March 23, 2020

White River National Forest
Scott Fitzwilliams, Forest Supervisor
c/o Shelly Grail Braudis, Project Leader
PO Box 309
Carbondale, CO 81623

Re: Scoping comments on the Redstone to McClure Pass Trail (#56913)

Dear Ms. Grail,

Thank you for the opportunity to submit scoping comments on the proposed Redstone to McClure Pass Trail. The following are the comments of Wilderness Workshop (WW) on the proposal, as described in the Scoping Letter dated January 20th, 2020, and map. WW is a 501(c)(3) dedicated to the protection and conservation of the wilderness and natural landscapes of the Roaring Fork Watershed, White River National Forest, and adjacent public lands. Many of our members live, work, recreate and otherwise use and enjoy lands managed by the White River National Forest including the Crystal Valley.

WW and our members care deeply about the public lands and resources in the Crystal Valley, and we recognize the challenge of balancing recreation with conservation and other multiple uses in this landscape. We appreciate that the Forest Service is carefully considering this trail proposal, including by completing an Environmental Assessment (EA) under the National Environmental Policy Act (NEPA) and offering public comment opportunities at both the scoping and draft EA stages.

We support sustainable recreation uses on our public lands, including in some cases development of new recreation experiences, and certainly having those opportunities right in our backyard is central to our community's quality of life. Additionally, WW does not oppose the general proposal of a Carbondale to Crested Butte trail or developing a trail in the Redstone to McClure Pass corridor. At the same time, we are concerned about the growing impacts of recreation and other human development on wildlife and public lands in our region, and any new trail in this area or elsewhere should be sited to have the least possible impacts to wildlife and ecosystems. No single trail can be held responsible for the declines in wildlife populations or other impacts – and yet collectively our trail systems and recreation uses are undeniably impactful. As an overarching matter, we suggest our communities and land managers should begin scrutinizing and prioritizing recreation projects within the context that there is a limit to the amount of recreation our local public lands can sustain. This is not a statement on the Redstone to McClure

Pass Trail, but rather a recommendation that a holistic and strategic approach starting now and moving forward would benefit our shared lands and resources.

I. NEPA Requirements

i. Purpose and Need

The Forest Service's scoping notice for this project states that the purpose and need is to "improve trail connectivity between Redstone, nearby subdivisions, and McClure Pass and to improve access of recreational use along Highway 133." The EA should articulate a more specific purpose and need for this specific segment of trail, such as by explaining why this particular stretch of Highway 133 needs improved recreation access, identifying the actual demand for such trail connectivity and what populations would be served, and documenting existing management issues that would benefit from this trail.

We note that the White River National Forest Travel Management Plan closed the Old McClure Pass (1966W.2) and Bear Creek (1966w.3) trail segments because these routes were determined to be "not needed for administrative or recreation purpose."[1] As part of defining the Purpose and Need for this project, the EA must explain why this previous decision is no longer applicable to these segments.

Importantly, the EA must demonstrate that this segment of the larger Carbondale to Crested Butte Trail proposal reasonably stands on its own and meets the purpose and need as an independent segment. If the Forest Service cannot show that to be the case, then this segment and other segments of the Carbondale to Crested Butte Trail must be considered connected actions. Agencies must describe connected actions in a single environmental review. 40 C.F.R. § 1508.25(a); *Klamath-Siskiyou Wildlands Ctr. v. U.S. Bureau of Land Mgmt.*, 387 F.3d 999 (9th Cir. 2004).[2] While we understand that no other current actions are being considered by the Forest Service to develop additional portions of the larger Carbondale to Crested Butte Trail north of Redstone, the two-year in-depth planning and public outreach process conducted by Pitkin County clearly indicates that the project proponent may seek to develop other segments of this trail in the future (see also section iii Cumulative Impacts below).

ii. Alternatives

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[1] Final Environmental Impact Statement White River National Forest Travel Management Plan. Attachment 2: Travel Management Plan – Route Specific Information p. A2-27 Available at: https://www.fs.usda.gov/nfs/11558/www/nepa/1118_FSPLT2_048804.pdf

[2] The purpose of this requirement "is to prevent an agency from dividing a project into multiple 'actions,' each of which individually has an insignificant environmental impact, but which collectively have a substantial impact." *Great Basin Mine Watch v. Hankins*, 456 F.3d 955, 969 (9th Cir. 2006) (internal quotation marks omitted). Where the proposed actions are "similar," the agency also should assess them in the same document when doing so provides "the best way to assess adequately the combined impacts of similar actions." *Klamath-Siskiyou*, 387 F.3d at 999.

The Forest Service must evaluate a reasonable range of alternatives in the EA. NEPA generally requires the lead agency for a given project to conduct an alternatives analysis for "any proposal which involves unresolved conflicts concerning alternative uses of available resources." 42 U.S.C. § 4332(2)(E). The regulations further specify that the agency must "rigorously explore and objectively evaluate all reasonable alternatives" including those "reasonable alternatives not within the jurisdiction of the lead agency," so as to "provid[e] a clear basis for choice among the option." 40 C.F.R. § 1502.14. This requirement applies equally to EAs and EISs. *Davis v. Mineta*, 302 F.3d 1104, 1120 (10th Cir. 2002); *Bob Marshall Alliance v. Hodel*, 852 F.2d 1223, 1228-29 (9th Cir. 1988).

The purpose of NEPA's alternatives requirement is to ensure agencies do not undertake projects "without intense consideration of other more ecologically sound courses of action, including shelving the entire project, or of accomplishing the same result by entirely different means." *Envnt'l Defense Fund., Inc. v. U.S. Army Corps. of Eng'rs*, 492 F.2d 1123, 1135 (5th Cir. 1974); *see also Or. Envtl. Council v. Kunzman,* 614 F.Supp. 657, 659-660 (D. Or. 1985) (stating that the alternatives that must be considered under NEPA are those that would "avoid or minimize" adverse environmental effects). The Council on Environmental Quality (CEQ) regulations instruct agencies to consider alternatives to their proposed action that will have less of an environmental impact, specifically stating that "[f]ederal agencies shall to the fullest extent possible: . . . Use the NEPA process to identify and assess the reasonable alternatives to proposed actions that will avoid or minimize adverse effects of these actions upon the quality of the human environment." 40 C.F.R. § 1500.2(e); *see also*, 40 C.F.R. §§ 1502.14, 1502.16. The range of alternatives is the heart of a NEPA document because "[w]ithout substantive, comparative environmental impact information regarding other possible courses of action, the ability of [a NEPA analysis] to inform agency deliberation and facilitate public involvement would be greatly degraded." *New Mexico v. BLM*, 565 F.3d 683, 708 (10th Cir. 2009).

That analysis must cover a reasonable range of alternatives, so that an agency can make an informed choice from the spectrum of reasonable options. An EA offering a choice between the proposed action and no action does not present a reasonable range of alternatives. For this project, the Forest Service should at a minimum analyze the following alternatives:

- A trail alignment that does not deviate from Highway 133.
- Other trail alignments the agency is able to develop. The fact that Pitkin County has evaluated the area and identified the proposed trail as its preferred alignment does not relieve the Forest Service of its obligation to also consider alternative alignments.
- An alternative that would defer the project until the Watershed Biodiversity Initiative has completed the Roaring Fork Watershed Biodiversity and Connectivity Study[3] so that the study can be used to inform the environmental analysis and decision-making for the proposed trail.

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[3] The Roaring Fork Watershed Biodiversity and Connectivity Study takes a landscape-scale approach to identify high-quality habitat for bighorn sheep, elk, and deer as proxies for biodiversity generally. There is broad consensus among Study stakeholders that a landscape-scale approach to biodiversity conservation provides the most useful context for considering proposals such as this project.

- An adaptive management alternative that would condition future maintenance and use of the trail on acceptable results being consistently produced by a monitoring strategy.
- Alternatives that vary by types of uses authorized and seasonal limitations.
- Alternatives to mitigate impacts to resources, including specifically mitigation for wildlife impacts such as seasonal closures.

Failing to analyze such middle-ground options would violate NEPA. *See TWS v. Wisely*, 524 F. Supp. 2d 1285, 1312 (D. Colo. 2007) (BLM violated NEPA by failing to consider "middle-ground compromise between the absolutism of the outright leasing and no action alternatives"); *Muckleshoot Indian Tribe v. US Forest Serv.*, 177 F.3d 800, 813 (9th Cir. 1999) (NEPA analysis failed to consider reasonable range of alternatives where it "considered only a no action alternative along with two virtually identical alternatives").

iii. Cumulative Impacts

The Forest Service must conduct cumulative impact analysis that evaluates the proposed trail in the context of other activities in the region that are impacting or could reasonably impact similar resources. It is particularly important that the EA analyze the many other recreation projects and uses in the region which collectively have significant impacts on resources such as wildlife, and that the EA analyze the cumulative impacts of the full Carbondale to Crested Butte Trail that has been proposed by Pitkin County.

NEPA regulations define "cumulative impact" as:

> the impact on the environment which results from the *incremental impact of the action when added to other past, present, and reasonably foreseeable future actions* regardless of what agency (Federal or non-Federal) or person undertakes such other actions. *Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time*.

40 C.F.R. § 1508.7 (emphasis added). To satisfy NEPA's hard look requirement, the cumulative impacts assessment must do two things. First, the Forest Service must catalogue the past, present, and reasonably foreseeable projects in the area that might impact the environment. *Muckleshoot Indian Tribe v. U.S. Forest Service*, 177 F.3d 800, 809–10 (9th Cir. 1999). Second, the Forest Service must analyze these impacts in light of the proposed action. *Id.* If the Forest Service determines that certain actions are not relevant to the cumulative impacts analysis, it must "demonstrat[e] the scientific basis for this assertion." *Sierra Club v. Bosworth*, 199 F.Supp.2d 971, 983 (N.D. Ca. 2002).

To meet these requirements, the Forest Service must catalogue the full portfolio of recreation projects in the region and analyze the collective impacts of those projects on all of the resources that would impacted by this additional trail. This analysis must document and evaluate the extent of past recreation use in the area, how this recreation use may have contributed to significant environmental impacts such as impacts to wildlife, and whether additional recreation use may have an "additive and significant relationship to those effects." Council on Environmental Quality, Guidance on the Consideration of Past Actions in Cumulative Effects Analysis at p. 1

(June 24, 2005); *Lands Council v. Powell*, 395 F.3d 1019, 1028 (9th Cir. 2005). Cumulative impact analysis of recreation projects is especially important for this proposed project due to the abundance of recreation use in this region that is being shown to harm resources such as wildlife; however, the Forest Service must also analyze other non-recreation actions that are impacting or have the potential to impact these same resources.

The Forest Service must also evaluate impacts associated with development of the full Carbondale to Crested Butte trail, which is a reasonably foreseeable future action given the detailed proposal which has been prepared by Pitkin County. A failure to include a cumulative impact analysis of additional trail development that is already planned in the region renders NEPA analysis insufficient. *See, e.g., Kern v. U.S. Bureau of Land Management*, 284 F.3d 1062, 1078 (9th Cir. 2002) (holding that an EA for a timber sale must analyze the reasonably foreseeable future timber sales within the area).

iv. Mitigation

The Forest Service must develop alternatives that are consistent with the mitigation hierarchy. NEPA and associated CEQ regulations require federal agencies to analyze potential impacts and consider ways to avoid, minimize and mitigate impacts – in accordance with the mitigation hierarchy. 40 C.F.R. §§ 1508.8, 1502.14, 1502.16. The mitigation hierarchy aims to minimize environmental harms associated with agency actions. First and foremost, the Forest Service must seek to avoid impacts; then minimize impacts (e.g., through project modifications, permit conditions, interim and final reclamation, etc.); and, generally, only if those approaches are insufficient to fully mitigate the impacts, seek to require compensation for some or all of the remaining impacts (i.e., residual effects). The Forest Service must apply the mitigation hierarchy to evaluation of the proposed project.

If the Forest Service determines it is appropriate to evaluate compensatory mitigation due to unavoidable impacts associated with the proposed trail, particularly on wildlife, compensatory mitigation measures must have additionality – that is, the offsetting conservation measures would not have occurred otherwise. Conservation designations and other land use allocations that are intended as compensatory mitigation measures must have strong protective management prescriptions to ensure effective and durable conservation, restoration, and management and adequate and continued funding for and commitment to enforcement. To achieve long-term durability, the Forest Service must commit to and implement management actions, such as restoration projects and enforcement, within mitigation-based conservation designations that are appropriate to specific unavoidable impacts.

II. Environmental Impact Analysis

NEPA is our "basic national charter for the protection of the environment." 40 C.F.R. § 1500.1. NEPA achieves its purpose through "action forcing procedures. . . requir[ing] that agencies take a hard look at environmental consequences." *Id.*; *Robertson v. Methow Valley Citizens Council*, 490 U.S. 332, 350 (1989) (citations omitted). This includes the consideration of best available information and data, as well as disclosure of any inconsistencies with federal policies and plans. Federal agencies must comply with NEPA before there are "any irreversible and irretrievable commitments of resources which would be involved in the proposed action should it be implemented." 42 U.S.C. § 4332(C)(v); *see also* 40 C.F.R. §§ 1501.2, 1502.5(a).

In order to take the "hard look" required by NEPA, the Forest Service is required to assess impacts and effects that include: "ecological (such as the effects on natural resources and on the components, structures, and functioning of affected ecosystems), aesthetic, historic, cultural, economic, social, or health, *whether direct, indirect, or cumulative*." 40 C.F.R. § 1508.8. The EA must specifically analyze the following resources and impacts:

i. Wildlife

We appreciate that portions of the Redstone to McClure Pass trail directly follow Highway 133, and that other portions such as the Bear Creek and McClure Pass segments follow linear disturbances that exist to some extent on the ground and already see some human use. However, all recreation trails have impacts on wildlife, and in developing this EA the Forest Service must thoroughly determine what those impacts may be and identify ways to avoid, minimize, and mitigate those impacts. Specifically for this trail proposal, the Forest Service must take a hard look at impacts to wildlife from increased human presence on the entire proposed trail; impacts specific to adding system trail where it doesn't currently exist, such as habitat fragmentation; and cumulative impacts of trail development and recreation users at a regional scale.

There is a large body of literature documenting the impacts that recreation has on wildlife, and research is growing on the impacts of non-motorized recreation specifically. In addition to analyzing impacts directly associated with recreation use on the trail, the Forest Service must analyze impacts associated with increased car traffic on Highway 133 resulting from people accessing the trail. For example, Cuiti et al. (cited below) found that road traffic of as little as one vehicle per two hours caused a notable increase in vigilance behavior. We are including with these comments a subset of literature we particularly recommend the Forest Service consult in developing this EA:

- Thompson, Richard W. *Crystal River Trail Preliminary Wildlife Analysis, Pitkin County, Colorado*. Western Ecosystems, Inc., 2017. Available online.

  Western Ecosystems, Inc. studied the wildlife issues associated with the Pitkin County portions of the proposed Carbondale to Crested Butte Trail. The study provides important data points for the Redstone to McClure Pass segment that the Forest Service must consider in the EA, as well as science-based management recommendations and a detailed literature review of trail impacts on wildlife.

- Millhouser, Paul. *Evaluating Landscape Connectivity and Habitat Fragmentation Effects on Elk in the Roaring Fork and Eagle Valleys.* Rocky Mountain Wild, 2019. Available online.

  This paper applies measures of human influence on the landscape, including habitat fragmentation and landscape connectivity, to the study area in a time series from 1981 to 2017, to identify possible correlations with elk populations changes during that period.

Analyzing Colorado Parks and Wildlife findings that population decline in the Roaring Fork and Eagle Valleys was more than 50% from 1999 to 2015, Millhouser concludes that human influence on the landscape has reduced the equilibrium calf to cow ratio.

- Naylor, Leslie M., Michael J. Wisdom, and Robert G. Anthony. "Behavioral Responses of North American Elk to Recreational Activity." *Journal of Wildlife Management* 73, no. 3 (April 2009): 328–38. Available online.

  Naylor et al. look at recreation impacts on elk by type, such as ATV riding, mountain biking, hiking, and horseback riding. All activities tended to increase the time elk spent traveling and reduce resting time; however this paper can help managers identify and analyze impacts associated with specific recreation activities.

- Ciuti, Simone, Joseph M. Northrup, Tyler B. Muhly, Silvia Simi, Marco Musiani, Justin A. Pitt, and Mark S. Boyce. "Effects of Humans on Behaviour of Wildlife Exceed Those of Natural Predators in a Landscape of Fear." Edited by Nei Moreira. *PLoS ONE* 7, no. 11 (November 28, 2012): e50611. Available online.

  Ciuti et al. found that human activity is a better predictor of increased elk vigilance – resulting in impacts such as reduced reproductive success – than any natural factor. The authors examine impacts from specific types of human activities and model relationships between traffic volumes and elk vigilance.

- Rocky Mountain Wild, "Trail Impacts on Wildlife Habitat." 2018 Annotated Bibliography. Available online.

  This annotated bibliography includes some of the seminal research on road ecology as well as recent research addressing the effects of trails and recreation use on wildlife behavior and habitat quality.

Additionally, last year Colorado Parks and Wildlife (CPW) initiated a 6-year study on elk in the Roaring Fork Valley. CPW is trying to determine why the calf-cow ratio in the valley has been persistently below the ratio needed to grow, and the study should shed light on whether and to what extent recreation is affecting elk recruitment. While the study is still in very early stages, the Forest Service should consult with CPW to ensure any information that has been gathered can be appropriately incorporated into the agency's analysis of the proposed trail.

The Forest Service must also analyze habitat fragmentation that may result from the trail, specifically concerning the Bear Creek and McClure Pass segments which depart from Highway 133. While these segments may follow historic corridors of disturbance and already see some use, designating them as system trails and allowing mechanized use as well as the existing foot and horse traffic would almost certainly increase use and therefore have an effect on fragmentation. The Crystal River Trail Preliminary Wildlife Analysis documents that the McClure Pass segment bisects important wildlife habitats that could be negatively affected by increased trail use, including breeding birds and the elk, bald eagle, black bear, and moose habitats, finding that, "Improving and increasing use of the old McClure Pass Road switchbacks through largely effective habitat would negatively affect a moderate number of important wildlife species in an area of approximately 223 ac. (0.35 mi.^{2}).” Thompson 2017 at 51.

Habitat fragmentation consists of two different processes that simultaneously and negatively affect wildlife species: (1) a reduction in the overall habitat available to wildlife species – habitat loss; and (2) the creation of isolated patches of habitat separated from what was once the contiguous landscape. Crooks and Sanjayan 2006. There are many ways to measure habitat fragmentation; three of the most useful metrics, due to their ease of calculation and direct connection to biological field research, are road or route density, number and size of core areas, and distance to a road or route. Conducting spatial analysis is critical to quantify these metrics and understand impacts to species and populations, and to ultimately make decisions that avoid, minimize or mitigate those impacts. We recommend the Forest Service utilize all three types of spatial analysis to measure habitat fragmentation and assess the ecological impact of the trail. The Forest Service can and should use wildlife literature to interpret fragmentation metrics developed through spatial analyses and adopt management decisions that best protect wildlife species.

Additionally, the Forest Service should assess any impacts of this trail to the Avalanche bighorn sheep herd and specifically their recovery, given the recent retirement of the only domestic sheep grazing allotment in the Crystal and Roaring Fork River Watersheds. Protection for and restoration of the local population of bighorn sheep (there has been approximately an 80% decline in Capitol to Avalanche Creek herd in the last ten years) is likely to be a priority of the Forest Service, CPW, Pitkin County and the public. Given this, the EA should analyze CPW’s Habitat Suitability Model for Bighorn sheep in the area, which includes a small amount of quality habitat on the west side of Highway 133. Effective recovery of bighorn sheep likely depends on identifying, protecting and restoring high quality habitat for this species, whether currently occupied or not; the EA should analyze impacts of the proposed trail to both occupied and potential bighorn sheep habitat.

At a broader level, we would suggest that recent wildlife studies indicate we may likely be approaching a recreation carrying capacity on the White River National Forest and in our region. The Forest Service should consider a programmatic analysis of recreation impacts on wildlife across the forest to appropriately evaluate cumulative impacts and determine what additional level of recreation is sustainable and/or what mitigation is required to ensure the viability of wildlife species on the forest. Ultimately, we should start prioritizing new trails in recognition of the fact that there is a limit to the amount of recreation the forest can sustain. We encourage the Forest Service, and all stakeholders, to consider whether this trail would be a top priority in the context of limited new trails being developed in the future.

In conclusion, the EA must incorporate the following elements to appropriately analyze and mitigate impacts to wildlife from the proposed project:

- Literature review and analysis of wildlife impacts from recreation, including the most recent local studies and information gathering that is in-process by Colorado Parks and Wildlife.
- Habitat fragmentation analysis, including quantification of metrics that can be tied to specific species.

- The EA should establish an adaptive management framework to identify and commit to a process for evaluating new science and data as it emerges in the future and applying that information to management of the trail.
- The EA must commit to a specific management, monitoring and enforcement plan.
- Mitigation measures encompassing the full mitigation hierarchy, including alternatives to avoid impacts to wildlife, measures such as seasonal closures to mitigate impacts, and compensatory mitigation to the extent that is feasible. For example, the Crystal River Trail Preliminary Wildlife Analysis makes several recommendations for addressing wildlife impacts on the McClure Pass segment. Thompson 2017 at 51.
- The EA should provide for modification of the permit to change alignment, closure dates or use type amount and type as new information and science is presented.
- Consider deferring this project until the Roaring Fork Watershed Biodiversity and Connectivity Study is complete. The study would provide valuable data and resources to inform this particular project.
- Analysis of cumulative impacts, noise impacts and climate change adaptation as discussed elsewhere in these comments.

ii. Noise Impacts

The Forest Service should analyze noise impacts on wildlife that would result from increased recreation use along the proposed trail, particularly the portion that does not follow Highway 133. Non-natural noise, such as that associated with human recreation, can affect the physiology, behavior, and spatial distribution of wildlife. *See, e.g.*, Shannon et al. 2016. While the particular impacts vary by species and habitat, studies have shown that recreation-based and other human-caused noise can impact species in ways crucial to survival and reproductive success. *Id.*

Analyzing the impacts of the proposed project on the natural soundscape and the resulting impacts on resources is important in order to take a hard look at the direct, indirect, and cumulative impacts of the project. As part of such an analysis, the EA should articulate an environmental baseline and analyze the foreseeable noise impacts of the trail, particularly on wildlife. Spatial or GIS-based sound modeling should be used to measure both the existing soundscape and noise impacts from each alternative. This type of analysis can and should be accomplished through existing acoustic modeling methodologies. *E.g.,* Keyel et al. 2018.

iii. Recreation

The EA must analyze the expected amount of recreation use on the new trail, both in terms of number of users and types of use. The EA should analyze how expected changes in recreation use and extent would impact the existing recreation experience along the trail segment, which is currently used as a primitive trail.

The EA must also analyze the potential for "social" trail development and use that may result from this trail being officially designated and constructed. The Forest Service should identify and analyze measures to mitigate potential development of unauthorized trails, including site-specific analysis where likely spurs or branches could occur. As one example there are two decommissioned routes that would become accessible from the proposed trail and could lead to much greater habitat fragmentation of larger wildlands: Spring Creek to Bear Creek (FS1955W.1) that connects all the way to Coal Basin and Hayes Creek (FS1955W.1H) which gives access to much of Hayes Creek. Creating the Redstone to McClure Pass Trail would be likely to increase the amount of foot and horse traffic on these routes and might lead to illegal user development of these routes for mechanized use.

iv. Cultural and Historic Resources

Section 106 of the National Historic Preservation Act (NHPA) requires federal agencies to "take into account the effect of [any] undertaking on any district, site, building, structure, or object that is included in or eligible for inclusion in the National Register [of Historic Places]." 16 U.S.C. § 470f. Federal courts have described section 106 as a "stop, look, and listen provision that requires each federal agency to consider the effects of its programs" on historic properties and cultural resources. *Mont. Wilderness Ass'n v. Connell* (*MWA*), 725 F.3d 988, 1005 (9th Cir. 2013). This proposed project, which is to issue Pitkin County a Special Use Authorization to construct and maintain a trail on national forest lands, constitutes an "undertaking" subject to the requirements of section 106. *See* 36 C.F.R. §§ 800.3(a), 800.16(y) (undertakings include any permit or approval authorizing use of federal lands).

For any undertaking, the federal agencies must: (1) "make a reasonable and good faith effort" "to identify historic properties within the area of potential effects," "which may include background research, consultation, oral history interviews, sample field investigation, and field survey;" (2) determine whether identified properties are eligible for listing on the National Register of Historic Places; (3) assess the effects of the undertaking on any eligible properties; and (4) avoid, minimize, or mitigate any adverse effects. 36 C.F.R. §§ 800.1(a), 800.4(b), 800.5, 800.6, 800.8(c)(1)(v) & (c)(4).

The inventory step is a critical prerequisite to the remainder of the section 106 process: "[i]t is simply impossible for an agency to take into account the effects of its undertaking on historic properties if it does not even know what those historic properties are in the first place." 65 Fed. Reg. 77,698, 77,715 (Dec. 12, 2000) (Advisory Council on Historic Preservation describing inventory requirement); *see also S. Utah Wilderness Alliance v. Burke* (*SUWA*), 981 F. Supp. 2d 1099, 1109-10 (D. Utah 2013) (where BLM failed to conduct a reasonable and good faith inventory effort, its "finding that there were likely no adverse effects . . . was arbitrary and capricious") (on appeal). Conducting a class III survey for the proposed trail is necessary to ensure the Forest Service has a complete inventory of cultural resources and historic properties and can accurately assess the impacts of the proposed trail on those sites.

Regardless of any cultural and/or historic surveys that Pitkin County has conducted in developing the trail proposal, the Forest Service must independently meet its obligations under the NHPA and agency regulations and policies. The EA must document how the Forest Service is meeting its obligations under the NHPA and evaluate alternatives to mitigate potential impacts to cultural and historic resources.

v. Climate Change

The Forest Service must analyze climate change impacts associated with this project, in terms of both greenhouse gas emissions generated and potential impacts on the adaptive capacity of ecosystems and species. It is well established that federal agencies must analyze the climate impacts of proposed actions, and courts have invalidated agency decisions for failure to do so. *See e.g.*, *Ctr. for Biological Diversity v. Nat'l Highway Traffic Safety Admin.*, 538 F.3d 1172, 1217, 1223-25 (9th Cir. 2008). For the Redstone to McClure Pass Trail, the Forest Service must estimate and quantify greenhouse gas emissions that would result from people driving to and from the trailhead, as well as whether and to what extent the trail could impair species' abilities to adapt to a changing climate.

Observed changes in climate and land use patterns are resulting in habitat fragmentation, loss of biodiversity, and are negatively impacting sensitive habitats and important ecological processes (Theobald 2010, Theobald et al. 2011). These changes are projected to continue causing an increase in habitat fragmentation and shifts in the distribution of plants, animals, and ecological processes across local, regional, and global scales (Opdam and Wascher 2004, Loarie et al. 2009, Dobrowski et al. 2013, Ordonez et al. 2014). The ability of ecosystems to adapt and persist in a changing climate will be dependent on the ability of species and ecological processes to migrate over and operate at broad scales (Theobald et al. 2012).

Scientific research and data exist to inform the Forest Service what areas are important to keep intact in order to facilitate species adaptation to climate change. In particular, we recommend the Forest Service utilize the following peer-reviewed research to evaluate the importance of the project area to climate adaptation:

- Landscape Permeability Model and Ecological Flow Routes (Theobald 2012)

  Landscape permeability describes the quality of a landscape that allows organisms to move freely across it and the degree to which the landscape impedes or facilitates species movement among suitable habitat and resource locations. This research defines natural landscapes as a function of land cover type, housing density, presence of roads and railways, and extractive activities (i.e. oil, gas, minerals etc.) and then assesses the connectivity of these natural landscapes to each other with a model of permeability. The results are presented as ecological flow routes across the landscape and represent the connectedness of large, undeveloped landscapes. This data is useful for identifying locations and their relative importance for maintaining landscape connectivity, protecting the movements of species, retaining landscape-scale ecological processes, and facilitating adaptation to climate change.

- Land Facet Diversity (Albano 2015)

  This research identifies geophysically diverse locations that may facilitate species' persistence and adaptation to climate change in the southwestern United States. The land facet diversity classifications are derived from a comprehensive suite of topographic and edaphic variables including but not limited to; topographic complexity, large elevation ranges, soil type and structure, soil chemistry, soil moisture availability, and underlying geological features. This information can be used to identify and prioritize areas that have a high capacity to provide highly diverse habitats for many different types of biodiversity. Landscapes with high land facet diversity may optimally facilitate species' capacity to migrate and adapt to climate change or serve as areas of refugia.

The Forest Service should use the best available science to analyze whether the proposed trail may have negative impacts on species' adaptation capacity, and mitigate any potential impacts through realignment of the trail.

III. Additional Constraints

i. Motorized Use

We appreciate that the Forest Service intends this trail to be a non-motorized trail.[4] Because the trail would be a multi-use trail open to bicycles and other mechanized use, the EA must specifically identify e-bikes of all classes as motorized vehicles which are not permitted on this non-motorized, multi-use trail. E-bikes cannot be permitted on non-motorized trails, in accordance with travel management laws and policies dating back to the Nixon administration that require all motorized recreational uses of national forest system and other public lands be confined to a system of roads, trails, and areas designated in compliance with the so-called "minimization criteria." *See* Exec. Order No. 11,644, §§ 1 & 3 (Feb. 8, 1972), *as amended by* Exec. Order No. 11989 (May 24, 1977).

The Forest Service's Travel Management Rule (TMR) echoes these criteria and restricts "motor vehicle use" to the designated system identified through travel management planning, and the associated public process and NEPA review, and depicted on the forest's Motor Vehicle Use Map (MVUM). *See* 36 C.F.R. part 212, subpart B. The TMR defines "motor vehicle" broadly as "[a]ny vehicle which is self-propelled," excluding vehicles operated on rails and battery-powered mobility devices. 36 C.F.R. § 212.1; *see also* Exec. Order No. 11,644, § 2 (defining "off-road vehicle" subject to travel management restrictions as "any motorized vehicle designed for or capable of cross-country travel on or immediately over land, water, sand, snow, ice, marsh, swampland, or other natural terrain," while excluding emergency, authorized, and official uses). On numerous occasions, the Forest Service has explicitly and correctly recognized that e-bikes – which by definition have a motor – are motor vehicles subject to the TMR. For instance, the response to comments on the agency's 2015 winter travel management rule (subpart C of the TMR) stated that "[n]ew technologies that merge bicycles and motors, such as e-bikes, are considered motor vehicles under § 212.1 of the TMR." 80 Fed. Reg. 4500, 4503 (Jan. 28, 2015).

If the Forest Service were to propose authorizing e-bike use on this trail, the agency must conduct a NEPA process to authorize that use that complies with all regulations governing motorized use on national forests, including specifically the minimization criteria. Federal courts have repeatedly sent Forest Service, BLM and National Park Service travel management plans

[4] See FS scoping letter, available at https://www.fs.usda.gov/nfs/11558/www/nepa/112357_FSPLT3_5222465.pdf.

back to the agencies for failure to satisfy their obligation to minimize resource damage and conflicts between recreational uses.[5]

ii. Consistency with Forest Plan

The National Forest Management Act (NFMA) requires that site-specific projects and activities must be consistent with an approved forest plan. 16 U.S.C.S. § 1604(i); 36 C.F.R. § 219.15(b). In its project approval document, the agency must describe how the project is consistent with the forest plan. 36 C.F.R. § 219.15(d). A project is consistent if it conforms to the applicable components of the forest plan, including the standards, guidelines, and desired conditions that are set forth in the forest plan and that collectively establish the details of forest management. Consistency under agency regulations depends upon the component type. The Forest Service must strictly comply with a forest plan's standards, which are binding limitations, but it may deviate from the forest plan's guidelines, so long as the project is as effective as the forest plan in achieving the purpose of the applicable guidelines. § 219.15(d)(3). When a site-specific project is not consistent with the applicable forest plan components, the Forest Service must either modify or reject the proposed project, or amend the plan. § 219.15(c).

We note that the Crystal River Trail Preliminary Wildlife Analysis identified the Bear Creek segment as inconsistent with the Forest Plan and requiring a plan amendment to site the trail in the proposed location.[6] Thompson 2017 at 50-51. The draft EA must specifically document that the proposed trail is consistent with the applicable components of the White River Forest Plan, rather than generally state that the proposed trail is consistent with the Forest Plan.

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[5] *See WildEarth Guardians v. U.S. Forest Service*, 790 F.3d 920, 929-32 (9th Cir. 2015) (Forest Service failed to "apply the minimization criteria to *each area* it designated for snowmobile use" and to provide the "granular analysis [necessary] to fulfill the objectives of Executive Order 11644"); *Friends of the Clearwater v. U.S. Forest Service*, No. 3:13-CV-00515-EJL, 2015 U.S. Dist. LEXIS 30671, at *37-52 (D. Idaho Mar. 11, 2015) (Forest Service's conclusory statements failed to show how it selected motorized routes with the objective of minimizing their impacts); *SUWA v. Burke* (*SUWA*), 981 F. Supp. 2d 1099, 1104-06 (D. Utah 2013) (BLM acknowledgment of minimization criteria insufficient where record showed no analysis of specific impacts of designated OHV routes); *The Wilderness Society v. U.S. Forest Service*, No. CV08-363-E-EJL, 2013 U.S. Dist. LEXIS 153036, at *22-32 (D. Idaho Oct. 22, 2013) (remanding travel plan where Forest Service relied on unsupported conclusion that route closures and elimination of cross-country travel minimized impacts); *Defenders of Wildlife v. Salazar*, 877 F. Supp. 2d 1271, 1304 (M.D. Fla. 2012) (record failed to demonstrate how Park Service decision to reopen trails was made with the objective of minimizing impacts); *Central Sierra Environmental Resource Center v. U.S. Forest Service*, 916 F. Supp. 2d 1078, 1094-98 (E.D. Cal. 2012) (Forest Service failed to show that it actually aimed to minimize environmental damage when designating motorized routes); *Idaho Conservation League v. Guzman*, 766 F. Supp. 2d 1056, 1071-74 (D. Idaho 2011) (record did not reflect whether or how the Forest Service applied the minimization criteria); *Center for Biological Diversity v. BLM*, 746 F. Supp. 2d 1055, 1071-81 (N.D. Cal. 2009) (record provided no indication that BLM considered or applied minimization criteria).

[6] Forest-wide, Wildlife, Standards 8 and 9 of the White River National Forest Management Plan specify the following related to peregrines:

> 8. Discourage land use practices and development that adversely alter the character of peregrine falcon hunting habitat or prey base within ten miles of the nest site and the immediate habitats within one mile of the nesting cliff.
>
> 9. Human activities will be restricted within one-half mile of the occupied peregrine falcon areas between March 15 and July 31 for nest sites, or July 1 to September 15 for hack sites.

iii. Reliance on Pitkin County

Lastly, the EA should discuss in detail the role of Pitkin County in maintaining and managing the trail and its use over the long term and what assurances, financial or otherwise, the County is able to provide that it will be able to continue fulfilling that role in the future. The EA must also analyze what measures the Forest Service will take in the event Pitkin County is no longer able to maintain the trail. While we appreciate Pitkin County's proposal to maintain the trail and fund a ranger on the trail, we are cognizant of those commitments being reliant on continued funding for the Open Space and Trails program, potentially shifting priorities for that program, and even electoral politics. Therefore, we recommend the EA evaluate and require all reasonable assurances that can be made by the County and also outline a plan of action in the event that the County is no longer able to fulfill part or all of its role regarding the trail. For example, the EA should explicitly provide for closure of the trail and revocation of the permit if the County can no longer provide funding for management and enforcement.

Thank you for considering our comments. We reiterate our appreciation that the Forest Service is completing a thorough NEPA process to analyze this trail proposal, and we look forward to reviewing and commenting on the draft EA.

Sincerely,

Will Roush, Executive Director
Wilderness Workshop
P.O. Box 1442 Carbondale, CO 81623
970.963.3977 | will@wildernessworkshop.org

Attachments

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Attachment 1

CRYSTAL RIVER TRAIL
PRELIMINARY WILDLIFE ANALYSIS, PITKIN COUNTY, COLORADO

Prepared for:

Wilderness Workshop

P.O. Box 1442
Carbondale, CO 81623
www.wildernessworkshop.org

JULY, 2017

Western Ecosystems, Inc.
Ecological Consultants
905 West Coach Road, Boulder, Colorado 80302 (303) 442-6144

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Prepared by:

Richard W. Thompson, Certified Wildlife Biologist

Western Ecosystems, Inc., 905 West Coach Road, Boulder, Colorado 80302

JULY, 2017

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TABLE OF CONTENTS

Section Page

TABLE OF CONTENTS (CONTINUED)

LIST OF TABLES

Table Page

LIST OF FIGURES

Figure Page

1.0 EXECUTIVE SUMMARY

Wilderness Workshop retained Western Ecosystems, Inc. to conduct an independent review of the more significant wildlife issues associated with potential effects of the Crystal River multi-use recreation trail in Pitkin County using the most current data and the best available science. Goals of the analysis were to (1) educate the public about the more significant wildlife-related issues and impacts arising from any new trail construction and (2) provide facts to Pitkin County and the U.S. Forest Service (USFS) for the National Environmental Policy Act (NEPA) process.

Wildlife concerns have been one of the most important resource issues associated with the proposed trail since its conception in the early 1990's. Findings of the more substantive and pertinent wildlife analyses and professional correspondence associated with the conceptual Crystal River trail were reviewed and summarized in the report. The wildlife record documenting the critical, high value, and diverse wildlife habitats in the valley was consistent and extensive. In particular, former analyses of wildlife and habitat use in the Crystal River valley highlighted the importance of the largely intact, isolated, unfragmented, and high value wildlife habitats on the east side of the Crystal River north of the town of Redstone.

Potential trail segments were based largely on those identified in the most recent and detailed trail feasibility study to date (Newland Project Resources 2004). That study identified potential trail segments located within the existing Highway 133 corridor, three trail segments following an historic railroad grade east of the Crystal River, existing Redstone Boulevard, the Hayes Creek Canyon bypass west of the highway, and the existing old McClure Pass Road switchbacks. That study indicated that with the exception of Hayes Creek Canyon, where a potential 1.5 mile bypass was identified, a bike trail could be located alongside, or offset from, Highway 133 through the entire length of Pitkin County's Crystal River Trail analysis area.

The evaluation of current wildlife use of the Crystal River valley was based largely on the large wildlife and ecological databases, particularly Colorado Parks and Wildlife (CPW) mapping. Federally-listed and proposed animal species, USFS Region 2 sensitive animal species, eight CPW-mapped wildlife species, habitat conditions, other wildlife groups, and other noteworthy resource issues were considered. Detailed CPW maps and descriptions of seasonal habitat use for the more sensitive wildlife species present are provided. Bighorn sheep and elk are the wildlife species of particular concern. Potential trail effects on wildlife and habitats are summarized, including the general effects of recreational use on wildlife and case studies documenting wildlife responses to different user groups pertinent to the particular species and potential trail issues in the Crystal River analysis area. The scientific literature review showed how all types of recreational activities can have negative effects on wildlife.

Potential trail siting considerations were based on (1) anticipated trail use effects on wildlife and their habitats, as documented in the scientific literature, (2) results of prior wildlife analyses in the Crystal River valley, and (3) the experience and recommendations of professional wildlife biologists and managers, particularly those from the state wildlife management agency.

Based on the analysis, the Crystal River trail would have the least negative effects on wildlife habitats and ecological communities if it was located within existing disturbance corridors (i.e., along Highway 133 and Redstone Boulevard) and along the Hayes Creek bypass (identified only because Newland Project Resources [2004] indicated that a viable trail was not possible through Hayes Creek canyon). A trail following this route would cross through some important wildlife habitats and result in direct and indirect habitat losses. However, with the exception of the Hayes Creek bypass, all of the affected habitat would be within the highway's and Redstone Boulevard's existing zones of influence, where habitat effectiveness has been reduced for most species, including those species of greatest concern (sheep and elk). The above trail alignment would be far better for the wildlife community than introducing new trail use into currently buffered, isolated, highly effective, and large unfragmented blocks of critical and important wildlife habitat. This recommendation is consistent with ecological recommendations: (1) in the scientific literature, (2) from CPW, (3) in the 2007 Crystal River Caucus Wildlife and Habitat Report, and (4) in the 2008 Filoha Meadows Management Plan. Additional construction timing, seasonal trail use, and other measures and considerations that would avoid, minimize, and mitigate negative wildlife effects resulting from development and use of all potential Crystal River trail segments are presented.

A considerable amount of adjacent habitat can be affected by recreational trail use. Depending on the trail segments selected, the Crystal River trail could either have relatively minor effects (with a highway, Redstone Boulevard, and Hayes Creek bypass alignment, affecting to some extent approximately 111 ac.) on wildlife and ecological communities, or have the largest, single, negative effect to wildlife habitats in the valley since Highway 133 was upgraded in the late 1960's (with highway segments, three trail sections east of the river, the Hayes Creek bypass, and the old McClure Pass switchbacks, affecting to some extent approximately 875 ac.).

2.0 INTRODUCTION

A public recreation trail in the Crystal River Valley has been under consideration since 1991 when the Colorado Scenic and Historic Byway Commission established the West Elk Loop Scenic and Historic Byway (hereinafter the "byway"). One of the most significant resource concerns consistently associated with a public recreation trail in the Crystal River Valley was, and remains, wildlife. Several trail feasibility studies have been conducted (Pitkin County Open Space and Trails 1994, Edaw[1] 2000, Newland Project Resources 2004). An unusually large number of analyses focusing on wildlife issues have also been conducted. Pitkin County has acquired nine open space parcels to protect wildlife habitat and facilitate a recreation trail on the east side of the Crystal River. The Colorado Division of Wildlife (CDOW, name changed to Colorado Parks and Wildlife [CPW] in June, 2012), the state wildlife agency, has commented since 2002 on open space parcel acquisition and potential trail development effects on wildlife. In 2016, the 2003 Crystal River Valley Master Plan, a community-based Master Plan developed jointly by Pitkin County and the residents and Caucus of the Crystal River Valley, was updated to reflect current concerns and goals, including wildlife.

In late 2016, Great Outdoors Colorado (GOCO) awarded a grant to Pitkin County for planning the Carbondale to Crested Butte Trail. The trail will extend roughly 83 miles between Carbondale and Crested Butte. The trail project was named to Governor John Hickenlooper's Colorado the Beautiful Initiative earlier in 2016, placing it on a list of 16 priority trail projects across the state. Planning for the Carbondale to Crested Butte Trail will be a year-long effort, involving the public, Pitkin and Gunnison Counties, the Town of Crested Butte, the Colorado Department of Transportation, CPW, and both the White River (WRNF) and Grand Mesa/Uncompahgre/Gunnison National Forests. Within Pitkin County, the planning will focus on route options between the existing terminus of the Crystal Valley Trail, south of Carbondale, and the top of McClure Pass. The GOCO-planning grant will be combined with an allocation from Pitkin County Open Space and Trails (PCOST) to fund planning work, and environmental

[1] Edaw, Inc. is a private landscape counseling and planning firm located in Fort Collins, CO.

and engineering studies for the envisioned trail. Pitkin County Open Space and Trails began the Crystal River trail planning phase early in 2017.

In early 2017, with trail planning in Pitkin County moving forward, Wilderness Workshop retained Western Ecosystems, Inc. to conduct an independent review of the more significant wildlife issues associated with potential Crystal River Trail effects in Pitkin County using the most current data and the best available science. Goals of the analysis were to (1) educate the public about the more significant wildlife-related issues, (2) provide detailed information to help inform PCOST and the Pitkin County Board of County Commissioners, and (3) serve as a foundation for Wilderness Workshop's engagement in the National Environmental Policy Act (NEPA) process.

Both the author and Wilderness Workshop recognize that while land use and development decisions, including recreation, often result in impacts to wildlife, this does not necessarily mean that no use or development should occur. This analysis is not intended to justify opposition to a trail up the Crystal Valley or definitively determine a set of alignments. Rather, the goal is to ensure a thorough third party analysis of impacts to wildlife. Pitkin County and the USFS are also committed to wildlife analyses for the proposed trail and this report is intended to complement and add to those analysis as well as providing the accountability that only an independent evaluation can. Additionally, aspects of the trail project including engineering, costs, safety, user experience, management, legal issues, private property rights, and many other considerations will be part of both Pitkin County's and the Forest Service's outreach and analyses including those conducted under the NEPA process. However, these important considerations are beyond the scope of this analysis. This report considers only what is in the best interest of wildlife.

3.0 ANALYSIS AREA AND POTENTIAL TRAIL ALIGNMENTS

3.1 ANALYSIS AREA

Figure 2-1 shows the proposed 83-mile Carbondale to Crested Butte trail system. Trail segment A, south of Carbondale, was completed in 2010. This report addresses the 20 miles of trail segments B and C in Pitkin County, north of McClure Pass. The analysis area focuses on wildlife use of the valley bottom where the trail would be located. It also extends outward to consider adjacent habitats of some species potentially affected by increased use of areas, which currently see little to no human use due to a lack of public access. The Crystal Trail has the potential to increase access to these areas both from people venturing off any new trail or as the result of new "social trails" (those trails created by recreational enthusiasts without any environmental review or authorization). The Roaring Fork Valley has a history of social trail development and limited capacity and enforcement from federal land management agencies has led to the continued use of these trails. Aerial photographic mapping of the Crystal River Trail corridor that was developed by PCOST for their January, 2017 public open house meetings is appended in Figures 10.1-1 to 10.1-10, in Section 10.1, below. Those maps show greater detail of corridor sections than the larger scale wildlife mapping.

3.2 POTENTIAL CRYSTAL RIVER TRAIL ALIGNMENTS

Currently, there are no proposed trail alignments. Potential trail segments will be identified and evaluated as part of PCOST's public outreach and the NEPA process. As a result, this analysis uses the most recent and detailed trail feasibility study to date as a basis for examining impacts to wildlife. Newland Project Resources (2004) identified several potential trail segments:

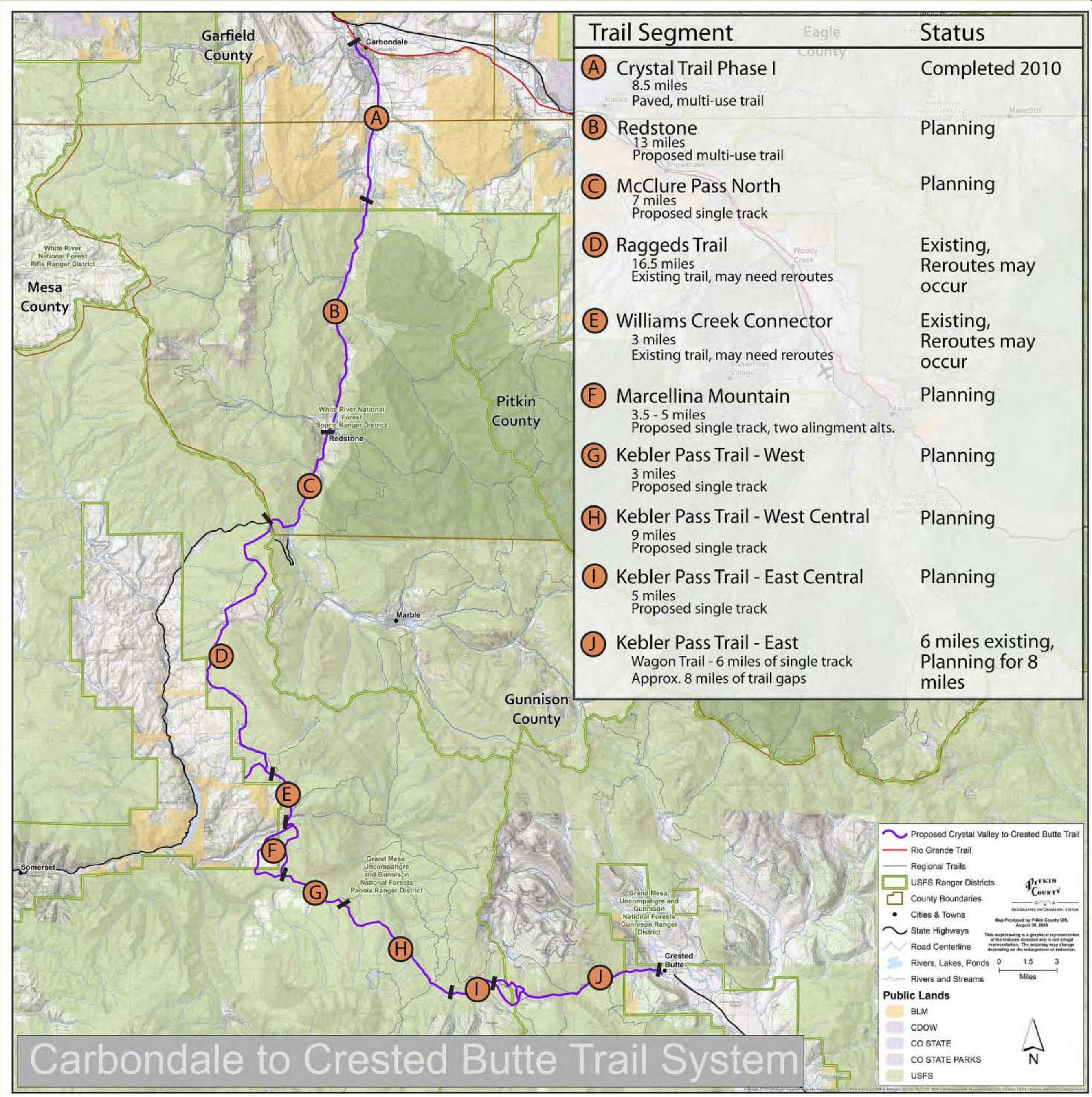

Figure 2-1. The proposed Carbondale to Crested Butte trail system. Trail segment A, south of Carbondale, was completed in 2010. This report addresses trail segments B and C in Pitkin County, north of McClure Pass. The map's dark green shading delineates the Maroon Bells-Snowmass Wilderness. Map developed by Pitkin County GIS, Aug. 30, 2016.

- First, an alignment offset from and along Highway 133, a two lane highway with posted speeds of between 55 mph and 30 mph, from south of Carbondale to the top of McClure Pass.
- Second, an alignment along discontinuous sections of an abandoned, historic railroad grade located east of the Crystal River. Portions of the railroad grade bisect private property where the grade is

used for subdivision access and driveways. However, the County has purchased parcels north of Redstone for use as open space that could physically accommodate three trail segments on the east side of the river (the Crystal River Open Space [CROS] trail segment, the Red Wind Point [RWP] segment, and Janeway and Filoha Meadows [J&F] segment) if accessed via new bridged river crossings.

- Third, an alignment through and north of Redstone along Redstone Boulevard, comingling with motorized traffic on the road.
- Fourth, south of Redstone, a trail alignment could occur along Highway 133 and diverge for two trail segments west of Highway 133, (1) following the abandoned Bear Creek railroad grade, bypassing Hayes Creek Canyon where a trail along the highway corridor was deemed unsafe (Newland Project Resources 2004), and (2) following the switchbacks of the historic McClure Pass Road.

Details and maps of each of these alignments are described in Newland Project Resources (2004, pp. 29-37). The trail feasibility study assumed trail segments north of Redstone would be paved and 8-10 feet wide to accommodate multiple user groups and trail segments south of Redstone would primarily be soft track and 3-5 feet wide. No final trail width or surface material decisions have been made by PCOST or any other entity. Because Newland Project Resources (2004) is the most recent and detailed trail feasibility study to date and because other potential routes have not yet emerged from the NEPA analysis, the above trail alignments will be considered, although this analysis is largely habitat-based.

4.0 METHODS

This analysis of potential trail effects is based largely on a synthesis of the large wildlife and ecological databases available for the Crystal River valley and the documented effects of recreational trail use on wildlife in the scientific literature. Considerable past effort and thought has been involved documenting seasonal wildlife use in the Crystal River valley. The results of key documents are summarized in Section 4.0, below. Of particular value were the (1) CPW seasonal wildlife mapping, (2) Crystal River Caucus Wildlife and Habitat Report (Crystal River Caucus 2007), (3) Pitkin County (2005, 2008) Management Plans for Crystal River parcels acquired as open space, and (4) CDOW/ CPW correspondence with Pitkin County on both the wildlife benefits associated with the open space parcel acquisitions and the subsequent wildlife concerns associated with the parcels' potential use as part of a regional trail system.

Current (updated Nov. 21, 2016 and Feb. 14, 2017) seasonal wildlife range maps were downloaded from CPW (http://cpw.state.co.us/learn/Pages/KMZ-Maps.aspx) for those species mapped with distributions overlapping the analysis area. Important limiting habitat types[2] were delineated on large-scale maps by Rocky Mountain Wild. Other more widespread habitats that would be less affected by potential trail effects and, therefore, less of a concern[3] are mentioned in the text, but not shown on figures, to focus graphics on the important ranges. The mapping downloaded from the CPW website was unaltered for this analysis. The larger map scale[4] used in this analysis was intended to provide an overview of important

[2] For example, big game winter range, winter concentration area, severe winter range, Pitkin County critical habitats, production areas, mineral licks, other concentration areas, migration corridors, migration patterns, nesting areas, etc.

[3] For example, overall range, summer range, resident population area, limited use area, summer concentration area, etc.

[4] For this analysis, the 20-mile Crystal River trail corridor was broken into three sections, compared to the 10 sections used for the January, 2017 Pitkin County open house displays. The purpose of this analysis was not to identify issues in great detail, that

wildlife habitats. The intent of this analysis was not to develop detailed mapping or identify other site-specific issues[5] in great detail; that will be done as part of the NEPA wildlife analysis.

March, 2017 field surveys were conducted along the length of the potential trail corridor to assess potential trail alignments, associated vegetation types and wildlife habitats, and to put the wildlife mapping in context. Sections of the railroad grade east of the river were hiked or driven where accessible and open.

Interviews were conducted with persons knowledgeable about Crystal River wildlife use. Of particular relevance were those with the former (Kevin Wright) and current (John Groves) CPW District Wildlife Managers (DWM) for the Crystal River valley, who clarified CPW seasonal wildlife range maps, provided details about wildlife numbers and use patterns, and provide other insights regarding local wildlife use. Both DWMs indicated that they provided the author the same information that they provided to the County and public.

5.0 FINDINGS OF PRIOR CRYSTAL RIVER TRAIL CORRIDOR ANALYSES

This section summarizes the findings of the more substantive and pertinent wildlife analyses and correspondence associated with the Crystal River Trail concept. Wildlife concerns have been one of the most important resource issues associated with the proposed trail. This extensive record (from the CDOW/CPW, PCOST, and the public), documents the critical, high value, and diverse wildlife habitats present and, in general, discourages placing trail segments east of the Crystal River.

5.1 1994 CRYSTAL RIVER VALLEY BICYCLE TRAIL STUDY

The PCOST Board began researching the open space and trails needs in the Crystal River valley in June, 1992. Important flora and fauna maps were developed and many public meetings were held in 1992 and 1993 to obtain the opinions of landowners, valley residents, and bicyclists on various trail, biking, and open space issues. The Crystal River Valley Bicycle Trail Study (Haefeli 1994) documented the results of what was the first, major, trail planning effort by Pitkin County. Constraints and potential improvements associated with locating a trail along Highway 133, trail segments east of the river, and off highway trail segments west of Highway 133 were conceptually identified. Other areas of further study were also identified.

With respect to wildlife, wildlife mapping was relatively crude (back then), but the same ancestor polygons of bighorn sheep (*Ovis canadensis canadensis*), elk (*Cervus elaphus*), mule deer (*Odocoileus hemionus*), black bear (*Ursus americanus*), etc. were shown in the same locations as they are today. In their comments on the Crystal River Valley Bicycle Trail Study, the CDOW (as cited in Haefeli 1994, pp. 38-39) identified the following concerns associated with a trail east of Highway 133 that are pertinent to the current analysis area:

- "Large game winter by river and are more stressed by pedestrians and cyclists than motorists. (Winter Concern)
- While grading for trail fill, debris may fall into the river.

will be done as part of the NEPA wildlife analysis, but to provide an overview of important wildlife habitats and related issues.

[5] For example, active raptor nests, Lewis' woodpecker nests, or bat roosts that might be avoided and buffered by trail siting.

- There will be impacts to riparian and aquatic vegetation. Marsh areas are very sensitive to impacts and may require extensive mitigation.
- Vegetation removal may cause erosion and degrade water quality.
- If the trail were to include equestrian use, there could be an increase in animal waste entering into the river. Animals may also impact the health or amount of riparian vegetation in these sensitive areas."

5.2 1996-1999 ROARING FORK WATERSHED BIOLOGICAL INVENTORY, CNHP

In 1996, Pitkin County, in partnership with Aspen Wilderness Workshop (now Wilderness Workshop) and the Roaring Fork Valley Audubon Society, contracted the Colorado Natural Heritage Program (CNHP) to assess the natural heritage values of lands in the Roaring Fork valley. That three-year effort was funded by two GOCO grants awarded to Pitkin County, as well as financial support from Roaring Fork watershed county, city and town governments. The primary goal of the project was to identify the locations of rare or imperiled plants, animals, and significant plant communities. The CNHP (Spackman et al. 1999) identified 55 potential conservation areas (PCAs) in the Roaring Fork watershed that required protection to ensure the watershed's natural heritage was not lost. The three PCAs in the Crystal River valley and their elements that could be affected by potential trail segments are summarized below (Fig. 5-1). Four other PCAs (Middle Thompson Creek, Avalanche Lake, East Creek, and Big Kline Creek) were also identified in the Crystal River valley for their rare or imperiled plants, significant plant communities, and animal elements. However, those four PCAs are removed or isolated from the Crystal River valley bottom such that whatever potential trail segments and anticipated trail use that may be approved through the NEPA process are unlikely to affect them, including social trail development..

5.2.1 Crystal River at Potato Bill Creek

This PCA is a narrow, 21-acre area between Highway 133 and the Crystal River. Because of its small area and linearity it is not discernable in Figure 5-1. Land ownership is unknown. It was designated to protect the rare canyon bog orchid (*Plantathera sparsiflora* var. *ensifolia*) from road maintenance activities. This PCA could be affected by a highway trail alignment.

5.2.2 Avalanche Creek

This PCA includes a ± five-mile reach of Avalanche Creek and a ± 3.5-mile reach of Bulldog Creek that extend down to the Crystal River. A potential section of the J&F trail segment east of the river following the railroad grade, including the spur up and over the saddle to avoid the geologic hazard north of Avalanche Creek, would bisect the western tip of this PCA. Animal elements of significance documented in the PCA include Colorado River cutthroat trout (*Oncorhyncus calrki pleuriticus*, a WRNF Region 2 [R2] sensitive species), nesting black swifts (*Cypseloides niger*, a WRNF R2 sensitive species), critical bighorn sheep and elk winter ranges, and western small-footed myotis (*Myotis ciliolabrum*; a bat).

5.2.3 McClure Pass

This PCA includes 2,174 acres at the top of McClure Pass, mostly on the south side, outside of the Carbondale to McClure Pass analysis area. From a wildlife perspective, this PCA is of value because its large, mature aspen stands support nesting purple martins (*Progne subis*, a WRNF R2 sensitive species).

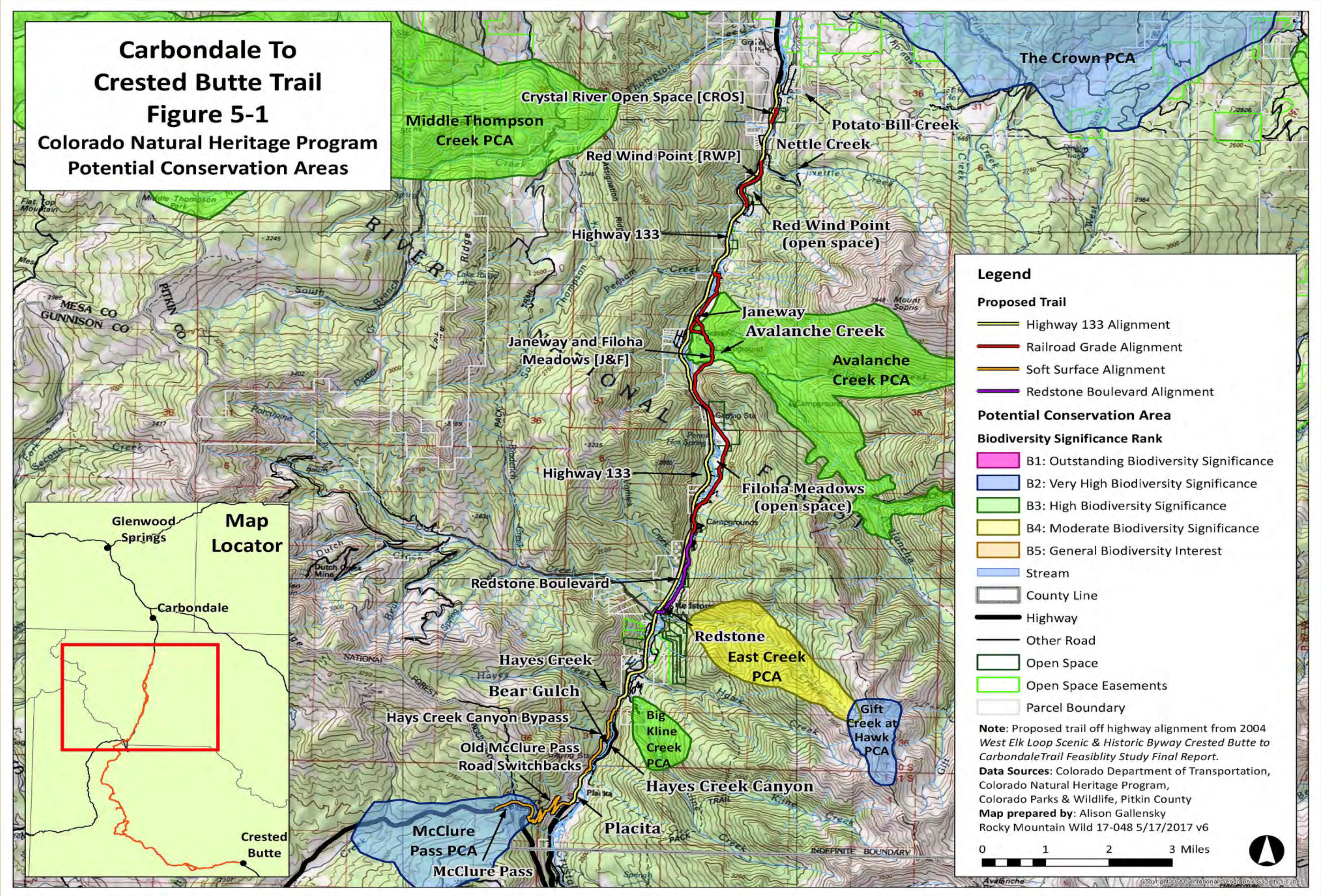

Figure 5-1. CNHP (Spackman et al. 1999) potential conservation areas in the Crystal River valley that could be affected by potential trail segments.

5.3 2004 WEST ELK LOOP SCENIC & HISTORIC BYWAY CRESTED BUTTE TO CARBONDALE TRAIL FEASIBILITY STUDY

The West Elk Loop Scenic & Historic Byway Crested Butte to Carbondale Trail Feasibility Study (Newland Project Resources 2004) was conducted to explore and determine the feasible options for the design and construction of a non-motorized recreation and transportation trail to accompany the byway. "Feasibility" was defined to mean an alignment that is physically capable of being implemented and capable of being successfully utilized. As further defined, a feasible alignment appears to have no fatal flaws that would prohibit its use based on the preliminary environmental information obtained in the field, through existing or known assessments or studies, and through discussions with authorities or experts knowledgeable of the area.

The feasibility study indicated that the Crystal River Trail would be managed as a "three-season" facility. General wildlife-related design criteria included

- Minimizing user impacts to wildlife
- Protecting habitat values and the river corridor
- Minimizing environmental impacts during construction
- Identifying sensitive natural areas and recommending mitigation measures
- Trail alignments avoiding or mitigating sensitive habitats
- Considering seasonal closures and providing seasonal detour routes if possible

None of the various alignments described in the feasibility study were preferred or favored over another. With the exception of Hayes Creek Canyon, where a 1.5-mile bypass was identified, the feasibility study determined that a bike trail could be safely located alongside, or offset from, the Highway 133 corridor through the entire length of Pitkin County's Crystal River Trail analysis area (Newland Project Resources 2004, T. Newland, Newland Project Resources, pers. comm., Mar.23, 2017).

The first issue of concern listed for the Crystal River section of the trail corridor was "the potential impacts of the trail to critical wildlife habitat, especially mountain sheep and elk" (Newland Project Resources 2004, p. 5). Because Newland Project Resources (2004) represents the most recent and thorough trail planning analysis to date and because other potential routes have not yet emerged from the NEPA analysis, trail corridors identified in that analysis are considered in this analysis and shown on the appended wildlife maps in Section 10.3.

5.4 2007 CRYSTAL RIVER CAUCUS WILDLIFE AND HABITAT REPORT

The Crystal River Caucus is an advisory board to the Pitkin County commissioners, giving Crystal River residents an opportunity to voice their opinions on a variety of local issues. In 2007, the Caucus commissioned an inventory and assessment of wildlife habitat in the Crystal River valley for their consideration in determining appropriate management, development, and recreational trail plans for the valley (Crystal River Caucus 2007). The report was prepared by professionals and unpaid professionals with backgrounds in wildlife, biological, and environmental sciences. The primary purpose of the study was to identify and evaluate areas that qualified as "critical habitat" (under definitions used in Pitkin County Land Use Code) in the Crystal River valley. The report stated that the analysis focused on the relatively unfragmented, intact County Open Space and NFS lands buffered from human activities by the Crystal River since approximately 1942 (65 years), now supporting bighorn sheep, elk, and a wide variety of other wildlife.

The Crystal River biological analysis divided the 18-mile analysis area into six, three-mile study or heritage areas (Placita, Redstone, Filoha Meadows, Avalanche Creek, Red Wind Point, and Thompson Creek). Element occurrences within each of the heritage areas were grouped in the following four categories and quantified following CNHP and CDOW rankings:

- Plant habitat and vegetation
- Rare and imperiled (threatened) species and communities
- Wildlife activity use areas
- Stream and riparian(streamside) habitat health

The wildlife component of the analysis was based, in part, on Natural Diversity Information System (NDIS) mapping[6] obtained from the CDOW. The CDOW assigned relative importance values of 1 to 5 for each seasonal activity (e.g., winter range=4, summer range=2, production area=5, winter concentration area (WCA) and severe winter range (SWR)=5, etc., called Impact Factors). By totaling the impact factors in a heritage area, an objective measure of importance and potential impact was determined for that area that contributed to the overall ranking (i.e., for all 4 categories) for the heritage area. Quantifying wildlife activity was used as a general indicator of high wildlife value areas. Colorado Division of Wildlife mapping was not altered despite animal sightings indicating that some seasonal ranges are more extensive than the mapping showed.[7]

Sixteen species of wildlife were mapped by CDOW in the Crystal River Valley and their seasonal ranges were ranked. Maps were only provided in the report for bighorn sheep. Polygons of the more important sheep habitats (winter range, winter concentration area, severe winter range, and production areas) shown in the 2007 report were the same or similar to those downloaded from CPW (last updated Nov. 21, 2016)[8] for this Wilderness Workshop analysis, with the possible exception that there were no sheep severe winter ranges mapped in 2007 as there are now.[9]

Tables 5-1 and 5-2 show the Crystal River Caucus (2007) results of the relative habitat value rankings and potential impact for bighorn sheep and elk, respectively, in the six heritage areas composing the Crystal River analysis area.

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[6] The last ancestor of current CPW GIS .kmz file mapping.

[7] A CDOW disclaimer associated with the NDIS mapping indicated that polygons represent the area where 90% of the animals occur during a specified period and it is recognized that a small subset of animals occur outside defined polygons.

[8] CPW mapping is now updated every five years. Because there were few, if any, habitat or land use changes between 2007 and 2016, mapping would be expected to change little.

[9] Sheep severe winter range (SWR) is identified in figure legends in the 2007 wildlife report, but no SWR polygons appear in any figure. However, sheep SWR occurrence is mentioned in the text for the Red Wind Point heritage area. In addition, 2008 was a winter that met CDOW SWR criteria (see definition in Section 10.2.1) and mapping after that date may have been further refined to reflect that.

Table 5-1. Bighorn sheep habitat importance/ impact potential rankings in the six heritage areas defined by Crystal River Caucus (2007) in the Crystal River analysis area.

Sheep Activity Area	Thompson Creek	Red Wind Point	Avalanche Creek	Filoha Meadows	Redstone	Placita
Overall Range	0	2	2	2	2	2
Winter Concentration Area	0	5	5	5	0	0
Production (lambing)	0	5	5	5	5	5
Winter Range	0	4	4	4	4	4
Summer Range	0	2	2	2	2	2
Grand Total	**0**	**20**	**20**	**20**	**15**	**15**

Source: Crystal River Caucus (2007).

Table 5-2. Elk habitat importance/ impact potential rankings in the six heritage areas defined by Crystal River Caucus (2007) in the Crystal River analysis area.

Elk Activity Area	Thompson Creek	Red Wind Point	Avalanche Creek	Filoha Meadows	Redstone	Placita
Severe Winter Range	2	2	4	4	4	4
Winter Concentration Area	2	2	5	5	5	5
Winter Range	3	3	3	3	3	3
Production (calving)	0	0	5	5	5	5
Summer Range	0	0	2	2	2	2
Highway Crossing	0	0	0	0	0	2
Overall Range	1	1	1	1	1	1
Grand Total	**10**	**10**	**22**	**22**	**22**	**24**

Source: Crystal River Caucus (2007).

The Crystal River Caucus (2007) defined the following relative impact potential categories for totals in each heritage area:

- Low: 9-14
- Moderate: 15-19
- High: 20-25

Five of the six sheep analysis areas were of high (Red Wind Point, Avalanche Creek, and Filoha Meadows) and moderate (Redstone and Placita) importance/ vulnerability, while four of the six elk areas were of high (Avalanche Creek, Filoha Meadows, Redstone, and Placita) importance/ vulnerability.

Table 5-3 shows the Crystal River Caucus (2007) summation of the overall biological value of the six heritage areas composing the Crystal River analysis area. These results consider four components: plant habitat, imperilment, wildlife activity, and stream/riparian values. See Crystal River Caucus (2007) for methods.

Table 5-3. Relative biological importance rankings of overall plant habitat, imperilment, wildlife activity, and stream/riparian values in the six heritage areas defined by Crystal River Caucus (2007) in the Crystal River analysis area.

Biological Component	Thompson Creek	Red Wind Point	Avalanche Creek	Filoha Meadows	Redstone	Placita
Plant Habitat	3	5	5	5	5	5
Imperilment	4	4	5	5	4	4
Wildlife Activity	5	8	9	10	9	8
Stream/Riparian	1	2	2	3	2	4
Composite Total	**13**	**19**	**21**	**23**	**20**	**21**
Critical Habitat Final Rank	**6**	**5**	**2**	**1**	**3**	**2**

Source: Crystal River Caucus (2007, Table 7-2).

The highest values were associated with Filoha Meadows, Avalanche Creek, and Placita with total values of 23, 21, and 21 (out of 25), respectively. The Crystal River Caucus (2007) analysis found Filoha Meadows and Avalanche Creek particularly vulnerable to incompatible development and activity because of the seasonal elk and bighorn sheep activities and their composite impact scores.

As a result of their analysis, the Crystal River Caucus (2007) provided a summary of recommendations, some of which are particularly pertinent to this analysis:

- "That accessing designated critical Open Space and Forest Service lands with high impact bicycle thoroughfare trails is not appropriate.
- That appropriate public access of critical habitat, Open Space, and U.S. Forest lands include minimal impact recreation and educational activities compatible with wildlife use patterns.
- That seasonal closures are not sustainable in protecting the winter range of elk and bighorn sheep and cannot be used to mitigate the impact of a bike-pedestrian trail.
- That the best long term use of the dedicated property tax is to include the proposed trail on a safe and expanded shoulder of Highway 133 and avoiding [critical] wildlife [habitats]."

The Crystal River Caucus endorsed the Crystal River Trail, as long as it would be located within the Highway 133 corridor.

The Crystal River Caucus (2007) also made the following recommendation to PCOST:

> "The Task Force recommends that no provision be made for including a trail alignment through Pitkin County Open Space within the Crystal River Valley. There should be no plans for a bicycle/pedestrian trail in the management plans for the Red Wind Point, Filoha Meadows Heritage Areas or other county open spaces. It is recommended that only minimal impact activities, compatible with existing wildlife patterns, be included. This will provide access into Open Space for the taxpayer and allow the recreation and educational return they deserve, while protecting wildlife and habitat."

The Crystal River Caucus (2007) report contains a great deal of additional site-specific trail and road alignments, closures, and other recommendations to minimize future human use impacts on plant and animals resources of high value and sensitivity. These details should be considered as part of the NEPA process.

5.5 PITKIN COUNTY MANAGEMENT PLANS FOR CRYSTAL RIVER PARCELS

Pitkin County Open Space and Trails properties are governed by Title 12 of the Pitkin County Code, which establishes general rules that apply to all of the open spaces and trails within the system (Fig. 5-2). In general, it is the set of regulations that prohibits motorized vehicles on open spaces and trails with some limited exceptions, prohibits fires, camping and hunting, requires dogs on leashes and picking up and properly disposing of dog waste.

In addition to Title 12, the use of some open space properties is governed by an adopted management plan that is specific to a particular property. The plans outline resource protection and allowed uses. Two PCOST parcels that might be impacted by a trail up the Crystal Valley have site-specific management plans and are relevant to this analysis: Red Wind Point and Filoha Meadows. Both are summarized below.

5.5.1 Red Wind Point Management Plan

The 65-acre Red Wind Point (RWP) Open Space protects critical bighorn sheep winter range and provides a unique recreation experience on the former Crystal River railroad grade along the Crystal River (Fig. 5-3). The CDOW identified this property ca. 1992 as extremely important to preserve due to the critical winter range of the upland dry meadow and upper slopes for bighorn sheep. From December through April, bighorn sheep forage on the upper sections of the property. Many other wildlife species use RWP for forage and breeding sites.

