# BOARD OF COMMISSIONERS

Anne Brown  Kris Holstrom  Lance Waring

October 30, 2023

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Grand Mesa, Uncompahgre, and Gunnison National Forests Headquarters
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Submitted electronically via the project webpage:
http://www.fs.usda.gov/goto/gmug/forestplan_objections

Notice of Objection to the Grand Mesa, Uncompahgre, and Gunnison National Forests Plan

**OBJECTOR CONTACT INFORMATION**

Pursuant to 36 C.F.R. § 219.54 (c)(3), the Board of County Commissioners of the County of San Miguel, State of Colorado ("San Miguel County" or "County") is designated as the objector.

Board of County Commissioners of the County of San Miguel, State of Colorado
Lance Waring
San Miguel County Commissioner
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San Miguel County files this objection to the Final Land and Management Plan ("LMP") for Grand Mesa, Uncompahgre, and Gunnison National Forests ("GMUG") under the process identified in 36 C.F.R. § 219 Subpart B. Notice of availability of the Record of Decision

("ROD"), Final Environmental Impact Statement ("FEIS"), and the Final Land Management Plan ("LMP", "Forest Plan" or "Plan") was published in a newspaper of record on August 30, 2023. Accordingly, this objection is timely.

**ELIGIBILITY TO OBJECT**

San Miguel County has participated in the planning process for the FEIS and LMP since their inception. The County submitted comments to the United States Forest Service regarding the draft on August 20, 2019, July 16, 2021, November 25, 2021, and November 26, 2021. Further, USFS entered into a Memorandum of Understanding 18-MU-11020400-050 on August 24, 2018, and 23-MU-11020400-086 on September 7, 2023, designating San Miguel County as a Cooperating Agency for the planning process. The issues raised in this Objection were either raised in the aforementioned comments or were unavailable at the Draft Environmental Impact Statement ("DEIS") stage.

**STATEMENT OF REASONS FOR OBJECTION**

San Miguel County submitted comments to the GMUG DEIS independently on August 20, 2019, and November 26, 2021, and in collaboration with Gunnison and Ouray Counties on July 16, 2021, and November 25, 2021. The USFS has requested "A statement that demonstrates the link between the objector's prior substantive formal comments and the content of the objection unless the objection concerns an issue that arose after the opportunities for formal comment;" therefore, we have indicated with dates which submitted comments to link our objection to.

**OBJECTIONS**

A. WE OBJECT TO THE AREA OF BEAVER PARK IDENTIFIED AS SEMI-PRIMITIVE MOTORIZED.
B. WE OBJECT TO BEAR CREEK, BRIDAL VEIL, AND NORTH OPHIR AS SEMI-PRIMITIVE MOTORIZED
C. THE ANALYSIS OF FENS IS INSUFFICIENT, AND THE BEST AVAILABLE SCIENCE WAS NOT USED TO DETERMINE FEN MANAGEMENT.
D. THE 100' BUFFER IS NOT SUITABLE FOR FEN PROTECTION.
E. WE OBJECT TO THE LACK OF CONSIDERATION OF RECREATION FOCUS AREAS.
F. WE OBJECT THAT THE BEST AVAILABLE SCIENCE WAS USED FOR WILDLIFE MANAGEMENT AREAS.
G. WE OBJECT TO THE NEW TRAIL DENSITY MODEL OF 1 MILE PER SQUARE MILE AS A SINGLE MANAGEMENT APPROACH TO WILDLIFE MANAGEMENT AREAS.
H. WE OBJECT TO THE GENERAL FOREST POLYGON AND SUGGEST IT BE ANALYZED AS A WILDLIFE MANAGEMENT AREA - LONE CONE BEAVER PARK.

We support the following Timber Suitability Objections made by Gunnison County and have included San Miguel County-specific data.

I. THE FEIS AND ROD IMPROPERLY ANALYZE THE IMPACTS OF INCREASED TIMBER HARVESTING.

J. THE FEIS OVERSIMPLIFIES AND OVERSTATES THE PURPORTED ECONOMIC BENEFITS OF INCREASED TIMBER HARVESTING AS COMPARED TO RECREATION.

   a. The FEIS's Conclusions Regarding the Technological Feasibility of Timber Harvesting on Steep Slopes is Misleading.
   b. The FEIS Fails to Robustly Analyze the Climate Impacts of Increased Timber Harvesting

K. WE REQUEST PRIORITIZING COMMUNITY AND LANDSCAPE-SCALE WUI TREATMENTS FOR TIMBER SUITABILITY.
L. ADD LANGUAGE IN FIRE AND FUELS MANAGEMENT, MANAGEMENT ACTION TO ADDRESS PUBLIC HEALTH AND SAFETY AND GREENHOUSE GAS EMISSIONS
M. THE FINAL PLAN MUST PROTECT LEGISLATIVELY PROPOSED SPECIAL MANAGEMENT AREA (SMA) IN THE SAN JUAN MOUNTAINS-LIBERTY BELL EAST SMA

## I. ROS

A. Summer ROS

1. WE OBJECT TO THE AREA OF BEAVER PARK IDENTIFIED AS SEMI-PRIMITIVE MOTORIZED.

   2021 Comment: We recommend this area be re-analyzed and potentially reduced in size due to wetland fens in the area.

   As noted in Fen Wetlands, FW-STND-RMGD-07 from Appendix 12, "With respect to hydrologic alteration, the impact of forest harvest on groundwater sources as well as the effectiveness of buffers (100-foot aquatic management zones) in protecting groundwater sources are largely unknown (Dwire 2021). Given the scientific uncertainty regarding appropriate fen protection, there is a current study by the Rocky Mountain Research Station and the Forest Service Groundwater Program in the Taylor Park and Grand Mesa, Uncompahgre, and Gunnison National Forests Revised Land Management Plan A12-9 Mesa areas of the GMUG."

   We are concerned that the Lone Cone Area Fens will not be protected under the semi-primitive motorized designation. According to Chimner, Lemly and Cooper in their research paper *Mountain Fen Distribution, Types and Restoration Priorities, San Juan Mountains, Colorado, USA,*

   > Mountain fens have long been altered by human activities, but little information exists on the types of impacts that have occurred and the proportion of fens in need of restoration. Disturbances may reverse the 10,000+ year old process of peat accumulation (Chimner and Cooper 2002) and lead to peatland destruction in many areas (Cooper et al. 1998; Chimner and Cooper 2003a; b; Patterson and

> Cooper 2007). Common anthropogenic disturbances that have been noted in western North American fens include hard rock and gravel mining, water reservoir construction, irrigation diversions for agricultural water use, trans-basin water diversions, road construction, timber and energy development, livestock grazing, housing and ski area development, and recreation (Cooper and Wolf 2006; Patterson and Cooper 2007; Zier and Baker 2006). Despite the ecological and hydrologic importance of mountain fens, there is little comprehensive information on their distribution, abundance, aerial extent, and type in any region of North America. Because many fens lack navigable waters, they may have little or no federal, state, or local protection and are often overlooked in largescale wetland and watershed protection programs (Tiner et al. 2002).[1]

**Suggestion:** Semi Primitive non-motorized designation for this area should be considered. We understand the uncertainty of buffers and protection but recreation, timber harvest, and grazing have shown to cause disturbance to fens.

**Suggestion:** If the semi-primitive motorized ROS designation is maintained, this polygon should be reduced in size to protect fens, or the entire polygon should become a Wildlife Management Area (see WMA objections) where road and trail density, grazing, timber harvesting are analyzed to prevent fen disturbance.

FEIS at 201 states: fen, wetland, and riparian species are especially vulnerable to increased sedimentation or hydrologic alteration that can be associated with improper grazing or uncharacteristically high use by wild ungulates. Species that occur on highly erodible soils may also be impacted by high levels of ungulate use and associated atypical rates of erosion

If the location and extent of groundwater-dependent systems are currently well understood, it is difficult to understand where practices such as grazing and timber harvesting, which are both known to cause erosion, can safely be implemented.

[1] Rod A. Chimner & Joanna M. Lemly & David J. Cooper, Mountain Fen Distribution, Types and Restoration Priorities, San Juan Mountains, Colorado, USA. 25 April 2010. https://sites.warnercnr.colostate.edu/davidcooper/wp-content/uploads/sites/15/2017/02/ChimnerLemlyCooper2010-San-Juan-Fens-1.pdf

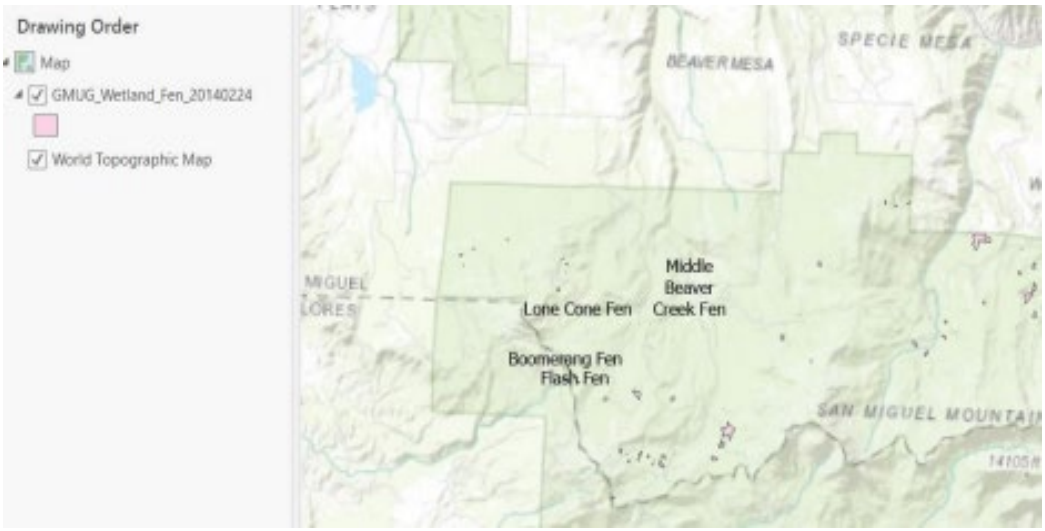


*Figure 1.* Fens within San Miguel County have been identified in the Cones area, according to the *Inventory of Fens in a Large Landscape of West Central Colorado*[2].

