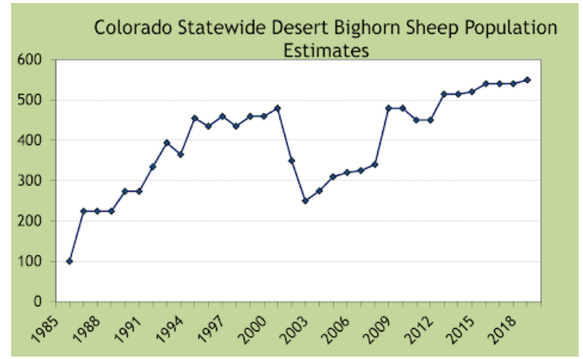

Figure 11. Colorado desert bighorn sheep population estimates from 1986-2019.

Based on a substantial volume of literature, one of the most important aspects of wild sheep management is to keep these species separated from domestic sheep and goats. There are a number of bighorn herds in the state that are in close proximity to active or vacant domestic sheep grazing allotments, particularly on the West Slope. An extensive set of recommendations has been developed for managing bighorn and domestic sheep on shared ranges to help minimize the risk of epidemics in bighorns (George et al 2009).

Monitoring and Inventory

Classification surveys for Rocky Mountain bighorns are typically conducted during December when rams associate with ewes, and lambs have survived past the late summer time period when lamb pneumonia typically impacts mortality. However, late winter aerial and ground surveys are conducted in March for some herds due to higher sightability rates in some high elevation in alpine and timbered habitats (George et al. 1996). Winter classification surveys conducted December through March provide lamb/ewe ratios representative of annual recruitment, but late winter surveys (February through March) may result in underestimated sex ratios.

Summer surveys (July/August) are necessary in some high-elevation areas where winter conditions preclude access; however, parturition may occur as late as July in high elevation herds (Stevens and Stevens 1991, George 1997) and surveys done mid-summer (June through August) may significantly underestimate lamb mortality. Sightability increases in August and September when ewes and lambs aggregate into larger groups and move into more open terrain (George et al. 2009). For desert bighorns, late summer (August through September) may be more appropriate for conducting classification surveys (George et al. 2009).

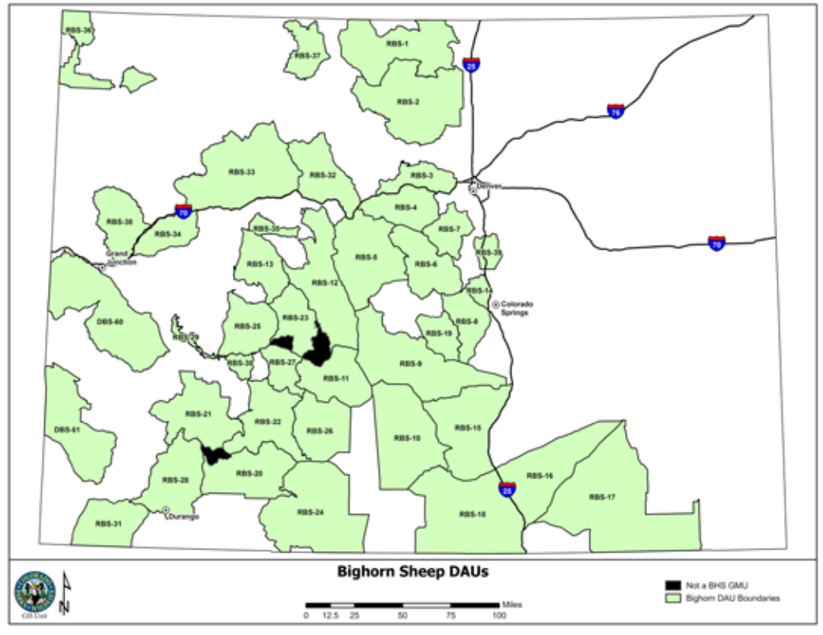

Figure 12. Bighorn sheep data analysis units.

Moose

Populations

Historically, moose were only sighted occasionally in Colorado, with limited sightings in northwest and north-central Colorado (Armstrong et al. 2011). Over the past several decades, CPW has worked to establish sustainable moose populations in Colorado to provide additional hunting and wildlife viewing opportunities. The first translocation of moose occurred in 1978-1979 into North Park. This was followed by additional translocations of moose into suitable moose habitat in Colorado including the Laramie River drainage in 1987; the San Juan Mountains in the early 1990's; the Grand Mesa in the early 2000's; and the Flat Tops in the 2010's.

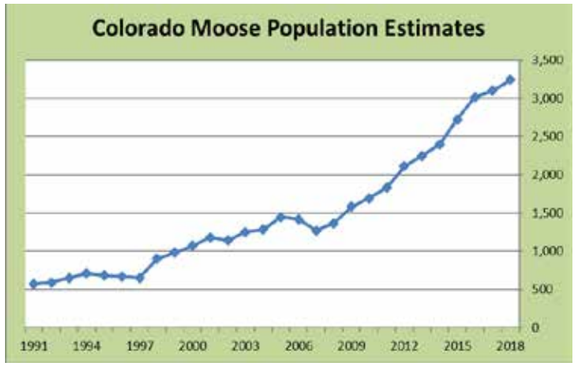

Figure 13. Colorado 2018 post-hunt moose population.

Colorado's overall moose population continues to increase in size as moose expand their range and pioneer new habitats. The estimated statewide 2018 post-hunt moose population is 3,240 (Figure 13). CPW has been increasing cow moose licenses to manage moose populations toward population objectives and to address moose conflicts in some areas. There are twelve moose DAUs in Colorado, 9 on the West Slope and 3 on the Front Range (Figure 14). Since 2017 CPW has allowed moose hunting in a total of 63 GMUs, an increase from 39 GMUs in 2013.

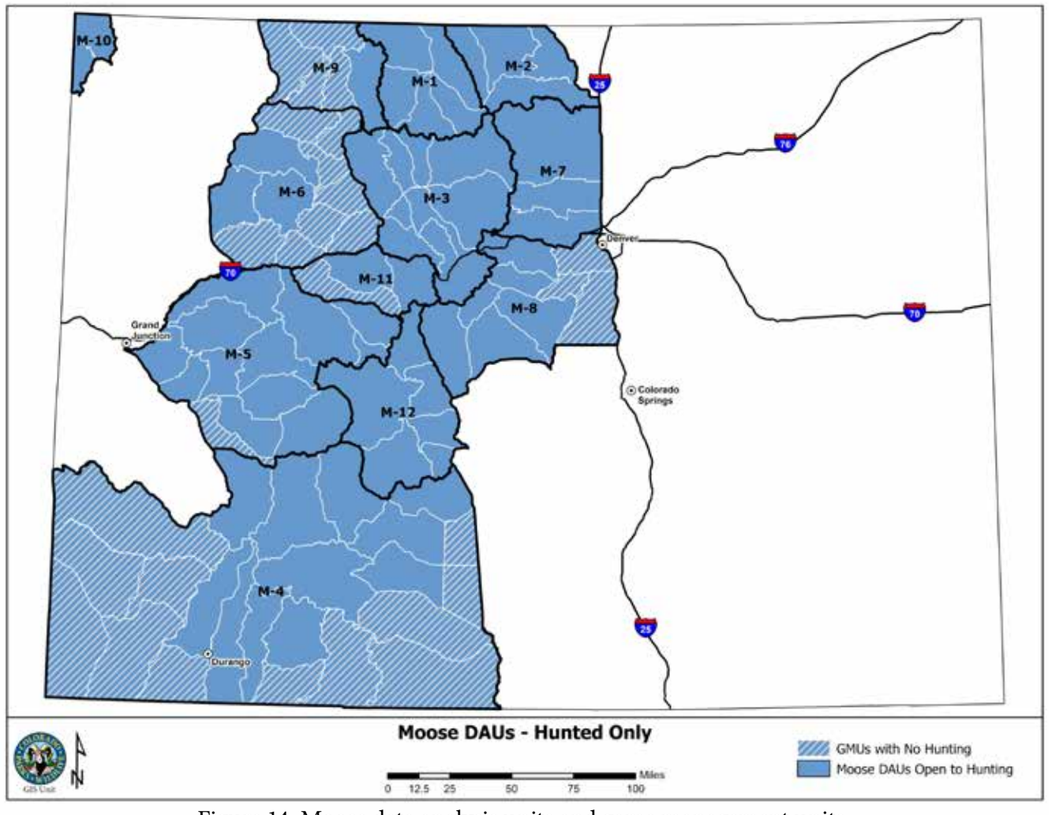

Figure 14. Moose data analysis units and game management units.