The 2005 RWP Management Plan indicates that this parcel meets the goals of the PCOST program by protecting wildlife habitat and scenic open space and by providing recreational access to the Crystal River and the 1.25-mile trail along the former Crystal River Railroad grade. Two of the five RWP Management Plan's resource management goals (p. 1) are relevant to this analysis:

- "Protect and enhance the bighorn sheep habitat"
- "Provide a multi-use trail along the former Crystal River Railroad grade"

The RWP Management Plan also indicates that:

- "One of the main reasons for the purchase of RWP is to protect wildlife habitat" (p. 6).
- "To protect bighorn sheep habitat, the upper slopes and dry meadow will be closed year-round to public use and a seasonal closure of the entire property will be implemented from December 1 - April 30… This closure is necessary because the wildlife characteristics of the upper portions of the property necessitate limiting public access to the trail along the former Crystal River Railroad grade and allowing sheep access to the river during the winter" (p. 7).

5.5.2 Filoha Meadows Management Plan

Pitkin County Open Space and Trails conducted five years of intensive study of the local natural resource values to acquire the level of knowledge needed to prepare the 2008 Filoha Meadows Management Plan. Detailed vegetation and wildlife reports are appended to the plan. Protection and enhancement goals for the property (Fig. 5-4) were outlined in the Plan with careful allowance made for visitors to experience one

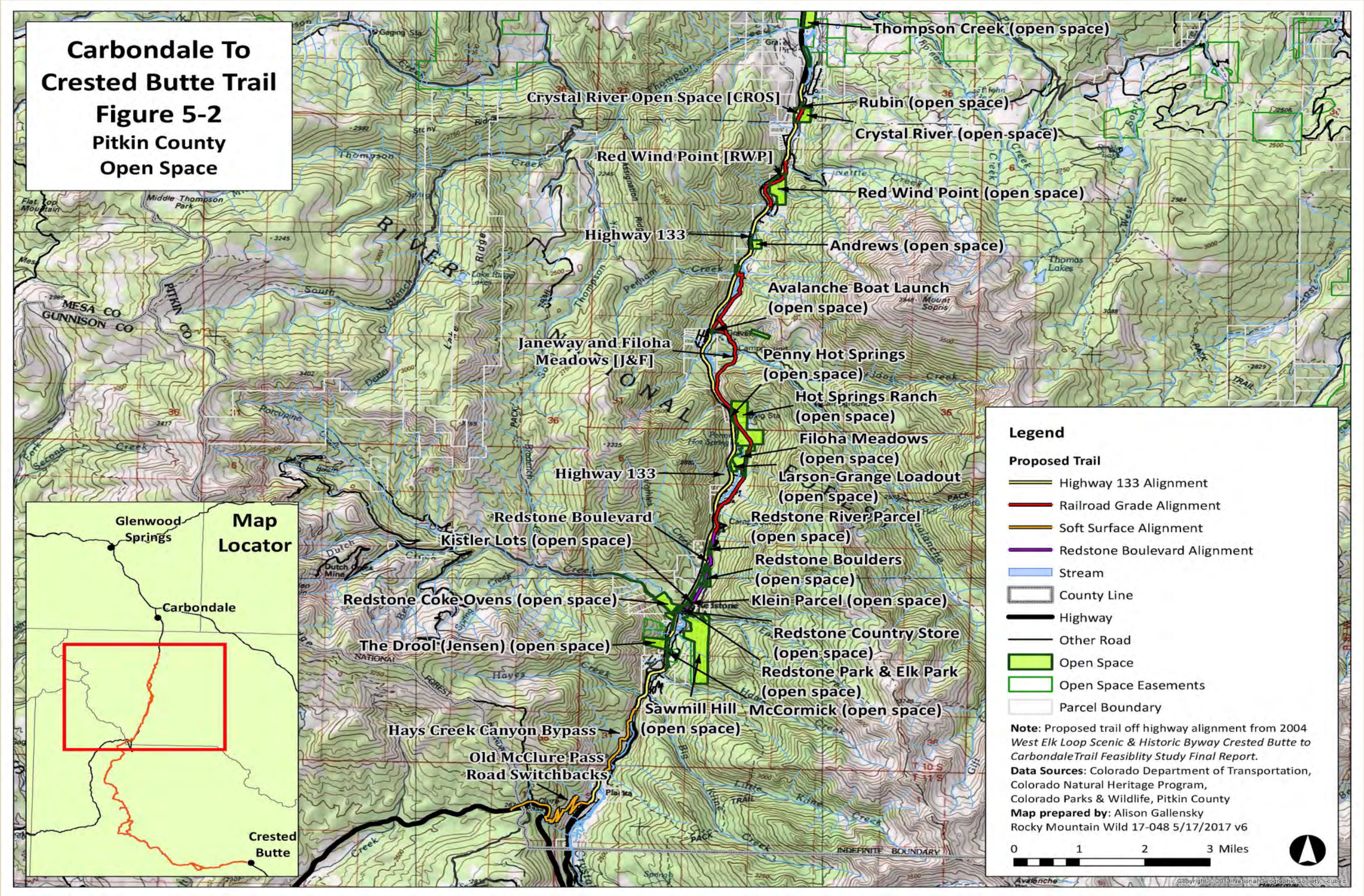

Figure 5-2. Pitkin County Open Space parcels in the Crystal River valley analysis area.

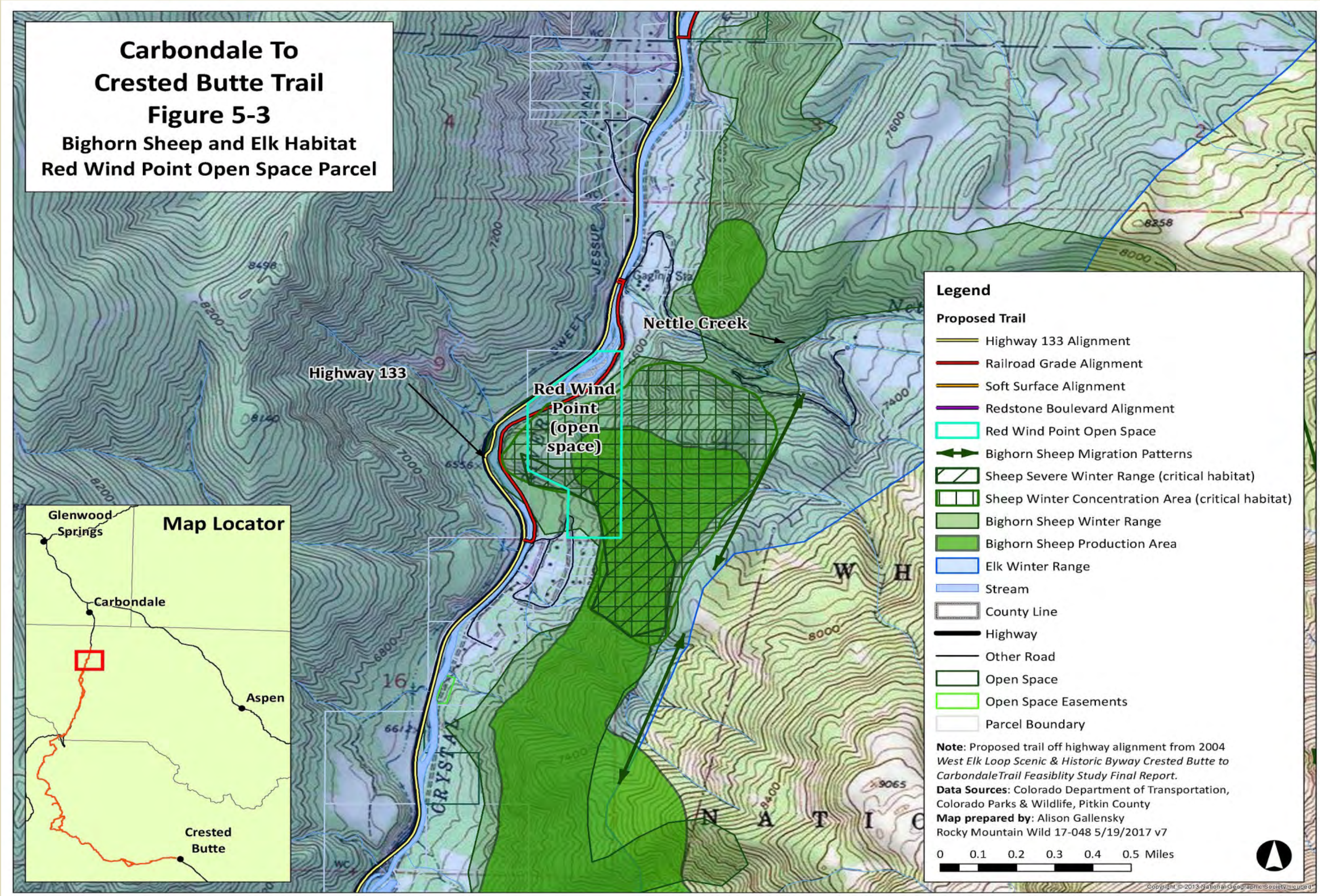

Figure 5-3. Bighorn sheep and elk seasonal ranges overlapping the Red Wind Point Open Space parcel.

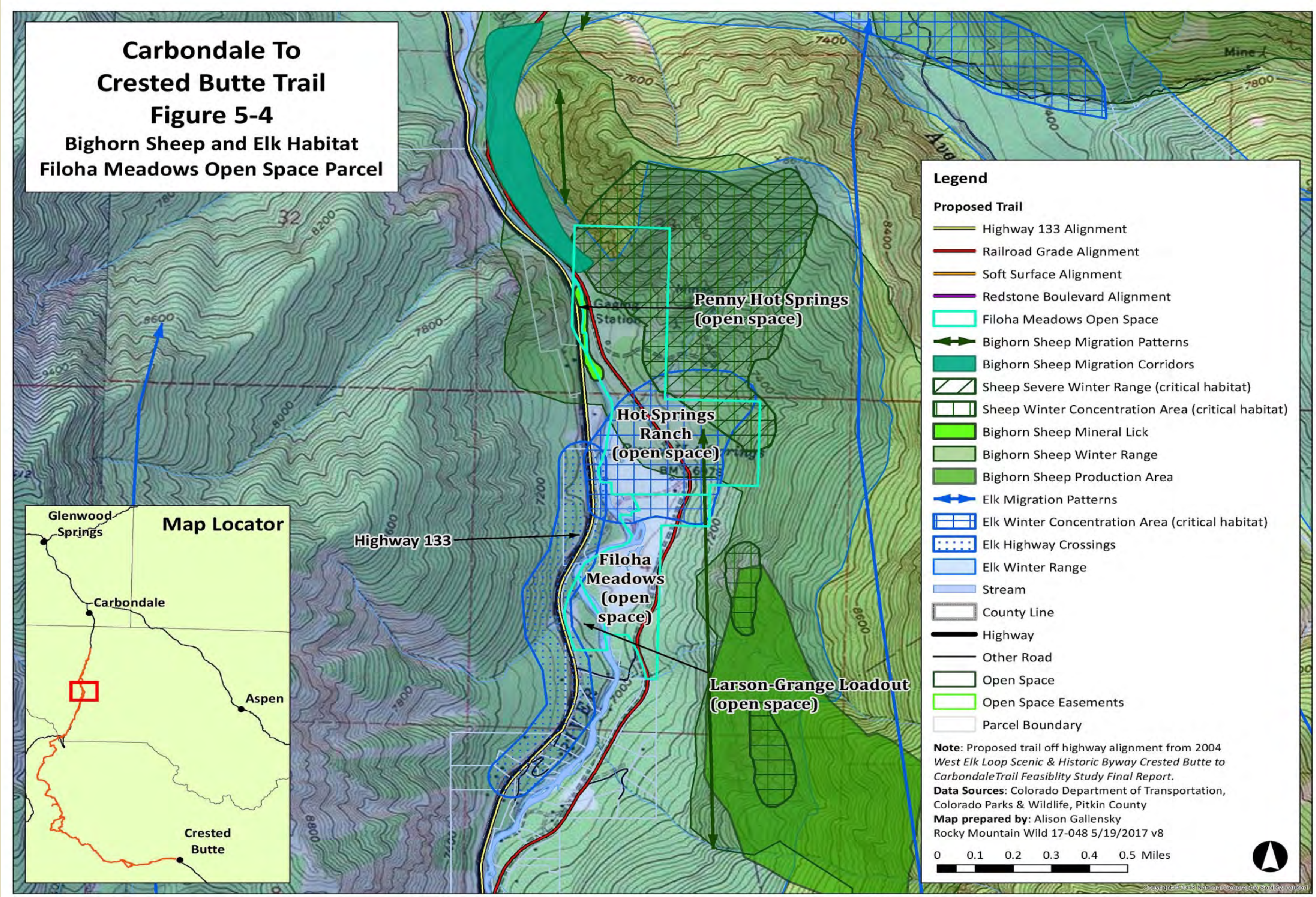

Figure 5-4. Bighorn sheep and elk seasonal ranges overlapping the Filoha Meadows Open Space parcel.

of the most beautiful and biologically diverse places in Colorado.

From the 2008 Filoha Meadows Management Plan's Introduction:

- Filoha Meadows Nature Preserve is comprised of three distinct acquisitions; 1.5-acre "Penny Hot Springs" (1991), 140-acre Hot Springs Ranch (2001), and 50-acre Filoha Meadows (2003), which protects over one mile of the Crystal River Valley from development.
- The property contains unique ecological communities due to the hot springs and geothermal activity underlying the property. The geothermal activity results in snow free meadows, providing critical winter range for bighorn sheep and elk. Elk calve near the Crystal River, beavers create wetlands, and predators like coyotes and foxes use the meadows for their hunting grounds. Filoha Meadows exemplifies the PCOST's mission of protecting areas with outstanding scenic, natural, and wildlife habitat values. The management of Filoha will protect and enhance the meadows and riparian habitat that are so important to wildlife. It will also provide soft surface nature trails and the opportunity for environmental education highlighting the extensive wetland and riparian habitat that exists on Filoha.

The three Filoha Meadows Management Plan's resource management goals include:

- To study, protect, and enhance the ecological communities with particular emphasis on those that are unique and rare.
- Enhance the outstanding wildlife habitat values.
- Provide low impact environmental education.

The Plan's Recreation Potential section indicated that prior to the adoption of the Plan, the property was closed to the public except for environmental education programs and the Penny Hot Springs, located on the west side of the Crystal River along Highway 133. This closure of the main property east of the river allowed PCOST to study the property without any additional human impacts. According to the Plan, this closure has been successful with very few violations witnessed by OST staff, CDOW, and local citizens. All reported violations have been prosecuted.

Based on results of the vegetation and wildlife studies, and considering CDOW/CPW recommendations (see Section 5.7) two travel management corridors have been established to limit human disturbance on the property and provide limited public access. The entire property on the east side of the Crystal River, including both travel management corridors, has a seasonal closure to protect critical bighorn sheep and elk habitat from October 1 – June 30. The Plan indicates that this closure will be strictly enforced through PCOST rangers and CDOW personnel, that there is zero tolerance for violations of the closure, and all violations will be prosecuted. The Plan indicates that PCOST will work to create a full-time seasonal ranger position, subject to budget approval, to regularly patrol PCOST property in the Crystal Valley.

Travel Corridor A follows the historic Crystal River railroad alignment paralleling the river through the meadows. There is a night closure of this trail from ½ hour before sunset to ½ hour after sunrise, presumably because wildlife were thought to mostly use this property at night. To minimize potential recreation management problems; neither equestrians nor bicycles are allowed on this trail.

Travel Corridor B is an old road from the south that leaves the rail bed and traverses downhill to a viewing blind. To protect the fragile wetlands, public access to Travel Corridor B will be limited to environmental education programs guided by staff or trained volunteers.

Dogs and all types of domestic pets/livestock are prohibited on the entire property to protect wildlife on the east side of the Crystal River and to protect the health and visitor enjoyment on the west side of the Crystal River. The Plan indicates that this restriction is strictly enforced with a zero tolerance policy.

5.6 CDOW/ CPW RECOMMENDATIONS RE: THE CRYSTAL RIVER TRAIL

This section summarizes public correspondence from the state wildlife management agency regarding important seasonal wildlife use areas, parcels, and CDOW/CPW concerns and recommendations a recreation trail in the Crystal River valley.

5.6.1 Feb. 25, 2002 Letter to GOCO re: Filoha Meadows Acquisition

Mr. Pat Tucker, CDOW Area Wildlife Manager, sent a February 25, 2002 letter to the State Board of GOCO in support of an open space grant application submitted by Pitkin County to acquire Filoha Meadows. Mr. Tucker noted the important elk and bighorn sheep winter range, riparian/ wetland habitat, and variety of small mammals, songbirds, waterfowl, raptors, wintering bald eagles, black bear and mountain lions using the parcel. Mr. Tucker further noted this was an excellent opportunity to preserve significant wildlife habitat in the face of great development pressures in the Roaring Fork and Crystal River valleys.

5.6.2 Dec. 19, 2003 Letter to PCOST re: Filoha Meadows Trail Use

In response to a December 3, 2003 clarification request from Mr. Dale Will, Director, PCOST, regarding the CDOW's position on public access to Filoha Meadows, Mr. Tucker responded in a Dec. 19, 2003 letter. Mr. Tucker emphasized that his February 25, 2002 letter of support of the GOCO proposal "was based entirely on protecting this critical area for wildlife." In addition to clarifying the CDOW's support of the parcel's acquisition, Mr. Tucker described the seasonal importance of this area to sheep and elk, the susceptibility of sheep to human-caused disturbances, the decline in lamb survival, and the need to avoid additional detrimental impacts to this sheep herd.

In his Dec. 19, 2013 letter, Mr. Tucker indicated that the CDOW believed a viable multi-use trail alternative exists that would have much less of an impact on wildlife. He described an alignment along Highway 133 on the west side of the Crystal River that would allow hikers and bikers to enjoy the scenic qualities and wildlife diversity of this area year-round with a minimal disturbance to wildlife using the area. His letter stated that trail could also be open year-round instead of the limited 4.5-month period (July 1 to Nov. 14) that the railroad trail would be subject to a seasonal closure to reduce impacts on bighorn sheep and elk.

He also indicated that the CDOW believes that a nature trail behind the Filoha Meadows cabins could provide the public with an educational experience and access to the beaver ponds blind. "This "minimal" impact trail could provide a valuable experience to wildlife viewers and educators while being limited in duration and season of use" (p. 2, para. 4). Such a trail would provide for the needs of trail users and their expectations as stated in the GOCO grant proposal while protecting wildlife, also a component of the GOCO proposal. This recommendation was later adopted as the type of use allowed on the parcel per the Filoha Meadows Management Plan, above.

Mr. Tucker went on to state that "it remains our professional judgement that a developed trail on the railroad right-of-way would be detrimental to wildlife and, for all the reasons above we strongly urge that it not be built there." Mr. Tucker went on to offer recommendations for reducing potential, trail-related wildlife impacts, but indicated that trail closures are ineffective, unenforced, and even low levels of noncompliance can displace animals from critical habitats.

5.6.3 March 31, 2008 Letter to PCOST re: Filoha Meadows Draft Management Plan

Mr. Perry Will, CDOW Area Wildlife Manager, sent a March 31, 2008 letter to Mr. Gary Tennenbaum, PCOST, commenting on the Filoha Meadows Draft Management Plan. The CDOW expressed great concern about allowing unlimited travel along this corridor even with a proposed seasonal closure and trail regulations, which, in the CDOW's experience, are ignored by a sufficient portion of the public to where the wildlife values are eventually lost. The CDOW noted the increased wildlife use of the parcel due to lack of disturbance and high quality habitats present. The CDOW reiterated their 2003 recommendation that public access to Filoha Meadows be restricted and consistent with the management desire to provide low impact educational opportunities by allowing only guided educational and interpretive program, as have been occurring. The CDOW expressed concern about adaptive management and changing personnel, political agendas, social desires, and recreation pressures changing, leading to altered management policies that are inconsistent with preserving the important wildlife and ecological values for which Filoha Meadows was originally acquired. It was recommended that wildlife values on the property be protected as intended by the property's purchase.

5.6.4 Dec. 26, 2006, Groves, Seasonal Closure Memo to Crystal River Wildlife Task Force

Mr. John Groves, current Crystal River CPW DWM, wrote a memo to the Crystal River Wildlife Task Force regarding the limited effectiveness and enforcement seasonal closures and that it is often local residents that are violating the closures.

5.7 PERTINENT PCOST CORRESPONDENCE

5.7.1 Dec. 8, 1992 Pitkin County Memo re: Filoha Meadows Open Space Trail and Wildlife

In a December 8, 1992 memorandum to the Pitkin County Planning and Zoning Board, Ms. Mary Lackner, Pitkin County Planner, wrote that the issue of purchasing part of the old railroad grade at Penny Hot Springs needs to be discussed further because "the board stated at its last meeting that it would recommend that no trail be placed through the property because of potential wildlife and visual impacts."

5.7.2 Dec. 14, 2003 PCOST Memo re: Filoha Meadows Open Space Trail and Wildlife

In a December 14, 2003 memorandum to Mr. Dale Will (PCOST Director), Pitkin County's Wildlife Biologist clarified wildlife concerns associated with a conceptual trail crossing Filoha Meadows. He identified the unique sheep habitat present, the recent decline of the herd due to hundreds of acres of winter range losses to subdivision development, recreation, and free-ranging dogs, and the sensitivity of sheep to human recreation. He also noted the unique and critical elk habitats present and provided examples of the negative effects that recreationists can have on elk. He concluded that "it is incumbent upon the County to actively pursue a bicycle trail alignment that will completely avoid the east side of the Crystal River at Filoha Meadows Open Space." If it was impossible to construct a trail on the west side of the river, wildlife impacts from a trail east of the river could be reduced via a November 1 through July 1 seasonal closure. However, it was noted that such "seasonal closures are very difficult to enforce" and both he, CDOW (Kevin Wright), and USFS (Phil Nyland) personnel observed numerous seasonal closure violations on other Crystal River open space parcels. Lastly, he noted that primitive education trails on Filoha Meadows that would be used between July 1 and November 1 would be unlikely to have any significant negative impacts on wildlife or wildlife habitat.

5.8 OTHER PERTINENT PUBLIC CORRESPONDENCE

5.8.1 Dec. 19, 2006, Seidel, Seasonal Closure Memo to Crystal River Wildlife Task Force

Mr. John Siedel, former CDOW Area Director, wrote a memo to the Crystal River Wildlife Task Force on the sustainability of seasonal closures and their limited effectiveness and enforcement.

5.8.2 Dec. 20, 2006, Wright, Seasonal Closure Memo to Crystal River Wildlife Task Force

Mr. Kevin Wright, former Crystal River CDOW District Wildlife Manager (DWM), wrote a memo to the Crystal River Wildlife Task Force on the public's non-compliance with seasonal closures, their limited effectiveness and enforcement, and how just a few violations can change and negatively affect big game winter range use.

5.8.3 Nov. 15, 2015, Wright, Ltr. to Pitkin County BOCC and PCOST

Mr. Kevin Wright, former, 31-year, Crystal River and Aspen District, CDOW DWM, wrote a letter of concern to the Pitkin County Board of County Commissioners (BOCC) and PCOST regarding the way the Roaring Fork Valley was progressing with respect to recreational pressures and its impact on wildlife resources. He indicated that Pitkin County has one of the strongest land use codes for protecting wildlife in Colorado and has been very good at implementing the Code for private development. However, the land use emphasis on public lands in the last 5-10 years "has become recreation at all costs with very little regard to the impacts it is having on our wildlife resources and their habitat. The dramatic increase in recreation and endless trail building is having significant negative impacts to wildlife. Impacts are often considered but are often dismissed as non-significant or believed they can be "mitigated"." He noted the collective effects of habitat lost to development, habitat maturation, an inability to improve forage conditions, and the dramatic increase in recreational pressure are having negative effects on mule deer and elk population demographics to where the deer population is at the lowest level it has been in 40 years. He summarized the types of impacts to wildlife that result from trail construction and use and how these effects are well established in the scientific literature. He commented on the double standard that exists in the Pitkin County Code between trails proposed on private vs. public lands. He provided more examples of how mitigation, including seasonal closures, do not work. Lastly, he lamented that "We are always compromising wildlife values for peoples' benefit and then we compromise the compromise," before requesting a balance between recreation and wildlife considerations.

5.8.4 Mar. 23, 2017, Wright, Ltr. to PCOST and Pitkin County BOCC

Mr. Kevin Wright, former, 31-year, Crystal River and Aspen District, CDOW/CPW DWM, wrote another letter to PCOST and the Pitkin County BOCC to provide input since the proposed Crystal River Trail was starting the analysis phase. He noted that the least environmentally damaging trail alignment is along the Highway 133 ROW on the west side of the river. He stated that if the trail is placed there, there would be minimal impact to the environment and wildlife, it would allow unrestricted use of the trail year-round, and meet the Governor's goal. In his opinion, placement of the trail along the old railroad grade on the east side of the river **will have significant negative impacts to wildlife and the environment** (emphasis in original). He described areas of particular importance to elk, deer, and sheep, how their populations are severely stressed in the Roaring Fork and Crystal River valleys, and how a trail east of the river would negatively affect them. He provided additional[10] results of scientific studies that assessed recreational effects on wildlife and refuted the notion that "the science is still out." He repeated his concern about ineffective seasonal closures.

6.0 WILDLIFE USE OF THE CRYSTAL RIVER VALLEY

This section characterizes wildlife use of the Crystal River valley based largely on the large wildlife and ecological databases. Seasonal CPW mapping was conducted consistently over the entire analysis area for a limited number of species, as were the broader ecological and wildlife surveys conducted by the Crystal River Caucus (2007). Elsewhere, extremely thorough and detailed vegetation and wildlife analyses are available (e.g., for Filoha Meadows), but only for a limited number of areas. For most species that are not mapped, they are assumed to be present if suitable habitat is present, following USFS policy. Species are addressed in the categories in which they are addressed in USFS NEPA documents.

6.1 THREATENED, ENDANGERED, AND PROPOSED WILDLIFE SPECIES

Federally listed and proposed animal species that were initially considered in this analysis included those identified by the U.S. Fish and Wildlife Service's (USFWS) on-line Information, Planning, and Conservation (IPaC) decision support system for the Crystal River Trail analysis area on March 29, 2017. The analysis area was defined as a 118 square mile area between the distal end of the existing Crystal River Trail to McClure Pass and adjacent portions of the Crystal River watershed. This area would contain most of the potential direct and indirect effects associated with the proposed Crystal River Trail. Uncompahgre fritillary butterfly (*Boloria acronema*), humpback chub (*G. cypha*), bonytail chub (*Gila elegans*), Colorado pikeminnow (*Ptychocheilus lucius*), razorback sucker (*Xyrauchen texanus*), greenback cutthroat trout (*Oncorhynchus clarkii stomias*), Mexican spotted owl (*Strix occidentalis lucida*), yellow-billed cuckoo (*Coccyzus americanus*), North American wolverine (*Gulo gulo luscus*), and Canada lynx (*Lynx canadensis*) were identified. With the exception of lynx, none of these 10 species identified are known or suspected of being present in the analysis area, nor would they be affected by management decisions associated with the proposed trail. There is no designated critical habitat for Federally-listed species that would be affected by the proposed trail.

6.1.1 Canada Lynx

The Canada lynx has been classified by the State of Colorado as a State endangered species since 1976. The lynx was listed in the contiguous United States as threatened, effective April 23, 2000 (65 FR 16052). Lynx are native to Colorado, however the population was considered non-viable in the 1990's. The CDOW began releasing lynx back into southern Colorado in 1999. During 1999-2006, a total of 218 wild-caught lynx from Canada and Alaska were released. On September 17, 2010, the CDOW announced that the lynx reintroduction project had successfully accomplished its goal of establishing a

[10] From Mr. Wright's Nov. 15, 2015 ltr.

breeding population in the Southern Rockies (CDOW 2010). Ongoing monitoring of the lynx population suggests that lynx are present within the Southern Rockies, including evidence of continued reproduction (Ivan 2015). A few of the radio-collared lynx relocations obtained from all 166 lynx released in Colorado from 1999 through 2004 as part of the Colorado lynx reintroduction program occurred in the Crystal River watershed (Shenk 2005). Colorado Division of Wildlife monitoring of radio-collared lynx from February 1999 to August 2010 (Theobald and Shenk 2011) estimated that the Crystal River watershed is located outside of lynx low-use areas. Because the monitoring of radio-collared lynx has ended, it is unknown if Theobald and Shenk's (2011) use data reflect current lynx use. Theobald and Shenk (2011) explicitly stated that their "study was not intended… to predict potential or future habitat use."

Potential lynx habitat in the Crystal River watershed occurs at the highest elevations of the montane and subalpine zones, not the habitats along the valley bottom up to McClure Pass where all direct and most indirect effects of the proposed trail would occur. The only possible trail effects to lynx habitat would be minor habitat loss and displacement of lynx from illegally built social trails through lynx habitat as a result of authorized trail segments east of the Crystal River providing access into large blocks of currently inaccessible NFS lands.

6.2 USFS REGION 2 SENSITIVE SPECIES

Region Two (R2) of the USFS has designated "sensitive species," representing species declining in number or occurrence or whose habitat is declining, either of which could lead to Federal listing if action is not taken to reverse the trend, and species whose habitat or population is stable, but limited. From the updated R2 animal list (Oct. 23, 2015), a subset of sensitive species, including three insects, five fish, two amphibians, 17 birds, and nine mammals (Table 6-1), was determined to be present or potentially present on the WRNF after consideration of all sensitive species on the R2 list. This subset of species is considered below in phylogenetically ordered taxa (insects, fish, amphibians, birds, and mammals) and discussed individually where appropriate. The proposed trail would have **no impact** on any other R2 sensitive species not on the WRNF list.

Table 6-1. USFS Region 2 sensitive animal species that occur on the WRNF and the rationale for potential project effects related to the proposed Crystal River Trail.

Common name, Scientific name	Rationale for Potential Project Effects (Habitat Affinity)
INSECTS	
Western bumblebee, *Bombus occidentalis*	Potential habitat (Montane and subalpine meadows)
Great Basin silverspot, *Speyeria nokomis nokomis*	Potential habitat (Wetlands supporting violet populations)
Monarch butterfly, *Danaus plexippus plexippus*	No host plant (milkweed) habitat
FISH [a]	
Roundtail chub, *Gila robusta robusta*	No suitable habitat (CO River up Roaring Fork)
Mountain sucker, *Catostomus platyrhynchus*	No suitable habitat (small to medium streams below 7000'; 4 populations documented on the Rifle and Blanco Districts)
Bluehead sucker, *Catostomus discobolus*	Occupied habitat downstream (CO River up Roaring Fork)
Flannelmouth sucker, *Catostomus latipinnis*	Occupied habitat downstream (CO River up Roaring Fork)
Colorado River cutthroat trout, *Oncorhynchus clarkii pleuriticus*	Present in Avalanche Ck & Lake (Isolated, headwater streams and lakes)

Table 6-1. USFS Region 2 sensitive animal species that occur on the WRNF and the rationale for potential project effects related to the proposed Crystal River Trail.

Common name, Scientific name	Rationale for Potential Project Effects (Habitat Affinity)
AMPHIBIANS	
Boreal western toad, *Anaxyrus boreas boreas*	Present[b]. Potential dispersal and hibernacula habitat (Subalpine marshes and wet meadows; ponds, margins of streams; adjacent uplands 8,500-11,000')
Northern leopard frog, *Lithobates pipiens*	Outside Range (Permanent wetlands)
BIRDS	
Northern goshawk, *Accipiter gentilis*	Present[c] (Closed montane forests > 7,500')
Northern harrier, *Circus cyaneus*	No habitat (Grasslands, agricultural lands, marshes, & alpine)
Ferruginous hawk, *Buteo regalis*	No habitat (Plains, grasslands)
American peregrine falcon, *Falco peregrinus anatum*	Active nest present (Cliffs, habitats concentrating/ exposing prey)
Bald eagle, *Haliaeetos leucocephalus*	Present (Open water bodies, big game winter range)
White-tailed ptarmigan, *Lagopus leucurus*	No habitat (Alpine habitat and upper elevation willow stands)
Greater sage grouse, *Centrocercus urophasianus*	No habitat (Sagebrush)
Columbian sharp-tailed grouse, *Tympanuchus phasianellus columbianus*	No habitat (Sagebrush and mountain shrub)
Flammulated owl, *Otus flammeolus*	Pot. habitat (Old-growth ponderosa pine and aspen)
Boreal owl, *Aegolius funereus*	Present[d] (Mature spruce-fir & mixed conifer)
Black swift, *Cypseloides niger*	Present[e] (Waterfalls, cliffs)
Lewis' woodpecker, *Melanerpes lewis*	Present in valley bottom cottonwoods (Ponderosa pine/cottonwoods)
Olive-sided flycatcher, *Contopus cooperi*	Pot. habitat (Open, upper elev. conifer forests)
Loggerhead shrike, *Lanius ludovicianus*	No habitat (Plains, low valleys, shrublands)
Purple martin, *Progne subis*	Present[f] (Old-growth aspen)
Brewer's sparrow, *Spizella breweri*	No habitat (Sagebrush and other structurally similar shrublands)
Sage sparrow, *Amphispiza belli*	No habitat (Low elevation big sagebrush and sage/greasewood)
MAMMALS	
Pygmy shrew, *Microsorex hoyi montanus*	Pot. habitat (Variety of subalpine habitats)
Fringed myotis, *Myotis thysanodes*	No habitat (Forests/woodlands to 7,500 ft.; unknown on WRNF
Hoary bat, *Lasiurus cinereus*	No habitat (Mixed conifer and lodgepole pine forest)
Spotted bat, *Euderma maculatum*	No habitat (Cliffs, arid terrain)
Townsend's big-eared bat, *Corynorhinus townsendii townsendii*	Pot. habitat (Structures, tree cavities, mines <9,500 ft.)
American marten, *Martes americana*	Pot. habitat (Conifer forests)
River otter, *Lontra canadensis*	No habitat (Year-round open water and streamflows of ≥ 10 cfs)
Rocky Mountain bighorn sheep, *Ovis canadensis canadensis*	Present (High visibility habitat near escape terrain)

Note: Species in **bold** are potentially present. Wildlife are listed phylogenetically.

Other R2 species are not listed because they have not been found on the WRNF, they have no affinities to project area habitats, the project area is outside of the species' range or elevational distribution. Potential pre-field survey occurrence on the project area, potential for project effects, and habitat affinity is summarized for each species.

[a] With the exception of Colorado River cutthroat trout, fish occurrence in the analysis area is poorly documented in available data sources.

[b] Documented in the Middle Thompson Creek PCA (Spackman et al. 1999), although the entire Crystal River valley is outside of overall boreal toad range mapped by CPW.

[c] Active nest documented in the Middle Thompson Creek PCA (Spackman et al. 1999).

[d] Documented in the Middle Thompson Creek PCA (Spackman et al. 1999).

[e] Documented in the Avalanche Creek PCA (Spackman et al. 1999).

f Documented in the Crystal River Valley by Crystal River Caucus (2007). Documented in the McClure Pass PCA, but possibly on the west side of the pass, outside the current analysis area (Spackman et al. 1999).

Table 6-1. USFS Region 2 sensitive animal species that occur on the WRNF and the rationale for potential project effects related to the proposed Crystal River Trail.	
Common name, Scientific name	**Rationale for Potential Project Effects (Habitat Affinity)**
Source: Forest Service Manual, Rocky Mountain Region, Denver, CO, Chapter 2670 – Threatened, Endangered and Sensitive Plants and Animals, Supplement No: 2600-2015-1, Effective Date: Oct. 23, 2015 (J. Austin, USFS, pers. comm., Nov. 17, 2016).	

Some of the R2 species contained in Table 6-1 require specific seasonal surveys to detect. Where those surveys have not been conducted, a species was considered to present if suitable habitat is present, following USFS policy. In summary regarding R2 animals, 17 species are known or are potentially present within the Crystal River Trail analysis area. As a worst case scenario, the proposed trail "may impact individuals, but is not likely to result in a loss of viability in the planning area, nor cause a trend toward federal listing"[11] for the following species: western bumblebee (*Bombus occidentalis),* Great Basin silverspot (*Speyeria nokomis nokomis),* Colorado River cutthroat trout (*Oncorhynchus clarki pleuriticus*), boreal western toad (*Anaxyrus boreas boreas*), northern goshawk (*Accipiter gentilis*), American peregrine falcon (*Falco peregrinus anatum*), bald eagle (*Haliaeetos leucocephalus*), flammulated owl (*Otus flammeolus*), boreal owl (*Aegolius funereus*), black swift (*Cypseloides niger*), Lewis' woodpecker (*Melanerpes lewis*), olive-sided flycatcher (*Contopus cooperi*), purple martin (*Progne subis*), pygmy shrew (*Microsorex hoyi montanus*), Townsend's big-eared bat (*Corynorhinus townsendii townsendii*), American marten (*Martes americana*), and Rocky Mountain bighorn sheep (*Ovis canadensis canadensis*). With respect to the determination for bighorn sheep, while some trail alignments could have negative direct and indirect effects that could further reduce the size of the local population, the population would likely persist or could be reintroduced if sufficiently effective habitat remains in the event recreational trails are developed in areas with critical sheep habitat. Furthermore, the project's potential impact on sheep is considered across the entire planning area, the WRNF, where other sheep populations occur and would be unaffected by the project. Excluding those species above, the proposed trail would have "no impact"[12] on any other R2 species.

6.3 COLORADO PARKS AND WILDLIFE-MAPPED SPECIES

Eight[13] wildlife species mapped by CPW have seasonal ranges overlapping proposed Crystal River Trail corridor sections B and C (Section 10.3). Wildlife activity area definitions and seasonal use dates (Section 10.2) were obtained from the CPW website and are applicable generally statewide. Some seasonal use dates are defined more accurately for the local Data Analysis Units (i.e., the local management areas) by the local DWM (J. Groves, pers. comm., Mar. 27, 2017) and the Terrestrial Biologist, per CPW direction. Other use periods are provided based on anecdotal observations by identified knowledgeable parties.

Species are listed in declining order of their susceptibility to significant potential trail effects along the bottom of the Crystal River Valley. Bighorn sheep and elk are the species of particular concern. The

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[11] This is the required wording for impacts to U.S. Forest Service sensitive species where effects are expected to be insignificant (unmeasurable) or discountable (extremely unlikely; Forest Service Manual R-2 Supplement 2672.42) at the Forest level.

[12] This is the required wording for impacts to U.S. Forest Service sensitive species where no effect is expected at the Forest level (Forest Service Manual R-2 Supplement 2672.42).

[13] Other wildlife species (e.g., mountain goat and lynx) mapped by CPW have seasonal ranges overlapping portions of the Crystal River watershed, but they are not focal species of concern on this project.

order of the remaining species is somewhat arbitrary. Other habitats of these CPW-mapped species may also be affected outside of the Crystal River Valley bottom. Habitats and potential trail segments not in conflict with potential trail use are not mentioned.

In the descriptions of the wildlife seasonal activity areas, metrics (e.g., whether important habitats would be bisected by potential trails or whether trails would approach within one-quarter mile of certain habitats) are provided that have implications regarding whether certain trail segments would be subject to seasonal construction and closure restrictions to protect certain wildlife activity areas if the county Land Use Code (7-20-70: Wildlife Habitat Areas) was applied.

6.3.1 Bighorn Sheep

6.3.1.1 Seasonal Sheep Activity Areas

Important bighorn sheep seasonal ranges throughout the proposed Crystal River trail corridor are shown in Figures 10.2-1 to 10.2-3. Other less important (to this analysis) seasonal ranges, including overall range, summer range, and summer concentration area, are more widespread in the analysis area, but are not shown on maps to more clearly illustrate important habitats.

Sheep winter range, used from December 1 to April 30, is continuous east of the Crystal River from Potato Bill Creek to East Creek, with another polygon to the south in Hawk and Big Kline Creeks. Sheep winter range is bisected by 0.62-miles of Highway 133 in The Narrows, north of Filoha Meadows and borders sheep winter range in Hayes Creek Canyon. Portions of two of the three potential trail segments (Red Wind Point [RWP] and Janeway and Filoha Meadows [J&F]) east of the river would bisect 3.0 miles of currently isolated[14] sheep winter range. The potential Crystal River Open Space (CROS) trail segment would approach (within one-quarter mile), but not bisect, sheep winter range. The potential Hayes Creek Canyon bypass and old McClure Pass Road switchback trail segments are outside of sheep winter range.

Sheep winter concentration areas are used from December 1 to April 30. These winter range subsets, support twice the animal density of overall winter range and also a critical wildlife habitat in Pitkin County, occur in eight polygons, all east of the river, in the analysis area. Locations include Potato Bill Creek, Red Wind Point, at the mouth of Avalanche Creek (north side), the south-facing slopes of Elephant Mountain north of Filoha Meadows, snow-shedding terrain east of Filoha Meadows, an area above Wild Rose Subdivision, and polygons on the south-facing slopes above East and Hawk Creeks. The Highway 133 corridor does not bisect any of this critical sheep habitat. Portions of the potential RWP trail segment east of the river would bisect 0.1 miles of currently isolated sheep winter concentration areas. Large acreages of critical, sheep, winter concentration areas occur within one-quarter mile of the RWP and J&F trail segments. The CROS trail segment east of the river would occur beyond one-quarter mile of the Potato Bill Creek sheep winter concentration area. A new north bridge that would likely be associated with the RWP trail segment would occur within one-quarter mile of the RWP, sheep, winter concentration area.

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[14] Wildlife habitats bisected by the three potential trail segments (CROS, RWP, and J&F]) east of the river are largely **isolated** from human disturbance during winter by the physical barrier imposed by the Crystal River, the width of the buffer of intervening habitat between human use areas along the Highway 133 corridor and habitats east of the river, and the largely effective seasonal closures. That isolation minimizes human disturbance and increases **habitat effectiveness**, the ability of animals to utilize habitats present without impairment from anthropogenic influences.

Sheep severe winter ranges are used from December 1 to April 30. These areas are composed of south-facing slopes used when the annual snowpack is at its maximum and/or temperatures are at a minimum in the two worst winters out of 10. They are critical wildlife habitats in Pitkin County and occur in six polygons, all east of the river, in the analysis area. Locations include Potato Bill Creek, Red Wind Point, Avalanche Creek, Elephant Mountain, and polygons above East and Hawk Creeks. None of the potential trail segments would bisect this critical sheep habitat. Portions of the potential RWP and J&F trail segments east of the river would occur within one-quarter mile of three, sheep, severe winter range polygons. The CROS trail segment east of the river would occur beyond one-quarter mile of the Potato Bill Creek sheep severe winter range. A new north bridge that would likely be associated with the RWP trail segment would occur within one-quarter mile of the RWP, sheep, severe winter range polygon.

Sheep production (lambing) areas, used from May 1 to June 30, occur in six polygons, all east of the river, in the analysis area. Locations include Potato Bill Creek, Nettle Creek, the west-northwest toe slope of Mt. Sopris, the north side of Avalanche Creek, a large polygon extending from west of Filoha Meadows to East Creek, and a polygon in Hawk Creek. No potential trail segment would bisect any sheep lambing area. The three potential trail segments east of the river would extend within one-quarter mile of portions of the Nettle Creek, Red Wind Point, Avalanche Creek, and Filoha Meadows lambing areas.

A **sheep migration corridor** occurs in The Narrows on the west side of Elephant Mountain. Much of the sheep movements through this corridor follow the historic railroad grade and a closely parallel grade. Overall sheep use of this local corridor occurs from November 15 to May 1, with ram use heightened during the rut from November 15 to December 31 (J. Groves, CPW, pers. comm., Mar. 27, 2017). Local CDOW/CPW DWMs have documented bighorn sheep traveling along the railroad corridor between Penny Hot Springs and Lower Avalanche Creek from as early as August to as late as June (Tucker 2003). The CDOW/CPW considers this area crucial for bighorns due to the adequate escape cover provided by the rockslide and cliffs to the east, the mineral rich grounds provided by the natural hot springs, and the effective buffer of the Crystal River from vehicle and other human caused disturbances. General movement patterns of sheep are also shown in Figures 10.2-1 to 10.2-3. Isolated by the river and buffered by distance and intervening terrain, sheep are largely habituated to traffic along the Highway 133 corridor such that it does not affect sheep use of this corridor. The potential J&F trail segment east of the river would develop and occupy one of the two parallel railroad grades that are the centerlines of this sheep migration corridor.

A **sheep mineral lick** is associated with Penny Hot Springs and extends approximately 1,500 feet upstream. This area provides minerals important to bighorn sheep for meeting basic nutritional needs. Lick use typically starts in mid-June, peaks the first week of July, then tapers off asymptotically, depending upon how much socialization is involved in lick use. Local use of the licks has been observed as late as mid-August (J. Groves, CPW, pers. comm., Mar. 27, 2017). Radio-collar data have shown extended movements over several days from high summer range, down to the mineral licks, and back to the high summer range. There is likely some displacement of sheep by humans in the immediate vicinity of Penny Hot Springs. There is some level of sheep habituation to this human activity because humans, predictably, don't cross the river. Most of the mineral licks upstream of Penny Hot Springs are not affected by human presence and are available to the sheep 24/7. None of the potential trail segments would directly bisect any sheep mineral lick, however sheep would have to cross the potential J&F trail segment to access any of the Penny Hot Springs' licks.

6.3.1.2 Disease in the Local Sheep Herd

This sheep herd is infected with pasteurellosis, a bacteria acquired from domestic sheep on bighorn winter range in the Marble area. It has caused pneumonia that has adversely this herd's lamb recruitment and survival and, to a lesser extent, reduced adult survival. Adults are carriers and pass it on to cohorts and offspring. Lamb mortality (at ± 95% by 6-8 weeks after birth) over the last 20 years has led to an approximate 80% decline in this herd (using estimate midpoints; from a peak of approx. 225-250 sheep in the mid- to late 1990's to approx. 45-50 sheep at present; J. Groves, CPW, DWM, pers. comm., Mar. 15, 2017). In 2002, the CDOW documented one lamb out of 28 sheep in the Avalanche Creek drainage and one lamb out of 26 sheep near Penny Hot Springs (Tucker 2003). The belief at that time was that while lamb production was adequate for positive population growth, there has been high lamb mortality in the first year (Colorado Wildlife Science 2008). Lamb mortality has remained high and the population decline has continued (J. Groves, CPW, pers. comm., Mar. 15, 2017).

Lungworm is also affecting the herd. The CDOW/ CPW have been and are treating the animals, but this disease continues to negatively affect herd growth and persistence. See Colorado Wildlife Science (2008, p.8) for a summary of lungworm/ bighorn life history. Both diseases increase the sheep's susceptibility to external stressors by weakening them and reducing their ability to forage and avoid predators. Sheep displacement from trail corridors and disturbance by trail users would exacerbate the disease effects and further impact this herd.

6.3.2 Elk

Important elk seasonal ranges throughout the proposed Crystal River trail corridor are shown in Figures 10.2-4 to 10.2-6. Other less important (to this analysis) seasonal ranges, including overall range, summer range, resident population area, and summer concentration area, are more widespread in the analysis area, but are not shown on maps to maximize the clarity of important habitats.

Elk winter range (Dec. 1 to Apr. 1) is continuous along the entire Crystal River valley bottom and toe slopes from above Marble to Carbondale. With the exception of a 1.3-mile section of highway below the McClure Pass summit, Highway 133 bisects 12.9 miles of elk winter range along the length of Crystal River trail Segments B and C. The entire lengths of the three potential trail segments (CROS, RWP, and J&F) east of the river would bisect 6.8 miles of currently isolated and highly effective elk winter range. The entire (1.4 mi.), potential Hayes Creek/ Bear Creek trail segment and the bottom (1.5 mi.) of the old McClure Pass Road switchback trail segment would bisect elk winter range. Winter range north of the old McClure Pass Road switchbacks extends further uphill (west) than what is currently designated on CPW mapping. It is also more effective habitat than that located further south along Highway 133, including the ascent to the pass, because of better snow shedding characteristics and a more valuable (as forage vs. mixed conifer and aspen) mountain shrub-dominated vegetation type.

Elk winter concentration areas, a critical wildlife habitat in Pitkin County, occur along both sides of the Crystal River valley bottom; four polygons are relevant to this analysis. Locations include the west and southwest toe slopes of Mt. Sopris from Potato Bill Creek to and up Avalanche Creek, Filoha Meadows, the area east of Redstone to Hawk Creek, and a large polygon approaching the highway near Placita that extends up valley to near Island Lake. The Highway 133 corridor bisects 0.4 miles of winter concentration area in the vicinity of Hawk Creek and Filoha Meadows, respectively. The potential J&F trail segment east of the river would bisect 2.0 miles of critical, highly effective, elk winter concentration area in the Janeway, Avalanche Creek, and Filoha Meadows areas. The potential CROS and RWP trail segments would occur beyond one-quarter mile of any elk winter concentration area. A new north bridge that would be associated with the J&F trail segment would likely occur within one-quarter mile of the Janeway, elk, winter concentration area.

Elk severe winter range, a critical wildlife habitat in Pitkin County, occurs along both sides of the Crystal River valley bottom; three polygons are relevant to this analysis. Locations include Avalanche Creek, the area east of Redstone to Hawk Creek, and a large polygon approaching the highway near Placita that extends up valley to near Island Lake. The Highway 133 corridor would bisect 0.1 miles of this critical elk habitat in the vicinity of Hawk Creek. The potential J&F trail segment east of the river would bisect 0.6 miles of critical, highly effective, elk, severe winter range in the mouth of Avalanche Creek.

Elk production (calving) areas, used May 15 to June 21, as currently protected in the Pitkin County Code, occur above the valley bottom mostly towards the southern end of the analysis area. Based on the Vail elk study (Phillips [1998] and Phillips and Alldredge [2000]), May 1 to July 1 would be a more biologically conservative closure period, allowing cows to select optimal calving sites, accommodating early and late calves, and including initial elk rearing when calves develop physically to where they can travel with their cow. Of note is that no calving polygon is shown for Filoha Meadows. The County's wildlife biologist addressed this issue (Colorado Wildlife Science 2008) as follows:

> Dr. Bernarr Johnson, who has lived across the river from FMNP for over 20 years, has reported observing very young spotted calves on the property in mid-June (Johnson 2003). In 2003 and 2004, OST staff confirmed that a few elk cows probably dropped their calves in the riparian forest on the southern half of the property. Three very young spotted calves were observed on 10 June 2003 and two were observed on 8 June 2004. Although the CDOW species distribution maps do not indicate this area as elk calving habitat (or "production area"), these observations combined with Dr. Johnson's many sightings over the years probably warrant this designation.

The Highway 133 corridor does not bisect any CPW-designated elk calving area nor would any of the potential trail segments east of the river. The Highway 133 corridor and portions of Redstone Boulevard come within one-quarter mile of elk calving polygons, but the calving areas are topographically, visually, and otherwise buffered from potential trail use along the existing roadway. No other potential trail segments would occur within one-quarter mile of elk calving areas.

However, one calving polygon warrants further consideration. There is an elk calving polygon on the west side of the Crystal River that starts 0.37 miles above the potential Hayes Creek/ Bear Creek trail segment. Above the potential trail segment was an historic homestead on a bench with a road that switchbacked up the mountain into the elk calving area. The road has apparently been decommissioned by the USFS, but there is a low level of existing hiker use associated with it. The potential Hayes Creek/ Bear Creek trail segment could facilitate unintended access to that road, facilitate social trail development, and negatively affect elk calving values in and beyond that polygon. Hiking and other recreational activities in or near elk calving areas can have a significant impact on reproductive success. Phillips (1998) and Phillips and Alldredge (2000) studied reproductive success of elk following disturbance by humans during calving seasons in central Colorado. They reported that human disturbance during the calving season resulted in a significant drop in reproductive success below that of an undisturbed control group, but it recovered to control levels in subsequent years when human disturbance was experimentally removed (Shively et al. 2005).

There is a dimensionless[15] **elk migration corridor** across Highway 133 approximately 0.33 miles north of where the old McClure Pass switchback meets the highway and approximately 0.26 miles south of where the south end of the Hayes Creek/ Bear Creek trail segment meets the highway. Local use of this corridor has been defined as October 15 to November 30 and April 15 to May 30, all dates inclusive. Two **elk highway crossings**[16] occur in the analysis area, the first overlapping the above elk migration corridor and the second across from Filoha Meadows and the southern end of the J&F trail segment.

6.3.3 Mule Deer

Important mule deer seasonal ranges throughout the proposed Crystal River trail corridor are shown in Figures 10.2-7 to 10.2-9. Other less important (to this analysis) seasonal ranges, including overall range and summer range, are more widespread in the analysis area, but are not shown on maps to maximize the clarity of important habitats.

Mule deer winter range extends up the Crystal River valley as far as Perham Creek on the west and Nettle Creek on the east. Most of the trail corridor analysis area is above deer winter range. Deer winter use occurs from December 1 to April 30, dates inclusive, after animals have migrated down valley from upper elevation summer ranges. Highway 133 bisects deer winter range from the south end of the existing bike trail, south to past Nettle Creek. The entire CROS potential trail segment and the northern 0.4 miles of the potential RWP trail segment east of the river would bisect currently isolated deer winter range.

No other important seasonal deer range in the analysis area would be affected by the highway or other tentatively identified off-highway trail segments.

6.3.4 Bald Eagle

Two, overlapping polygons of seasonal bald eagle (*Haliaeetus leucocephalus*) habitat, **winter range** (Nov. 15 – Apr. 1) and **winter foraging habitat** (Nov. 15 – Mar. 15), occur in the analysis area (Figs. 10.2-10 to 10.2-12). The winter habitat is widely distributed across the valley bottom and side slopes, south up to Perham Creek, then closely associated with the river further south. However, winter eagle foraging south of Perham Creek also extends to the periphery of big game winter range polygons where eagles forage occasionally away from the river on winter-killed ungulates. Highway 133 bisects bald eagle winter range through almost the entire analysis area up to south of where the old McClure Pass switchbacks meet the highway. With the exception of where the J&F trail segment would cross over the ridge saddle near the mouth of Avalanche Creek, the entire lengths of the three potential trail segments (CROS, RWP; and J&F) east of the river would bisect currently isolated bald eagle winter range. The entire, potential Hayes Creek/ Bear Creek trail segment and the bottom of the old McClure Pass Road switchback trail segment would bisect winter bald eagle habitats.

[15] Mapped migration corridors typically have a width and length along the associated highway segment. This corridor is represented simply by an arrow within the elk highway crossing. It is a reasonable assumption that the migration corridor's dimension is consistent with that of the highway crossing.

[16] Defined in Section 10.2.2.

6.3.5 Peregrine Falcon

An **active peregrine falcon** (*Falco peregrinus anatum*) **nesting area** and three **potential nesting areas** are located in the analysis area (Figs. 10.2-13 to 10.2-15). The active eyrie[17] is located in the vicinity of Hayes and Hawk Creeks. According to Jerry Craig, the former CDOW Raptor Biologist (ret.; pers. comm., ca. 2007), eggs are laid as early as April 15, young hatch mid- to late May, and fledge in mid- to late June. So, the most important nesting period would be April 15-June 30. This does not include courtship or post-fledging use of the area.

The following peregrine life history information is not present in the Crystal River wildlife documents and is needed for this analysis. Viable peregrine nesting sites possess two components: (1) adequate nesting habitat, and (2) extensive hunting habitat with an adequate prey base to support the adults and their offspring (Craig 1978). Nesting sites are located on precipitous cliffs ranging in height from 40 to 2,100 feet, averaging 200 to 400 feet tall. Several ledges, potholes, or small caves must be present in the cliff face to function as a suitable nest site. A breeding pair will frequently alternate their nesting activities to different ledges on a cliff face between years, and they will often relocate to adjacent cliff faces. As a result, protective measures must address an entire cliff complex (and potential nesting areas) rather than an individual cliff.

Nesting peregrines will not tolerate excessive human encroachment or prolonged disturbance in the vicinity of the nesting cliff. Any activity or development above the nesting cliff will likely cause abandonment. Breeding peregrines become extremely agitated and may abandon the nest site if disturbance occurs during courtship, prior to the initiation of egg laying. One explanation regarding why some sites are occupied in spite of excessive human activity in the vicinity of the nesting cliff is that the falcons occupied the site early in the nesting season prior to spring increases in human activity and had eggs or young when the disturbance occurred. Once birds have eggs or young, they have a strong fidelity to their invested resources. Such bird were, therefore, attached to the site and would not abandon it at that time.

In Colorado, peregrines usually return to nesting cliffs in late February or early March and initiate courtship activities, which continue to mid- or late April when eggs are laid. The young hatch from mid- to late May and fledge (i.e., leave the eyrie) in mid- to late June. The young and adults remain in the vicinity of the nesting cliff up to several months after fledging.

Extensive hunting habitat is a second key component of a viable peregrine nest site. Peregrines will frequently travel at least 10 miles from their eyrie to procure prey and they have been documented hunting up to 30 miles away from nest sites (G. Craig, CDOW, pers. comm.). It is, therefore, important to maintain the integrity of important hunting areas within at least 10 miles of the nesting cliff. All habitats within the 10-mile radius need not be considered essential habitat, since only those areas that attract or support peregrine prey need be protected. The primary prey captured by nesting Colorado peregrines are small to moderately-sized birds, such as blackbirds, doves, robins, flickers, jays, nutcrackers, meadowlarks, and pigeons, but prey as large as waterfowl are also taken. Any habitat that supports or concentrates birds should be considered essential to locally nesting peregrines.

Key hunting areas fall into two categories: (1) those habitats that concentrate or support important prey species, and (2) those habitats that expose prey and make them vulnerable to peregrine attack. Peregrines capture their prey through precipitous dives from considerable height above their quarry. Peregrines must, therefore, frequent habitats permitting this type of pursuit. Peregrines do not hunt

[17] The shape of the CPW nesting polygon suggests that at least three active nest sites have occurred on the nest cliff.

below the forest canopy, but capture birds flying above forests or across open expanses. Larger prey are raked (with talons) or knocked out of the air and peregrines need open areas on the ground to recover them. Nesting cliffs, are generally situated at considerable heights above the surrounding terrain, so peregrines have a broad panorama from favorite hunting perches near the cliff top.

Peregrine falcons are an R2 sensitive species on the WRNF. The following, applicable, Forest Plan, Forest-wide, Wildlife Standards 8 and 9 specify the following:

> 8. Discourage land use practices and development that adversely alter the character of peregrine falcon hunting habitat or prey base within ten miles of the nest site and the immediate habitats within one mile of the nesting cliff.
>
> 9. Human activities will be restricted within one-half mile of the occupied peregrine falcon areas between March 15 and July 31 for nest sites, or July 1 to September 15 for hack sites.

One and 1.8 miles of Highway 133 occur within 0.5 and 1.0 miles of the active peregrine nest site, respectively.[18] Approximately 0.4 miles of the potential Hayes Creek/ Bear Creek trail segment occurs within one mile of the active eyrie. The habitat bisected by that trail does not support a concentrated prey base, but does provide settings where prey expose themselves to peregrine attack. Standard 8 in the WRNF Forest Plan would discourage development of that trail.

With the exception of the northern one-half (approx.) of the potential CROS trail segment and the adjacent highway trail alignment, the entire lengths of the highway and all off-highway trail alignments would occur within 10 miles of the active eyrie and, therefore, represent potential foraging habitat. All three potential peregrine nesting areas would also have foraging ranges that overlap most of the river valley's riparian corridor, wetlands, and meadows that support the greatest potential prey densities and expose birds to predation. Mapping of potential peregrine nesting areas in the Crystal River valley has undoubtedly changed over the years. In the wildlife report for Filoha Meadows, Colorado Wildlife Science (2008) indicated:

> There is an historic peregrine falcon nesting area on cliffs within a ½ mile of Filoha Meadows Nature Preserve... There have been active peregrine eyries (nest sites) on nearby cliffs in at least 4 of the last 7 seasons.

The current edge of the potential peregrine nesting area adjacent to Filoha Meadows is approximately 0.5 miles away from the closest approach of that trail segment. Filoha Meadows meets all of criteria to be considered high quality peregrine hunting habitat (Colorado Wildlife Science 2008).

As for the other wildlife species considered in this analysis, potential trail impacts to peregrines are not so much the habitat lost to trail development as the considerably greater area of adjacent habitat disturbed by trail users where some peregrine prey (i.e., birds) are displaced and could occur in reduced abundance.

6.3.6 Black Bear

Important black bear seasonal ranges throughout the proposed Crystal River trail corridor are shown in Figures 10.2-16 to 10.2-18. Other less important (to this analysis) seasonal ranges, including overall

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[18] For the purposes of this analysis, the distances are measured from a generalized central point in CPW's polygon, which was generated from three alternate nest sites on the nest cliff.

range and summer concentration area, are more widespread in the analysis area, but are not shown on maps to maximize the clarity of important habitats.

Fall concentration areas include montane shrublands and other habitats providing higher forage quality and abundance during the fall (Aug. 15 until Sept. 30) hyperphagic period when bears maximize pre-winter weight gain in preparation for winter. Virtually the entire Highway 133 corridor bisects black bear fall concentration area, from north of Nettle Creek nearly to the summit of McClure Pass. The entire potential RWP, J&F, and Hayes Creek/ Bear Creek trail segments would bisect currently isolated black bear fall concentration areas.

Black bear human conflict areas are associated with some local subdivisions, usually where inappropriate garbage management has led to two or more confirmed black bear complaints per season resulting in CPW investigation, damage to persons or property (cabins, tents, vehicles, etc.), and/or the removal of the problem bear(s). The Highway 133 corridor would not bisect any black bear human conflict area. A short section of the potential CROS trail segment bisecting a corner of the subdivision at the mouth of Potato Bill Creek and that portion of the potential trail following the road through Redstone and outlying subdivisions would bisect black bear human conflict areas. This habitat is not one of particular concern regarding potential trail siting.

6.3.7 Moose

Important moose (*Alces alces*) seasonal ranges throughout the proposed Crystal River trail corridor are shown in Figures 10.2-19 to 10.2-21. Other less important (to this analysis) seasonal ranges, including overall range and summer range, are more widespread in the analysis area, but are not shown on maps to maximize the clarity of important habitats.

Moose winter range use extends from November 15 to April 1. In the analysis area, it occurs above the west side of the valley to just south of Redstone, after which it occurs along the valley bottom and side slopes is bisected by most of the Highway 133 corridor, the potential Hayes Creek/ Bear Creek trail segment, and the old McClure Pass switchbacks.

The edge of a large **moose concentration area**, where densities are 200% higher than the surrounding area, overlaps the top of Highway 133 at McClure Pass and the top of the old McClure Pass switchbacks.

6.3.8 Wild Turkey

Important wild turkey (*Meleagris gallopavo*) seasonal ranges throughout the proposed Crystal River trail corridor are shown in Figures 10.2-22 to 10.2-24. Other less important (to this analysis) seasonal ranges, including overall range, are more widespread in the analysis area, but are not shown on maps to maximize the clarity of important habitats.

Turkey winter range is where 90% of the individuals are located from November 1 to April 1 during the average five winters out of 10. Two areas of turkey winter range are mapped in the analysis area, on the southwest toe slopes of Mt. Sopris and at the mouth of Coal Creek west of Redstone. The Highway 133 corridor would not bisect any turkey winter range. A portion of the potential J&F trail segment would bisect turkey winter range in the mouth of Avalanche Creek.

6.3.9 Quantification of Impacts to Colorado Parks and Wildlife-Mapped Species

Table 6-2 quantifies the distances of potential trail segments bisecting important wildlife habitats in the Crystal River analysis area. Table 6-2 indicates that there would be potential wildlife conflicts with all potential trail segments. The trail segment with the least negative effects on wildlife would be Redstone Boulevard, because there would be no habitat loss and virtually no reduced effectiveness of adjacent habitat because of existing road condition and use.[19] The trail segment with the greatest negative effects on wildlife would be J&F, whose 5.5 miles would bisect a total of 32.1 miles of important, highly effective wildlife habitats. The longest potential segment, the Highway 133 corridor, has the greatest intersect mileage, including that of some critical habitats, but those apparent conflicts are misleading. Since its inception in the 1970's, wildlife seasonal range mapping has been conducted at a relatively coarse 1:50,000 scale. Highways per se have little to no value to the specific species considered herein and are generally avoided by those wildlife. If it were meaningful and practical to exclude highway ROWs from mapping they would have been. Therefore, with the possible exception of highway crossing for some species, the intercepts of Highway 133 with various wildlife ranges is a specious artifact of mapping practicalities.

Nevertheless, there would be direct habitat losses associated with trail segments along Highway 133. Some of those habitats are highly effective for some species (e.g., Lewis' woodpecker nesting). However, all of the affected habitat would be within the highway's existing zone of influence that most wildlife, including those species of greatest concern (elk and sheep), currently avoid. Therefore, the negative effects of the highway alignment trail segments are largely discountable for most wildlife species, including all CPW-mapped species, with the exception of the elk highway crossings where road-mortality has occurred. Furthermore, even though the highway ROW may locally support some habitats with high functional values to some species, there would be less year-round impacts to the wildlife community if a trail was located within the highway's disturbance corridor rather than introducing new trail use into currently buffered, isolated, and highly effective habitats. This is particularly true for the J&F, RWP, and CROS trail segments (in that order) east of the Crystal River. Those three trail segments would total 6.8 miles and would bisect 39.2 miles of important wildlife habitats, including 9.8 miles of elk and bighorn sheep winter range and 2.7 miles of critical elk and bighorn sheep winter concentration area and severe winter range. This is explained in greater detail in Section 8.1, below.

Table 6-2. Distances (mi.) of potential trail segments bisecting important wildlife habitats in the Crystal River analysis area. Critical habitats are indicated with a symbol (*).

Wildlife Species	**Potential Trail Segment** [a]					
Activity Area [b]	**Hwy. 133**	**CROS**	**RWP**	**J&F**	**HC/BC**	**Old MP**
TRAIL SEGMENT MILES	12.9	0.3	1.0	5.5	1.4	2.8
Bighorn Sheep						
Winter Range	1.0		0.5	2.5	0.0	
WCA*			0.1*			
SWR*						
Production						

19 For that reason, the Redstone trail segment is not included in Table 6-2.

Table 6-2. Distances (mi.) of potential trail segments bisecting important wildlife habitats in the Crystal River analysis area. Critical habitats are indicated with a symbol (*).

Wildlife Species	**Potential Trail Segment [a]**					
Activity Area [b]	**Hwy. 133**	**CROS**	**RWP**	**J&F**	**HC/BC**	**Old MP**
Migration Corridor				0.5		
Mineral Lick	0.0					
Sum Sheep	**1**		**0.6**	**3**	**0**	**0**
Elk						
Winter Range	12.9	0.3	1.0	5.5	1.4	1.5
WCA*	0.4*			2.0*		
SWR*	0.1*			0.6*		
Production						
Migration Corridor	0.0					
Highway Crossing	1.7					0.1
Sum Elk	**15.1**	**0.3**	**1**	**8.1**	**1.4**	**1.6**
Mule Deer						
Winter Range	1.7	0.3	0.3			
Bald Eagle						
Winter Range & WFH	12.9	0.3	1.0	4.6	1.4	0.6
Peregrine Falcon [c]						
Active nesting area 0.5 mi.	1.0					
Active nesting area 1.0 mi.	1.8				0.4	
Active nesting area 10 mi.	12.1		1.0	5.5	1.4	2.8
Active nesting area CPW	1.5				0.2	
Potential nesting area	0.4					
Black Bear						
Fall Concentration Area	11.8		1.0	5.4	1.4	2.2
Human Conflict Area	2.4					
Moose						
Winter Range	**2.2**				1.4	2.6
Concentration Area						1.1
Wild Turkey						
Winter Range				0.9		
TOTAL ALL SPECIES	**77.2**	**1.2**	**5.9**	**32.1**	**9.0**	**11.5**
TOTAL SHEEP AND ELK	16.1	0.3	1.6	11.1	1.4	1.6
COUNT [d]	**18**	**4**	**8**	**10**	**9**	**8**

[a] Potential trail segments: Highway 133, Crystal River Open Space (CROS), Red Wind Point (RWP); Janeway and Filoha Meadows (J&F), Hayes Creek / Bear Creek (HC/BC), and old McClure Pass Road (Old MP) switchbacks. The Redstone trail segment is not included because trail use would be located entirely along the existing road and would have negligible wildlife effects. Note: the potential alternative trail segment following the railroad grade around the ridge south of Janeway was not included in the table's

Table 6-2. Distances (mi.) of potential trail segments bisecting important wildlife habitats in the Crystal River analysis area. Critical habitats are indicated with a symbol (*).

Wildlife Species Activity Area [b]	Potential Trail Segment [a]					
	Hwy. 133	CROS	RWP	J&F	HC/BC	Old MP

quantification to avoid double counting intercepts.

[b] Wildlife activity area abbreviations: Severe winter range (SWR), winter concentration area (WCA), and winter foraging habitat (WFH, for bald eagles).

[c] Following WRNF, Forest Plan, Forest-wide, Wildlife Standard 8, the most meaningful peregrine consideration for this analysis is if potential trail development and use would alter the character of peregrine falcon hunting habitat or prey base within ten miles of the nest site and the immediate habitats within one mile of the nesting cliff.

[d] Count = Number of wildlife activity areas (not the number of polygons) bisected by the trail segment.

Data Sources: CDOT, CPW, Pitkin County.

Quantification by A. Gallensky, Rocky Mountain Wild.

6.4 HABITAT CONDITIONS AND OTHER WILDLIFE GROUPS

Detailed, multi-year wildlife investigations (e.g., Colorado Wildlife Science 2008) and more extensive wildlife and ecological characterizations (e.g., Crystal River Caucus 2007) of the Crystal River valley indicated that the area supports relatively high habitat diversity and virtually all native wildlife species are still present on the valley. This occurs because the habitat is mostly intact, occurs in large blocks, and is connected to extensive surrounding public lands, much of which on both sides of the valley are difficult to access. The diverse plant communities supporting diverse wildlife populations are due in part to the valley's broad (6,518 ft.) topographic gradient (from 6,447 ft. at the north end of the CROS parcel to the summit of Mt. Sopris [12,965 ft.]) containing four (foothills to alpine) life zones, and steep perpendicular side canyons. Habitats historically disturbed by mining, logging, and other disturbances have largely recovered and provide productive wildlife values, if not native vegetation types. Residential developments have converted habitats and their associated activities have displaced wildlife from surrounding habitats. These residences, either clustered in subdivisions or dispersed, are generally confined to the valley bottom with large blocks of high quality intervening habitats (on Open Space tracts and NFS lands). Highway 133 activity is a chronic predictable disturbance with reduced habitat effectiveness flanking its length. However, with the exception of road-kills, wildlife have habituated to it to the extent they are going to.

Unfortunately, other than CPW's wildlife mapping of a relatively low number of wildlife species of greater concern, there is no meaningful systematic mapping of other species, wildlife groups, high wildlife diversity areas, or high value habitats to display. The closest available information was the Crystal River Caucus's (2007) individual and composite rankings of plant habitat, species' imperilment, wildlife activity, and stream/riparian for their six, three-mile-long subsets of the Crystal River valley, shown in Table 5-3, above.

Many of the open space parcels along the Crystal River were acquired by Pitkin County specifically for their high wildlife diversity and unique ecological communities, as well as for the critical habitats of a few wildlife species. Thus, the locations and distribution of Open Space parcels are indicators of higher wildlife values.

Graphic consideration of other important species (e.g., lynx, R2 wildlife and plants), wildlife groups (e.g., breeding birds, cavity nesters, and raptor nests), and habitats (e.g., wetlands, riparian, hot springs, and mines) may be considered in the more detailed and site-specific NEPA analyses. Consideration of most of these are addressed in Section 7.0, Potential Trail Effects on Wildlife and Habitats, below.

Lastly, those individual species mapped by CPW have affinities to a wide variety, and the majority, of habitats present in the valley. If the extensive habitats required to avoid and preserve sheep, elk, peregrine falcon, riparian, and other unique habitat values, can be considered and protected during trail planning, then the habitat values of virtually all other species present in the valley are also likely to be protected.

6.5 OTHER NOTEWORTHY RESOURCE ISSUES

6.5.1 Isolation of Habitats East of the Crystal River

In the analysis area, Highway 133 occurs entirely on the west side of the Crystal River. Habitats on the Open Space parcels east of the river, and those more extensive habitats on NFS lands to the east, are currently difficult for the public to access due to the river, intervening private property, and limited public access portals (e.g., Avalanche Creek Road). The river provides an effective barrier to public access and buffers human disturbances west of the river from the high value habitats to the east. Although some residents east of the river may violate seasonal wildlife closures by hiking sections of the abandoned railroad grade, most residents comply with the closures and most sections of the railroad grade and adjacent habitats are highly effective for wildlife. The critical nature of seasonal sheep and elk habitats east of the river is not only due to the habitats present, but also because of the lack of human disturbance that allows the habitats to be used effectively.

6.5.2 Contiguous Isolated Drainages

A lack of easy public access to public and private lands east of the Crystal River has effectively protected large tracts of habitat from human disturbance that would otherwise have occurred. Remarkably, three contiguous drainages, Thomas Creek (mostly privately owned and just north of the analysis area), Potato Bill Creek (part pvt./ part NFS), and Nettle Creek (NFS) are trail-free (there are no trails going up those drainages). These are the only substantial drainages in the Crystal River valley without trails and their association protects a large habitat block on the northwest and north sides of Mt. Sopris.

6.5.3 Wildlife Access to the Crystal River

The potential CROS, RWP, and J&F trail segments occur on public lands that provide approximately six miles of unfettered year-round wildlife access to the Crystal River. The Red Wind Point and Filoha Meadow areas are two of the few places where critical sheep and elk habitats extend down to the Crystal River.

6.5.4 Crystal River Riparian Corridor

The Crystal River supports a botanically diverse, structurally varied, and locally broad riparian corridor. This habitat and its associated wetlands generally support the highest wildlife diversity and abundance of any local habitat. All of the new bridges that would be needed to access potential trail segments east of the river would affect flanking riparian habitat to some extent. Broader widths of riparian habitat that would have to be cleared to accommodate potential bridges occur at the north end of the CROS trail segment and the north end of the J&F trail segment. Sections of all three potential trails east of the river have railroad grades bisecting riparian habitat. It is unknown to what extent additional riparian clearing would be required to develop a functional trail corridor, but that would be a concern.