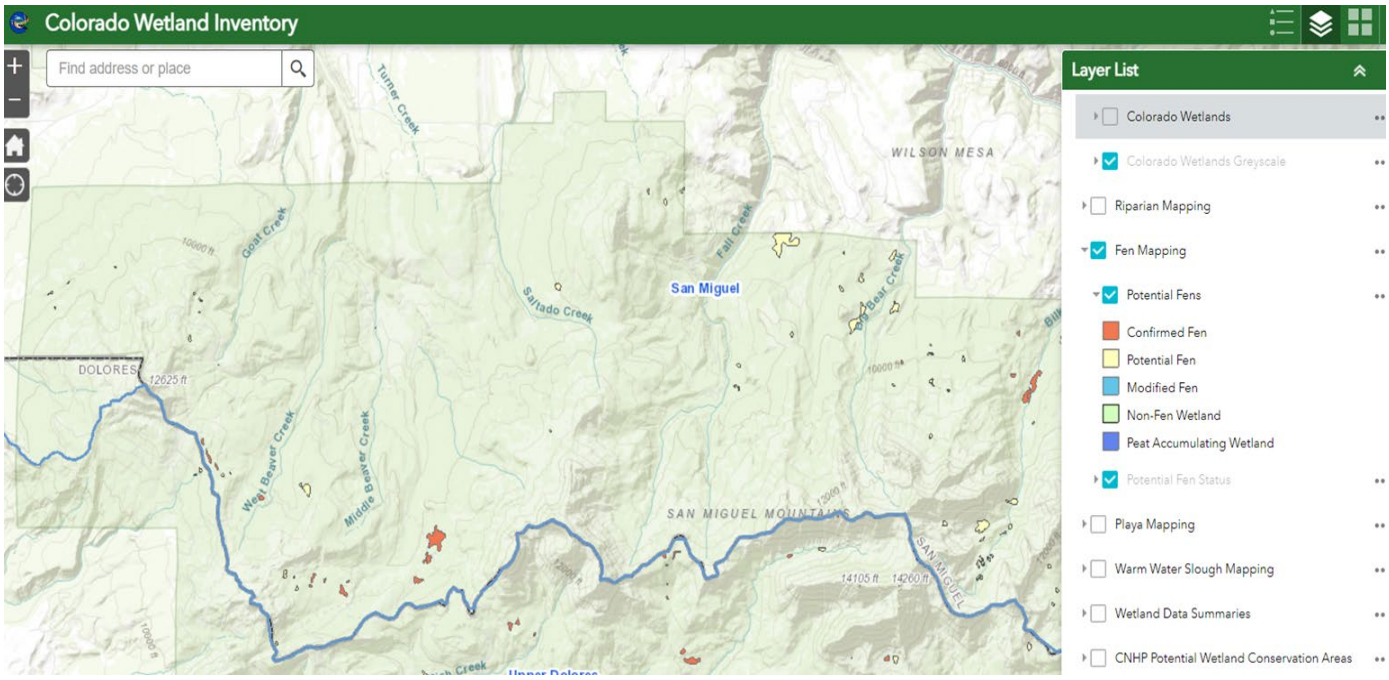


*Figure 2.* Colorado Wetland Inventory Mapping. Colorado Wetland Information Center. https://csurams.maps.arcgis.com/apps/webappviewer/index.html?id=a8e43760cb934a5084e89e46922580cc

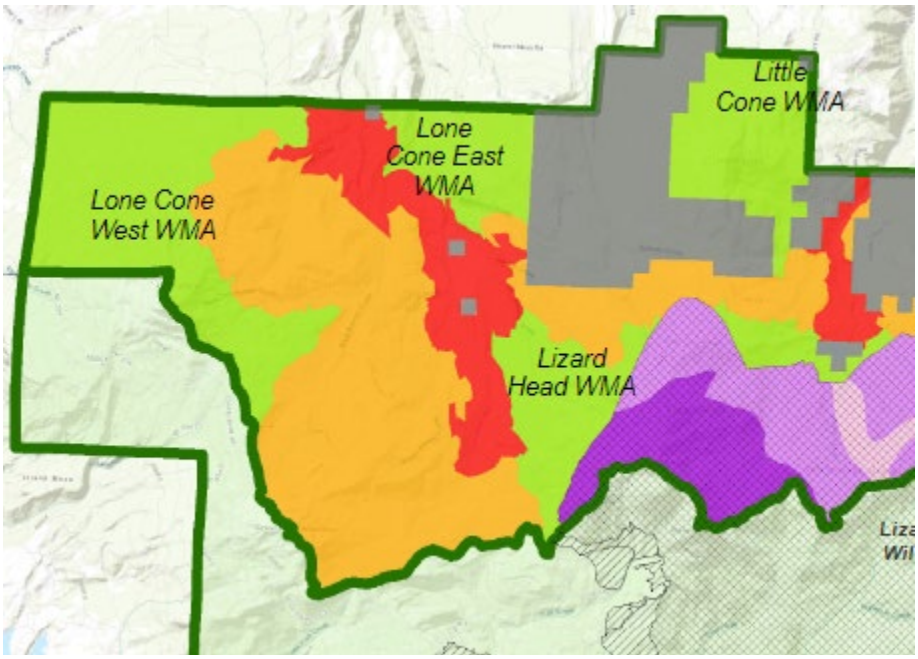


*Figure 3*. Semi Primitive Motorized- Orange polygon

B. Winter ROS

1. WE OBJECT TO BEAR CREEK, BRIDAL VEIL, NORTH OPHIR AS SEMI PRIMITIVE MOTORIZED.

   2021 Comment: We have recognized discrepancies between the ROS and San Miguel County's Comprehensive Development Plan in the Telluride/Ophir High Country area. To align with The San Miguel County Comprehensive Plan, we recommend semi-primitive non-motorized in Bridal Veil Falls, Upper Bear Creek (next to the Telluride Ski Resort) and the North Side of Ophir. These areas have high alpine-sensitive ecosystems and provide quality backcountry skiing experiences from the Town of Ophir and side country access from the ski area that deserve protection.

   The Town of Ophir provides winter parking across from Town Hall for Ophir Pass Road recreationists. There is limited parking space due to snow plowing and private residences at the proper winter trailhead for the pass. Additionally, snow machines are prohibited from the Town of Ophir; therefore, they cannot park trailers and unload and ride through the Town to access the Ophir Pass Road.

   Finally, safety is a significant concern when accessing these areas, the narrow, steep canyon corridors entering Bridal Veil Falls and Bear Creek. This use would be inappropriate and conflicting with backcountry/side country uses in these areas. Additionally, avalanche potential from well above these access roads and communities in

Bridal Veil, Bear Creek and Ophir create a significant safety concern.

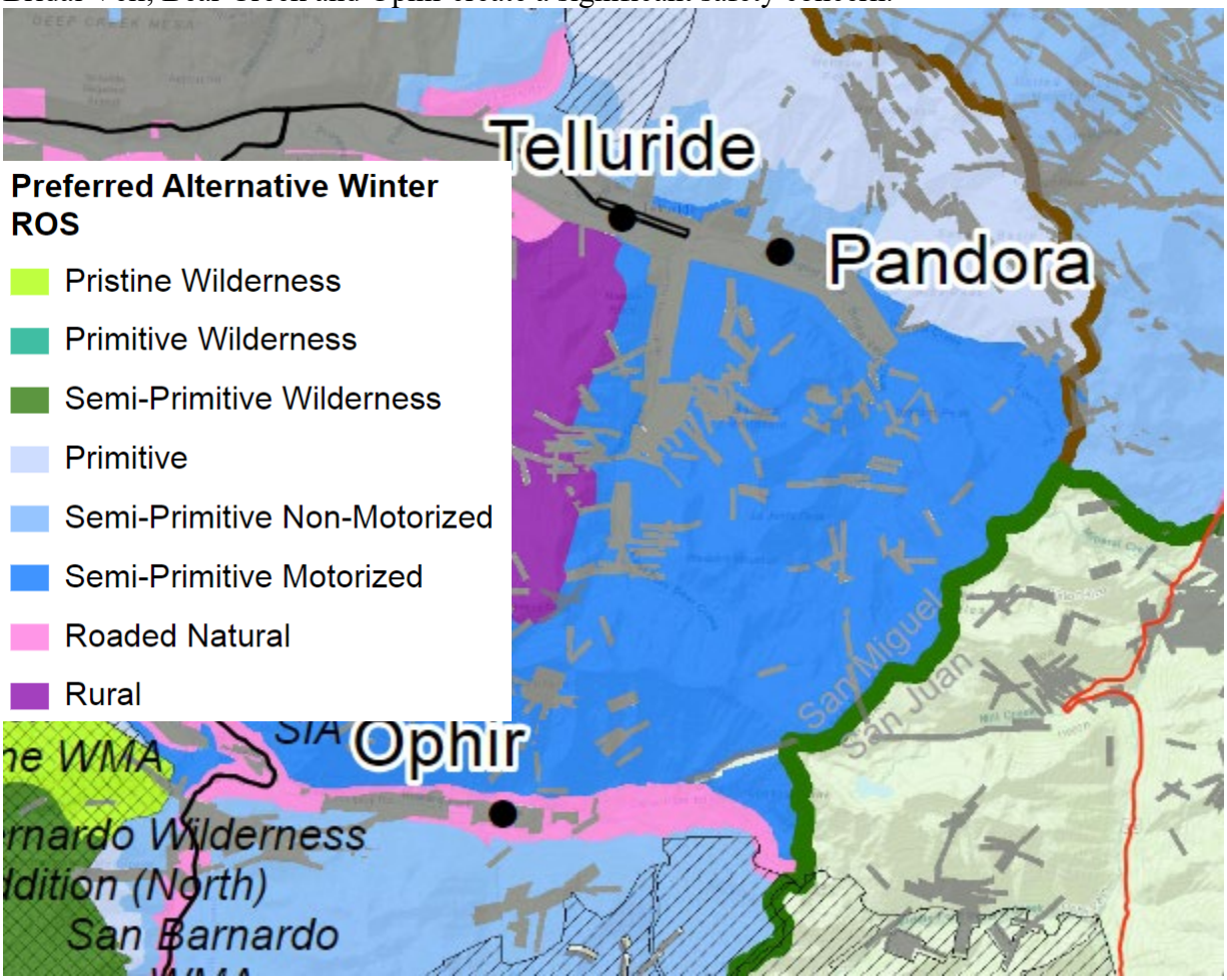


*Figure 4.* The current preferred alternative is labeled Semi-Primitive Motorized.

**Suggestion:** We are requesting the designation be changed to Semi-Primitive Non-Motorized while allowing the local district Ranger to manage the zone for permitted motorized uses

## II. Fens

A. THE ANALYSIS OF FENS IS INSUFFICIENT, AND THE BEST AVAILABLE SCIENCE WAS NOT USED TO DETERMINE FEN MANAGEMENT

2021 Comment: The location of fens within San Miguel County raises concerns due to the proximity of motorized and mechanized trails, ski area operations, logging, wildfire mitigation, future development, and human activity. Active restoration needs and protective measures to reduce the risk of impacts should be considered, for example, relocating dispersed campsites, managing motorized and mechanized recreation (such as ATVs and snowmobiles), or addressing user-created routes.[2]

[2] Barry C. Johnston, Benjamin T. Stratton, Warren R. Young, Liane L. Mattson, John M. Almy, Gay T. Austin. 2012. https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5363703.pdf

According to the fen research in 2009-2010, additional research is needed to improve accuracy. The search image applied during the photo-interpretation step identified wetlands reasonably well (81%accuracy) but less so for fens (36%). The characterization of fens could be improved with an initial field season focused solely on developing and refining a fen search image. Improved photo interpretation could facilitate a more efficient and intensive field season with more specific objectives and a highly skilled crew.

We would like to request a Fen Management Zone, which will not allow their hydrology to be altered or degraded. Develop a standard that requires no disturbance, dewatering, degradation, ditching, damming, flooding or sediment deposition to a fen on the GMUG.