Colorado Parks and Wildlife Species Activity Mapping

CPW's Species Activity Mapping (SAM) process involves capturing the knowledge and experience of agency field personnel for wildlife populations in the areas they work. This mapping process was initiated in the 1980's and field personnel were asked to draw seasonal range polygons on Mylar topographic maps at the 1:50,000 scale. These mapped seasonal ranges were then digitized with the advent of Geographic Information System (GIS) software to create a spatially defined dataset.

In 2002, the method for data capture was updated in an effort to make the process more inclusive and accurate (Cowardin and Flenner 2003). With guidance from CPW GIS specialists, data is digitized directly by field personnel using a SMART Board (interactive whiteboard) and ESRI's ArcMap program. CPW personnel are able to update seasonal habitat use maps for each species by viewing the existing GIS data and making edits based on field experience, observations and knowledge of animal movements and locations. The decades of expert, on-the-ground knowledge contributed by CPW field personnel is invaluable. This institutional knowledge is augmented with other data such as annual winter classification flight data locations and radio/GPS collar data from various studies. Collar data is displayed with the current mapped seasonal ranges to verify, edit and update the SAM maps. SAM data is reviewed and updated by each region every four years, with one of the four regions completed each year.

Big Game Seasonal Habitats

Big game seasonal habitats identified by CPW vary by big game species but are generally defined by where each species spends the majority of the summer season or the winter season (Figure 15). Seasonal habitats are defined by several criteria: the number (density or percentage) of animals in an area, geographic location of animals during the calendar year, and the weather conditions that describe those calendar segments.

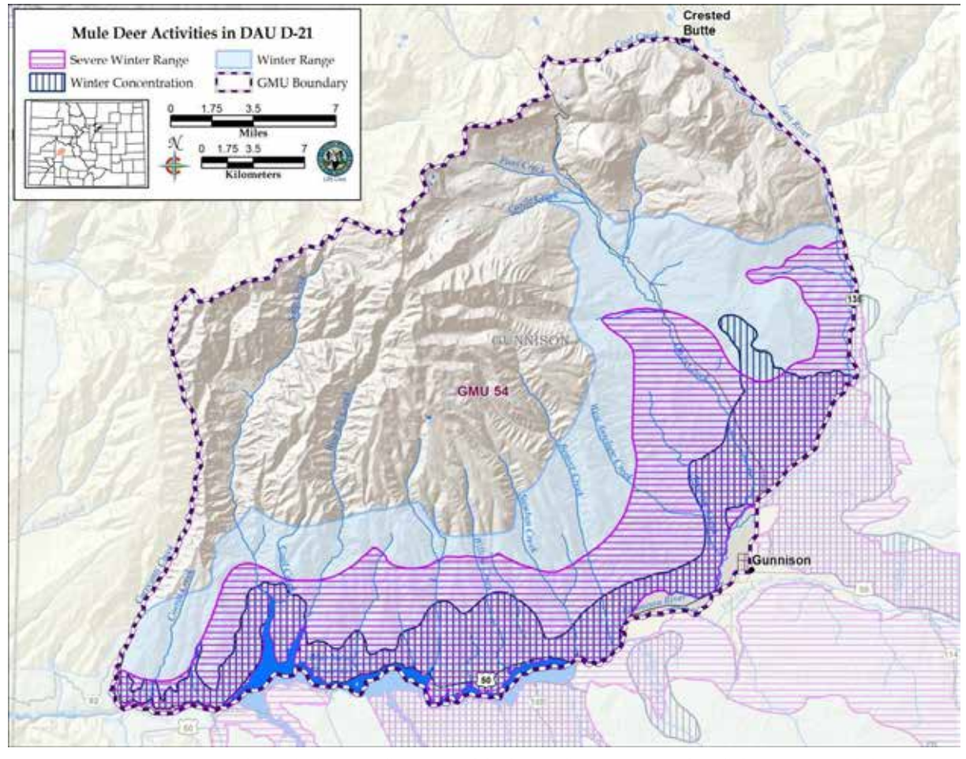

Figure 15. CPW's SAM of seasonal habitat for area north of Gunnison, CO

While there may be habitat cover types that also correspond to these seasonal locations (e.g. sagebrush, pinyon-juniper or aspen and spruce-fir), CPW defines the following seasonal habitats for big game:

Summer Range: That part of the overall range where 90% of the individuals are located between spring green-up and the first heavy snowfall. Summer range is not necessarily exclusive of winter range; in some areas winter range and summer range may overlap.

Winter Range: That part of the overall range where 90% of the individuals are located during the average five winters out of ten from the first heavy snowfall to spring green-up, or during a site specific period of winter as defined for each DAU. Winter range is only delineated for migratory populations. On the Eastern Plains, winter range is defined as areas that provide thermal cover for deer. Examples of this cover are: riparian areas dominated by trees and shrubs, areas of pinyon-juniper, topographic cover such as gullies, draws, canyons, and shelter belts, and Conservation Reserve Program fields that provide adequate forage and cover.

Severe Winter Range: That part of the overall range where 90% of the individuals are located when the annual snowpack is at its maximum and/or temperatures are at a minimum in the two worst winters out of ten.

Winter Concentration Area: That part of the winter range where densities are at least 200% greater than the surrounding winter range density during the same period used to define winter range in the average five winters out of ten.

Management and research have shown that winter range quality and quantity is one of the primary limiting factors for big game population performance. CPW has observed multiple severe winter events over the past several decades that have had significant impacts on big game populations. Human recreation and development; which are occurring at unprecedented levels in Colorado, increasingly overlap with, fragment and impact big game winter range habitats.

Mule Deer Winter Range Analysis

A study that utilized long-term data (1980-2010) on residential and energy development across western Colorado quantified annual changes and overlap of these land uses with mule deer seasonal habitats in each DAU west of I-25. Changes in land use and weather variables (seasonal temperature and precipitation) were modeled to evaluate possible correlated recruitment responses in each individual mule deer DAU (Johnson et al 2016).

