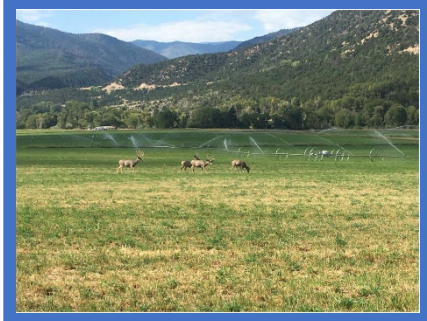
# Roaring Fork Watershed Biodiversity & Connectivity Study

# EXECUTIVE SUMMARY



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SEPTEMBER 2022

Recommended Citation:
Renée Rondeau, Michelle Fink, Andrea Schuhmann, and Lee Grunau. 2022. Roaring Fork Watershed Biodiversity and Connectivity Study Executive Summary. Colorado Natural Heritage Program, Colorado State University, Fort Collins, CO and Watershed Biodiversity Initiative, Basalt, CO.

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Front cover: top photo: view facing east from Frigid Air Pass of columbine (*Aquilegia coerulea*) and ridge between Belleview Mountain and Maroon Peak. Bottom photos left to right: elk summer grazing in an irrigated pasture, rich spruce-fir forests and wetlands of Chapman Gulch, and an aerial view from plane of the lower Roaring Fork valley between Glenwood Springs and Carbondale. 

# EXECUTIVE SUMMARY

*"…because migrating ungulates must plod hoof by hoof across increasingly human-impacted landscapes, their conservation status can serve as an early warning signal for the erosion of wildlife habitats and their functional connectivity (Middleton et al. 2020)" Kaufman et al. 2021.*

## Background

The Roaring Fork Watershed is among the most ecologically intact and varied landscapes in Colorado. Elevations ranging from 5,700 feet to over 14,000 feet above sea level support several distinct native plant communities, from sagebrush, oak, and pinyon-juniper in the low elevations, transitioning to aspen and conifer forests as elevation increases, before finally reaching up to alpine tundra on the highest peaks, ridges, and passes. These communities in turn support a remarkable diversity of animal life, from jackrabbits to bighorn sheep, hundreds of bird species, and thousands of insects. Altogether these species knit the landscape together into a living whole. The Watershed is among the wettest watersheds in the state with wetlands and riparian areas representing known biodiversity hotspots. This species-rich landscape is both an important natural resource and a stewardship responsibility that is best approached on a solid scientific footing.

The Watershed's 928,640-acre landscape supports over 32,000 people as well as abundant wildlife populations. Iconic species such as elk and mule deer can be found in most habitats throughout the Watershed, while bighorn sheep roam the high country. Declines in the elk and mule deer populations have become a concern in recent decades; bighorn sheep, once common, are now rare in the Watershed. These concerning downward trends in wide-ranging common animals, coupled with a community commitment to use the best available science to protect and restore biodiversity, led in 2018 to the creation of the non-profit Watershed Biodiversity Initiative (WBI). WBI's purpose is to support a study to identify landscape-scale areas to protect and restore in order to maintain the Watershed's biodiversity. This report is the culmination of the Roaring Fork Watershed Biodiversity and Connectivity Study.

WBI and partners' overarching goal was to develop a science-based strategy for the protection and restoration of natural biodiversity and habitat connectivity on a landscape scale. In order to achieve this goal, they determined that they needed to work with independent researchers to conduct a study that would objectively identify and map biodiversity conservation and restoration priorities from a landscape perspective. The concept was that the study would be designed and implemented in concert with local funders, scientific experts, and stakeholders, and that development and implementation of methods would be an ongoing collaboration over the life of the study. The purpose of this approach was to foster widespread acceptance and use of the process and the results. To that end, WBI engaged Colorado Natural Heritage Program (CNHP) to lead the study and organized a Science Team (Appendix A) to oversee and participate in development of the study design.