Similarly, the railroad grade closely approaches the very top of the riverbank in many places where additional clearing to obtain adequate trail width could result in further riparian losses and present water quality and aquatic habitat challenges. These same issues would also be valid concerns associated with a trail along Highway 133.

6.5.5 Other Localized Habitat Features

There are other more localized rare plant and unique wildlife habitats along the Crystal River. Many of these occur on Open Space parcels, located and identified because of more rigorous study (e.g., Colorado Wildlife Science 2008). Some of these, such as the hot springs and mineral licks at Filoha Meadows, have been previously addressed. Others, including, but not limited to rare plants, fireflies, abandoned mines supporting a maternity roost of pale Townsend's big-eared bat (a USFS R2 sensitive species), beaver ponds, a great blue heron nesting area, etc., occur on some of the open space parcels and elsewhere in the valley. Filoha Meadows is particularly rich in these resources. However, few of these resources would be affected directly by trail siting and use, although all could be affected by trampling and other disturbances associated with off-trail use and new access to the otherwise largely inaccessible areas supporting these species.

7.0 POTENTIAL TRAIL EFFECTS ON WILDLIFE AND HABITATS

Wildlife issues have been a major concern associated with a public recreation trail in the Crystal River valley in all prior analyses that considered local natural resources. Many of the basic issues are the same as those identified in the early 1990's. Other wildlife issues have emerged as recreational use and its effects on wildlife have increased in and beyond Pitkin County, as bicycle technology has improved, as more scientific studies have examined this issue, and as user's behaviors have evolved. This section, developed for the interested public and Decision Makers as they consider the best alignment for the Crystal Valley trail, provides the scientific basis for assessing wildlife impacts associated with various Crystal River trail segments. It starts with a summary of general effects that recreationists can have on wildlife, then provides summaries of detailed case studies relevant to the wildlife community in the Crystal River valley.

7.1 GENERAL EFFECTS OF RECREATIONAL USE ON WILDLIFE

In their comprehensive synthesis, *Wildlife and Recreationists*, Knight and Gutzwiller (1995) stated:

> "Outdoor recreation has historically been viewed as an environmentally benign activity. Yet with growing numbers of recreationists visiting public lands, and with a greater understanding of the role of public land in safeguarding biodiversity, it is becoming apparent that the effects of recreation on both the environment and wildlife are chronic and pervasive."

Outdoor recreational activity has increased enormously and will continue to increase, while the amount of land free of human disturbance and available for effective wildlife use has decreased and will continue to do so. Outdoor enthusiasts rarely view themselves as having a degrading effect on the environment (e.g., Flather and Cordell 1995, Hamman et al. 1999). Long ago, Boyle and Samson (1983) reported that in 81% of 166 studies reviewed, nonconsumptive outdoor recreation had negative effects on wildlife. Most recently, Larson et al. (2016) analyzed 274 scientific articles on the effects of non-consumptive recreation on animals worldwide. Of 93% of the articles documenting at least one effect of recreation on animals, 59% were classified as negative effects. Most articles focused on mammals (42%) or birds (37%). Counter to public perception, non-motorized recreational activities had greater negative effects than motorized activities. Examples of other literature reviews and synthesis studies relevant to wildlife and recreationists include Joslin and Youmans (1999), Olliff et al. (1999), Lathrop (2003), and Marzano and Dandy (2012).

The conflict between wildlife and recreationists is not rocket science. The issue has been examined worldwide. Most research is from the United States, but considerable research, and even synthesis studies, is available from Europe, Canada, Australia, and New Zealand.[20] In the U.S., recreational effects on wildlife have been examined in National Parks being "loved to death" (e.g., Lee et al. 1984, Olliff et al., 1999), at National Wildlife Refuges (e.g., Drabelle 1985, Pomerantz et al. 1988), in travel management plans associated with the most heavily recreated National Forest in the U.S. (USFS 2011a,b), and in cities with some of the largest open space systems in the U.S. (e.g., Miller et al. 1998, 2001). Management plans have been implemented at all these levels attempting to allow wildlife and recreationists to coexist. Wildlife managers know what works, what doesn't, and why. When trail siting and management don't work, the trail and associated wildlife impacts generally remain. It is rare for trails, once built, to be decommissioned, even when negative effects are known and documented.

All types of recreation can negatively affect wildlife. Wildlife see humans hiking, with or without their dogs, and those on snowshoes, skies, or bikes as predators (Bowles 1996) and flee a certain distance to where the humans are no longer perceived as an immediate threat. That displacement distance and the zone of influence[21] surrounding trails, varies by wildlife species. It may be a matter of dozens of yards (e.g., for birds) or hundreds of yards and over a ridge (e.g., for elk). It is the animal's displacement from otherwise effective habitat (affecting hundreds of acres or more), the associated energetic expenditures (Ward and Cupal 1979, MacArthur et al. 1982, Gabrielsen and Smith 1995), and the loss of foraging and resting time (Hobbs 1989, Knight and Cole 1995a) that represent the greatest negative effects of trails, not the direct loss of a few acres of habitat from a trail several feet wide, albeit miles long (Taylor and Knight 2003).

Wildlife responses to human disturbances are influenced by (1) the type of disturbance, (2) the predictability of the disturbance, (3) the frequency and magnitude of the disturbance, (4) the time of year the disturbance occurs, (5) the relative location of the disturbance (above vs. below on a slope), and (6) the type of animal disturbed (including size, specialized versus generalized niche, group size, and sex and age; Knight and Cole 1995b).

First, a recreationist's speed and behavior can influence wildlife responses (e.g., Richens and Lavigne 1978, Burger 1981, Klein 1993). Rapid movement directly towards wildlife frightens them, while movements away or at oblique angles to the animal are less disturbing. Slow moving disturbances generally elicit milder responses from wildlife. Snowmobiles moving at high speeds alarmed white-tailed deer more than those moving at slower speeds, but when people stopped to observe the deer, they invariably caused the deer to flush (Richens and Lavigne 1978).

Second, disturbance predictability influences an animal's response. When animals perceive a disturbance as frequent enough to be "expected" and non-threatening, they show little overt response.

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[20] This analysis almost entirely limits studies cited to those conducted in North America, if not only the U.S., and to those specific species and wildlife groups that could be affected by the Crystal River trail proposal, unless otherwise warranted.

[21] The "area of influence" is generally considered to be indicative of the relative impacts of recreational activities. Area or zone of influence is defined as the area that parallels a trail or line of human movement within which wildlife will flush from, or be otherwise affected by, a particular activity with a certain probability (Miller et al. 2001).

In Alberta, bighorn sheep encountering passing vehicles at 25-30 vehicles per hour showed minimal (<1%) avoidance and minor (<9%) increased heart rates (MacArthur et al. 1982). The same habituation of sheep to high-speed traffic can be seen along I-70 northeast of Georgetown, where 2015 traffic volumes were 36,000 average annual daily vehicles.[22] Feeding bald eagles were more vigilant and fed less in areas of active persecution compared to sites where birds were unharmed (Knight and Knight 1986).

On-trail recreation may appear more predictable to wildlife because it occurs frequently and along a particular line of movement, and animals in non-hunted populations may habituate somewhat to this type of activity (Knight and Cole 1995a, Whittaker and Knight 1999, Taylor and Knight 2003). If recreationists believe they can approach wildlife more closely than animals will actually allow, then recreationists will disturb wildlife in a majority of encounters. Animals flushing from recreational activity may come at the cost of energy needed for normal survival, growth, and reproduction (Geist 1978), and may cause animals to avoid otherwise suitable habitat (Hamr 1988, Gander and Ingold 1997, Miller et al. 2001). By understanding and altering recreationists' perceptions with regard to their impacts on wildlife, public lands managers can influence visitor behavior and reduce the potential negative effects of recreation on wildlife.

Third, when animals perceive a disturbance as frequent and threatening, they exhibit a more acute response. The most acute responses are to unpredictable, erratic, and threatening disturbances. There are thresholds of disturbance frequencies above which wildlife reduce their use or abandon habitats. For example, in Missouri, when human activity levels exceeded 0.45 hunters per hectare (1 ha. = 2.47 ac.), white-tailed deer movements increased (Root et al. 1988). Four species of waterbirds in Wales virtually abandoned areas when recreation exceeded 8-10 boats on a lake at any one time (Tuite et al. 1983).

Fourth, recreational use can be most detrimental to wildlife during the breeding season (for birds, with the greatest sensitivity during nest building and incubation) and winter (for ungulates, on negative energy budgets), however disturbance at other times of the years can also have appreciable negative effects (Hobbs 1989, Skagen et al. 1991). Breeding season disturbance may affect an individual's productivity, while winter disturbances can affect energy balances and an individual's survival. Mammals show less and weaker responses to humans during the winter months than at other times of the year. Ungulates respond less to recreationists when snow is deep, forage inaccessible, temperatures are lowest, body reserves are depleted, and energy conservation is decisive for survival. Under such conditions, ungulates are starving and can't afford the additional energy expenditures to flee (Parker et al. 1984). However, it has been shown repeatedly, and for virtually every ungulate species in North America, including (1) bighorn sheep (MacArthur et al. 1979, 1982, Stemp 1983, Geist 1971, Geist et al. 1985, MacArthur and Geist 1986, Hayes et al. 1994), (2) elk (Ward and Cupal 1979, Lieb 1981, Chabot 1991, Cassirer et al. 1992, Phillips 1998, Phillips and Alldredge 2000), and (3) mule deer (Freddy 1977, 1984, 1986, Freddy et al. 1986), that even minor, seemingly harmless human disturbances causes elevated heart rates that can result in relatively high energy expenditures (Stemp 1983, Chabot 1991, Canfield et al. 1999). This can lead to habitat avoidance, lowered body weight, increased starvation probabilities, increased susceptibility to predators, and smaller pre-winter body mass of offspring leaving them less fit for overwinter survival.

Fifth, wildlife often show more pronounced responses to disturbances above and closer to them as greater threats to their safety and ability to escape. Hikers approaching bighorn sheep from above

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[22] http://dtdapps.coloradodot.info/otis/TrafficData#ui/1/1/0/station/103036/criteria/070A/0/449.589/true/true/

elicited stronger reactions than hikers approaching from below (Hicks and Eldar 1979). While nesting peregrine falcons were disturbed by recreationists at the base of their nesting cliffs, any approach from the cliff top elicited a more immediate and intense alarm (Herbert and Herbert 1965).

Sixth, larger wildlife generally flush at greater distances than smaller species. Animals feeding in groups detect and respond to approaching threats at greater distances and are less vulnerable to attack than individuals.

Negative trail use effects can occur year-round and affect all wildlife present to some extent. Even temporary displacement of breeding birds from a trail corridor can disrupt breeding activity, increase vigilance, reduce foraging time, the amount of prey brought to the nest, the number of chicks fledged, and cause nest abandonment (e.g., Luckenbach 1979, Knight and Gutzwiller 1995, Miller et al. 1998, Hamann et al. 1999). At certain levels of trail use, some width of otherwise suitable habitat along trail corridors may either be avoided or abandoned entirely during the nesting season. Miller et al. (1998) investigated the influence of recreational trails on breeding bird communities in forest and mixed-grassland habitats in Boulder County, Colorado. Bird species composition was altered adjacent to trails in both habitats. Generalist species were more abundant near trails, whereas specialist species were less common. Within the grasslands, birds were less likely to nest near trails. Within both habitats, nest predation was greater near trails. The average zone of influence of trail use extended about 241 feet away from trails, but extended to more than 320 feet for some sensitive species. Trail corridors and their use can also fragment songbird habitat by disrupting continuous effective habitat and reducing the patch size of interior habitat (e.g., Rich et al. 1994, Hutto 1995, Hamann et al. 1999, Malone and Emerick 2003).

For sheep, elk, and mule deer, the effects of recreationists are a year-round issue. Disturbance on summer range was once thought to be less of a concern because it is the most widespread seasonal habitat. However, the quality and availability of spring, summer, and fall ungulate forage is now known for its importance (1) to males growing antlers, horns, and fat reserves for the fall rut, (2) to females to meet the energy demands of lactation while simultaneously recovering from prior winter and pregnancy weight losses, and (3) to both sexes for building fat reserves to maximize upcoming winter survival probabilities (e.g., Verme 1967, Mautz 1978). Recreationist impacts on all other ranges, including spring and fall transitional ranges (i.e., migration), production (lambing, calving, and fawning) areas, and the various winter ranges can also be appreciable. Winter range is the most spatially restricted seasonal habitat and its availability generally dictates the size of a local herd. Big game are starving when on winter range (Mautz 1978). The forage they eat on winter range is insufficient to meet their metabolic needs, but it slows the rate of starvation. Reduced forage availability in recreational corridors and the increased energy expenditures fleeing recreationists have contributed to smaller herd sizes and reduced productivity of local big game herds (Will et al. 2011, Mao et al. 2013). In 2011, the CDOW reduced the mule deer population objective for the local Data Analysis Area containing the Crystal River valley, in part because of negative recreation effects (Will et al. 2011).

While most investigations of recreationist-wildlife interactions have focused on ungulates and birds (because of recreational, social, economic interest, and ease of study), human recreational activities have been documented to impact other wildlife groups, including herpetofauna (e.g., Hecnar and M'Closkey, 1998; Lacy and Martins, 2003; Rodrıquez-Prieto and Fernandez-Juricic, 2005), rodents (e.g., Mainini et al., 1993; Malone and Emerick 2003, Magle et al., 2005), and mesocarnivores (e.g., Malone and Emerick 2003, George and Crooks 2006).

With increased trail development and recreational use in recent decades, some of the associated negative effects on wildlife have been caused by social trail[23] development. In Eagle County, within several miles of trailheads, there is often no effective habitat; no ridge for animals to cross over to escape recreational activity (e.g., Havlick 2002). These trails meet a growing community need, yet despite their impacts on wildlife, there is little to no effective enforcement to reduce social trail use or decommission such trails. Once wildlife are displaced from high use areas, recreational enthusiasts assert that wildlife are no longer present and seek to have the trails adopted as part of the local/ regional trail system. Such trail use is not limited to Eagle County. It is occurring in and between many of Colorado's communities surrounded by large tracts of public lands. The Crown is a local example in Pitkin County where habitat succession and year-round human recreation have diminished mule deer winter range habitat quality (Will et al. 2011).

Lastly, this analysis did not seek to examine whether hikers or bikers had different impacts on wildlife. That question is irrelevant for this project, since a multi-use trail is proposed. Various studies showed interesting results, but all studies showed that both uses can have negative effects on the wildlife species warranting protection in the Crystal River valley. A crucial consideration that has been ignored in virtually all of the case studies summarized below, is the different distances that different recreationist groups travel. For example, even if hiker vs. biker impacts per animal encounter are equal, because bikers typically travel several times as far as hikers, bikers have the opportunity to disturb more wildlife per unit of time (Taylor and Knight 2003) and, therefore, can have several times as much impact on wildlife as hikers if total incidents and area of habitat affected are considered.

7.2 PERTINENT WILDLIFE - RECREATIONIST CASE STUDIES

For this analysis, recreational trail use focuses on hikers and bikers, the two anticipated principal user groups of the Crystal River trail. Below are several case studies documenting wildlife responses to different user groups that are pertinent to the particular species and potential trail issues in the Crystal River analysis area.

7.2.1 Freddy et al. (1986) - Mule Deer; Persons on foot vs. Snowmobiles

In North Park, Colorado, Freddy et al. (1986) compared the overt behavioral responses of adult female mule deer (in a hunted population) to humans on foot (usually on snowshoes) and snowmobiles. Snowmobiles will be prohibited on the Crystal River trail, but the study is relevant regarding deer reactions to persons afoot, their flight distances, and trail corridor effects. Mule deer were disturbed more by persons afoot than by snowmobiles. This finding supported previous research that persons afoot elicited more intense reactions by ungulates than they do to vehicles (Ward et al. 1976, Richens and Lavigne 1978, Schultz and Baily 1978, Eckstein et al. 1979, MacArthur et al. 1982). Responses by deer to persons were longer in duration, involved running more frequently, and were greater in estimated energy expenditures. Intensity of responses by deer was dependent on distances between animals and disturbances. Snowmobiles elicited initial attention by deer at greater distances than humans on foot, but deer ran away from persons on foot starting at greater distances than from snowmobiles. Freddy et al. (1986) concluded that minimizing all levels of deer responses (e.g., mild alert, moderate alert [lying animals stood or foraging ceased], and flight) would require persons afoot and snowmobiles to remain 365 and 514 yards from deer, respectively. Further, preventing flight by deer would require persons on foot and snowmobiles to remain 209 and 145 yards from deer,

[23] Defined in Section 3.1.

respectively. These flight distances from persons afoot and snowmobiles were similar to values documented for mule deer and elk elsewhere (Ward et al. 1976, Schultz and Baily 1978, MacArthur et al. 1982). Freddy et al. (1986) further noted that (1) their threshold distances could be used to establish corridors of human activity within sagebrush winter ranges occupied by deer that may reduce the effects of human intrusion and (2) that if human activities were restricted to trails (i.e., specific disturbance corridors), deer might perceive the activity as more predictable and acceptable (MacArthur et al. 1982).

7.2.2 Taylor and Knight (2003) - Mule Deer; Hikers and Mountain Bikers

Taylor and Knight (2003) examined the responses of three big game species, including mule deer, to hikers and mountain bikers at a Utah State Park by comparing animal alert distance, flight distance, and distance moved. The study did not include experimental controls needed to assess cause-effect relationships or consider quantitatively the different distances that hikers and bikers travel (they only measured animal responses per incident). At 100 m from a trail, mule deer exhibited an approximate 70% probability of flushing from on-trail recreationists. Mule deer exhibited a 96% probability of flushing within 100 m of recreationists off trails and their probability of flushing did not drop to 70% until the perpendicular distance from recreationists reached 390 m. Study results indicated that there was little difference in wildlife response to hikers vs. mountain bikers on a per encounter basis. Taylor and Knight (2003) speculated that characteristics of each activity may have affected the wildlife responses. While both activities involved humans traveling by non-motorized means, hikers retained their human form while mountain bikers appeared unlike humans because they were on a bike. Typically, pedestrians induce a more intense wildlife response than do motorized vehicles, because animals are thought to react most to the human form (Richens and Lavigne 1978, Eckstein et al. 1979, MacArthur et al. 1982, Freddy et al. 1986). However, mountain bikers travel at a higher speed and are less apt to be talking than hikers, which may cause mountain biking to be less predictable for wildlife. They speculated that the lack of difference in wildlife responses to hiking vs. biking (per incident) may be attributable to a balance between the disturbing attributes of each activity. Based on observed flushing responses, Taylor and Knight (2003) found the area around existing trails that may be impacted by recreationists on those trails was a 200-m "area of influence." Taylor and Knight (2003) also surveyed 640 backcountry trail users to investigate their perceptions of the effects of recreation on wildlife. Approximately 50% of recreationists felt that recreation was not having a negative effect on wildlife. Most recreationists felt that it was acceptable to approach wildlife at a much closer distance (mean acceptable distance to approach = 65 yds.) than wildlife would typically allow a human to approach (mean flight distance of all species = 165 yds.). Recreationists also tended to blame other user groups for stress to wildlife rather than holding themselves responsible. Taylor and Knight (2003) concluded that if management objectives include minimizing disturbance to wildlife habitat, new trails should follow existing edges and avoid water and forage resources, wildlife travel corridors, and escape terrain. That conclusion has remarkable applicability to the Crystal River trail siting.

7.2.3 Miller et al. (1998, 2001) - Mule Deer and Birds; Pedestrians and Dogs

On City of Boulder Open Space, Miller et al. (1998, 2001) measured the summer responses of mule deer and three bird species to on- and off-trail pedestrians alone, a pedestrian with a dog on-leash, and a dog alone. Mule deer exhibited the greatest response when a pedestrian was accompanied by a dog on leash and greater responses to off-trail interactions where activities were less frequent and predictable. That finding regarding greater wildlife responses to unpredictable disturbances was consistent with other studies (e.g., Schultz and Baily 1978, MacArthur et al. 1982, Hamr 1988). Boulder Open Space regulations have no leash laws (dogs under sight or voice control only) and dogs are known to harass and attack deer. Miller et al. (2001) speculated that because dogs are common on open space trails and rarely leashed, deer have become sensitized to the presence of dogs, explaining the greater reaction of when a pedestrian was accompanied by a dog. Birds (vesper sparrow [*Pooecetes gramineus*], western meadowlark [*Sturnella neglecta*], and American robin [*Turdus migratorius*]) also exhibited greater responses when disturbances occurred off-trail vs. on-trail. Vesper sparrows and western meadowlarks showed the least responses to dogs alone and the greatest responses when a pedestrian was present. The authors speculated that because dogs resemble coyotes (*Canis latrans*) and because coyotes rarely prey on birds, bird may not perceive dogs as a significant threat. However, dogs may pose a greater threat to birds than humans, so birds may hold their position to the last moment attempting to remain undetected. Bird responses to pedestrians alone and a pedestrian with a dog on-leash were similar, indicating that the presence of a dog with a pedestrian did not have an additive effect. Off-trail recreation is infrequent and spatially unpredictable, thus birds unaccustomed to such activities exhibit greater responses.

7.2.4 Naylor et al. (2009) - Elk; ATV Riding, Mountain Biking, Hiking, & Horseback Riding

Naylor et al. (2009) measured responses of elk to four types of recreational disturbance: all-terrain vehicle (ATV) riding, mountain biking, hiking, and horseback riding, to determine if different types of recreation elicited different responses. Elk travel time (i.e., associated with flight) increased in response to all four disturbances, which reduced time spent feeding or resting. Travel time was highest during ATV exposure, followed by exposure to mountain biking, hiking, and horseback riding. Feeding time decreased during ATV exposure and resting decreased when elk were subjected to mountain biking and hiking disturbances. Resting time was similar during both mountain biking and hiking replicates. There was no difference in duration of feeding between mountain biking and hiking treatments. Elk showed no evidence of habituation to mountain biking. Reduction in foraging time as a result of disturbances was not compensated for after the disturbance ended, because elk did not increase feeding intensity or duration beyond that of controls. Their results demonstrated that elk activities can be substantially affected by off-road recreation. Specifically, off-road recreation produces a change in elk behavior and different types of human activity cause different behavioral responses in elk.

7.2.5 Papouchis et al. (2001) - Desert Bighorn Sheep; Vehicles, Mountain Bikes, & Humans on Foot

Papouchis et al. (2001) compared behavioral responses of desert bighorn sheep to recreational activity (vehicles, mountain bikers, and humans on foot) between a low visitor use area and a high visitor use area in Canyonlands National Park, Utah. They found that sheep exhibited a greater probability of flushing, longer distances moved, and longer response durations when disturbed by hikers compared to mountain bikers or vehicles. Responses of bighorn sheep were greater when human activity approached at the same elevation, when sheep were moving or standing, when interactions with ewes occurred in spring and summer and when with rams interactions occurred in autumn, and when sheep were farther from escape terrain. Their results contrasted with the results Taylor and Knight (2003). The difference in findings between the two studies may be attributable an experimental design artifact. Papouchis et al. (2001) compared the responses of sheep approached directly and off-trail by hikers (research assistants who were told to meander towards the sheep) with those of sheep approached tangentially on a road or trail by mountain bikers and vehicles. Generally, wildlife exhibit a stronger response to humans that approach them directly and to humans located off designated trails (MacArthur et al. 1982, Moen et al. 1982, Knight and Cole 1995a, Miller et al. 2001). Therefore, the differences in sheep response to hiking and mountain biking seen in Papouchis et al.'s study actually compared hikers that approach bighorn sheep directly and off-trail and on-trail bikers that ride by sheep.

7.2.6 Malone and Emerick (2003) - Impacts of Trails and Recreationists on Wildlife

In Pitkin County, Malone and Emerick (2003) evaluated the effects of multi-use recreational trails on breeding birds, small mammals, mesocarnivores (e.g., weasels, raccoons, and red fox up to black bears), and vegetation structure in four habitat types. Comparing survey results between treatment and control areas, vegetation structure between on- and off-trail point-pairs was generally >90% similar. However, similarity between on- and off-trail animal communities was always much less than 90% and varied with ecosystem and animal community studied. Breeding bird, small mammal, and mesocarnivore community composition (i.e., species abundance and distribution) differed between on- and off-trail plots in each habitat. Along trails, the bird community was dominated by human tolerant species and those species that benefitted from the trail habitat. Birds intolerant of disturbance were not detected within 30m of trails. The zone of trail influence varied with species, but was frequently observed at about 30m. Thus, trails seemed to affect bird community composition for at least a 60m wide corridor. That was a narrower zone of influence than the average zone of influence found around pedestrian trails in Boulder (Miller et al. 1998, see Section 7.2.3, above), although that may be due to definitions used and habitat differences. Along trails, the small mammal community was dominated by disturbance indicator species and specialist mammals were more frequently captured away from trails. Trails with increased human use experienced greater changes in abundance, diversity, and composition of the small mammal community. Along trails, the composition and distribution of mesocarnivores differed. Edge-adapted, open-country, mesocarnivores (e.g., red fox) were more common, while interior species (e.g., American marten) were never detected along trails.

Malone and Emerick (2003) concluded that even narrow and lightly used recreational trails can fragment forests, create smaller, isolated forest patches, increase habitat edge effects, and alter wildlife community composition. Wildlife species respond to trails and their associated disturbances in different ways. To some species, trails present a challenge and warrant avoidance. Trails present an advantage to other species, who seek them out. Some species are successful in trail corridors while others may be displaced. Trail-induced edge effects don't stop at the trail edge. Trail-effects permeate the interior of adjacent habitats. Edge-adapted mesocarnivores invade forests on trails and humans displace these species away from the trail, further into the forest. Recreational disturbances and predation pressures radiate from trails into surrounding wildlife communities, enlarging the zone of disturbance that surrounds the trail corridor and affecting wildlife both along and away from trails.

While the effects of recreational trail use on wildlife measured by Malone and Emerick (2003) were apparent, their results could also explain why some recreationists misunderstand their effects on wildlife…wildlife always seem to remain. In this study, in some habitats, the on- and off-trail bird communities were only 42% similar, but birds were still present to the casual observer. Common, disturbance-tolerant birds had replaced the less common intolerant birds near trails, but there were still birds to be seen.

7.2.7 Wisdom et al. (2005) - Mule Deer and Elk; ATV, Horseback, Mountain Bike, and Hiking

In a well-designed study, Wisdom et al. (2005) measured[24] effects of off-road recreation (ATV, horseback, mountain bike, and hiking activities) on mule deer and elk. Movement rates (i.e., associated with flight) were substantially higher for elk during the morning vs. afternoon disturbances for all four activities. This was attributed to elk moving away from the disturbance routes and avoiding them for the remainder of the day, which reduced the need for more travel and conserved energy, a finding also made by Naylor et al. (2009). Movement rates of elk during afternoon disturbances, however, stayed well above the rates observed during the periods of no human activity (control period). For morning disturbances, movement rates of elk were highest during ATV riding, second-highest during mountain bike riding, and lowest during hiking and horseback riding. Peak movement rates of elk during morning disturbances were highest for ATV riding (21 yds./min.), followed by mountain bike riding (17 yds./min.), and horseback riding and hiking (both about 15 yds./min.). In contrast, peak movement rates of elk during the control periods did not exceed 9 yards/minute. In contrast to elk, mule deer showed less change in movement rates during the four off-road activities compared to the control periods.

They estimated probability of elk flight from a human disturbance was highly dependent on distance. Higher probabilities of flight response occurred during ATV and mountain bike activity, in contrast to lower probabilities observed during hiking and horseback riding. Probability of a flight response declined most rapidly during hiking, with little effect when hikers were beyond 550 yards from an elk. By contrast, higher probabilities of elk flight continued beyond 820 yards from horseback riders, and 1,640 yards from mountain bike and ATV riders. Daytime movement rates of deer were higher, as compared to control periods, during mountain bike riding, horseback riding, and hiking, especially in the morning. Estimated probabilities of flight response for mule deer were nearly identical among all four activities and not significantly different for control periods, suggesting that deer were not exhibiting the same tendency for flight as shown by elk in relation to off-road activities.

Wisdom et al. (2005) concluded that off-road recreational activities appear to have a substantial effect on elk behavior. Animal energy budgets may be adversely affected by the additional energy required to flee from an off-road activity and from displacement from foraging habitat. In contrast to elk, mule deer showed little measurable response to the off-road disturbances. They speculated that deer may be responding to the treatments with fine-scale changes in habitat use, rather than substantial increases in movement rates and flight responses. For example, it is possible that deer may respond to an off-road activity by seeking dense cover, rather than running from the activity. Nevertheless, if mule deer are spending more time in dense cover, in reaction to any of the off-road activities, this could result in reduced foraging opportunities, and a subsequent reduction in opportunities to put on fat reserves during summer that are needed for winter survival.

7.2.8 Cassirer et al. (1992) - Elk, Cross-country Skiers

In northern Yellowstone Park, Cassirer et al. (1992) measured the immediate movements of adult female elk when disturbed by cross-country skiers to assess energy costs associated with movements and to identify factors influencing elk behavior. For this Crystal River analysis, results from one of the

[24] Electronically, using an automated telemetry system (to track animal movements) and GPS units (to track human movements), allowing control measurements to be made "blind," with no humans present.

three study areas (Mammoth Hot Springs) were excluded because those elk were habituated to humans (Crystal River elk are not habituated to humans). The median distance at which elk started to move in response to approaching skiers was 437 yards. The median distance that elk moved in response to skiers was 0.35 miles. After being disturbed, elk moved uphill, to steeper slopes, away from the road, and closer to trees. Distance moved was correlated with the distance to the nearest ridge and wind speed. Elk were displaced from the drainage for at least the duration of human presence and on average returned within two days. Elk responses did not seem to be affected by the total number of skiers, frequency of skier groups, or number of skiers in the first group. Energy expended moving away from skiers represented approximately 5.5% of an estimated average daily energy expenditure for elk in winter. This does not consider energy not gained as a result of lost foraging opportunities. Energy cost of movements increases exponentially with increasing snow depths (Parker et al. 1984) and would be most critical during winter, with reduced forage availability and when elk are in poor condition (Hobbs 1989). Cassirer et al. (1992) concluded that restricting cross-country skiers (or other recreational users) to locations >711 yards (or on the opposite side of a ridge) from elk wintering areas would probably minimize displacement of most non-habituated elk on shrub steppe winter range. Skiers (or other recreational users) would likely have to remain at distances of 0.35 miles to completely avoid disturbing elk. Locating recreational trails in areas with abundant topographic relief and providing wildlife security areas in drainages adjacent to where skiing occurs might minimize added energy costs and lost foraging opportunities.

7.2.9 George and Crooks (2006) - Bobcats, Coyotes, and Mule Deer; Snowfree Recreational Activities

George and Crooks (2006) investigated the relationship between human recreation and the spatial and temporal activity patterns of large mammals and mesocarnivores in an urban nature reserve. Results suggested that bobcats (*Lynx rufus*), and to a lesser degree coyotes (*Canis latrans*), exhibited both spatial and temporal displacement in response to human recreation. Bobcats were not only detected less frequently along trails with higher human activity, but also appeared to shift their daily activity patterns to become more nocturnal in high human use areas. Negative associations between bobcat and human activity were particularly evident for bikers, hikers, and domestic dogs. They did not find a clear and consistent pattern of avoidance of human recreation by mule deer, but the probability of detecting deer during the day was lower with increasing levels of human recreation.

7.2.10 Road Effects on Big Game Habitat Effectiveness - Summary

There have been thousands of studies examining the effects of highways and roads on wildlife and their habitats. Following Trombulak and Frissell (2000), the impacts of roads on wildlife may be grouped into seven categories: (1) mortality from road construction, (2) mortality from vehicle collisions, (3) modification of animal behavior, (4) disruption of the physical environment, (5) alteration of the chemical environment, (6) spread of exotic species, and (7) resulting changes in human use. As a synthesis of road effect issues most pertinent to the Crystal River trail project (categories 3 and 4, above), are the effects of roads on adjacent habitat effectiveness.

A number of studies have examined elk[25] response to roads. Vehicular use of roads adversely affects elk use of adjacent habitats (Burbridge and Neff 1976, Hershey and Leege 1976, Leege 1976, Marcum 1976, Perry and Overly 1976, Ward 1975, Ward et al. 1976, Hinschberger et al. 1978, Lyon 1979, Rost

[25] Hunted populations, non-habituated to humans.

and Bailey 1979, Johnson and Lockman 1981, Rowland et al. 2000). The same studies can be extrapolated generally to bighorn sheep and deer and more generally to the broader wildlife community. The zone of disturbance adjacent to roads that is avoided by elk has been reported as 220 yards to 1.8 miles, depending on the type and use of roads and the adjacent habitat. This zone is not completely abandoned by elk, but use of this area (i.e., the habitat effectiveness) may be reduced depending on a number of factors. Greater traffic volume on unpaved roads through more open habitats generally produces a wider zone of avoidance (Perry and Overly 1976, Hershey and Leege 1976, Rost and Baily 1979).

Habitat management guidelines for northern Idaho predict 10-70% reductions in elk use within 0.25 miles of open roads (Interagency Study Team 1977). One-quarter mile (1,320 yds.) is the distance most commonly used to assess the influence of proposed secondary roads, open to the public, on elk habitat effectiveness. Consistent with the other case studies above, it is not the roads themselves that elk avoid, but the disturbances associated with human activity along the roads. Elk show little or no avoidance of roads completely closed to vehicular traffic (Marcum 1976).

With respect to applying the above road effects studies to the Crystal River valley, those studies were conducted on "wild" elk herds. The hunted elk and deer in undeveloped areas of the Crystal River valley are not habituated to human activities to any extent; the bighorn sheep show some habituation in some areas and contexts. Based on the above, there is an existing zone of Highway 133 traffic disturbance that reduces adjacent wildlife habitat effectiveness (probably broadest for elk, followed by deer, and bighorn sheep) for 220 yards to one-quarter mile or more. Following Freddy et al. (1986) and Taylor and Knight (2003), as examples, the additional recreational use along a trail located within the existing highway disturbance corridor would likely have discountable additional contributions to habitat effectiveness that is currently impaired adjacent to the highway. Conversely, the recreational use zone of influence would be much greater for a new trail bisecting generally unused higher quality habitat, than for one closely paralleling and located within the existing Highway 133 disturbance corridor.

7.2.11 Case Studies Summary

The above case studies are examples of how wildlife respond to different recreational activities. The intent was not to provide evidence that one trail user group or another may be more problematic to wildlife, but to (1) educate the reader about how wildlife respond to different perceived threats and (2) provide examples of how <u>all</u> types of recreational activities can have negative effects on wildlife. Many other similar studies are available and some have been summarized in other Crystal River trail documents (e.g., Colorado Wildlife Science 2008, Wright 2015, 2017). Some of the older studies examining the wildlife-recreationist issue were used intentionally in this analysis to indicate how long (40+ years) the issue has been analyzed. Studies examining certain issues (e.g., the displacement of elk from roads) are no longer conducted because the issue has been “settled.” Additional studies are warranted, but they are not necessary to make decisions for proposed multi-use trails. While further studies would refine our knowledge of how wildlife respond to recreation, there already exists a large body of scientific evidence documenting the significant and varied impacts recreation and human use of the landscape can have on wildlife. Our existing knowledge is sufficient to understand the impacts potential trail alignments would have on wildlife in the Crystal River valley.

7.3 POTENTIAL TRAIL EFFECTS CONCLUSION

Section 6.0 described the wildlife groups and species present in the Crystal River valley. Section 7.0 described how recreational use can affect wildlife negatively. To reiterate from Section 7.1, it is the animal's displacement from otherwise effective habitat, the associated energetic expenditures, and the loss of foraging and resting time that represent the greatest negative effect of trails, not the direct loss of a few acres of habitat from a trail several feet wide, albeit miles long. In the few case studies detailed, mule deer avoided people on foot that were 103 yards (Taylor and Knight 2003) to 365 yards away (Freddy et al. 1986). Elk avoided hikers (Wisdom et al. 2005), skiers (Cassirer et al. 1992), and bikers (Wisdom et al. 2005) that were 550, 711, and 1,640 yards away, respectively.

Conservatively (for impact assessment) applying Taylor and Knight's (2003, Section 7.2.2) findings for deer (i.e., that habitat within 100m of trails would be "potentially unsuitable"[26] for wildlife due to disturbances from recreation) to the conceptual 20-mile-long Crystal River trail and applying their terminology, 1,591 acres[27] (or 2.49 mi.^{2}) of habitat surrounding the trail could be negatively affected. This area would likely be larger for elk and similar, or smaller, for sheep. This 300-foot zone of influence on each side of the trail is not biologically conservative. For example, the Pitkin County Land Use Code (Section 7-20-70, [d], 2) requires 1,000-foot to one-quarter mile setbacks to protect some wildlife habitat areas. With this consideration in mind, the Crystal River trail could have moderate, but relatively minor effects (with a Highway 133, Redstone Boulevard, and Hayes Creek bypass alignment) on wildlife habitats and ecological communities, largely resulting from the Hayes Creek bypass. The remainder of the trail located within the highway disturbance corridor would have minimal effects because of existing chronic traffic effects. Following similar assumptions and discounting the additional indirect trail effects adjacent to the Highway 133 (see Section 7.2.10) and Redstone Boulevard (see Section 6.3.9) trail segments, habitats affected by that alignment would be limited largely to approximately 111 acres[28] (or 0.17 mi.^{2}) associated with the 1.4-mile-long[29] Hayes Creek bypass. Alternatively, a trail corridor could have the largest, single, negative effect to wildlife habitats in the valley since Highway 133 was upgraded in the late 1960's (with highway segments, three trail sections east of the river [totaling 6.8 mi.], the Hayes Creek bypass [1.4 mi.], and the old McClure Pass switchbacks [2.8 mi.]) because of effects to 11.0 miles of trail located in currently buffered, isolated, interior, highly effective, and unfragmented habitats. Following the same assumptions, the collective off-highway trail alignments would affect 875 acres (or 1.37 mi.^{2}),[30] 7.9 times the area of the Highway 133/ Redstone Boulevard/ Hayes Creek bypass alignments.

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[26] In the author's opinion, this is an overstatement by Taylor and Knight (2003). More accurately, this zone of influence would experience reduced habitat effectiveness and habitat would remain suitable, though impaired to a certain extent.

[27] 200m * 3.281 ft./m = 656.2 ft. (656.2 ft. * 18 mi. * 5,280 ft./mi.)/ 43,560 ft^2/ac. = 1,591 ac. = 2.49 mi.^{2}. This assumes, simplistically, that all habitat within 100m of trails is currently functional, is occupied by animals, would be exposed to recreational disturbances along trails, does not have overlapping zones of influence, etc. While this quantification may be inexact, it provides relative quantifications of the habitat area that could be affected by trail use.

[28] 200m * 3.281 ft./m = 656.2 ft. (656.2 ft. * 1.4 mi. * 5,280 ft./mi.)/ 43,560 ft^2/ac. = 111 ac./640 ac./mi^2 = 0.17 mi.^{2}.

[29] As measured in this analysis.

[30] 200m * 3.281 ft./m = 656.2 ft. (656.2 ft. * 6.8+1.4+2.8 mi.) * 5,280 ft./mi.)/ 43,560 ft^2/ac. = 875 ac. = 1.37 mi.^{2}.

8.0 TRAIL RECOMMENDATIONS

This section considers potential sections of the Crystal River multi-use recreation trail identified in the West Elk Loop Scenic & Historic Byway Crested Butte to Carbondale Trail Feasibility Study (Newland Project Resources 2004) and summarizes their effects on wildlife and ecological resources. A trail alignment is identified that would have the least negative effects. As described above, the Newland trail alignments were used because they are the most recent specific trail alignments. Any specific route chosen by Pitkin County or the Forest Service may follow a slightly different alignment, however due to the topography and broad areas covered by wildlife habitat those differences are unlikely to affect the conclusions of this report. Mitigation measures to avoid, minimize, and mitigate negative effects are identified for the preferred alignment and for other potential trail sections that might be selected. To the extent this report is ambiguous or does not address certain matters, decision makers are encouraged to follow the recommendations of the local staff of the state wildlife management agency, Colorado Parks and Wildlife. They are the wildlife professionals who have spent the most time on the ground in the Crystal Valley.

8.1 POTENTIAL TRAIL SEGMENT WILDLIFE CONSIDERATIONS

8.1.1 Redstone Boulevard

The Redstone Boulevard bypass would have no meaningful, negative, direct or indirect effects on wildlife and the adjacent ecological community because it is an existing paved road, largely through existing development, that is currently functional as a share-the-road trail. Of all trail segments, it would have the least negative effects.

8.1.2 Highway 133 Corridor

In the most recent trail feasibility study to date, Newland Project Resources (2004) indicated that with the exception of Hayes Creek Canyon, where a potential 1.5 mile bypass was identified, a bike trail could be located alongside, or offset from, Highway 133 through the entire length of Pitkin County's Crystal River Trail analysis area (T. Newland, Newland Project Resources, pers. comm., Mar.23, 2017). A trail associated with the Highway 133 corridor would cross through some important wildlife habitats and result in direct and indirect habitat losses. However, all of the affected habitat would be within the highway's existing zone of influence where habitat effectiveness has already been reduced for most species and adjacent habitat generally avoided by most wildlife, including those species of greatest concern (sheep and elk). Locating trail activity disturbances within an existing disturbance corridor would minimize the additional disturbances to wildlife (e.g., Freddy et al. 1986, Taylor and Knight 2003). The new recreational activity that would occur along the trail adjacent to the highway ROW would appear as predictable benign disturbances that generally elicit less intense wildlife responses (e.g., Schultz and Baily 1978, MacArthur et al. 1982, Hamr 1988).

The Highway 133 trail alignment would provide the following advantages and benefits to wildlife:

1. It would locate the direct (trail construction) and indirect (trail use) trail effects almost entirely within[31] an existing, chronic, human activity corridor.

[31] With the possible exceptions of the two short bypasses near the top of McClure Pass to avoid erosive highway road cuts (see Section 8.1.4).

2. It would avoid all critical wildlife habitats that were not already impaired by existing highway traffic effects.
3. With the exception of the Hayes Creek bypass, the highway alignment would completely avoid introducing relatively high levels of human disturbance into currently buffered, isolated, highly effective, and large unfragmented blocks of critical wildlife habitat east of the river.
4. The highway trail alignment would bisect some important wildlife habitats and occur close to (within ¼ mile of) some critical habitats. Some direct disturbances associated with trail development along the highway could have negative effects on some wildlife species (e.g., potential removal of decadent cottonwoods used by nesting Lewis' woodpeckers). However, the highway trail alignment would almost entirely avoid the more concerning indirect effects associated with animal displacement from active trails (i.e., it would not expand the highway's existing zone of influence). There should be minimal, additional, recreational use displacement of big game from habitats flanking the highway if the trail is located within the highway's existing zone of disturbance. Therefore, the highway trail alignment would avoid the need for seasonal closures to protect critical and important wildlife habitats because local wildlife have already adapted to existing traffic effects (either through habitat abandonment or behavior modification) and the additional recreational use within the highway corridor should only have insignificant incremental disturbances.
5. The Highway 133 trail alignment would largely maintain the status quo for wildlife in the Crystal River valley and avoid considerable, significant, year-round impacts to critical sheep and elk habitats and impacts to imperiled and important habitats outside existing disturbance corridors supporting a high diversity of other plants, plant communities, and animal species.
6. The Highway 133 trail alignment would avoid the need to build new bridges across the Crystal River, which would fragment and bisect some locally broad areas of riparian habitat (e.g., up to 121 feet wide at the likely site of a bridge to access the north end of the CROS property).
7. The Highway 133 trail alignment would continue the impediment to public access to large blocks of trail-free and largely unused (by humans) NFS lands on the east side of the river containing critical and important wildlife habitats that could be impacted by the increased access and use provided by any trail alignments on the east side of the river.

8.1.3 Hayes Creek Canyon Bypass

The abandoned Bear Creek railroad grade, bypassing Hayes Creek Canyon, was identified as a potential off-highway trail segment because a trail could not be safely located along the highway through the canyon (Newland Project Resources 2004). There are important wildlife habitats (though none designated as critical by CPW) that would be bisected by the bypass trail in an area of approximately 111 ac. (0.17 mi.^{2}, see footnote 29) and other adjacent habitat that could be negatively affected by unintended consequences of the bypass trail (see the peregrine falcon and elk subsections in Section 6.3, above). Approximately 30% of that trail segment would be within one mile of an active peregrine falcon eyrie, occupied between March 15 and July 31. If it is determined, after further analysis, that a trail cannot be constructed thorough Hayes Creek Canyon adjacent to Highway 133, then the only alternatives are to either let trail users continue to follow the highway, as they do now, or construct the bypass, with immutable long-term commitments (see Section 8.2) to avoid, minimize, and mitigate negative impacts to vegetation and wildlife. Should the bypass alternative in the EIS be selected by the

Responsible Official, a Forest Plan amendment would be required to address the inconsistency with WRNF Management Plan Forest-wide, Wildlife, Standard 8 and possibly 9.[32]

8.1.4 Old McClure Pass Road Switchbacks

The old McClure Pass Road switchbacks are currently used to some extent year-round. Their use is limited by parking availability, winter snowpack on the trail, and the site's relative remoteness from recreationist starting points. There are important wildlife habitats (though none designated as critical by CPW) that are bisected by the switchbacks that could be negatively affected by increased trail use, including breeding birds and the elk, bald eagle, black bear, and moose habitats, described in Section 6.3, above.

Because a recreation trail could likely be located along the highway or as a share-the-road option (better for wildlife) from the southern intersection with the Hayes Creek Canyon bypass all of the way up to the McClure Pass summit, with the exception of two short trail sections near the summit where the trail would swing to the north around steep erosive highway cuts (Newland Project Resources 2004), impacts to wildlife would be minimized if the trail was associated with the highway. Such a trail would occur largely within habitats whose effectiveness is already compromised by highway effects. Improving and increasing use of the old McClure Pass Road switchbacks through largely effective habitat would negatively affect a moderate number of important wildlife species in an area of approximately 223 ac. (0.35 mi.^{2}).[33] This recommendation, which would avoid an expanded (i.e., from existing conditions) zone of influence in habitats adjacent to the trail (i.e., as of result of trail upgrading and increased recreational use) would be most valid if the existing switchback trail was decommissioned effectively. If that would not be the case, then the above recommendation may still make sense if future use of the switchbacks was limited to on-foot activities (i.e., bikes excluded, to maintain near current trail use levels) and increased use was not encouraged by increasing parking availability for hikers (or if existing parking opportunities were eliminated). If such use restrictions were not implemented and enforced, then it would likely be better for wildlife if no new trail segment was built along the highway (although the two short trail sections near the summit would still be needed), and trail use increased along the existing switchback alignment, because such use would occur mostly outside the winter period when most, but not all, of the important wildlife use occurs.

8.1.5 Trail Segments East of the Crystal River

In general, the three potential trail segments east of the Crystal River that would follow the existing railroad grade would have the greatest negative effects on wildlife and other ecological resources compared to other potential trail segments. The railroad grade would require some improvements, some local bypasses, and other improvements that could have similar, negative direct effects to some wildlife species as described for the Highway 133 trail development. However, the significant potential

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[32] Forest-wide, Wildlife, Standards 8 and 9 of the White River National Forest Management Plan specify the following related to peregrines:

> 8. Discourage land use practices and development that adversely alter the character of peregrine falcon hunting habitat or prey base within ten miles of the nest site and the immediate habitats within one mile of the nesting cliff.
>
> 9. Human activities will be restricted within one-half mile of the occupied peregrine falcon areas between March 15 and July 31 for nest sites, or July 1 to September 15 for hack sites.

[33] 200m * 3.281 ft./m = 656.2 ft. (656.2 ft. * 2.8 mi. * 5,280 ft./mi.)/ 43,560 ft^2/ac. = 223 ac./640 ac./mi^2 = 0.3 mi.^{2}. See assumptions in footnote 28.

wildlife impacts resulting from these trail segments would be (1) the new and/or farther displacement of wildlife from the new and/or increased use of the trail corridors through otherwise undisturbed and/or effective habitat (affecting hundreds of acres), (2) the associated energetic expenditures of displaced animals (Ward and Cupal 1979, MacArthur et al. 1982, Gabrielsen and Smith 1995), and (3) the loss of animal foraging and resting time (Hobbs 1989, Knight and Cole 1995a) in adjacent habitat along the trails. The effectiveness of approximately 541 acres (0.85 mi.) of habitat[34] would be affected adjacent to these three trail segments. These effects represent the greatest negative consequences of trail development, not the direct loss of a few acres of habitat from upgrading an existing trail, albeit miles long (Taylor and Knight 2003).

Habitats that would be bisected by potential trail segments east of the river, and those more extensive habitats on NFS lands farther to the east, are currently difficult for the public to access due to the river, intervening private property, and limited public access portals (e.g., Avalanche Creek Road). The river provides an effective barrier to public access and buffers and isolates human disturbances west of the river from the high value habitats to the east. Those habitats are used by a wide variety of wildlife <u>year-round</u>. Some of those habitats are considered seasonally critical to bighorn sheep and elk. The value of those habitats is not only due to the large and unfragmented habitats present, but also because their isolation and the lack of human disturbance that allows the habitats to be used effectively.

Seasonal closures of at least the RWP and J&F segments would be warranted to minimize human disturbance in bisected critical elk and sheep habitats.[35] The J&F closure should extend from October 1 to June 30[36] (8 months) to protect sheep and elk habitat use periods,[37] consistent with the current seasonal closure. The RWP closure should extend from December 1 to April 30 (5 months) to protect critical sheep habitat,[38] consistent with the current seasonal closure. The potential CROS segment would not bisect nor closely approach (within 1/4 mile)[39] any critical habitat and would have the least negative effects on wildlife of the three trail sections east of the river. However, while the seasonal closures would minimize human disturbance in critical habitats, seasonal closures are not 100% effective and it has been the consistent opinion of CPW DWMs and other wildlife professionals that closures are difficult to enforce and are not sufficiently effective to protect critical wildlife habitat use (see Sections 5.6, 5.7.2, and 8.2.2). It takes a relatively few closure violations and few people to alter wildlife behavior and habitat use. Furthermore, when the trails are open, the associated recreational disturbances will negatively affect habitat use of the broader wildlife community in affected habitats on each side of the trail.

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[34] 200m * 3.281 ft./m = 656.2 ft. (656.2 ft. * 6.8 mi. * 5,280 ft./mi.)/ 43,560 ft^2/ac. = 541 ac./640 ac./mi^2 = 0.85 $mi.^2$. See assumptions in footnote 28.

[35] In addition to the (1) elk winter concentration area and severe winter range (J&F) and (2) sheep winter concentration area (RWP) and migration corridor (J&F) bisected by these trail segments, they would also bisect non-critical, but important, sheep and elk winter range. While trail closures through such spatially limited habitats are warranted biologically, development in Pitkin County has not been required to avoid winter range, nor have trails through such habitats been closed to protect habitat values.

[36] This closure also apparently extends from May 30 to June 30 to protect current, undelineated elk calving use of Filoha Meadows.

[37] Sheep winter range and migration corridor; elk winter range, winter concentration area, and severe winter range.

[38] And to allow sheep access to the river during the winter, per the RWP Management Plan.

[39] While it is recognized that there is no one distance that would sufficiently buffer human effects from all wildlife use in all possible contexts, ¼ mile is used based on its use in the Pitkin County Land Use Code (7-20-70: Wildlife Habitat Areas) to protect important and critical wildlife habitats.

Trails east of the river would require the construction of new bridges across the Crystal River, which would fragment and bisect some locally broad areas of riparian habitat (e.g., up to 121 ft. wide at the likely site of a bridge to access the north end of the CROS property).

Trails east of the river would increase public access to large blocks of trail-free and largely unused (by humans) NFS lands on the east side of the river containing critical and important wildlife habitats that could be impacted by the increased access and recreational use.

8.1.6 Trail Siting Summary

Based on (1) the scientific literature, (2) prior Crystal River valley ecological analyses, (3) recommendations of wildlife professionals, (4) this updated wildlife-focused analysis, and (5) potential trail segments identified in the most recent trail feasibility study to date (Newland Project Resources 2004), the trail alignment that would have the least negative effects on wildlife and the ecological community would be an alignment located in existing, chronic, human activity corridors. As such, the trail should be located alongside, or offset from, Highway 133 through the length of Pitkin County's Crystal River Trail analysis area, to the extent possible. The Redstone Boulevard bypass would have no meaningful, negative, direct or indirect effects on wildlife because it is an existing road, largely through existing development, that is currently functional as a trail. If it is determined, after further analysis, that a trail cannot be constructed adjacent to Highway 133 through Hayes Creek Canyon, then the only alternatives are to either let trail users continue to follow the highway, as they do now, or construct and use the Hayes Creek bypass, with immutable long-term commitments (see Section 8.2) to avoid, minimize, and mitigate negative impacts to vegetation and wildlife). There are important wildlife habitats (though none designated as critical by CPW) that would be bisected by the Hayes Creek bypass trail and other adjacent habitats that could be negatively affected by the unintended consequences of the bypass trail.

The highway ROW locally supports habitats with high functional value to some wildlife species. However, there would be far fewer and less severe impacts to the wildlife community if the trail was located along and within the influence of a high speed highway rather than introducing eventually high levels of new trail use into generally unused (by humans), currently buffered and isolated, highly effective, and large unfragmented blocks of critical and important wildlife habitats east of the river. A highway trail alignment would preclude the need for new bridges crossing the river. New bridges would open public access to large blocks of trail-free and largely unused (by humans) NFS lands on the east side of the river containing additional critical and important wildlife habitats. Those habitats could be impacted by the increased access and use facilitated by trail alignments on the east side of the river. A highway trail alignment would also preclude the need for seasonal closures that are difficult to enforce and not 100% effective at protecting critical and important wildlife habitats.

8.2 RECOMMENDED MITIGATION MEASURES

This section provides measures and considerations that would avoid, minimize, and mitigate negative wildlife effects resulting from development and use of the Crystal River multi-use recreation trail. The measures address mostly "big picture" issues. More detailed measures, such as avoiding and buffering site-specific features (e.g., decadent cottonwoods supporting active Lewis' woodpecker nests, etc.), will presumably be developed following site-specific surveys associated with the EIS process. Throughout this section, recognize that (1) mitigation is a less desirable alternative to trail siting that does not avoid certain impacts and (2) that not all mitigation is 100% effective.

8.2.1 Trail Alignment within Existing Disturbance Corridors

For the reasons explained above in Section 8.1, it is a well-founded principal (e.g., Freddy et al. 1986 and Taylor and Knight 2003) that locating a trail (and, most importantly, its associated human activity) within an existing disturbance corridor greatly reduces potential wildlife impacts and minimizes the need for mitigation measures. Applicable mitigation measures and considerations associated with a highway trail alignment include:

1. Because a trail associated with the highway would be located within an existing zone of disturbance and generally affect habitat whose effectiveness has already been diminished by traffic effects and because the road is open year-round, the trail could be open year-round with only insignificant incremental disturbances associated with trail construction and recreational trail use.
2. Engineer and site the trail to protect riparian and wetland habitats flanking the Crystal River, riverbank soils, and water quality. Some impacts to those resources would likely still occur, but they should be minor relative to those associated with any new bridges that would be required to access trail alignments on the east side of the Crystal River and railroad grade upgrading where existing trail sections bisect riparian habitat and are closely associated with thee Crystal River. Depending on bridge locations, some could be located in particularly broad riparian corridors.
3. Public access to the west shoreline of the river should be allowed and designed only where the above resources could be protected adequately.
4. Even if the trail is located along the Highway 133 corridor, west of the river, the current seasonal closures and management policies associated with open space parcels east of the river should be continued to protect the functional values of those critical and important wildlife habitats and ecological communities.
5. Dogs accompanying their owners along the Highway 133 and Redstone Boulevard trail corridors should be leashed.

8.2.2 Seasonal Closures

Seasonal closures are a common management tool used to restrict disturbances to particularly important plants and animals during seasonally sensitive periods of growth and habitat use. For example, rare orchid habitat may be protected during growth, flowering, capsule maturation, and seed dispersal, after which the habitat can be grazed by cattle with little effect to the orchid population. Also, critical big game winter range may be closed to human use during winter, allowing that habitat use to occur without disturbances that would otherwise impair habitat effectiveness.

Because most trail alignments outside of the highway ROW would bisect important and critical wildlife habitats seasonal construction and use closures should be utilized if these trail segments are built. Because, almost without exception, wildlife managers find seasonal closures ineffective, this section is warranted. The author (Thompson) is not a resource manager. However, he has worked with CDOW/ CPW District Wildlife Managers throughout Colorado for 40 years, and he knows their consistent professional opinion that, in general, seasonal closures are not sufficiently effective to protect wildlife habitats. During the March, 2017 field surveys for this assessment, two of the three open space closures that were approached had relatively fresh human tracks entering them.

On paper, seasonal closures appear practical and should work, but to adequately maintain the effectiveness of wildlife habitat they require near 100% compliance. In general, closures are largely respected, at first, but over time, trail use and non-compliance increases. It takes a relatively small percentage of closure violations and few people to alter wildlife behavior and habitat use. As documented in Section 7.1, even minor, seemingly harmless human disturbances cause elevated heart rates that can result in relatively high energy expenditures (Stemp 1983, Chabot 1991, Canfield et al. 1999), which can lead to habitat avoidance, lowered body weight, increased starvation probabilities, increased susceptibility to predators, and smaller pre-winter body mass of offspring leaving them less fit for overwinter survival. Presently, managers cannot consider the multiple relevant independent variables and predict human disturbance frequency and intensity that would have X effect on wildlife habitat use. Nevertheless, in critical habitats, such violations can have appreciable negative effects. Closures are only as effective as the enforcement that accompanies them. This analysis makes no assumptions concerning how effective Pitkin County or the USFS might be at enforcing any seasonal closures associated with the Crystal Valley Trail. However, in similar critical habitats with seasonal closures around the state, even with enforcement, people still go into closures, go around signs, climb over gates, cut locks, etc. (see Sections 5.6.3 and 5.8). More locally relevant, a December 14, 2003 PCOST memo written by the Pitkin County wildlife biologist about wildlife concerns associated with a conceptual recreation trail crossing Filoha Meadows noted that "seasonal closures are very difficult to enforce." Additionally, the County biologist noted that he, the CDOW DWM (Kevin Wright), and the local USFS wildlife biologist (Phil Nyland) all observed numerous seasonal closure violations on other Crystal River open space parcels (see Section 5.7.2). Over the years, letters from six different CDOW/ CPW wildlife managers (see Sections 5.6 and 5.8) commented on the public's non-compliance with seasonal closures, their limited effectiveness and enforcement, how just a few violations can change and negatively affect big game winter range use, and they cited several examples. Based on the opinions of CDOW personnel the Crystal River Caucus (2007) concluded that trail segments bisecting critical wildlife habitats east of the river could not be justified because of the ineffectiveness of seasonal closures.

Former and current state personnel (Sections 5.6 and 5.8) also identified pragmatic difficulties involved with enforcing seasonal closures. It can be cost prohibitive to have an effective level of closure enforcement. Having enough enforcement to patrol an extensive open space system frequently enough is a considerable commitment. The most effective enforcement requires patrolling closures from dawn until dusk, every day of the week. It is difficult to catch violators on remote trail segments. Game cameras have caught people violating closures, but identifying them was difficult. Enforcement of more remote social trails that may develop elsewhere is even more difficult. They also found it difficult to aggressively enforce and prosecute violations. Courts are often reluctant to prosecute $50.00/ incident closure violations under increased workloads, time constraints of the courts, and higher priority cases when there are no human victims?

Given the distributions of critical and important wildlife habitats in the Crystal River valley and the consistent consensus of wildlife professionals that seasonal closures are often ineffective at protecting those wildlife values, locating multi-use trail segments east of the Crystal River increases the risk that Crystal Trail use will negatively impact wildlife populations. This risk is heightened given the declining status of the local bighorn sheep, mule deer, and elk populations[40].

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[40] Over the last 20 years, the local bighorn sheep population has declined by approximately 80% (see Section 6.3.1.2). The local deer population has declined by approximately 46% from the historical objective (Will et al. 2011) in the 1980's and 1990's and is now close to its lowest level in 40 years (see Section 5.8.4). The elk population is stressed (see Section 5.8.4) and below its herd objective with declining calf:cow ratios that will continue that declining population trend (Mao et al. 2013).

8.2.3 Off-highway Trail Segments

The mitigation measures below apply to all off-highway trail segments. Specific recommendations are provided for each trail segment further below.

8.2.3.1 General Recommendations

1. Locate trail segments on the alignments of existing trails (e.g., railroad grade, Hayes Creek bypass trail, and old McClure Pass road switchbacks) to minimize further direct habitat loss and reduced effectiveness of adjacent habitats. Although most of these trail segments are largely unused by humans because of restricted access, wildlife use of the bisected habitats will have already been altered somewhat by current seasonal levels of human use.

2. Limit trail construction (i.e., implement seasonal trail construction closures) bisecting critical and important wildlife habitats outside of the use periods identified by CPW (see Sections 6.3 and 10.2).

3. Implement and enforce seasonal trail use closures through critical and important wildlife habitats during periods of wildlife use, as identified by CPW. As described in Section 8.2.2, above, it is the consensus of wildlife professionals that seasonal closures will not be sufficiently effective to protect the wildlife values and there likely will be appreciable negative impacts resulting from trail use violations. Regardless of their efficacy, seasonal closures would be better than no closures. Specific closure periods are provided under individual trail sections. Seasonal closures should include:

   (a) A commitment in perpetuity by Pitkin County to fund and implement a level of seasonal closure enforcement that CPW considers sufficient to protect the target wildlife resources.

   (b) A commitment in perpetuity by Pitkin County to regularly survey all Crystal River trail segments to identify and promptly close social trails that develop on public and private lands as a result of new public access to those lands east of the Crystal River.

   (c) A commitment in perpetuity by Pitkin County to work with CPW to develop and implement adaptive management to resolve seasonal closure violations. Include in the adaptive management plan the ability to completely close the trail if seasonal closures are ineffective and not being complied with.

   (d) Install locked gates with restrictive fencing and signage on all access points to trail segments with seasonal closures to restrict and educate the public (e.g., what the closure period is, why the area is closed, penalties for violations, etc.). It is recommended that closure gates be installed on the west side or at the mid-span of any new bridges crossing the river and that gates and peripheral fencing be designed to effectively thwart access. Access across the two potential new bridges to the potential CROS trail segment could be effectively restricted with gated fencing,[41]

[41] Recognizing that the author is not an engineer.

although there may be some conflict with the highway's scenic status. Physically blocking committed user access to the RWP and J&F trail segments during the seasonal closures would be ineffective because of existing bridge and road access.

(e) Identify additional seasonal construction and use closures that might be needed to protect site-specific, plant, aquatic, animal, and habitat issues identified during EIS baseline surveys.

4. Prohibit all dogs on off-highway trail segments. Dogs on leashes generally present few conflicts with wildlife, but the compliance rate of dogs on leashes is generally very low.

5. Develop and maintain educational materials at trail access points. Some key issues to include are:

    (a) The biological needs for seasonal trail closures along the Crystal River trail.
    (b) That the trail bisects important wildlife habitats.
    (c) Users are required to stay on trails.
    (d) Users should be discouraged from approaching wildlife (do not approach big game closer than 100 yards) that causes them to become alert (and stop foraging) or flee (increasing energetic expenditures).
    (e) Recreationists should be aware of wildlife responses, such as alert distances, flight distances, the distances they may flee, increased stress levels, lost foraging opportunities, lost energy reserves, reduced survivorship, the possibility for reduced carrying capacity of public lands, and the fact that each additional user may have a small yet cumulative impact on the environment.
    (f) Maintain the educational material on the county's website and provide newspaper materials in advance of seasonal closure periods.

6. Consider increasing the penalty for seasonal closure violators to something that would change human behavior and encourage compliance.

8.2.3.2 Crystal River Open Space Segment

1. Construction Closures
    (a) A December 1st through March 31st construction closure of the entire CROS trail segment would be warranted because the entire trail segment would be located close to (within ¼ mile of) sheep winter range and the entire alignment would bisect elk and mule deer winter range.

2. Seasonal Trail Closures
    (a) The CROS trail segment would bisect elk and deer winter range. Development in Pitkin County has not been required to avoid such habitats, nor have trails through such habitats been closed to protect habitat values. However, trail closures through such spatially limited habitats are warranted biologically, particularly if the level of winter trail use could approach that of a high impact recreational use. Such a

seasonal trail closure to protect winter range should extend from December 1st through March 31st.

(b) Access across the two new bridges to the potential CROS trail segment could be effectively restricted with gated fencing, although there may be some conflict with the highway's scenic status.

8.2.3.3 Red Wind Point Segment

1. Construction Closures
   (a) A December 1st through March 31st construction closure of the entire RWP trail segment would be warranted because the entire alignment would bisect elk winter range and the entire trail segment would be located within ¼ mile of sheep winter range.

   (b) A May 15th through June 30th construction closure of the entire RWP trail segment would be warranted because the entire trail segment would be located within ¼ mile of a sheep production area.

2. Seasonal Trail Closures
   (a) Portions of the RWP trail segment would bisect a bighorn sheep winter concentration area (a critical habitat), and come within ¼ mile of severe winter range (a critical habitat) and sheep lambing polygons. Seasonal trail closures warranted to protect these habitats should extend from December 1st through March 31st to protect winter range and May 15th through June 30th to protect sheep lambing habitat.

8.2.3.4 Janeway and Filoha Meadows Segment

1. Construction Closures
   (a) A December 1st through March 31st construction closure of the entire J&F trail segment north of Redstone Boulevard would be warranted because that segment would (1) bisect or be located within ¼ mile of sheep winter range, (2) the entire alignment would bisect elk winter range, (3) portions of the alignment through Janeway Flats, Avalanche Creek, and Filoha Meadows would bisect and come within ¼ mile of elk winter concentration area (a critical habitat), and (4) portions of the alignment through Avalanche Creek would bisect and come within ¼ mile of elk severe winter range (a critical habitat).

   (b) October 15th through November 30th and April 15th through May 30th construction closures of the J&F trail segment in the vicinity of The Narrows would be warranted to protect the bighorn sheep migration corridor.

   (c) A May 15th through June 30th construction closure of the J&F trail segments in the vicinity of Avalanche Creek and Filoha Meadows would be warranted to protect those two sheep production areas.

(d) In summary, construction closures to avoid critical and sensitive sheep habitats would allow construction of the J&F trail segment to occur from July 1 to October 14.

1. Seasonal Trail Closures
   (a) Portions of the J&F trail segment would come within ¼ mile of bighorn sheep winter concentration area (a critical habitat), severe winter range (a critical habitat), and sheep lambing polygons. Seasonal trail closures warranted to protect these habitats should extend from December 1st through March 31st to protect winter range and May 15th through June 30th to protect sheep lambing habitat.

   (b) Portions of the J&F trail segment would bisect and come within ¼ mile of elk winter concentration area (a critical habitat) and severe winter range (a critical habitat). Seasonal trail closures warranted to protect these habitats should extend from December 1st through March 31st.

2. Other Mitigation
   (a) North of Avalanche Creek Road and south of Janeway flats, there is a ridge that drops steeply down to the Crystal River. The railroad grade cut through the toe of this ridge. The ridge sloughs boulders, cobble, and soil onto the old grade. It is unknown if this site warrants geologic hazard status or if the bypass identified in Newland (2004) over the saddle into Avalanche Creek was to avoid private lands. However, the potential trail segment identified in Newland (2004) avoids the old railroad grade. A trail segment following the old railroad grade around the point, reinforced with a retaining wall or other engineering, would keep the trail out of bighorn sheep winter range, along the existing Avalanche Creek Road, away from the bypass's close (approx. 171 ft.) approach to bighorn winter concentration area and SWR polygons, and avoid creating a new disturbance corridor.

8.2.3.5 Hayes Creek Canyon Bypass

1. Construction and Seasonal Trail Closures
   (a) The potential Hayes Creek Canyon bypass bisects elk winter range that would be better protected with December 1st through March 31st construction and seasonal use closures. This trail segment on NFS land would also be governed by the WRNF Forest Plan, Forest-wide, Wildlife Standards 8 and 9 related to peregrine falcons (see Section 6.3.5). If this trail segment is rationalized and approved (requiring a Forest Plan Amendment explaining the Selected Alternative's inconsistency with Standard 8, it would be consistent with Standard 9 if human activities were restricted within one-half mile of the occupied peregrine falcon eyrie between March 15 and July 31. The early part of the nesting period is most sensitive.

8.2.3.6 Old McClure Pass Road Switchbacks

1. Construction Closures
   (a) A December 1st through March 31st construction closure of the lower one-half of the old McClure Pass Road switchbacks would be warranted because it bisects elk winter range.

2. Seasonal Trail Closures
   (a) The old McClure Pass Road switchbacks bisect elk winter range that would be best protected with a December 1st through March 31st seasonal use closure.

3. Other Mitigation
   (a) Hiker, snowshoer, and Nordic use of the old McClure Pass Road switchbacks is largely governed by parking availability. If desired, those uses could be reduced for the benefit of wildlife (e.g., wintering elk, breeding birds, and other mapped wildlife) by the removal of the small defacto parking area near the base. Conversely, expanded parking would increase on-foot use and increase the seasonal displacement of wildlife.

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10.0 APPENDICES

10.1 PCOST AERIAL PHOTOGRAPHIC MAPPING OF THE CRYSTAL RIVER TRAIL CORRIDOR

Aerial photographic mapping of the Crystal River Trail corridor that was developed by PCOST for their January, 2017 public open house meetings is provided in Figures 11-1 to 11-10, below. These maps show greater detail of corridor sections than the larger scale wildlife mapping. Map index as follows.

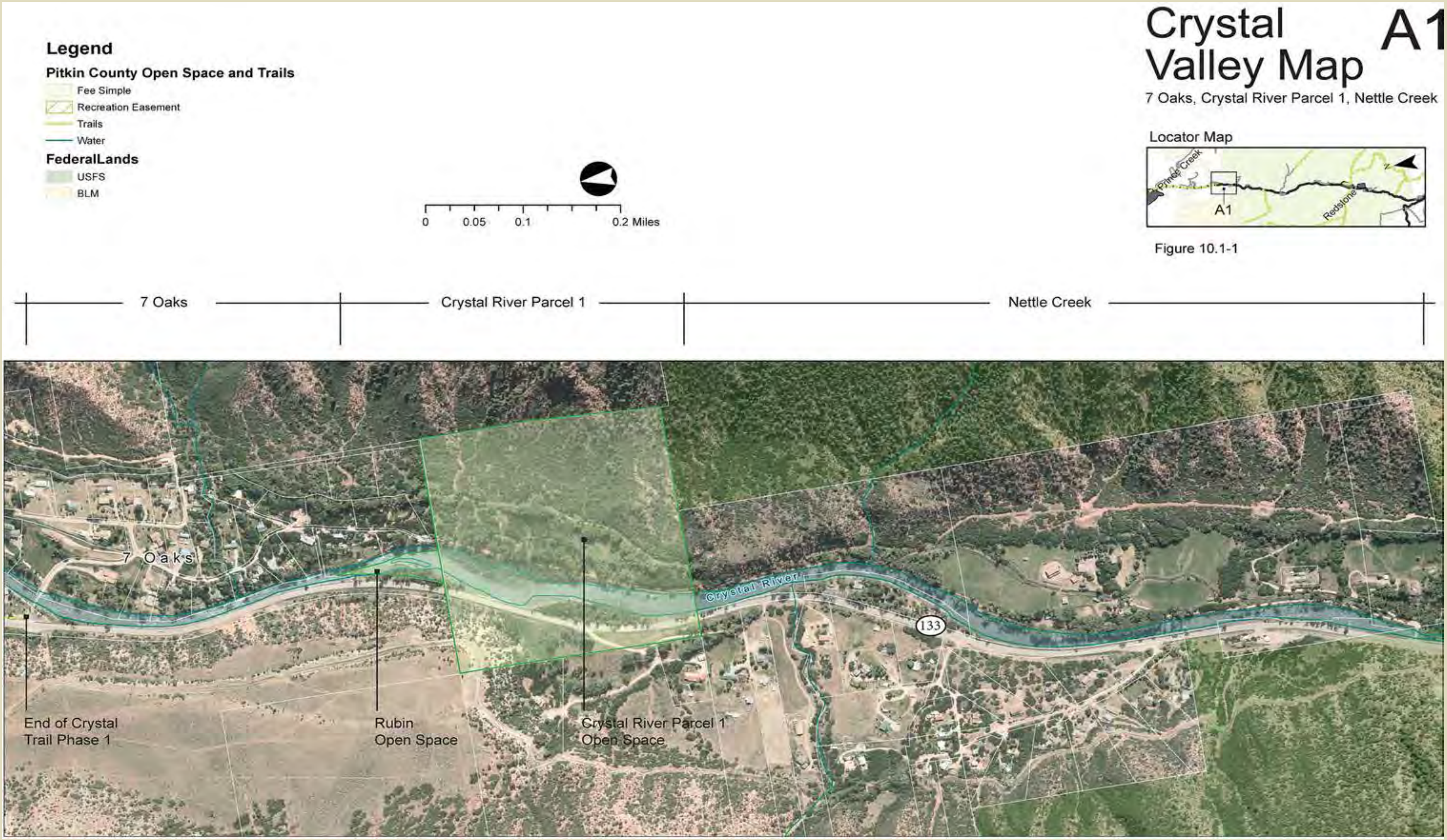

Figure 10.1-1. Crystal Valley Map A-1, 7 Oaks, Crystal River Parcel 1, and Nettle Creek.