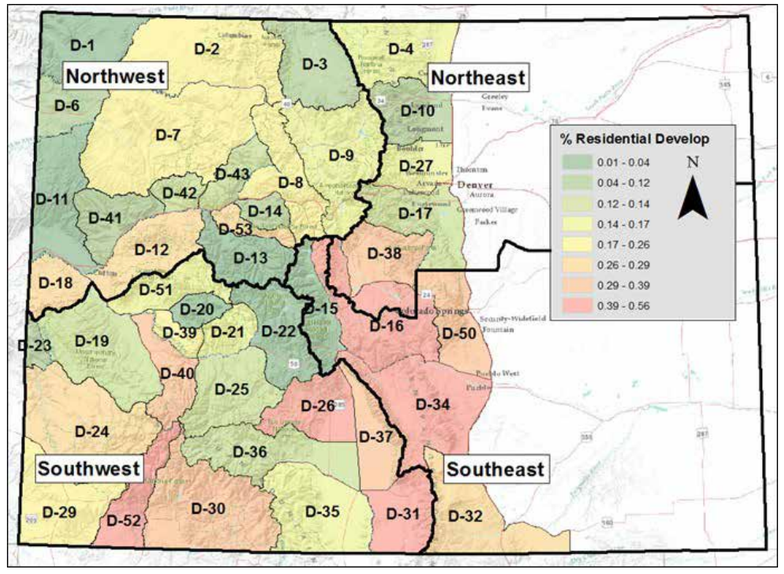

Figure 16. Colorado DAUs representing percent residential development.

Johnson et al. 2016 found that increasing human development within mule deer habitats was correlated with declining recruitment rates, particularly development within seasonal winter ranges. Residential development had twice the magnitude of effect of any other factor investigated. Energy development had a similar effect to key weather variables known to be important to mule deer herd population performance. Based on the results of this study, the researchers concluded that further increases in human development on deer ranges may not be compatible with the goal of maintaining highly productive deer populations. Over the period analyzed in the study, an additional 3.29 million acres (5,156 square miles) of winter range was negatively impacted by land use change, such that by 2010, an average of 31% of mule deer winter ranges were affected by residential development (Figures 16-17). These results underscore the negative impact of residential development could have on mule deer populations, a factor which has received minimal research attention in recent years, despite its rapidly increasing footprint across the landscape (Johnson et al 2016).

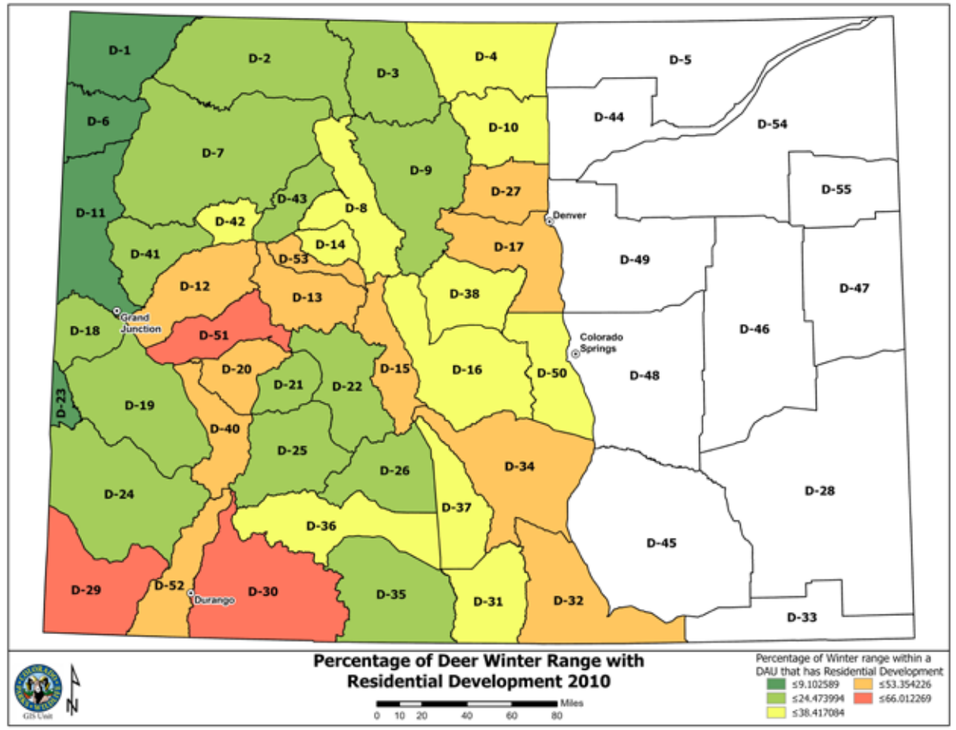

Figure 17. Colorado DAUs representing percentage of winter range and residential development overlap as of 2010.

Big Game Winter Range Habitat Restoration

Based on the recommendation of the WSMDS, CPW began work in 2015 to conduct winter range restoration treatments for deer and elk in high priority landscapes. These landscapes were selected based on CPW's professional judgement of deer and elk population performance, amounts of public land and land use threats. The intent of these restoration treatments were to increase the quality and quantity of available forage on remaining winter range. These restoration treatments have been implemented on both private (20%) and public lands (80%). Restoration treatments consist of a variety of habitat practices from restoring nonproducing agricultural lands back to sagebrush shrublands; to enhancing sagebrush shrublands productivity by altering age class diversity. Several restoration projects have been completed in partnership with the following organizations: BLM, USFS, Natural Resource Conservation Service (NRCS), United States Fish and Wildlife Service (USFWS), Colorado State Land Board (SLB), Colorado State Forest Service (CSFS), Great Outdoors Colorado (GOCO), Mule Deer Foundation (MDF), and private landowners.

Through habitat restoration efforts associated with the WSMDS, CPW has completed 29 projects treating a total 29,716 acres of big game winter range habitat. CPW's financial contributions have been $1.2 million while

our conservation partners have contributed $1.4 million. CPW has planned 11,604 acres of habitat restoration treatments to be completed in the next 5 years. In addition, Colorado RESTORE is a new grant opportunity, through the National Fish and Wildlife Foundation (NFWF), which offers funding to restore winter range habitat and big game migration corridors. Although this is a commendable effort with limited dedicated staff and no permanent dedicated budget; the effort appears to be not keeping pace with the annual loss of big game winter range habitat. This type of habitat restoration work needs to increase in both pace and scale with additional financial and staff resources being allocated to avoid, minimize and mitigate the loss of quality winter range for big game in Colorado.

Big Game Winter Range Habitat Protection

CPW's Colorado Wildlife Habitat Program (CWHP) is a statewide program that provides funding opportunities for landowners who wish to voluntarily protect their private property containing important wildlife habitat, and/or provide sustainable wildlife-related recreational access to the public (Figure 18). By statute, the program's budget prioritizes funding big game winter range and migration corridors, public access for hunting, fishing, and wildlife viewing, and protecting habitat for species of concern. Since the program's inception in 2006, CPW has invested approximately $152 million across the state to secure conservation easements on 250,000 acres. In addition to securing the habitat, public access is allowed on 128,000 acres of the 250,000 acres protected. CPW holds the conservation easements on 100,000 acres of the properties while the conservation easement of 150,000 acres are held by third party entities. Of the total 250,000 acres protected by conservation easements, over 130,000 acres protects big game winter range with 90% of that protected winter range occurring on the West Slope of Colorado.

Brian Holmes, CPW

Figure 18. CPW conservation easement in winter range.

In 2018, the Parks and Wildlife Commission recommended funding conservation easement projects that support wildlife crossings, strengthening CPW's efforts to conserve migration corridors. During 2019, one project was selected in Chaffee County that includes the ability to build a wildlife crossing which will connect two parcels that have conservation easements along US Highway 285 near Salida. We anticipate a 2020 Request for Proposals for the CWHP, including an $11 million budget and funding priorities to include additional conservation of big game winter range and migration corridors.

Big Game Migrations

Many big game species exhibit annual migrations by moving along traditional routes between seasonal ranges, often associated with plant phenology and weather (Lendrum et al. 2014). Colorado's big game is no exception; CPW has been observing big game migrations for decades and documenting these movement corridors. Wildlife professionals, through observation, research and GPS tracking of movements, continue to identify where big game migrations are occurring across the landscape. Road kills and observations can be cost efficient surrogates for mapping migration routes. Big game migrations consist of animals transitioning between winter and summer habitats. Big game in Colorado typically migrate from higher elevations in the summer to lower elevations as winter approaches; and migrate in the spring from winter range back to summer range, following the spring green up. CPW uses the definitions below to describe, big game migration patterns and migration corridors for multiple species throughout the state.