Because the Watershed is so large and the interests of the participants were so broad, the Science Team determined that the best way to frame the study was through the use of "focal species." The highest priority focal species were defined as **mule deer (*Odocoileus hemionus*)**, **elk (*Cervus elaphus*)**, and **bighorn sheep (*Ovis canadensis*)**. The primary reasons for this decision were widespread concern over declining populations of these iconic animals, and urgency of land-use decisions with potential to affect these species. Also, there was the thought among Project and Science Teams that, by identifying high quality, well-connected areas across the multiple habitat types used by these wide-ranging species, habitats important to many other species would be included as well. The ungulate-focused analyses were supplemented by additional existing data layers representing biodiversity importance (rare and imperiled species and habitats, climate change resilience), and key areas identified as important (specific places such as Audubon's Important Bird Areas, ungulate calving areas mapped by Colorado Parks and Wildlife, CPW)—in other words, species and places whose needs may not be adequately captured through a broad-scale habitat management approach.

## Goal and Objectives

The overarching goal of the project was to develop a science-based set of models and maps to identify areas for the protection and restoration of natural biodiversity and habitat connectivity on a landscape scale. Study objectives were:

1. Identify high quality habitats for focal species, and places on the landscape that provide connectivity between these locations.
2. Map high priority places where conservation and restoration could enhance landscape function and expand core habitats.
3. Use existing data to combine other significant biodiversity information with focal species data into a watershed-scale conservation and restoration priority map.

## Methods Overview

The study consisted of field data collection in 2019-2021 and multiple GIS analyses. The key analyses and mapped outputs (models) of the study were 1) **Habitat Quality** for elk, mule deer, and bighorn, and 2) **Conservation Importance**—critical areas for focal species as well as other biodiversity values, culminating in 3) **Conservation and Restoration Priorities** across the landscape (Figure ES-1).

Over the summers of 2019 and 2020, field biologists collected vegetation data for forage resources (grasses, forbs, shrubs, and trees) at 129 randomly selected sites across the Watershed. These data formed the basis of the forage quality models for elk and mule deer during winter and growing seasons (Figure ES-2). The models were validated in the field at an additional 102 randomly selected sites during the summer of 2021. Additional data layers representing shelter, water availability, forage contributions from agricultural fields, and anthropogenic disturbance were combined with the forage quality models to create habitat quality models (Figures ES-3 and ES-4). These models were classified into relative quality categories of Low, Moderate, and High, using distinct rule sets specific to species and season, and then connectivity between moderate and high quality habitat areas was modeled (Figure ES-4). Bighorn were not included in this step because of the availability of existing habitat models for this species. To generate the habitat quality model for bighorn, existing habitat models (from CPW and Rocky Mountain Wild) were combined, escape habitat was added, and the resulting model (Figure ES-5) was classified into the same relative quality categories of Low, Moderate, and High as was used for elk and mule deer.

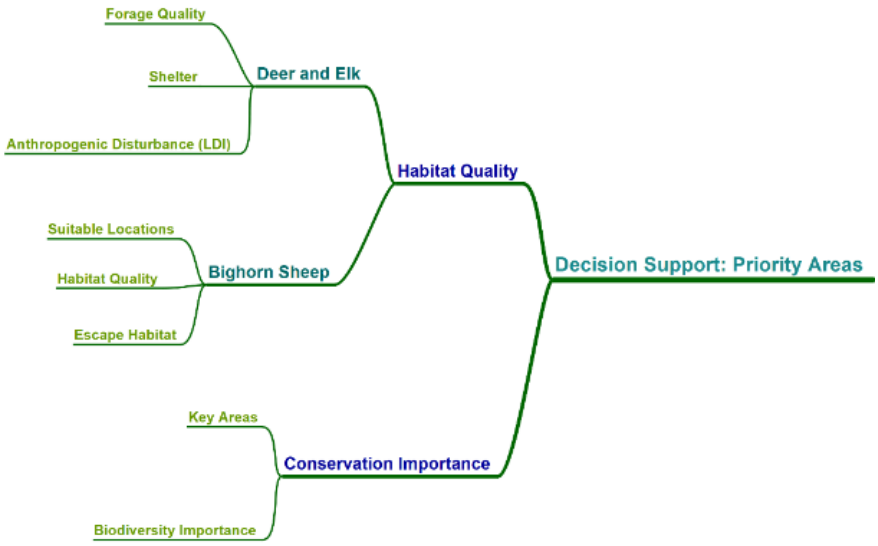


*Figure ES-1. Schematic showing sequence of analyses used to create the Watershed Conservation and Restoration Priorities map.*