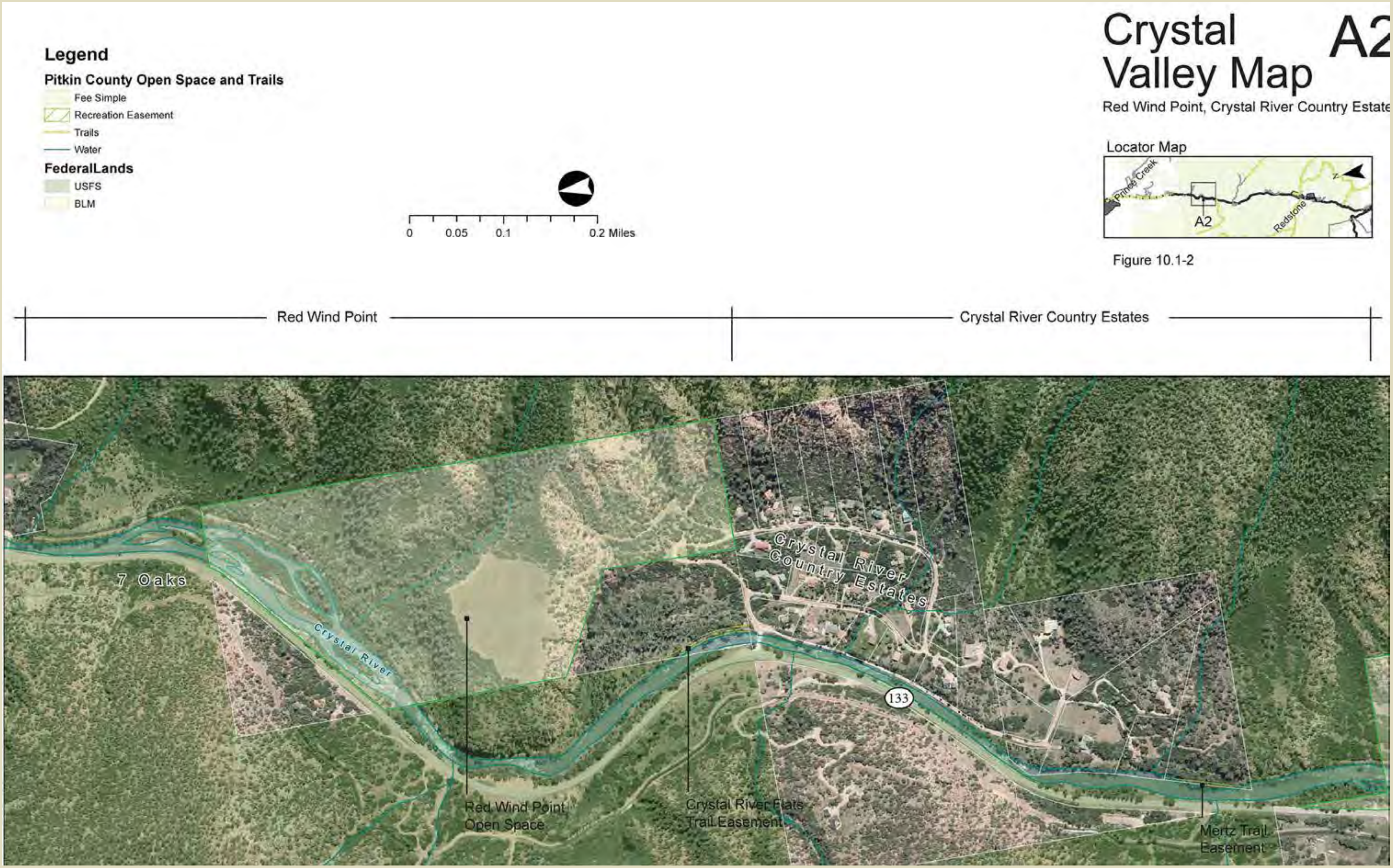

Figure 10.1-2. Crystal Valley Map A-2, Red Wind Point, Crystal River Country Estates.

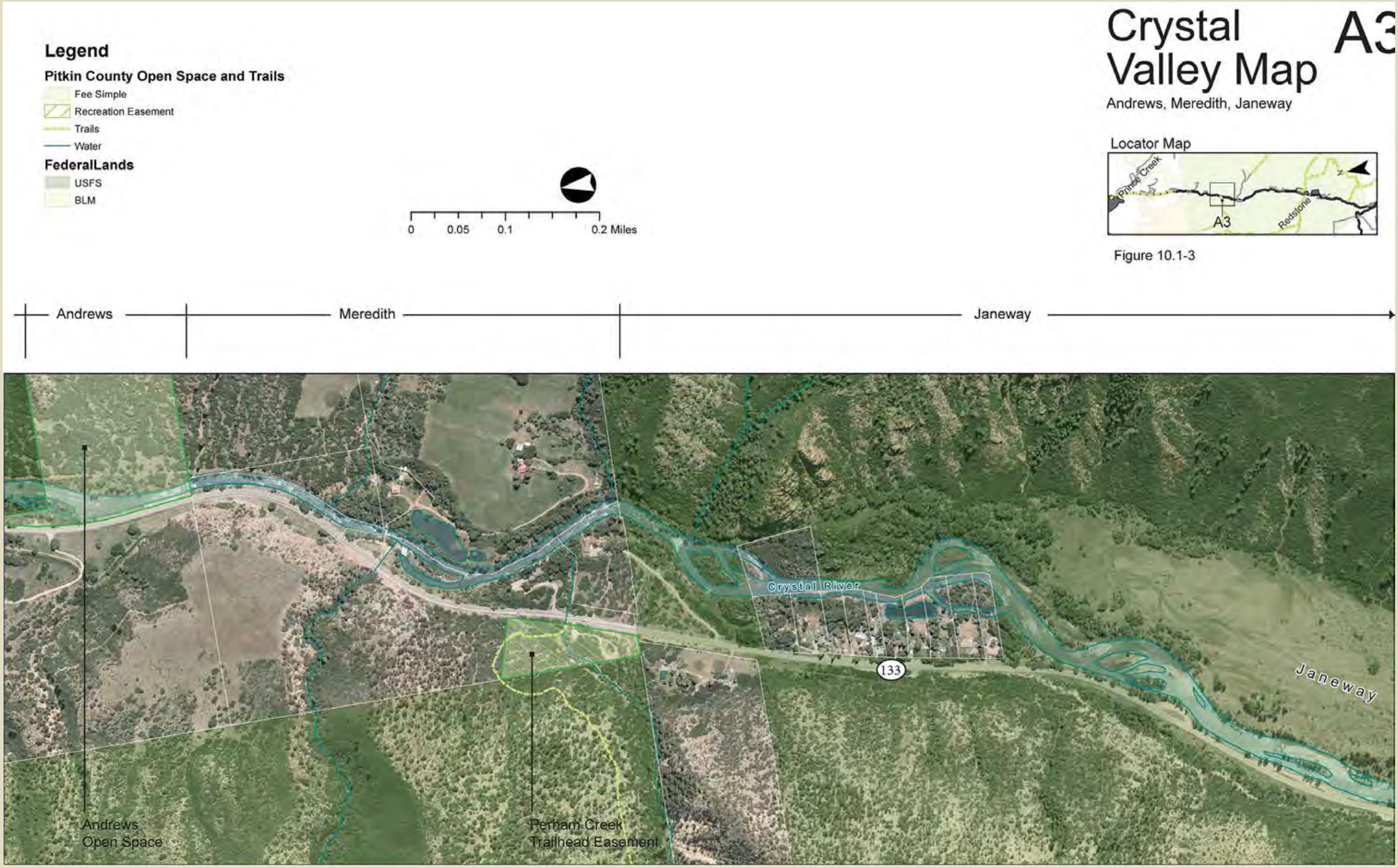

Figure 10.1-3. Crystal Valley Map A-3, Andrews, Meredith, Janeway.

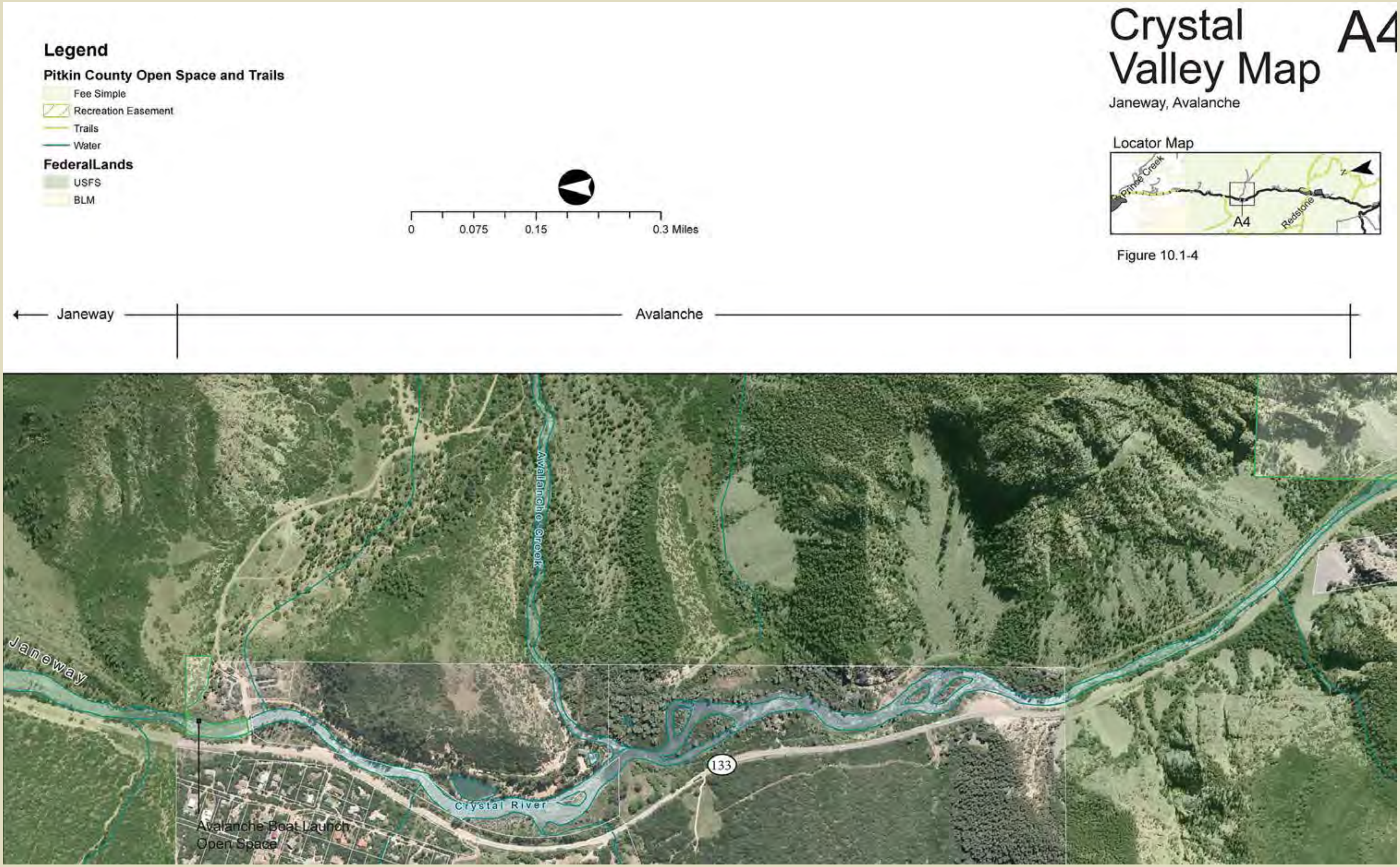

Figure 10.1-4. Crystal Valley Map A-4, Janeway, Avalanche.

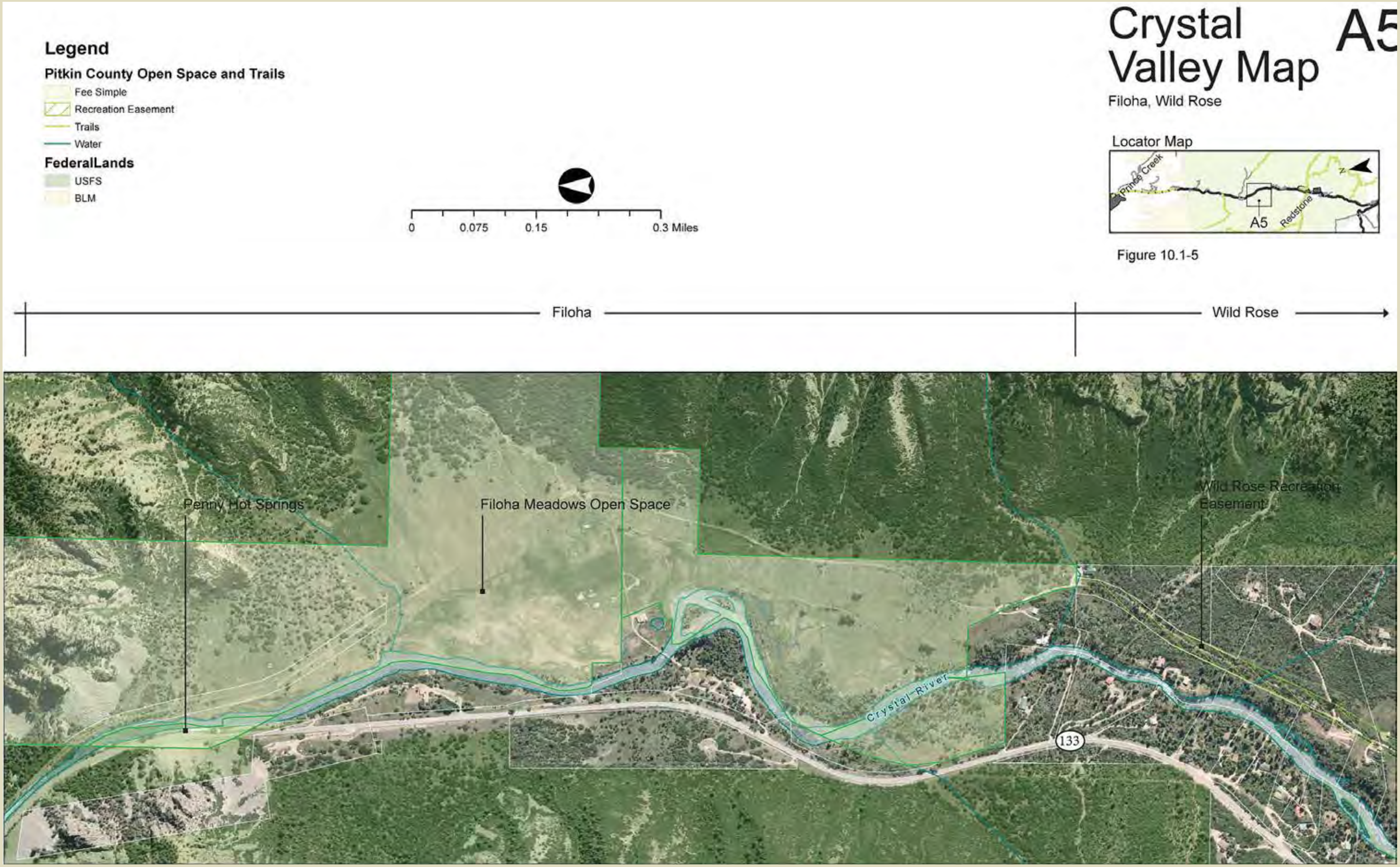

Figure 10.1-5. Crystal Valley Map A-5, Filoha, Wild Rose.

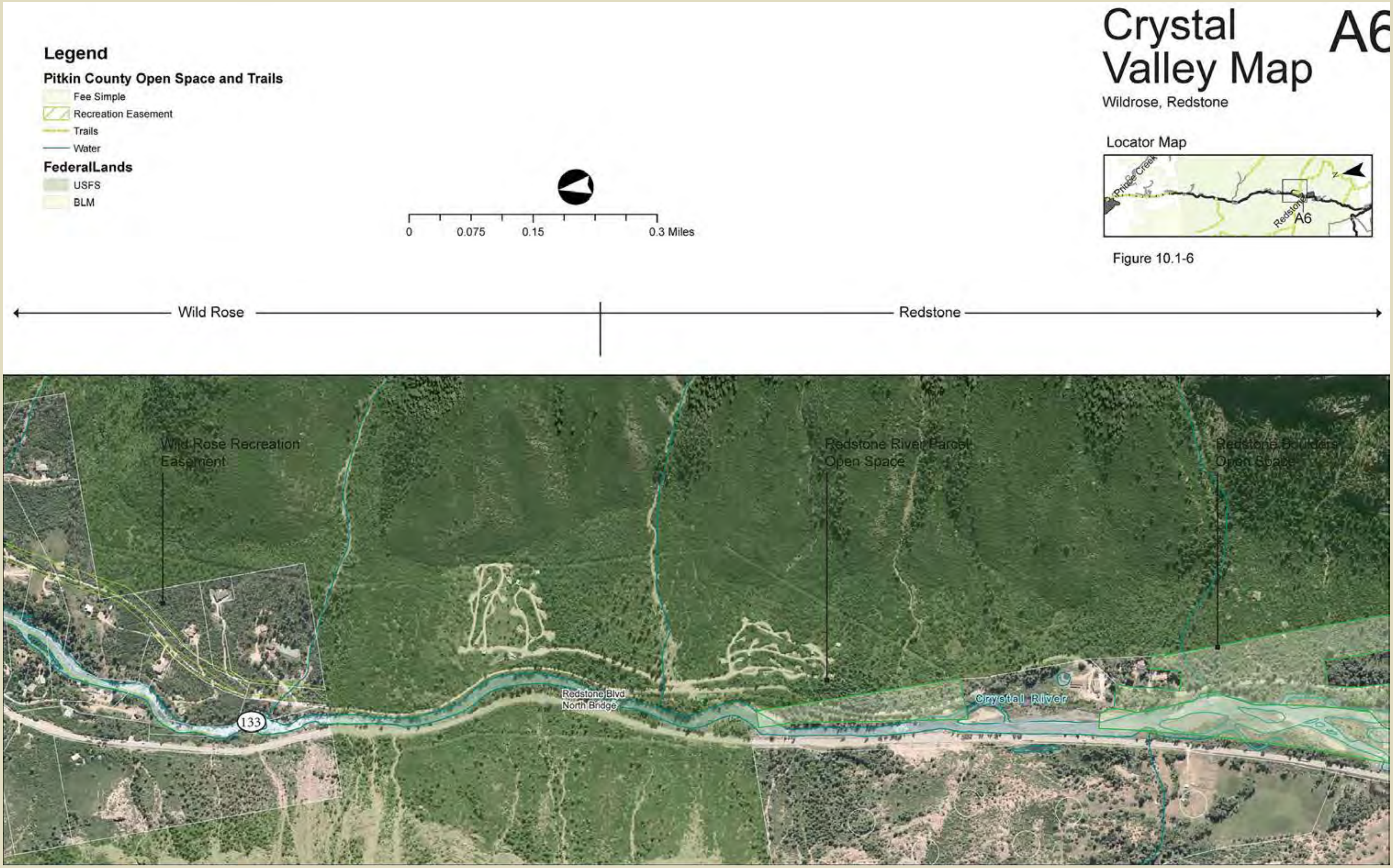

Figure 10.1-6. Crystal Valley Map A-6, Wild Rose, Redstone.

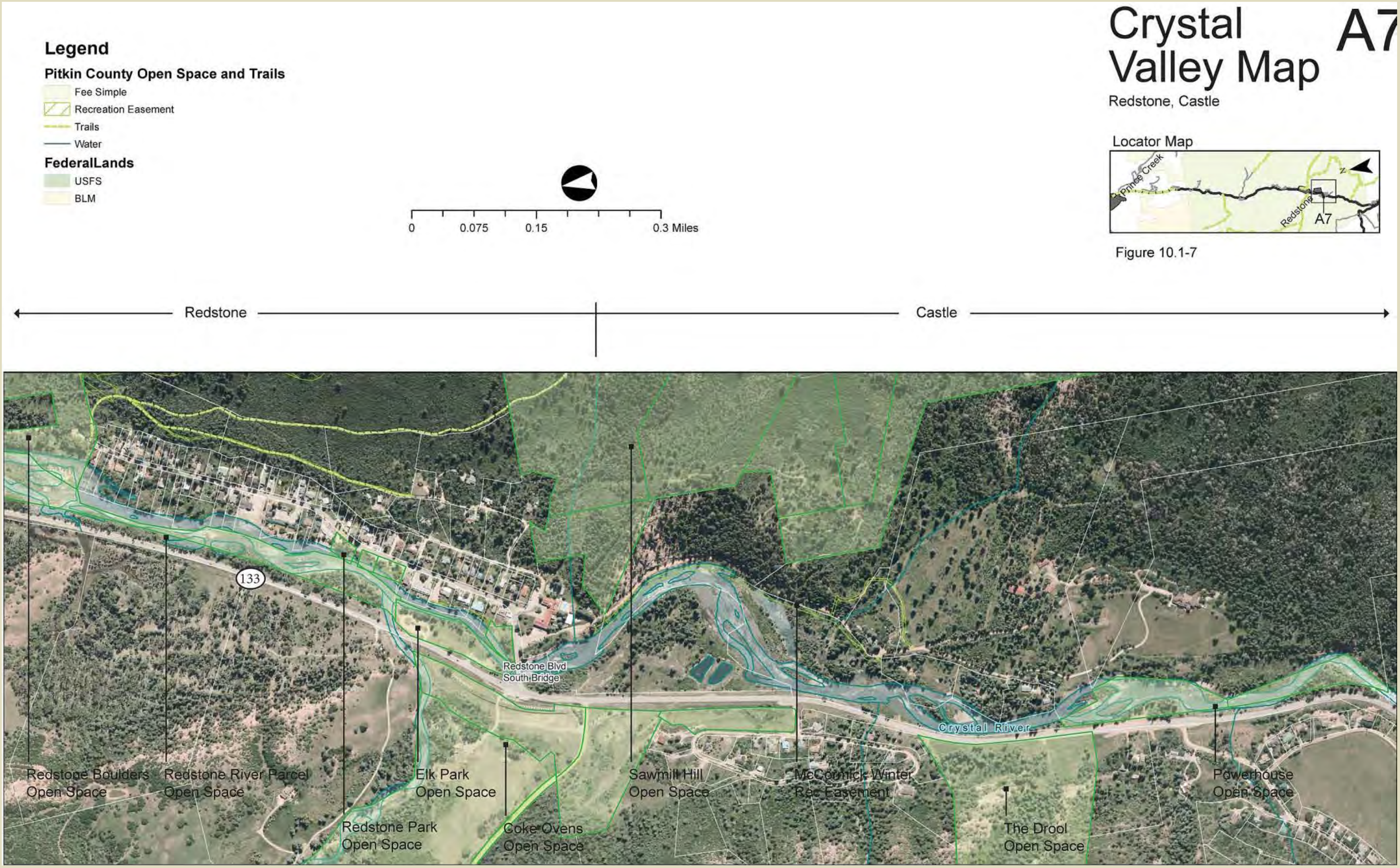

Figure 10.1-7. Crystal Valley Map A-7, Redstone, Castle.

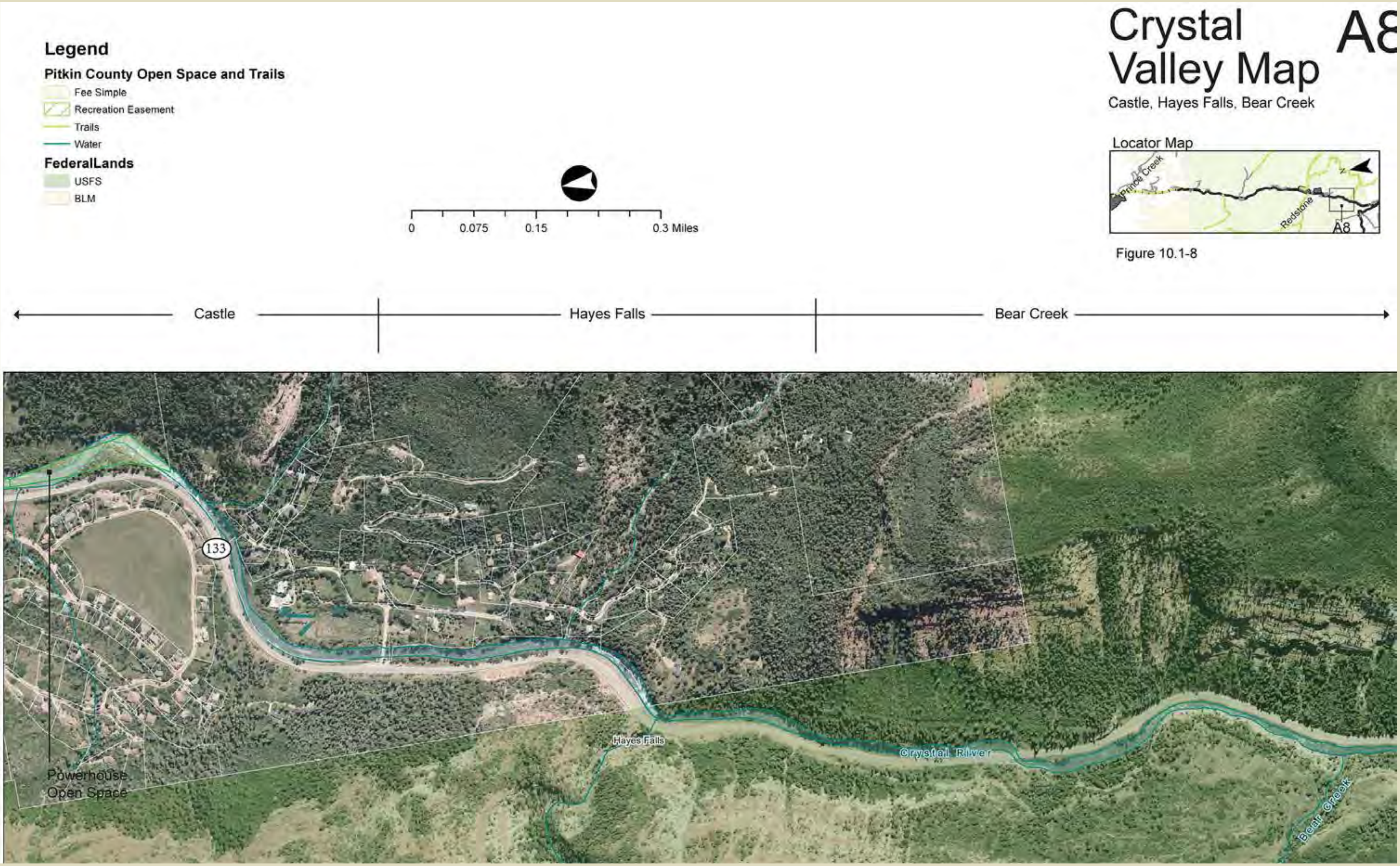

Figure 10.1-8. Crystal Valley Map A-8, Castle, Hayes Falls, Bear Creek.

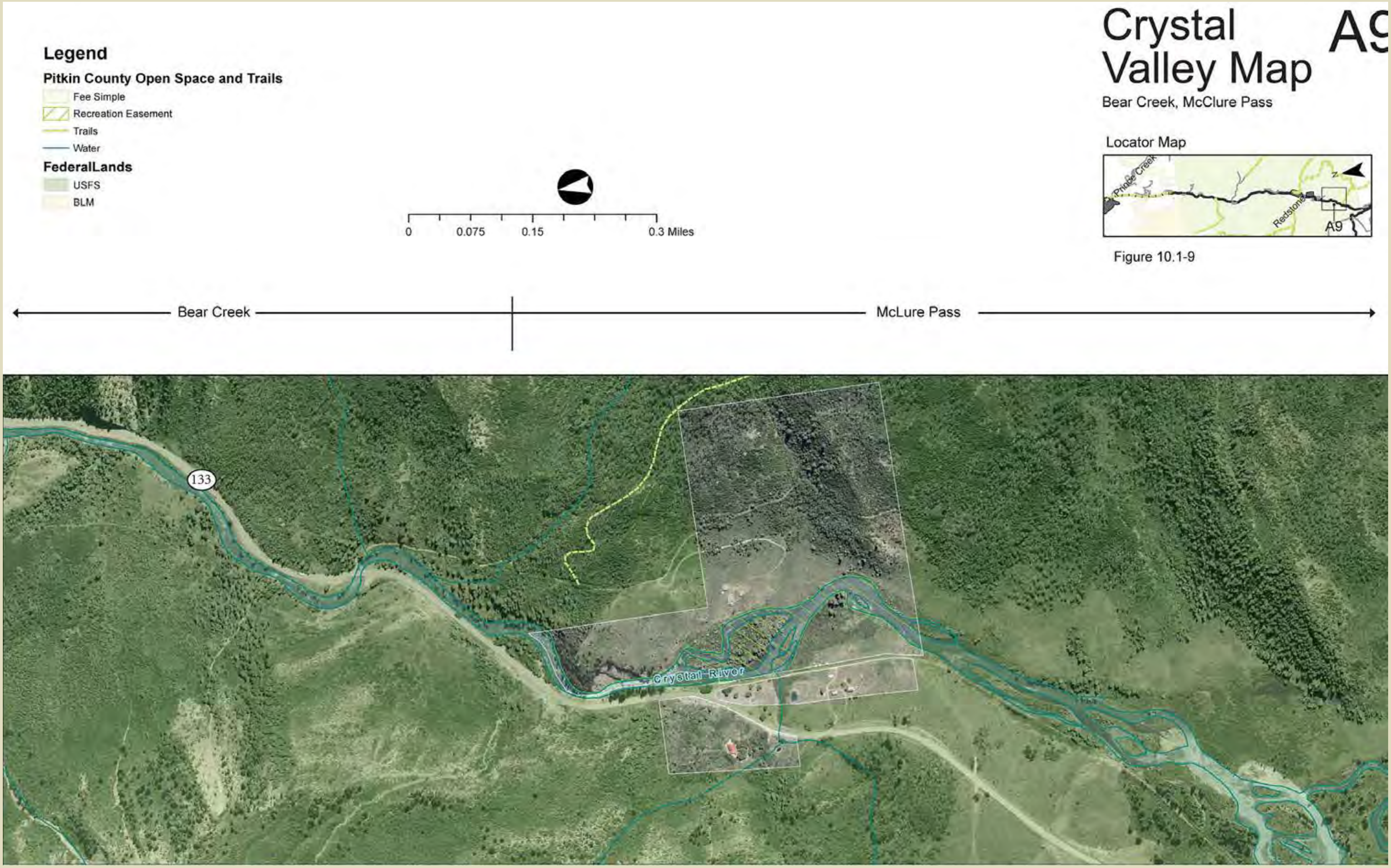

Figure 10.1-9. Crystal Valley Map A-9, Bear Creek, McClure Pass.

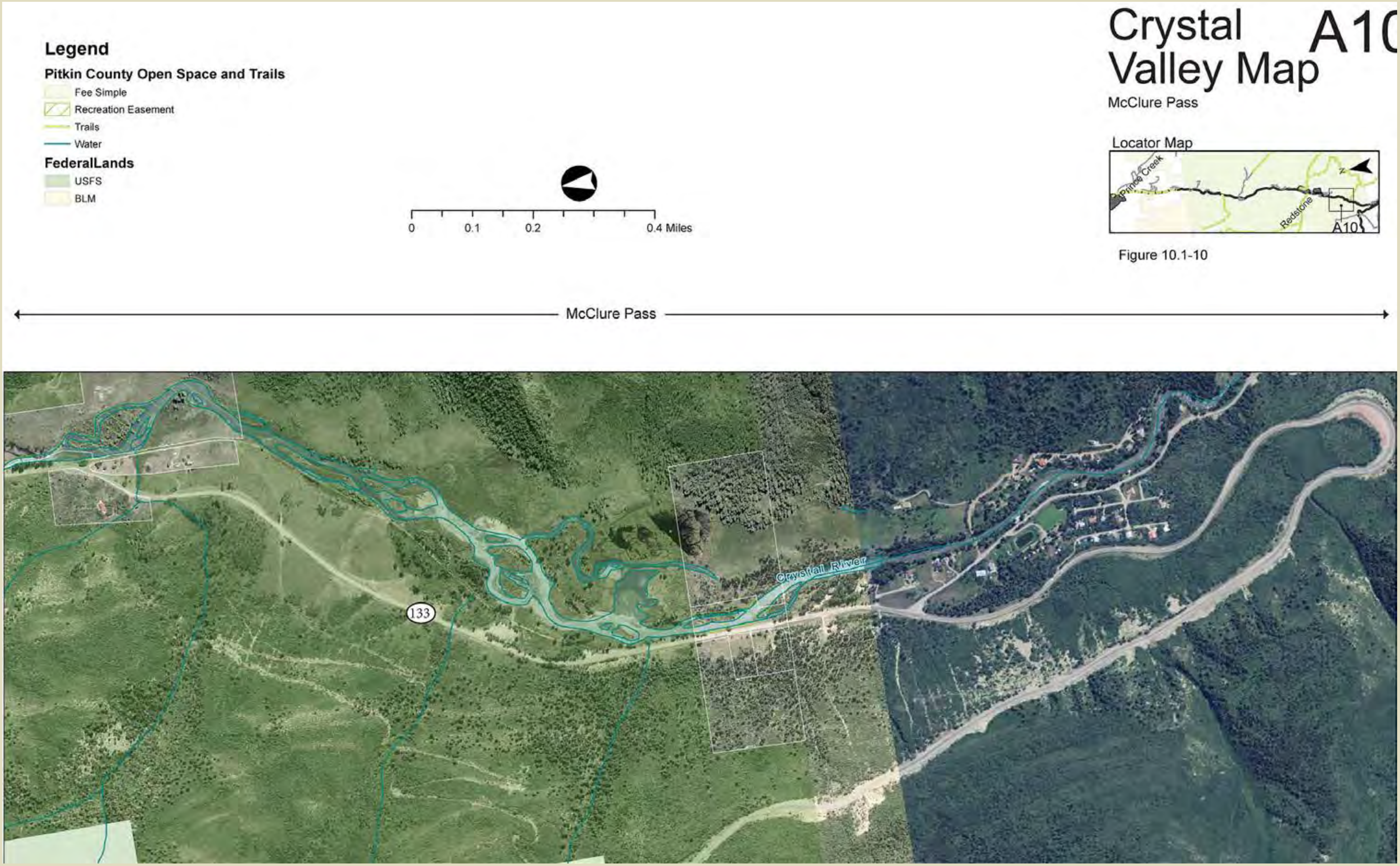

Figure 10.1-10. Crystal Valley Map A-10, McClure Pass.

10.2 COLORADO PARKS AND WILDLIFE SEASONAL WILDLIFE ACTIVITY AREA DEFINITIONS

The following wildlife species have seasonal ranges overlapping proposed Crystal River Trail corridor sections B and C. Seasonal activity area definitions and use dates, below, are those obtained from the CPW website and are applicable generally statewide. Some dates were defined more accurately for the local Data Analysis Units (i.e., the local management areas) by the local DWM (J. Groves, pers. comm., Mar. 27, 2017) and the Terrestrial Biologist, per CPW direction. Other use periods are provided based on anecdotal observations by identified knowledgeable parties.

Species are listed in declining order of significant potential trail effects along the bottom of the Crystal River Valley. Bighorn sheep and elk are the species of particular concern. The order of the remaining species is somewhat arbitrary. Other habitats of these CPW-mapped species may also be affected outside of the Crystal River valley bottom.

10.2.1 Rocky Mountain Bighorn Sheep

Migration Corridor: A specific mappable site through which large numbers of animals migrate and loss of which would change migration routes. Overall sheep use of the local corridor through The Narrows occurs from November 15 to May 1, with ram use extending from November 15 to December 31, all dates inclusive.

Migration Patterns: A subjective indication of the general direction taken by migratory ungulate herds.

Mineral Lick – Specific natural sites known to be utilized by bighorn sheep for obtaining minerals to meet basic nutritional needs. The use period is not specified by CPW data. Lick use typically starts mid-June, peaks the first week of July, then tapers off asymptotically, depending upon how much socialization is involved (e.g., Thompson 1981). Local use of the licks has been observed as late as mid-August. Radio-collar data have shown extended movements over a several days from high summer range, down to the mineral licks, and back to the high summer range.

Production area: That part of the overall range of bighorn sheep occupied by pregnant females during a specific period of spring. This period is May 1 to June 30 for Rocky Mountain bighorn sheep.

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.

Summer Concentration Area: Those areas where bighorn sheep concentrate from mid-June through mid-August. High quality forage, security, and lack of disturbance may be characteristic of these areas to meet the high energy demands of lactation, calf rearing, antler growth, and general preparation for the rigors of fall and winter.

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.

Water Source: Water sources known to be utilized by bighorn sheep in dry, water scarce areas. Up to a 1.6 km radius should be described around a point source, and up to a 1.6 km band be drawn along a river or stream.

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.

Winter Range: That part of the overall range where 90 percent of the individuals are located during the average five winters out of ten from the first heavy snowfall to spring green-up, December 1 to April 30, dates inclusive, for this DAU.

10.2.2 Elk

Highway Crossing: Those areas where elk movements traditionally cross roads, presenting potential conflicts between elk and motorists.

Limited Use Area: An area within the overall range which is occasionally inhabited by elk and/or contains a small scattered population of elk.

Migration Corridor: A specific mappable site through which large numbers of animals migrate, the loss of which would change migration routes. Local use of this corridor has been defined as October 15 to November 30 and April 15 to May 30, all dates inclusive.

Migration Patterns: A subjective indication of the general direction taken by migratory ungulate herds.

Overall Range: The area which encompasses all known seasonal activity areas within the observed range of an elk population.

Production Area: That part of the overall range of elk occupied by the females from May 15 to June 15 for calving, (May 15 to June 21 as currently applied in the Pitkin County Code). Based on the Vail elk study (Phillips [1998] and Phillips and Alldredge [2000]), May 1 to July 1 would be a more biologically conservative closure period, allowing cows to select optimal calving sites, accommodating early and late calves, and including initial elk rearing when calves develop physically to where they can travel with their cow. Only known areas are mapped and this does not include all production areas for the DAU.

Resident Population: An area used year-round by a population of elk. Individuals could be found in any part of the area at any time of the year; the area cannot be subdivided into seasonal ranges. It is most likely included within the overall range of the larger population.

Severe Winter Range: That part of the range of a species where 90 percent 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. The winter of 1983-84 is a good example of a severe winter.

Summer Concentration Area: Those areas where elk concentrate from mid-June through mid-August. High quality forage, security, and lack of disturbance are characteristics of these areas to meet the high energy demands of lactation, calf rearing, antler growth, and general preparation for the rigors of fall and winter.

Summer Range: That part of the range of a species where 90% of the individuals are located between spring green-up and the first heavy snowfall, or during a site-specific period of summer as defined for each

DAU. Summer range is not necessarily exclusive of winter range; in some areas winter range and summer range may overlap.

Winter Concentration Area: That part of the winter range of a species 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.

Winter Range: That part of the overall range of elk where 90% of the individuals are located during the average five winters out of ten from the first heavy snowfall to spring green-up, December 1 to April 1, dates inclusive, for this DAU.

10.2.3 Mule Deer

Concentration Area: That part of the overall range where higher quality habitat supports significantly higher densities than surrounding areas. These areas are typically occupied year round and are not necessarily associated with a specific season. Includes rough break country, riparian areas, small drainages, and large areas of irrigated cropland.

Highway Crossing: Those areas where mule deer movements traditionally cross roads, presenting potential conflicts between mule deer and motorists.

Limited Use Area: An area within the overall range of mule deer that is only occasionally inhabited and/or contains only a small population of scattered mule deer.

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

Migration Patterns: A subjective indication of the general direction taken by migratory ungulate herds.

Overall Range: The area that encompasses all known seasonal activity areas within the observed range of a mule deer population.

Resident Population: An area that provides year-round range for a population of mule deer. The resident mule deer use all of the area all year; it cannot be subdivided into seasonal ranges although it may be included within the overall range of the larger population.

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.

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 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.

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, December 1 to April 30, dates inclusive, for this DAU.

10.2.4 Bald Eagle

Winter Range: Winter range is defined as those areas where bald eagles have been observed between November 15 and April 1.

Winter Foraging Area: Winter foraging areas are defined as areas frequented by wintering bald eagles between November 15 and March 15.

10.2.5 Peregrine Falcon

Nesting Area: Nesting area is defined as an area that includes good nesting sites and contains one or more active or inactive nest locations. The boundaries are drawn based on professional judgment to include most known nesting habitat in the vicinity. Usually these areas are mapped as polygons around cliffs and include a 0.5 mile buffer surrounding the cliffs. The specific nesting use period was not provided by CPW. According to Jerry Craig, the former CDOW Raptor Biologist (ret.), eggs are laid as early as April 15, young hatch mid- to late May, and fledge in mid- to late June (Craig 1978). So, the most important nesting period would be April 15-June 30. This does not include courtship or post-fledging use of the area.

Potential Nesting Area: Potential nesting is defined as an area which appears to include the necessary components for peregrine falcon nesting, but in which no known active or inactive nest sites are present.

10.2.6 Black Bear

Fall Concentration Area: Fall concentration areas are defined as those parts of the overall range that are occupied from August 15 until September 30 for the purpose of ingesting large quantities of mast and berries to establish fat reserves for the winter hibernation period.

Human Conflict Area: Human/bear conflict areas are defined as that portion of the overall range where two or more confirmed black bear complaints per season were received which resulted in CPW investigation, damage to persons or property (cabins, tents, vehicles, etc.), and/or the removal of the problem bear(s). This does not include damage caused by bears to livestock.

10.2.7 Moose

Concentration Area: That part of the range of a species where densities are 200% higher than the surrounding area during a specific season. This definition is vague. Ungulate concentration areas are usually specified as summer or winter.

Winter Range: That part of the overall range where 90% of the individuals are located during the winter months, November 15 to April 1.

10.2.8 Wild Turkey

Winter Range: Defined as that part of the overall range where 90% of the individuals are located from November 1 to April 1 during the average five winters out of ten.

10.3 COLORADO PARKS AND WILDLIFE-MAPPED SPECIES

Eight[42] wildlife species mapped by CPW have seasonal ranges overlapping proposed Crystal River Trail corridor sections B and C. Activity area definitions and seasonal use dates are described above in Section Appendix 10.2. The bighorn sheep (Figs. 10.3-1 to 10.3.3), elk (Figs. 10.3-4 to 10.3.6), and peregrine falcon (Fig. 10.3-15) figures show buffer zones and setbacks that have been used in Pitkin County to avoid critical and other important wildlife habitats. Map index as follows.

[42] Other wildlife species (e.g., mountain goat and lynx) mapped by CPW have seasonal ranges overlapping portions of the Crystal River watershed, but they are not focal species of concern on this project.

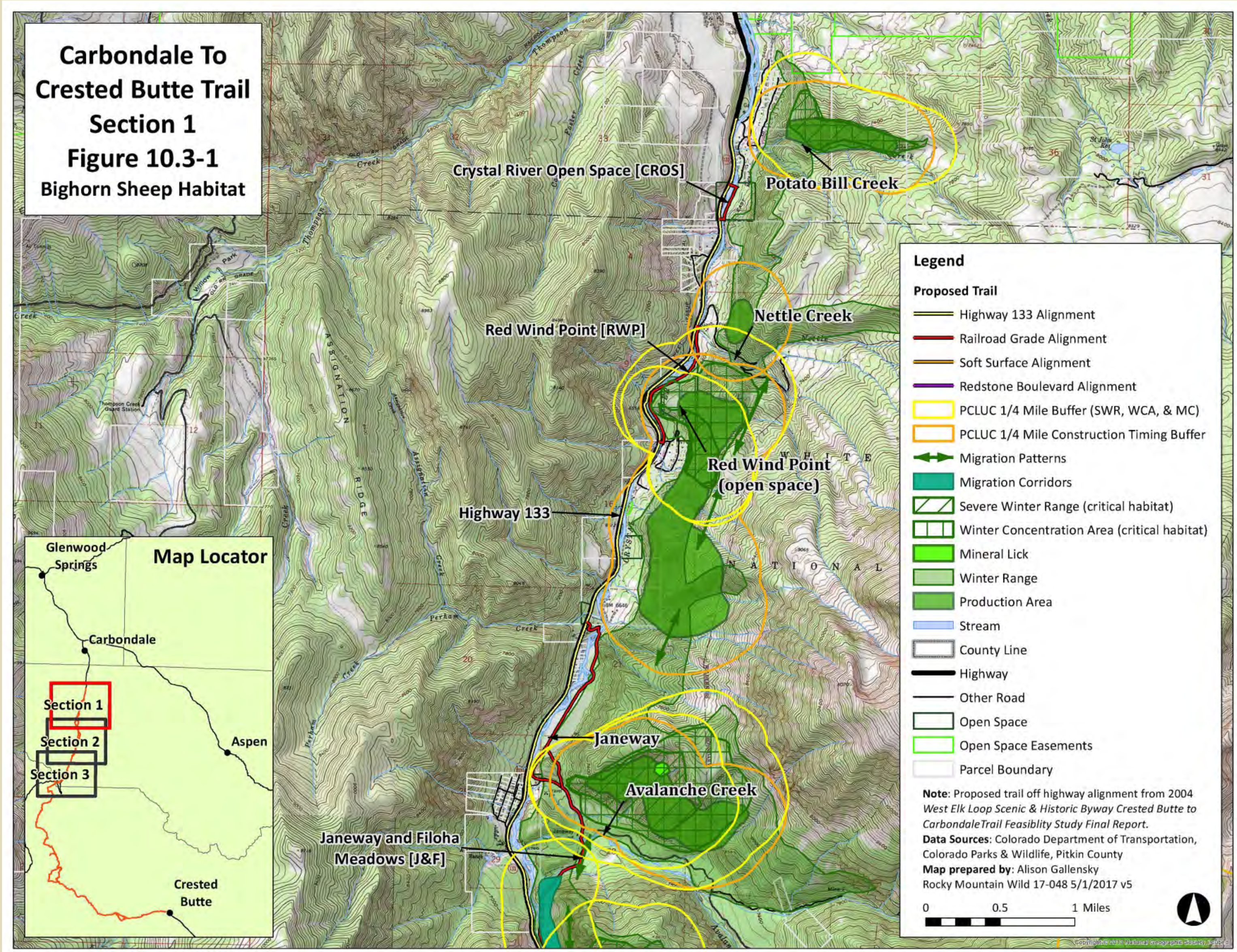

Figure 10.3-1. Bighorn Sheep, Crystal Valley Trail Section 1, Potato Bill Creek to Avalanche Creek

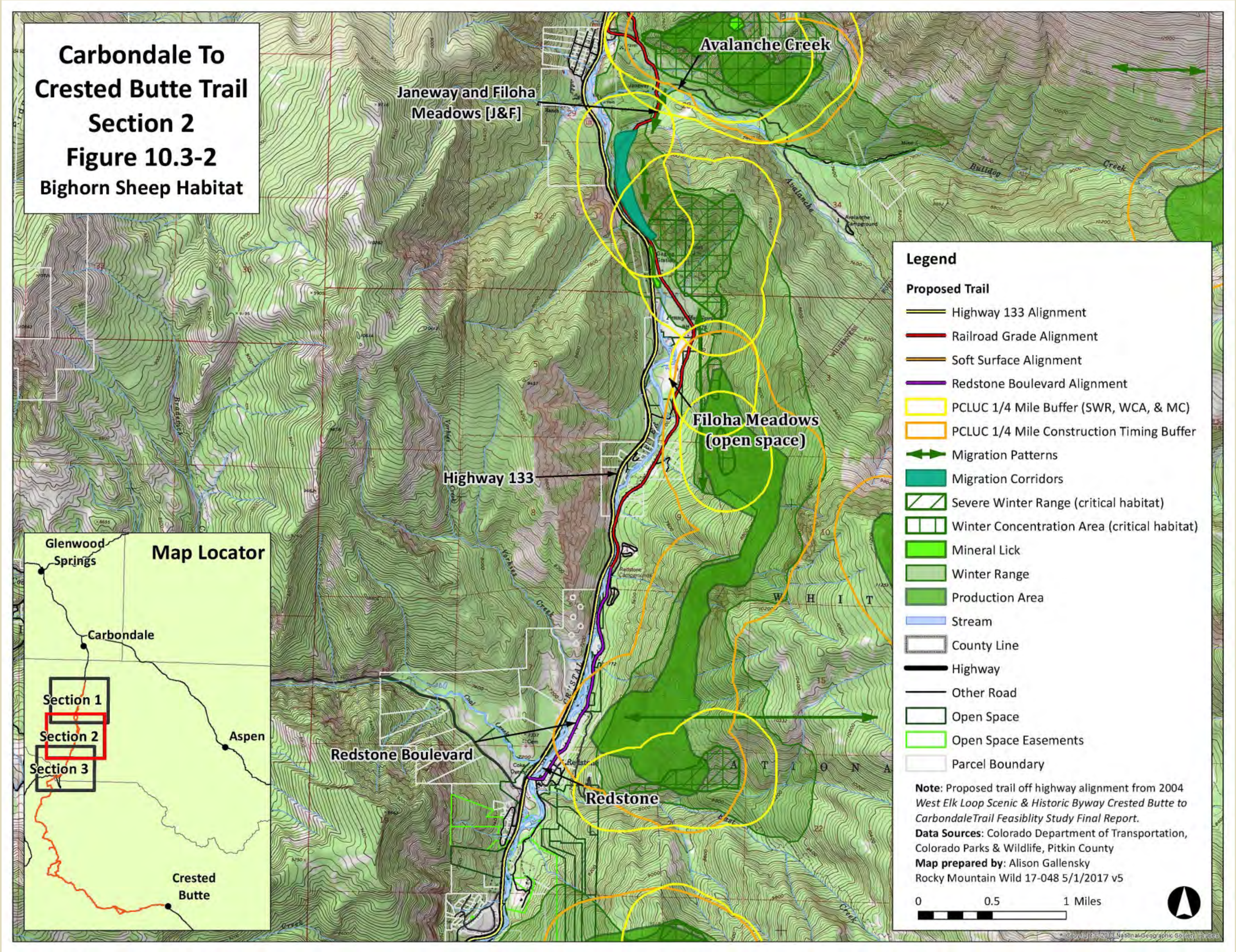

Figure 10.3-2. Bighorn Sheep, Crystal Valley Trail Section 2, Avalanche Creek to Redstone

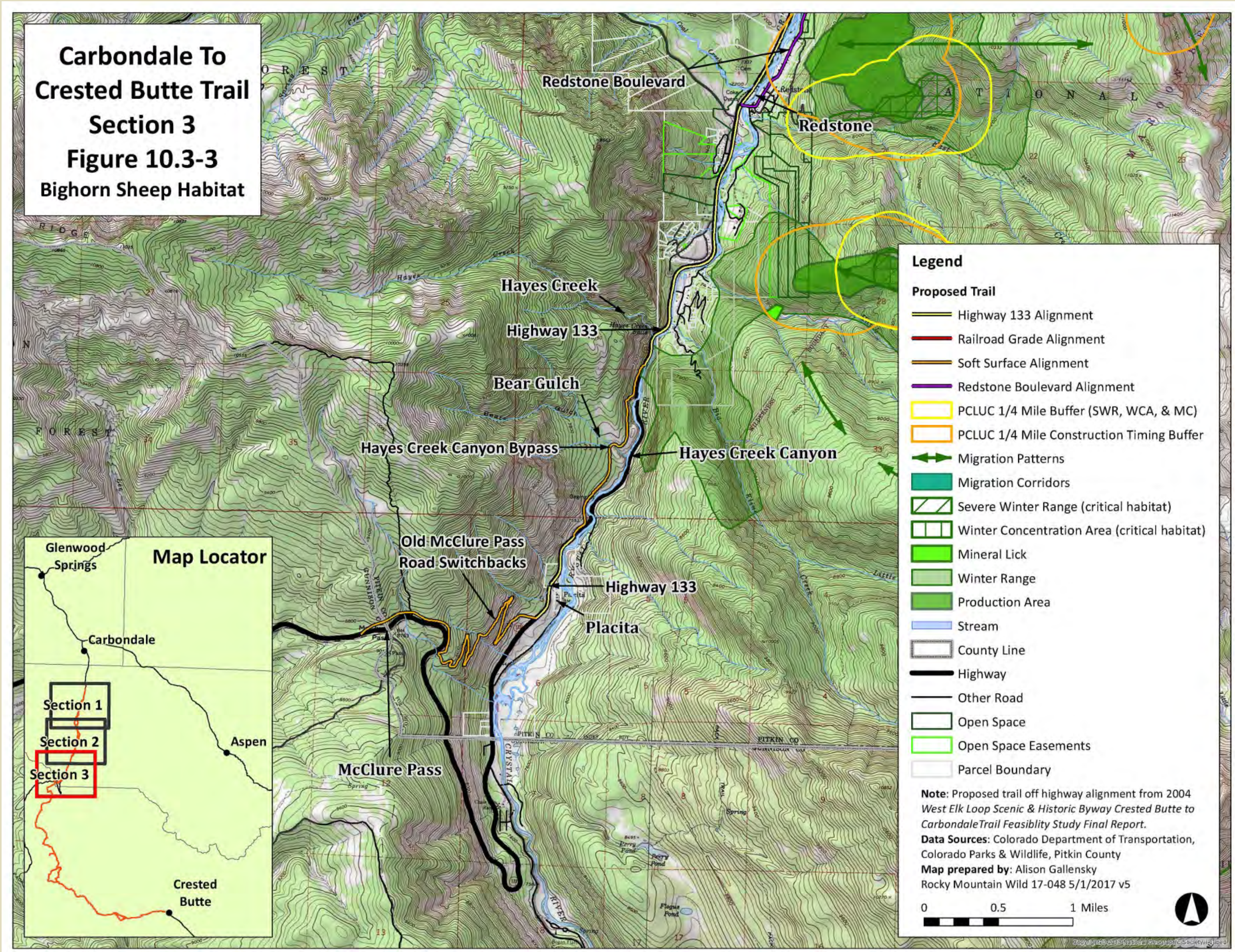

Figure 10.3-3. Bighorn Sheep, Crystal Valley Trail Section 3, Redstone to McClure Pass

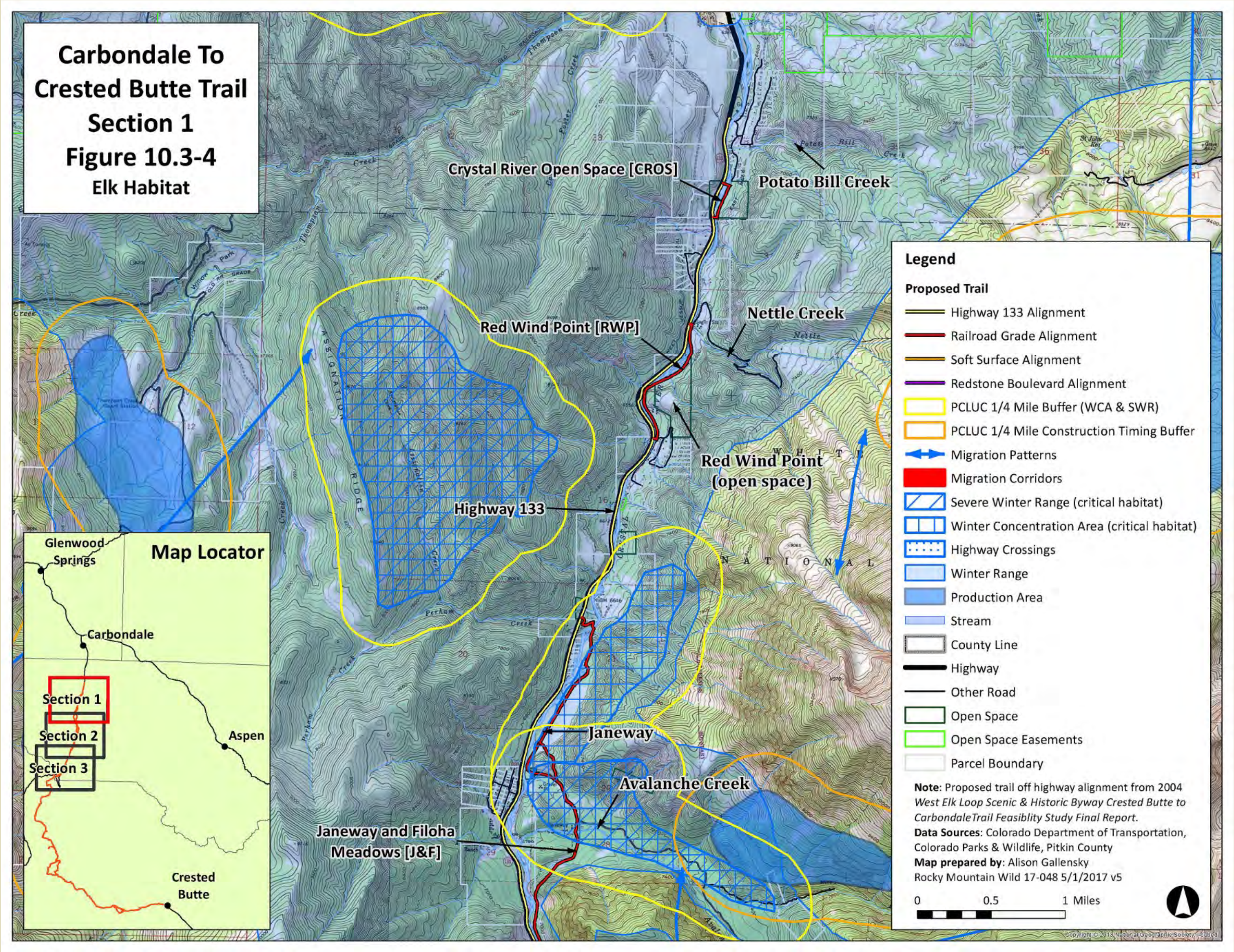

Figure 10.3-4. Elk, Crystal Valley Trail Section 1, Potato Bill Creek to Avalanche Creek

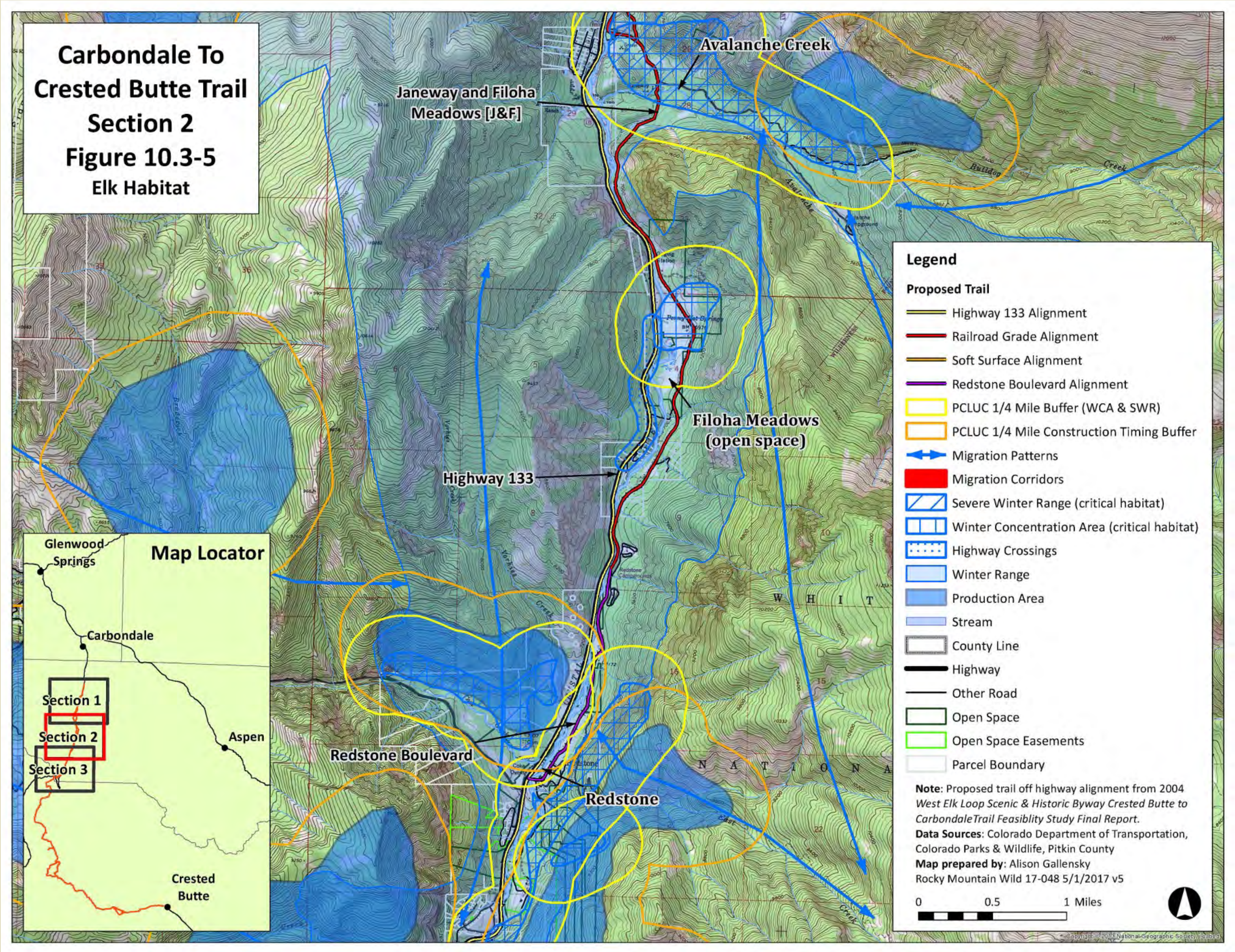

Figure 10.3-5. Elk, Crystal Valley Trail Section 2, Avalanche Creek to Redstone

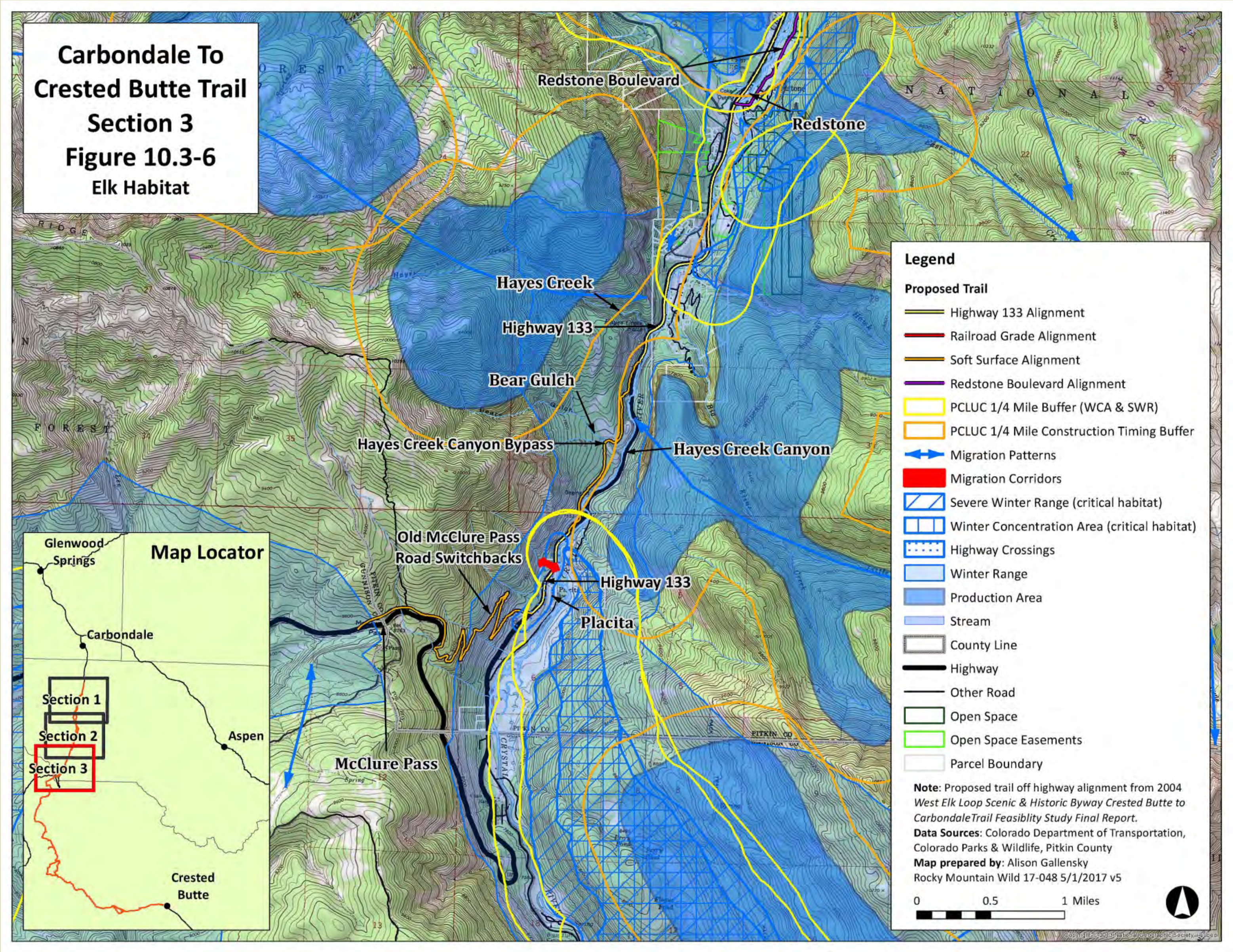

Figure 10.3-6. Elk, Crystal Valley Trail Section 3, Redstone to McClure Pass

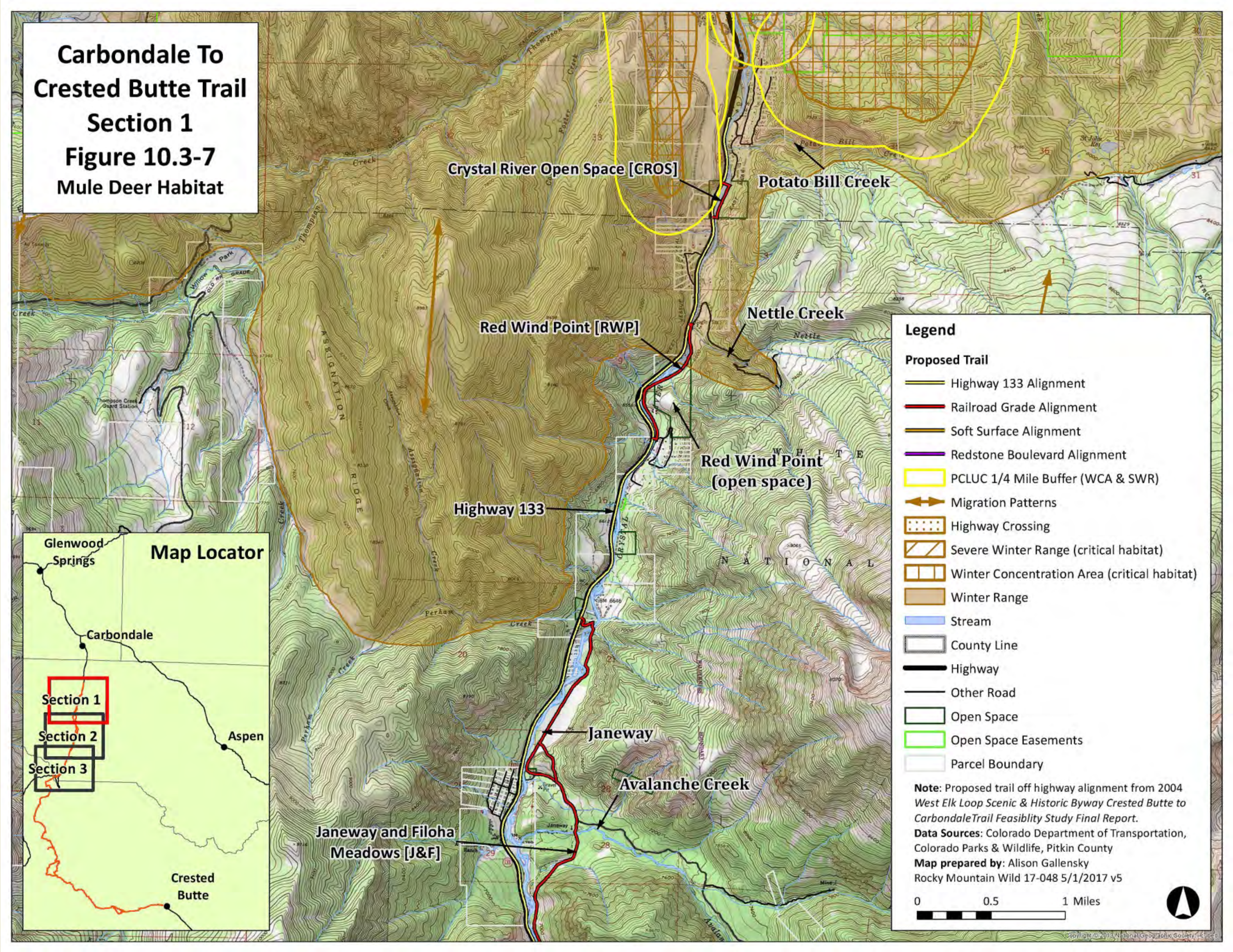

Figure 10.3-7. Mule Deer, Crystal Valley Trail Section 1, Potato Bill Creek to Avalanche Creek

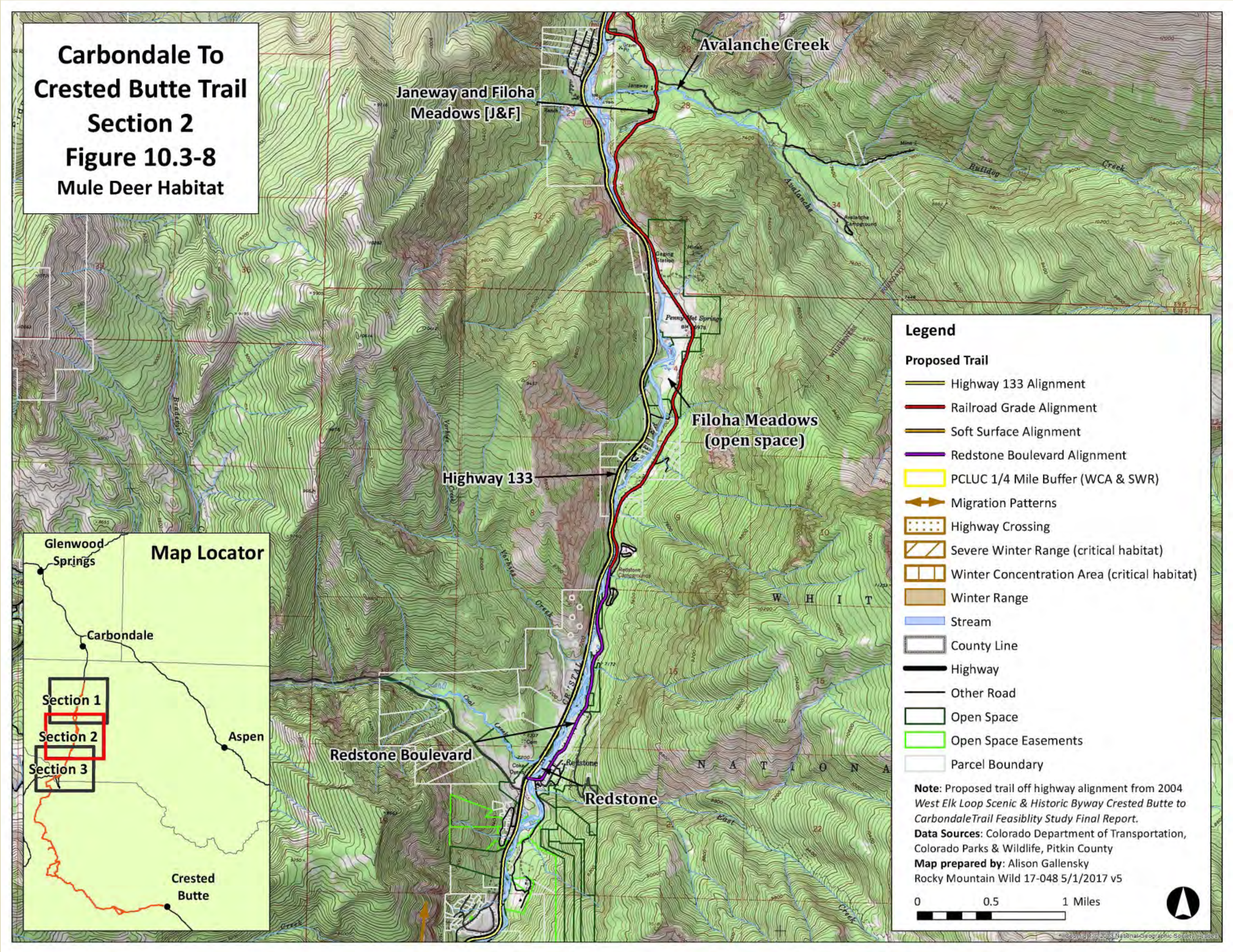

Figure 10.3-8. Mule Deer, Crystal Valley Trail Section 2, Avalanche Creek to Redstone