Migration Pattern: A subjective indication of the general direction of the movements of migratory big game herds.

Migration Corridor: A specific mappable site through which large numbers of animals migrate and loss of which would change migration routes.

GPS Collar Technology

The integration of GPS technology in wildlife tracking has revolutionized our understanding of animal migrations (Millspaugh et al. 2012). GPS collars obtain location data through calculations from an array of satellites orbiting the earth. GPS collars will then transmit the location data from the collar back to a communication satellite. The communication satellite transmits the data to a server and wildlife biologists can then view and upload location data to their computers. This technology has allowed biologists to obtain large volumes of accurate location data anywhere across the globe. Through this technology, we have found that many species of animals move much farther than previously thought because it was difficult to track animals with older technology (e.g., VHF radio-collars) due to the large search areas and limited transmission of radio signals. For example, it was recently observed that a GPS collared pronghorn in eastern Colorado moved 55 miles in 10 days. That equates to a search area of 9,500 square miles and it would have been unlikely that we would have detected that movement using older technology.

GPS collars can be programmed to obtain locations at specified time intervals (for example, every 2 hours, 4 hours, or 13 hours) depending on the purpose of the study. The resolution of the data collected is much higher with shorter time intervals, with the trade-off being shorter battery life reducing the number of years of data collection for each collar. GPS locations on shorter time intervals are important when biologists are gathering data on fine scale questions, such as determining a location where an animal crosses a road. Two-hour intervals between locations and at least 30 GPS-collared animals are recommended when mapping migration corridors for deer, elk, pronghorn, and bighorn sheep in Wyoming (Wyoming Migration Initiative 2019). CPW believes that Colorado consists of relatively connected big game seasonal ranges and anticipates that more than 30 GPS collars will be needed to accurately map and understand animal movement patterns. Animals within the same herd may exhibit several types of migratory behavior; therefore, it is important to have a sufficient sample size. For example, approximately 25-30% of pronghorn from one study in eastern Colorado exhibited migratory behavior while the remaining 70-75% resided in the same area throughout the year.

GPS tracking-collars can be expensive and the cost of the collar is partially determined by the time-interval between location fixes. For example, the initial purchase price of a collar with 2-hour time intervals (>$1500/collar) can be more than double the price of a collar programmed for 13-hour time intervals (~$700/collar). There is an additional charge associated with transmitting the GPS location data to satellites that varies depending on the type of collar. Capturing animals can be expensive as well. Many of the animals collared for migration studies are captured with contracted helicopters crews, and capture rates range from $500/animal for deer to over $1000/animal for a moose.

Jason Clay, CPW

Figure 19. Staff fitting GPS collar on cow elk

As with any technology, GPS collars do not always work as intended. Sometimes collars fail to obtain locations. This can be due to the collar's

inability to connect to the satellite, which is a common problem with animals living in very dense vegetation or animals that live in deep canyons. Collars may also fail to obtain locations because of a collar malfunction. Sometimes collar malfunctions occur intermittently while other times the collar will completely fail and will no longer transmit data.

Given the expenses of both purchasing GPS collars and wildlife capture operations, wildlife biologists face a tradeoff between the number of animals that they can collar and the resolution of data that can be obtained from the collars. Additionally, biologists are often looking to answer multiple questions beyond just movement analyses when tracking collared animals. Other common questions include how many animals live through the year and how many females produce young. When the 13-hour time interval GPS collars were first made available, many biologists opted to purchase the $700 collars to increase the number of animals they could study versus getting more GPS locations in a day. Although the location data is coarser-scale and not ideal for answering questions about migration patterns, these collars can still provide data on movement patterns. The researchers at the Wyoming Migration Initiative have developed a tool to analyze migration corridors from data collected from 2 to 13 hour time intervals (Wyoming Migration Initiative 2019). A 13-hour time interval between locations is now considered to be the minimum rate necessary to map migration corridors, using programs R and Migration Mapper. Although a 13-hour time interval data is considered the minimum, CPW recommends 2-hour or 4-hour intervals to accurately map migration patterns. Along with the new collar capabilities, innovative methods to analyze big game movement data are evolving as well.

CPW GPS Collar Data and Analysis

CPW invests a large amount of time and financial resources capturing animals and deploying GPS tracking-collars to collect big game movement data. CPW captures 1,000 to 1,500 big game animals annually through a combination of helicopter net-gunning, trapping and darting. CPW currently has GPS collars collecting big game animal movements for mule deer, elk, pronghorn, bighorn sheep and moose. Table 1 below represents the number of current GPS collar projects by wildlife species.

These projects vary in size and scope with some focusing on wildlife management objectives, while others are long-term research projects (Figures 20-21).

Table 1. Number of GPS collar projects by big game species.

WILDLIFE SPECIES	NUMBER OF GPS COLLAR PROJECTS
Deer	15
Elk	18
Pronghorn	1
Rocky Mountain Bighorn Sheep	17
Desert Bighorn Sheep	2
Moose	1

Most of CPW's GPS collar projects are on-going with GPS data in the process of being collected. Once enough data becomes available to analyze, CPW will begin processing it and incorporating the results into wildlife management decisions. There are several projects that would not meet the minimal interval rate or number of animals (at least 30 individuals) necessary to map migration corridors as outlined by Wyoming researchers. The pronghorn and moose projects are in A6, A8, A35 and M9, respectively. CPW does have some GPS collar datasets that have been analyzed with either R or Migration Mapper across the West Slope of Colorado.

With a move towards using GPS collars to collect animal location data, CPW can more readily identify species movement corridors, seasonal ranges and home ranges. One method that CPW has been using is the Brownian Bridge Movement Model (BBMM). A Brownian Bridge is a continuous-time stochastic model of movement in which the probability of being in an area is conditioned on starting and ending locations, the elapsed time between points, and the mobility or speed of movement (Horne et al. 2007). The shorter the time between locations, the better the estimation of the movement, especially for species that are highly mobile, such as big game. Migration Mapper is another application that will run BBMM on GPS collar data. The Migration Mapper Application was developed by researchers at the University of Wyoming specifically to map migration corridors and winter range using GPS collar data (Wyoming Migration Initiative 2019). The application requires GPS location data to be collected at least every 13 hours, although more frequent locations are recommended. The Migration Mapper application analyzes data from multiple animals and creates movement patterns for each individual, and will perform a prioritization analysis that takes into account the number of animals using the same or similar paths of migration to show areas of high utilization for the herd (Figure 22). The analysis also identifies areas termed as stop-over areas, where animals spend more time during their transit to winter or summer range. Stopovers seem to be less common in Colorado where big game migrate more rapidly. Finally, the application helps better identify winter range habitats.