To complement the habitat quality analyses for the focal species, we added "Conservation Importance," which incorporates rare species, small-scale habitats such as wetlands, climate resilient areas, and locally significant natural areas. We created two GIS layers to map Conservation Importance (Figure ES-5): Key

Areas and Biodiversity Importance. Key Areas are small and/or discrete places that have critical importance to a functioning natural landscape. These included 1) birthing areas, severe winter and winter concentration areas for elk, mule deer, and bighorn, as mapped by CPW; 2) modeled potential local movement corridors; 3) places where the landscape inhibits the potential for population movements and range shifts in response to climate change (TNC-CRCS 2021); and 4) sites of local significance (Audubon Important Bird Areas, nature preserves). Biodiversity Importance included CNHP data on rare and imperiled species and plant communities, wetlands, and landscape diversity (to represent areas more likely to be resilient to climate change, TNC-CRCS 2021).

All these data layers were combined into the Watershed Conservation and Restoration Priorities map ("priorities map," Figure ES-6, Table ES-1) using a decision matrix based on relative habitat quality for the focal ungulates and conservation importance scores (Figure ES-7). The final priorities map highlights areas of high-quality ungulate habitat that also support additional high biodiversity values, as well as areas of degraded ungulate habitat quality that nonetheless have significant conservation importance for other biodiversity values. This map offers a landscape-scale view of opportunities for employing strategies to conserve important, high-quality places and restore degraded habitat in places that still support significant biodiversity values.

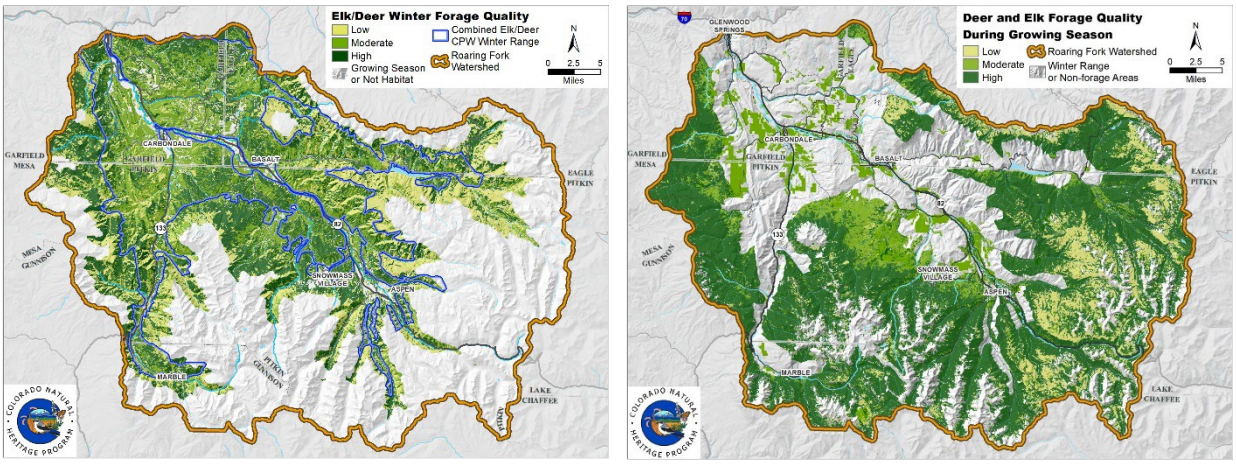


*Figure ES-2. Forage quality model for elk and mule deer during winter (left) and growing season (right).*