Fens are rare, complex, and little-understood peat-forming wetlands that require vegetation and groundwater hydrology protection. A simple surficial buffer does not protect fens and their groundwater hydrology.

The Final Plan needs to address groundwater-dependent systems systematically. First, per FW-OBJ-RMGD-6. a, the inventory of fens within the GMUG is actively underway. The USFS failed to acknowledge the fen research conducted by Rod A. Chimner, Joanna M. Lemly, and David J. Cooper in San Miguel and Ouray Counties. Nor does it acknowledge its own research, which identifies and studies fens in San Miguel County (this footnote was provided in the 2021 comments)[3]

A map of the currently inventoried fens (from Dwire, 2012 inventory, Chimney and Cooper) was not provided or used to determine the effects of Summer and Winter ROS, cattle grazing, timber suitability, etc. While continuing research is essential to better understand these riparian and groundwater-dependent ecosystems, the lack of current information about fens' locations, sizes, and nearby land use indicates a current lack of knowledge regarding the presence and functionality of fens throughout the GMUG.

GMUG FEIS Vol 1. Chapter 3 states, "Fen, wetland, and riparian species are especially vulnerable to increased sedimentation or hydrologic alteration that can be associated with improper grazing or uncharacteristically high use by wild ungulates. Species that occur on highly erodible soils may also be impacted by high levels of ungulate use and associated atypical rates of erosion."

If the location and extent of groundwater-dependent systems are currently well understood, it is difficult to understand where practices such as grazing and timber harvesting, which are both known to cause erosion, can safely be implemented.

As defined by FW-STND-RMGD-07, "fen and non-fen wetlands, lakes, ponds, seeps/springs and reservoirs" must possess one of the following characteristics: 1) the

[3]Barry C. Johnston, Benjamin T. Stratton, Warren R. Young, Liane L. Mattson, John M. Almy, Gay T. Austin. 2012. https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5363703.pdf

body of water or wetland to the outer edges of the riparian/wetland vegetation; 2) the extent of the seasonally saturated soil; or 3) 100-foot slope distance from the edge of the wetland/water feature OR, for constructed ponds and reservoirs with shorelines composed of riparian vegetation, the maximum pool elevation. These criteria are sufficiently broad and must be utilized to identify fens across the GMUG landscape correctly.

**Suggestion:** Review and analyze additional scientific research in San Miguel and Ouray Counties: *Mountain Fen Distribution, Types and Restoration Priorities, San Juan Mountains, Colorado, USA*[4]

**Suggestion:** Per FW-OBJ-RMGD-6. a, an analysis of Fen locations in the GMUG will be underway for the next three years. As such, FW-OBJ-RMGD-6. a should specify that new logging activity and livestock grazing should not occur near groundwater-dependent systems and fen study areas.

B. THE 100' BUFFER IS NOT SUITABLE FOR FEN PROTECTION

Fens are rare, complex and little-understood peat-forming wetlands that require protection of both vegetation and groundwater hydrology. Fens and their groundwater hydrology are not protected by a simple surficial buffer.

FEIS Vol 1 states that fen, wetland, and riparian species are especially vulnerable to increased sedimentation or hydrologic alteration that can be associated with improper grazing or uncharacteristically high use by wild ungulates. Species that occur on highly erodible soils may also be impacted by high levels of ungulate use and associated atypical rates of erosion.

**Suggestion**: David Cooper states, "adapting a buffer around fens, based on what is suitable for streams/riparian zones, is not a good idea. When sediment or nutrients from a forest enter a riparian zone of stream, they can be flushed away by future flows. However, fens are sumps. All sediment that enters the fen is there pretty much forever. The keys for fen protection, which we implemented in Prospect Basin, were no excavations that could affect groundwater flow in any way. Ground disturbance should be minimized to reduce or eliminate any possible sediment flux downgradient. All stream crossings should include sufficient culverts or permeable rock bases to allow water to flow through unimpeded. Road construction should be minimized so sediment from the road surface is not mobilized down the road surface and into receiving waters, including fens. If the area around a fen is relatively flat, a smaller buffer would be

[4]Rod A. Chimner & Joanna M. Lemly & David J. Cooper, *Mountain Fen Distribution, Types and Restoration Priorities, San Juan Mountains, Colorado, USA* https://sites.warnercnr.colostate.edu/davidcooper/wp-content/uploads/sites/15/2017/02/ChimnerLemlyCooper2010-San-Juan-Fens-1.pdf

suitable, but if the fen is adjacent to a steeper flow, a much larger buffer is needed as disturbances far up the slope could influence the fen. One size will not fit all."[5]

## III. Wildlife Management Areas (WMA)

November 25, 2021 comments: We support the prioritization of wildlife habitat core and corridor areas through Wildlife Management Areas, additional Wilderness and Colorado Roadless areas and recognize that the protection of wildlife habitat needs to happen across jurisdictions. At the same time, we are all experiencing increased demand for recreational opportunities. We would like to see the Draft Plan more adequately identify areas where increased recreational opportunities can be responsibly prioritized.

A. WE OBJECT THAT THE BEST AVAILABLE SCIENCE WAS NOT USED FOR WILDLIFE MANAGEMENT AREAS

The 2012 Planning Rule directs the Forest Service to use the best available scientific information when revising a plan and must publish what information was used, why it was used, and how the information was applied to the issue (36 CFR §219.3).

1. The Final Plan failed to justify how peer-reviewed science on route density standards for roads can be applied in the same manner to human-powered recreational trails. Multiple papers cited in the Draft and Final Plans indicated that more research is needed to determine the effects of trail-based recreation on wildlife, including the following cited papers in the plan: Wisdom et al. (2015) and Rogala et al. (2011).

2. Only one paper provided in the Draft Plan (Canfield et al., 1999) and one paper provided in the Final Plan Response to Comments document (Lyon, 1983) made recommendations for limiting route density to the 1 mi./1 mi., and both of these studies were explicit regarding roads, not trails. Additionally, CPW's own recommendation for 1 mi./1 mi. in the Route Density Primer is within the section on roads. It does not specify trails in their recommendation in the first paragraph under Route Density. CPW later refers to "route densities" that they claim include trails.

3. The USFS failed to include reference to or publish which trail and road shapefiles were used in the route density analysis. This makes it impossible to review the route density analysis done in ArcGIS. The data used by the Forest may omit specific trails, leading to inaccurate results published in Table 98 of the Final EIS.

[5]DAVID JONATHAN COOPER, (personal communication October 6, 2023) 2003-present. Senior Research Scientist/Professor, Department of Forest and Rangeland Stewardship, Colorado State University, Fort Collins, Colorado USA 80523 Phone: 970-491-5430 David.Cooper@colostate.edu *https://sites.warnercnr.colostate.edu/davidcooper/david-jonathan-cooper/*

B. WE OBJECT TO THE NEW TRAIL DENSITY MODEL OF 1 MILE PER SQUARE MILE AS A SINGLE MANAGEMENT APPROACH TO WILDLIFE MANAGEMENT AREAS.

2021 Comment: San Miguel County supports the inclusion of the WMA polygons into the County as requested in our 2019 comments. We recognize it is a delicate balance to manage for Recreation and Wildlife. San Miguel County is facing increased pressure to build more recreational trails, but we have limited suitable landscapes. We are surrounded by steep slopes and Wilderness, which allow fewer options for trail development.

The new Trail Density model of 1 mile per square mile should be analyzed more thoroughly using trail and road data per County, including use type and visitor number and not a one-size-fits-all approach. Strategies should be applied based on current conditions, route densities, development, etc.

2021 Comments: San Miguel County recognizes an increased demand for more recreational opportunities across the Forests, especially trail development. Trail advocates need better direction on areas that are suitable for the development of loop trail systems, trailhead infrastructure and existing trail connections. Outdoor Alliance has identified several recreation emphasis areas where different recreational uses are concentrated and receive more visitors than other areas of the GMUG and have identified areas that may see increasing use in the future. The Planning Team should review Outdoor Alliance's proposed "Recreation Focus Areas".

This Plan needs to better identify appropriate recreation areas to address the growing demand while preserving the health and integrity of the surrounding natural and cultural resources. In the Outdoor Alliance, *GMUG Vision 2*[6] recommended multiple areas as Recreation Focus Areas and Backcountry Areas that now conflict with Wildlife Management Areas in the Final Plan. These conflicts can be viewed in Outdoor Alliance's online GIS map under the OAGV vs. GMUG Final Plan tab. 3

The Wildlife Management Area route density maximum is overly restrictive for human-powered trail-based recreation, does not consider site-specific needs, and is not informed by the best available science. The 1 mi./1 mi. route density limit would apply to 28% of the entire GMUG landscape, limiting the development of trail-based recreation on almost a third of the entire Forest, while less than 1% of the Forest is proposed as Recreation Emphasis Areas. Additionally, the USFS will need tools for the uncertainty of e-bike use and a significant trail user increase to disperse users on our public lands over the lifetime of this plan.

[6]OUTDOOR ALLIANCE GMUG VISION. A vision for world-class sustainable recreation in the Grand Mesa, Uncompahgre, and Gunnison National Forests. August 2020 (v2)
https://static1.squarespace.com/static/54aabb14e4b01142027654ee/t/5f4447cf4de0e201344c8034/1598310359489/Outdoor +Alli ance+GMUG+Vision+v2+Aug+2020.pdf

**Suggestion:** When reviewing Colorado's *Guide to Planning Trails with Wildlife in Mind*[7] *(Guide),* minimization strategies were suggested rather than a blanket trail density model. Additionally, the Guide states that instead of using a single management approach for WMAs, each should be considered singularly based on the sensitivity of the disturbed habitat, current routes that exist, and restrictions / seasonal closures that could mitigate the wildlife impacts. Per the same document, there are complications with route density as topography has an influence that is not accounted for in the calculation and route density does not account for spatial distribution.

A trail density model of 1 mile per square mile is a blanket approach that has not been tested or reviewed on any forest. WMAs should be evaluated singularly based on the various factors present in that specific area.

The Guide also suggests considering minimization strategies. "When reviewing potential trail alignments, strive to minimize habitat fragmentation by maintaining large blocks of undisturbed core habitat in the project area. One way is to redirect trails around, rather than through, areas of intact habitat. Three strategies can be considered to minimize habitat fragmentation:

- Consolidate high-density trail networks and recreation facilities in less sensitive or already disturbed habitats.
- Limit route densities within high-priority habitats to an average of 1 linear mile of road or trail per total square mile for the species indicated in the best management practices table.
- Restrictions, such as seasonal trail closures or dog limitations, may also be needed.

Depending on the existing levels of disturbance, habitat type, wildlife sensitivity, and intended trail use(s), one strategy may be more applicable than the others."

[7] Colorado Parks and Wildlife, *Colorado's Guide to Planning Trails with Wildlife in Mind,* https://cpw.state.co.us/Documents/Trails/Planning_Trails_with_Wildlife_in_Mind(without_appendices).pdf

*The Guide* also states, "For example, higher route densities may be appropriate in areas already impacted by development or located outside of high priority habitats; whereas low route density may be appropriate, or required, to maintain the effectiveness of large blocks of unfragmented or sensitive habitat areas."