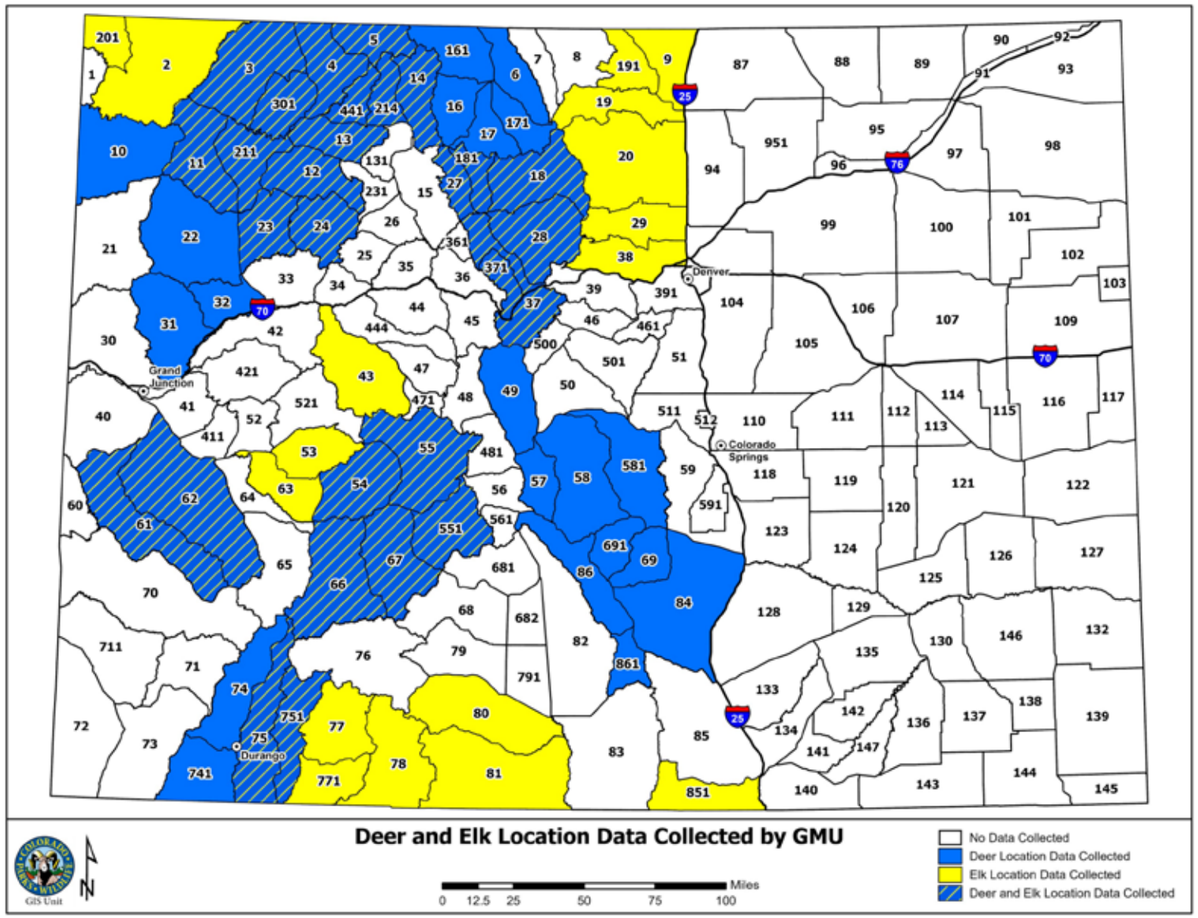

Figure 20. Deer and Elk GMU's with GPS collar data.

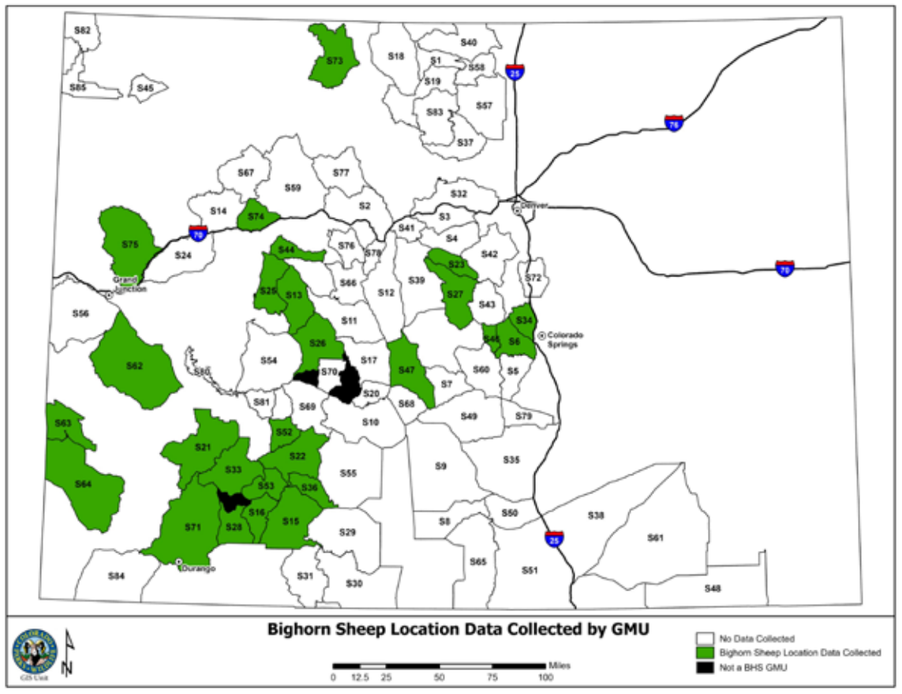

Figure 21. Bighorn sheep GMUS with GPS collar data.

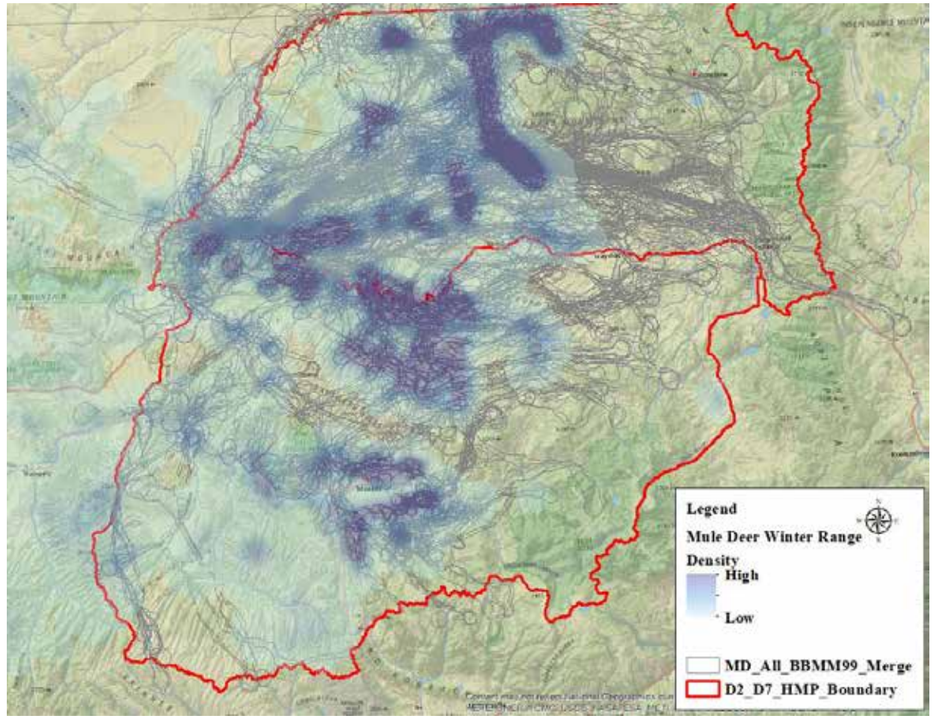

Figure 22. BBMM analysis for White River and Bear's Ear mule deer

Big Game Winter Range, Migration Threats and Conservation Actions

Colorado's big game populations face many threats and challenges as they move across the landscape seeking preferred seasonal habitats and resources for their survival. Threats and associated conservation actions to big game winter range and migration corridors are identified in Table 2. The listed threats and actions were intentionally developed to provide only general guidance. Future efforts to develop more specific threats and conservation actions should include involvement from internal and external stakeholders.