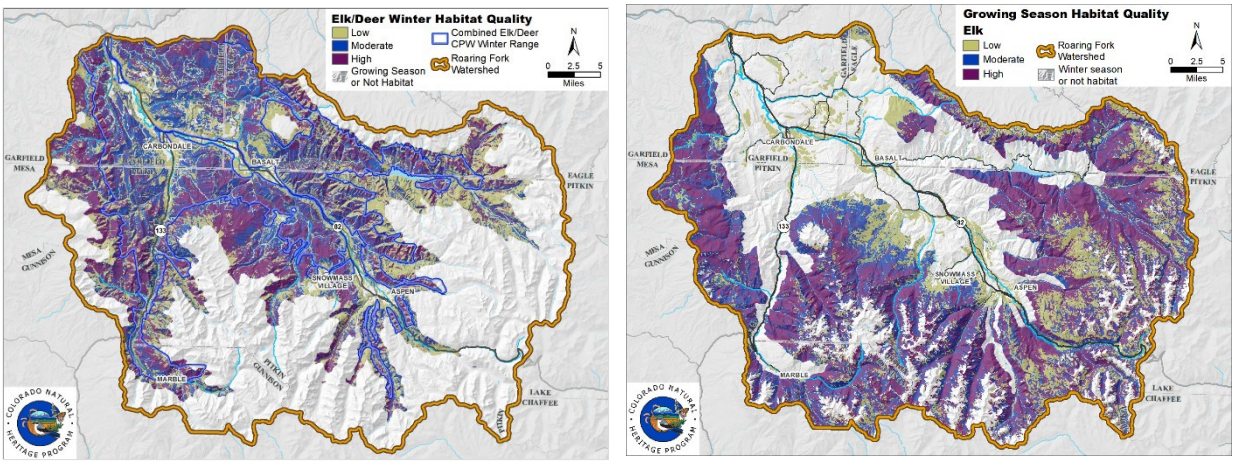


*Figure ES-3. Habitat quality model for elk and mule deer during winter (left) and for elk during growing season (right).*

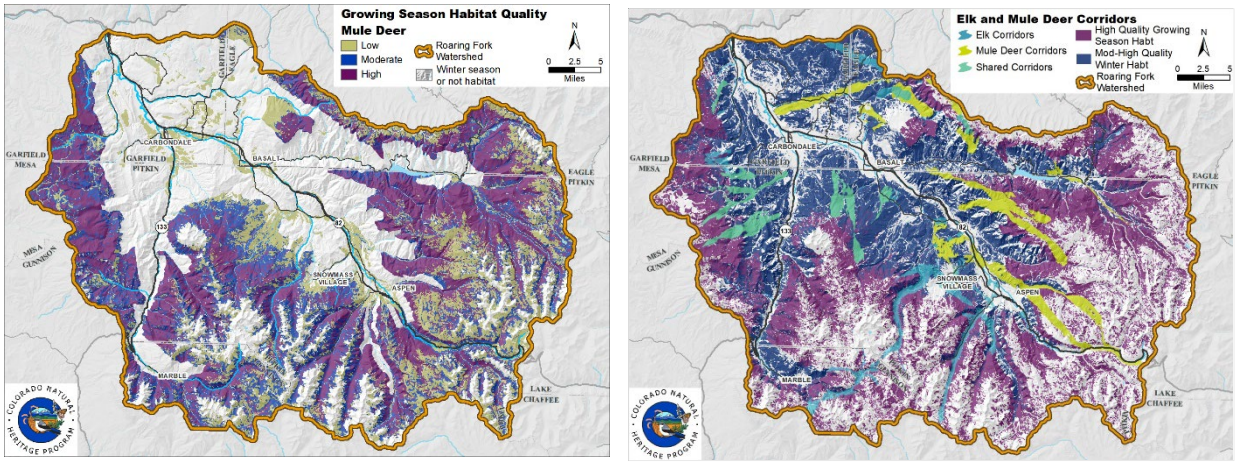


*Figure ES-4. Habitat quality model for mule deer during growing season (left); movement corridors for elk and mule deer (right).*