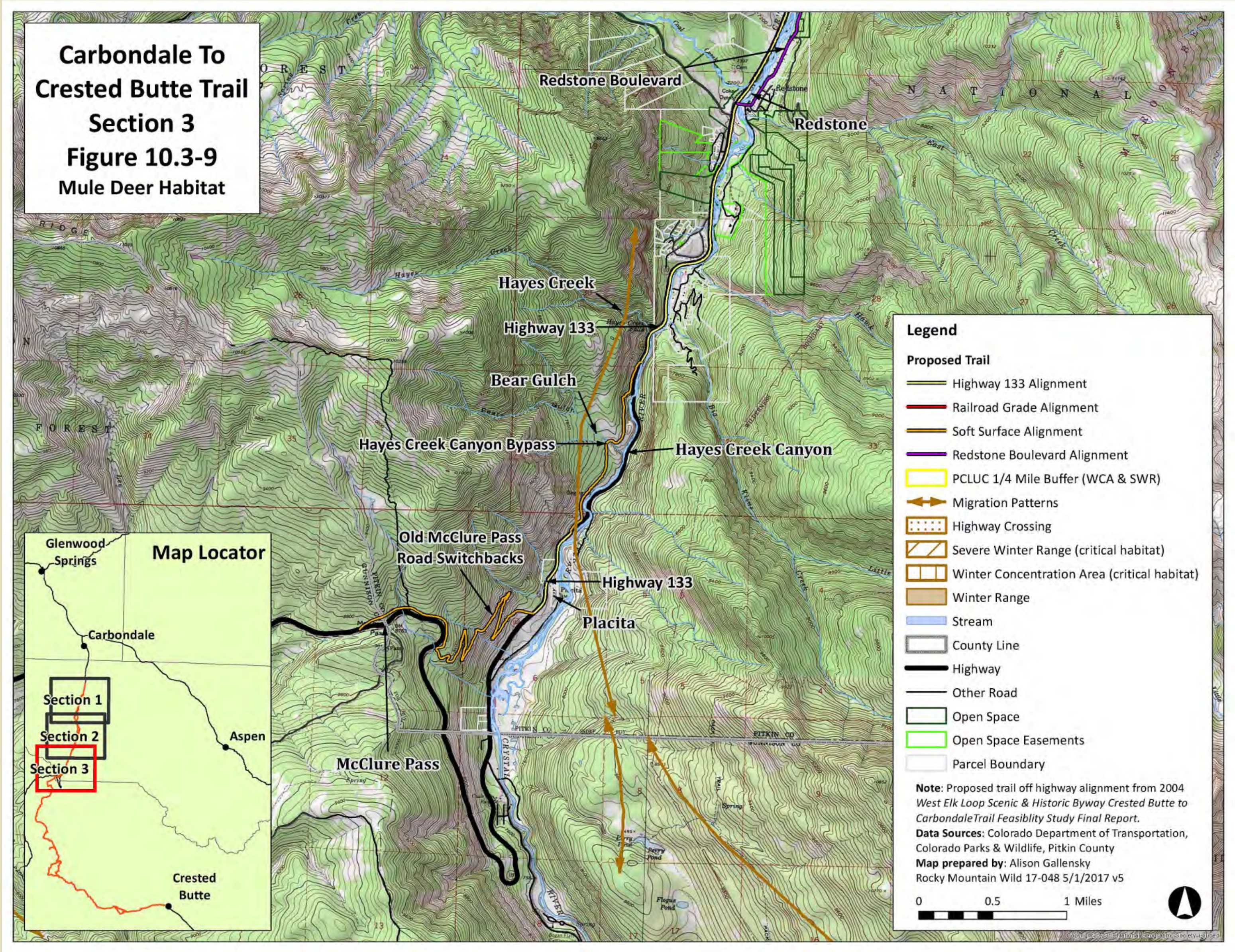

Figure 10.3-9. Mule Deer, Crystal Valley Trail Section 3, Redstone to McClure Pass

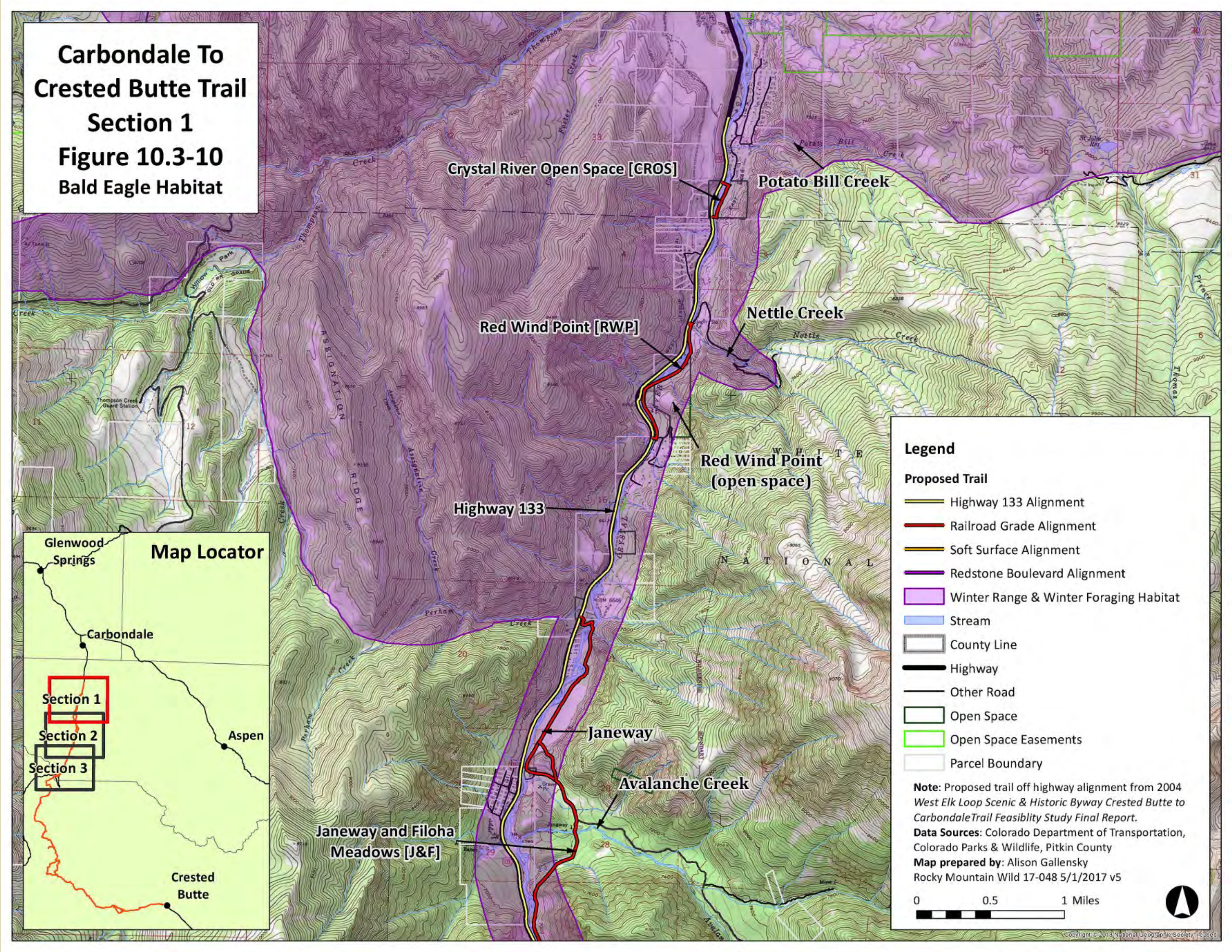

Figure 10.3-10. Bald Eagle, Crystal Valley Trail Section 1, Potato Bill Creek to Avalanche Creek

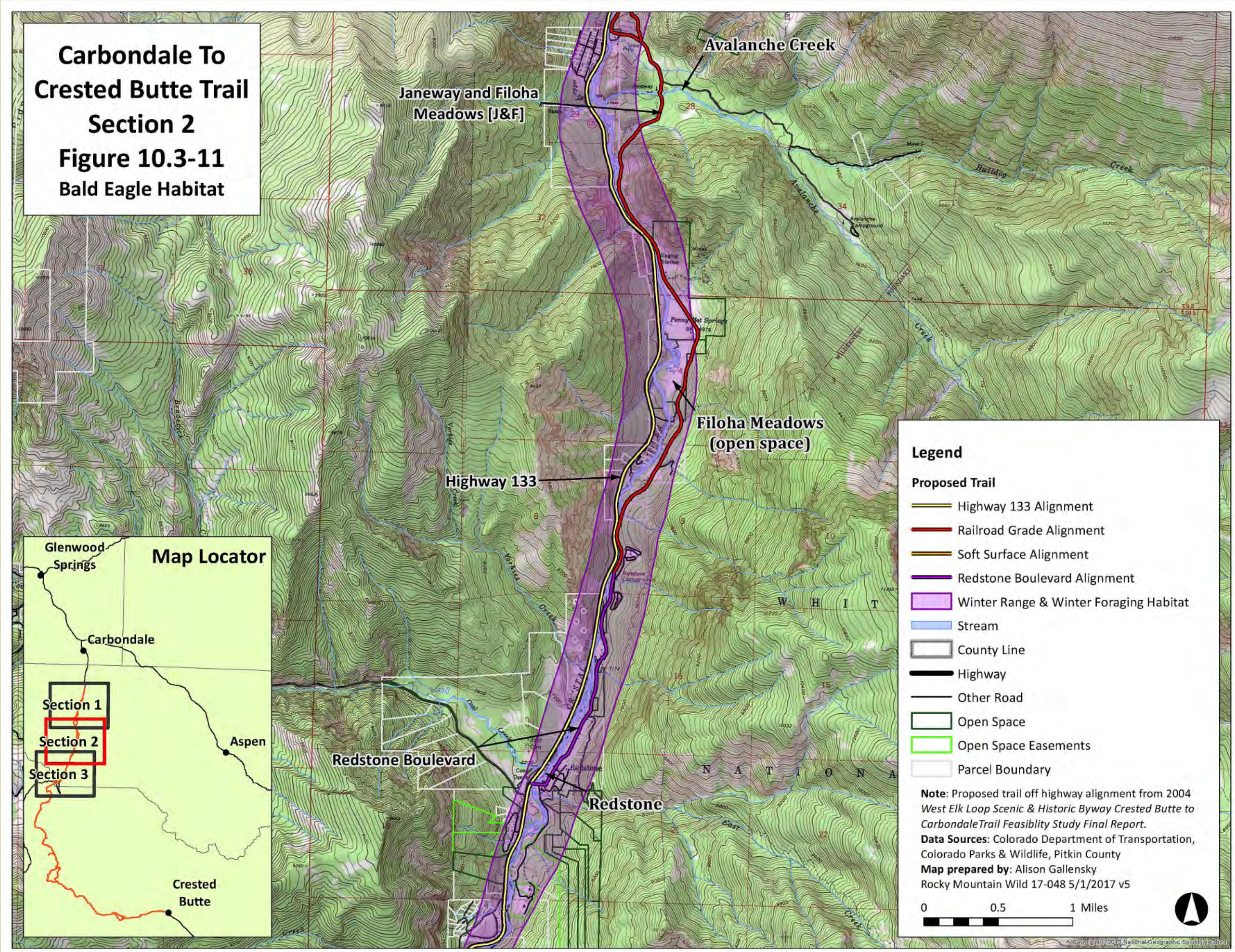

Figure 10.3-11. Bald Eagle, Crystal Valley Trail Section 2, Avalanche Creek to Redstone

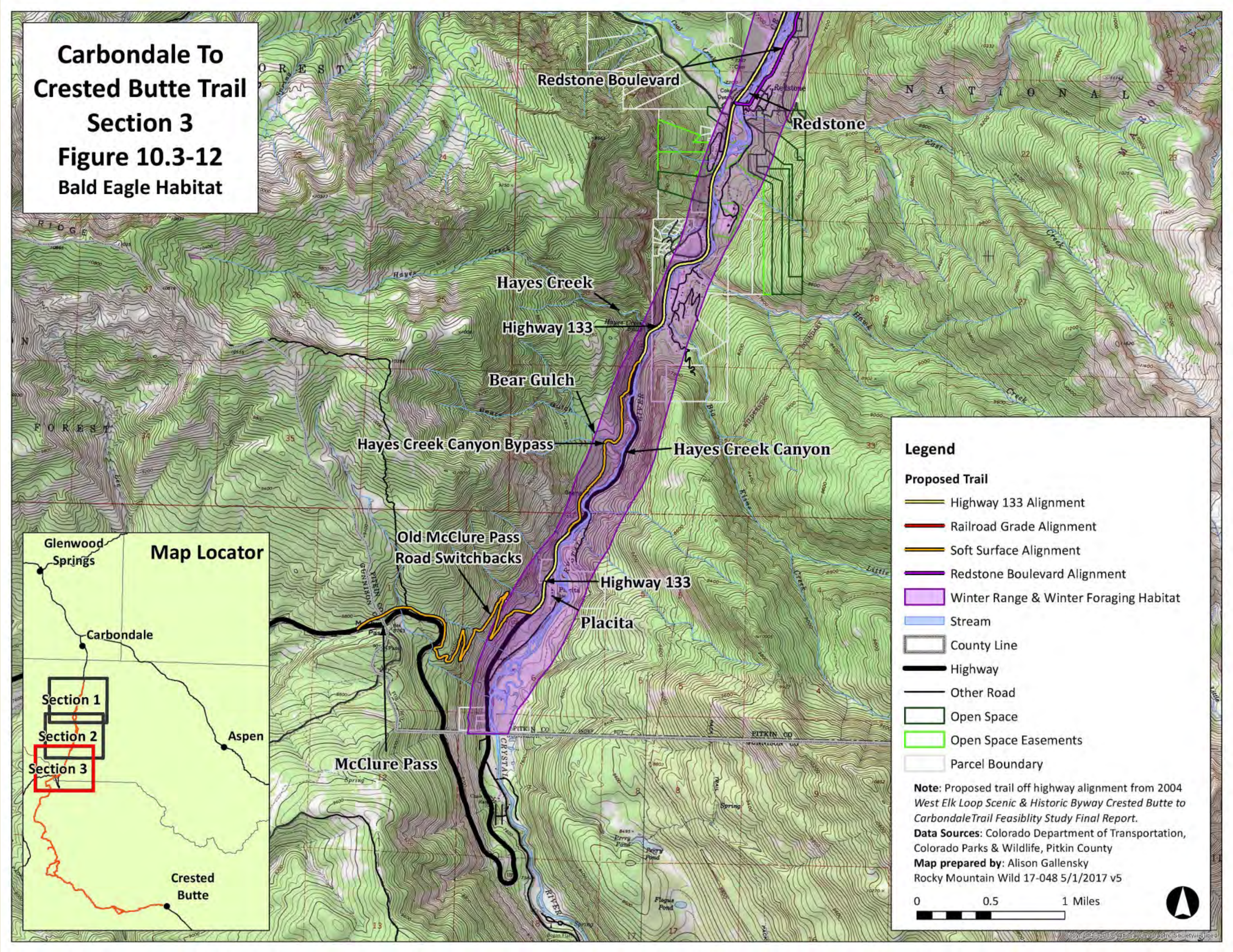

Figure 10.3-12. Bald Eagle, Crystal Valley Trail Section 3, Redstone to McClure Pass

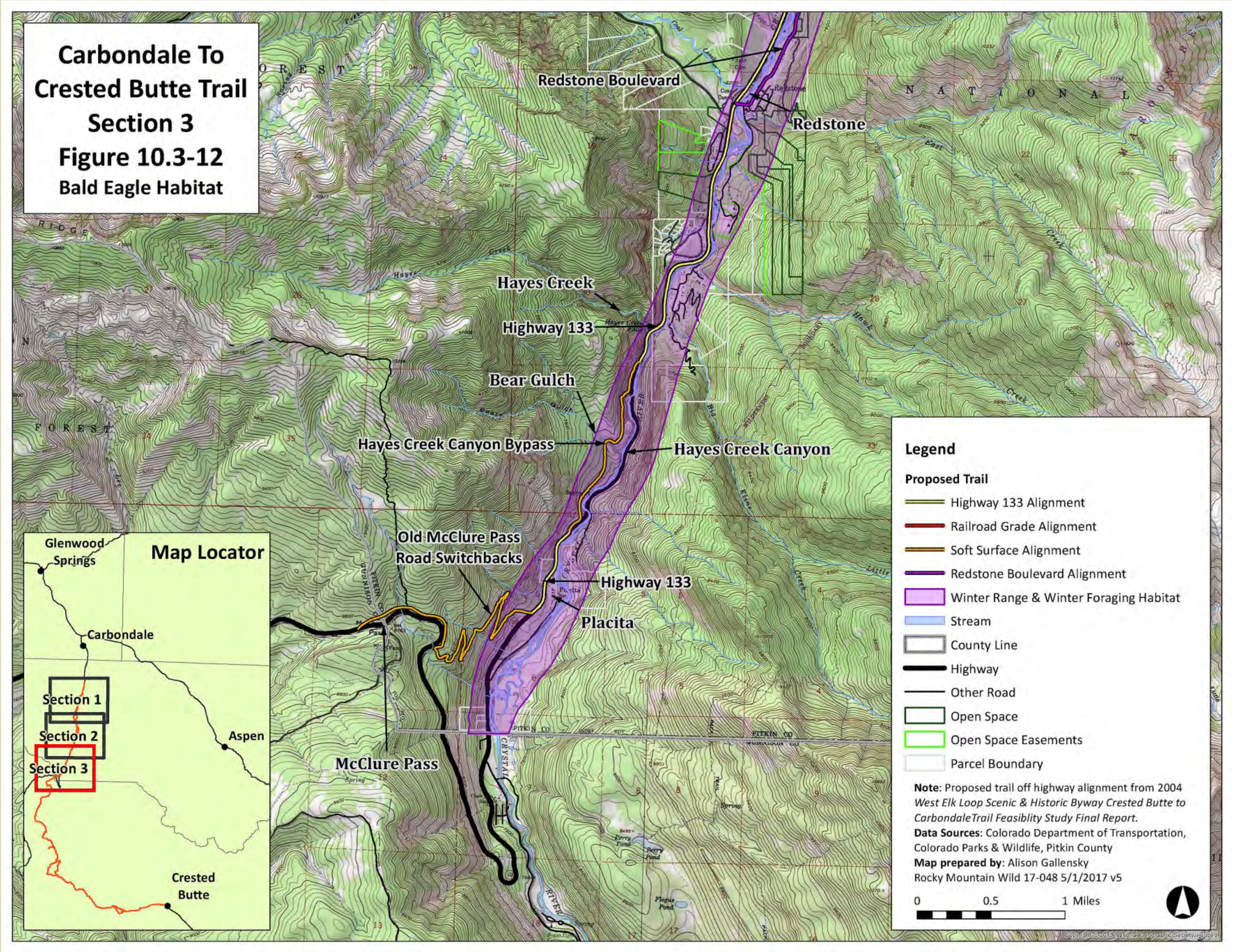

Figure 10.3-13. Peregrine Falcon, Crystal Valley Trail Section 1, Potato Bill Ck. to Avalanche Creek

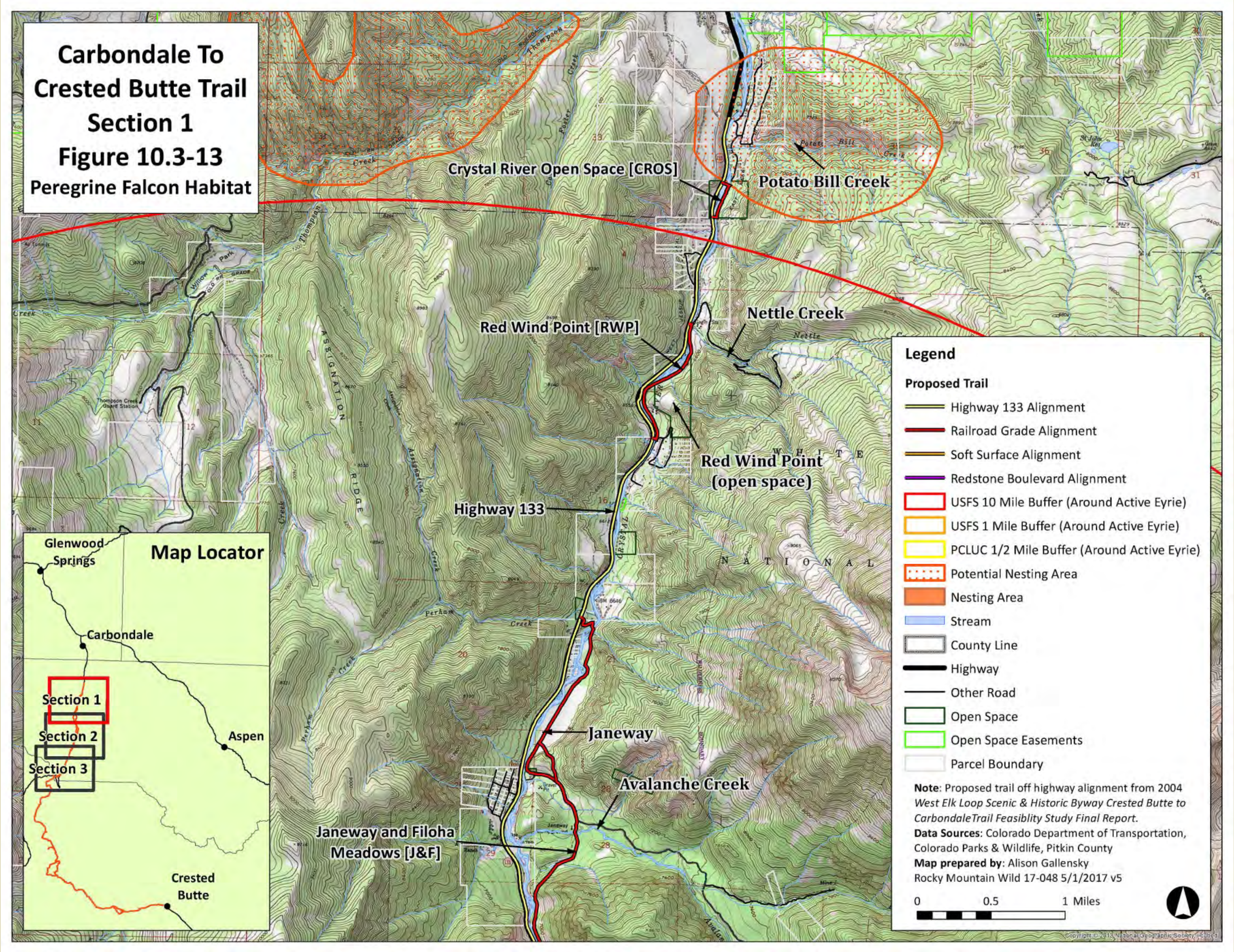

Figure 10.3-14. Peregrine Falcon, Crystal Valley Trail Section 2, Avalanche Creek to Redstone

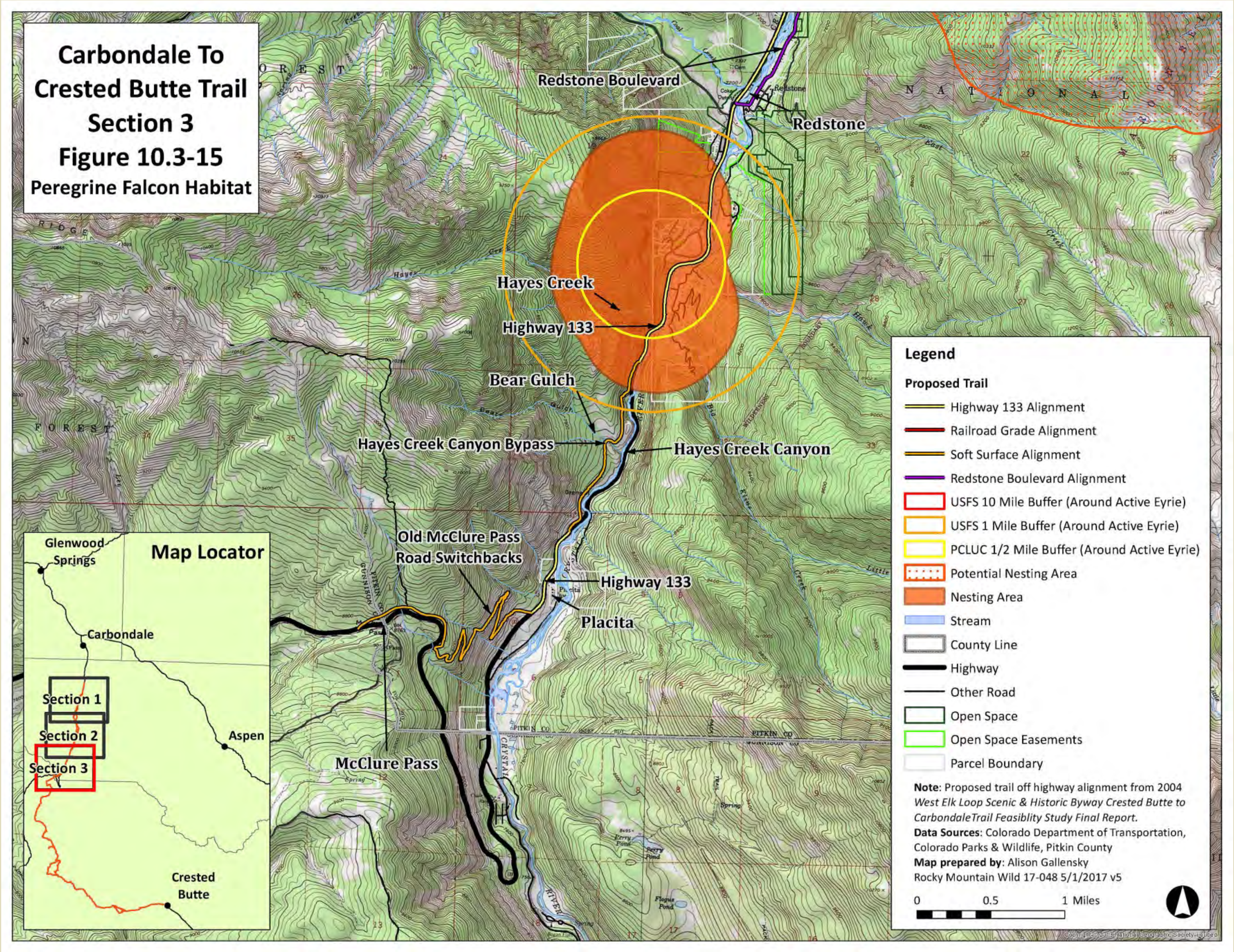

Figure 10.3-15. Peregrine Falcon, Crystal Valley Trail Section 3, Redstone to McClure Pass

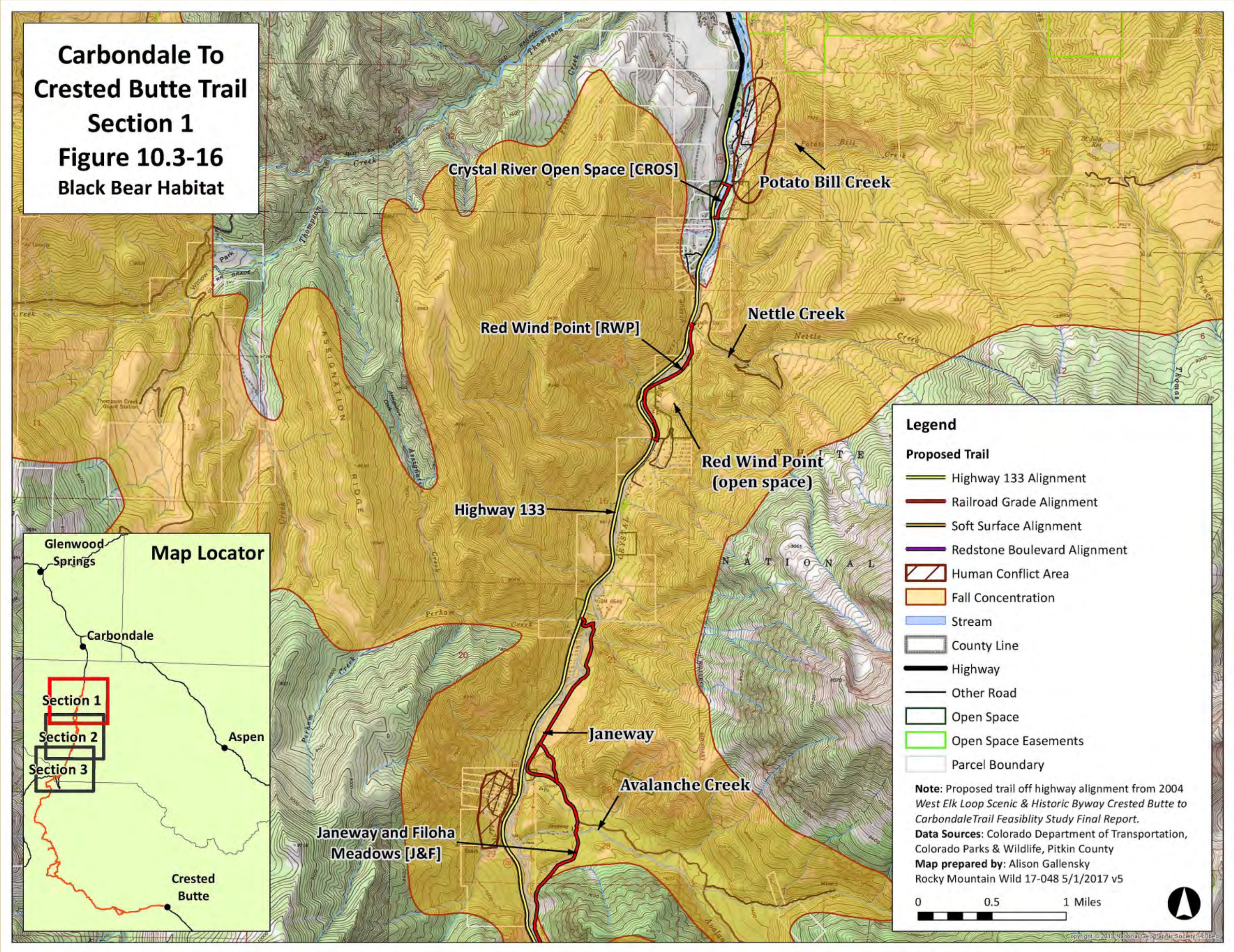

Figure 10.3-16. Black Bear, Crystal Valley Trail Section 1, Potato Bill Creek to Avalanche Creek

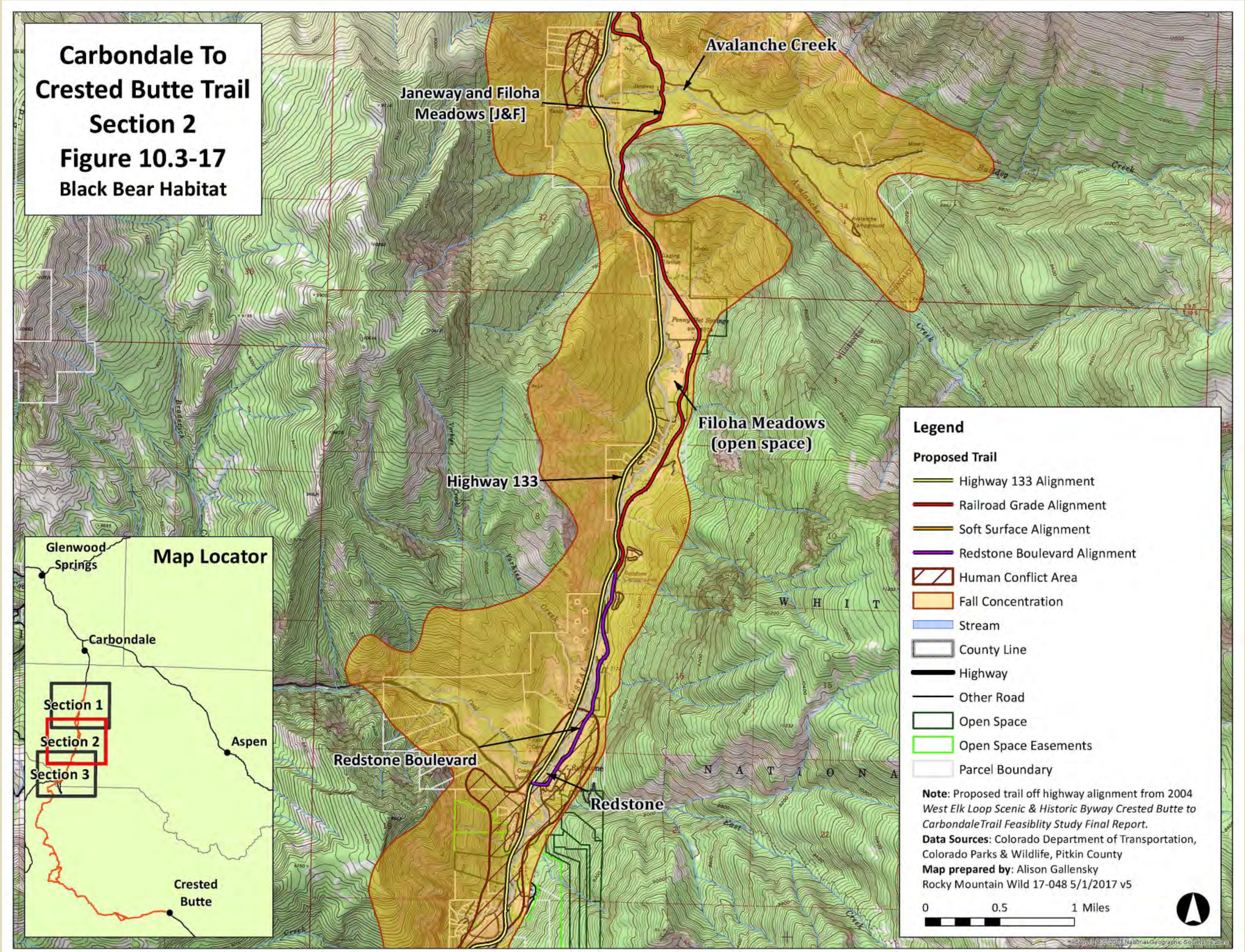

Figure 10.3-17. Black Bear, Crystal Valley Trail Section 2, Avalanche Creek to Redstone

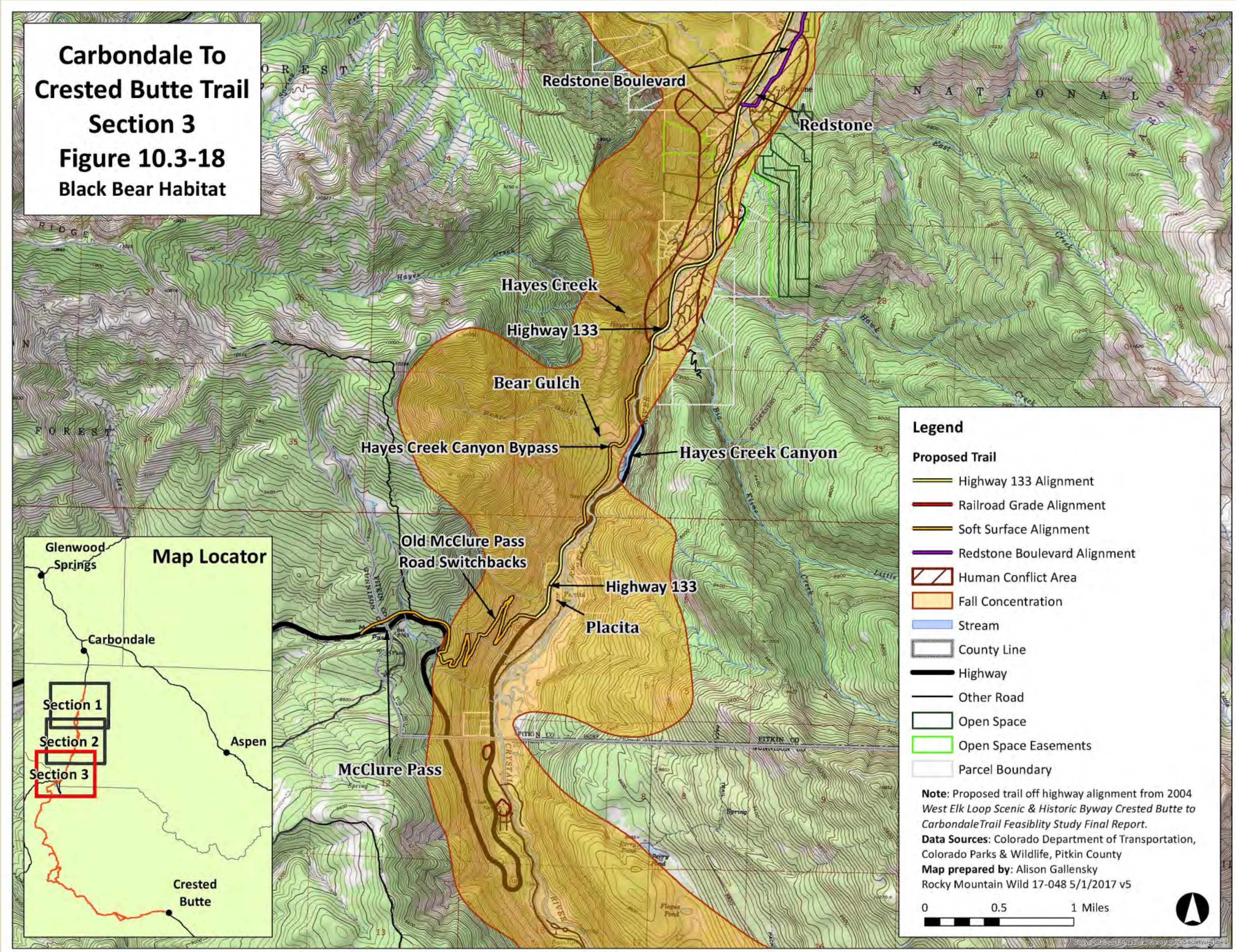

Figure 10.3-18. Black Bear, Crystal Valley Trail Section 3, Redstone to McClure Pass

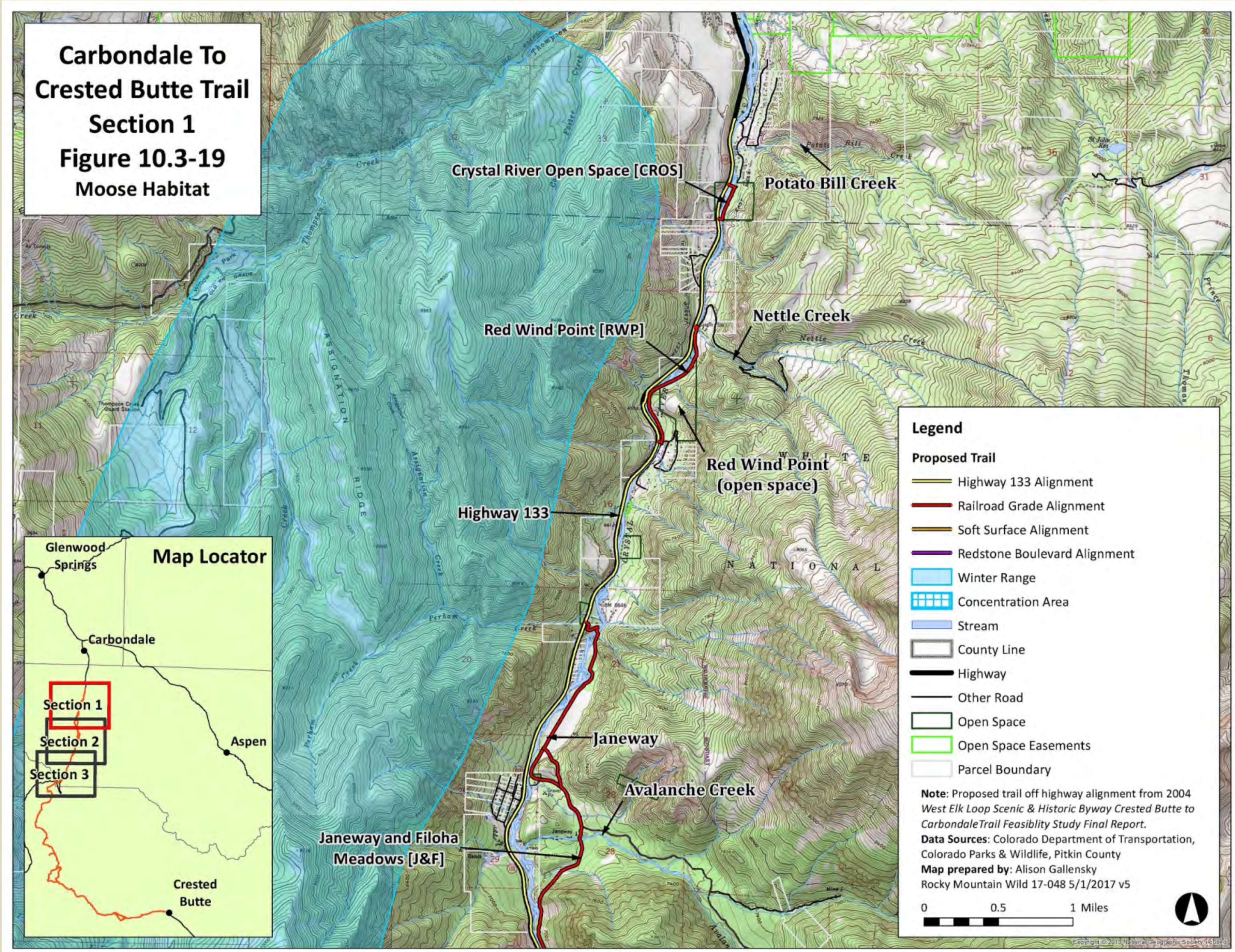

Figure 10.3-19. Moose, Crystal Valley Trail Section 1, Potato Bill Creek to Avalanche Creek

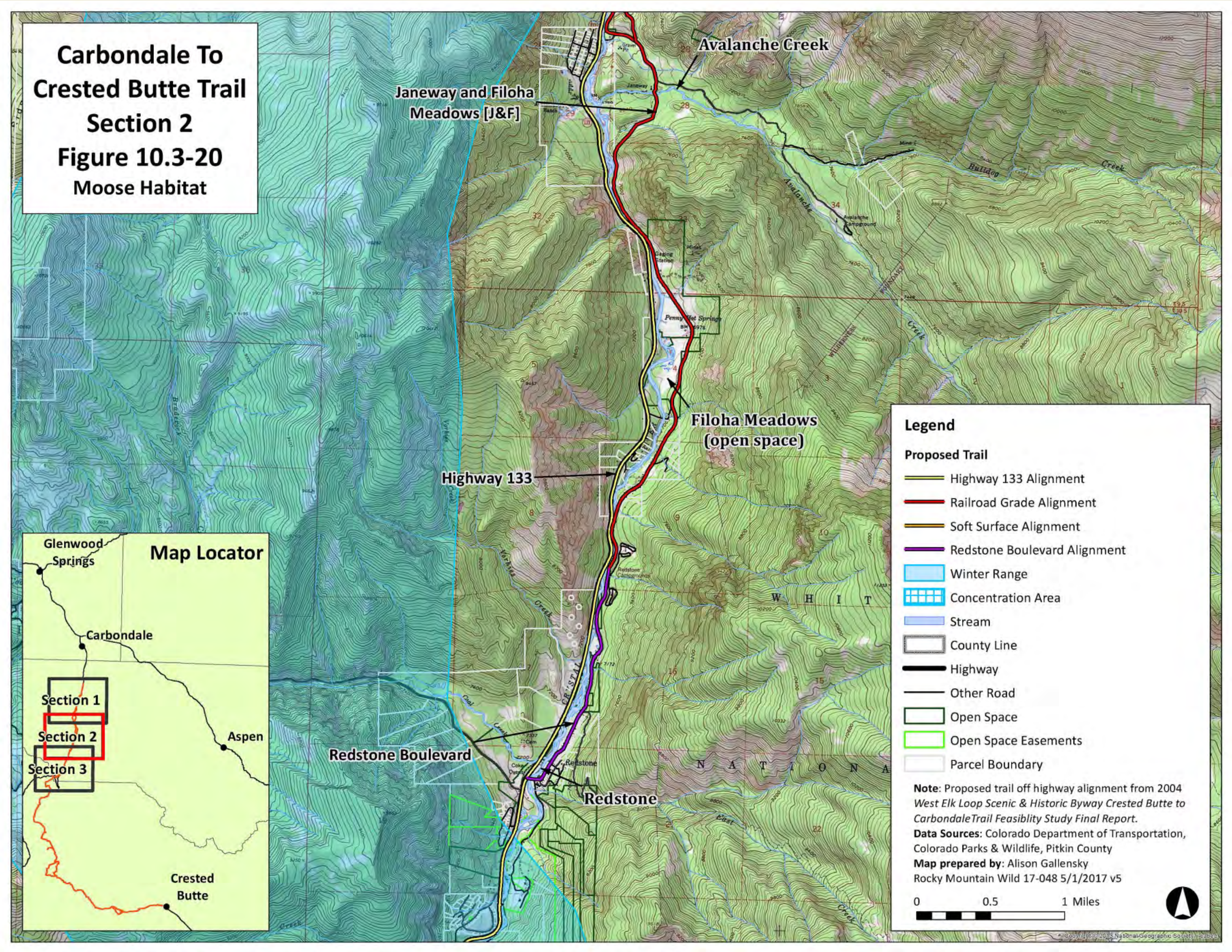

Figure 10.3-20. Moose, Crystal Valley Trail Section 2, Avalanche Creek to Redstone

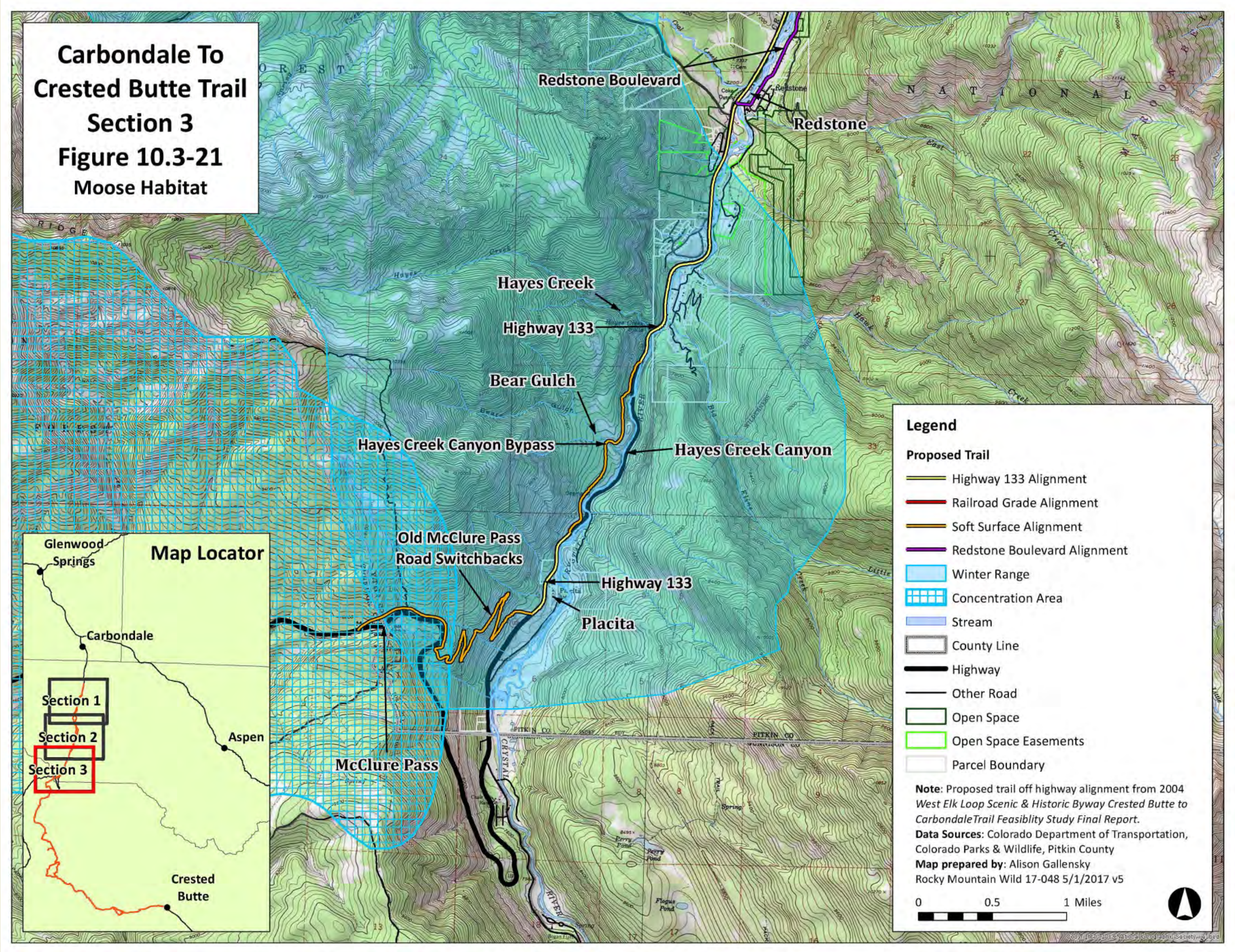

Figure 10.3-21. Moose, Crystal Valley Trail Section 3, Redstone to McClure Pass

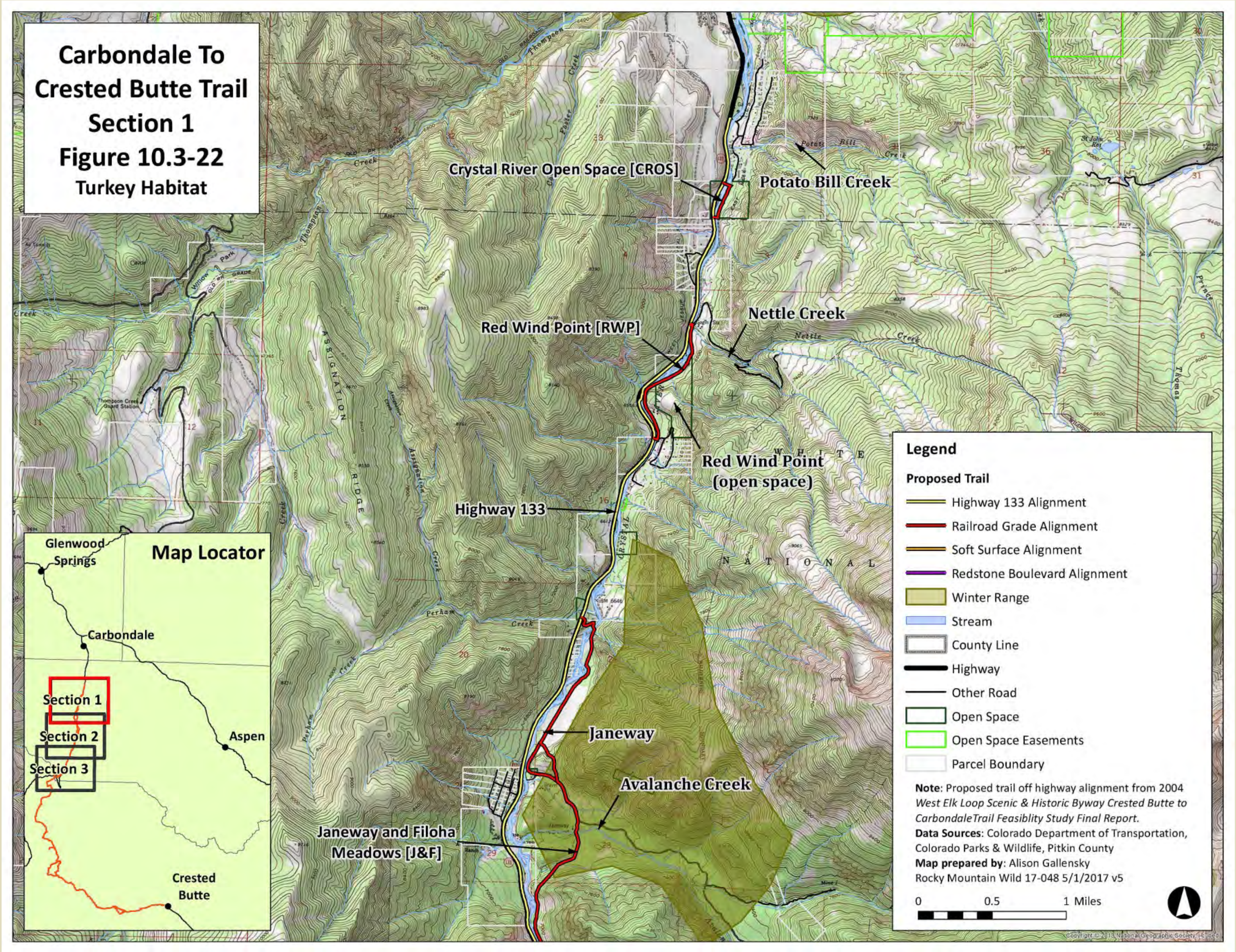

Figure 10.3-22. Wild Turkey, Crystal Valley Trail Section 1, Potato Bill Creek to Avalanche Creek

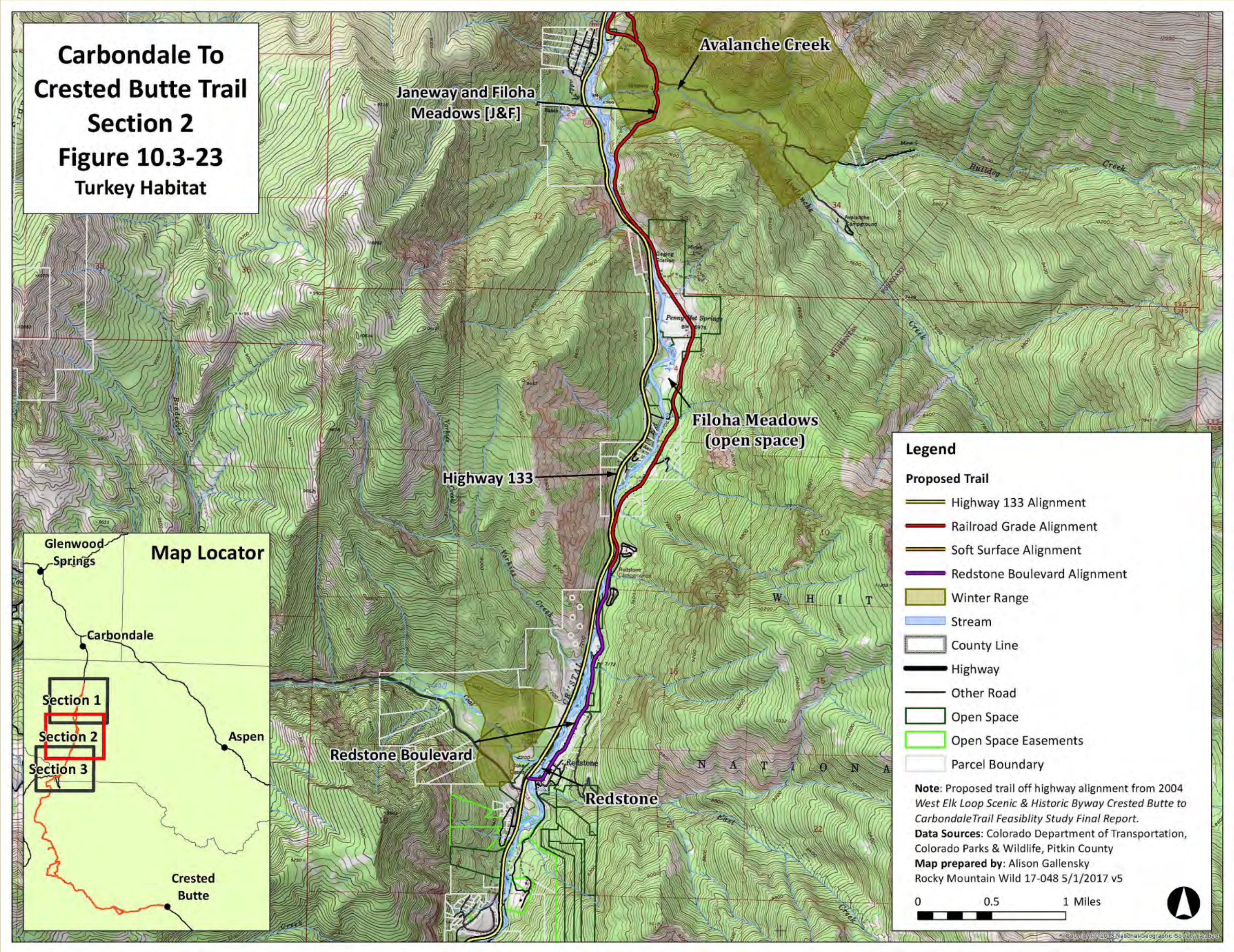

Figure 10.3-23. Wild Turkey, Crystal Valley Trail Section 2, Avalanche Creek to Redstone

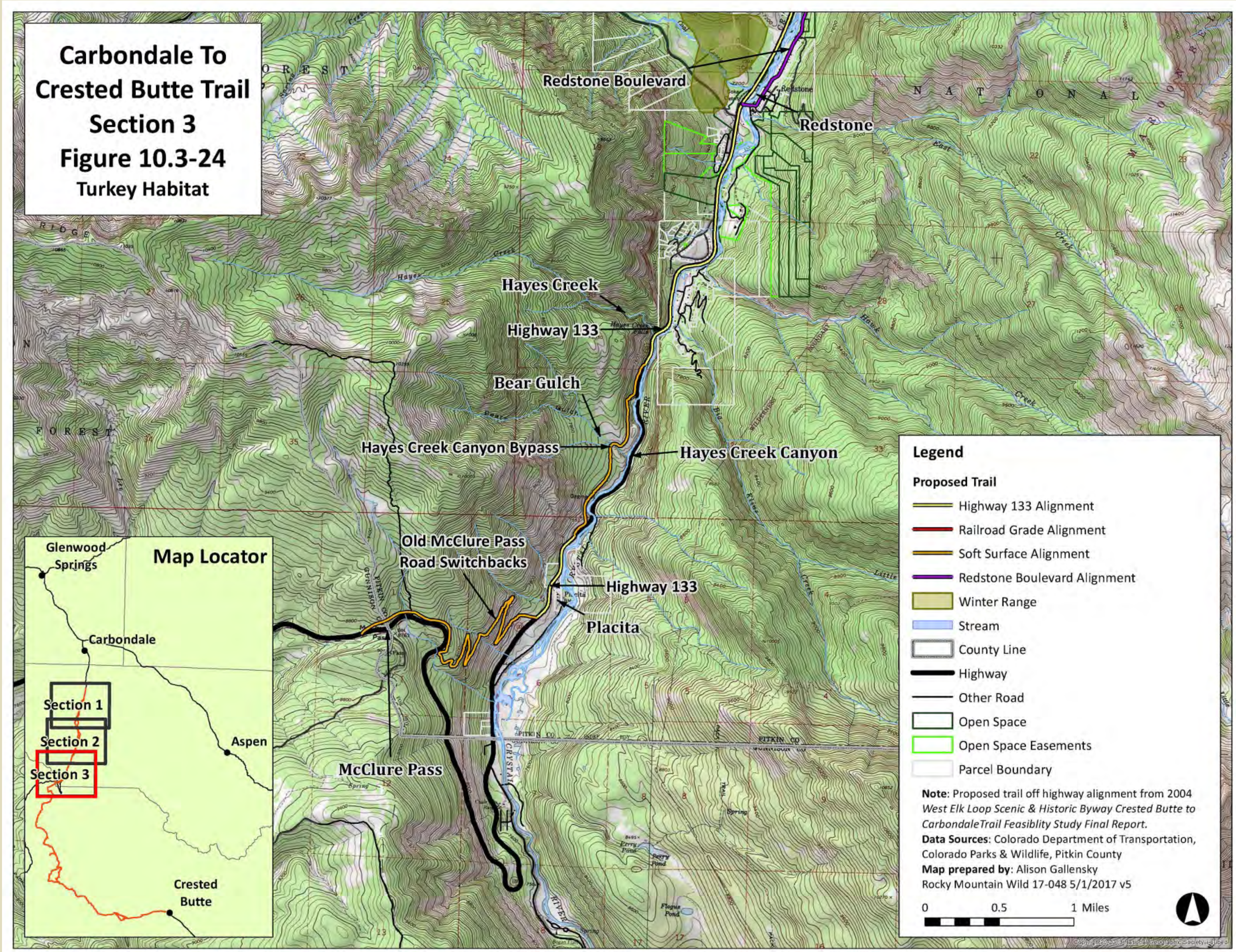

Figure 10.3-24. Wild Turkey, Crystal Valley Trail Section 3, Redstone to McClure Pass.

Attachment 2

Evaluating Landscape Connectivity and Habitat Fragmentation Effects on Elk in the Roaring Fork and Eagle Valleys

August 2019

Prepared by Paul Millhouser
Rocky Mountain Wild

ROCKY MOUNTAIN WILD

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Additional Information

For more information or access to the GIS data please contact:

Paul Millhouser
paul@rockymountainwild.org

Rocky Mountain Wild
1536 Wynkoop Street, Suite 900
Denver, CO 80202
303-546-0214

www.rockymountainwild.org

Abstract

Recent studies conducted by Colorado Parks and Wildlife have identified an alarming decline in elk populations in the Eagle and Roaring Fork valleys of Colorado (Boyd 2018). Based on elk censuses for the area conducted by Colorado Parks and Wildlife, the population decline was more than 50% from 1999 to 2015, exacerbated by an increase in hunting pressure in 2003-4, followed by a failure to recover as expected when that pressure was reduced. Even more alarming, the rate of elk calf production per cow has decreased to a level that suggests populations may not recover, and may decline still further. This paper applies measures of human influence on the landscape, including habitat fragmentation and landscape connectivity, to the study area in a time series from 1981 to 2017, to identify possible correlations with elk population changes during that period. Additional variables thought likely to contribute to elk population change, including hunting pressure, phenological patterns, and human population change, were also analyzed using linear regression. Because elk utilize different habitats seasonally and these habitats may not be uniformly affected by human or phenological processes, I differentiated among these seasonal habitats in my analysis where possible. Because data required to measure habitat fragmentation and loss of connectivity were not available for the entire 1981 to 2017 period, I explored the use of a recently published building development index as a proxy. It proved to correlate strongly (R-squared value 0.76 to 1.00 depending on measure) with the direct measures of habitat fragmentation and connectivity loss, and thus served as useful proxy for those measures. This study finds that, when a threshold of accumulated landscape influence is reached, the relationship among predictor variables and elk population growth rate changes. I conclude that human influence on the landscape has reduced the equilibrium calf to cow ratio, and thus increased the effect of hunting and other human activities on the growth rate of the elk population in the Roaring Fork and Eagle valleys, lessening the population's resilience and possibly establishing a new equilibrium population. In order to manage this elk population to prevent further decrease, wildlife managers will need to account for the effect of these landscape level changes in the study area when setting hunting targets and evaluating other human uses of public lands.

Introduction

Over the last twenty years, research on the effects of human changes to the landscape has increasingly emphasized the impacts of habitat fragmentation and loss of landscape connectivity on the continued viability of wildlife populations. Development, in the form of roads, trails and other infrastructure, can have negative effects on habitat suitability and wildlife more generally. Impacts include changes in wildlife behavior and activity due to an increase in human presence; reduced species abundance; loss of habitat and spread of invasive species; increased forms of pollution, including noise and light; species' loss of access to crucial habitat and resources due to road and human avoidance; decreased population viability; and, increased potential for human-wildlife conflicts; and direct wildlife mortality (for example, Benítez-López et al. 2010; Bennett et al. 2011; Gelbard and Belnap 2003; Jaeger et al. 2005; Jones et al. 2015; Mortensen et al. 2009; Trombulak et al. 2000).

Landscape connectivity and habitat fragmentation, while distinct concepts, both affect wildlife access to critical habitat. *Habitat fragmentation* occurs when a large, contiguous area of uniform habitat "is transformed into a number of smaller patches of smaller total area, isolated from each other by a matrix of habitats unlike the original" (Wilcove et al. 1986, p. 237). Wilcove's definition "implies four effects of the process of fragmentation on habitat pattern: (a) reduction in habitat amount, (b) increase in number of habitat patches, (c) decrease in sizes of habitat patches, and (d) increase in isolation of patches" (Fahrig 2003, p. 491). While fragmentation is not always driven by human activity, development and resource extraction are important causes, in addition to "natural" factors such as fire and insect activity. While reducing the amount and connectivity of habitat, fragmentation has the effect of altering the relative proportions of edge and core habitat, which results in disproportionate effects on different species (Bennett and Saunders 2010). Ever-smaller habitat patches are less resilient in the face of drought, fire, disease, and other unpredictable events that are likely to increase as a result of global climate change.

Landscape connectivity most commonly refers to permeability of the landscape to the movement of terrestrial vertebrates (Bissonette and Cramer 2008; Theobald et al. 2012). Connectivity permits animals to disperse into new territories, access seasonal resources and breeding habitat, and maintain the flow of individuals and genes across the landscape (Manel et al. 2003; Rudnick et al. 2012). Much as in the case of fragmentation, impediments to connectivity may be natural, but increasingly come in the form of human-caused change to the landscape. Continued landscape connectivity is critical to sustaining species richness and populations, and becomes increasingly important as fragmentation grows and climate change alters habitat distribution (Heller and Zavaleta 2009).

This study evaluates changes over time in measures of habitat fragmentation and landscape connectivity as predictors of changes in elk population in a single landscape, whereas prior studies of habitat fragmentation and landscape connectivity have most commonly characterized a single landscape (or collection of landscapes) at a moment in time or compared two otherwise similar landscapes differing in those variables (see, for example, Dickson et al. 2016; Fernandez at al. 2018; Jaeger et al. 2005; McClure et al. 2017; Watson et al. 2005; but, see Haddad et al. 2015). While in some cases a time series analysis has been applied to habitat fragmentation or landscape connectivity, the analysis has not generally focused on evaluating the correlation between these variables and empirically-measured species population (see, for example, Bishop-Taylor et al. 2018; Jaeger et al. 2007; Santini et al. 2019).

Elk populations in the Roaring Fork and Eagle valleys of Colorado from 1981 to 2017 have failed to recover from substantial population declines in the last two decades, despite efforts by the Colorado Department of Parks and Wildlife to manage for population growth. This decline in population may be correlated with reduced connectivity and increased habitat fragmentation in the region, suggesting that human influence may have altered the resilience and/or stability of this population. To address this possibility, I tested the following hypothesis:

> Failures of elk populations in the Roaring Fork and Eagle valleys of Colorado to recover from substantial population declines are correlated with, and possibly a result of, changes to connectivity and habitat fragmentation over recent decades, after accounting for other possibly contributing variables (e.g., hunting pressure, precipitation, and vegetative health).

Methods

Study Area

The Roaring Fork and Eagle Rivers are tributaries of the Colorado River located in the Rocky Mountains in the west central region of Colorado (see Figure 1). Both flow through public and private lands around the White River National Forest, and their watersheds include the resort towns of Vail and Aspen as well as wilderness areas. The rivers' valleys and surrounding watersheds provide habitat for a variety of wildlife, and in particular are home to elk herds totaling more than 10,000 individuals. My study area consists of two "Data Analysis Units" (DAUs) designated by Colorado Parks and Wildlife as E-15 and E-16, totaling 576,633 hectares. Each DAU corresponds to the entire range of a single elk herd, and these two roughly correspond to the Roaring Fork and Eagle Valleys. My habitat fragmentation and connectivity analyses included a 25-kilometer buffer around the DAUs, for a total analysis area of 1,602,080 hectares. In addition to considering the study area in terms of elk herd DAUs, my analysis considered the landscape in terms of (1) seasonal elk habitat and (2) land ownership. The Roaring Fork and Eagle valleys are dominated by federally-owned lands; 432,510 hectares (75.00%) of the study area falls within the White River National Forest, and an additional 48,186 hectares (8.35%) is managed by the Bureau of Land Management.

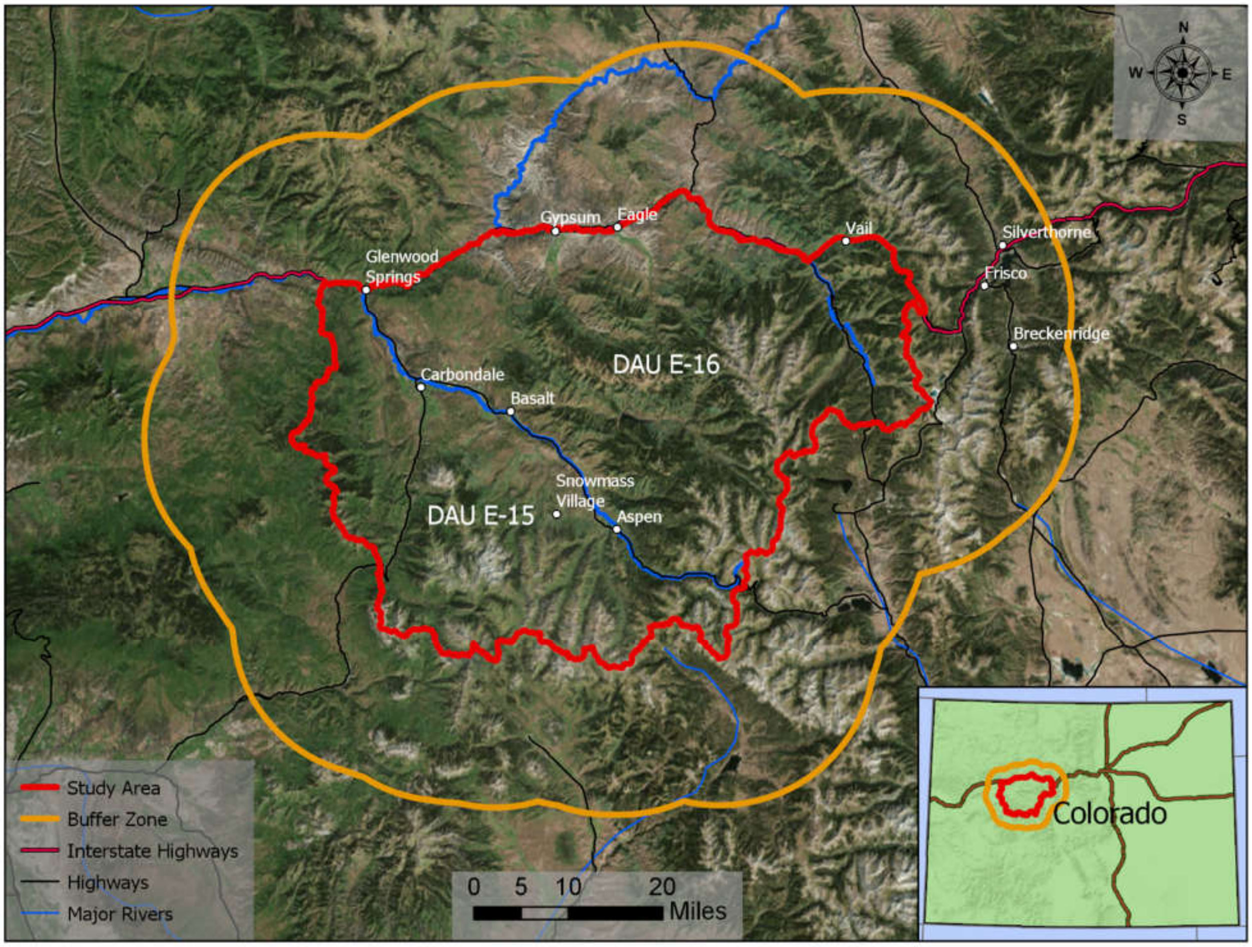

Figure 1: Map of the study area, with study area delineated in red and the buffer zone in orange. Data Analysis Units E-15 and E-16 are contained within the southwestern and northeastern parts, respectively, of the study area and are separated by the Roaring Fork River. Map data: ESRI; United States Geological Survey.

The herds in each of these DAUs increased in population from the late 1980s into the 1990s, peaking in 1995 at an estimated 20,036 elk in the combined DAUs. Concerned that these population levels might result in starvation events or habitat degradation, CPW issued larger numbers of hunting licenses, particularly for cow elk, in response (Petch 2019). The reduction in population exceeded what CPW intended, so it subsequently—and indeed, to this day—issued fewer hunting licenses; based on models and past population trends, CPW anticipated that population would trend upward toward prior levels. From 2010 to the present, the total elk population has fluctuated between 9,000 and 11,500.

During the study period, human population and human infrastructure have increased substantially in the study area. Human population of the study area, as estimated from U.S. Census Bureau figures, increased by more than 150% between 1990 and 2018. From 1990 to 2000, the period of most rapid growth, the increase exceeded 55%. Statistics measuring habitat fragmentation, building construction, and landscape connectivity all showed increasing human influence over the landscape during the 1981-2017 period; given that 75% of the study area is within the White River National Forest, where human population is very small and new construction has been greatly limited, the increase on the remaining 25% of the landscape is of higher intensity than the overall statistics suggest.

Overview of Approach

To understand the causes of elk population decline in the study area, I used two tools of landscape ecology to understand changes in habitat fragmentation and loss of connectivity in the study area from 1990 to present. To understand habitat fragmentation, I used FRAGSTATS software (McGarigal et al. 2012); to understand changes in connectivity, I used Circuitscape software (McRae et al. 2008, 2013; www.circuitscape.org). Both of these tools are described in detail below. In addition to the data required for these tools, I considered data regarding hunting pressure, precipitation, and vegetative health to evaluate the contribution of other variables.

To evaluate the effect of human influence on elk population across different seasonal habitats as well as on the entire landscape, I used polygon shapefiles published by the Colorado Department of Parks and Wildlife (CPW) that classify the study area into seasonal elk habitat types (Colorado Department of Parks and Wildlife 2018). Reflecting the tendency of elk to use some areas during more than one season and prefer certain areas within seasonal habitat, these polygons overlap substantially. To create a raster permitting analysis with other datasets, I classified each 30 meter by 30 meter cell based on the perceived highest value seasonal use. For example, if a location fell within both the "Production Area" (used for calving and calf-rearing) and general summer range, I classified it as "Production Area." CPW also provided elk population data, including estimated annual population, and the hunting data, including number of hunting licenses, and kills by bull, cow and calf (see Appendix 1 for complete data).

My analysis of habitat fragmentation considered seasonal elk habitat as delineated by CPW, and focused on roads, motorized trails, and nonmotorized trails as the basis for evaluating human contribution to habitat fragmentation. To characterize landscape connectivity, I constructed a surface approximating resistance to movement by elk based on the inverse of an existing habitat model based on land cover type and proximity to roads (Colorado Division of Wildlife 2006), with further resistance provided by slope, major rivers, and road crossings. I considered both mean resistance by each elk seasonal habitat type and the results of a Circuitscape analysis of this surface.

Fragmentation Analysis

FRAGSTATS is the most widely used software tool for calculating fragmentation-related metrics (McGarigal et al. 2012). It is capable of producing dozens of metrics of fragmentation, but many of them are largely duplicative. In addition, landscape level metrics may not be able to differentiate among within-landscape patterns—for example, the mean habitat patch size of a landscape with numerous equal-sized patches might be similar to that of a landscape with a broad range of patch sizes. Riiters et al. (1995), sought to distill these measures to a few key categories, each represented by a single metric. Despite considerable research in the field since 1995, their approach remains relevant, although some of the metrics they recommend have since been further refined and recategorized (see McGarigal 2015).