This section provides a brief overview of the primary threats associated with impacts to big game winter range and migration corridors. The information provided here is not exhaustive, but a synopsis of how primary threats can negatively impact big game species and/or their seasonal habitats. It is also important to note that a single threat likely has multiple adverse impacts, and multiple threats are often compounded causing cumulative impacts to a given herd. Many of the threats discussed below are expected to increase in the foreseeable future, further exacerbating the negative impacts.

Human Population Growth

Colorado's human population is currently (2019) around 5.7 million people, and is projected to reach nearly 8.5 million people by 2050, according to the Colorado's State Demography Office (CDOLA, 2018). Although the majority of growth will occur on the Front Range and existing urban areas, growth will likely continue in many counties across the state. The most growth outside of the Front Range will probably include counties along the western I-70 corridor and in the southwest corner of the state (CDOLA, 2016). The threats associated with a growing human population include habitat loss, degradation and fragmentation caused by increasing residential and commercial development, recreation activities, and road density. There is a finite amount of available land to accommodate a growing human population, housing needs, increasing visitors and recreation activities while also maintaining healthy and sustainable big game habitats and populations.

Recreation

According to the 2019 Statewide Comprehensive Outdoor Recreation Plan (SCORP), approximately 92% of Coloradans recreate at least every few weeks to four (or more) times per week. Projected available per capita recreation acres per capita are expected to decline from around 5.5 acres to less than 3.5 acres by 2050 as the number of people recreating increases (SCORP 2019). This loss of space will not only increase potential conflicts between recreationists but also with Colorado's wildlife populations and habitat. Recreation activities have direct impacts on wildlife and habitat by causing wildlife disturbance, habitat loss, habitat degradation, and habitat fragmentation. Indirect recreation impacts include but are not limited, to increased traffic and associated amenities such as hotels, restaurants and shops to accommodate recreationists. Therefore, it is imperative that CPW participates in recreational planning and works with partners to lessen these impacts to wildlife populations.

Transportation

Many of Colorado's major roadways are in low-lying areas (such as canyons, waterways and riparian corridors) that are important big game winter range and movement corridors. The network of roads built across Colorado causes direct habitat loss and fragmentation and can create temporary or permanent movement barriers to wildlife species that desire to cross in order to access food and habitat resources. Wildlife-vehicle collisions (WVCs) can have detrimental consequences to both humans and wildlife when animals attempt to cross roadways and are struck.

In Colorado, nearly 4,000 WVCs are reported to law enforcement each year, with an estimated property and damage cost of $66.4 million. Research has shown that WVCs documented by law enforcement may be underreported by up to 80% or more (Kintsch et al. 2018, Olson 2013). Most of the reported accidents are primarily associated with larger big game species that cause damage and

Kevin Blecha, CPW

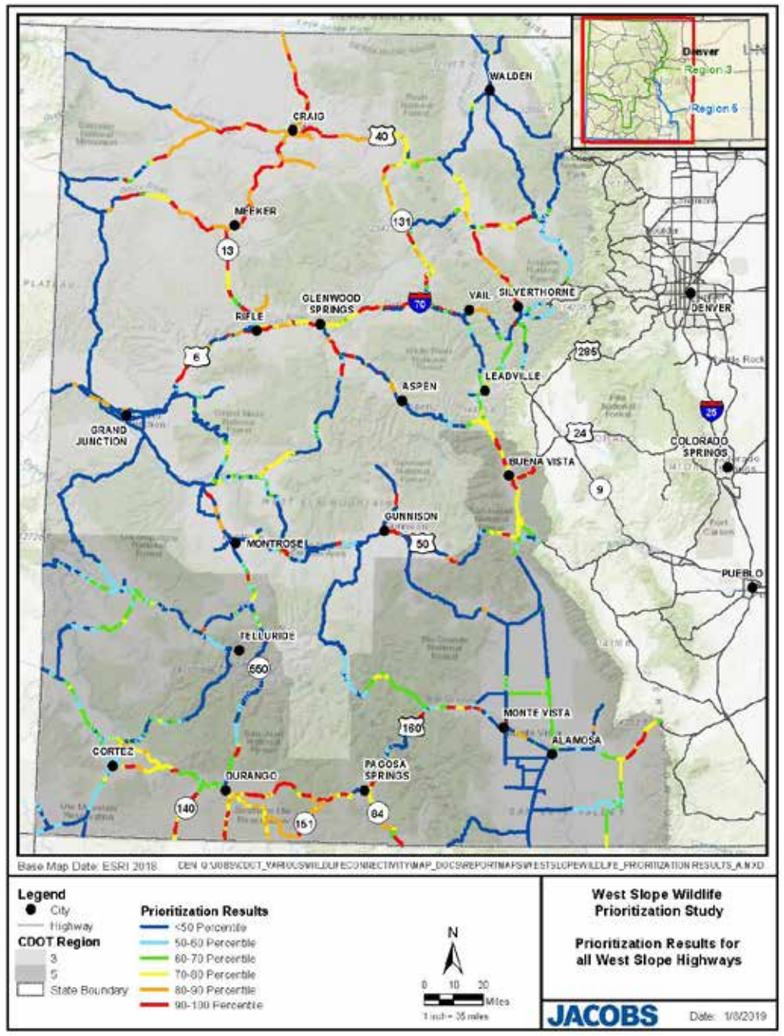

Figure 23. Aggregated highest priority highway segments for the West Slope (Kintsch et al. 2019)

often do not include smaller species such as mountain lions, coyotes, or foxes. In addition, the cost estimates do not include the value of wildlife loss, nor the positive impact of wildlife populations and their relation with society.

Based on CPW's mule deer intensive monitoring studies, 2% of collared doe mule deer are killed by vehicle collisions annually. This is more than the amount of doe deer harvested by hunters each year. Future traffic volumes are expected to rise as Colorado's population grows, as is the number of highways that will be expanded to add more lanes for capacity.

These actions will continue to have a significant, negative impact on big game herds from direct WVCs and present an increasing barrier to wildlife attempting to safely reach preferred seasonal habitats and resources. There are currently many efforts underway to address the threat of WVCs to Colorado's wildlife. In 2017, CPW and CDOT held a wildlife and transportation summit to identify themes, goals and suggested strategies to address the West Slope Mule Deer Strategy (WSMDS) management priority: reduce the impacts of highways on mule deer survival, movement and migration. One of the outcomes of the transportation summit was the development

of the Colorado Wildlife and Transportation Alliance (CWTA). This alliance represents a coalition between CPW, CDOT, United States Forest Service (USFS), United States Department of Transportation-Federal Highway Administration, MDF, Rocky Mountain Elk Foundation (RMEF) and the Southern Ute Indian Tribe (SUIT). CWTA's mission is to provide safe passage for people and wildlife. This is a collaborative effort to improve human safety, while fully integrating wildlife movements into Colorado's transportation system. CDOT and CPW further partnered by co-funding the West Slope Wildlife Prioritization Study (Kintsch et al. 2019).The study's objective involved identifying wildlife-highway segments where targeted transportation mitigation could have the greatest impact on reducing WVCs. To meet this objective, the WSWPS identified, mapped and prioritized highway segments across the West Slope based on the risk of WVC and the need for mule deer and elk to make cross highway movements, particularly during migration or within winter range (Figure 23). CWTA is working to help implement the WSWPS findings and supporting efforts to conduct a similar East Slope Wildlife Prioritization study, which has been recently funded by GOCO.