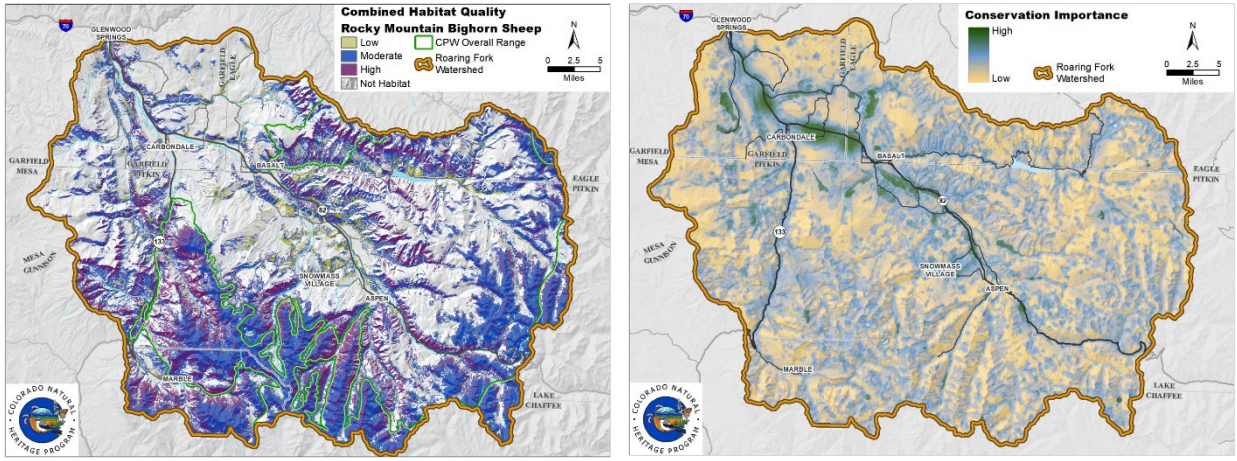


*Figure ES-5. Habitat quality model for bighorn sheep (left); Conservation Importance model (right).*

*Table ES- 1. Legend definitions for Conservation and Restoration Priorities map.*

| Matrix Color | Definition |
|---|---|
| | Highest quality habitat for focal ungulates AND highest priority for biodiversity. |
| | High or moderate quality habitat for focal ungulates AND moderate priority for biodiversity. |
| | High or moderate habitat quality for focal ungulates that are generally unfragmented but lacking other biodiversity values. |
| | Lower quality habitat for focal ungulates and fewer biodiversity values documented. |
| | Lower habitat quality for focal ungulates but very high conservation importance for other biodiversity values. |
| | Important for biodiversity but improvements in habitat quality/connectivity are likely needed for focal ungulates. |
| | Not practical conservation or restoration opportunities due to the dominance of urban or other developed areas and established transportation networks. |

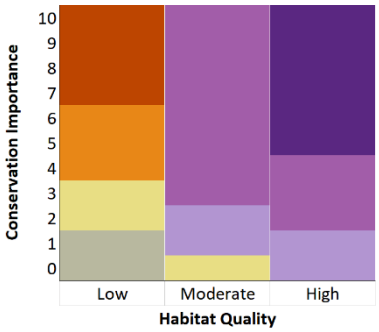


*Figure ES-6. Decision matrix used to create Conservation and Restoration Priorities map.*