Fragmentation analysis using FRAGSTATS requires a land cover dataset as its primary input. I used the GAP/LANDFIRE National Terrestrial Ecosystems 2011 dataset from the U.S. Geological Survey (GAP 2011), which characterizes vegetation cover/habitat type at a spatial resolution of 30 meters, which is well suited to the scale of analysis. The land cover categories can be evaluated at 7 different levels of increasing specificity, ranging, for example, from "Shrub & Herb Vegetation" to "Western Great Plains Foothill and Piedmont Grassland" or from "Forest & Woodland" to "Rocky Mountain Lodgepole Pine Forest." To consider the fragmenting effect of roads and trails, which are not included in GAP 2011, I used current and historic data regarding their locations. For state and municipal roads, I used 1990-2017 TIGER data from the US Census Bureau and Colorado Department of Transportation data. Reliable data on road construction dates from earlier time periods were not available, and so my fragmentation and connectivity analyses were limited to the 1990 to 2018 period. TIGER data may not be complete for roads without human habitation and is of inconsistent positional accuracy in earlier periods. Because I used a buffered area around road centerlines as the zone of fragmenting effect, small discrepancies in positional accuracy are unlikely to be significant. Roads and trails in the National Forest were identified from the United States Forest Service (USFS) Transportation Line dataset, which is derived from USFS and USGS data that is supplemented with local, county, and state data to create the best available dataset of transportation feature in National Forests (USFS 2018). Because the latter dataset is compiled from multiple sources of different vintages, my analysis was unable to track some changes within the National Forest. As new construction of roads and trails within the National Forest, particularly in designated Wilderness Areas, have been restricted throughout the study period, this may not be a major limitation. Figure 2 shows the uneven distribution of fragmentation among different seasonal habitats as of 2018. Fragmentation is most notable in winter habitat areas, which tend to be at lower altitudes along valley floors. Appendix 5, Figure 1 and Appendix 5, Figure 2 show closeup views of the fragmentation of the Roaring Fork and Eagle valleys, respectively, and further highlight the degree of fragmentation along the valley floors.

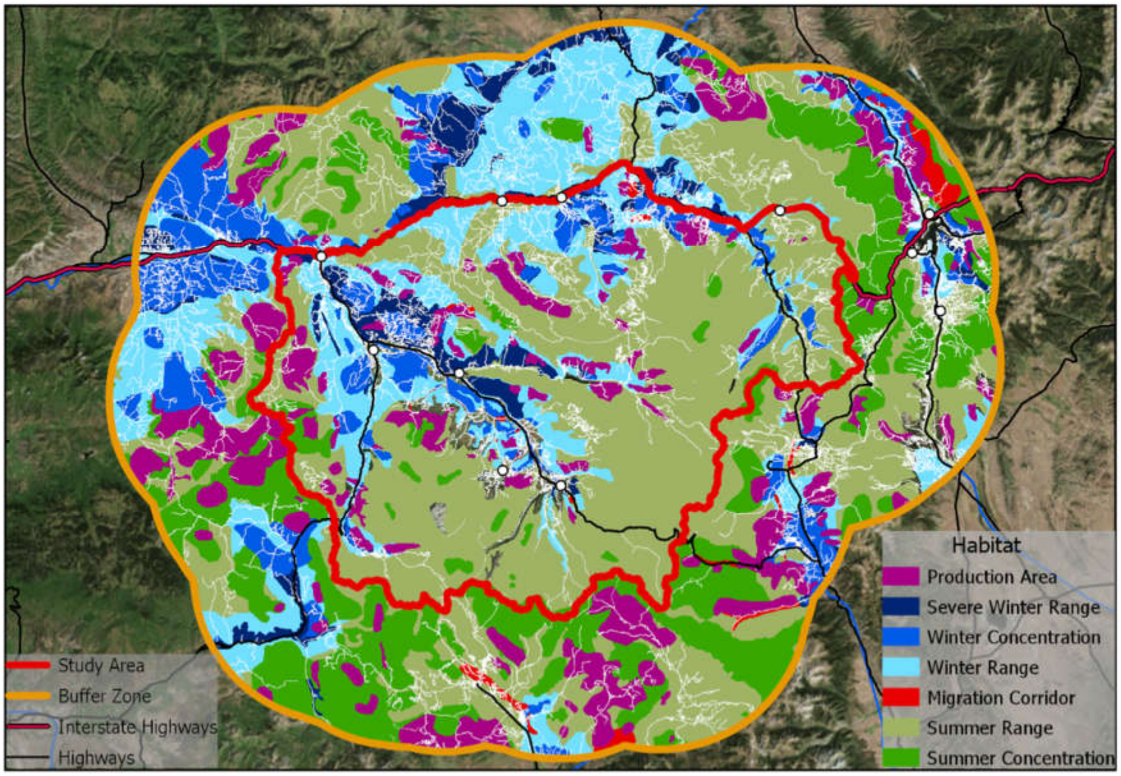

Figure 2: Fragmentation by elk habitat type as of 2018. Fragmenting roads and trails depicted in white. Elk Data: Colorado Parks and Wildlife.

To provide a broad view of the effects of fragmentation and to allow fragmentation to be distinguished from habitat loss, I chose measures provided by FRAGSTATS that reflected both changes in the total amount of different habitat classes and changes in the structure of that habitat. I analyzed the data based on the elk seasonal habitat classes discussed above, as well as at a landscape level. No single measure combines a complete characterization of fragmentation, but together they describe both the degree and kind of fragmentation that has occurred. For a complete description of the metrics considered in this study, see Appendix 2. To avoid edge effects, I included a 25-kilometer buffer zone around the study area in my analysis; habitat within the buffer zone was included for purposes of considering adjacency and similar factors regarding the study area itself. I selected Core Area Index and Proximity Index for summer concentration and migration areas as candidate predictor variables for modeling because they displayed the greatest change over the study period, perhaps because winter habitat areas had already become highly fragmented in earlier periods.

Connectivity Analysis

Most connectivity research involves creating a “resistance surface” raster in which each cell is assigned a value based on the ease or difficulty of wildlife movement across it. Typical parameters for constructing a resistance surface might include, for example, human-built infrastructure, vegetation type, distance to water, slope, etc. Some researchers have successfully employed a landscape integrity approach that posits that landscape suitable for residence and for movement are not necessarily the same, and that human alteration to the landscape is the largest factor in resistance to movement. (see, e.g., Belote et al. 2016; Theobald 2013; Krosby et al. 2015). Given the smaller area of landscape to be considered in my capstone project, the more limited range of human activities occurring there, and the focus on a single species, I based my resistance surface on an inverse of an elk habitat suitability model, then applied various penalty factors.

The Colorado State Wildlife Action Plan's "Making Connections for Wildlife" program was an interagency effort that assembled a team of biologists and GIS experts to model wildlife movement corridors based on habitat suitability parameters for a variety of species, including elk, that are specifically applicable to the Colorado portion of the Rocky Mountains (Colorado Division of Wildlife 2006). The resulting habitat suitability model, based on vegetation cover type and distance to nearest road, was created through expert consultation and has the advantage of having been used successfully in prior research. The data required to transform this habitat suitability model into my final resistance surface included the GAP 2011 and road/trails data discussed above under Fragmentation Analysis. In addition, I used USGS NHD Plus datasets for hydrographic data to assign resistance to major rivers (USEPA/USGS 2012). I also used USGS 3DEP digital elevation data, at a spatial resolution of 1/3 arc seconds (~10 meters), downsampled to 30 meter resolution, to create a slope resistance layer (USGS 2017).

I modeled connectivity using the open source software Circuitscape, which simulates running electric current across the resistance surface, based on the premise that wildlife movement will flow across the landscape in the same fashion (McRae et al. 2008). In particular, I used a relatively novel approach to Circuitscape, known as Omniscape, that measures overall flow across the landscape, rather than simply between predetermined locations (McRae et al. 2016; McClure et al. 2017). By avoiding arbitrary selection of movement start and end points required by other approaches to evaluating connectivity, Omniscape presents a broader view of the possibilities of movement available to wildlife.

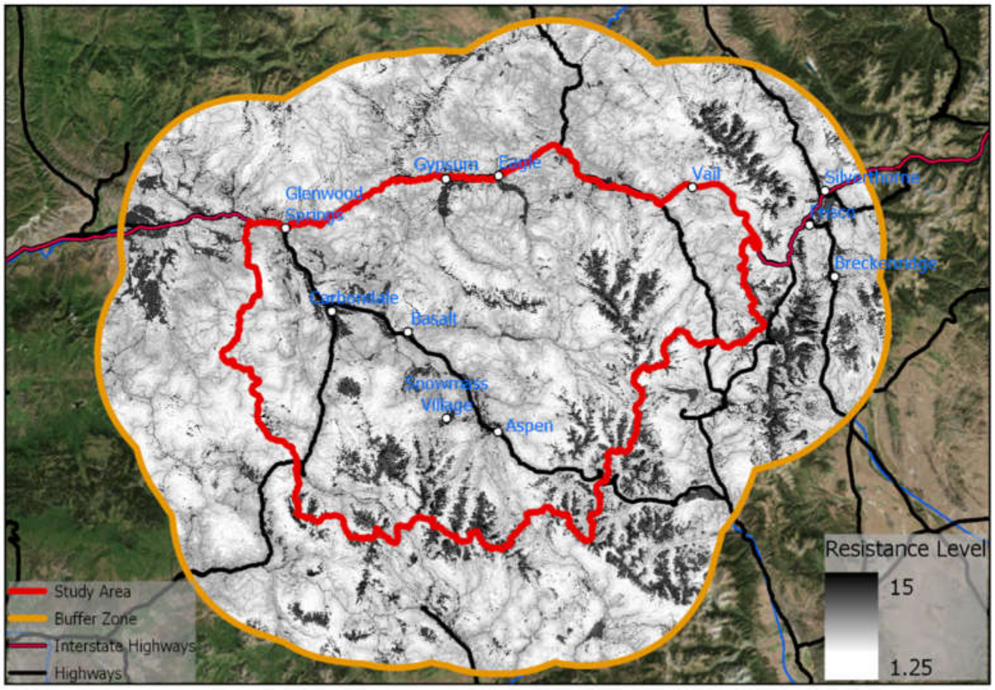

Figure 3: Resistance layer as of 2018 for the study area and buffer zone.

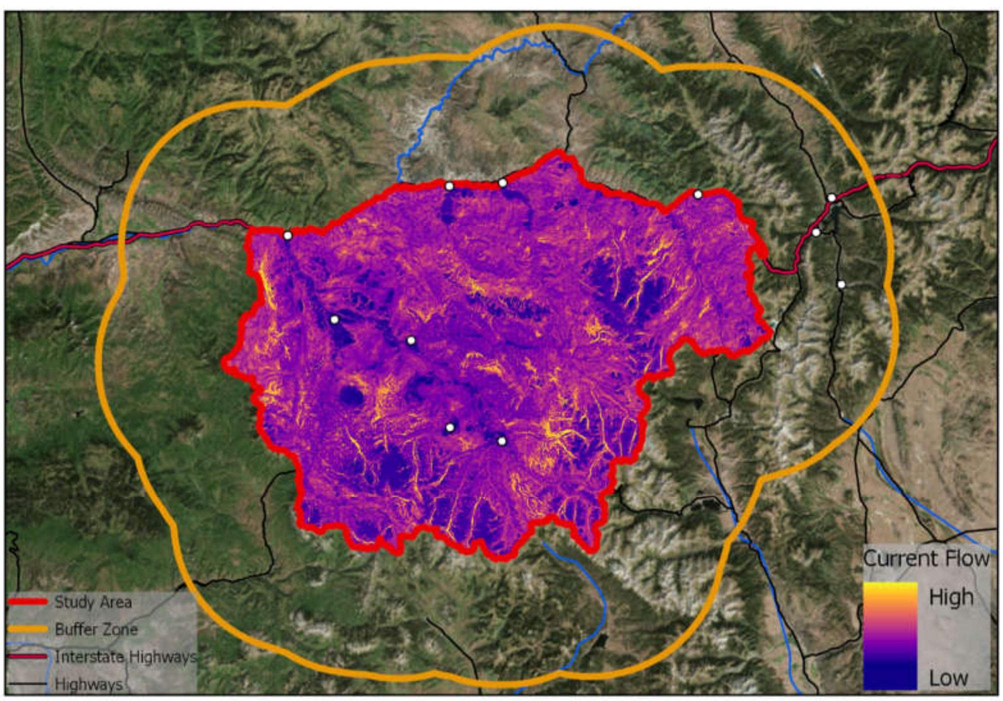

Figure 4: Results of Circuitscape/Omniscape analysis of the study area for 2018.

Figure 3 shows the resistance layer created for 2018; Figure 4 shows the results of Omniscape analysis of that layer. As expected, areas of high resistance correspond to areas of rugged terrain, rivers, roads, and other human developments. While the Omniscape analysis provided a visual depiction of movement potential that can also be compared to empirical wildlife movement data where available and can also be used to identify critical connectivity areas, it is not well-suited to comparing connectivity changes over time, as it does not produce meaningful numeric data. My analyses evaluating connectivity against other variables contributing to elk population thus used resistance surface data, in the form of a mean value for each year for the study area, rather than Circuitscape output.

Fragmentation and Connectivity Data Limitations

While the elk population for the entire 1981 to 2017 study period was available annually, measures of habitat fragmentation and landscape connectivity were subject to limitations: (1) all measures were available less frequently than annually; (2) FRAGSTATS and connectivity metrics were available for only a portion of the study period; (3) human population was an indirect proxy for landscape changes; (4) measures varied in degree of spatial resolution from census block group to 30 meters; and (5) FRAGSTATS and connectivity measures metrics were constructed from data that did not capture all change over time. Appendix highlights these characteristics for the habitat fragmentation and landscape connectivity measures used in this study. In addition to these limitations, resistance value did not display substantial variability among habitat classes; I therefore used the mean value across the study area for analysis. U.S. Census population data was not available at adequate spatial resolution to permit analysis based on habitat class or indeed to include only areas within the precise study area boundaries, so I used best estimate values for the study area based on evaluation of census block groups.

To address the unavailability of direct measures of habitat fragmentation and landscape connectivity prior to 1990, I used the recently-developed Built-up Intensity measure as a proxy (Leyk and Uhl 2018). Built-up Intensity is reported on a 1 to 15 scale for the conterminous United States at five year intervals for the period 1810 to 2015. Higher scaled scores are assigned to each 250 meter pixel based on the number of square feet of human construction within the pixel. To permit analysis of the dependent variables relating to habitat fragmentation and landscape connectivity with the annual elk data, I used linear interpolation between measurement dates for each independent variable to provide annual values. In the case of the Built-up Intensity, which was last produced for 2015, I used linear extrapolation based on the slope from 2010 to 2015 to produce values for 2016-18.

Other Variables and Data Sources

I considered other datasets that measured variables with the potential to affect elk population, including hunting pressure, phenology, precipitation, and human presence in the study area:

1) Elk Data: Colorado Parks and Wildlife provided records of annual elk population and herd structure estimates from 1981 to 2018, and also annual hunting license and

harvest data from 1996 to 2018. Elk population and herd structure estimates were based on data collected annually, but years prior to 2018 were re-modeled by Colorado Parks and Wildlife staff using their most current modeling approach, ensuring comparability of data.

2) Phenology: To evaluate possible effects relating to forage quality, I used data from the United States Geological Survey's Remote Sensing Phenology (RSP) collection, which includes a variety of NDVI-based metrics based on data from the Advanced Very High Resolution Radiometer (AVHRR) and the Moderate Resolution Imaging Spectroradiometer (MODIS) (USGS 2001-17). This dataset (or comparable data) is not available for years prior to 2001, but as it was not included in any of the preferred models for the 2001 to 2017 period, I did not seek to evaluate phenology for earlier periods.

3) Precipitation: In addition to its effect on phenology, precipitation may directly affect elk population based on the amount of snow and other precipitation occurring during the year. Snowfall may affect access to preferred habitat areas and may restrict access to food even in reachable areas. These effects are dependent on both the total snowfall and its timing. Total precipitation, regardless of form, may affect availability of drinking water and may, through the impact of runoff on stream flows, limit connectivity. The Colorado Climate Center provides historic weather data from several stations in the study area, but only the Aspen 1SW station provides consistent data for the entire study period of 1981 to 2018 (Colorado State University, 1981-2018).

Results

Prior to statistical analysis, I reviewed the elk population and other data to review trends that might inform model selection. As an initial matter, I considered the pattern of elk population and population growth rate over time (Figure 5). Consistent with anecdotal reports, the elk population more than doubled from the late 1980s through the late 1990s, then declined rapidly from 2000 through 2015. An increase in growth rate commenced in 2013, leading to a climb in population from 2016 to the present. To understand these trends, I identified possible predictor variables from the datasets described above.

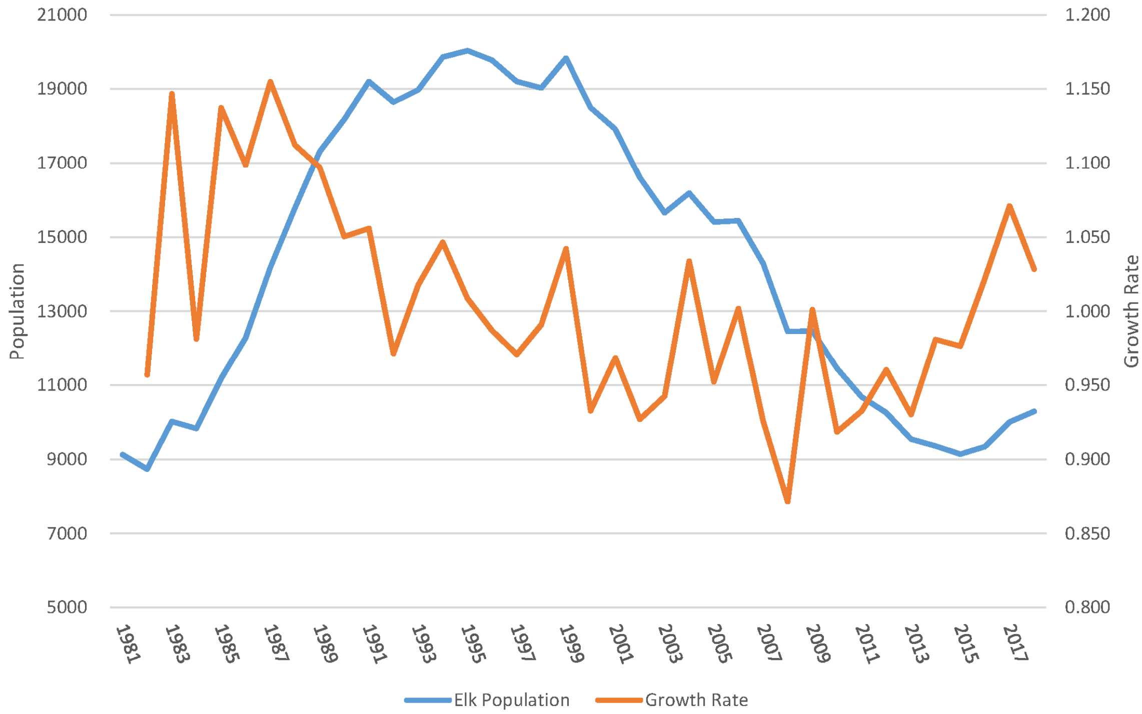

Figure 5: Elk population and population growth rate from 1981 to 2018. Note that the growth rate was less than one (declining population) for most of the period 2000 to 2015. Data: Colorado Parks and Wildlife.

Correlation among Human Influence Variables

To understand the covariance of these habitat fragmentation and landscape connectivity variables and their abilities to serve as proxies for one another, I constructed a Pearson correlation matrix (see Table 1) covering the period for which all measures were available, 1990 to 2018. As Table 1 shows, there is a high degree of correlation between these variables, suggesting that they are suitable proxies for one another, most importantly in the case of Built-up Intensity when considering periods prior to 1990.

	Population	Built-up Intensity (Mean)	Resistance (Mean)	Core Area Index (Migration)	Proximity Index (Migration)	Core Area Index (Summer)	Proximity Index (Summer)
Population	1						
Built-up Intensity (Mean)	0.97	1					
Resistance (Mean)	0.94	0.99	1				
Core Area Index (Mean Migration Corridors)	-0.96	-1	-0.99	1			
Proximity Index (Mean Migration Corridor)	-0.96	-1	-0.99	1	1		
Core Area Index (Mean Summer Concentration)	-0.76	-0.80	-0.89	0.79	0.81	1	
Proximity Index (Mean Summer Concentration)	-0.85	-0.89	-0.95	0.89	0.90	0.99	1

Table 1: Pearson matrix showing correlation among direct and indirect measures of habitat fragmentation and landscape connectivity.

Predictor Variable Selection by Evaluating Correlation

Based on these results, I chose to include Built-up Intensity in my modeling, as it serves as a useful proxy for habitat fragmentation and landscape connectivity loss and covers the entire study period. BUI does show an inverse correlation with the following year's growth rate (see Figure 6, although that correlation weakens at higher levels of BUI—which also correspond with more recent years. I also included measures of hunting pressure in my model, as control of hunting licenses and resulting deaths is the management technique perhaps most widely used by wildlife agencies. While elk deaths due to hunting ("harvest") have an obvious direct effect on population, its correlation with the following year's growth rate (and also when lagged to second and third years) proved negligible. To the extent that population and harvest are correlated, the causation may run in both directions; harvest does reduce population, but

Colorado Parks and Wildlife may issue fewer licenses in response to reduced population (see Appendix 5, Figure 3). On the other hand, the proportion of the harvest comprised of cow elk showed a clear inverse correlation with the following year growth rate (see Appendix 5, Figure 4).

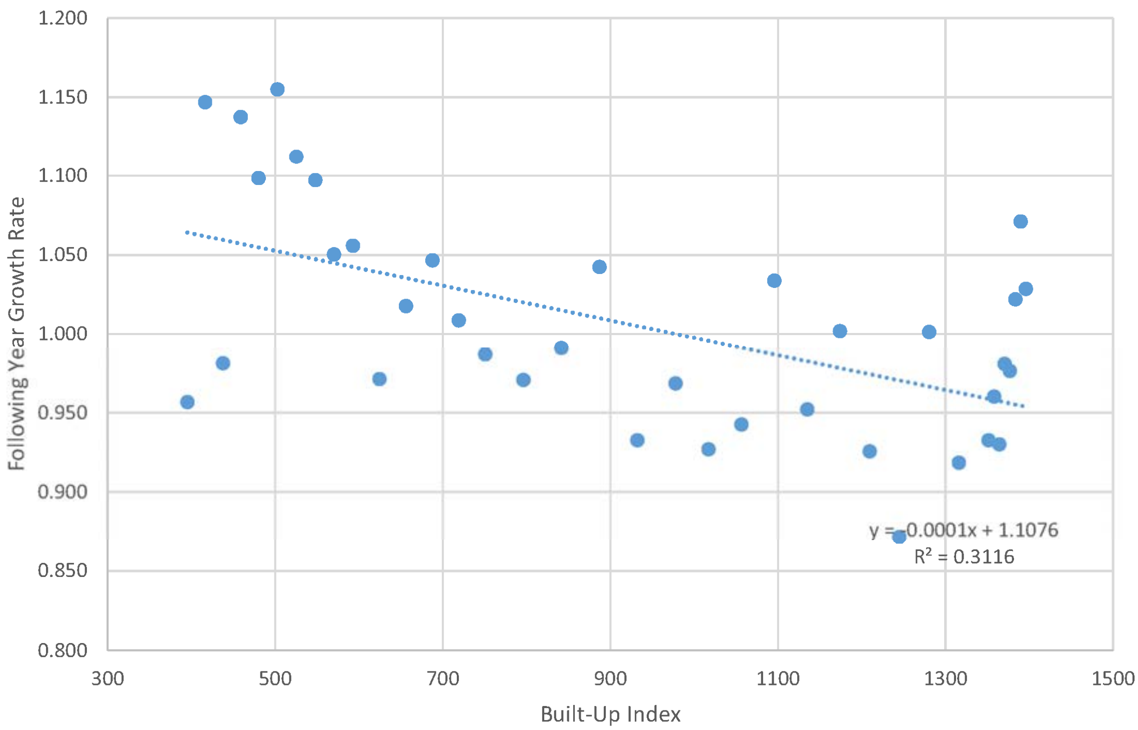

Figure 6: Chart showing the correlation of the Built-up Intensity with the following year growth rate for 1981 through 2017. Data: Colorado Parks and Wildlife; Leyk and Uhl 2018.

Due to the complexity of the relationships among these and other possible predictor variables, I used R to construct a Pearson correlation matrix to evaluate the correlations of more than thirty variables regarding elk population structure, hunting pressure, human influence on the landscape, weather, and phenology among one another and with following year population growth rate (R Core Team 2019). Using the *rcorr* function from the Hmisc package allowed this matrix to include p-values for each correlation coefficient (Harrell et al. 2019). Figure 7 shows a correlogram produced using this process. I then selected a subset of these predictor variables to use in modeling based on their degree of correlation with following year growth rate, the p-value of that correlation, and consistency with factors believed to influence elk population growth.

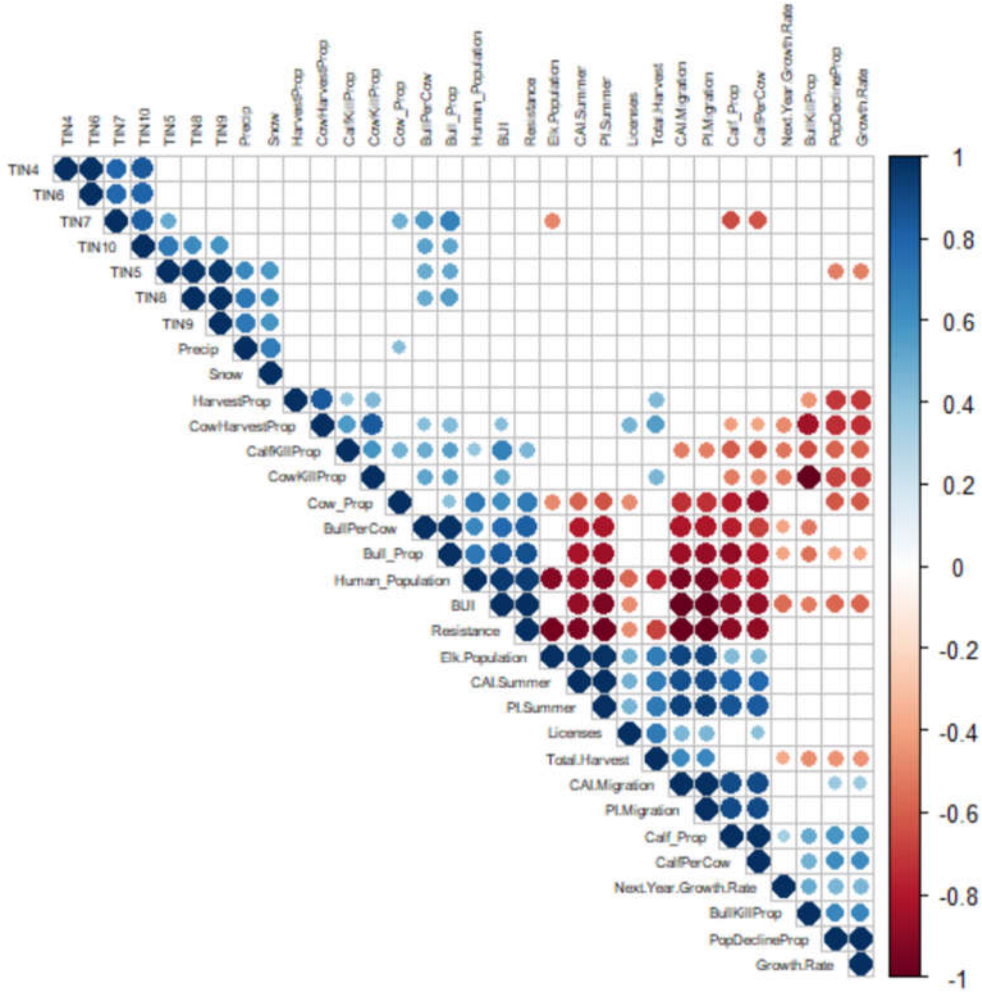

Figure 7: Correlogram showing candidate predictor variables. Color and size of circles indicate the strength and direction of correlation. Blank squares indicate correlations with a p-value of greater than 0.05.

Built-up Intensity and Elk Population as Key Model Variables for 1981 to 2017

I used the stepAIC function from the MASS R package, which allows for simultaneous consideration of multiple models using a stepwise process, to identify candidate linear regression models to explain following year elk population growth rate (Venables and Ripley 2002). This function constructs models from all submitted predictor variables and tests them against the designated dependent variable, then returns the models with the best Akaike information criterion (AIC) values. Because of the differing availability of predictor variables for different time periods and in order to explore the possibility of models performing differently over different time periods, I applied this approach to different chronological subsets of my data. To address AIC's tendency to overfit models with small sample sizes, as is the case in this study, I also performed exploratory linear regression with the identified models to determine if models with similar r-squared and multiple r-squared values could be obtained when omitting one or more predictor variables (Bedrick and Tsai 1994). Although this study's goal is not to predict future growth rates, I applied the predictive r-squared value to further limit the possibility of overfitting. The predictive r-squared is based on iteratively removing an observation from the dataset, determining the regression equation from the remaining observations, then applying it to the removed observation (Minitab Blog 2013).

The model for 1981 to 2017 (the last year for which the following year's growth rate is available) with best fit (Model A) resulted from applying linear regression to the following baseline year variables: calf to cow ratio, total precipitation, the third degree polynomial of the total elk population, and the third degree polynomial of the Built-up Intensity. This model returned a multiple R-squared value of 0.7727, an adjusted R-squared value of 0.697, and a predictive R-squared value of 0.551 (see Appendix 5, Table 1). Note that annual license numbers and phenology data, as well as direct measures of resistance and fragmentation, were not available for the entirety of this time period; the Built-up Intensity stood in for the human influence variables, but license numbers and phenology were omitted. Both the plot of actual versus predicted following year growth rate (Appendix 5, Figure 5) and absolute residual value versus predicted next year growth rate (Appendix 5, Figure 6) show that the model as a whole lacks a systematic error relating to growth rate, suggesting it does not suffer from serious heteroskedastic errors. There is a tendency toward more variability for growth rate values closer to one, however.

Considering that the effects of the population structure variables in the preceding models have high p-values and are in one case inconsistent with anticipated ecological processes, I applied the model omitting those variables (Model B). I also eliminated precipitation as a predictor variable, as it was both low in significance and of limited contribution to the goodness of fit. The only two remaining variables were the third degree polynomials of elk population and of Built-up Intensity. The resulting model returned a multiple R-squared value of 0.7264, an adjusted R-squared value of 0.6716, and a predictive R-squared value of 0.5534 (see Appendix 5, Table 2).

Variables Subject to Threshold Effects

Statistical models of ecological phenomena are of limited value unless the predictor variables can be persuasively associated with ecological processes. In the case of the models described above, population structure variables such as calf per cow ratio and proportion of cows harvested were expected to influence population growth rate; adding other such variables to the model, including the ratio of bulls to cows, unexpectedly did not improve fit. Indeed, the population structure variables used in the models above have p-values high enough to suggest their exclusion, as shown by Model B. The negative effects of a higher cow harvest, shown in Appendix 5, Figure 4, obviously reduce the following year's potential calf population (and thus growth rate), but the *negative* effect of a higher calf to cow ratio (whether lagged or not) is less straightforward to explain. Given that female calves have long been thought to typically begin breeding in their third year, the lagged calf to cow ratio would seem more likely to predict an *increased* growth rate (see, *e.g.*, Kittams 1953 regarding age of first breeding for elk). The small number of observations in the underlying dataset, the low significance of this variable, nonlinearity, and covariance with other variables may explain this unexpected result. More broadly, the strong influence of elk population and human influence on the landscape may render the effect of other variables difficult to distinguish from noise.

To understand the variation in, and influence of, the calf to cow ratio, I applied the R package "segmented" to find breakpoints for the ratio that might better explain its possible nonlinear effect (Muggeo 2008). Analysis showed that when the calf per cow ratio was less than 0.4808, the mean following year growth rate was 0.971483; when the calf per cow ratio was greater than or equal to 0.4808, the mean following year growth rate was 1.034469 (see Figure 8).

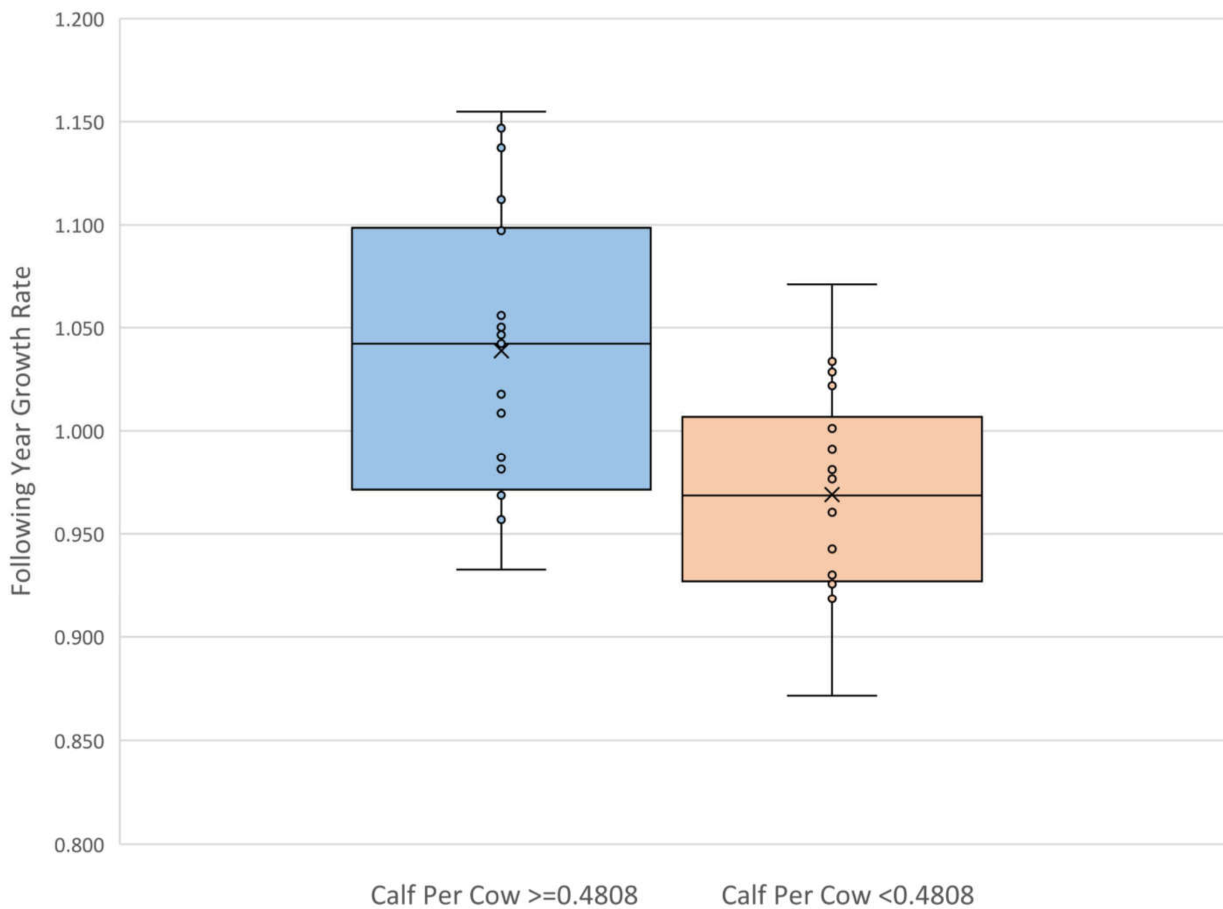

Figure 8: Whisker plot showing range of following year growth rates assuming a calf per cow ratio breakpoint of 0.4808. Elk Data: Colorado Parks and Wildlife.

Most notably, this breakpoint marks the difference between a declining and increasing population, and suggests an important positive relationship between calf to cow ratio and growth rate not evident in a linear regression analysis. All of the years of lower calf to cow ratio (and lower growth rate) except 1997 occur between 2001 and 2017 (excluding 2004), suggesting a temporal aspect to its variance, and possible covariance with a variable that also varies temporally. Figure 9 illustrates the strong negative correlation between the calf to cow ratio and the Built-up Intensity, which has a consistent temporal trend. One possible interpretation of this covariance is that the range of variation of the calf to cow ratio becomes depressed when the Built-up Intensity crosses a threshold value. Based on the calf to cow ratio dipping below the breakpoint of 0.4808 between 2000 and 2001, this BUI value would be in the range of roughly 978 to 1017; at higher BUI values, other variable(s) would presumably explain variance within the lower range of calf to cow ratios and following year growth rates.

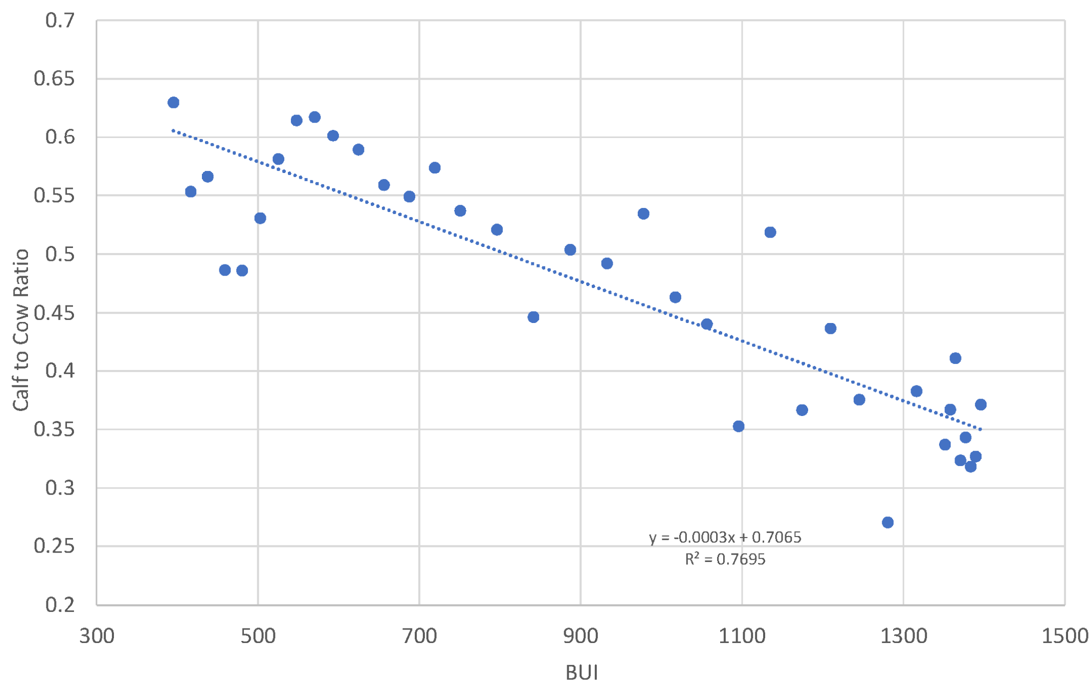

Figure 9: Scatterplot showing the correlation between calf to cow ratio and Built-up Intensity for 1981 to 2017. Note the increased variability of the calf to cow ratio at higher BUI values, which corresponds to more recent years. Data: Colorado Parks and Wildlife; Leyk and Uhl 2018.

The negative effect of the total elk population on following year growth rate in Models A and B is consistent with the finding by Taper and Gogan (2002) that Yellowstone elk growth rate was negatively affected by increased population density. Figure 10 suggests that the correlation is relatively weak at lower population levels, but that the mean growth rate is depressed when population approaches 20,000. In the case of this variable, it may be that the negative effect is negligible until a threshold value is reached.

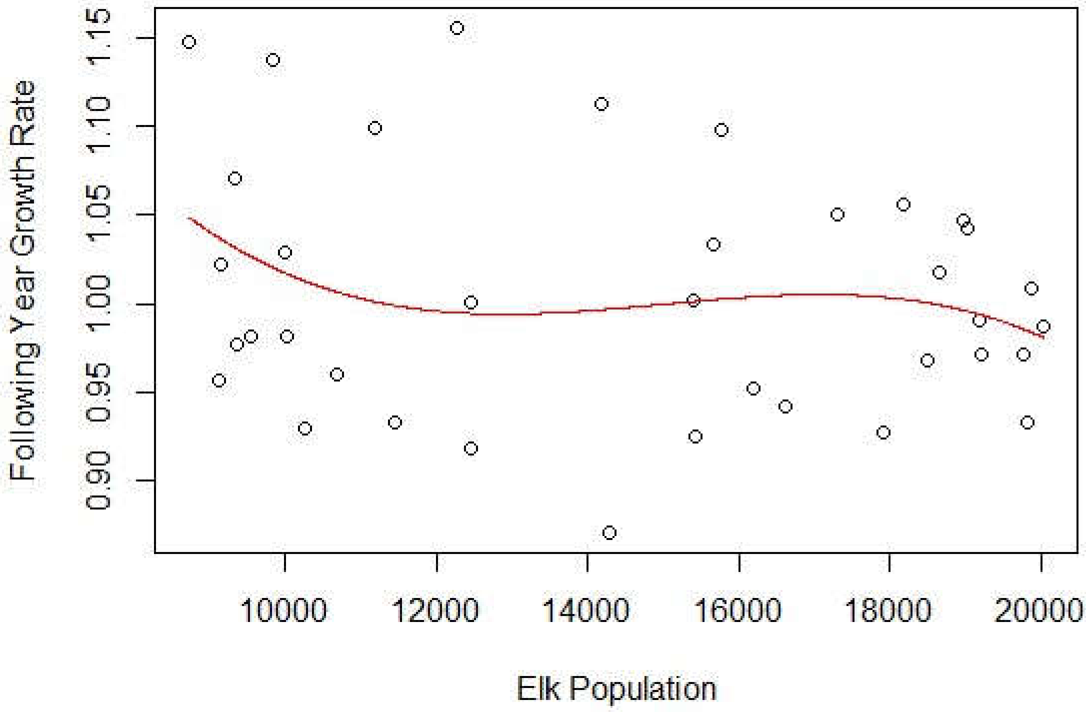

Figure 10: Scatterplot showing the third order polynomial model of the effect of total elk population on the following year growth rate. Elk Data: Colorado Parks and Wildlife.

To understand the variation in the relationship between the elk population and following year growth rate, I again performed breakpoint analysis using the “segmented” R package (Muggeo 2008); none of the generated breakpoints operated consistently throughout the study period. Reviewing the suggested breakpoints did, however, reveal that the relationship had a strong temporal element, and that applying different coefficients for different time periods provided a better explanation of the variation in correlation. High degrees of correlation exist between elk population and following year growth rate when considered separately for the periods 1993 to 2008 (mean following year growth rate 1.014) and 2009 to 2017 (0.9800) (see Appendix 5, Figure 7 and Appendix 5, Figure 8). The latter period’s negative correlation is 50% stronger, suggesting that the limiting effect of population may have increased over time.

Increased Influence of Hunting Variables: Modeling 2001 to 2017

To better understand more recent trends in elk population, I applied both Model A and Model B as devised for 1981-2017 to observations from 2001 to 2017 only. While the multiple R-squared score of 0.84 and the adjusted R-squared score of 0.8074 suggest even better fit of Model A for this time period, the predictive R-squared value of -0.1805 implies some weaknesses in the model; the simpler Model B produced similar results. While a good compromise fit for the entire period, changes over time in the relationship between predictor variables (including the threshold effects discussed above) may reduce the overall model’s usefulness when analyzing shorter and, particularly, more recent time frames. Given my findings regarding the changes over time in the behavior of calf per cow ratio and elk population, I used the broader array of predictor variables available for more recent years to construct a new model, again using the stepAIC function in R and exploratory linear regression.

Eliminating years prior to 1990 allowed adding direct resistance and fragmentation measures to the model, while eliminating years prior to 1996 allowed adding hunting licenses. Finally, eliminating years prior to 2001 allowed the use of phenology data from the United States Geological Survey's Remote Sensing Phenology (RSP) collection. In this case, the use of the stepAIC function was not useful, as the models it rated highest based on AIC were inconsistent with any reasonable ecological interpretation (e.g., increased resistance led to increased following year growth rate). Exploratory linear regression yielded a model with strong R-squared and p values that resulted from applying linear regression to the preceding year elk population, the proportion of cows (vs. bulls and calves) in the total harvest in the preceding year, the mean resistance in the preceding year, the Core Area Index for summer concentration areas in the preceding year, and the number of hunting licenses issued in the preceding year (Model C). This model resulted in a multiple R-squared value of 0.871, an adjusted R-squared value of 0.8124 and a predictive R-squared value of 0.6952579 (see Appendix 5, Table 3). Appendix 5, Figure 9 and Appendix 5, Figure 10 confirm that the model fit is good, although with a wide range of residuals at lower predicted values of following year growth rate.

Discussion

Examination of elk population trends in the study area from 1980 to 2018 shows substantial variation that is not fully explained by the expected predictor variables of elk population structure or hunting pressure (see Monello et al. 2014; Raithel et al. 2007; Hebblewhite 2000). Rather, as hypothesized, variables relating to human influence on the landscape and to elk population structure explain a substantial portion of the variability in elk population growth in the Eagle and Roaring Fork valleys, either directly or through their apparent effect on the behavior of other variables, particularly calf to cow ratio. Models A, B, and C all incorporated one or more variables measuring some aspect of human influence on the landscape: habitat fragmentation, resistance, or Built-up Intensity. Given the substantial number of available predictor variables, the parsimony and goodness of fit of Model B—which considered only elk population and Built-up Intensity—was surprising.

Analysis over the period 1990 to 2015 further demonstrates that four measures of human influence—total population, resistance, habitat fragmentation, and Built-up Intensity—are also highly correlated with one another. This correlation permitted modeling the effect of human influence on elk population growth as far back as 1981, whereas reliance on other measures would have limited the analysis to periods after 1990, missing important trends during a period of rapid elk and human population growth.

The degree of variability over time of various habitat fragmentation metrics differed when applied to different seasonal habitat classes (Appendix 4). All seasonal habitat classes showed increased fragmentation during the study period, but summer concentration areas and migration corridors displayed the largest changes overall. While the negative effect of winter disturbance of elk population has been stressed historically (see, e.g., Kittams 1953), there is increasing concern over the effect of summer disturbance (Canfield et al. 1999). This study suggests this concern is warranted, as the changes in summer concentration areas and migration corridors evidenced higher correlation with variation in growth rate than did other seasonal habitats. These metrics were not available prior to 1990, so it is possible that severe winter, winter concentration, and production areas had been disproportionately fragmented in earlier periods, limiting the potential for their further fragmentation.

As mentioned above, breakpoint analysis showed a segmentation in the relationship between calf to cow ratio and following year growth rate, with calf to cow ratios below 0.48 showing a substantially lower growth rate. This breakpoint is largely temporal, with most ratio values above it occurring prior to 2001 and most values below it occurring thereafter. This result, when combined with the high degree of correlation (R-squared = 0.7695) between calf per cow ratio and Built-up Intensity, strongly suggests that human influence on the landscape may have a depressing effect on elk population growth. With the exception of proportion of cows in harvests, harvest data was not strongly correlated with population growth rate. For years after 2000, however, the number of hunting licenses issued did show correlation, suggesting that mere human presence during hunting season may play a larger role than the number of elk killed in at least some circumstances.

Phenology and precipitation are also widely considered to be predictive of elk population growth (Lubow and Smith 2004; Hebblewhite 2000). However, none of the evaluated models that included one or more phenology variables produced a p value of 0.05 or better for those variables, and the explanatory value of variables relating to precipitation was also weak. Data regarding overall precipitation, snowfall, and phenology, were not prerequisites for modeling population growth rate during the study period; it is possible that these variables take on importance only at (i) levels of elk population not reached during the study period or (ii) in the case of phenological variables, for elk population levels not reached during the period of data availability.

The changes over time in the relationships between expected predictor variables such as calf to cow ratio and elk population and the dependent variable of population growth rate point toward possible changes in the stability and resilience of elk populations in the Roaring Fork and Eagle valleys. Holling (1973) formalized the understanding of resilience and stability as distinct, but related, concepts. He proposed that “resilience determines the persistence of relationships within a system and is a measure of the ability of these systems to absorb changes . . . and still persist” rather than move toward extinction, while stability describes “the ability of a system to return to an equilibrium state after a temporary disturbance” (Holling 1973, p. 17). In the present case, the elk population seems unstable, as it has fluctuated substantially in response to changes in the ecosystem; whether it is resilient remains to be seen, but the changes in the behavior of predictor variables over the last two decades suggest otherwise. It instead seems likely that changes in the landscape have resulted in a change to the equilibrium population of elk in the study area that may be sustainable, or that may be below the extinction threshold (Hanski and Ovaskainen 2002; Levins 1969).

Certainly, close monitoring of population trends is warranted by this possibility. While this study found changes in the behavior of calf per cow ratio and elk population occurring during the period 2000 to 2008 that seems correlated with human influence on the landscape, it is not clear whether the relevant threshold for this effect was crossed at that time or earlier. Elaborating on the concept of extinction thresholds, Tilman et al. (1994) coined the term "extinction debt" to refer to the cumulative effect of habitat destruction that sets a species on an inexorable path to extinction over the course of multiple generations. In the case of the elk of the Roaring Fork and Eagle valleys, it is not clear if such an extinction threshold has been crossed, but the cumulative debt of connectivity loss and habitat fragmentation seems to have reached a level that has increased the limiting effect of other factors on elk populations.

The increased predictive value after 2000 of variables related to hunting pressure suggests that the elk population in the region may no longer support levels of hunting that were previously thought to be sustainable; as noted above, the fact that number of hunting licenses issued each year seems to have an effect independent of harvest level implies a negative effect on growth rate relating to human presence outside of developed areas. This effect begs the question of whether other forms of recreational activity have a similar negative effect on growth rate. Unfortunately, the majority of elk habitat in the study area is located on National Forest land for which no systematic data on recreational use is collected. The lack of information on the construction date of trails may also understate the degree of change in habitat fragmentation and loss of connectivity from 1980 to 2018. Recreational use of these lands on a year-round basis is anecdotally reported to have increased in recent years, but in the absence of data it is unclear to what extent this growth is correlated with other measures of human influence—and thus at least partially accounted for in the models above—or if it has an independent trend not accounted for by these models.

Conclusion

Understanding the effects on elk population of increasing human influence on the landscape over time presents practical and methodological challenges. Perhaps the largest practical challenge is finding temporally accurate data on the construction of human infrastructure that has been collected in a consistent fashion over the relevant time period and with sufficient frequency to require minimal interpolation. The Built-up Intensity index covers a broad range of time with a shorter sampling frequency than other data sources; this study demonstrates its strong correlation with measures of habitat fragmentation and connectivity, and its potential as a valuable resource for time-based studies. From a methodological standpoint, this study shows that the relationship between human influence on the landscape and elk population growth rate in the study area cannot be adequately described through purely linear modeling. This study instead suggests that, when a threshold of accumulated landscape influence is reached, the relationship among various predictor variables and elk population growth rate changes.

Further study using other modeling techniques may allow for a better understanding of this relationship.

This study has shown that habitat fragmentation, loss of landscape connectivity, and related human impacts on the landscape have played a major role in the variation of elk population growth rate in the Roaring Fork and Eagle valleys from 1981 to 2017. To the degree that these human impacts are less directly predictive for the most recent periods, that may because their accumulated effects are expressed in a new equilibrium state in which other variables play a larger role in explaining variation. In addition, the region's elk population may have lost resilience in the face of other variables, including long-studied ones like hunting pressure and others, like recreational pressure, that have not yet been accounted for. Future management of elk populations in the Roaring Fork and Eagle valleys by the Forest Service and the Colorado Department of Parks and Wildlife should be based on an understanding that previously valid assumptions about the anticipated population growth rate of elk herds in response to changes in hunting and other variables may no longer hold true.

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Appendix 1

Elk Population and Hunting Data, 1981 to 2018

Year	Calves	Cows	Bulls	Elk Population	Licenses	Calves Harvested	Bulls Harvested	Cows Harvested	Total Harvest
1981	3,186	5,060	884	9,130	-	48	1,088	540	1,676
1982	2,895	5,233	608	8,736	-	73	1,093	546	1,712
1983	3,290	5,812	916	10,018	-	64	827	433	1,324
1984	2,919	6,002	910	9,832	-	108	978	625	1,711
1985	3,168	6,519	1,496	11,183	-	62	663	543	1,268
1986	3,723	7,014	1,549	12,285	-	61	760	290	1,111
1987	4,534	7,802	1,852	14,188	-	45	734	287	1,066
1988	5,180	8,431	2,169	15,780	-	86	1,015	709	1,810
1989	5,656	9,163	2,496	17,314	-	105	1,161	782	2,048
1990	5,933	9,870	2,382	18,185	-	108	1,621	874	2,603
1991	6,240	10,591	2,369	19,200	-	133	1,591	903	2,627
1992	6,000	10,734	1,917	18,651	-	146	1,819	1,186	3,151
1993	5,905	10,753	2,324	18,981	-	154	954	1,147	2,255
1994	6,390	11,139	2,336	19,865	-	92	1,258	823	2,173
1995	6,099	11,360	2,577	20,036	-	84	1,148	1,039	2,271
1996	6,058	11,630	2,087	19,775	4,468	148	1,688	901	2,737
1997	5,231	11,715	2,253	19,199	4,507	74	1,057	965	2,096
1998	5,574	11,066	2,388	19,029	4,362	159	973	1,440	2,572
1999	5,758	11,701	2,374	19,833	3,788	108	1,297	634	2,039
2000	5,683	10,628	2,186	18,497	4,452	115	1,168	1,693	2,976
2001	4,892	10,556	2,468	17,916	3,625	83	751	904	1,738
2002	4,318	9,809	2,480	16,607	4,189	240	1,291	1,771	3,302
2003	3,379	9,581	2,695	15,654	5,193	118	1,088	1,348	2,554
2004	4,667	8,998	2,516	16,182	5,333	132	1,110	1,308	2,550
2005	3,357	9,160	2,893	15,410	4,524	174	1,068	1,182	2,424
2006	3,885	8,905	2,647	15,437	3,959	114	1,131	1,022	2,267
2007	3,193	8,509	2,588	14,290	3,747	113	898	1,061	2,072
2008	2,142	7,930	2,383	12,455	3,881	95	915	1,099	2,109
2009	2,840	7,422	2,208	12,470	3,665	120	844	1,005	1,969
2010	2,340	6,947	2,166	11,453	4,330	116	852	1,115	2,083
2011	2,356	6,421	1,904	10,682	4,203	73	903	1,018	1,994
2012	2,448	5,959	1,852	10,259	4,428	160	755	1,010	1,925
2013	1,886	5,830	1,826	9,542	3,983	50	846	871	1,767
2014	1,943	5,659	1,759	9,361	3,352	91	603	616	1,310
2015	1,803	5,664	1,675	9,141	3,213	56	716	581	1,353
2016	1,896	5,800	1,645	9,341	3,402	52	620	422	1,094
2017	2,264	6,100	1,641	10,004	3,496	38	630	320	988
2018	2,599	6,255	1,435	10,289	3,713	32	697	316	1,045

Appendix 2

Fragmentation Metrics

Measures of Overall Habitat Loss and Structural Change

Total Class Area: While this metric does not strictly measure fragmentation, it does illustrate the habitat loss caused by roads and trails. Because of their surrounding zones of disturbance, roads and trails have a particular harsh effect on classes composed of small patches, many of which may be rendered uninhabitable.

Percent Landscape: This metric, which is simply the percentage of the total landscape comprised by each habitat class, highlights the structural changes in landscape composition caused by road/trail-based habitat loss. While all habitat classes will experience reduction as the road/trail disturbance zones reduce available habitat, the classes are differentially affected depending on the size and distribution of their patches.

Fragmentation Metrics

Many of these metrics are reported as means over the entire landscape or on a per habitat class basis, as these are the levels of analysis considered for this study. Large patches have a disproportionate effect on fragmentation at the landscape and habitat class level, so I evaluate the area-weighted mean, which gives more weight to larger patches, as well as the simple mean. Most metrics, other than those involving means, can be considered at the individual patch, class, or landscape level, as indicated with each description.

1. Patch Size and Shape Metrics

Mean Patch Area: This metric is simply the mean of the size of all patches, and can be measured for the entire landscape or by habitat class. Decreased patch size has a negative effect on both species richness and population and is thus useful despite its simplicity. In addition, it is used in the calculation of a number of other metrics (McGarigal 2015). (class and landscape)

Shape Index (area-weighted mean): This metric addresses the complexity and compactness of patch shape and uses the ratio of patch perimeter to area. Higher values indicate more complex, less compact shapes. Geometry dictates that, regardless of shape, this ratio is lower for patches of greater area. Shape Index normalizes that ratio against the ratio of a perfect square of equal area, so the metric is comparable across different patch sizes (McGarigal et al. 2012; see also Riiters et al. 1995). (class and landscape)

2. Core Habitat Metrics

Total Core Area/Core Area Percent of Landscape: For purpose of this measure, core habitat includes that portion of a habitat patch that is at least 100 meters from the patch edge, including edges with other habitat classes or with roads or trails. While this distance is somewhat arbitrary, using a single distance avoids attempting to make more nuanced, species-specific, and debatable distinctions between different habitat borders. Because fragmentation has the effect of introducing more edges into the landscape, core habitat is more severely reduced by roads and trails than overall habitat. (class and landscape)

Mean Core Area/Mean Core Area (area-weighted): These metrics are calculated for each habitat class. The first metric is simply the mean core area per patch (including patches too small to have any core area), while the second weights the mean based on patch area. Distinguishing core areas by habitat class allows a better understanding of which species may be affected by fragmentation (McGarigal et al. 2012). (class and landscape)

Core Area Index: This metric simply provides the percentage of each habitat class that is composed of core habitat, calculated on an area-weighted basis. (class)

3. Isolation Metric

Proximity Index/Proximity Index (area-weighted): This metric aims to measure the isolation of patches of a habitat class—that is, the extent to which it consists of scattered small patches versus patches of mixed sizes that tend to clump together. For each patch of a habitat class, this metric identifies all patches of the same habitat class with edges that are within a user-designated distance; the area of each such patch is then divided by the square of the distance to the target patch. Finally, these values are summed over the entire habitat class. This approach is intended to highlight the greater ecological contribution of neighboring patches that are large and nearby versus smaller and more distant patches (McGarigal et al. 2012). (class)

Appendix 3

Measures of Habitat Fragmentation and Landscape Connectivity

Variable	Measure	Interval	Time Period	Direct Measure	Spatial Resolution	Other Limitations
Habitat Fragmentation	FRAGSTATS analysis	~10 years	1990-2018	Yes	30 meters	Based primarily on TIGER road data
Connectivity	Resistance surface	~10 years	1990-2018	No	30 meters	Based primarily on TIGER road data
Fragmentation and Connectivity	U.S. Census Population	5 to 10 years	1980-2015	No	Census block group	Poor spatial resolution
Fragmentation and Connectivity	Built-up Intensity	5 years	1980-2015	No	250 meters	Untested measure

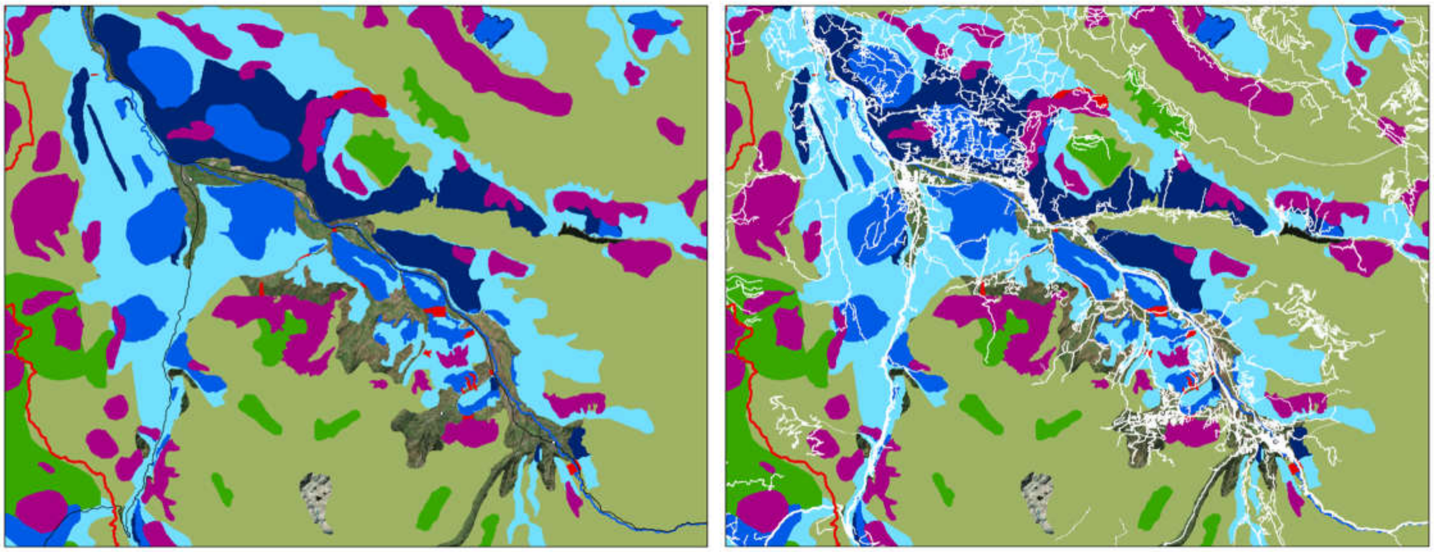
Appendix 4

Selected FRAGSTATS results, 1990 to 2018

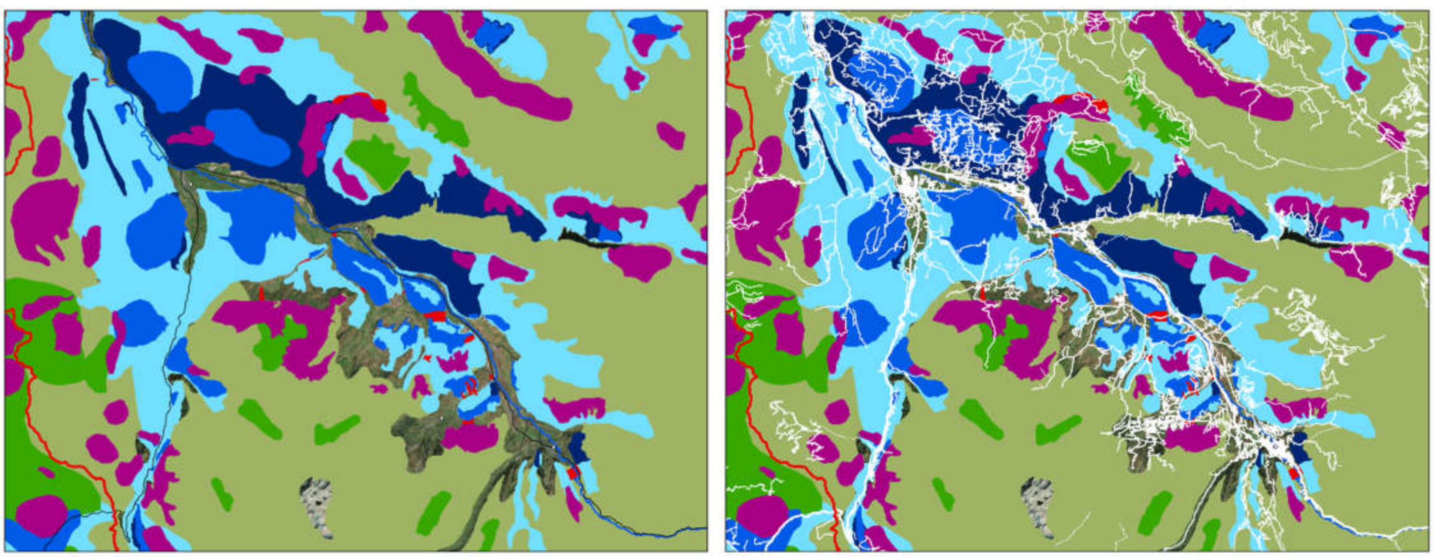
Year	Habitat Class	Total Class Area (hectares)	Percent Landscape	Landscape Index	Mean Patch Area (hectares)	Mean Shape Index	Shape Index-area weighted	Total Core Area (hectares)	Core Area Percent Landscape	Mean Core Area (hectares)	Mean Core Area-area weighted	Mean Core Area Index	Mean Core Area Index-area weighted	Mean Proximity Index	Mean Proximity Index-area weighted	Division	Mesh
1990	Summer Range	304,456.9500	54.1829	37.4773	154.2335	1.4149	3.2242	281,001.2400	50.0085	142.3512	7,511.5701	19.6261	92.2959	5,540.5919	34,685.3328	0.9924	4,259.2816
	Winter Range	79,614.4500	14.1686	41.8507	48.7834	1.4705	2.4157	66,623.3100	11.8567	40.8231	793.8009	22.4983	83.6824	498.0387	1,731.9943	0.9998	123.5211
	Summer Concentration	19,290.4200	3.4330	13.6469	58.9921	1.2667	2.2475	17,189.1000	3.0591	52.5661	793.5831	13.2802	89.1069	395.8659	1,727.3179	0.9999	30.0167
	Migration Corridor	1,288.3500	0.2293	11.9958	13.5616	1.4884	1.7456	839.7000	0.1494	8.8389	42.2069	29.3548	65.1764	50.7212	77.5298	1.0000	0.1302
	Severe Winter Range	21,418.3800	3.8117	25.2285	35.7569	1.4343	2.5905	17,402.6700	3.0971	29.0529	712.1100	19.6629	81.2511	301.4474	861.6425	0.9999	30.1454
	Winter Concentration	30,197.7900	5.3742	26.9905	45.7542	1.4352	2.1989	24,991.2000	4.4476	37.8655	374.3821	23.4733	82.7584	337.6222	791.3993	1.0000	22.8636
	Production Area	38,739.6900	6.8943	24.0769	70.0537	1.4343	2.0371	33,406.4700	5.9452	60.4095	619.2223	29.5312	86.2332	525.2816	1,058.9898	0.9999	46.8109
	MEAN	70,715.1471	12.5849	25.8952	61.0193	1.4206	2.3514	63,064.8129	11.2234	53.1296	1,549.5536	22.4895	82.9292	1,092.7956	5,847.7438	0.9988	644.6814
2000	Summer Range	305,853.2100	52.2976	38.4196	153.0031	1.4348	3.3383	281,826.3600	48.1893	140.9837	7,786.1311	19.0779	92.1443	4,943.5824	35,714.0880	0.9927	4,265.2585
	Winter Range	79,986.3300	13.6768	43.0095	45.9692	1.4801	2.4387	66,694.3200	11.4040	38.3301	798.6360	21.1696	83.3821	474.9201	1,834.9182	0.9998	120.0226
	Summer Concentration	19,228.9500	3.2879	13.1470	68.9210	1.2418	2.2482	17,175.8700	2.9369	61.5623	800.5185	15.3372	89.3230	405.2090	1,675.9634	1.0000	28.9954
	Migration Corridor	1,255.3200	0.2146	12.5865	10.3745	1.4600	1.6920	805.6800	0.1378	6.6585	42.6235	22.6470	64.1812	37.9638	81.5804	1.0000	0.1215
	Severe Winter Range	21,515.7600	3.6790	26.1595	32.2575	1.4206	2.9666	17,375.8500	2.9711	26.0507	1,029.1763	17.2359	80.7587	458.5560	727.9934	0.9999	42.1193
	Winter Concentration	30,068.4600	5.1414	28.9741	38.3526	1.4359	2.2647	24,586.5600	4.2040	31.3604	355.7797	20.5125	81.7686	299.2214	826.6163	1.0000	20.9072
	Production Area	38,691.5400	6.6158	24.4764	64.2717	1.4223	2.0442	33,301.7100	5.6942	55.3185	618.4116	27.0126	86.0697	493.5014	1,081.6251	0.9999	44.8590
	MEAN	70,942.7957	12.1304	26.6818	59.0214	1.4136	2.4275	63,109.4786	10.7910	51.4663	1,633.0395	20.4275	82.5182	1,016.1363	5,991.8264	0.9989	646.0405
2010	Summer Range	302,382.9900	51.7479	38.7559	157.0005	1.4782	3.2979	278,311.9500	47.6286	144.5026	7,645.0536	20.6839	92.0396	4,821.2004	34,196.7362	0.9929	4,142.7996
	Winter Range	78,057.4500	13.3583	42.8712	46.6293	1.4902	2.4433	64,953.6300	11.1158	38.8015	768.6569	21.8955	83.2126	423.5161	1,624.1054	0.9998	113.0827
	Summer Concentration	19,112.1300	3.2707	14.2169	33.2964	1.1612	2.3033	17,002.8000	2.9098	29.6216	794.7064	7.3094	88.9634	190.6172	1,673.3531	1.0000	28.7396
	Migration Corridor	1,211.7600	0.2074	12.7940	7.4341	1.3354	1.6994	775.4400	0.1327	4.7573	41.9080	16.1548	63.9929	24.0017	74.3254	1.0000	0.1157
	Severe Winter Range	20,993.1300	3.5926	26.1242	32.2971	1.4354	2.5935	16,915.7700	2.8949	26.0243	656.4152	17.9497	80.5776	352.7385	723.6791	1.0000	26.2228
	Winter Concentration	29,150.8200	4.9887	29.2054	37.9074	1.4520	2.2637	23,711.1300	4.0578	30.8337	345.6354	21.1954	81.3395	290.4765	682.8405	1.0000	19.7476
	Production Area	38,109.0600	6.5217	24.6759	61.2686	1.4325	1.9900	32,742.6300	5.6034	52.6409	585.4903	27.1478	85.9182	416.1360	1,021.7820	0.9999	41.8606
	MEAN	69,859.6200	11.9553	26.9491	53.6905	1.3978	2.3702	62,059.0500	10.6204	46.7403	1,548.2665	18.9052	82.2920	931.2409	5,713.8317	0.9989	624.6527
2018	Summer Range	302,337.8100	51.7372	38.7400	157.2220	1.4776	3.2979	278,275.2300	47.6195	144.7089	7,645.6910	20.6939	92.0412	4,835.5919	34,181.1026	0.9929	4,142.2758
	Winter Range	78,022.8000	13.3516	42.8202	46.6923	1.4897	2.4430	64,931.9400	11.1114	38.8581	768.9073	21.9114	83.2218	422.8574	1,623.7451	0.9998	113.0615
	Summer Concentration	19,110.9600	3.2703	14.2158	33.2944	1.1612	2.3033	17,001.8100	2.9094	29.6199	794.7385	7.3030	88.9637	190.5344	1,673.2783	1.0000	28.7373
	Migration Corridor	1,207.8900	0.2067	12.8190	7.4104	1.3377	1.7032	773.1000	0.1323	4.7429	41.9586	16.0632	64.0042	23.8868	74.2429	1.0000	0.1155
	Severe Winter Range	20,985.5700	3.5911	26.0911	32.4854	1.4380	2.5928	16,912.2600	2.8941	26.1800	656.5744	18.0603	80.5899	352.4299	723.5415	1.0000	26.2172
	Winter Concentration	29,138.1300	4.9862	29.2276	37.6949	1.4503	2.2631	23,700.6000	4.0557	30.6605	345.5365	21.0554	81.3388	289.2793	682.3555	1.0000	19.7325
	Production Area	38,102.2200	6.5202	24.6820	61.1593	1.4320	1.9899	32,734.8900	5.6017	52.5440	585.5415	27.1477	85.9133	415.7668	1,021.8097	0.9999	41.8540
		69,843.6257	11.9519	26.9422	53.7084	1.3981	2.3705	62,047.1186	10.6177	46.7592	1,548.4211	18.8907	82.2961	932.9066	5,711.4394	0.9989	624.5705
Percent Change 1990 to 2018																	
	Summer Range	-0.70%	-4.51%	3.37%	1.94%	4.43%	2.29%	-0.97%	-4.78%	1.66%	1.79%	5.44%	-0.28%	-12.72%	-1.45%	0.05%	-2.75%
	Winter Range	-2.00%	-5.77%	2.32%	-4.29%	1.31%	1.13%	-2.54%	-6.29%	-4.81%	-3.14%	-2.61%	-0.55%	-15.10%	-6.25%	0.00%	-8.47%
	Summer Concentration	-0.93%	-4.74%	4.17%	-43.56%	-8.33%	2.48%	-1.09%	-4.89%	-43.65%	0.15%	-45.01%	-0.16%	-51.87%	-3.13%	0.01%	-4.26%
	Migration Corridor	-6.25%	-9.86%	6.86%	-45.36%	-10.12%	-2.43%	-7.93%	-11.45%	-46.34%	-0.59%	-45.28%	-1.80%	-52.91%	-4.24%	0.00%	-11.29%
	Severe Winter Range	-2.02%	-5.79%	3.42%	-9.15%	0.26%	0.09%	-2.82%	-6.55%	-9.89%	-7.80%	-8.15%	-0.81%	16.91%	-16.03%	0.01%	-13.03%
	Winter Concentration	-3.51%	-7.22%	8.29%	-17.61%	1.05%	2.92%	-5.16%	-8.81%	-19.03%	-7.70%	-10.30%	-1.72%	-14.32%	-13.78%	0.00%	-13.69%
	Production Area	-1.65%	-5.43%	2.51%	-12.70%	-0.16%	-2.32%	-2.01%	-5.78%	-13.02%	-5.44%	-8.07%	-0.37%	-20.85%	-3.51%	0.00%	-10.59%

Appendix 5

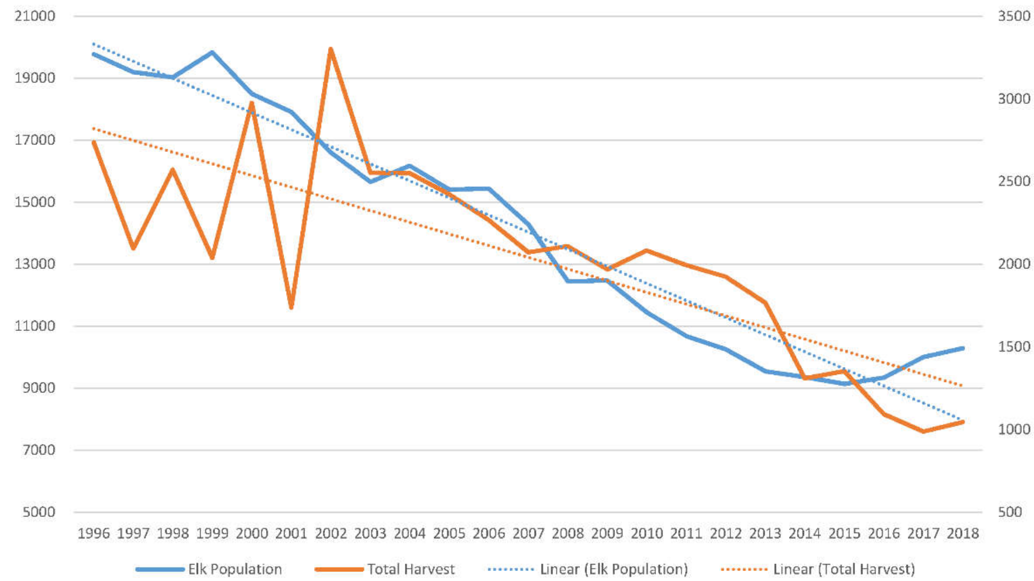
Additional Figures and Tables



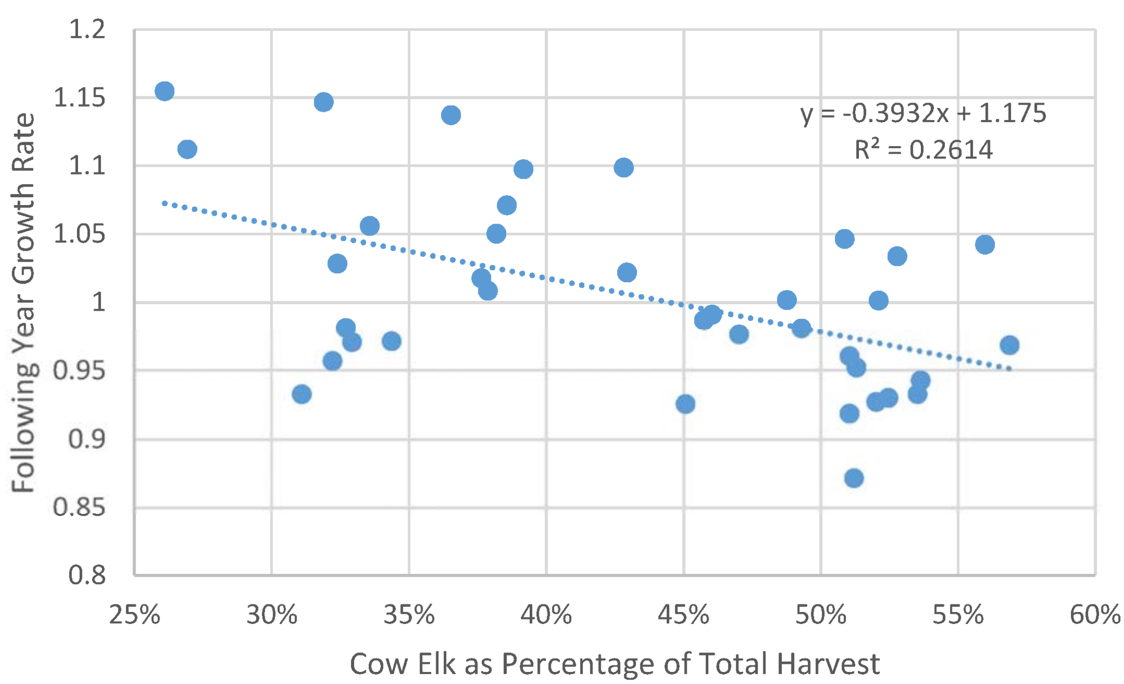
Appendix 5, Figure 1: Left: Elk seasonal habitat areas in the Roaring Fork Valley. Right: Fragmenting roads and trails as of 2018 are depicted in white. Elk Data: Colorado Parks and Wildlife.