In addition to the WSWPS, potential wildlife-highway mitigation areas are identified through other local and regional efforts including but not limited to CDOT's Statewide Transportation Plan, Planning and Environmental Linkage studies, I-70 Linkage Interference Zones, CDOT's regional transportation plans, and county-level connectivity plans (Eagle County Safe Passages and Summit County Safe Passages). CDOT and CPW signed a Memorandum of Understanding in December 2019, and are continuing to collaborate to reduce WVCs, including segments of Interstate 25, State Highway (SH) 9, SH 13, US Highway 160, US Highway 285, and US Highway 550.

Mining and Energy Development

Energy development in Colorado generally includes oil and gas exploration and production, coal and uranium mining, and installation of renewable energy facilities (photovoltaic (PV) solar and wind energy). Adverse impacts to big game from energy development result from the direct loss of habitat occurring from the development's footprint, and indirect impacts associated with the development (increased traffic, noise and light pollution, invasive plants).

Oil and gas development in Colorado generally requires between 5-40 acres (average 13 acres) to develop necessary infrastructure including well pads, access roads, flowlines, pipelines, compressor stations, tank batteries, and water processing facilities. Big game species typically demonstrate some level of avoidance to these locations due to increased noise levels and human presence. Individually, these facilities may not result in impacts to big game at a population level; however, the cumulative effects of all disturbance on a landscape can result in impacts that are more significant. Generally, as the density of oil and gas facilities increases, the resulting impacts to wildlife increase. High-density oil and gas development can fragment seasonal habitats and obstruct movement corridors utilized by big game species. For example, rates of travel for mule deer in the Piceance Basin were more rapid over shorter migration distances in areas of high natural gas development resulting in delayed departure and early arrival for females migrating in areas with high development, compared with less developed areas (Lendrum et al. 2013). CPW works with the Colorado Oil and Gas Conservation Commission (COGCC), Colorado SLB, BLM, and various counties, in addition to working with specific oil and gas operators to avoid, minimize, and mitigate impacts by locating facilities outside high priority habitats, implementing seasonal timing limitations, utilizing best management practices, and mitigating unavoidable impacts through habitat enhancement/protection projects.

Jon Holst, CPW

Energy-related mining in Colorado primarily consists of coal mining, with some uranium mining in the southwest corner of the state. Impacts to wildlife from mining are generally similar to oil and gas operations. Depending on the size of the disturbance, location, and type of mining operation (e.g. strip mining vs. subsurface longwall mining), the impacts to wildlife can vary. CPW currently works with the Colorado Department of Reclamation Mining and Safety (DRMS), various municipalities and project proponents to incorporate wildlife recommendations during the permitting process for new mining proposals.

Taylor Elm, CPW

Renewable energy development is increasing rapidly in Colorado. Wind and PV solar are the most common projects with project sizes ranging from a few acres to thousands of acres. Wind energy development has occurred almost exclusively on Colorado's eastern plains where golden eagles, pronghorn antelope, and white-tailed deer have the greatest potential to experience adverse impacts. Solar energy development in Colorado has been occurring at various scales. Local, small-scale "solar garden" projects have increased in popularity for many municipalities and generally result in minor impacts to big game, due to their small size. Large utility-scale solar projects can result in the direct loss of thousands of contiguous acres of wildlife habitat. Due to federal requirements for fencing around solar panel arrays, the footprint of a solar project typically results in the complete loss of habitat for big game species. The siting of new wind and solar energy projects should be done in close coordination with CPW staff during early planning stages to avoid the loss of sensitive habitats and minimize impacts to big game movement corridors.

Habitat Alterations and Loss

Colorado is home to a broad range of habitats; this habitat diversity results in an abundant variety of wildlife species. Colorado also contains a large amount of public land that helps to sustain large populations of wildlife. These two measures, habitat diversity and animal diversity, are the basis of healthy ecosystems. These habitats and ecosystems are being impacted by a host of threats (some of which have been discussed above) that cause habitat alterations and direct habitat loss, which are serious threats to big game populations in Colorado.

Altering habitat, in both quality and quantity, by land use activities can have significant and long-term effects (both positive and negative) on big game habitats and populations. Examples of habitat alteration include, but are not limited to, land use conversion from agriculture to residential, habitat type change by natural cause (wildfire, parasite infestation), habitat quality change as a result of land management, habitat fragmentation, and climate change. Many of these land use impacts are largely outside CPW's regulatory authority, but do have an influence on wildlife populations and habitat, which CPW addresses by providing input into land use decisions. Habitat quality can be degraded by changes in vegetative species composition and structure modification. Examples include invasive, non-native plants with little to no forage value, such as cheatgrass, that are increasing on the landscape. In some areas, fire suppression has allowed forested areas to mature and accumulate unnaturally high fuel loads. Another example is sagebrush habitat encroached by pinyon-juniper resulting in a loss of understory plant diversity and productivity, and decreased forage quality and quantity for wildlife (Watkins et al 2007).

Elissa Slezak , CPW

Table 2. Big Game Winter Range and Migration Corridor Threats & Actions

GENERAL THREATS	SPECIFIC THREATS	CPW CONSERVATION ACTIONS	
Agriculture	Loss of native vegetation (conversion to cropland, reduced grass/forb diversity, noxious weed establishment)	CPW will continue to work with landowners to enhance native vegetation for the benefit local wildlife species, particularly on winter range and migration corridors.	CPW will continue to promote noxious weed and cheatgrass control in all land use practices (public and private); this includes discouraging introduction of non-native ornamental species, mapping of weed infestations, implementing weed/pest management plan, and establishing sensitive zones.
	Grazing (timing, intensity, changes in vegetation)	CPW will continue to work with landowners to implement grazing practices that are sustainable and compatible with big game species (particularly on winter ranges and migration corridors).	CPW will encourage sustainable grazing as a tool for compatible vegetation cover, structure and composition to restore degraded habitats.
	Livestock fencing (abandoned fencing, new fencing)	CPW will continue working with landowners and land managers to implement wildlife-friendly fencing and remove abandoned fencing (particularly on winter ranges and migration corridors).	
Development - Commercial	Housing, Urban, and ex-urban development (suburbs, villages, PUDs, condos, ranchettes)	CPW will continue working with local municipalities (via land use review, code updates and Master Development Plans) to prioritize the protection of priority wildlife habitats including big game winter ranges and migration corridors	CPW will continue to work with private landowners to establish conservation easements to protect habitat in big game winter range and migration corridors (utilizing the CO Wildlife Habitat Protection Program and other mechanisms).

GENERAL THREATS	SPECIFIC THREATS	CPW CONSERVATION ACTIONS	
Development - Commercial	Non-housing development associated with urban growth (shopping centers, offices, schools, hospitals, industrial parks, hotels, factories, manufacturing plants, landfills, sewer treatment facilities, military bases, power plants, airports) Disturbance, habitat loss & fragmentation (roads, well-pads, facilities, pipelines, activities, noise)	CPW will continue working with local municipalities and counties (via land use review, code updates and Master Development Plans) to prioritize the protection of priority wildlife habitats including big game winter ranges and migration corridors.	
Energy Production - Oil & Gas	Disturbance, habitat loss & fragmentation (roads, well-pads, facilities, pipelines, activities, noise)	CPW will continue to work with COGCC, operators, land managers and local governments to establish and implement industry standards, best management practices and mitigation requirements to avoid, minimize and mitigate impacts to big game winter range and migration corridors.	CPW will actively work to educate operators and industries about impacts to wildlife from oil and gas production and related activities and seek cooperative methods to mitigate these impacts.
Energy Production – Mining	Disturbance, habitat loss & fragmentation (exploration, extraction, production activities)	CPW will continue working with DRMS, operators, land managers and local governments to establish and implement industry standards, best management practices and mitigation requirements to avoid, minimize and mitigate impacts to big game winter range and migration corridors.	CPW will actively work to educate operators and industries about impacts to wildlife and seek cooperative methods to mitigate these impacts.