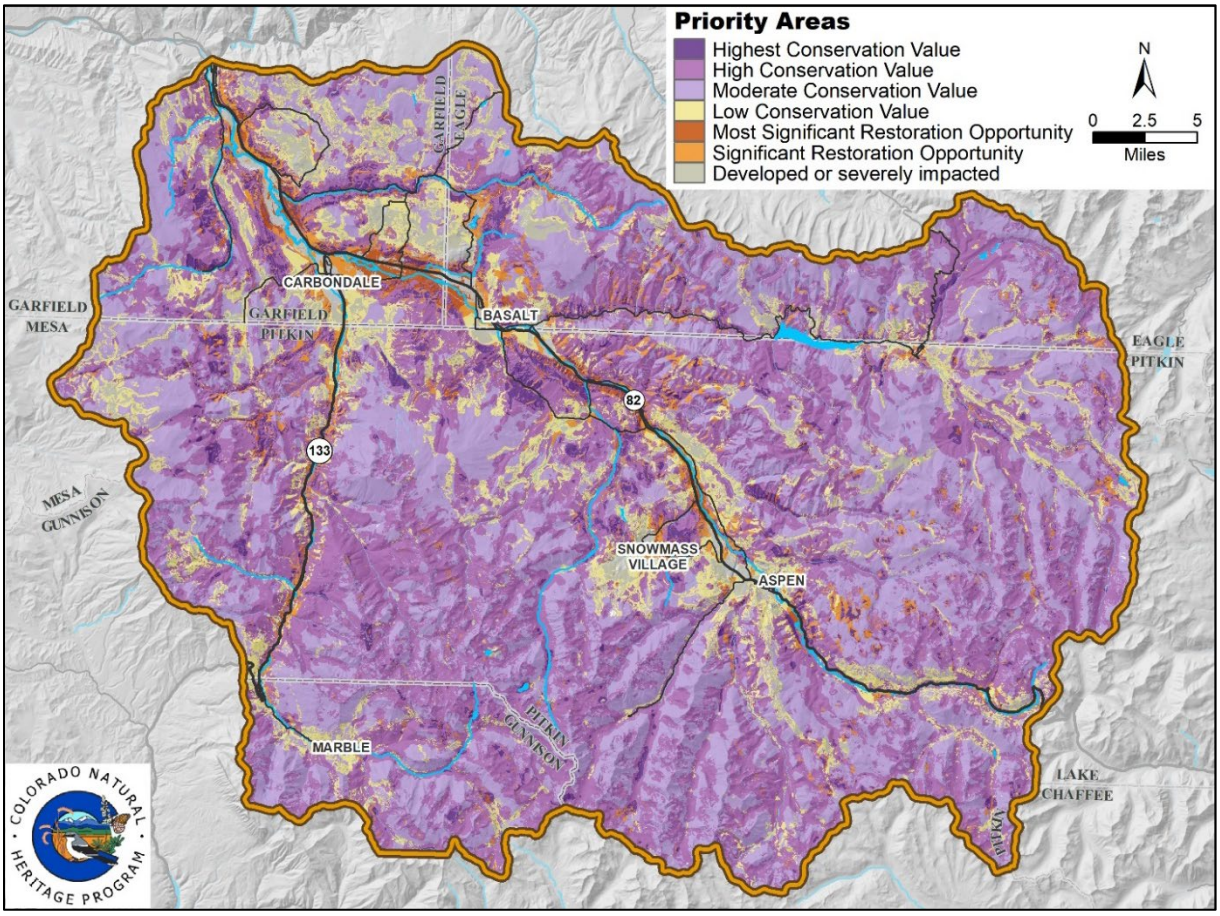


*Figure ES- 7. Conservation and restoration priorities for the Roaring Fork Watershed.*

# Key Findings

1. Overall, the vast majority of the Roaring Fork Watershed supports land with Moderate, High, or Highest Conservation Value, and these areas are well-distributed across the watershed. Significant opportunities exist to restore degraded habitats and improve connectivity, especially along major transportation corridors and near developed areas.

2. Forage quality does not appear to be a limiting factor by itself in either winter or growing season ranges for elk and mule deer according to our models. Seventy percent of modeled winter range and 80% of known winter range (based on CPW maps) was classified as high or moderate forage quality, and 87% of the growing season has high to moderate forage quality. Within each seasonal range, the dominant ecological systems (for example, Spruce-Fir, Aspen, Oak/Mixed Shrub) are comprised primarily of moderate or high quality forage.