For example, the San Bernardo and Yellow Mountain WMAs are surrounded by multiple HOAs, USFS-designated and dispersed camping (Matterhorn Campground, which will soon be expanded), and current and future deed-restricted housing (the

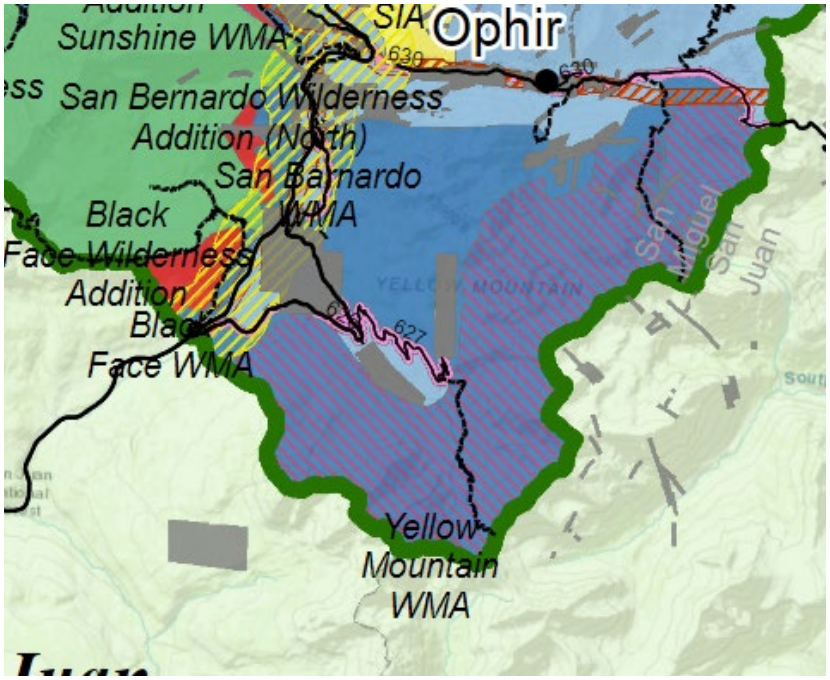


*Figure 5.* San Bernardo and Yellow Mountain WMAs

County recently purchased the Pathfinder property for affordable housing), Trout Lake (a popular recreation area) and access to Lizard Head Pass, Hope Lake, and other existing trails in a densely populated area as a stand-alone trail through an already disturbed area, serving the residents and visitors of San Miguel County. These WMAs are excellent examples of how each polygon should be managed site-specific.

This area would be an ideal location for additional trails to serve residents and visitors while also considering climate impacts; nearby trails and campgrounds reduce vehicle miles traveled to access trailheads, thus reducing greenhouse gas emissions. When trails can be accessed from homes and campgrounds, this also means fewer facilities, such as parking lots and restrooms, need to be provided by the agency.

**Suggestion**: With all of these items in mind, a future non-motorized trail loop originating from the campground would be an excellent addition to this area when the infrastructure is in place and NEPA has been analyzed. However, because of the blanket trail density model, the best alignment and trail plan for this polygon would likely not be possible. The need for trails in this specific area is obvious and can be seen by way of user-created trails. The USFS can eliminate future user-created trails and provide more opportunities in these already-established heavily used recreation areas.

C. WE OBJECT TO THE GENERAL FOREST POLYGON AND SUGGEST IT BE ANALYZED AS A WILDLIFE MANAGEMENT AREA- LONE CONE BEAVER PARK

*Colorado's Guide to Planning Trails with Wildlife in Mind* suggests considering minimization strategies. "When reviewing potential trail alignments, strive to minimize habitat fragmentation by maintaining large blocks of undisturbed core habitat in the project area. One way is to redirect trails around, rather than through, areas of intact habitat. For example, higher route densities may be appropriate in areas already impacted by development or located outside of high-priority habitats, whereas

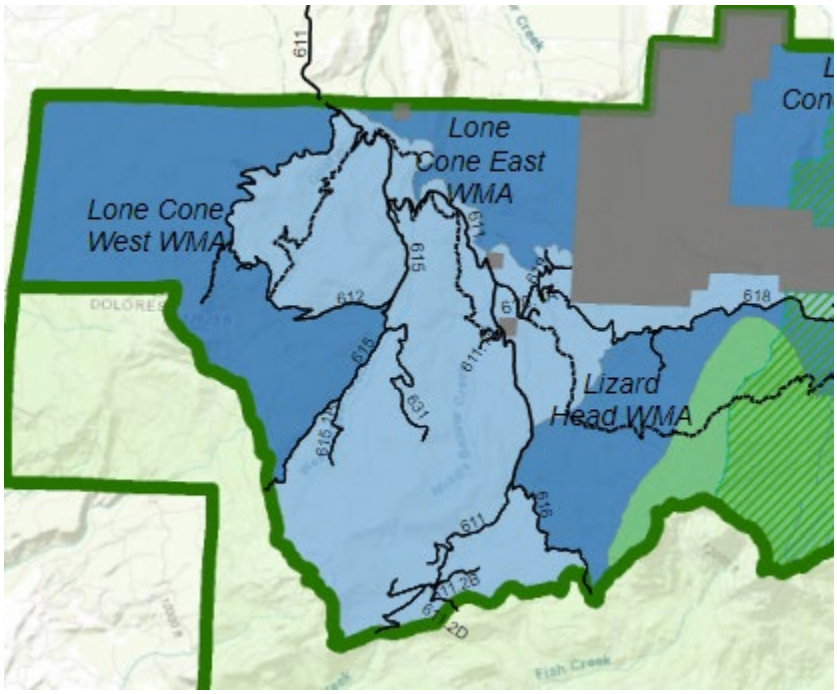


*Figure 6.* General Forest Polygon

low route density may be appropriate or required to maintain the effectiveness of large blocks of unfragmented or sensitive habitat areas."

The Beaver Park area, as proposed, is fragmenting the landscape, and the Summer ROS of semi-primitive motorized is also a concern. We request that this area be reduced in size to consider the fens in the southern portion of the polygon. The Forest Plan states,

Wildlife Management Areas (MA 3.2): MA-STND-WLDF-02 The best available science documents a relationship between big game hunting opportunities and management and the emphasis in wildlife management areas on unfragmented habitat, including migration corridors. As summarized in Canfield et al. (1999: 6.13):

**Suggestion:** Create a Wildlife Management Area to replace the General Forest designation.

## IV. Suitable Timber

November 26, 2021 Comment: We continue to oppose the substantial increase of suitable timber proposed in this Draft Plan. The implementation of SBEADMR has made it clear that even with a ten-year programmatic NEPA decision, the industry cannot support a significant increase in timber production. During negotiations for the designations of the CORE Act, the Suitable Timber overlay was used as an effective delay. Even with broad stakeholder support from surrounding communities and the recognition of the low probability for timber production, a

single industry was able to impede the progress of the widely supported and economically beneficial protective designations proposed. As stated in the 2012 Planning Rule: "This final planning rule requires that land management plans provide for ecological sustainability and contribute to social and economic sustainability, using public input and the best available scientific information to inform plan decisions. The rule contains a strong emphasis on protecting and enhancing water resources, restoring land and water ecosystems, and providing ecological conditions to support the diversity of plant and animal communities while providing for ecosystem services and multiple uses".[1] Following this direction, any increase in timber suitability and production must be adequately balanced with increased protections of ecological systems, wildlife, and recreation opportunities that are a growing economic benefit for surrounding communities.

The primary objective of any timber harvest should be to promote resiliency for future forests and the ecosystem services they provide. We also ask that the GMUG prioritize wildfire mitigation that protects communities and critical infrastructure, including watersheds. We agree that timber production technology has improved since the last forest plan was completed. However, the addition of steeper slopes should only be considered if the natural resources can be protected to enhance the opportunity for resiliency of the forests.

November 25, 2021 comments: According to a report commissioned by the Outdoor Alliance 2 "human-powered outdoor recreation is a major economic engine on the GMUG contributing $392 million annually, $112 million in wages and 5802 jobs. The Draft Plan and preferred alternative must offer a more comprehensive socioeconomic analysis which recognizes the benefits to our communities from the outdoor recreation economy. Our forests must be managed for multiple uses and many if not all of our communities are facing increasing demands for a wide spectrum of recreational opportunities. Human-powered outdoor recreation is a major economic engine on the Grand Mesa, Uncompahgre, and Gunnison National Forests (GMUG) and should be recognized as such in the Plan's socioeconomic analysis.

Between outdoor recreation, ecosystems services and wildlife-related tourism, which all have quantifiable values, it is safe to assume that these uses of the GMUG far outweigh the
socioeconomic benefits of the timber industry and yet the Draft Plan continues to only measure the socioeconomic benefits of that single industry, and appears to prioritize timber production over all other uses. We would like to suggest that if recreational uses need an "opportunity spectrum" or ROS to identify appropriate uses, that timber should also be regulated by a "Timber Opportunity Spectrum" or TOS.

Again, we recognize that timber harvest techniques have come a long way from the destructive methods of the past and we support the implementation of responsible timber production. We also recognize that we need Montrose Forest Products and its contractors and subsidiaries in order to support our increasing wildfire mitigation needs. At the same time, we would like to see a stronger balance of the other potentially more valuable uses and resources of the forest. Recreational visitor numbers have seen an upward trend for many decades and, especially the past two years, have seen a 40% to 50% sustained increase. These contributions and corresponding adequate management responses must be presented in further versions of the Draft Plan and DEIS.

San Miguel County supports the following Gunnison County's objections and has included our economic data.

A. THE FEIS AND ROD IMPROPERLY ANALYZE THE IMPACTS OF INCREASED TIMBER HARVESTING

The ROD selects a modified version of "Alternative B," now labeled the "Preferred Alternative," which dramatically increases the designation of areas in the GMUG suitable for timber production, without the robust, objective and good faith analysis required by NEPA. As the FEIS reveals, the Preferred Alternative designates 772,000 acres as suitable for timber production, which, as the ROD confesses, is a "significant 66% increase (300,000 acres)" compared to the 1983 plan. *See* ROD at 20; FEIS Vol. 1 at 77, Table 7, 143, Table 28 (projecting close to double projected timber sales over 1983).

USFS acknowledges throughout the FEIS that its selection of the Preferred Alternative will have discernable, harmful effects on the environment. *See*, *e.g.*, FEIS Vol. 1 at 158 (acknowledging significant timber harvest impacts on aquatic and riparian resources under Preferred Alternative); 424 (recognizing timber harvest impacts on "erosion, displacement, compaction, and soil changes"); 441, 444 (same as to watershed and stream health). Although NEPA does not necessarily require USFS to forgo increased timber designations due to these negative environmental impacts, it does require USFS to properly and faithfully analyze these and other consequences. The agency has not done so.

In analyzing and selecting the timber-friendly Preferred Alternative, USFS commits at least four errors under NEPA and NFMA.

B. THE FEIS OVERSIMPLIFIES AND OVERSTATES THE PURPORTED ECONOMIC BENEFITS OF INCREASED TIMBER HARVESTING AS COMPARED TO RECREATION.