Appendix 5, Figure 2: Left: Elk seasonal habitat areas in the Eagle Valley. Right: Fragmenting roads and trails as of 2018 are depicted in white. Elk Data: Colorado Parks and Wildlife.



Appendix 5, Figure 3: Trends in elk population and total harvest for the period 1996 to 2018. While correlation is apparent, the causal relationship is less clear. Data: Colorado Parks and Wildlife.



Appendix 5, Figure 4: Chart showing the correlation of proportion of the harvest comprised of cow elk with the following year growth rate for 1981 through 2017. Data: Colorado Parks and Wildlife.

Following Year Growth Rate ~ poly(ElkPop, 3) + poly(BUI, 3) + Calf per Cow + Cow Harvest Proportion + Precipitation

Residuals:

Min	1Q	Median	3Q	Max
-0.068243	-0.025881	0.004741	0.025926	0.063760

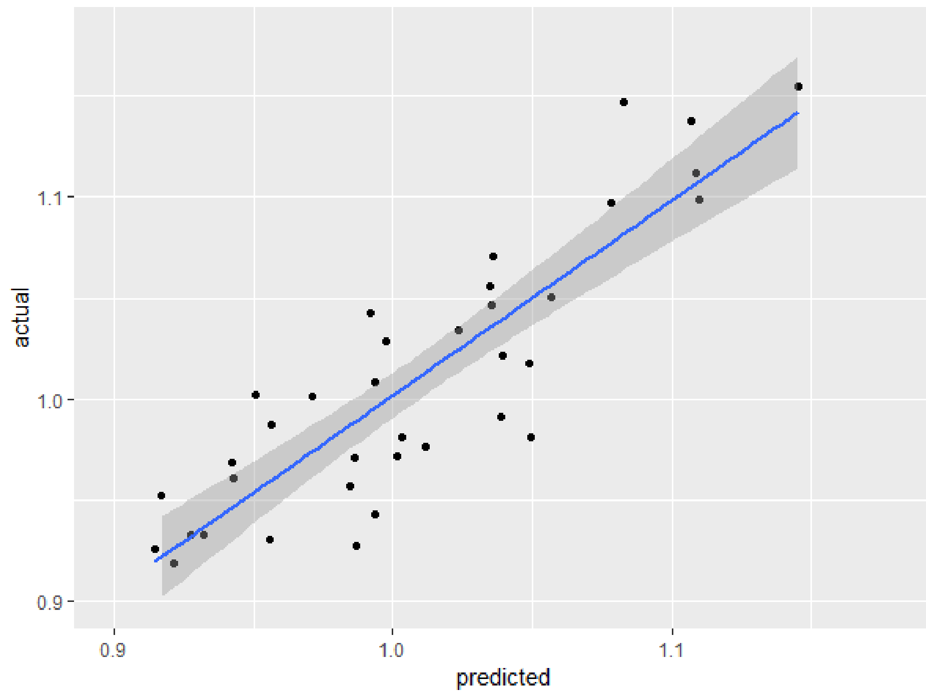
Coefficients:

	Estimate	Std. Error	t value	Pr(>|t|)	
(Intercept)	1.276936	0.138301	9.233	7.64E-10	***
poly(Elk Pop 1)	-0.671383	0.258130	-2.601	0.014901	*
poly(Elk Pop 2)	-0.076085	0.048013	-1.585	0.124682	
poly(Elk Pop 3)	-0.095656	0.043873	-2.180	0.038124	*
poly(BUI 1)	-0.584709	0.102428	-5.708	4.58E-06	***
poly(BUI 2)	-0.522123	0.227218	-2.298	0.029544	*
poly(BUI 3)	0.288485	0.066710	4.324	0.000187	***
Calf per Cow	-0.396354	0.226833	-1.747	0.091946	.
Cow Harvest Prop	-0.279545	0.231219	-1.209	0.237142	
Precipitation	-0.002316	0.002144	-1.081	0.289454	

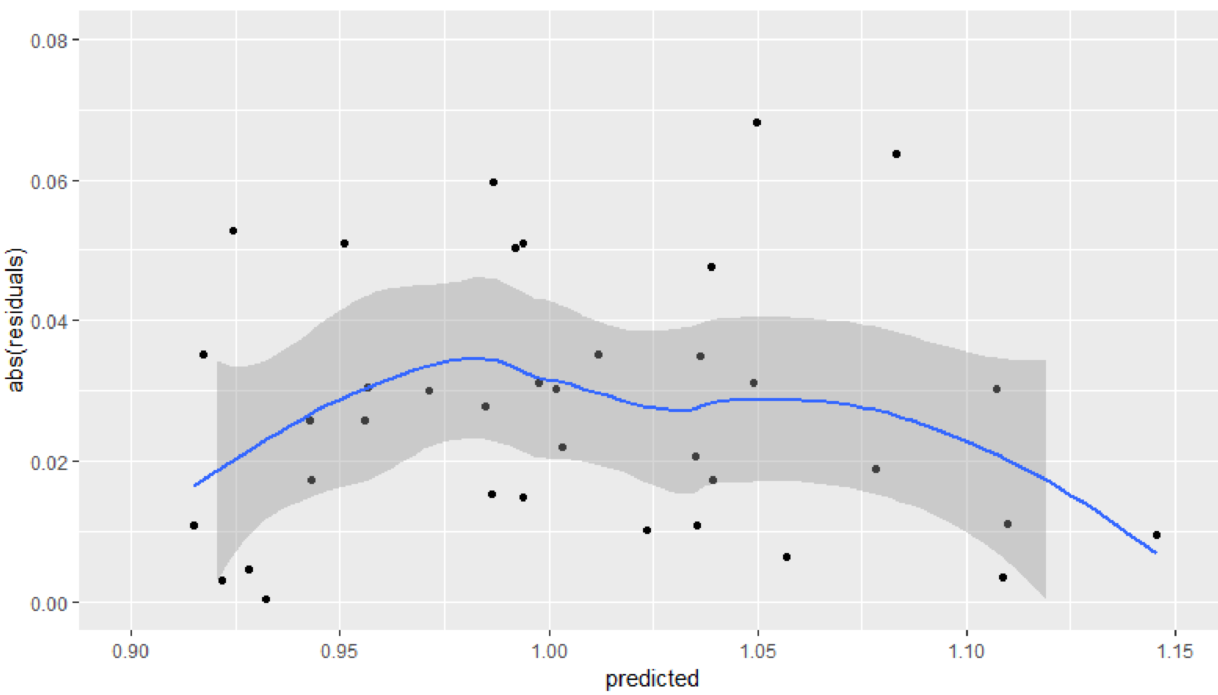
Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.03823 on 27 degrees of freedom
Multiple R-squared: 0.7727 Adjusted R-squared: 0.697 Predictive R-squared: 0.5510011
F-statistic: 10.2 on 9 and 27 DF, p-value: 1.186e-06

Appendix 5, Table 1: Table showing results of the linear regression of Model A, the best fit model for 1981 - 2017. Elk Data: Colorado Parks and Wildlife.



Appendix 5, Figure 5: Actual and predicted next year growth rates using Model A for 1981-2017 show relatively high goodness of fit. The gray band represents the 95% confidence interval. Elk Data: Colorado Parks and Wildlife.



Appendix 5, Figure 6: Absolute value of residuals by predicted next year growth rates using Model A for 1981-2017 show a slight increase in variability for central values of the predicted next year growth rate. The gray band represents the 95% confidence interval.

Following Year Growth Rate ~ poly(Elk Pop, 3) + poly(BUI, 3)

Residuals:

Min	1Q	Median	3Q	Max
-0.08006	-0.02598	-0.00350	0.02409	0.07762

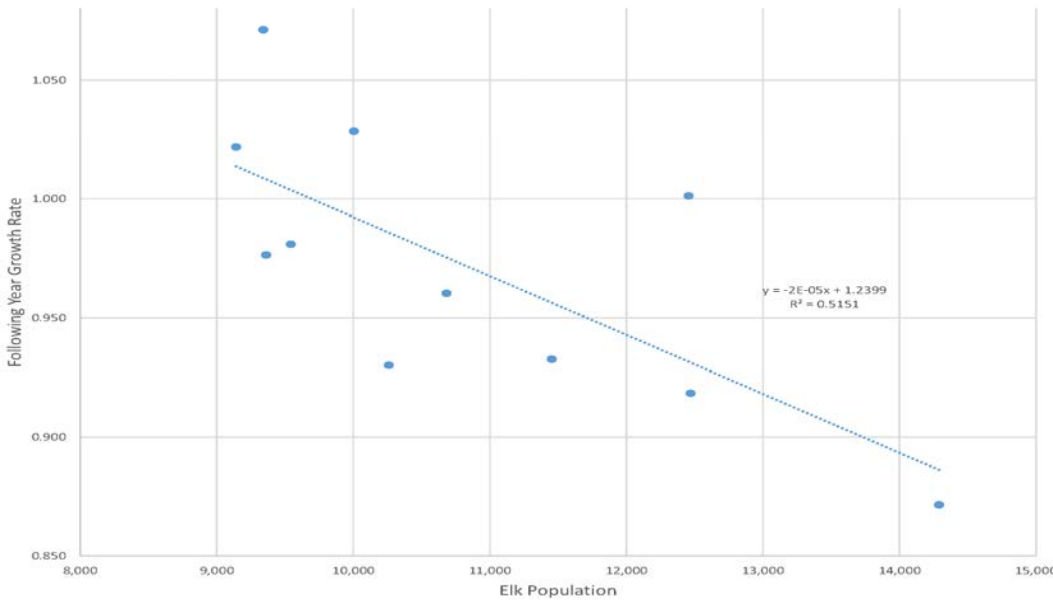
Coefficients:

	Estimate	Std. Error	t value	Pr(>|t|)	
(Intercept)	1.00553	0.006542	153.693	2.00E-16	***
poly(Elk Pop 1)	-0.965148	0.19807	-4.873	3.34E-05	***
poly(Elk Pop 2)	-0.101419	0.044148	-2.297	0.028757	*
poly(Elk Pop 3)	-0.078271	0.041545	-1.884	0.06929	.
poly(BUI 1)	-0.487703	0.065311	-7.467	2.53E-08	***
poly(BUI 2)	-0.749764	0.186469	-4.021	0.000361	***
poly(BUI 3)	0.355254	0.062217	5.71	3.14E-06	***

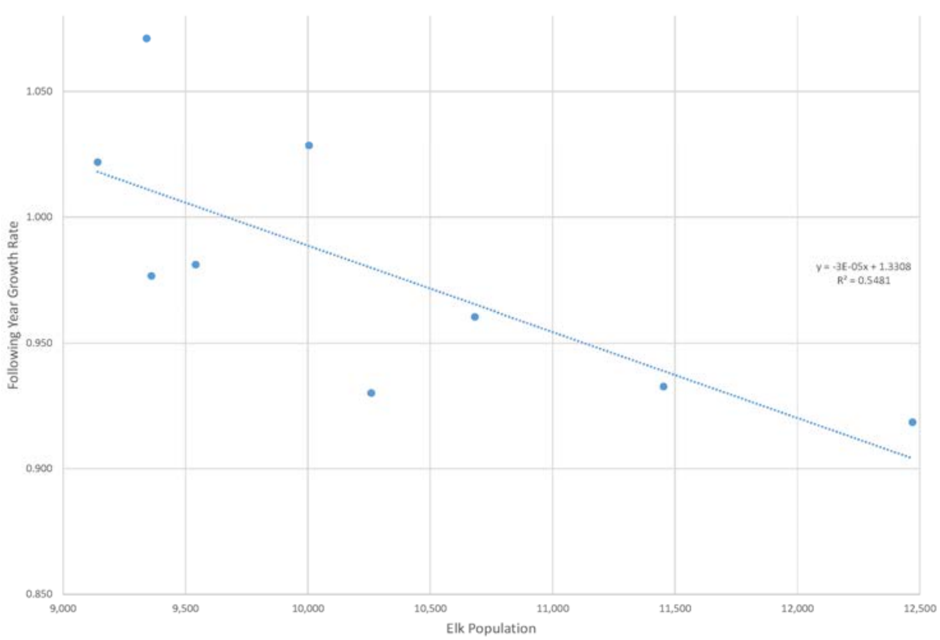
Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.0398 on 30 degrees of freedom
Multiple R-squared: 0.7264, Adjusted R-squared: 0.6716 Predictive R-squared: 0.5533755
F-statistic: 13.27 on 6 and 30 DF, p-value: 2.716e-07

Appendix 5, Table 2: Table showing results of the linear regression of Model B, the final model for 1981-2017.



Appendix 5, Figure 7: Scatterplot showing correlation between elk population and following year growth rate for 1993 to 2008. Elk Data: Colorado Parks and Wildlife.



Appendix 5, Figure 8: Scatterplot showing correlation between elk population and following year growth rate for 2009 to 2017. Elk Data: Colorado Parks and Wildlife.

Following Year Growth Rate ~ Elk Pop + Cow Kill Proportion + Resistance + Core Area Index Summer Conc + Licenses

Residuals:

Min	1Q	Median	3Q	Max
-0.034280	-0.009275	-0.002074	0.009536	0.033757

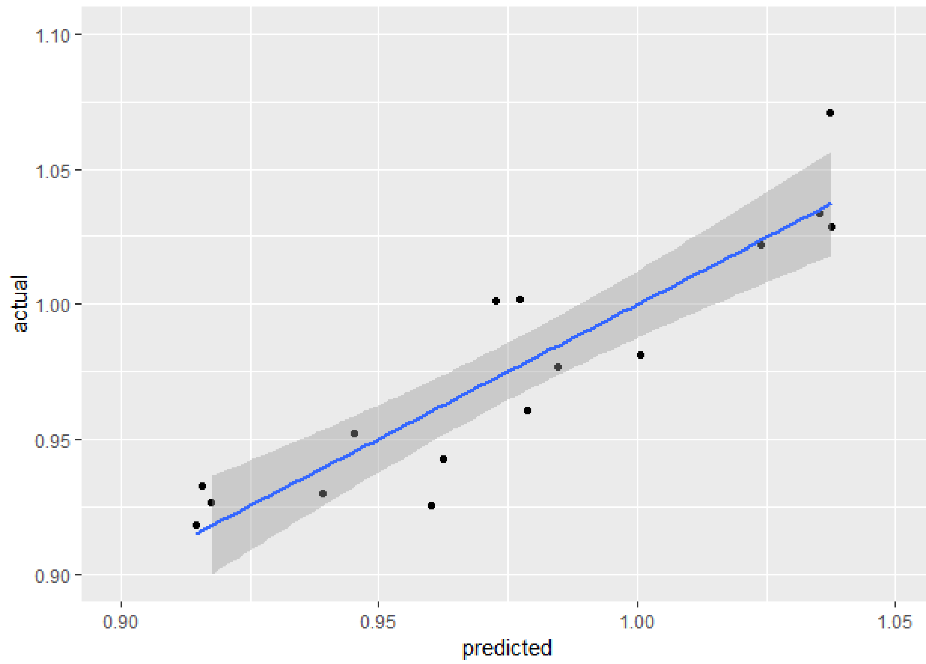
Coefficients:

	Estimate	Std. Error	t value	Pr(>|t|)	
(Intercept)	1133.000000	295.600000	3.832000	0.002785	**
Elk Pop	-0.000100	0.000019	-5.302000	0.000252	***
Cow Kill Proportion	-2.016000	0.409800	-4.920000	0.000457	***
Resistance	-224.100000	58.560000	-3.828000	0.002805	**
Core Area Index Summer Conc	-3.182000	0.839800	-3.789000	0.003001	**
Licenses	0.000031	0.000012	2.660000	0.022198	*

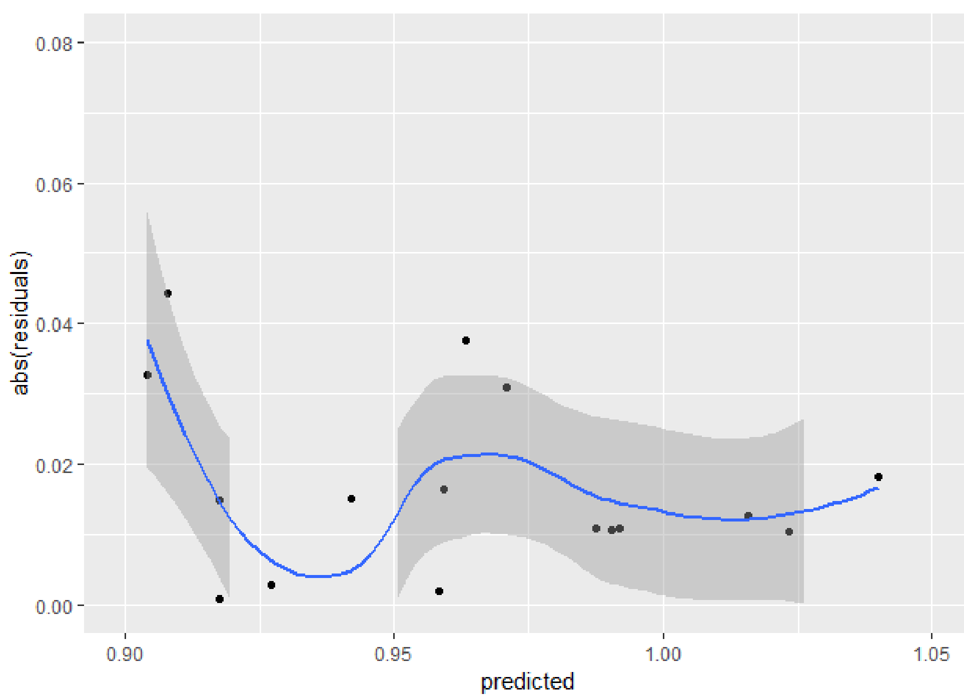
Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.02241 on 11 degrees of freedom
Multiple R-squared: 0.871, Adjusted R-squared: 0.8124 Predictive R-squared: 0.6952579
F-statistic: 14.86 on 5 and 11 DF, p-value: 0.000142

Appendix 5, Table 3: Table showing results of the linear regression of the model selected for 2001-2017 (Model C).



Appendix 5, Figure 9: Actual and predicted next year growth rates of the model selected for 2001-2017 show relatively high goodness of fit. The gray band represents the 95% confidence interval. Elk Data: Colorado Parks and Wildlife.



Appendix 5, Figure 10: Absolute value of residuals by predicted next year growth rates using of the model selected for 2001-2017 show a slightly improved accuracy for higher values of the predicted next year growth rate. The gray band represents the 95% confidence interval.

Attachment 3

Behavioral Responses of North American Elk to Recreational Activity

LESLIE M. NAYLOR,[1,2] *Department of Fisheries and Wildlife, Oregon State University, Corvallis, OR 97331, USA*

MICHAEL J. WISDOM, *United States Department of Agriculture Forest Service, Pacific Northwest Research Station, 1401 Gekeler Lane, La Grande, OR 97850, USA*

ROBERT G. ANTHONY, *United States Geological Survey Oregon Cooperative Fish and Wildlife Research Unit, 104 Nash Hall, Oregon State University, Corvallis, OR 97331, USA*

ABSTRACT Off-road recreation on public lands in North America has increased dramatically in recent years. Wild ungulates are sensitive to human activities, but the effect of off-road recreation, both motorized and nonmotorized, is poorly understood. We measured responses of elk (*Cervus elaphus*) to recreational disturbance in northeast Oregon, USA, from April to October, 2003 and 2004. We subjected elk to 4 types of recreational disturbance: all-terrain vehicle (ATV) riding, mountain biking, hiking, and horseback riding. Motion sensors inside radiocollars worn by 13 female elk recorded resting, feeding, and travel activities at 5-minute intervals throughout disturbance and control periods. Elk fed and rested during control periods, with little time spent traveling. Travel time increased in response to all 4 disturbances and was highest in mornings. Elk travel time was highest during ATV exposure, followed by exposure to mountain biking, hiking, and horseback riding. Feeding time decreased during ATV exposure and resting decreased when we subjected elk to mountain biking and hiking disturbance in 2003. Our results demonstrated that activities of elk can be substantially affected by off-road recreation. Mitigating these effects may be appropriate where elk are a management priority. Balancing management of species like elk with off-road recreation will become increasingly important as off-road recreational uses continue to increase on public lands in North America. (JOURNAL OF WILDLIFE MANAGEMENT 73(3):328–338; 2009)

DOI: 10.2193/2008-102

KEY WORDS all-terrain vehicles (ATVs), *Cervus elaphus*, elk, elk behavior, hiking, horseback riding, human disturbance, mountain biking, recreation.

Recreational use of public lands in the United States has increased dramatically since the 1970s, especially off-road recreation such as all-terrain vehicle (ATV) riding (United States Department of Agriculture Forest Service 2004). Other popular types of off-road recreation include mountain biking, horseback riding, and hiking. Off-road recreation, especially ATV riding, can negatively impact wildlife (Knight and Gutzwiller 1995, Havlick 2002), but the topic has received little research attention. Only recently have a few studies examined effects of different types of off-road recreation on wildlife in a comparative manner (Taylor and Knight 2003, Wisdom et al. 2004*a*, Preisler et al. 2006).

Although effects of off-road recreation are not well-known, effect of roads and road use on wildlife has been well-documented (Trombulak and Frissell 2000). Wild ungulates such as North American elk (*Cervus elaphus*) have been shown to consistently avoid roads open to motorized vehicles across a variety of environments (e.g., Perry and Overly 1977, Lyon 1979, Edge and Marcum 1985, Cole et al. 1997, Rowland et al. 2000). Moreover, human disturbances associated with road access increases movements and decreases survival of elk (Cole et al. 1997). Accordingly, we evaluated effects of off-road recreation on elk because of the species' noted sensitivity to human disturbances, combined with its economic, social, and recreational importance. We also selected elk for study because the species may habituate to some road uses and other human disturbances in nonhunted areas such as National Parks (Schultz and Bailey 1978). Elk may also habituate to human disturbances in urban fringe areas, where elk find refuge from hunting pressure (Thompson and Henderson 1998). We designed our study so that we monitored the same individuals before, during, and after disturbance events, thereby making it possible to detect potential habituation to those events.

Our objective was to evaluate effects of off-road recreational activities on elk behavior and to determine if different types of recreation elicited different responses. We were specifically interested in elk responses to 4 recreational activities: ATV riding, mountain biking, hiking, and horseback riding. We developed 4 hypotheses to guide our research: 1) off-road recreation (also called disturbance) produces a change in elk behavior patterns, altering the percentage of time that elk travel, rest, and feed; 2) different types of off-road recreation cause different behavioral responses in elk, with each type of recreation causing a different change in time spent traveling, resting, and feeding; 3) the time required for elk to return to predisturbance behavior patterns of traveling, feeding, and resting varies with each disturbance type; and 4) continued exposure to off-road recreation leads to conditioning of elk to the disturbance, resulting in reduced behavioral responses (i.e., habituation).

STUDY AREA

We conducted our research from April to October 2003 and 2004 at the United States Department of Agriculture Forest Service Starkey Experimental Forest and Range (hereafter,

[1] *E-mail: Leslie.M.Naylor@state.or.us*
[2] *Present address: Oregon Department of Fish and Wildlife, 107 20th Street, La Grande, OR 97850, USA*

Starkey), 35 km southwest of La Grande in northeast Oregon, USA (45°12′N, 118°3′W). In 1987, approximately 10,125 ha (25,000 acres) of elk summer range within the area was enclosed by a 2.4-m-(8-foot)-high elk-proof fence for long-term ungulate research (Thomas 1989, Bryant et al. 1993, Rowland et al. 1997). We conducted our study in the 1,453-ha northeast study area (Northeast) which was further subdivided by an elk-proof fence into 2 pastures, East (842 ha) and West (610 ha; Stewart et al. 2005). Vegetation was a mosaic of forests and grasslands dominated by ponderosa pine (*Pinus ponderosa*), grand fir (*Abies grandis*), Douglas fir (*Pseudotsuga menziesii*), bluebunch wheatgrass (*Pseudoroegneria spicatum*), and Idaho fescue (*Festuca idahoensis*). The study area and its extensive history of ungulate research are described in detail in Wisdom (2005).

METHODS

Actiwatch Calibration

We used motion-sensitive accelerometers (Actiwatch™; Mini Mitter Company Inc., Sunriver, OR) to record elk behaviors. These sensors were housed in battery packs of Global Positioning System (GPS) collars worn by female elk. We calibrated sensors to detect 3 behaviors—feeding, resting, and traveling—using visual observations of 6 randomly selected, tame female elk (Gates and Hudson 1983, Kie et al. 1991). Sensors collected activity data over 1-minute time periods and calibration followed methods described by Naylor and Kie (2004).

During summer 2003 we observed tame elk equipped with activity sensors for 1,073 minutes over 12 observation periods (Trials), ranging from 25 minutes to 106 minutes each. To ensure that only one behavior was causing the Actiwatch measure, we selected data when we observed only one behavior during a given 1-minute period, providing 868 minutes of observations for analysis. We recorded elk behavior on a hand-held personal digital assistant (Newton MessagePad™; Apple Computer, Inc., Cupertino, CA) running Ethoscribe™ dedicated software (Tima Scientific™, Halifax, NS, Canada). We then identified class intervals for the range of Actiwatch measures associated with each behavior for each 1-minute recording period.

We used Discriminant Function Analysis (DFA) to establish the percentage of correct classifications of Actiwatch measures into each of the 3 behaviors (Naylor and Kie 2004). Sample sizes and frequencies of behaviors were not equal; therefore, prior probabilities in the DFA were proportional to sample sizes. Activity monitors on wild elk recorded activity over 5-minute periods. Consequently, we established class intervals for Actiwatch data associated with traveling, resting, and feeding for the time frame of 5 minutes. Actiwatches recorded the aggregate of motion over the recorded interval, not an average (Mini Mitter 1998). We estimated class intervals for the 5-minute periods for each behavior by ordering the 1-minute data chronologically and summing the recorded measure of each continuous 5-minute period where only one behavior occurred.

Disturbance Method

Field work began each year in April, when we fitted 16 female elk (8 animals/pasture) with GPS radiocollars containing Actiwatch activity monitors set to record at 5-minute intervals. We released these elk as part of a larger herd of approximately 24 and 97 individuals into the West and East pastures. We released the same female elk into the study area each year.

Following the early April release of elk we implemented a 14-day period of no human activity. We then randomly selected and implemented each of the 4 recreation activities, individually, for 5 consecutive days, with no other human activities occurring in the study area during a particular treatment. Each treatment period was followed by 9 days of control, during which no human activity occurred in the study area, thereby providing data on elk activity in the absence of human disturbance.

Elk may return to areas associated with disturbance within a few hours or days after cessation of human activity (Stehn 1973, Wisdom et al. 2004*a*). Consequently, we assumed that the 9-day control period between treatments provided sufficient time to allow animals to return to predisturbance activity patterns. The alternating pattern of 5-day treatments and 9-day controls allowed for us to replicate each of the 4 treatment types 3 times each year (Apr to Oct).

We applied each treatment by establishing approximately 32 km of routes, composed of trails and primitive roads, which encompassed all portions of the study area. We traveled these routes twice a day (once each morning and afternoon) during each 5-day treatment. To allow coverage of the entire study area by each of the 4 recreation activities, one group (1–3 people) of ATV riders covered the 32 km of routes each morning and afternoon, traveling at approximately 5.3–5.7 km/hour. By contrast, to cover the same distance along the routes required 2 groups of mountain bikers (each covering approx. 50% of the 32-km routes), traveling at 2.6–2.9 km/hour, and 3 groups of hikers and horseback riders (each covering approx. 33% of the 32-km routes), traveling at 1.6–1.9 km/hour. This design provided the same coverage of routes among all activities and saturated the study area such that all 4 activities were applied to all portions of East and West pastures (Wisdom et al. 2004*b*). Each treatment followed a tangential experimental approach in which observers did not directly pursue animals but remained along the predetermined routes (Taylor and Knight 2003). Each group of recreationists traveled together under an interrupted movement design, which allowed momentary stops to record observations of elk and take short rest breaks (Wisdom et al. 2004*b*).

During data collection in 2003, one elk activity monitor failed and 2 were not retrieved from the study area; therefore, we used data from 13 elk in our analysis. During 2004, one monitor was not retrieved and 2 monitored elk crossed from the East to the West pasture when a gate was left open at the end of a treatment week. Consequently, we

Table 1. Discriminant Function Analysis results, based on Actiwatch recordings (from 868 1-min record intervals collected over 12 trials) to discriminate among 3 behavior classes of Rocky Mountain elk at Starkey Experimental Forest and Range, La Grande, Oregon, USA, during summer 2003. We set prior probabilities to proportional in the Discriminant Function Analysis.

Observed behavior	Classified behavior (min)				% correct
	Resting	Feeding	Traveling	Total	
Resting	459	11	4	474	96.84
Feeding	20	299	3	322	92.86
Traveling	0	7	65	72	90.28
Total	479	317	72	868	93.32

did not include data from these elk in our analysis, resulting in 13 elk for the analysis.

Data Analysis

We organized data for each replicate into 10-day periods, 5 days for each treatment paired with the last 5 days for its prior control. We calculated the difference in activities for each elk as percentage of time spent in each behavior within the treatment period minus percentage of time spent in each behavior during the paired control period. Consequently, a positive value for the activity difference indicated elk spent more time in that behavior during the treatment compared to the control, and a negative value indicated less time was spent. We then calculated and plotted the mean difference and 95% confidence intervals for each behavior per treatment, replicate, and year. We summarized behavior of female elk hourly and averaged it for each hour across all control periods to describe how animals allocated their activities in the absence of human disturbance.

We used a univariate procedure to check for a normal distribution of the residuals of activity differences between each treatment type and its control. Plots of residuals showed that data were normally distributed. We analyzed the activity difference for each year using a Proc Mixed Repeated Measures model (SAS Institute 2001) to test for differences among treatments, replicates, and treatment × replicate interaction, with each female elk repeatedly measured throughout the year. We determined covariance structure for each model using the lowest Akaike's Information Criterion score. For 2003, the covariance structure was a first-order ante-dependence (ANTE [1]); for 2004, we used a first-order autoregressive structure (AR [1]). A priori significance level for all statistical tests was 0.05. We adjusted significance level of all pairwise comparisons of least-square means using the Tukey Honestly Significant Difference procedure (Harris 1998).

To test for differences among pastures and time-of-day (morning or afternoon), we analyzed the activity difference for travel, resting, and feeding for each year using a Proc Mixed Repeated Measures model. This model included treatment, replicate, pasture, and time-of-day variables and all interaction terms. We adjusted significance levels of all pairwise comparisons using a Bonferroni critical value (Harris 1998).

RESULTS

Actiwatch Calibration in Lotek GPS collars

Calibration of activity data with tame elk, using DFA based on 1-minute data, correctly classified 96.8% of resting, 92.9% of feeding, and 90.3% of travel activities (Table 1), with an overall correct classification of 93.3%. Ranges of Actiwatch measures for each 5-minute data were estimated as 0–1,896 for resting, 1,900–5,135 for feeding, and $\geq$6,166 for traveling. We could not correctly classify Actiwatch measures that were between these intervals and we discarded them from the wild elk dataset (<2% of data).

Treatment and Replicate Differences

Elk spent little time traveling during all control periods (<5% of each hr); feeding and resting comprised most of their activities (Fig. 1). Resting was highest at approximately 0800 hours (80% of their activity budget) and gradually decreased during daylight hours as feeding increased. Peak feeding activity occurred at dawn and dusk (Fig. 1). Activity budgets were similar for 2003 and 2004 (Naylor 2006).

Results of the mixed-model repeated-measures analysis of travel activity showed a treatment × replicate interaction in both 2003 and 2004 (2003 $F_{6,72} = 12.28$, $P < 0.001$; 2004 $F_{6,72} = 2.31$, $P = 0.042$; Table 2). Percentage of travel time also was different among treatments for both years (2003: $F_{3,36} = 32.25$, $P < 0.001$; 2004: $F_{3,36} = 7.65$, $P < 0.001$). In addition, there was a treatment × replicate interaction for resting (2003: $F_{6,72} = 15.11$, $P < 0.0001$; 2004: $F_{6,72} = 8.29$, $P < 0.0001$). We also found differences among treatments in resting time for both years (2003: $F_{3,36} = 10.60$, $P < 0.001$; 2004: $F_{3,36} = 11.62$, $P < 0.001$; Table 2).

Similarly, time elk spent feeding was different for the treatment × replicate interaction (2003: $F_{6,72} = 21.45$, $P < 0.001$; 2004: $F_{6,72} = 7.89$, $P < 0.001$). As with travel and resting, time spent feeding also was different among treatments (2003: $F_{3,36} = 16.41$, $P < 0.001$; 2004: $F_{3,36} = 13.35$, $P < 0.001$; Table 2).

Elk traveled more during ATV and mountain biking treatments than during controls in all 2003 and 2004 replicates (Fig. 2, Table 3). Elk traveled more than the controls during 5 of 6 hiking replicates and during 3 of 6 horseback riding replicates (Fig. 2, Table 3). Elk spent more time resting during 4 of 6 ATV treatments compared to controls. Elk rested less during mountain biking in contrast to controls during 4 of 6 replicates. Resting time by elk was not different from controls for 3 of 6 hiking replicates and was less than controls during 2 replicates. Elk rested more than controls during 4 of 6 horseback replicates (Fig. 3). Elk spent less time feeding compared to controls during 5 of 6 ATV replicates, 3 mountain biking replicates, 2 hiking replicates, and 4 horseback replicates (Fig. 4).

Mean travel during all ATV replicates in 2003 was higher than the other treatments (Fig. 2, Table 3). For 2004, travel during ATV riding was not different from other treatments except for being higher than horseback riding during replicate 2 (Fig. 2). Travel time by elk was higher during mountain biking compared to horseback riding for replicate 3 of 2003

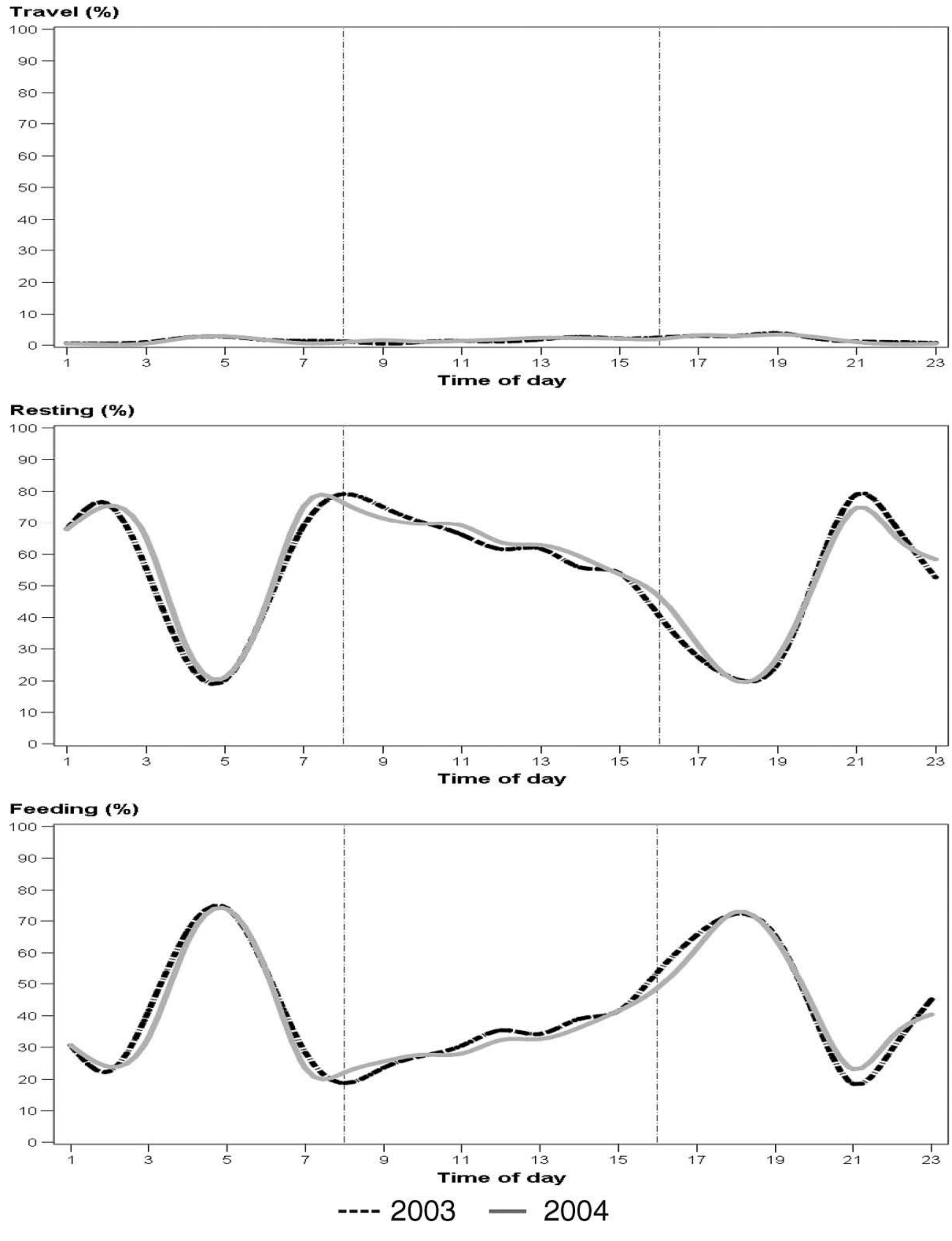


Figure 1. Activity budgets (% time spent traveling, resting, and feeding) of female elk during the first 2-week control periods of 2003 and 2004 at Starkey Experimental Forest and Range, La Grande, Oregon, USA. We averaged data for each hour, over 24-hour periods, expressed in Pacific Daylight Time.

and 2004. Hiking and horseback treatments were similar in the percentage of time that elk traveled during both years. Time elk spent resting was greater during ATV treatments compared to other treatments for 3 of 6 replicates and was greater during the horseback treatment compared to mountain biking and hiking for 4 of 6 replicates. Resting time was similar during both mountain biking and hiking replicates each year (Fig. 3). Elk fed less during ATV riding compared to other treatments in 4 of 6 replicates (Naylor 2006: fig. 4, appendix 1, tables A4, A7). There was no difference in duration of feeding between mountain biking and hiking treatments during 2003 or 2004. Elk fed less during the horseback treatment compared to mountain biking and hiking for 2 of 6 replicates (Naylor 2006: fig. 4, appendix 1, tables A4, A7).

Table 2. Results of a mixed-model repeated-measures analysis of elk activity time. Test was for differences between treatments and replicates of mean activity time by 13 female elk in the Northeast study area of Starkey Experimental Forest and Range, La Grande, Oregon, USA, 2003 and 2004.

Effect	Numerator df	Denominator df	2003 *F*-value	2003 *P*-value	2004 *F*-value	2004 *P*-value
Feeding						
Treatment × replicate	6	72	21.45	<0.001	7.89	<0.001
Treatment	3	36	16.41	<0.001	13.35	<0.001
Replicate	2	24	30.05	<0.001	9.87	<0.001
Resting						
Treatment × replicate	6	72	15.11	<0.001	8.29	<0.001
Treatment	3	36	10.60	<0.001	11.62	<0.001
Replicate	2	24	11.19	0.004	6.36	0.006
Travel						
Treatment × replicate	6	72	12.28	<0.001	2.31	0.042
Treatment	3	36	32.25	<0.001	7.65	0.001
Replicate	2	24	8.50	0.001	1.74	0.196

Differences in elk behavior between treatments and controls were evident only during the periods of each day that treatments occurred. Elk behavior patterns were similar to control periods before treatments commenced each day, showed differences during each treatment activity, and returned to a predisturbance level approximately 1–2 hours after each treatment ended (Fig. 5). Behavior patterns outside the treatment times appeared unaffected by the treatment activity (Naylor 2006: appendix 1, figs. A2–A13).

Travel time by elk was greater than controls for ATV treatments both years, with the greatest response of the 4 treatments being for ATV replicate 1 of 2003. Travel response by elk to ATVs during 2003 declined with each replicate (Fig. 2, Table 3). This decline continued through replicate 1 of 2004. However, travel time then increased for replicates 2 and 3 of 2004 to levels similar to those recorded in 2003 (Fig. 2, Table 3).

Elk also reduced travel time during each horseback riding replicate in 2003, with no difference observed between the treatment and control for replicate 3. During 2004, travel response to horseback riding was less than that of 2003 and was not different from control periods in 2 of 3 replicates (Fig. 2). Overall, horseback riding caused the lowest travel response in elk among treatments. By contrast, elk were consistent in their travel time during all mountain biking treatments, with travel time being higher than controls. Elk travel time during hiking was the most variable among treatment responses, with no evident pattern.

Pasture and Time-of-Day Differences

Differences in travel response between the high elk density (East pasture) versus low elk density (West pasture) areas, considering time-of-day, replicate, and treatment indicated a 4-way interaction of these variables for both years (2003: $F_{6,132} = 21.94$, $P < 0.001$; 2004: $F_{6,132} = 6.40$, $P < 0.001$). All 3-way and most 2-way interactions were significant as were all individual effects. For each treatment, elk travel time in the 2 pastures was similar during mornings. Exceptions to this pattern were ATV, replicate 1 of 2003 and horseback riding, replicate 2 of 2003, when elk traveled more in the east than west pastures. Differences between pastures during the afternoons for 2003 were not significant (Naylor 2006: appendix 1, table A15) with the exception of replicate 1 of the ATV treatment, when travel time was higher in the west pasture ($P < 0.001$).

Elk travel time also differed between pastures during the afternoons in 2004 for ATV replicate 3, mountain bike replicates 2 and 3, and hiking replicate 2 (Naylor 2006: appendix 1, table A16). At these times, elk traveled more in the east pasture during the ATV treatment and more in the west pasture during biking and hiking. Differences in travel time between morning and afternoon in the same pasture showed some significance for 2003, with the morning disturbance causing the greater travel response (Naylor 2006: appendix 1, table A17). There were fewer differences in mean travel activity between mornings and afternoons in 2004 for the same pasture (Naylor 2006: appendix 1, table A18).

DISCUSSION

Activity budgets of elk during control periods were consistent with the literature on elk circadian cycles (Green and Bear 1990, Ager et al. 2003, Kie et al. 2005). Movements of elk (m/min), estimated from telemetry relocation data during the 2002 phase of our study, provided further evidence of elk circadian patterns of movement in the absence of human disturbance (Preisler et al. 2006). Our activity budgets during control periods provided a compelling basis for evaluating changes in activity budgets during each of the recreational activities.

Our results supported hypothesis 1, which postulated that off-road recreation produces a change in elk behavior. Results clearly demonstrated that activity budgets of elk were altered during off-road recreation treatments. Elk increased their travel time during most treatments, which reduced time spent feeding or resting. We recorded an increase in travel throughout the period of disturbance but it was generally greater in mornings than in afternoons. This response was similar to that recorded by Wisdom et al. (2004*b*), where movement rates of elk were higher than that

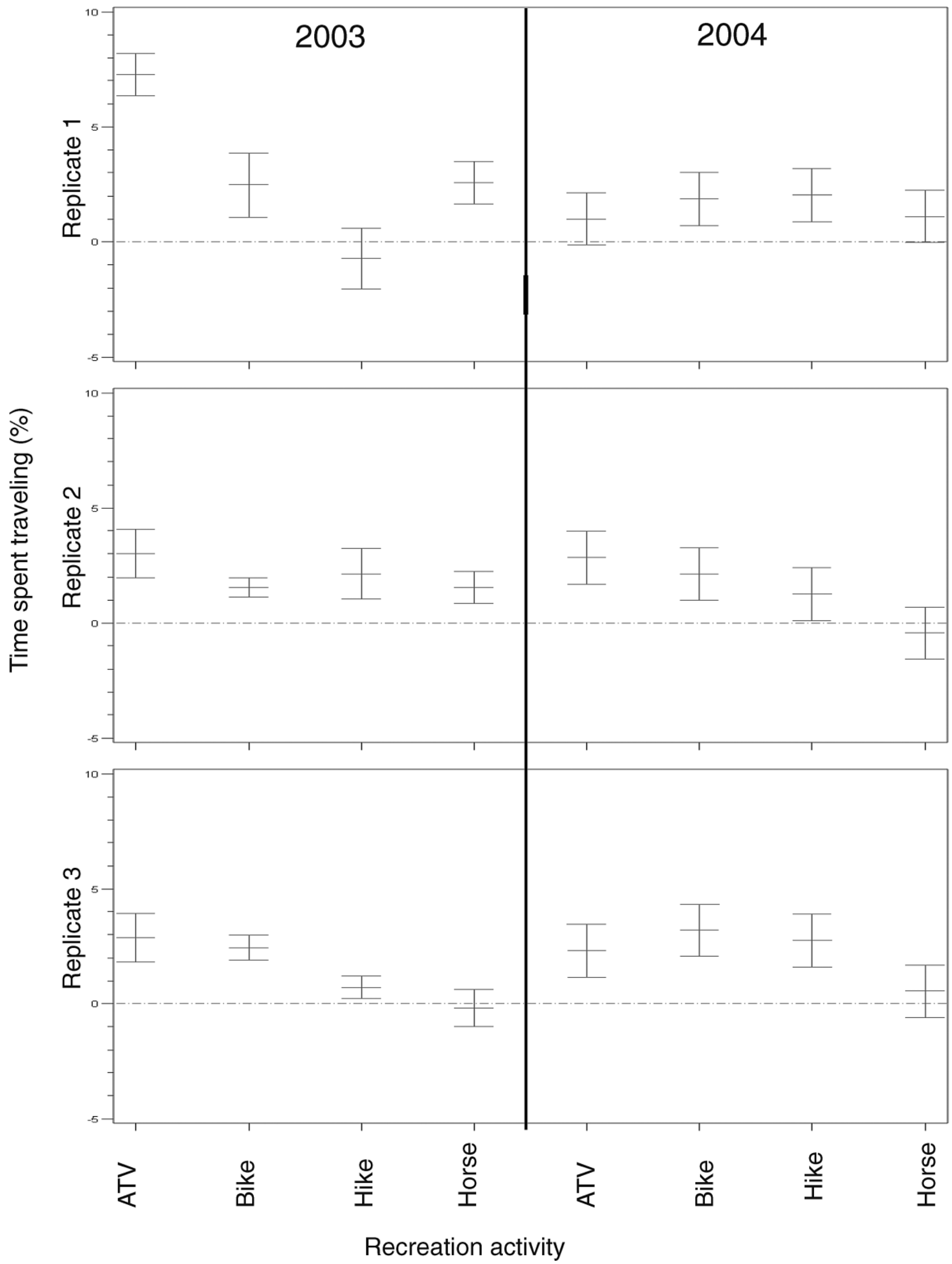


Figure 2. Mean and 95% confidence intervals of the difference in the percent travel time by elk between paired treatments and control periods. Data are for 13 female elk in the Northeast study area of Starkey Experimental Forest and Range, La Grande, Oregon, USA, 2003 and 2004. We calculated activity difference as percent time spent traveling during treatment minus that during control; negative values indicate activity less than that of the control. Treatments were all-terrain vehicle (ATV) riding, mountain biking (Bike), hiking (Hike), and horseback riding (Horse).

of controls in the hours immediately after initiation of the disturbance each morning. The reduced response by elk to each treatment in afternoons compared to mornings was likely due to elk moving away from the disturbance routes and avoiding them for the remainder of the day, which reduced the need for more travel and thus conserved energy (M. J. Wisdom, United States Department of Agriculture Forest Service, personal communication).

Table 3. Weekly averages and standard errors of percent time spent traveling above that of paired control periods for 13 female elk at Starkey Experimental Forest, La Grande, Oregon, USA, 2003 and 2004. A positive number indicates elk spent more time traveling during the treatment compared to the control period (no human activity) and a negative number indicates less time was spent traveling. ATV = all-terrain vehicle riding, Bike = moutain biking, Hike = hiking, and Horse = horseback riding.

	ATV		Bike		Hike		Horse	
Replicate	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
2003								
1	7.27	0.46	2.47	0.70	−0.70	0.66	2.56	0.45
2	3.00	0.52	1.55	0.20	2.14	0.54	1.54	0.34
3	2.87	0.52	2.44	0.27	0.72	0.24	−0.18	0.40
2004								
1	0.99	0.57	1.86	0.57	2.03	0.57	1.11	0.57
2	2.83	0.57	2.13	0.57	1.26	0.57	−0.43	0.57
3	2.31	0.57	3.20	0.57	2.75	0.57	0.54	0.57

The reduced travel by elk in the afternoons also could be due to the benefits of conserving energy by remaining in a particular habitat. Presumably, more time spent hiding would outweigh the loss of energy caused by fleeing from disturbance. Our study did not include information on elk locations in relation to disturbance routes; therefore, we could not determine any shifts in habitat use during treatments. However, Preisler et al. (2006) demonstrated that elk in our study area moved away from the routes to hiding places near or against fences during 2002.

Hypothesis 2, which postulated that different types of human activity cause different behavioral responses in elk, also was supported by our results. The highest travel response by elk was during ATV exposure and was followed by increased resting time. This type of recreational activity may have forced elk to forgo foraging in favor of hiding until the disturbance ended. In contrast to this any disturbance during the mountain biking and hiking treatments resulted in feeding activity increasing. It is possible that, being quieter than the ATVs, mountain biking and hiking did not disturb elk once they moved away from the routes; elk were, therefore, able to make up any energy lost by resuming foraging activity.

For horseback riding, travel activity during 3 of the 6 replicates was not different from the controls, indicating that elk were not affected as much by this recreational activity. When elk did display an increased travel response to horseback riding, the effects on feeding and resting time were mixed.

Hypothesis 3, which postulated that time required for elk to return to predisturbance behavior varies with disturbance type, was not supported by our results. For all treatments, elk returned to behavior patterns similar to those of the controls once the disturbance ended each day (Naylor 2006: appendix 1, figs. A2–A13). Reduction in foraging time during treatments was not compensated for after the disturbance ended, because elk did not increase feeding intensity or duration beyond that of controls.

Our study design mimicked the daytime pattern of motorized traffic on National Forests (Wisdom 1998), most of which does not occur during peak elk feeding activity at dawn and dusk. Thus, our treatments did not overlap with peak feeding periods of elk. With their main intake of digestible material being unaffected by disturbances, reduced foraging time during treatments may not have had substantial short-term biological consequences for these elk. Elk may have satisfied their immediate nutritional requirements before and after disturbances occurred.

A potential disadvantage to elk is the energy expense of traveling during each disturbance, coupled with a loss in forage intake. A shift away from disturbance routes (as noted by Preisler et al. 2006) to areas of potentially lesser quality forage could have a cumulative effect on long-term body condition. Cook et al. (2004) suggested that if elk body fat was reduced below 9% as the animal enters winter, there is an increased probability of that individual not surviving winter. Comparisons of elk body condition before and after each treatment were beyond the scope of our study. Consequently, we could not conclusively assess long-term physiological effects of repeated disturbance to elk from April to October each year.

Hypothesis 4, which postulated that continued exposure to disturbance leads to conditioning of elk to the disturbance and results in unaltered or reduced behavioral responses (i.e., habituation), was partially supported by our findings.

A complicating factor in our evaluation of potential habituation of elk to recreation treatments is that we did not simultaneously evaluate changes in elk distributions. However, as part of the radiotelemetry monitoring of the same elk we studied, Preisler et al. (2006) found that elk moved away from travel routes during ATV riding with repeated ATV treatments. These movements allowed elk to resume activities similar to those of controls, while avoiding recreation routes. Such avoidance would not be considered habituation, but rather a different type of negative response to recreation.

Travel by elk during 2 horseback replicates was not different from control periods in 2004. Reduction in elk travel during horseback riding in 2004 compared to 2003 suggested that, unlike other treatments, elk may have habituated to horseback riding. Alternatively, elk could have simply avoided areas near horseback routes during 2004, as was done by elk in response to ATV treatments over time (Preisler et al. 2006). Under this possibility, elk could have maintained the same activity patterns as during controls, but farther away from travel routes.

In contrast to horseback riding, elk travel time during mountain bike riding was above that of controls for each year and was consistent among years. Thus, elk showed no evidence of habituation to mountain biking. Similarly, elk travel time in response to hiking was above that of control periods, with the exception of replicate 1 for 2003, suggesting a similar response by elk to each hiking disturbance (i.e., no habituation).

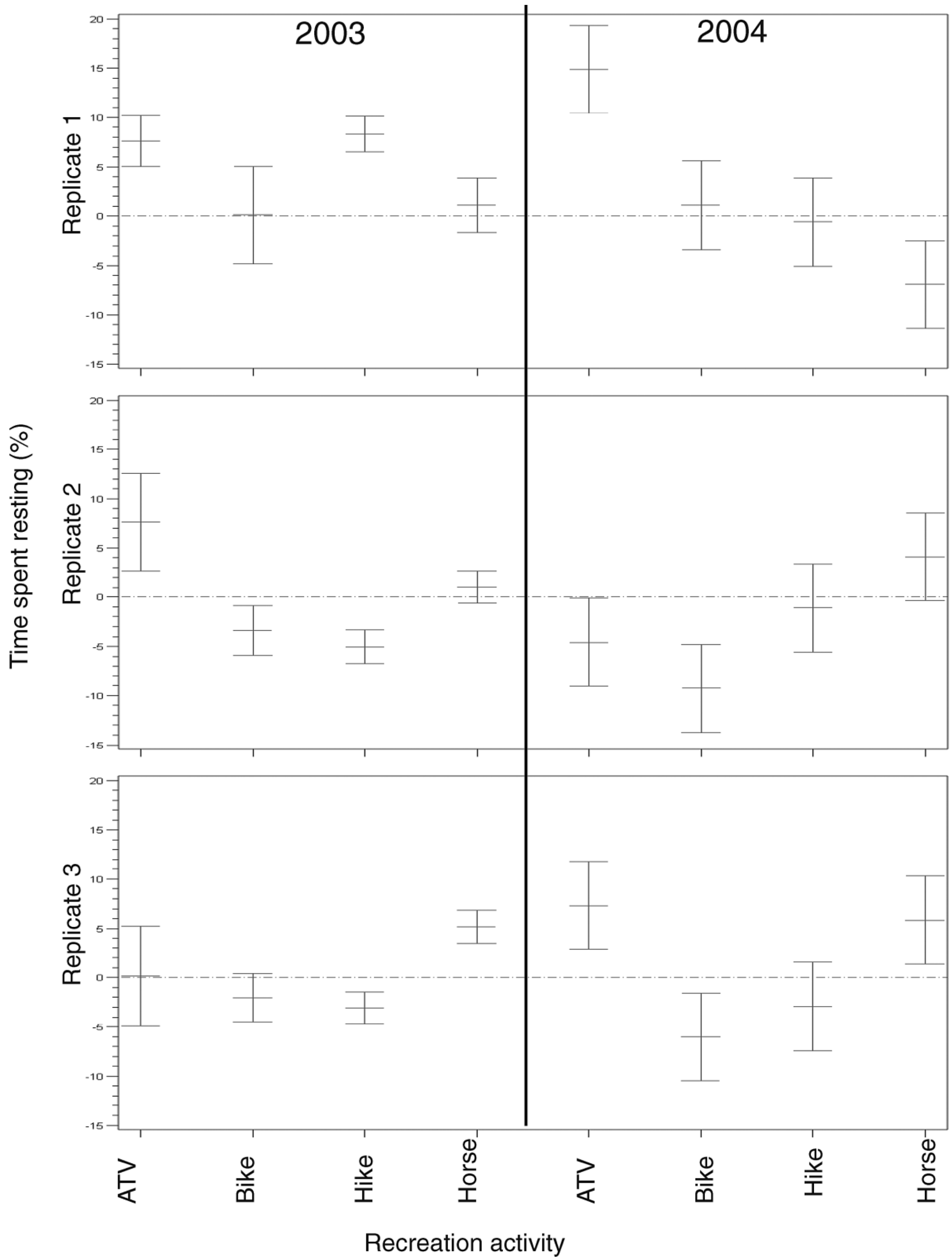


Figure 3. Mean and 95% confidence intervals of the difference in percent resting time by elk between paired treatment and control periods. Data are for 13 female elk in the Northeast study area of Starkey Experimental Forest and Range, La Grande, Oregon, USA, 2003 and 2004. We calculated activity difference as percent time spent resting during treatment minus that during control, so negative values indicate activity less than that of the control. Treatments were all-terrain vehicle (ATV) riding, mountain biking (Bike), hiking (Hike), and horseback riding (Horse).

MANAGEMENT IMPLICATIONS

A comprehensive approach for managing human activities to meet elk objectives should include careful management of off-road recreational activities, particularly ATV riding and mountain biking, which caused the largest reductions in feeding time and increases in travel time. Evidence of little or no changes in travel by elk as a response to horseback riding can also be used by managers when planning access to

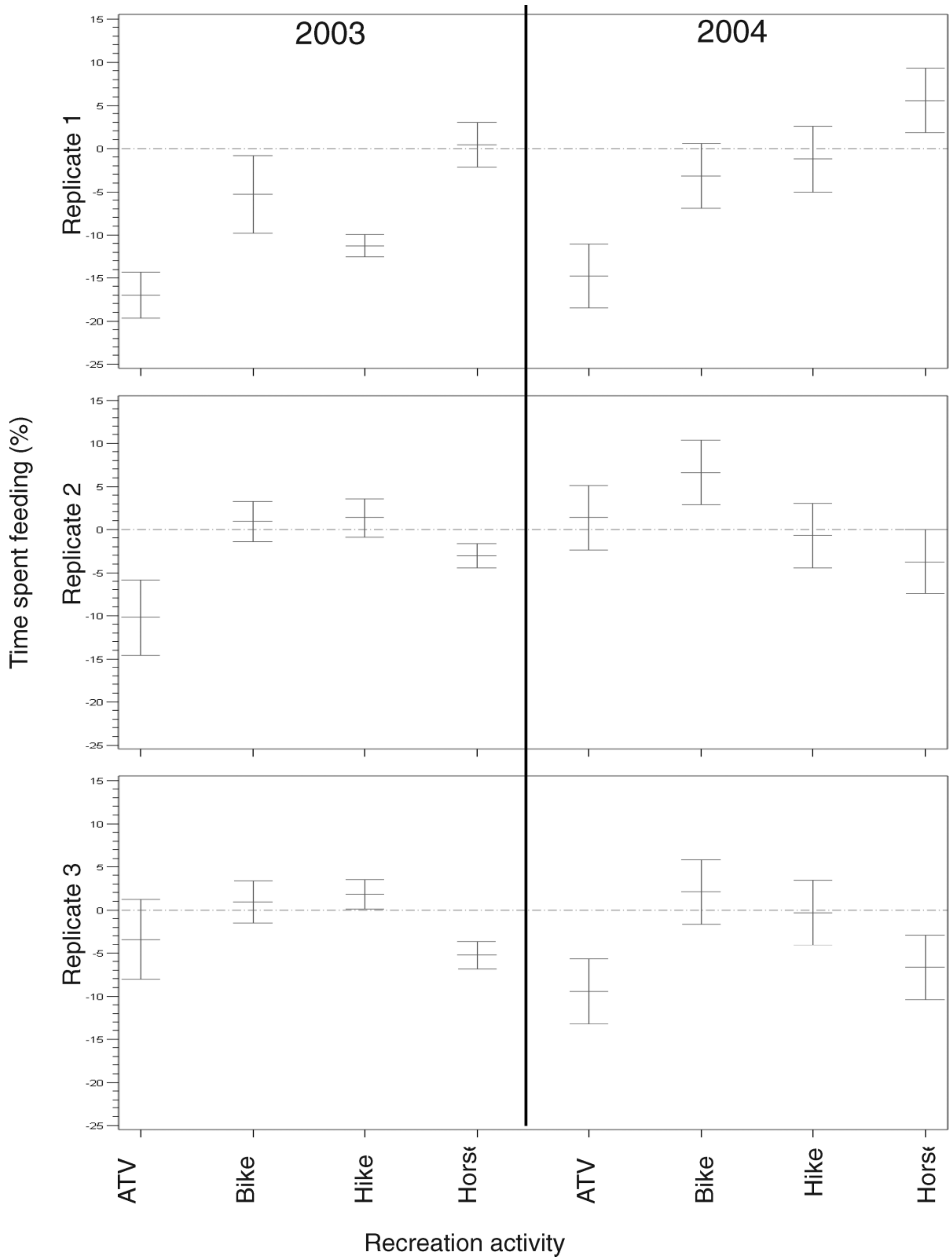


Figure 4. Mean and 95% confidence intervals of difference in the percent feeding time by elk between paired treatment and control periods. Data are for 13 female elk in the Northeast study area of Starkey Experimental Forest and Range, La Grande, Oregon, USA, 2003 and 2004. We calculated activity difference as percent time spent feeding during treatment minus that during control, so negative values indicate activity less than that of the control. Treatments were all-terrain vehicle (ATV) riding, mountain biking (Bike), hiking (Hike), and horseback riding (Horse).

areas where disturbance of elk is to be minimized. Such resource allocation trade-offs between management of elk and off-road recreation will become increasingly important as off-road recreation continues to increase on public lands.

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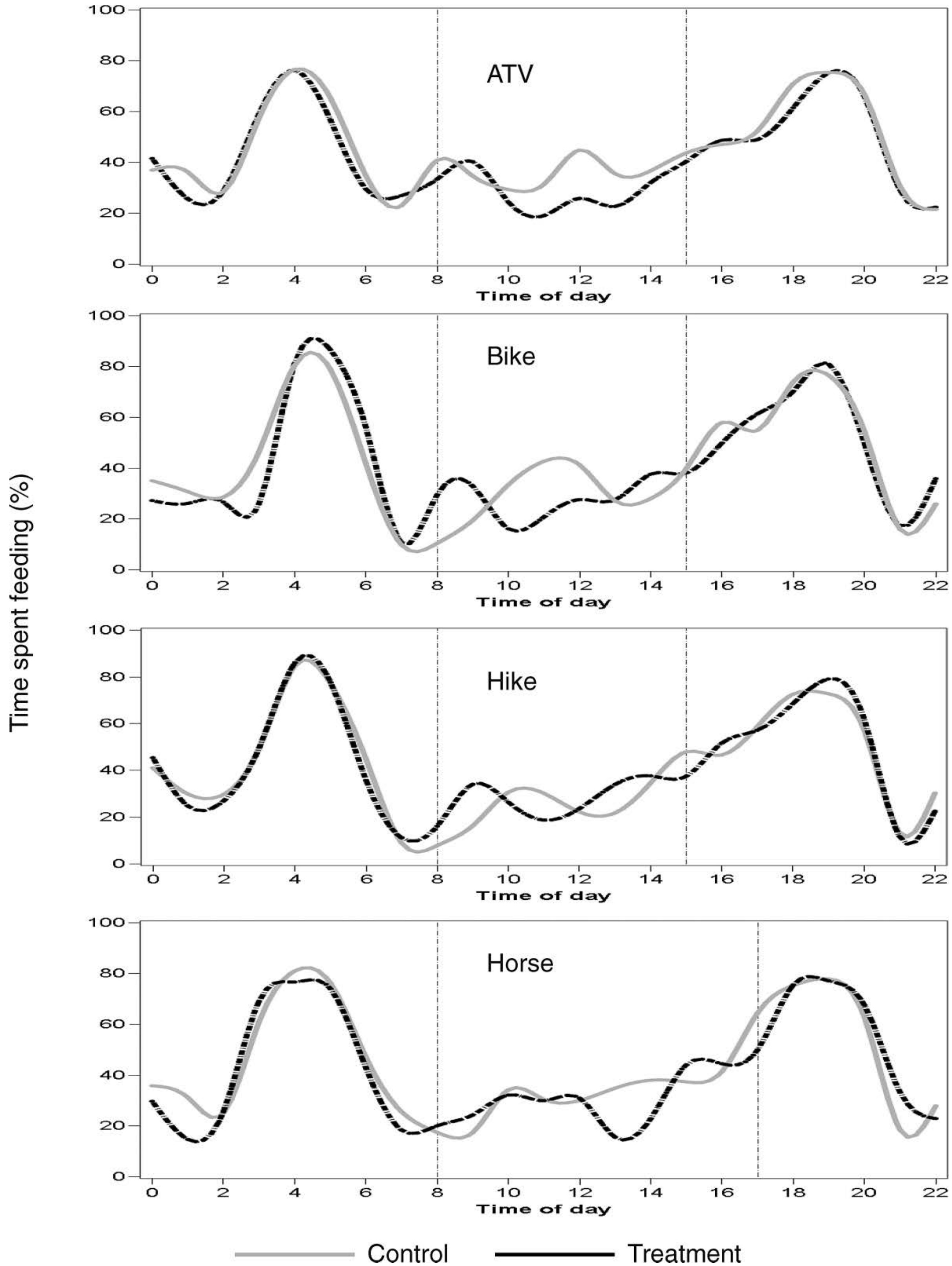

Figure 5. Feeding activity (%) of 13 female elk for replicate 2 of each treatment and its paired control during 2003 at Starkey Experimental Forest and Range, La Grande, Oregon, USA. Area between dotted vertical lines represents times (hr) treatments occurred. Results in this figure typify the pattern of elk activity returning to that like controls each day after a recreation treatment ended.

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Attachment 4

PLOS | ONE
TENTH ANNIVERSARY

Effects of Humans on Behaviour of Wildlife Exceed Those of Natural Predators in a Landscape of Fear

Simone Ciuti, Joseph M. Northrup, Tyler B. Muhly, Silvia Simi, Marco Musiani, Justin A. Pitt, Mark S. Boyce

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Abstract

Background

Human disturbance can influence wildlife behaviour, which can have implications for wildlife populations. For example, wildlife may be more vigilant near human disturbance, resulting in decreased forage intake and reduced reproductive success. We measured the effects of human activities compared to predator and other environmental factors on the behaviour of elk (*Cervus elaphus* Linnaeus 1758) in a human-dominated landscape in Alberta, Canada.

Methodology/Principal Findings

We collected year-round behavioural data of elk across a range of human disturbances. We estimated linear mixed models of elk behaviour and found that human factors (land-use type, traffic and distance from roads) and elk herd size accounted for more than 80% of variability in elk vigilance. Elk decreased their feeding time when closer to roads, and road traffic volumes of at least 1 vehicle every 2 hours induced elk to switch into a more vigilant behavioural mode with a subsequent loss in feeding time. Other environmental factors, thought crucial in shaping vigilance behaviour in elk (natural predators, reproductive status of females), were not important. The highest levels of vigilance were recorded on public lands where hunting and motorized recreational activities were cumulative compared to the national park during summer, which had the lowest levels of vigilance.

Conclusions/Significance

In a human-dominated landscape, effects of human disturbance on elk behaviour exceed those of habitat and natural predators. Humans trigger increased vigilance and decreased foraging in elk. However, it is not just the number of people but also the type of human activity that influences elk behaviour (e.g. hiking vs. hunting). Quantifying the actual fitness costs of human disturbance remains a challenge in field studies but should be a primary focus for future researches. Some species are much more likely to be disturbed by humans than by non-human predators: for these species, quantifying human disturbance may be the highest priority for conservation.

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Introduction

Understanding the effects of human disturbance is critical for effective management and conservation of wildlife in an increasingly human-dominated world. The human population has exploded in recent decades with a subsequent acceleration in demands for resources [1]. This demand has led to a growing and increasingly pervasive network of roads that extends the reach of humans into wildlife habitats [2], [3]. Human activity along road networks can have an impact on wildlife behaviour that is often complex and varies among species and across both space and time [4]–[6]. Indeed, it is not just the number of people but the type of human activity that is expected to cause shifts in behavioural responses of wildlife: for instance, previous studies suggested that certain hunting modalities and motorized recreational activities can have a stronger impact on wildlife than less intrusive disturbances [6]–[10]. However, the actual effect of human disturbance on behaviour, population dynamics and life history are still poorly documented [9], [11]–[13].

With the exception of large protected areas, where it is relatively easy to measure and control human disturbance, human-dominated landscapes are complex environments where it can be challenging to disentangle all sources of human disturbance. Within large protected areas, anti-predator behaviour of wildlife is often primarily shaped by natural predators [14], [15], but little is known about shifts in anti-predator behaviours when humans are likely to be the major driving force. Humans can have a different influence on wildlife depending on land-use management – for instance whether hunting or motorized recreational activities are permitted [7], [16]. Measurements of the types and levels of human disturbance and their effects on wildlife are needed not only to guarantee functional ecosystems in currently human-dominated landscapes [3], [17], but also to plan conservation policies for those remote areas where human exploitation of resources is expected [1].

Behaviour can indicate how animals respond to disturbance in their environment [11], [18]. For instance, vigilance, or scanning of the environment, is adopted by a wide range of birds and mammals to increase the probability of detecting predators or other sources of disturbance – including humans [18]. Thus, vigilance responses can be a useful way to measure disturbance of wildlife. Vigilance patterns are indeed finely shaped by predator presence [19], human disturbance [20], habitat characteristics [21], and prey group size and composition [22], including age differences among individuals of the group [23]. Vigilance levels may also increase in males during the mating season [15] and in females with offspring [24]. The principal cost of vigilance is thought to be time, where opportunities for alternative behaviours are forfeited [18] with the most common trade-off between vigilance and foraging [25]. Most models assume that vigilance is incompatible with foraging and that, across species, time spent vigilant is usually inversely correlated with time spent feeding [26]. In regard to ungulates, it is still unclear how much feeding time is actually lost due to vigilance because ungulates are capable of maintaining their rate of food intake despite being vigilant, because of their ability to scan the environment while chewing vegetation [27], [28]. Although foraging costs of vigilance are likely less important than traditionally assumed [26], vigilance certainly induces some foraging costs [29], [30]. Empirical studies suggest that disturbance and related vigilance in ungulates can reduce reproductive success and potentially impact populations [31]–[35].