3. The value of moderate and high quality forage is reduced when availability of other habitat resources (water, shelter) and anthropogenic disturbance are considered in the habitat quality models for elk and mule deer. Sixty-four percent of modeled winter range and 69% of known winter range (based on CPW maps) was classified as high or moderate habitat quality, and 74% of the growing season has high to moderate habitat quality. Even with this quality reduction compared to the forage quality models, the majority of all seasonal ranges are comprised primarily of moderate and high quality habitat. Dominant ecological systems in each seasonal range are also still comprised primarily of moderate and high quality habitat.

4. The Watershed has an abundance of wetlands, especially in the high country. Wetlands within the ecotone between Spruce-Fir and Alpine systems were consistently observed by the field biologists to offer very abundant palatable forage, and to be very heavily used by ungulates. These are, therefore, high priority places for minimizing human disturbance (e.g., via trails, roads).

5. According to the habitat quality model for modeled winter range, Aspen is the dominant ecological system in the transition zone between known winter range and growing season range. This transition zone is likely to be increasingly important to ungulates in winter as climate change warms temperatures and reduces snowpack. The majority of this area currently supports moderate or high quality habitat; maintaining habitat quality in these areas warrants attention.

6. Private lands represent approximately one-third of modeled winter range, but almost half of known winter range for elk and mule deer. Within both modeled and known winter range, there is very little difference in the relative percentage of moderate and high quality habitats on private lands compared to public lands. Because habitats on private lands are more vulnerable to loss (conversion to development, for example), supporting habitat conservation on these lands is very important for wintering ungulates. Within the growing season range, private lands make up a much smaller proportion of the area compared to public lands; the majority of moderate and high quality habitats are on public lands.

7. There are a number of areas within the Watershed where higher quality habitats are bisected by well-traveled roads (especially Highways 82 and 133) and other human developments. These places offer excellent opportunities to improve landscape connectivity. Places where movement pinch points occur between high quality habitat amidst a mix of land ownership types offer excellent opportunity for public/private partnerships. Even small patches of high quality habitat are used by elk and mule deer as they move among habitats. Improving connectivity (safe animal passage and use) in places such as these would increase the value of these habitats.
8. The habitat model for bighorn sheep identifies several areas with moderate to high quality habitat where sheep are not currently present. These may present opportunities to expand the bighorn population if CPW determines that such a strategy is justifiable.

# Recommendations

## *The Big Picture*

The results of our study and the feedback we received during our test drives with the Science Team, private owners of large holdings, local caucuses, and more, led WBI and CNHP to four "big ideas" for moving forward with conserving biodiversity in the Roaring Fork Watershed.

**Big idea # 1 – "Stitching it back together."** Reconnect large landscapes that have been fragmented in the Watershed. This will improve habitat quality for deer and elk, and therefore hopefully restore and maintain healthy populations of these species. Using the forage and habitat quality models, CPW's SAM maps, and our connectivity model can help identify places where improved connectivity is needed. Examples of key opportunities include areas around Cattle Creek, Missouri Heights, and Carbondale (see Figure 24), but there are others. Opportunities for public/private partnerships exist in many of these places.

**Big Idea # 2 – Guide development and land conservation decisions** to avoid additional fragmentation and maintain connectivity amongst swaths of large intact landscapes. Any introduction of additional infrastructure or disturbance (including land development, roads and trails) will affect habitat quality. Careful consideration of potential impacts are especially needed for areas associated with ungulate winter concentration areas and severe winter range, areas that serve as movement corridors through or between high or moderate quality habitats, areas where restoration could raise habitat quality scores and/or improve connectivity, and wetlands and wet meadows (especially in the ecotone between subalpine forests and the alpine). Public/private partnerships will be key to success in many of these places.

**Big Idea # 3 – Protect large, isolated landscapes for bighorn sheep.** Because disease transmission is an issue for this species, these populations benefit from isolation. Recovering the State's and region's bighorn sheep population is a widely shared goal among conservationists and wildlife managers. This goal serves as a clear rallying point to generate support for protecting and restoring the natural biodiversity that is critical to healthy ecosystem functioning.