In selecting the timber-friendly Preferred Alternative, the ROD makes much over the "150 more jobs and $7.6 to $8.4 million more in labor income annually from the projected production and harvest of timber and other forest products." *See* ROD at 35. Yet, in this same section of the ROD, USFS hints at its failure to properly account for the much larger economic benefits other uses of the Forest, particularly recreation, generate. As the ROD and FEIS all but concede, the 150 jobs and $7.6-$8.4 million from timber harvesting pales in comparison to the $90 million and 2,940 jobs created by recreation, livestock grazing and other uses of GMUG.[1] See ROD at 35; FEIS Vol. 1 at 468. Further, the FEIS acknowledges, as it must, that because the GMUG has "received nearly 2.6 million annual visits and ranked eighteenth in the nation for total recreation visits[,]" *see* FEIS Vol. 1 at 536, timber harvest activity in these Forests pales in comparison to recreational uses. *See id.* at 559 (noting decline in timber harvest volume from the

GMUG since 1980); FEIS Vol. 2 at 8-3; *see also* ROD at 2 (showcasing recreational opportunities within GMUG); LMP at 9 ("Recreation is the GMUG's largest economic contributor").

However, the selection of the Preferred Alternative in favor of timber over recreation not only glosses over these differences but also fails to consider the non-timber-based economies of the counties within the GMUG and the recreation economic benefits of wilderness, all in violation of NEPA.

An agency fails to comply with NEPA when it over-inflates the economic benefits of a plan or when it relies on incomplete or misleading market data. *See Nat. Res. Def. Council v. U.S. Forest Serv.,* 421 F.3d 797, 811-12 (9th Cir. 2005) (internal citations omitted). As one court has explained,

> Misleading economic assumptions can defeat the first function of an EIS by impairing the agency's consideration of the adverse environmental effects of a proposed project. NEPA requires agencies to balance a project's economic benefits against its adverse environmental effects. The use of inflated economic benefits in this balancing process may result in approval of a project that otherwise would not have been approved because of its adverse environmental effects. Similarly, misleading economic assumptions can also defeat the second function of an EIS by skewing the public's evaluation of a project. Because of the potential for misleading economic assumptions to defeat the functions of an EIS, we will engage in a narrowly focused review of the economic assumptions underlying a project to determine whether the economic assumptions were so distorted as to impair fair consideration of the project's adverse environmental effects.

*Hughes River Watershed Conservancy v. Glickman*, 81 F.3d 437, 446 (4th Cir. 1996) (internal citations and quotations omitted). Here, USFS has employed misleading assumptions regarding the economic benefits of increased timber harvesting, notwithstanding potential adverse environmental effects.

Relying upon the USFS-developed Economic Profile System-Human Dimensions Toolkit, USFS claims that "timber harvest . . . will continue to play an important economic and social role" in the counties constituting the GMUG, ignoring the fact that USFS's data demonstrates that none of the counties in the GMUG count timber extraction as a significant economic driver. *See* FEIS Vol. 1 at 465-66, 471-482. For example, although "Delta County has the largest share of timber-related employment relative to other counties" in the GMUG, its timber sector is only 0.4 percent of its economy. *See* FEIS Vol. I at 472. By comparison, travel and tourism, in terms of percentage of employment, is over ten times that amount. Indeed, in San Miguel County, **zero percent** of the labor sector works in the timber industry.

| Indicators | San Miguel County, CO | Delta County, CO |
|---|---|---|
| Population, 2021 | 8,074 | 31,661 |
| **Trends** | | |
| Population % change, 1970-2021 | 311.9% | 107.0% |
| Employment % change, 1970-2021 | 1066.2% | 171.7% |
| Personal Income % change, 1970-2021 | 2171.5% | 327.9% |
| **Prosperity** | | |
| Unemployment rate, 2022 | 3.1% | 3.6% |
| Average earnings per job, 2021 (2022 $s) | $55,269 | $41,208 |
| Per capita income, 2021 (2022 $s) | $118,383 | $49,726 |
| **Economy** | | |
| Non-Labor % of personal income, 2021 | 55.8% | 57.9% |
| Services % of employment, 2021 | 77.2% | 57.0% |
| Government % of employment, 2021 | 9.5% | 17.2% |
| **Use Sectors*** | | |
| Timber % of private employment, 2020 | 0.0% | ~1.7% |
| Mining % of private employment, 2020 | 0.4% | 0.1% |
| Fossil fuels (oil, gas, & coal), 2020 | ~0.2% | ~0.1% |
| Other mining, 2020 | ~0.2% | ~0.0% |
| Agriculture % of employment, 2021 | 1.9% | 9.8% |
| Travel & Tourism % of priv. emp., 2020 | ~43.7% | 10.9% |
| **Federal Land** | | |
| Federal Land % total land ownership | 59.6% | 55.3% |
| Forest Service % | 21.1% | 25.7% |
| BLM % | 38.5% | 29.5% |
| Park Service % | 0.0% | 0.0% |
| Military % | 0.0% | 0.0% |
| Other % | 0.0% | 0.1% |
| Fed. payments % of gov. revenue, 2017 | 0.0% | |
| **Development** | | |
| Residential land area % change, 2000-2010 | 16.8% | 12.5% |
| Wildland-Urban Interface % developed, 2010 | 0.0% | 0.0% |

Estimates for data that were not disclosed are indicated with tildes (~) and gray text.

*Figure 7.* Headwaters Economics, *National Forest Socioeconomic Indicators Rpt*., comparison bet. San Miguel Cnty. and Delta County

Despite this, rather than conclude that the Preferred Alternative's timber-based economic benefit is minimal, the FEIS and ROD promote this phantom benefit as one of the main reasons for selection of the Preferred Alternative. *See* ROD at 19-20, 35, 42; EIS Vol. 1 at 483; LMP at 10. USFS then commits a further error by 1) failing to robustly analyze the potential negative effects of increased timber harvesting on the recreation uses, *see, e.g.,* FEIS Vol. 1 at 471, and 2) falsely assuming that wilderness designations preventing timber suitability designation constitutes a net negative for recreation economics.

Acknowledging that "desired conditions for social, economic, and ecological sustainability are achieved through varying degrees of more active conservation management or more restrictive preservation [,]" *see* FEIS Vol. 1 at 45, the Preferred Alternative downgrades priorities for active recreation management in favor of focusing on timber and fuels-related activities, to the detriment of the GMUG and the economics

of affected communities. By way of example, the FEIS anticipates that Preferred Alternative's timber emphasis will result in 250,000 acres of fuels treatment in the next 20 years, compared to 90,500 acres under the No Action Alternative and 50,000 acres under Alternative D. *See* FEIS Vol. 1 at 81. By contrast, the Preferred Alternative intends to:

- Delay actions to minimize the harmful effects from off-road travel on at-risk plants – five years instead of one year as compared to Alternative D;
- Reduce by half the number of alpine acres restored through recreation management plans and road and trail decommissioning as compared to Alternative D (100 versus 200 acres);
- Downgrade the elimination of unauthorized travel routes from 4 to one per year as compared to Alternative D;
- de-emphasize actions to minimize harms to at-risk plants from off-road travel to a five-year rather than a one-year action horizon; and
- Decrease by half USFS actions to improve degraded day and overnight dispersed use areas as compared to Alternative D.

*See* FEIS Vol. 1 at 81-82, 144. This is notwithstanding the fact that the FEIS concludes that active recreation management is critical to protect against human-caused wildfires and negative impacts on native plant species and wildlife from unmanaged or mismanaged recreation uses. *See id.* at 316-318. Moreover, San Miguel County can uncover **no** robust analysis of the potential negative effects that increased timber operations could have on recreational users and, in turn, the recreation-based economy central to the many counties comprising the GMUG. In particular, San Miguel County cannot find a detailed analysis in the FEIS regarding the Preferred Alternative's de-emphasis of active recreation management in favor of timber industry promotion, which may sour outdoor recreation visitors to the Forests by creating negative backcountry experiences in the form of illegal off-roads uses, damaged natural areas and unsanitary or unsightly day and overnight dispersed use areas, which in term damages the GMUG counties' recreation-based economies.

Instead, the FEIS makes the poorly supported and misleading assumption that "economic contributions from the GMUG are a very small portion of total jobs in the analysis area; while local impacts may be greater, the overall impact of changes to the economy from the plan direction is minimal." *See* FEIS Vol. I at 483. The data urges a contrary conclusion. The National Forest Socioeconomic Indicators Report demonstrates that close to 47 percent of private employment in San Miguel County directly relates to Forest use sectors, with a full 43.7 percent in travel and tourism. *See* Headwaters Economics, *National Forest Socioeconomic Indicators Rpt.*, comparison bet. San Miguel County. and Delta County. (run October 26, 2023). This, of course, does not take into account the indirect benefits of Forest use for the local economy. For example, according to United States Department of Agriculture ("USDA") National Visitor Use Monitoring Data relied upon by the FEIS, *see* FEIS Vol. 1 at 536, over 35 percent of GMUG visitors stayed

overnight in hotels or short-term rentals when using the Forest, an obviously positive impact to the local economies where these lodging nights occurred. *See* USDA Forest Service Region 2, *Visitor Use Rpt. Grand Mesa, Uncompahgre and Gunnison NF* (June 26, 2023). Undoubtedly, those visitors also dined at local restaurants, hired local guides and outfitters, and shopped for supplies at local stores – data that USFS apparently took no time to collect and analyze as part of their obligations under NEPA.

USFS also appears to base its "no impact on recreation" conclusion on the misleading assumption that economically beneficial recreation visits to GMUG wilderness and wildlife areas are minimal compared to the supposed benefits of increased timber harvesting and because the Preferred Alternative de-emphasizes wilderness and wildlife management designations as compared to Alternative D, the Preferred Alternative will promote local economies to a greater degree. *See* FEIS Vol. 1 at 470. USFS bases this assumption that wildlife-related activities are the primary uses of wilderness, wildlife and special management areas. *See id.* Indeed, USFS goes so far as to conclude that "[c]ounties with tourism-driven economies may experience the greatest benefit from the preferred alternative because it proposes a balance between wildlife-related recreation and trail-based recreation." *See* FEIS Vol. 1 at 476. Had USFS taken the time to review and digest its own data, it would have learned that out of the top 5 Forest activity types visitors identified to USDA, three such activities – viewing natural features, hiking, and relaxing -- are not only permitted in wilderness areas but are also unrelated to wildlife and therefore properly classified as "trail-based recreation." *See Visitor Use Rpt.* at 21. To conclude, as USFS does, Alternative D's special management area emphasis is somehow more harmful to Western Slope economies than the "timber first, recreation second." The Preferred Alternative is simply wrong and contrary to NEPA.

We support the following objections from Gunnison County.

1. The FEIS's Conclusions Regarding the Technological Feasibility of Timber Harvesting on Steep Slopes is Misleading.

   The ROD makes clear that USFS made the "deliberate decision" to allocate significantly more areas of timber suitable than the No-Action Alternative, including production on steep slopes that could have negative impacts on soil and wetland resources. *See* ROD at 20. The dramatic inclusion of steep-slope timber harvesting relies heavily on USFS's misguided assumptions about the feasibility of steep-slope harvesting technology, in violation of NEPA and NFMA.