GENERAL THREATS	SPECIFIC THREATS	CPW CONSERVATION ACTIONS	
Habitat Alteration & Loss	Parasites (beetle infestation)	CPW will continue to support land managers and landowners in managing beetle infestations to allow restoration of habitats, particularly big game winter range and migration corridors.	
	Logging & Timber Sales	CPW will continue to work with land managers to implement sustainable timber harvest that is compatible with big game habitat use and migration patterns.	
	Weather & Climate Change (drought, severe winter, extreme wildfire, floods, etc.)	CPW will continue to perform, support and collaborate on research and monitoring that explores wildlife species habitat distribution, critical life histories, habitat components, barriers to species movement, and response to habitat management for big game species, winter range habitats and migration corridors.	CPW will support actions to develop, change, influence, and help implement formal legislation, regulations, and voluntary standards to reduce the impacts of climate change on big game winter range and migration corridors.
Recreation	Non-motorized Trails (hiking, mountain biking, horseback, ski/snowshoe)	CPW will continue working with trail users, non-governmental organizations (NGOs), land managers, local municipalities, and other stakeholders to avoid, minimize, and mitigate negative effects from non-motorized recreation to big game, sensitive species and their habitats.	CPW will continue to educate recreationists regarding their impacts to wildlife and seek methods to effectively influence behavior of non-motorized trail users.
	Motorized Trails (OHV/ATV, motorbike, 4WD, snowmobile, ebike)	CPW staff will continue working with trail users, NGOs, local municipalities, and other stakeholders to avoid, minimize, and mitigate negative effects from motorized recreation to big game and migration corridors.	CPW will continue to educate recreationists regarding their impacts to wildlife and seek methods to effectively influence behavior of motorized trail users.

GENERAL THREATS	SPECIFIC THREATS	CPW CONSERVATION ACTIONS	
Recreation	Established Recreation Sites (ski resorts, golf courses, campgrounds, parks)	CPW will continue to work with land managers and private entities for responsible development of established recreation sites to avoid, minimize and mitigate impacts to big game winter range and migration corridors.	CPW will continue to educate the public regarding their impacts to wildlife from recreational activities and seek methods to effectively influence behavior of recreationists.
	Ecotourism/Guided Recreation (backcountry skiing, rafting, bike tours, hiking fourteeners)	CPW will continue to work with land managers and developing enterprises whose livelihood is directly dependent on the sustainability of natural resources, and seek out methods to effectively change recreationist behaviors and attitudes to protect and conserve big game winter range, and migration corridors.	
	Illegal activity (off-trail use, violation of closures, dogs at large, harassment of wildlife)	CPW will continue to work with land mangers (federal, state, county, city/town) to enforce laws and curb illegal activities that negatively impact wildlife species (i.e.; violation of seasonal closures for winter range; dogs at large, harassment of wildlife, etc.).	CPW Officers will directly enforce Title 33, C.R.S. violations (poaching, harassment of wildlife, etc.).
Transportation (Highways, Railroads)	Habitat fragmentation	CPW will continue to identify important habitat linkages and work with CDOT (per Executive Order D-2019-011), the CO Wildlife and Transportation Alliance, land managers and landowners to conserve connected habitats.	CPW will continue to identify opportunities to conserve and protect intact habitat, including big game winter range and migration corridors, through partnerships, conservation easements, and fee title acquisition.

GENERAL THREATS	SPECIFIC THREATS	CPW CONSERVATION ACTIONS	
Transportation (Highways, Railroads)	Animal-vehicle collisions, associated wildlife mortality	CPW will continue to work with CDOT (per Executive Order D-2019-011), the CO Wildlife and Transportation Alliance, and other partners to identify locations to increase permeability for wildlife and increase human safety on roadways, and promote wildlife crossing projects (overpasses, underpasses, fencing) or other approved methods to reduce animal-vehicle conflicts.	CPW will continue to explore new and innovative options to fund projects that reduce wildlife-vehicle collisions and reduce wildlife mortality.

Big Game Winter Range and Migration Current Research Needs

Current research projects are addressing various aspects of wildlife management and ecology to enhance understanding and management of wildlife responses to habitat alterations, human-wildlife interactions, and investigating improved approaches for wildlife and habitat management. CPW's Research, Policy, and Planning Branch has the following on-going projects:

- Mule deer/energy development interactions to inform future development planning
- Addressing the utility of habitat treatments to mitigate energy development activity
- Evaluation of moose demographic parameters that will inform future moose management in Colorado
- Identify factors influencing elk calf recruitment
- Address elk response to human recreation to establish mitigation and planning options

Big Game Winter Range and Migration Data Gaps and Management Needs

Current data gaps inhibit our ability to identify and protect specific, high priority big game winter range and migration areas on a statewide or regional level (Table 3). Although there is local knowledge around the state of important winter range habitat, and in some cases migration corridors, it is difficult to prioritize these habitats on a landscape scale. Acquiring the data to address the data gaps will require funding support and cooperation with conservation partners.

Big game winter range and migration corridors have always been a priority for CPW. However, the signing of the SO 3362 and the Executive Order D 2019 011 have provided additional opportunities for CPW to further big game conservation of winter range and migration corridors. These orders have placed additional workloads and requirements that CPW is working towards addressing into the future. Moving forward, the following management needs were identified to accomplish CPW's responsibilities associated with the conservation of big game winter range and migration corridors. The short term needs are management actions or planning that will occur in the next one to three years by CPW. The long term needs are management actions or planning that would inform management decisions but CPW has nor the staff or the resources to complete at this time.

Table 3. Identified big game winter range and migration data gaps and management needs

Short Term (1-3 years)	Long Term (Indeterminate)
Develop a prioritization process to collect additional big game movement data to identify big game migration (i.e. locations, species).	Data to identify physical barriers and land use practices that threaten movement corridors, and winter range (i.e., energy development, trails/recreation, fences, roads, roadway infrastructure, residential and commercial development).
Standardize method and tools for CPW and CDOT to record WVCs and associated wildlife mortalities.	Develop a risk assessment process with conservation partners for existing threats, potential threats, cumulative threats and opportunities for conservation actions.
Conduct the East Slope Wildlife Prioritization study.	Housing and urban development projections maps for Colorado identifying detailed growth areas.
Research related to understanding wildlife movement patterns relative to roadways (Research Landscapes related to SO 3362).	Data and method to identify bottleneck areas for big game movements.
Recommendations on consistent monitoring to determine effectiveness of wildlife-highway mitigation projects at reducing wildlife vehicle collisions.	Landscape scale assessment of habitat quality associated with transitional range, stopovers along migration corridors and critical winter range.
Define and identify big game transitional range (migration swaths).	Assessment to determine thresholds for levels of disturbance and fragmentation that impacts big game population health.
Develop a central database to house CPW's big game migration data.	Landscape scale mapping and analysis of cumulative impacts (existing and potential) to big game winter range and migration corridors from identified threats.
Continue to analyze migration data as it becomes available and share with CDOT and other conservation partners.	Data and methods to determine impacts of train collisions on big game herds.
Recommendation on standard data collection when mapping big game movement patterns for highway crossing (GPS collars should be programmed for 2-hour time intervals).	Updated landscape scale habitat mapping to assess long term habitat change.
Landscape scale analysis to identify regional priority habitat restoration areas in relation to big game winter range and migration corridors.	Research into how to address habitat carry capacity, appropriate stocking rates (density), and animal body condition in the herd management planning process.

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