**Big Idea # 4 – "Rewet the sponge."** Protect and/or restore wetlands throughout the Watershed. Wetlands, especially in growing season and transitional areas offer abundant high quality forage. Nearly one-third of the Watershed is blanketed with upper to high elevation conifer forests where 80% of annual precipitation is captured as snow and preserved in cool, shady conditions. Wetlands within the ecotone between Spruce-Fir and Alpine systems were consistently observed by our field team to be very heavily used by ungulates. Minimizing human disturbance (e.g., via trails, roads) is particularly important in these areas. Elk and mule deer herds have calves during the time of year that they use these high elevation habitats, and they are especially sensitive to disturbance at this time. Restoring degraded wetlands can slow the water down, increase infiltration into the soil, assimilate nutrients, and improve forage and habitat for elk, mule deer, and an abundance of other wildlife species.

## *Additional Recommendations*

1. Plan for the future, but act in the present. The maps and data contained herein represent current conditions. We expect these condition to change, albeit in unknown ways, in the coming years as the climate continues to change. Anticipating these changes will be an important component of planning for conservation and restoration strategies. For example, our models suggest that Aspen areas within the modeled winter range will become more important habitat in future winters. Meanwhile, though, continuing to strive for improved quality where habitats occur now, as in the known winter range, is needed. High and moderate quality habitats associated with known severe winter and winter concentration areas are high priorities for conservation, as well as restoration of connectivity where needed.

2. Use these data in combination with other resources when evaluating potential conservation or restoration projects. There are at least two studies currently underway that will provide additional insights to the quality of habitats and connectivity within the Watershed when results become available. These include a collar study of elk movement by CPW, and a wetland study by CNHP. Results from CPW's collar study are still at least two years out. Final data from CNHP's wetland study are expected in 2022.

3. Periodic vegetation-based monitoring would be useful to detect changes in habitat quality over time. Monitoring every ten years would likely be sufficient. Other monitoring opportunities would include after disturbances (e.g., wildfire, flood, extended extreme drought), when conservation or restoration projects are being undertaken, or if observed changes warrant review of habitat condition. The detailed field data collection used to build the forage quality model is not necessary to repeat for periodic monitoring assessments. The condensed field methods used to validate the model (described in Appendix C) would be a relatively efficient means of quickly evaluating a site for basic forage quality. The most difficult component to assess is palatability. Creating a handbook or "cheat sheet" of the most palatable species would support monitoring even by trained volunteers.

4. Revisit study assumptions and analyses when CPW's animal movement and habitat use data become available.

5. Consult with CNHP for proper use and interpretation of the maps and data provided with this study as a regular practice to ensure the study is used to its fullest capacity. Spatial data are freely available from CNHP, and WBI will be supporting our biologists to provide as-needed assistance through the end of 2022. The spatial data layers developed during this study have been provided to the Science Team members, and will be uploaded into CODEX (https://codex.cnhp.colostate.edu) for general public use.
6. These maps and data layers were developed to be used at a scale of approximately 1:24,000. On-the-ground field assessments are recommended for all site-specific projects.

## Conclusion

This study did not seek to address reasons behind herd decline(s) or evaluate ideal population numbers for focal species in the Watershed. Nonetheless, the strategies outlined in this report—protecting high quality habitat and connectivity where possible, and improving habitat quality and connectivity where needed—will contribute toward the future viability of elk, mule deer, and bighorn herds, as well as all the other components of the Watershed's biodiversity.

The maps and spatial data layers created during this project provide a science-based means of identifying and prioritizing biodiversity conservation and restoration needs within the context of the entire Watershed. Though individual stakeholder's priorities may vary depending on mission, goals, and interests, these products can ensure that the Watershed's interested parties and decision makers share the same basic understanding of biodiversity and connectivity across the Watershed. It is the hope of WBI and all the partners who participated in the study that this document and the spatial data layers that accompany it will support the development of the multi-partner collaborations needed to steward the Roaring Fork Watershed's biodiversity heritage now and into the future.