   An agency cannot rely on unsupported assumptions about future technologies and remain in compliance with NEPA or NFMA. *See*, *e.g.*, *High Country Conservation Advocates v. United States Forest Serv.*, 52 F. Supp. 3d 1174, 1197 (D. Colo. 2014). Yet the LMP, FEIS and ROD do precisely that. The FEIS discloses that under the Preferred Alternative, a full 14 percent of areas identified

as suitable for timber production are on slopes of 40 percent grade or higher, constituting 112,000 acres of the GMUG. *See* FEIS Vol. 1 at 56; FEIS Vol. 2 at 8-10. The FEIS justifies this decision on the grounds that, supposedly, "[n]ew technology and approaches could make timber harvest in areas with steep slopes (greater than 40 percent) economically feasible." *See* FEIS Vol. 2 at 8-12; *see also* LMP at 8-8. The only evidence that Gunnison County could locate in the FEIS that purports to support this statement, however, relates to a pilot steep slope logging operation conducted by USFS around Monarch pass. *See* FEIS Vol. 1 at 566, 570. Absent from the discussion of this project is the fact that **USFS is paying a contractor to perform this work** for wildfire mitigation purposes; it is not, as the FEIS implies, a free-market commercial logging operation. *See* Jason Blevins, "Monarch Pass Could Serve as A New Model for Wildfire Mitigation in Treacherous Areas," *The Colorado Sun* (October 6, 2021). This is, therefore, inadequate evidence of "economically feasible" steep slope timber operations and, in turn, improper under NEPA and NFMA.

2. The FEIS Fails to Robustly Analyze the Climate Impacts of Increased Timber Harvesting.

   As the FEIS appears to concede, "[C]limate change is precisely the kind of cumulative impacts analysis that NEPA requires agencies to conduct." *See Ctr. for Biological Diversity v. Nat'l Highway Traffic Safety Admin.*, 538 F.3d 1172, 1217 (9th Cir. 2008). Despite this, the FEIS improperly analyzes the full climate effects of increased timber production in the GMUG, in violation of NEPA and potentially other laws.[1]

   The FEIS acknowledges the increased carbon emissions, decreased carbon stock, and dust that will be caused by the increased timber harvest operations under the Preferred Alternative as compared to the No-Action Alternative. *See* FEIS Vol I at 50, 351-356 (revealing that Preferred Alternative estimated emissions almost two times the amounts generated under No-Action Alternative and Alternative D); 360-61; 375; 392; ROD at 3; *see also* LMP at 10 (describing size and importance of GMUG's carbon storage). It further admits that, "[t]he greenhouse gas effects of projected vegetation management activities would be highest in the Preferred Alternative, followed by Alternative C, the No-Action, and least from Alternative D." *See id.* at 395. However, the FEIS characterizes the Preferred Alternative's impacts as "minor," theorizes that such operations "may reduce overall emissions from unplanned wildfires," and then claims that total emissions are an "unknown" and therefore unworthy of robust analysis. *See* FEIS Vol. I at 358, 363, 393. And, while arguing that increased wilderness allocations in alternatives other than the Preferred Alternative could reduce vegetation management that in turn would serve to reduce emission-producing wildfires, the FEIS admits that "[l]ong-term,

net greenhouse gas effects of the recommended wilderness allocation is uncertain and would be contingent upon contemporary environmental conditions and site-specific factors." *See id.* at 393; *see also id.* at 395. ("The long-term net effect of implementation of the revised forest plan alternatives is therefore difficult to quantify.").

The law is clear that "[r]easonable forecasting and speculation is ... implicit in NEPA, and we must reject any attempt by agencies to shirk their responsibilities under NEPA by labeling any and all discussion of future environmental effects as 'crystal ball inquiry." *See High Country Conservation Advocates*, 52 F. Supp. 3d 1174, 1196 (internal citations and quotations omitted); *see also New York v. Nuclear Regulatory Comm'n*, 681 F.3d 471, 482 (D.C. Cir. 2012) (agency conducting NEPA analysis "generally must examine both the probability of a given harm occurring and the consequences of that harm if it does occur. Only if the harm in question is so 'remote and speculative' as to reduce the effective probability of its occurrence to zero may the agency dispense with the consequences portion of the analysis."). Here, USFS appears to bypass a robust examination of climate impacts associated with increased timber harvesting by labeling such impacts "to difficult to quantify." This is inconsistent with its obligations under NEPA.

### C. WE RECOMMEND PRIORITIZING COMMUNITY AND LANDSCAPE-SCALE WUI TREATMENTS FOR TIMBER SUITABILITY

FW-STND-TMBR-03: Timber shall not be harvested for the purpose of timber production on lands not suited for timber production (36 CFR 219.11(d)(1)). Timber harvest may occur on these lands as a tool to assist in achieving or maintaining one or more applicable desired conditions or objectives of the plan to protect other multiple-use values and for salvage, sanitation, public health, or safety. This standard is required by law and policy; see 36 CFR 219.11(c). Examples of using timber harvest as a tool to protect other multiple use values include, but are not limited to, ecological restoration, climate change adaptation, restoring meadows or savanna ecosystems, improving wildlife or fish habitat, and thinning to reduce fire risk. See plan appendix 8, Timber Suitability Analysis, and the Climate Change and Carbon section of the plan, for adaptive management approaches to climate change adaptation through vegetation management.

**Suggestion:** The objective of any timber harvest should be to promote resiliency for future forests and the ecosystem services they provide. We also ask that the GMUG prioritize wildfire mitigation that protects communities and critical infrastructure, including watersheds.

## V. CORE ACT

A. THE FINAL PLAN MUST PROTECT LEGISLATIVELY PROPOSED SPECIAL MANAGEMENT AREAS (SMAs) IN THE SAN JUAN MOUNTAINS- LIBERTY BELL EAST SMA

November 25, 2021 Comment: We appreciate the inclusion of the Wilderness and Special Management Area designations of the CORE Act.

November 26, 2021 Comment: We appreciate the inclusion of the Special Management Areas from the CORE Act in Alternative D. SMA's are a key tool to help achieve the ecological integrity that is a central purpose of the 2012 Planning Rule, while allowing for the management of existing uses. Liberty Bell Corridor Special Management Area – This should be removed as a separate SMA in Table 21, as the "corridor" is encapsulated within the Liberty Bell East SMA. Liberty Bell East Special Management Area – "None identified" should be changed to "Limited new" to allow for mountain bike use in the "corridor" within Liberty Bell East.

The Liberty Bell East SMA, part of the Colorado Outdoor Recreation and Economy Act (CORE), has long-established business, public, and elected official support. The SMAs were carefully designed to protect these highly valued landscapes while allowing existing non-conforming uses such as heliskiing, a competitive long-distance running race and mountain biking. These proposed areas, both legislatively and through the GMUG plan revision process, are home to outstanding and unique landscapes home to recreational, wildlife, and ecological values. These proposals are the results of decades of advocacy and public process. The 2012 Planning Rule grants the Forest Service authority to designate and protect these areas as Special Management Areas (SMAs) in forest plans.[8] Agency regulations make clear that the Forest Plan must "reflect the unit's expected distinctive roles and contributions to the local area, region, and Nation, and the roles for which the plan area is best suited…" as well as "the unit's unique capabilities, and the resources and management of other lands in the vicinity."[9] The Forest Service should adopt the proposed SMA with specific plan components to ensure the final forest plan provides clear, concise management direction for the Forest Service and the public.

Protecting high-value public lands is also an important priority for the Biden-Harris Administration. President Biden has issued a call to action urging us to work together "to conserve, connect, and restore 30 percent of our lands and waters by 2030 for the sake of

[8]The regulations specifically require that "[e]very plan must have management areas or geographic areas or both. The plan may identify designated or recommended designated areas as management areas or geographic areas." 36 CFR § 219.7(d). The responsible official with delegated authority may designate new areas or modify existing areas, when approving the plan, plan amendment, or plan revision. 36 CFR § 219.7(c)(2)(vii). SMAs are managed to emphasize specific values (e.g., ecological, geological, scenic, recreation, or other specific values). Management activities and uses are permitted in these areas only to the extent that they are in harmony with the purpose for which an area is specially designated. The plan or decision designating each area is supposed to provide specific objectives, standards, and guidelines for management of each area.

[9]36 C.F.R. § 219.2(b)(1).

our economy, our health, and our well-being."[10] Agriculture Secretary Tom Vilsack also recently directed the Forest Service to protect our National Forests by restoring ecosystems, among other goals.[11] The directive highlights important ecosystem services provided by protecting our national forests, including: "sequestering carbon, providing clean drinking water, stabilizing soil, buffering floods, protecting biodiversity, providing sustainable forest resources, protecting cultural resources and places of tribal importance, and enabling access to the outdoors for hundreds of millions of visitors."[12] Protecting these SMAs on the GMUG would support and further the Administration's conservation goals. San Miguel County has long been in support of the designation of the above SMAs both in DEIS comments and official communications with Colorado Senators.[13]

**Suggestion*:*** The Forest Service should designate the proposed SMA as reflected in the Colorado Outdoor Recreation and Economy Act (CORE) to reduce conflict and create a seamless management transition.

## VI. **Fire and Fuels Management**

A. ADD LANGUAGE IN FIRE AND FUELS MANAGEMENT, MANAGEMENT ACTION TO ADDRESS PUBLIC HEALTH AND SAFETY AND GREENHOUSE GAS EMISSIONS

December 2022 Ophir residents experienced extreme smoke from five 40'x 40' slash piles from the TriState Powerline Vegetation removal project, containing wet, green vegetation. The Town was notified on a Friday afternoon, and piles were lit on Monday. The Town clearly expressed concerns to the USFS and was working with San Miguel County on alternative solutions to burning the piles and were told the piles would not be burned until the following year.

Due to the topography of Ophir and its typical inversions and often windy winters, combined with green wet vegetation, these burning piles created poor air quality for residents and visitors over the Holidays and smoldered throughout the winter months. The County helped the Town install a Purple Air Monitor due to the severity of the smoke.

According to the article, *Emissions from prescribed burning of timber slash piles in Oregon*

[10] *See* U.S. Dept. of Interior, "America the Beautiful" webpage, available at https://www.doi.gov/priorities/america- the-beautiful (last accessed 7/6/22).

[11] U.S. Dept. of Agriculture, "Climate Resilience and Carbon Stewardship of America's National Forests and Grasslands," Secretary's Memorandum 1077-004 (June 23, 2022).

[12] *Id.*

[13] https://legistarweb-production.s3.amazonaws.com/uploads/attachment/pdf/1555824/President_Biden_Core_Act_9.8.22.pdf

> Field sampling of eleven biomass pile burns determined emission factors for a wide range of pollutants. Comparison of piles that were naturally wetted versus those that were dry showed statistically higher emission factors for PM2.5, PAHs, VOCs, and PCDD/PCDF for the wet piles. Emission levels were negatively correlated with combustion quality, as represented by MCE. Variation of PE cover size and thickness showed no statistically significant difference in emission factor for any of the pollutants, suggesting that the PE was not contributing significantly to any of the measured pollutants. Time-resolved PM2.5 emissions were highest at the beginning of the burns; for the Dry pile tests, this startup period lasted for less than 4 min; for the Wet pile tests, it was four times longer, about 16 min. For the Wet pile tests, PM2.5 emission factors were higher than those of the Dry pile tests for at least half of the burn durations, after which they were similar. These tests suggest that use of PE as a biomass pile cover results in lower emission factors than those from piles exposed to moisture, reducing pollutant levels during slash pile burns. **These emission factors, together with estimates of burn pile numbers, size, and fuel consumption, can be used by management and regulatory communities to minimize smoke impacts while limiting the potential hazard of biomass fuel loading.**[14]

**Suggestion:** The USFS creates management direction to protect the Health and Safety of residents and visitors by taking responsibility for their actions and not rely on a State Agency that will not be on-site for the duration of the project. The EPA has pollution standards and installs air quality monitors at their project sites for public health and safety; this could be a management strategy for pile burning.