Here we disentangle the effects of human disturbance (i.e., vehicle traffic) [3], [36], [37] and different types of human activities on the vigilance behaviour of elk (*Cervus elaphus* Linnaeus 1758) in southwest Alberta, Canada. Alberta has a growing road network due to increased demands for resources and recreation, which creates concern for wildlife conservation (*e.g.*, for grizzly bears *Ursus arctos* Linnaeus 1758 see [38]). Roads pose a major risk to many animal populations [39]–[40], and elk are a good model species because they are of keen economic and social interest across North America and Europe and may act as a charismatic flagship species [41] in conservation and management actions. A few studies have shown the effect of human disturbance on the behaviour of elk [7], [42], [43], while several have focused on the effect of natural predators on the behaviour of this species [24], [44], [45]. However, the majority of these studies were performed during short periods (e.g. summer, rut) or within single-use human activity areas (e.g., protected areas), given that it is challenging to collect behavioural data where hunting is permitted and ungulates adopt more secretive behaviour [6]. Thus, here we analysed original elk behavioural data collected across a range of land-use types and seasons in the same population subjected to a variety of management policies. We documented for the first time the effect of fine-scale traffic patterns on the behaviour of a large herbivore across an entire road network.

Methods

Ethics Statement

Our data collection complied with all relevant federal laws of Canada and provincial laws of Alberta. Procedures adopted in this study were reviewed and approved by the University of Alberta Animal Care and Use Committee ACUC – Biosciences (Animal care protocol # 536-1003 AR University of Alberta, Edmonton, Canada), by all jurisdictions of the Alberta Government (Permit Numbers: BI-2008-19, RC-06SW-001 and 23181CN), and by Parks Canada (Permit Numbers: WL-2010-7292, WL-2010-5755).

Study Area

The study occurred within a montane ecosystem along the eastern slopes of the Rocky Mountains in southwest Alberta, Canada. This is a diverse landscape, ranging from flat agricultural grasslands, in the east, to mixed conifer/hardwood forests and mountains, in the west. The study area (~5000 km^2) was composed of private agricultural land, public land (a.k.a. Crown land of Canada), and a national park (Waterton Lakes National Park). Private land in the eastern half of the study area was dominated by cattle ranches where recreational use and other activity was controlled and restricted by landowners. Activities in the public land were uncontrolled and dominated by recreational use including all-terrain vehicle (ATV) use, hunting, fishing, and hiking, with only a small fraction of road traffic related to natural gas extraction. Activities in the national park were strictly controlled and limited along designated paths.

Elk Behavioural Observations

From June 2010 to May 2011, observations were carried out at dawn and dusk using binoculars (10×50) and spotting scopes (25–40×60) to observe elk within open areas of the national park, private and public land. Observations were performed by the same 2 observers (SC, SS) from roads without leaving the vehicle at a distance always greater than 500 meters (distance between the observers and elk herd, mean ± SE: 729.8±60.1 m in public land, 752.83±49.4 m in the national park, and 957.3±31.6 m in private land). No elk were observed on public land from winter to early spring, when elk were usually on private land or in the national park (winter range). We defined a herd as a group of elk with a nearest-neighbour distance of less than 100 m, regardless of their behavioural state [23]. We recorded date, time, location, herd size and sex and age class composition for each herd observed. The exact position of each herd was assessed with the combined use of a GPS (eTrex Legend, Garmin International Inc., Olathe, KS, USA), a compass and a rangefinder (elite 1600 Arc, Bushnell, Overland Park, KS, USA). We divided elk into three age–sex classes. “Mothers” were defined as adult females with a nursing calf present. “Females” were defined as adult females with no nursing calf present. "Yearlings" were markedly smaller females and those males with only one antler point per side. Male vigilance is known to be partly devoted to looking for competitors (i.e. other males) for a long period of time before, during and after the rut [15]. We thus collected data on female dominated herds only (i.e., males <50%, [23]; males were adults with two or more antler points per side). We divided elk activity into six mutually exclusive behavioural states [23] as follows: feeding - standing or walking slowly with the head below the level of the shoulder; scanning - standing with the head at or above the shoulder level; travelling - walking, trotting or running with the head at or above the shoulder level; grooming - licking or scratching oneself or another; aggression - kicking, biting or charging another with head fully raised; and resting - any behaviour while lying on the ground.

For each herd observed we recorded both group vigilance and individual vigilance. Group vigilance was estimated using a group scan sampling rule and a fixed-interval, time-point recording rule [46]. We used a voice recorder to note the behaviour (feeding, scanning, travelling, grooming, aggression, and resting) of each member of the herd from left to right at the instant of the scan sample signal. The fixed-point interval was 15s for herds of fewer than 15 individuals and was extended to 30s, 45s or 60s for larger herds. We took 30 samples (usually 7.5 min total duration) for each herd scanned. Group vigilance was estimated as the percentage of time- intervals where at least one elk was scanning. Group vigilance accounts for the number of bedded individuals. Several elk resting within open areas for long time is a clear sign of low group vigilance levels.

Individual vigilance was estimated by a focal animal sampling rule and a continuous recording rule [46]. Active focal individuals were selected from the herd based on their age–sex class (females, mothers, and yearlings, as defined above) and position in the herd (peripheral or interior). We defined interior animals as those that a predator from outside the herd could not approach without first encountering another herd member [47]. Peripheral animals were those individuals that could first be encountered by a predator that approached from outside the herd [47]. According to Childress and Lung [23], we assigned to each focal elk the distance to the nearest-neighbour elk (inter-individual distance). To reduce the probability that the same individual elk was observed more than once, only one to four individuals were observed in each herd. Each focal individual was observed for 15 min, until they were no longer visible, or they began to rest, whichever came first. Observations for less than 3 min were excluded from the analysis [23]. Behavioural states were recorded using a voice recorder. We used the free software JWatcher v.0.9 (http://www.jwatcher.ucla.edu/) to digitize and process voice records. We calculated scan frequency (number of scans/min) and the proportion of time scanning (time scanning/time active) for each individual. We also computed proportion of time travelling (time travelling/time active), proportion of time grooming (time grooming/time active), proportion of time feeding (time feeding/time active, i.e. foraging efficiency), and the average length of foraging bouts. The more an elk interrupts feeding behaviour to scan the landscape, the shorter the expected length of foraging bouts.

We recorded vigilance behaviours in elk that attempt to reduce their probability of being selected as a prey and to detect the predator (e.g. humans and natural predators) at a safe distance. We did not investigate elk behaviours that try to deter the predator when it is encountered. Observations carried out when hunters or grizzly bears were observed chasing elk groups were discarded from analyses due to low sample size.

Vehicle Traffic and Human Land Use Data

Fifty-two randomly distributed traffic counters (Apollo, Diamond Traffic Products, Oakridge, OR, USA) were deployed on trails and a variety of road types (i.e., paved roads, gravel roads, unimproved roads, truck trails and ATV trails). Moreover, 21 trail cameras (Silent Image RM30, RECONYX, Creekside, WI, USA) were deployed at randomly selected locations on roads and trails. Trail cameras provided time-stamped photographs of motorized use that triggered the camera's infrared sensor. Pictures of motorized vehicles were used to quantify traffic. Using this large dataset, Northrup et al. [48] modeled traffic volume for the entire road network in our study site. Traffic volumes were modelled for 3 seasons: summer, hunting, and winter-spring (see below for further details on how we defined seasons).

The location of each elk herd was assigned the following two road variables: the linear distance to the nearest road (km) and the density of roads (km/km^2) in a 3 km-wide circular buffer. The buffer area was chosen based on average daily mobility of elk in the area computed as the sum of distances between successive GPS locations recorded for $n = 168$ collared elk monitored in this area (MS Boyce, unpublished data). We classified roads based on disturbance rate (traffic volume thresholds) following an exponential fashion:

i. all roads, regardless of traffic volumes (i.e. even considering roads estimated by the traffic models to be travelled by 0 vehicles per day);
ii. only roads with a traffic volume of at least 1 vehicles every 8 hours (at least 3 vehicles per day),
iii. only roads with at least 1 vehicle every 4 hours (at least 6 vehicles per day),
iv. only roads with at least 1 vehicle every 2 hours (at least 12 vehicles per day),
v. only roads with at least 1 vehicle every hour (at least 24 vehicles per day),
vi. only roads with at least 1 vehicle every 30 minutes (at least 48 vehicles per day),
vii. only roads with at least 1 vehicle every 15 minutes (at least 96 vehicles per day),

We calculated the distance from the closest road – or the density of roads around a 3-km wide buffer – for each elk location and traffic class based on the above volume thresholds, resulting in 14 different road variables (7 for distance from roads, 7 for density of roads).

Forty-three trail cameras (RECONYX, Creekside, Wisc.) were deployed on roads and trails at randomly selected locations [49]. We used data derived from 32 cameras located in the areas (public land $n = 19$, private land $n = 13$) where we sampled elk behavioural observations to calculate the average daily occurrence of recreational land users, *i.e.*, hikers, bikers, equestrians and ATV users.

Based on trail camera data, ~95% of motorized traffic recorded within public lands was related to recreational activities (cars, trucks, RVs: ~80%; ATVs such as quads and motorbikes: ~15%), while only ~5% was related to industrial activities (natural gas extraction). About 99% of motorized traffic recorded within the national park was of recreational type (cars, trucks, RVs), while ~95% of motorized traffic recorded within private lands was related to recreational and ranching activities with only a small fraction of ATVs (cars, trucks, RVs: ~93%; ATVs: ~2%).

Definition of Seasons According to Human Disturbance

The study area was seasonally visited by thousands of tourists and recreationists. We thus divided the study period into specific recreational periods, i.e. summer, hunting, and winter-spring (Table 1). Intense recreational use occurred during summer from late May through early September both in public lands and the national park, although with extremely different modalities – i.e., strictly managed and limited along paths in the national park, uncontrolled on public lands, where ATVs, free camping and activities both on and off trails were permitted. Activities on private lands were similar to those recorded on public lands (e.g. ATVs, camping) but restricted by landowners. Hunting seasons were mostly limited to early September through the end of November (Table 1). There were no restrictions on the number of licensed hunters having access to public land, while access to private land was strictly controlled by landowners. Hunting was not allowed in the national park, whereas hunting was allowed immediately outside its borders from early September through late February (Table 1). Although elk in Waterton Lakes National Park are not actively hunted within the park, animals are hunted along park boundaries when elk use lower-elevation areas during fall and winter due to shallow snow and higher forage availability. This is the reason why elk in this park do not show signs of habituation, as previously suggested for this specific area by St. Clair and Forrest [42]. During the winter-spring season, from December 1st to late May, recreational use of this area was largely absent, irrespective of the local land management (Table 1).

	Summer			Hunting			Winter-Spring*	
	(late May through early September)			(early September through the end of November)			(December through late May)	
	Public land	Private land	National Park	Public land	Private land	National Park	Private land	National Park
HUNTING	X	X	X	√	√LR	X PRB	X	X PRB
ATVs	√	√LR	X	√	√LR	X	X	X
Human presence† mean vehicles per day ± SE	167±11	64±3	436±32	137±10	90±3	338±25	27±1	60±4
vehicles per hour	7	3	18	7	4	14	1	2

[illegible]

Table 1. Seasonal and spatial variation of human disturbance recorded in a complex multi-use landscape of SW Alberta, Canada.
https://doi.org/10.1371/journal.pone.0050611.t001

Wolf and Grizzly Bear Resource Selection Functions (RSFs)

Wolf (*Canis lupus* Linnaeus 1758) and grizzly bear are predators of elk in this area. Cougars (*Puma concolor* Linnaeus 1771) are also present, though predation upon elk in this area is rare (based on $n=10$ GPS collared cougars monitored in this area, J. E. Banfield unpublished). We used pre-existing models for the spatial distribution of wolves and grizzly bears in the study area (for wolves: [50]; for grizzly bears: Foothills Research Institute Grizzly Bear Project, S. E. Nielsen unpublished data). In both cases, satellite-telemetry location data from wolves and bears were obtained, and population-averaged resource selection functions (RSFs) were developed. RSFs are any function proportional to the probability of selection of a resource unit, and have been widely used to model species distributions [51], [52]. RSFs were estimated using logistic regression, where resource units at telemetry locations are compared to resource units at random landscape locations [53]–[55]. Wolf and bear home ranges were estimated using a 95% kernel density estimator [56] of telemetry location data. The “two-stage” method was followed to calculate population-level RSFs [57]–[58] where an RSF is calculated for each individual animal and these are averaged across all individuals. Predictive ability of the RSF models was evaluated using k-fold cross validation [59].

Data Analyses

We modelled group vigilance and scan frequency of focal individuals using linear mixed models with Gaussian distributions of errors. The dependent variables were transformed (arcsine square root [group vigilance]; ln[scan frequency +1], where ln = natural logarithm) to improve normality of residuals and reduce skew. We included the identity code of each herd as a random intercept in our mixed models to account for replicated observations on the same herd through time [60]. Herds were identifiable given that more than 100 individuals in the area were individually recognizable by numbered and coloured ear tags and fitted with GPS radiocollars at the time of this study. Following Burnham et al. [61], we constructed 14 *a priori* mixed models based on biological relevance and field observations using 6 variables to predict group vigilance, and 17 *a priori* mixed models using 9 variables to predict scan frequency in focal individuals. Predictor variables were defined as follows:

Human disturbance:.

1). land-use/season, i.e. a dummy variable resulting from the combination of 3 seasons (summer, hunting, and winter-spring) with 3 land management strategies (public land, private land, national park). Based on location and date, one of the following codes was assigned to each elk observation: national park-summer, national park-hunting, national park-winter-spring; private land -summer, private land-hunting, private land-winter-spring; public land-summer, public land-hunting. No elk were observed on public land during winter-spring;

2). road variables (distance or density) based on traffic volume thresholds.

Natural predators:

3). wolf RSF and grizzly bear RSF.

Elk anti-predator strategies (within-group factors):

4). ln [herd size], where ln = natural logarithm;

5). inter-individual distance;

6). within-group position, i.e. an elk peripheral or interior to the herd;

7). age-sex class, i.e. females, mothers, yearlings.

Anti-predator strategies (environmental factors):

8). distance from the nearest tree cover, with tree cover characterized by a canopy cover ≥25%;

9). terrain ruggedness [62].

All variables were used to build the set of *a priori* models predicting scan frequency in focal individuals, while specific variables related to focal elk (predictor variables 5, 6, and 7) were excluded when we modelled group vigilance. Herd size was included in all *a priori* models to control for the effect of group size on both group vigilance and scan frequency [63].

The models best predicting group vigilance and scan frequency were identified by minimum AIC, model ranking and weighting [61], [64]. The use of AIC to select the best model could be problematic when using mixed models given that AIC penalizes models according to the number of predictor variables [65], which is not clear because of the random effect. Both Gelman and Hill [66] and Bolker et al. [67] noted this and advocate for the use of the deviance information criterion (DIC) in such instances. As a consequence, we also examined our model selection using the DIC approach. A likelihood ratio based R^2 [68] was used as an approximate measure of explained variation in the mixed models, according to the formula $R_{LR}^2=\{1-\exp[-2n^{-1}(L_M-L_0)]\}/\{1-\exp(2n^{-1}L_0)\}$ where L_M is the log-likelihood of the model of interest, L_0 is the log-likelihood of the intercept-only model and n is the number of observations.

Each set of *a priori* models predicting group vigilance was built using only 1 of the 14 road variables described above (7 variables for the distance from nearest road, 7 variables for road density). We ran these 14 independent sets of models to identify which road variable was the best predictor of group vigilance (based on AIC, verified with DIC). After this step, we presented the set of models built with the best road variable in predicting group vigilance. We repeated the same procedure when we modeled scan frequency in focal elk.

We were aware of the potential for spatial autocorrelation in our data given that close observations were suspected to have similar vigilance levels as a response to similar environmental factors. Indeed, Diniz-Filho et al. [69] stressed that AIC is particularly sensitive to the presence of spatial autocorrelation and may generate unstable and overfit minimum adequate models to describe ecological data. We ran a Mantel test [70] which showed no spatial autocorrelation in either the dataset dealing with group vigilance (Mantel test based on 9999 replicates, $r_M=-0.006$) or scan frequency ($r_M=0.022$).

We observed elk from roads without leaving the vehicle. Prior to generating our sets of *a priori* models, we examined whether our data on group vigilance were affected by the presence of observers in some way. Thus, we fit a linear mixed model to test for the effect of the distance between the observer and the elk herd (measured with a rangefinder) on group vigilance, taking into account wind strength and wind direction which might increase the probability of the observer being spotted by the elk. We included the identity code of each herd as a random intercept in our mixed models to account for replicated observations on the same herd through time [60]. Wind strength was measured with an anemometer, while wind direction was measured with a compass and computed as deviation from 0 in degrees, with 0 degrees being the direction of the wind blowing from the observer and the herd.

We used least squares linear regression to test the effect of various types of human users recorded by cameras (average daily presence of hikers, bikers, equestrians, and ATV users) on elk behavioural patterns (average scan frequency, proportion of time grooming, proportion of time scanning, and proportion of time travelling) during summer and the hunting season on private lands and public land. We also used linear regression to test the effect of scan frequency on length of foraging bouts, proportion of time feeding (i.e. foraging efficiency), and proportion of time travelling in focal elk.

All analyses were performed with R 2.14.1 [71]. All GIS analyses were performed with ARCMAP 9.2 (ESRI Inc., Redlands, CA).

Results

We made 424 direct observations of elk herds (15,032 elk) and 870 observations of focal individuals from June 2010 to May 2011. We observed 124 groups (220 focal individuals) in summer, 92 groups (154 focal individuals) during the hunting season, and 208 groups (496 focal individuals) during winter and spring. We observed 212 mothers, 336 adult females without calves, and 322 yearlings. Calf/female ratios - including within females both adult females and mothers - were (mean ± SE) 0.22±0.07 on public lands, 0.32±0.02 in the national park, and 0.37±0.01 on private lands. Female productivity recorded on public lands was lower than that in the national park (independent samples t-test, $t=-2.336$, $p=0.022$) and on private lands ($t=-3.436$, $p=0.001$).

We did not find a significant effect of the distance between observer and herd or wind direction and strength on group vigilance (linear mixed model: effect of distance between observer and herd $t=-0.252$, $p=0.800$; effect of wind strength: $t=0.100$, $p=0.920$; combined effect of wind strength with wind direction: $t=-1.035$, $p=0.301$).

Human Disturbance Exceeded other Factors in Triggering Increased Vigilance in Elk

A comparison of models predicting group vigilance is reported in Table 2 (upper panel). The best model explained approximately 83% of the variability of group vigilance. Taking into account herd size, the top-ranked model included both the predictor variables of human disturbance, i.e. land-use/season and distance from the nearest road with a traffic volume of at least 12 vehicles per day. The distance from the nearest tree cover was also included in the best model. The selection of the top-ranked model using AIC was confirmed using DIC (Table S1, upper panel). Models including the variable for the nearest road with a traffic volume of at least 12 vehicles per day consistently outperformed models excluding this term (Table S2).

Model #	Dep. variable: arcsine square root (group vigilance), n = 424 elk groups	AIC	ΔAIC	w_i	ER	logLik
1	**ln(herd size)×land-use/season+dist. nearest tree cover + dist. nearest road (≥12 vehicles per day)**	**118.6**	**0**	**0.9003**	**1**	**−45.3**
2	ln(herd size)×land-use/season+dist. nearest road (>12 vehicles per day)	124.2	5.6	0.0547	16	−49.1
3	ln(herd size)×land-use/season+ dist. nearest road (>12 vehicles per day)+Terrain ruggedness	125.4	6.8	0.0301	30	−48.7
4	ln(herd size)×land-use/season+ dist. nearest road (>12 vehicles per day)+wolf RSF+grizzly bear RSF	127.0	8.4	0.0134	70	−48.5
5	ln(herd size)×land-use/season+dist. nearest tree cover	131.3	12.7	0.0015	600	−52.7
6	ln(herd size)×land-use/season	141.7	23.2	<0.0001	10^{5}	−58.9
7	ln(herd size)×land-use/season+ wolf RSF+grizzly bear RSF	142.3	23.7	<0.0001	10^{5}	−57.2
8	ln(herd size)×land-use/season+ Terrain ruggedness	143.7	25.2	<0.0001	10^{5}	−58.9
9	ln(herd size)+dist. nearest road (>12 vehicles per day)	190.7	72.2	<0.0001	10^{15}	−89.4
10	ln(herd size)+dist. nearest tree cover	203.2	84.6	<0.0001	10^{18}	−95.6
11	ln(herd size)	203.9	85.3	<0.0001	10^{18}	−96.9
12	ln(herd size)+Terrain ruggedness	205.2	86.6	<0.0001	10^{18}	−96.6
13	ln(herd size)+wolf RSF+grizzly bear RSF	206.4	87.8	<0.0001	10^{19}	−96.2
14	Intercept only	379.5	261.0	<0.0001	10^{56}	−185.8
Model #	**Dep. variable: ln(scan frequency +1), n = 870 focal elk**	**AIC**	**ΔAIC**	**w_i**	**ER**	**logLik**
1	**ln(herd size)×land-use/season + dist. nearest road (>12 vehicles per day)**	**75.3**	**0**	**0.9476**	**1**	**−24.7**
2	ln(herd size)×land-use/season+inter-individual distance	81.9	6.5	0.0361	26	−27.9
3	ln(herd size)×land-use/season+wolf RSF+grizzly bear RSF	84.5	9.1	0.0098	97	−28.2
4	ln(herd size)×land-use/season+ dist. nearest tree cover	87.6	12.3	0.0020	464	−30.8
5	ln(herd size)×land-use/season	88.1	12.8	0.0016	587	−32.0
6	ln(herd size)×land-use/season+age/sex class	88.6	13.3	0.0012	758	−30.3
7	ln(herd size)×land-use/season+within-group position	89.3	13.9	0.0009	1062	−31.6
8	ln(herd size)×land-use/season+Terrain Ruggedness	89.8	14.5	0.0007	1396	−31.9
9	ln(herd size)+dist. nearest road (≥12 vehicles per day)	173.4	98.1	<0.0001	10^{21}	−80.7
10	ln(herd size)+wolf RSF+grizzly bear RSF	190.9	115.6	<0.0001	10^{25}	−88.5
11	ln(herd size)+age/sex class	191.7	116.3	<0.0001	10^{25}	−88.8
12	ln(herd size)+inter-individual distance	194.8	119.5	<0.0001	10^{25}	−91.4
13	ln(herd size)+dist nearest tree cover	195.9	120.5	<0.0001	10^{26}	−91.9
14	ln(herd size)	197.4	122.0	<0.0001	10^{26}	−93.7
15	ln(herd size)+Terrain Ruggedness	199.0	123.7	<0.0001	10^{26}	−93.5
16	ln(herd size)+within-group position	199.3	124.0	<0.0001	10^{26}	−93.7
17	Intercept only	315.4	240.1	<0.0001	10^{52}	−153.7

Two sets of linear mixed models fit to predict group vigilance (upper panel) and scan frequency (lower panel) in elk observed in SW Alberta, Canada. Best models (in bold, first rows) explained 83% of the variability of group vigilance and 86% of variability of scan frequency, respectively, as approximated by a likelihood ratio R_{LR}^2. (AIC = Akaike information criterion; ΔAIC = difference in AIC value between the AIC of a given model and the best model (lowest AIC); w_i = Akaike weights; ER = evidence ratio; logLik = log-likelihood value).
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Table 2. Sets of models predicting group vigilance and scan frequency in elk.
https://doi.org/10.1371/journal.pone.0050611.t002

According to predictions of the best model, group vigilance increased as the herd size increased (β = 0.182, SE = 0.011, Fig. 1a), confirming that larger groups have a higher probability of at least 1 elk scanning every 15 seconds. Large units (50 or more elk) were characterized by a higher probability of at least 1 elk scanning every 15 seconds (n = 96, mean ± SE, 85.7±1.7%), and had more than twice the probability of such behaviour than smaller units (3 or less elk; n = 74, 36.3±2.7%). Group vigilance increased when the distance from the nearest road decreased (i.e. when elk were closer to roads; β = −0.132, SE = 0.034, Fig. 1a). Indeed, group vigilance increased by 23% in magnitude from groups that were observed greater than 1000 m from a road (54.8±3.2%, n = 80) compared to groups observed less than 250 m from roads with a traffic volume of at least 12 vehicles per day (67.7±2.7%, n = 108). Group vigilance also increased as the distance from the nearest tree cover increased (β = 0.157, SE = 0.057). Group vigilance was 58.5±2.7% (n = 129) for groups less than 10 m from the closest tree line, while it was 70.8±4.4% (n = 40) for those greater than 500 m from tree line.

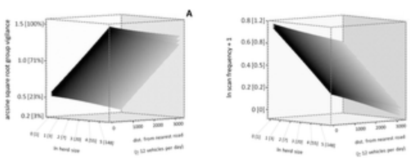

Figure 1. Effect of herd size and distance from nearest road on elk vigilance levels.
Effect of ln herd size and distance (in meters) from the nearest road with a traffic volume of at least 12 vehicles per day on a) arcsine square root group vigilance (n = 424 groups) and b) ln (scan frequency +1) (n = 870 focal individuals) in elk observed in SW Alberta, Canada. Back transformed data are indicated within square parentheses.
https://doi.org/10.1371/journal.pone.0050611.g001

Coefficients and standard errors estimated by the best model for the land-use/season variable are reported in Table 3 (upper panel). The highest level of group vigilance was recorded on public land during the hunting season. Group vigilance recorded on public land in summer was higher than that recorded in the national park during winter-spring and hunting season, and on the private lands during winter-spring. Intermediate values of group vigilance were recorded on private lands during summer and hunting season. The lowest value of group vigilance was recorded in the national park during summer (Table 3, upper panel). Group vigilance increased by 84% in magnitude from groups observed in the national park in summer (47.9±4.9%) to those observed on public land during the hunting season (88.3±4.3%).

	Land-use/season variable	β	SE
High group vigilance	Public land – hunting	0	
	Public land – summer	−0.37	0.12
	PRIVATE LAND – hunting	−0.51	0.12
	PRIVATE LAND – summer	−0.55	0.12
	National Park – winter-spring	−0.72	0.15
	National Park – hunting	−0.72	0.15
	PRIVATE LAND – winter-spring	−0.76	0.12
Low group vigilance	*National Park* – summer	−0.92	0.15
	Land-use/season variable	**β**	**SE**
High scan frequency	Public land – hunting	0	
	Public land – summer	−0.20	0.08
	PRIVATE LAND – summer	−0.25	0.08
	PRIVATE LAND – hunting	−0.36	0.09
	National Park – hunting	−0.38	0.10
	National Park – winter-spring	−0.47	0.10
	National Park – summer	−0.50	0.10
Low scan frequency	PRIVATE LAND – winter-spring	−0.51	0.08

Coefficients and standard errors (β±SE) estimated for the land-use/season variable by the best linear mixed effect models (see Table 2) predicting group vigilance in 424 elk groups (upper panel) and scan frequency (lower panel) in 870 focal elk observed in SW Alberta, Canada. The land-use/season dummy variable was derived from the combination of 3 seasons (summer, hunting, and winter-spring) with 3 different management strategies (public land, private land, and national park). No elk were observed in the Public land during winter-spring. All coefficients are in reference to the public land during the hunting season.
doi:10.1371/journal.pone.0050611.t003

Table 3. Effect of spatial and temporal variation of human disturbance on elk vigilance levels.
https://doi.org/10.1371/journal.pone.0050611.t003

A comparison of models predicting scan frequency of focal elk is reported in Table 2 (lower panel). The best model explained 86% of the variability of scan frequency and, taking into account herd size, included only those predictor variables related to human disturbance, i.e. land-use/season and distance from the nearest road with a traffic volume of at least 12 vehicles per day. The selection of the top-ranked model based on AIC was confirmed by the DIC analysis (Table S1, lower panel). Models including a variable for the distance from the nearest road with a traffic volume of at least 12 vehicles per day consistently outperformed models excluding this term (Table S3).

According to predictions of the best model, the scan frequency in focal individuals increased when the herd size decreased (β= −0.067, SE=0.008, Fig. 1b) or when the distance from the nearest road (≥12 vehicles per day) decreased (β=−0.095, SE=0.024, Fig. 1b). Scan frequency was (mean ± SE) 0.48±0.04 scan/min (n=264) when distance from the nearest road with at least 12 vehicles per day was ≥1000 m, while scan frequency was 0.52±0.03 scan/min (n=264) when the distance from the nearest road was 500 to 1000 m, 0.60±0.03 scan/min (n=230) when the distance was 250 to 500 m, and 0.72±0.04 scan/min (n=185) when the distance was 0 to 250 m.

Coefficients and standard errors estimated by the best model for the land-use/season variable are reported in Table 3 (lower panel). The highest scan frequency level in focal individuals was recorded on public land during hunting season (mean ± SE: 1.27±0.02 scan/min). This was higher than that recorded both on public (1.16±0.07 scan/min) or private land (1.02±0.06 scan/min) during summer (Table 3 lower panel). Lowest scan frequencies for focal individuals were recorded in the national park during winter-spring (0.44±0.03 scan/min) and summer (0.51±0.04 scan/min), and on private land in winter-spring (0.38±0.02 scan/min). Intermediate values of scan frequency were recorded during the hunting season in both the national park (0.65±0.07 scan/min) and on private land (0.68±0.05 scan/min) (Table 3, lower panel).

ATVs Exceeded Any other Human Land-use Type in Triggering Increased Vigilance in Elk

We did not find a significant effect of the number of bikers or equestrians recorded by motion-activated cameras (n=32) on the 4 behavioural variables recorded in focal individuals (Table 4). An increase in the number of hikers was responsible for a significant increase of the proportion of time travelling in focal individuals (R^2=0.55, p=0.002), but it did not affect other behavioural states (Table 4). An increase of the number of ATV users was responsible for a significant increase of scan frequency (R^2=0.35, p=0.004) and of proportion of time scanning (R^2=0.52, p<0.001) by focal individuals, while it resulted in a significant decrease in proportion of time grooming (R^2=0.32, p=0.007). The number of ATV users did not affect the proportion of time travelling by focal individuals (Table 4).

	scan frequency	grooming	scanning	travelling
HIKERS	−0.009±0.034 ns	−0.005±0.008 ns	−0.025±0.035 ns	**0.109±0.027** **
BIKERS	−0.983±1.317 ns	0.117±0.337 ns	0.672±1.435 ns	−0.779±1.161 ns
EQUESTRIANS	0.055±0.190 ns	−0.012±0.048 ns	0.145±0.201 ns	−0.126±0.228 ns
ATVs	**0.067±0.020** **	**−0.017±0.005** **	**0.078±0.017** ***	0.011±0.025 ns

Effect of different human use types – number of hikers, bikers, equestrians, and All Terrain Vehicles (ATV) users spotted by 32 motion activated cameras (public land n = 19; private land n = 13) – on 4 behavioural patterns recorded for focal elk (ln [scan frequency +1]; arcsine square root proportion of time grooming, scanning and travelling) observed during summer and hunting season in SW Alberta, Canada. The effect (β±SE) of each relationship was reported as estimated by linear regression (ns: not significant (p>0.4 in all cases); *: 0.05<p<0.01; **: 0.01<p<0.001; ***: p<0.001).
doi:10.1371/journal.pone.0050611.t004

Table 4. Effect of different human use types on behaviour of elk.
https://doi.org/10.1371/journal.pone.0050611.t004

Decreased Foraging Time by Elk from Increased Vigilance

Variation of scan frequency recorded among 870 focal elk explained 49% of the variability in the length of foraging bouts (linear regression analysis, Fig. 2a), 40% of the variability in total feeding time (i.e., foraging efficiency Fig. 2b), and 14% of the variability in total travelling time (Fig.2c). Increased scan frequencies were significantly related to a decrease in the length of foraging bouts, a decrease in total feeding time, and an increase in total travelling time by focal individuals (Fig. 2).

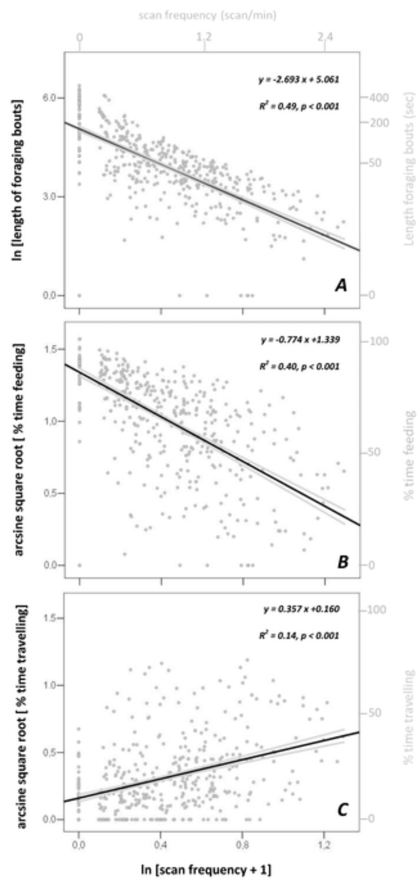

Figure 2. Effect of scan frequency on proportion of time feeding and travelling in elk.

Effect of scan frequency (bottom x-axis, ln[scan frequency +1]; see top x-axis for back transformed data) on a) ln [length of foraging bouts], b) arcsine square root [proportion of time feeding], and c) arcsine square root [proportion of time travelling] in 870 focal elk observed in SW Alberta, Canada. Right y-axes represent back transformed data. Black lines in each graph represent linear relationships, while grey lines represent 95% confidence intervals of mean. Linear regression equations, R^2 values and *p*-values are reported for each graph.

https://doi.org/10.1371/journal.pone.0050611.g002

Scan frequency strongly influenced the other behavioural states (Fig. 2). In turn, scan frequency was shaped by the distance to the nearest road with traffic volume of at least 12 vehicles per day (Table 2 lower panel, Fig. 1b). All behavioural states were clearly shaped by the distance from roads as well. We show the magnitude of such effect in Fig. 3. Length of foraging bouts were at least 2-times longer in elk observed at distances greater than 1 km from roads than those observed close to roads (<250 m, Fig. 3a). The same applied to feeding time (Fig. 3b), with an increase of at least +20% of total feeding time by elk observed greater than 1 km from roads. Elk observed closer to roads (<250 m) increased at least +10% the time spent travelling than those elk observed greater than 1 km from roads (Fig. 3c).

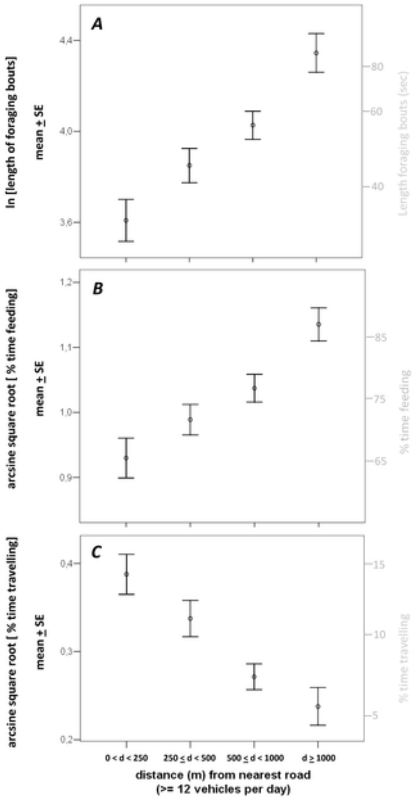

Figure 3. Effect of distance from nearest road on behaviour of elk.

Effect of the distance from the nearest road with a traffic volume of at least 12 vehicles per day on a) ln [length of foraging bouts], b) arcsine square root [proportion of time feeding], and c) arcsine square root [proportion of time travelling] in 870 focal elk observed in SW Alberta, Canada. Right y-axes represent back transformed data. The sample size was distributed as follows: n = 188 elk (0< *d* <250 meters, where *d* is the distance from the nearest road with a traffic volume of at least 12 vehicles per day), n = 230 elk (250≤ *d* <500 meters), n = 264 elk (500≤ *d* <1000 meters), and n = 188 elk (*d* ≥1000 meters).
https://doi.org/10.1371/journal.pone.0050611.g003

Discussion

Effects of Humans on Elk Behaviour Exceed those of Natural Predators and of other Environmental Factors

In a human-dominated landscape, we found that the effects of humans in shaping behaviour of elk exceed those of habitat and natural predators. Factors commonly thought to be primary drivers of vigilance behaviour in elk – terrain ruggedness, natural predators, position in the group, inter-individual distance, reproductive status of females [15], [23], [47] – may play a lesser role within human-dominated landscapes. In our analysis the only habitat variable that affected vigilance levels was the distance from tree cover. This strong habitat effect was evident for groups but not individuals, meaning that elk increased scan duration (i.e., higher likelihood of at least one elk scanning in the group) but not scan frequency (i.e. number scans/min) as the distance from safe habitat increased.

We documented elk behaviour across different land-use types (treatment areas) and seasons in the same population subjected to a variety of management policies. To date, no studies have collected behavioural data within protected areas, private lands and public lands simultaneously. This is a true landscape of fear, where each human is perceived by elk to be a potential predator, even within the protected area, as animals are threatened by hunting pressure immediately along its borders. We measured actual human use on roads in these treatment areas, and we documented the effect of fine-scale traffic patterns on the behaviour of a large herbivore across an entire road network. Road traffic volumes of at least 1 vehicle every 2 hours (12 vehicles per day) induced elk to switch into a more alert behavioural mode (increased vigilance) with an actual loses in feeding time. We expected a higher traffic volume threshold although we could not make precise predictions based on previous research because this is the first study in which vigilance data have been associated with estimates of traffic volumes. In this landscape of fear, where humans are perceived by elk to be potential predators, extremely low traffic volumes were sufficient to trigger a behavioural response by elk.

We found the highest levels of elk vigilance on public lands during the hunting season, when hunting and intrusive recreational activities occurred cumulatively, whereas the lowest levels were found in the national park in summer – even when crowded with people – and on private lands during winter-spring – when human activities were almost absent after hunting season. Both public lands and national park were crowded with people in summer, but our study clearly showed that it was not just the number of people but above all it was the type of human activity that shaped elk behaviour. More people can have less of an effect if the type of human activity is relatively benign, i.e., the effect of hikers on elk behaviour in the national park was definitely lower than that of motorized recreational activities occurring on public lands in summer. ATVs and intrusive summer recreational activities can have strong influence on elk behaviour as recently documented by Naylor et al. [7]. Our camera data collected outside the national park confirmed this pattern, showing that motorized vehicles had a stronger impact than non-motorized activities (hikers, bikers, equestrians) on elk behaviour. Among non-motorized activities, bikers and equestrians had no effect on elk behaviour likely because they are more predictable and rarely leave roads and trails. In contrast, hikers evoked an increase of proportion of time travelling in elk. This response is likely linked to the flight behaviour in elk, confirming that humans on foot are more evocative than other more predictable stimuli [6]. Running in elk can be an extreme alarm behaviour, and future studies should consider this behavioural category separated from walking to better disentangle the effect of different human types on elk behaviour.

Interestingly, we found levels of vigilance on private land during summer and the hunting season that were intermediate to those recorded in the public land and the national park, reflecting that access restrictions imposed by landowners lead to lower disturbance on elk compared with the uncontrolled human disturbances occurring in the public land. Vigilance levels in the national park during the hunting season, when hunting was allowed immediately along its borders, were not different than recorded on private lands when hunting was permitted there.

Management and Conservation of Wildlife in Human-dominated Landscapes

If we assume no human disturbance (traffic volumes of 0 vehicles per day, Fig. 4), we can expect a base level of vigilance due to natural predators, habitat characteristics and group size and composition [15], [23]. The traffic model developed by Northrup et al. [48] for our study site is the first detailed characterization of motorized human use along an entire road network to be used to evaluate large mammal behaviour. Our results showed that elk occupying areas close (e.g., <500 m) to roads (Fig. 4) switch into a more-alert behavioural mode (increased vigilance) when traffic surpasses 12 vehicles per day. This does not necessarily mean elk are displaced, but this level of traffic clearly leads to a significant rearrangement of the time spent in other activities such as feeding. High traffic volumes can have different impacts that depend on whether hunting is allowed or not (Fig. 4). If hunting is not permitted, then behavioural adaptations, such as habituation, can evoke a decrease in vigilance levels (Fig. 4; [72]). Human developments can affect the distribution of predators [73], [74]. In such cases, high human activity can even displace predators, and create spatial refuge for prey that can benefit from reduced predation risk [72], [75]. However, in a human-dominated landscape where hunting is allowed, behavioural responses to road traffic can be extreme (Fig. 4), potentially leading to high vigilance levels (elk and bison: [76]; Tibetan antelope *Pantholops hodgsonii* Abel 1826: [77]), increased flight distance (elk: [78]; other ungulates: [6]), increased movement rates (elk: [7]), and, eventually, displacement from areas surrounding roads and thus habitat loss (moose *Alces alces* Linnaeus 1758: [79]; woodland caribou *Rangifer tarandus caribou* Gmelin 1788: [80]; mule deer *Odocoileus hemionus* Rafinesque 1817: [81]; grizzly bear: [48]; elk [82], [83]).

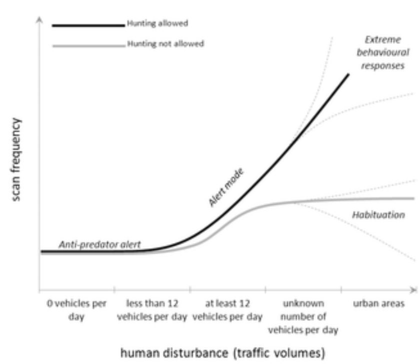

Figure 4. Theoretical relationship between traffic volumes and vigilance in elk.
Theoretical model describing the relationship between a proxy of human disturbance (traffic volumes) and the scan frequency in elk. A constant distance (<500 m) from the nearest road and a constant habitat (open area) for each elk observed were assumed. Elk are assumed to switch to the alert mode when the nearest road has a traffic volume of at least 12 vehicles per day. Higher traffic volumes (still unknown thresholds) are predicted to have different impacts on elk behaviour depending on whether the population is hunted or not, respectively.
https://doi.org/10.1371/journal.pone.0050611.g004

Increased vigilance has a cost in terms of decreased feeding time, as we showed with our data, and this certainly causes reduced feed intake [18], [25], [29], [30]. We showed how elk re-arrange activity patterns depending on the distance to roads where traffic surpasses 12 vehicles per day, with more frequent interruptions of foraging bouts, decreased feeding time and increased travelling time. If disturbed, we showed that elk can even reduce certain behaviours such as grooming to minimum levels as the presence of motorized vehicles increases. Vigilance and activities such as resting or grooming are incompatible [84].

We documented the complex link between disturbance and behavioural response in a human-dominated landscape, though we were not able to estimate the actual cost of human disturbance on wildlife in terms of fitness and population dynamics. Behavioural responses by elk to the risk of predation by wolves have been shown to be correlated with increased vigilance, reduced foraging and food intake [23], [45], [47], [85]. Parallel to these behavioral responses, physiological data have revealed a decrease in the quantity of food obtained by elk in the presence of wolves and changes in the composition of their diet that exacerbate nutritional deficits in winter [86], [87]. Ultimately, predation risk induced decreased fecal progesterone concentrations [34] and decreased calf recruitment in elk [47], [87], [88]. Thus, the actual cost of predation risk by natural predator has already been documented, at least for the wolf-elk predator prey system, but not for ecological contexts where humans are a major source of disturbance for wildlife. The effects of predation risk by humans arguably could be similar to those of natural predators, given that prey have evolved anti-predator responses to threatening stimuli including lethal (e.g. hunting) and non-lethal (e.g. noises or approaching vehicles) human disturbance. Animal responses are likely to follow the same principle used by prey encountering predators [11], [89].

According to the rationale “higher disturbance – lower reproductive success” [35], we could expect lower female reproductive success in sites most heavily disturbed by humans in our study area. In fact, we recorded the lowest calf female/ratio in public lands, where we recorded higher vigilance levels than elsewhere. However, the complex link between female productivity and disturbance has yet to be fully documented. Risk effects can be manifest by reduced survival, growth, or reproduction [34], [90]–[93]. Experiments allow risk effects to be clearly identified and quantified [94], [95], but this task is more difficult in field studies [91]. The link between increased human disturbance and reduced fitness in wildlife has been only partially documented in the field for few mammal and bird species [31]–[33], [96]. The cost of disturbance is a waste of time and energy [97], and some species are much more likely to be disturbed by humans than by non-human predators ([98], [99], this study). For these species, quantifying human disturbance and its fitness cost may be the highest priority for conservation. Human factors can affect behaviour, habitat use and distribution of wildlife with potential consequences on trophic cascades [100]: these factors should play a more prominent role in conservation or wildlife management within human-dominated landscapes.

Supporting Information

Table S1.

Sets of models predicting group vigilance and scan frequency in elk (ranked using DIC).
https://doi.org/10.1371/journal.pone.0050611.s001
(DOCX)

Table S2.

Selection of the best road variable predicting group vigilance in elk.
https://doi.org/10.1371/journal.pone.0050611.s002
(DOCX)

Table S3.

Selection of the best road variable predicting scan frequency in elk.
https://doi.org/10.1371/journal.pone.0050611.s003
(DOCX)

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Author Contributions

Conceived and designed the experiments: SC. Performed the experiments: SC SS. Analyzed the data: SC. Contributed reagents/materials/analysis tools: JMN TBM MM JAP MSB. Wrote the paper: SC JMN TBM MSB.

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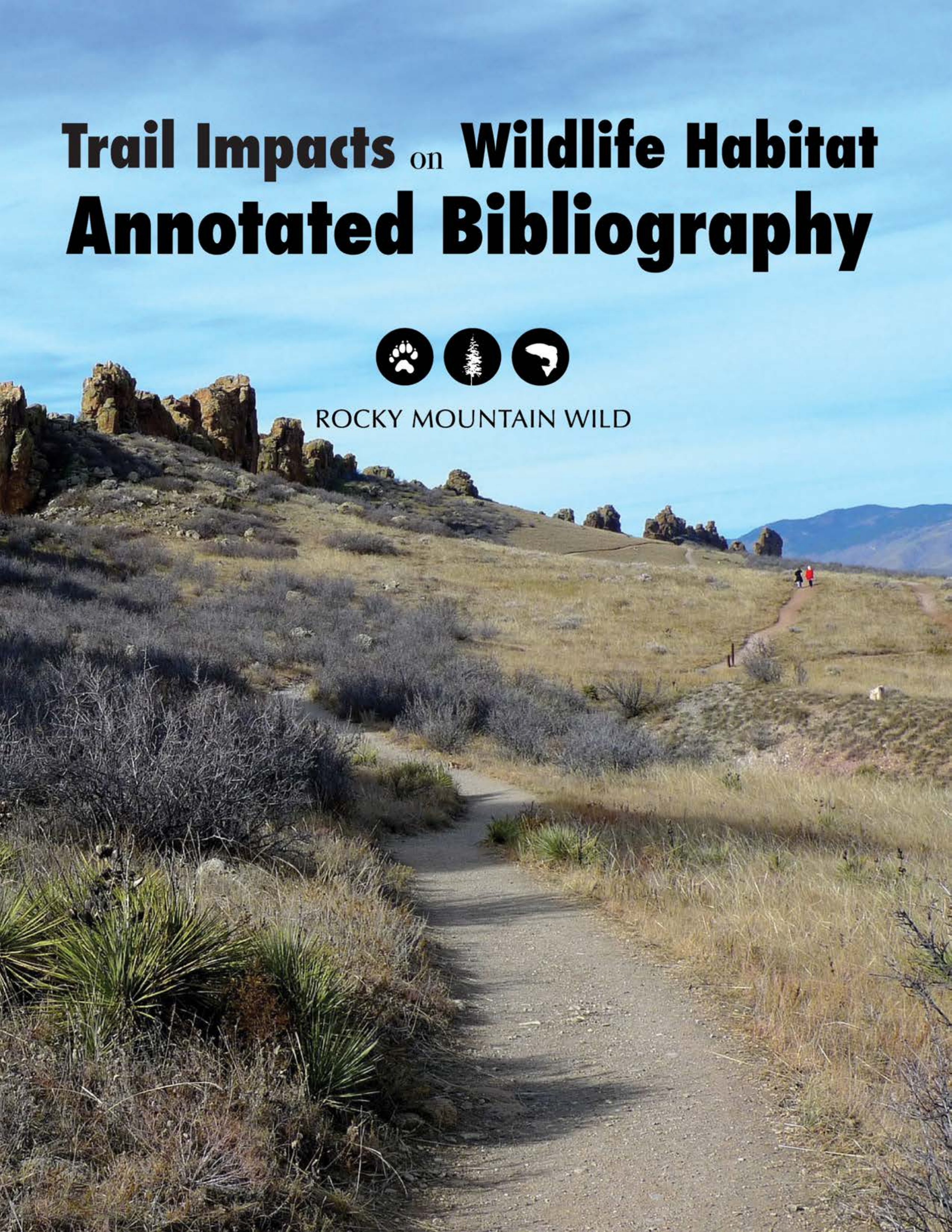
Attachment 5

Trail Impacts on Wildlife Habitat
Annotated Bibliography

ROCKY MOUNTAIN WILD



Trail Impacts on Wildlife Habitat

Annotated Bibliography

Rocky Mountain Wild has prepared this annotated bibliography in order to provide a listing of recent research—and also a few, still-important earlier studies—addressing the effects of recreational trails on wildlife behavior and habitat quality. Because research on non-motorized trails is much more scant than that on roads and motorized trails, we include such studies on roads and trails in the belief that useful analogies, though not conclusive inferences, can be drawn between them and non-motorized trails. We conducted a substantial, but not exhaustive, review of relatively recent literature in this area, primarily through Google and Google Scholar searches on a wide variety of key words and phrases. In order to capture the most relevant recent studies, we used Google Scholar to locate recent studies that cited earlier studies we had already deemed pertinent.

After reviewing the literature we retrieved, we culled it to include only publications that were most relevant, with a goal of limiting our bibliography to a manageable size. We then categorized the selected publications as follows:

1. Landscape-Scale Effects of Trails and Roads
2. Trail Planning and Management
3. Physiological and Population Effects of Trail Use
4. Behavioral Effects of Trails and Roads on Wildlife
5. Literature Reviews and Trail Impact Overviews
6. Insights into Government Agency Approaches (publications in this category may also appear in other categories)

All referenced publications may be viewed at the corresponding web link.

Landscape-Scale Effects of Trails and Roads

Bennett, Victoria J., Winston P. Smith, and Matthew G. Betts. "Toward Understanding the Ecological Impact of Transportation Corridors." United States Forest Service, 2011. https://drive.google.com/open?id=12NDm3bcAlUI-lyWTGYje7TeJWsyWZl-3
This general technical report produced for the Forest Service provides a useful overview of the field of road ecology. It discusses the primary effects of roads on the landscape: loss of permeability, habitat loss/degradation, and habitat fragmentation. Simple avoidance behavior by wildlife has been the focus of most studies, and the authors call for more studies considering functional connectivity (including the three effects cited above) and road networks as a whole (rather than individual roads) in order to understand community and ecosystem-level effects.

Jaeger, Jochen A. G., Lenore Fahrig, and Klaus C. Ewald. "Does the Configuration of Road Networks Influence the Degree to Which Roads Affect Wildlife Populations?" *Proceedings of the 2005 International Conference on Ecology and Transportation*, August 29, 2005, 151–63.
https://drive.google.com/open?id=1k0X5kv7cZz6UEnpvKd31arr3LtUDPNii

The authors used a statistical population model to compare the effects of distributing the same traffic volume over different road patterns, with variables including the likelihood of animal death from traffic and the degree to which animals avoid roads. The model shows that using fewer roads is always preferable, but whether parallel or gridded road patterns are preferable depends on the degree to which a species avoids roads.

United States Forest Service. "Arapaho-Roosevelt National Forest/Pawnee National Grassland 1997 Revision of the Land and Resource Management Plan," 1997. https://drive.google.com/open?id=1y81ZWATTBMQCx1sVkrpaFTg8AcJ4OB2o
In Appendix B to this document, "Description of the Analysis Process," the Forest Service discusses how it determines the effects of roads and other "travelways" (including nonmotorized trails) on wildlife habitat. While older studies considered the average road density of an area, this plan further considers the impact of travelways on the habitat effectiveness of the surrounding area. Depending on the terrain and degree of cover, the zone of effect could be up to 500 meters.

Wilderness Society, The. "Scoping Comments for the White River Field Office Travel and Transportation Management RMP Amendment," December 4, 2015. https://drive.google.com/open?id=1BfxWp9m2rpy-GN5o9sQvhTpa7TZmBDZT
This letter comments extensively on the both the need and methodology for assessing habitat fragmentation and the effect of roads and trails at a landscape scale. The importance of considering road density, the extent of zones of disturbance, and the resulting core areas are stressed. Although the discussion does not address nonmotorized trails, the principles are broadly applicable.

Trail Planning and Management

Bentrup, G. "Conservation Buffers—Design Guidelines for Buffers, Corridors, and Greenways." Gen. Tech. Rep. SRS-109. United States Forest Service, 2008. https://drive.google.com/open?id=1Tbx1wh3iDXNPIbGQ2JwF_kId1h3jm3gm
While primarily discussing designs for buffers, corridors, and greenways, this report also addresses trail planning principles designed to protect wildlife and habitat. The discussion is brief, but it provides some insight into the approach of the USFS's own experts.

Colorado State Parks. "Planning Trails with Wildlife in Mind: A Handbook for Trail Planners," 1998. https://drive.google.com/open?id=1QwQqFIlmmtFbTXWunCk7ehPJn_CgAXKR
Although published twenty years ago, this handbook remains useful as a concise summary of how to plan trails to minimize their impact on wildlife. While more recent science could inform an updated version of this handbook, its underlying principles remain sound.

Brown, Casey L., Amanda R. Hardy, Jesse R. Barber, Kurt M. Fristrup, Kevin R. Crooks, and Lisa M. Angeloni. "The Effect of Human Activities and Their Associated Noise on Ungulate Behavior." Edited by Matt Hayward. *PLoS ONE* 7, no. 7 (July 10, 2012): e40505. https://drive.google.com/open?id=1tm7aozrPjydhJDuitesKfx2kDh4AluR7
The authors used direct observations to study elk and pronghorn response to traffic and other human activity in Grand Teton National Park, hypothesizing that animals would have increased negative response to higher traffic levels and the resulting noise. In fact,

increased traffic resulted in a reduced response. Elk and pronghorn were more disturbed by pedestrians and by motorcycles. The authors suggest that perhaps individuals sensitive to noise are less likely to inhabit areas near roads, or that individuals living near roads become habituated and no longer respond to traffic noise. Pedestrians and motorcycles may cause more disturbance because they are less frequent in occurrence.

Indiana Wildlife Federation. "Sustainable Wilderness Trail Program," 2016. https://drive.google.com/open?id=1SRV4X7hyrQ-W44Kz7TZZXOX2bXdLJyVf The Indiana Wildlife Federation produced this document to set out the requirements for receiving its Sustainable Wilderness Trail certification. While it touches on several key areas regarding wildlife habitat, its approach is not detailed and does not address broader issues of the effects of trail networks. A trail designated as sustainable may not, in fact, be sustainable in an ecological sense.

Jones, Jennifer. "Trail Planning and Design for Wildlife Impacts." presented at the 2015 Massachusetts Trails Conference, 2015. https://drive.google.com/open?id=1ntf_uK6uMAOqyoi_w2FUxhIBHyIgMXJ2 Although it is brief, this PowerPoint presentation lays out a number of key principles for trail planning. It provides specific guidance for woodlands, grasslands, riparian areas, wetlands, and vernal pools. Its approach is very accessible to a nonspecialist audience.

Marion, Jeffrey L., and Yu Fai Leung. "Environmentally Sustainable Trail Management." In *Environmental Impacts of Ecotourism*. CAB International, 2004. https://drive.google.com/open?id=1KMZKcqZjVBo4m4hAshrfj9VO9d1JgJCm Although focused on trail effects on soil and erosion rather than wildlife, the authors espouse a thorough approach to evaluating the environmental impacts of trails before construction. They stress the need to look at each trail as part of a system, rather than a single entity. In addition, the authors stress the need to determine environmental indicators, and appropriate means of monitoring them, so that managers can determine whether environmental goals are met.

Marzano, Mariella, and Norman Dandy. "Recreational Use of Forests and Disturbance of Wildlife." UK Forestry Commission, 2012. https://drive.google.com/open?id=1XI59M88g1le0a_nTO5mkmysxrvFZoLuN The authors review literature from 1990 to 2010 regarding the effect on wildlife of recreational activities, including hiking, cycling, ORV travel, and others. While activities involving motorized vehicles consistently caused the greatest disturbance, the literature on the relative effects caused by walking, biking and horseback riding did not show consistent results. This report is primarily concerned with addressing issues that affect recreational planning in protected areas, but does include useful information, including a list of articles with substantial bibliographies, on the effects of roads and trails more broadly.

Massachusetts Department of Conservation and Recreation. "Trails Guidelines and Best Practices Manual," 2014. https://drive.google.com/open?id=1f9OnYPzEMvaXzylJLjtoUXaPinaxtfPM This manual provides detailed information about trail planning, design, and maintenance, with an emphasis on sustainability. Minimizing negative impacts on wildlife and habitat is part of every stage of the process. New trails require formal review and approval based on need and impact, and trails with sufficient potential for ecological impact require permitting from state agencies. While it does not have as many substantive observations about planning for wildlife as the Colorado guide, it is very clearly written and thorough regarding process.

National Park Service. "Rocky Mountain National Park: East Shore Trail Finding of No Significant Impact," 2014.
https://drive.google.com/open?id=1OXJrSLVJbelYFrmorCQE18FUreLPTJtn
The National Park Service approved permitting mountain bike use on an existing trail in Rocky Mountain National Park, despite finding that was not the environmentally preferable alternative. In order to protect natural resources, NPS did impose some restrictions on the timing of trail construction and required re-routing of a portion of the trail. While NPS clearly considers impacts on wildlife of trail changes, it does not necessarily perform a detailed review and it may choose alternatives that are not environmentally preferable.

Robinson, C., P.N. Duinker, and K.F. Beazley. "A Conceptual Framework for Understanding, Assessing, and Mitigating Ecological Effects of Forest Roads." *Environmental Reviews* 18, no. NA (December 2010): 61–86.
https://drive.google.com/open?id=1VEtFfHNBIUcxEqsntfL9PYOf1njBsbh8
The authors discuss the range of effects of forest roads on wildlife and the environment, then propose a methodology for evaluating these effects. The methodology includes a checklist requiring consideration of numerous factors that may affect wildlife by road planners and managers. Although it addresses roads, this article's approach is equally applicable to trails.

Schoenbauer, Jeff. "Trail Planning, Design, and Development Guidelines." Minnesota Department of Natural Resources, 2007.
https://drive.google.com/open?id=1VxhQoFXsUF80vWAqqniM4Q6guxSnf1hR
Although published ten years ago, Minnesota's guide to trail planning is in many ways one of the best trail planning resources available. The guide devotes an entire chapter to principles of ecological sustainability, and advocates consideration of ecological issues from the earliest stage of trail planning.

Switalski, T. Adam, and Allison Jones. "Off-Road Vehicle Best Management Practices for Forestlands: A Review of Scientific Literature and Guidance for Managers." *Journal of Conservation Planning* 8 (2012): 12–24.
https://drive.google.com/open?id=1ePLzi1J8eey0TuAtP4dD367t2zDx-rIC
Although this article is directed towards ORV trails, its approach is still instructive in considering best practices for nonmotorized use trails. It requires that wildlife concerns be addressed at the planning, implementation, and monitoring phases of trail development. The process includes route selection, construction, and use management issues in a way that should also be applied to nonmotorized use trails.

United States Forest Service. "Magnolia Non-Motorized Trails: Environmental Assessment," August 2016. https://drive.google.com/open?id=1o_NTpXAhftwXXkmPbaF4hHcDo-3N348x

This recent environmental assessment of a proposed trails project, although reaching a similar result (no EIS required), differs significantly from the contemporary Buffalo Pass assessment. Unlike the Buffalo Pass EA, it accounts for more recent research into the impact of recreation on wildlife. It also contains a detailed plan to monitor and respond to negative effects of wildlife by trail use.

United States Forest Service. "Trail Fundamentals and Trail Management Objectives." United States Forest Service, Washington Office, Recreation, Heritage and Volunteer Resources, Updated 2016. https://drive.google.com/open?id=18GXnRVVcXoIv5NrTc1dnEhoFyusu-GKR
The Forest Service's guide to the trail planning, which includes only minor references to concern for habitat and threatened species. While it provides little information of direct use, it does document the need for more consideration of habitat and wildlife issues in trail planning.

Physiological and Population Effects of Trail Use

Bejder, L, A Samuels, H Whitehead, H Finn, and S Allen. "Impact Assessment Research: Use and Misuse of Habituation, Sensitisation and Tolerance in Describing Wildlife Responses to Anthropogenic Stimuli." *Marine Ecology Progress Series* 395 (December 3, 2009): 177–85.
https://drive.google.com/open?id=11HOFJf_nAbPwVcb7ZZvWVokHs0vMdk4C
The authors address the distinctions between tolerance and habituation, finding that the latter is misunderstood and much harder to identify and measure. They also argue that what is often referred to as habituation (actual desensitization to a stimulus) may merely be tolerance (not reacting in a particular way to the stimulus). For example, a deer that does not flee disturbance may nevertheless suffer physiological effects, or may not flee due to external factors. Studies regarding habituation often measure only tolerance.

Canfield, Jodie E., L. Jack Lyon, J. Michael Hillis, and Michael J. Thompson. "Ungulates." In *Effects of Recreation on Rocky Mountain Wildlife: A Review for Montana*, 6.1-6.25. Committee on Effects of Recreation on Wildlife, Montana Chapter of The Wildlife Society, 1999.
https://drive.google.com/open?id=1mI_AXATSiVaaDWuPgYHcD_dSGatfG3Jg
This literature review breaks out the different ways in which human intrusion and disturbance can affect ungulates, with an emphasis on physiological and population consequences. The authors suggest various means, including limitations on roads and trails, to limit disturbance.

Jachowski, David, Scott McCorquodale, Brian Washburn, and Joshua Millspaugh. "Human Disturbance and the Physiological Response of Elk in Eastern Washington." *Wildlife Biology in Practice* 11, no. 1 (May 20, 2015).
https://drive.google.com/open?id=1OA0rNPEYTCsTwU9XSbJcaEiE-LpeYo5B
The authors studied elk fecal glucocorticoid metabolite (FGM) levels in three different areas to compare elk living in a natural area with those exposed to human disturbance (including road networks). After accounting for seasonality and other factors, elk in more disturbed areas showed consistently higher FGM levels, suggesting they were

physiologically affected by greater stress. The human-induced stress was of sufficient magnitude to exceed any season or climate-based effects.

Phillips, Gregory E., and A. William Alldredge. "Reproductive Success of Elk Following Disturbance by Humans during Calving Season." *The Journal of Wildlife Management* 64, no. 2 (April 2000): 521.
https://drive.google.com/open?id=1LMh7xZkF50o4ZIyHMOy3umBeVuTGOBow
The authors studied elk reproductive success in two Colorado locations when mothers and calves were repeatedly approached by humans on foot. Greater numbers of disturbance events corresponded to lower likelihood of calf survival. The likeliest cause appeared to be increased vulnerability to predation "through increased calf movement, nutritional stress, desertion, or a combination of these factors."

Wiedmann, Brett P., and Vernon C. Bleich. "Demographic Responses of Bighorn Sheep to Recreational Activities: A Trial of a Trail: Bighorn Sheep Responses to Recreation." *Wildlife Society Bulletin* 38, no. 4 (December 2014): 773–82.
https://drive.google.com/open?id=13hGNXsicQX_oiBWW4V7aNMJ2vlrME9CF
Researchers tracked bighorn sheep in North Dakota over a twelve year period to understand the effects of a new hiking trail that passed near traditional lambing grounds. In areas where hikers went off-trail, lambing grounds were ultimately abandoned; where use was less intense and users less frequently strayed off-trail, lambing grounds in the area continued to be used. While this article does not discuss fragmentation, it offers strong evidence of the impact of trail disturbance on population viability.

Behavioral Effects of Trails and Roads on Wildlife

Ciuti, Simone, Joseph M. Northrup, Tyler B. Muhly, Silvia Simi, Marco Musiani, Justin A. Pitt, and Mark S. Boyce. "Effects of Humans on Behaviour of Wildlife Exceed Those of Natural Predators in a Landscape of Fear." Edited by Nei Moreira. *PLoS ONE* 7, no. 11 (November 28, 2012): e50611.
https://drive.google.com/open?id=1FnOQQTU9cFCOYN1GaydzXxofq81H8q4L
The authors observed elk response to human activity (primarily along roads) versus response to natural predators. The study compared behavior on public, private, and protected lands in the Canadian Rockies, and accounted for type and amount of road traffic. While the exact impact of different activities varies, human activity is a better predictor of increased elk vigilance than any natural factor; road traffic of as little as one vehicle per two hours caused a notable increase in vigilance behavior.

Gaines, William L., Peter H. Singleton, and Roger C. Ross. "Assessing the Cumulative Effects of Linear Recreation Routes on Wildlife Habitats on the Okanogan and Wenatchee National Forests." Gen. Tech. Rep. PNW-GTR-XXX. United States Forest Service, 2003.
https://drive.google.com/open?id=1MTiLCGQTwOEW_xkdmHd36t-cfpWIGSA7
The authors conducted a literature review to evaluate the range of effects resulting from disturbance by roads and recreational trails. They concluded that trails had effects similar to roads, but that trail-specific studies were much less common. Methodologies for using GIS to evaluate the effects in a particular area are discussed.

Marion, Jeff, and Jeremy Wimpey. "Environmental Impacts of Mountain Biking: Science Review and Best Practices." In *Managing Mountain Biking: IMBA's Guide to Providing Great Riding*. International Mountain Bicycling Association, 2007. https://drive.google.com/open?id=1lQaQ3Cr-3Fsnv4Oh0Gyn-tXkNbxon2y6
The authors broadly review the literature on various effects of mountain biking, including the effects on wildlife. They acknowledge that all trail uses have negative effects on wildlife, but argue that the scientific literature shows mountain biking is no worse than hiking. They rely on older studies even considering their 2007 publication date, and acknowledge but do not address the fact that mountain biking covers longer distances than hiking. "Habituation," in the sense of animals not moving when disturbed, is put forth as a positive, neglecting studies of hormones and heart rates that show the physiological impacts of disturbance.

Naylor, Leslie M., Michael J. Wisdom, and Robert G. Anthony. "Behavioral Responses of North American Elk to Recreational Activity." *Journal of Wildlife Management* 73, no. 3 (April 2009): 328–38. https://drive.google.com/open?id=1vAykg-gTz7mO_18kQm7mSIxq-bXiVE7j
The authors observed the responses of elk to ATV riding, mountain biking, hiking, and horseback riding under controlled conditions. All activities tended to increase the time elk spent traveling and reduce resting time. ATV riding was the most disturbing activity, but mountain biking has a stronger effect than either hiking or horseback riding.

Rogala, James Kimo, Mark Hebblewhite, Jesse Whittington, Cliff A. White, Jenny Coleshill, and Marco Musiani. "Human Activity Differentially Redistributes Large Mammals in the Canadian Rockies National Parks." *Ecology and Society* 16, no. 3 (2011). https://drive.google.com/open?id=1Q5qroO1mLoPiNPGv_KoQuKqiGeE-4CJW
The authors conducted an empirical study using GPS collars on wolves and elks to consider the effects of human trail activity on both species. Both species avoided areas less than 50 m from trails regardless of whether there was low or high human activity levels, but their behavior differed at distances of 50 to 400 m: Wolves consistently avoided these areas, but elk used them so long as human activity levels remained low. The authors hypothesize that elk sometimes use these areas as refuges from predation.

United States Forest Service. "Arapaho-Roosevelt National Forest/Pawnee National Grassland 1997 Revision of the Land and Resource Management Plan," 1997. https://drive.google.com/open?id=1y81ZWATTBMQCx1sVkrpaFTg8AcJ4OB2o
In Appendix B to this document, "Description of the Analysis Process," the Forest Service discusses how it determines the effects of roads and other "travelways" (including nonmotorized trails) on wildlife habitat. While older studies considered the average road density of an area, this plan further considers the impact of travelways on the habitat effectiveness of the surrounding area. Depending on the terrain and degree of cover, the zone of effect could be up to 500 meters.

United States Forest Service. "Buffalo Pass Trails Project: Environmental Assessment & Finding of No Significant Impact," May 2016. https://drive.google.com/open?id=1wcNDqBHpZjff-9LG_v-RlvVveXG5lyjS
This recent environmental assessment of a proposed trails project offers some insight into how the Forest Service accounts for possible impacts on wildlife. The Forest Service

argues that, even in 2016, there is limited research on the effect of recreational activities on wildlife, ignoring the studies found in this bibliography. While habitat fragmentation is mentioned, it is not incorporated into the analysis. Concerns about the effect of trails on lynx, for example, are dismissed on the basis that human trail use is diurnal, while lynx hunt at night.

Wisdom, Michael J., Alan A. Ager, Haiganoush K. Preisler, Norman J. Cimon, and Bruce K. Johnson. *Effects of Off-Road Recreation on Mule Deer and Elk*. Vol. 69, 2004. https://drive.google.com/open?id=1jy4XJ1ehcwxr8UkEfPeoXAe3OcFW6dUh
The researchers conducted controlled studies of the reactions of elk and mule deer to ATVS, mountain bikes, hikers, and horseback riders. The study was set in a fenced forest with roads closed to eliminate other disturbance sources. ATVs consistently had the strongest effect; mountain bikes generally had a stronger effect than hikers and horseback riders. Because of their slower speed compared to ATVs, twice the number of mountain bikers and three times the number of hikers were required to create the same effects along the entire transacts being measured. The authors propose considering "off-road use rates" and "off-road recreational equivalents" to quantify the increased impact of faster modes of travel. They suggest management strategies where high numbers of hikers could be permitted because they would not create as much disturbance as an equal number of ATVs or mountain bikes.

Literature Reviews and Trail Impact Overviews

Larson, Courtney L., Sarah E. Reed, Adina M. Merenlender, and Kevin R. Crooks. "Effects of Recreation on Animals Revealed as Widespread through a Global Systematic Review." Edited by Hideyuki Doi. *PLOS ONE* 11, no. 12 (December 8, 2016): e0167259. https://drive.google.com/open?id=1OTdNUn3pYiIe4my3SrshNOOutpMK5itt
The authors conducted an exhaustive literature search for studies on the effects of recreation on animals. The authors determined that such effects were primarily negative. They also determined that, contrary to conventional wisdom, nonmotorized recreation apparently had greater effects than motorized recreation; the authors point out, however, that motorized recreation may cover a larger area and thus may have a greater effect than the studies report. In addition, the authors observe that literature containing management recommendations was sparse and often not detailed.

McCorquodale, Scott M. "A Brief Review of the Scientific Literature on Elk, Roads, & Traffic." Washington Department of Fish and Wildlife, Olympia, USA, 2013. https://drive.google.com/open?id=12_D45cAcaL8xrDdY6epefExTLjZAdnsP
This literature review, while focused on road effects, provides a great deal of useful background on the responses, both physiological and behavioral, of elk to human disturbance. It includes an extensive bibliography that was current as of 2013.

Will, Perry. "Letter Re: Town of Avon Recreational Trails Master Plan Update." Colorado Parks and Wildlife, July 21, 2016. https://drive.google.com/open?id=1RhNksstiuyyxNLcmsQZHHGavx8M9Guxo
While it addresses a particular plan, this letter lays out the range of obvious and hard to observe effects of human presence on wildlife. It points out a number of limitations in

existing studies that may cause them to underestimate the effects of human disturbance. The letter also provides suggestions for trail planning and for ongoing mitigation measures.

Insights into Government Agency Approaches

Bureau of Land Management. "Spring Creek Canyon Connector Trails: Determination of NEPA Adequacy," June 2015. https://drive.google.com/open?id=1sjD3kLYu9cqxe39HF9tsZjlrsKl5AXH6
This determination is brief, and it addresses conservation issues in a cursory way, citing previous plans within which the current effort is claimed to fall. No attention is given to the effect on fragmentation and habitat quality of this substantial trail expansion.

United States Forest Service. "Magnolia Non-Motorized Trails: Environmental Assessment," August 2016. https://drive.google.com/open?id=1o_NTpXAhftwXXkmPbaF4hHcDo-3N348x
This recent environmental assessment of a proposed trails project, although reaching a similar result (no EIS required), differs significantly from the contemporary Buffalo Pass assessment. Unlike the Buffalo Pass EA, it accounts for more recent research into the impact of recreation on wildlife. It also contains a detailed plan to monitor and respond to negative effects of wildlife by trail use.

United States Forest Service. "Trail Fundamentals and Trail Management Objectives." United States Forest Service, Washington Office, Recreation, Heritage and Volunteer Resources, Updated 2016. https://drive.google.com/open?id=18GXnRVVcXoIv5NrTc1dnEhoFyusu-GKR
The Forest Service's guide to the trail planning, which includes only minor references in concern for habitat and threatened species. While it provides little information of direct use, it does document the need for more consideration of habitat and wildlife issues in trail planning.

United States Forest Service. "Arapaho-Roosevelt National Forest/Pawnee National Grassland 1997 Revision of the Land and Resource Management Plan," 1997. https://drive.google.com/open?id=1y81ZWATTBMQCx1sVkrpaFTg8AcJ4OB2o
In Appendix B to this document, "Description of the Analysis Process," the Forest Service discusses how it determines the effects of roads and other "travelways" (including nonmotorized trails) on wildlife habitat. While older studies considered the average road density of an area, this plan further considers the impact of travelways on the habitat effectiveness of the surrounding area. Depending on the terrain and degree of cover, the zone of effect could be up to 500 meters.

United States Forest Service. "Buffalo Pass Trails Project: Environmental Assessment & Finding of No Significant Impact," May 2016. https://drive.google.com/open?id=1wcNDqBHpZjff-9LG_v-RlvVveXG5lyjS
This recent environmental assessment of a proposed trails project offers some insight into how the Forest Service accounts for possible impacts on wildlife. The Forest Service argues that, even in 2016, there is limited research on the effect of recreational activities

on wildlife, ignoring the studies found in this bibliography. While habitat fragmentation is mentioned, it is not incorporated into the analysis. Concerns about the effect of trails on lynx, for example, are dismissed on the basis that human trail use is diurnal, while lynx hunt at night.

Will, Perry. "Letter Re: Town of Avon Recreational Trails Master Plan Update." Colorado Parks and Wildlife, July 21, 2016.
https://drive.google.com/open?id=1RhNksstiuyyxNLcmsQZHHGavx8M9Guxo
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