**Suggestion:** This project was an example of poor communication and timing. This management action, FW-MA-FFM-10: Coordinate public education efforts regarding fire and fuels with local governments, Tribes, and partners, may need to be strengthened.

**Suggestion:** FW-MA-TMBR-13: Partner with local stakeholders and industry to innovate and support economically viable markets for both timber and nontimber forest products, including aspen, wood biomass, biochar, and small- diameter material (USDA Forest Service Climate Adaptation Plan 2022). Actively apply for agency funds dedicated to support emerging, alternative forest product markets (Resilience).
FW-MA-SOIL-08: Seek opportunities to support production of biochar (a charcoal soil amendment made from biomass) from waste woody biomass generated by fuel treatments and forest restoration. When applied as a soil amendment, biochar improves soils by reducing bulk density, increasing porosity, providing a substrate for microorganisms, improving water-holding capacity, retaining nutrients, and increasing organic matter,

[14] Aurell J, Gullett BK, Tabor D, Yonker N. Emissions from prescribed burning of timber slash piles in Oregon. Atmos Environ (1994). 2017 Feb; 150:395-406. doi: 10.1016/j.atmosenv.2016.11.034. Epub 2016 Nov 12. PMID: 30713461; PMCID: PMC6355151.

among other benefits. Producing biochar helps to mitigate climate change by storing carbon in long-lived material that would otherwise be released more quickly into the atmosphere and has the added benefits of reducing smoke and burn scars from disposal by pile burning (Rodriguez Franco et al. 2022). (Resistance, Resilience).

We highly recommend these Management Actions and would like to work with the USFS to support biochar and woody biomass systems that support clean and local energy, such as the systems used at Mount Bachelor, created by Wisewood Energy.[15]

**Suggestion:** The following Management Actions and Guidelines should be strengthened/mandatory and considered for pile-burning projects.

FW-MA-AQ-07: An air quality analysis may be required for Forest Service approval of activities that would result in emissions. The appropriate complexity of the analysis is determined on a case- by-case basis at the project level, in consultation with air quality regulatory agencies and other federal land management agencies.

FW-MA-AQ-08: Provide early notification to the public about potential smoke from fire activities to promote awareness and protect human health and safety. Smoke from prescribed burning is managed per State of Colorado requirements via burn permits.

Thank you for your serious consideration of our objections. We look forward to working with you to find solutions.

Sincerely,

Lance Waring, Chair

Kris Holstrom, Vice Chair

Anne Brown, Commissioner

San Miguel County
Board of Commissioners

[15]https://wisewoodenergy.com/solutions

FS Agreement No. 23-MU-11020400-086

Cooperator Agreement No. _____

**MEMORANDUM OF UNDERSTANDING**
**Between**
**COUNTY OF SAN MIGUEL**
**And The**
**USDA, FOREST SERVICE**
**GRAND MESA, UNCOMPAHGRE AND GUNNISON NATIONAL FORESTS**

This MEMORANDUM OF UNDERSTANDING (MOU) is hereby made and entered into by and between County of San Miguel hereinafter referred to as "the County," and the United States Department of Agriculture (USDA), Forest Service, Grand Mesa, Uncompahgre and Gunnison National Forests, hereinafter referred to as the "U.S. Forest Service."

Background: As provided for by the National Environmental Policy Act (NEPA), as well as the 2012 Planning Rule (36 CFR 219), the U.S. Forest Service must prepare an Environmental Impact Statement (EIS) to revise the Grand Mesa, Uncompahgre and Gunnison National Forests Land Management Plan (Forest Plan). The EIS process is meant to inform both the U.S. Forest Service and the public about the environmental impacts of the Forest Plan before a final decision is made.

Title: Forest Plan Revision

**I. PURPOSE:** The purpose of this MOU is to document the cooperation between the parties to elicit the County to become a cooperating agency, with the U.S. Forest Service acting as lead agency, for the purpose of preparing a revised Forest Plan and EIS. The U.S. Forest Service recognizes that the County has knowledge, experience, and expertise with respect to environmental conditions to inform the proposed Forest Plan revision process as defined at 36 CFR 219, otherwise known as the 2012 Planning Rule. The County recognizes that the U.S. Forest Service has final decision-making authority regarding the scope of the analysis. In particular, the U.S. Forest Service is seeking assistance from the County to help provide knowledge and information that will help address management issues related to, but not limited to, land use plans, local social and economic conditions, and natural resource management concerns related to range, roads, timber, wildlife, fire, recreation, land and water conservation. Additionally, the U.S. Forest Service invites the submittal of other information, data, and comments from the County pertaining to the Forest Plan revision process. The establishment of this MOU further promotes responsible, transparent, and timely dialogue during the Forest Plan revision analysis between the County and the U.S. Forest Service in accordance with the following provisions.

## II. STATEMENT OF MUTUAL BENEFIT AND INTERESTS:

The County has significant portions of the Grand Mesa, Uncompahgre, and Gunnison National Forests within its borders. It is in the interest of the County to provide information and expertise for use in the development of the revised Forest Plan, including the formulation and analysis of options/alternatives. As a cooperating agency, the County may assist in reviewing the components of the Forest Plan and the monitoring program/proposals as they relate to individual agency resources and jurisdiction.

The U.S. Forest Service has a mutual interest in incorporating information and expertise provided by the County for a complete analysis of impacts and formulation of a full spectrum of alternatives during the Forest Plan revision.

Through this cooperative effort, the U.S. Forest Service and the County will be more likely to develop a higher quality revised Forest Plan and gain a greater understanding of how the revised Forest Plan may impact or affect the associated ecological concerns of the County. Both parties will benefit through increased communication, sharing of information, and cooperation in implementing their respective missions as a part of the Forest Plan revision process

In consideration of the above premises, the parties agree as follows:

## III. THE COUNTY SHALL:

A. Be identified as a cooperating agency for the Forest Plan revision coincident with the initiation of the formal environmental review process under NEPA.

B. Designate a representative and an alternate to participate in the Forest Plan revision process. Ensure that the County designees are full-time or permanent part-time employees of the County (or their designated employee with authority to act on their behalf), acting in their official capacity (41 CFR 102-3.40(g)).

C. Provide the U.S. Forest Service with relevant existing ecological, social, and economic resource information for the Forest Plan revision process.

D. Provide individual or collective comments on any aspect of the Forest Plan revision process.

E. Provide timely response to any reviews agreed upon by both the U.S. Forest Service and the County.

F. Maintain the confidentiality of documents and deliberations during the period prior to public release of any NEPA documents, in order to implement the National Environmental Policy Act of 1969, 43 CFR 46.225(d)

G. Assist with public meetings and with distributing Forest Plan revision information and documents to the public as the parties agree.

## IV. THE U.S. FOREST SERVICE SHALL:

A. Be the lead agency for Forest Plan revision.

B. Consider the County input in the development of issues, options, and alternatives addressed in the Forest Plan revision process.

C. Consider any appropriate County plans as part of the Forest Plan revision process.

D. Provide information and drafts to the County with adequate time for review. For products that will be released for an informal public comment period not required by NEPA, provide the County with such drafts two weeks prior to the public release. This early review would provide the County a longer review period. For products that will be released for a formal public comment period that is required by NEPA (the Proposed Plan/Draft EIS), provide the County with such drafts one month prior to the public release for a preliminary two-week review period. This early review would provide the County the opportunity to provide input that could be incorporated into the Draft EIS. The County would subsequently have the same 90-day comment period as the public.

## V. IT IS MUTUALLY UNDERSTOOD AND AGREED BY AND BETWEEN THE PARTIES THAT:

A. PRINCIPAL CONTACTS. Individuals listed below are authorized to act in their respective areas for matters related to this agreement.

**Principal Cooperator Contacts:**

| Cooperator Program Contact | Cooperator Administrative Contact |
|---|---|
| Lance Waring, Chair, San Miguel County Board of Commissioners<br>333 W Colorado Avenue 3rd Floor<br>Telluride, CO 81435<br>Telephone: 970-369-5429<br>Email: lancew@sanmiguelcountyco.gov | Starr Jamison<br>333 W Colorado Avenue 3rd Floor<br>Telluride, CO 81435<br>Telephone: 970-369-5441<br>Email: starrj@sanmiguelcountyco.gov |

**Principal Forest Service Contacts:**

| Forest Service Program Manager Contact | Forest Service Administrative Contact |
|---|---|
| Samantha Staley<br>Forest Planner<br>2250 Main Street<br>Delta, CO 81416<br>Telephone: 970-852-9812<br>Email: samantha.j.staley@usda.gov | Amy Sharp<br>Grants Management Specialist<br>1617 Cole Boulevard<br>Lakewood, CO 80401<br>Telephone: 605-515-8812<br>Email: amy.sharp@usda.gov |

B. NOTICES. Any communications affecting the operations covered by this agreement given by the U.S. Forest Service or the County is sufficient only if in writing and delivered in person, mailed, or transmitted electronically by e-mail or fax, as follows:

To the U.S. Forest Service Program Manager, at the address specified in the MOU.

To the County at the County's address shown in the MOU or such other address designated within the MOU.

Notices are effective when delivered in accordance with this provision, or on the effective date of the notice, whichever is later.

C. PARTICIPATION IN SIMILAR ACTIVITIES. This MOU in no way restricts the U.S. Forest Service or the County from participating in similar activities with other public or private agencies, organizations, and individuals.

D. ENDORSEMENT. Any of the County's contributions made under this MOU do not by direct reference or implication convey U.S. Forest Service endorsement of the County's products or activities.

E. NONBINDING AGREEMENT. This MOU creates no right, benefit, or trust responsibility, substantive or procedural, enforceable by law or equity. The parties shall manage their respective resources and activities in a separate, coordinated and mutually beneficial manner to meet the purpose(s) of this MOU. Nothing in this MOU authorizes any of the parties to obligate or transfer anything of value.

Specific, prospective projects or activities that involve the transfer of funds, services, property, to a party requires the execution of separate agreements and are contingent upon numerous factors, including, as applicable, but not limited to: agency availability of appropriated funds and other resources; cooperator availability of funds and other resources; agency and cooperator administrative and legal requirements (including agency authorization by statute); etc. This

MOU neither provides, nor meets these criteria. If the parties elect to enter into an obligation agreement that involves the transfer of funds, services, property, and/or anything of value to a party, then the applicable criteria must be met. Additionally, under a prospective agreement, each party operates under its own laws, regulations, and/or policies, and any U.S. Forest Service obligation is subject to the availability of appropriated funds and other resources. The negotiation, execution, and administration of these prospective agreements must comply with all applicable law.

Nothing in this MOU is intended to alter, limit, or expand the agencies' statutory and regulatory authority.

F. USE OF U.S. FOREST SERVICE INSIGNIA. In order for the County to use the U.S. Forest Service insignia on any published media, such as a Web page, printed publication, or audiovisual production, permission must be granted from the U.S. Forest Service's Office of Communications. A written request must be submitted and approval granted in writing by the Office of Communications (Washington Office) prior to use of the insignia.

G. MEMBERS OF U.S. CONGRESS. Pursuant to 41 U.S.C. 22, no U.S. member of, or U.S. delegate to, Congress shall be admitted to any share or part of this agreement, or benefits that may arise therefrom, either directly or indirectly.

H. FREEDOM OF INFORMATION ACT (FOIA). Public access to MOU or agreement records must not be limited, except when such records must be kept confidential and would have been exempted from disclosure pursuant to Freedom of Information regulations (5 U.S.C. 552).

I. TEXT MESSAGING WHILE DRIVING. In accordance with Executive Order (EO) 13513, "Federal Leadership on Reducing Text Messaging While Driving," any and all text messaging by Federal employees is banned: a) while driving a Government owned vehicle (GOV) or driving a privately owned vehicle (POV) while on official Government business; or b) using any electronic equipment supplied by the Government when driving any vehicle at any time. All cooperators, their employees, volunteers, and contractors are encouraged to adopt and enforce policies that ban text messaging when driving company owned, leased or rented vehicles, POVs or GOVs when driving while on official Government business or when performing any work for or on behalf of the Government.

J. TRIBAL EMPLOYMENT RIGHTS ORDINANCE (TERO). The U.S. Forest Service recognizes and honors the applicability of the Tribal laws and ordinances developed under the authority of the Indian Self-Determination and Educational Assistance Act of 1975 (PL 93-638).

K. PUBLIC NOTICES. It is the U.S. Forest Service's policy to inform the public as fully as possible of its programs and activities. The County is/are encouraged to give public notice of the receipt of this agreement and, from time to time, to announce progress and accomplishments. Press releases or other public notices should include a statement substantially as follows:

"Grand Mesa, Uncompaghre, and Gunnison National Forests of the U.S. Forest Service, Department of Agriculture, Forest Plan Revision."

The County may call on the U.S. Forest Service's Office of Communication for advice regarding public notices. The County is/are requested to provide copies of notices or announcements to the U.S. Forest Service Program Manager and to the U.S. Forest Service's Office of Communications as far in advance of release as possible.

L. U.S. FOREST SERVICE ACKNOWLEDGED IN PUBLICATIONS, AUDIOVISUALS AND ELECTRONIC MEDIA. The County shall acknowledge U.S. Forest Service support in any publications, audiovisuals, and electronic media developed as a result of this MOU.

M. NONDISCRIMINATION STATEMENT – PRINTED, ELECTRONIC, OR AUDIOVISUAL MATERIAL. The County shall include the following statement, in full, in any printed, audiovisual material, or electronic media for public distribution developed or printed with any Federal funding.

***In accordance with Federal law and U.S. Department of Agriculture policy, this institution is prohibited from discriminating on the basis of race, color, national origin, sex, age, or disability. (Not all prohibited bases apply to all programs.)***

**To file a complaint of discrimination, write USDA, Director, Office of Civil Rights, Room 326-W, Whitten Building, 1400 Independence Avenue, SW, Washington, DC 20250-9410 or call (202) 720-5964 (voice and TDD). USDA is an equal opportunity provider and employer.**

If the material is too small to permit the full statement to be included, the material must, at minimum, include the following statement, in print size no smaller than the text:

***"This institution is an equal opportunity provider."***

N. TERMINATION. Any of the parties, in writing, may terminate this MOU in whole, or in part, at any time before the date of expiration.

O. DEBARMENT AND SUSPENSION. The County shall immediately inform the U.S. Forest Service if they or any of their principals are presently excluded, debarred, or suspended from entering into covered transactions with the federal government according to the terms of 2 CFR Part 180. Additionally, should the County or any of their principals receive a transmittal letter or other official Federal notice of debarment or suspension, then they shall notify the U.S. Forest Service without undue delay. This applies whether the exclusion, debarment, or suspension is voluntary or involuntary.

P. MODIFICATIONS. Modifications within the scope of this MOU must be made by mutual consent of the parties, by the issuance of a written modification signed and dated by all properly authorized, signatory officials, prior to any changes being performed. Requests for modification should be made, in writing, at least 60 days prior to implementation of the requested change.

Q. COMMENCEMENT/EXPIRATION DATE. This MOU is executed as of the date of the last signature and is effective through **August 22, 2028** at which time it will expire.

R. AUTHORIZED REPRESENTATIVES. By signature below, each party certifies that the individuals listed in this document as representatives of the individual parties are authorized to act in their respective areas for matters related to this MOU.

In witness whereof, the parties hereto have executed this MOU as of the last date written below.

LANCE WARING, Chair, Board of County Commissioners
San Miguel County — Date

CHAD STEWART, Forest Supervisor
U.S. Forest Service, Grand Mesa, Uncompahgre and Gunnison National Forests — Date

The authority and format of this agreement have been reviewed and approved for signature.

AMANDA MARR Digitally signed by AMANDA MARR
Date: 2023.08.29 12:29:45 -06'00'

AMANDA MARR Date
U.S. Forest Service Grants Management Specialist

Burden Statement

According to the Paperwork Reduction Act of 1995, an agency may not conduct or sponsor, and a person is not required to respond to a collection of information unless it displays a valid OMB control number. The valid OMB control number for this information collection is 0596-0217. The time required to complete this information collection is estimated to average 3 hours per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information.

The U.S. Department of Agriculture (USDA) prohibits discrimination in all its programs and activities on the basis of race, color, national origin, age, disability, and where applicable, sex, marital status, familial status, parental status, religion, sexual orientation, genetic information, political beliefs, reprisal, or because all or part of an individual's income is derived from any public assistance. (Not all prohibited bases apply to all programs.) Persons with disabilities who require alternative means for communication of program information (Braille, large print, audiotape, etc.) should contact USDA's TARGET Center at 202-720-2600 (voice and TDD).

To file a complaint of discrimination, write USDA, Director, Office of Civil Rights, 1400 Independence Avenue, SW, Washington, DC 20250-9410 or call toll free (866) 632-9992 (voice). TDD users can contact USDA through local relay or the Federal relay at (800) 877-8339 (TDD) or (866) 377-8642 (relay voice). USDA is an equal opportunity provider and employer.

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ORIGINAL PAPER

# Mountain Fen Distribution, Types and Restoration Priorities, San Juan Mountains, Colorado, USA

**Rod A. Chimner · Joanna M. Lemly · David J. Cooper**

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**Abstract** Mountain fens are vital ecosystems for habitat, biodiversity, water and carbon cycling, but there is little comprehensive information on their distribution, abundance or condition in any region of the western U.S. Our study objectives were to: 1) evaluate fen distribution, abundance and characteristics in the San Juan Mountains of Colorado, 2) quantify disturbances, and 3) prioritize restoration needs of fens. We mapped 624 fens in 37 watersheds and collected field data on 182 of these fens. We estimated that approximately 2,000 fens occur in the San Juan Mountains, primarily in the subalpine zone at an average elevation of 3,288 m. Fens ranged from 0.2 to 20.5 ha in size, peat thickness ranged between 0.40 to >4.00 m, and surface slope ranged from 0–21%. Groundwater pH ranged from 3.1–7.6 and $Ca^{+2}$ from 1–341 mg/L, reflecting the diverse geochemistry of watershed parent materials. We identified 188 vascular and 63 bryophyte taxa, and classified the 309 sampled stands into 20 plant communities that formed along complex hydrogeomorphic and geochemical gradients. The majority of fens were in excellent condition; however 10% of our sampled fens had high to very high restoration potential due to impacts from roads, mining, and ditching.

**Keywords** Disturbances · Fens · Peatlands · Restoration · Vegetation

## Introduction

Mountainous regions cover nearly a quarter of the earth's land area and, although they house only 10% of the world's population, are heavily utilized for forestry, livestock grazing, energy and mineral production, and recreation (Millennium Ecosystem Assessment 2005). Mountain ranges are also globally important for carbon storage and water cycling (Viviroli et al. 2003; Schimel and Braswell 2005). Many of the world's major rivers originate in mountains because of high precipitation rates from orographic lifting. These processes support a high density of rivers and a vast array of wetlands, including riparian areas, wet meadows, and marshes (Cooper and Andrus 1994; Gerdol 1995; Clausen et al. 2006; Chimner et al. 2007). Among mountain wetlands, peatlands can be the most abundant type in many high-elevation regions (Cooper and Andrus 1994).

In the southern Rocky Mountains of the United States, all peatlands are classified as fens, supported by groundwater input and not solely by direct precipitation (Cooper and Andrus 1994). These fens are often areas of high biodiversity and are regionally important refugia for rare plant and animal species that are otherwise limited to colder environments of boreal and arctic regions (Cooper 1996). Species such as Altai cottongrass (*Eriophorum altaicum*), buckbean (*Menyanthes trifoliata*), purple cinquefoil (*Comarum palustre*), and *Sphagnum balticum* occur within the

**Electronic supplementary material** The online version of this article (doi:10.1007/s13157-010-0039-5) contains supplementary material, which is available to authorised users.

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southern Rocky Mountains, disjunct by hundreds or thousands of km from their main ranges in boreal North America (Cooper et al. 2002; Weber 2003). Rocky Mountain peatlands also provide important habitat for elk (*Cervus elaphus*), moose (*Alces alces*), and many species of amphibians and migratory birds.

Mountain fens have long been altered by human activities, but little information exists on the types of impacts that have occurred and the proportion of fens in need of restoration. Disturbances may reverse the 10,000+ year old process of peat accumulation (Chimner and Cooper 2002) and lead to peatland destruction in many areas (Cooper et al. 1998; Chimner and Cooper 2003a; b; Patterson and Cooper 2007). Common anthropogenic disturbances that have been noted in western North American fens include hard rock and gravel mining, water reservoir construction, irrigation diversions for agricultural water use, trans-basin water diversions, road construction, timber and energy development, livestock grazing, housing and ski area development, and recreation (Cooper and Wolf 2006; Patterson and Cooper 2007; Zier and Baker 2006). Despite the ecological and hydrologic importance of mountain fens, there is little comprehensive information on their distribution, abundance, aerial extent, and type in any region of North America. Because many fens lack navigable waters, they may have little or no federal, state, or local protection and are often overlooked in large-scale wetland and watershed protection programs (Tiner et al. 2002). Our objectives were to: 1) determine the distribution, abundance, and characteristics of fens, 2) document the range of disturbances to fens, and 3) prioritize restoration needs for fens in the San Juan Mountains in southern Colorado.

## Methods

### Study Area

The San Juan Mountains (Fig. 1) are geologically complex, with a core of Precambrian crystalline rocks, localized areas of volcanism and intrusive igneous rock, and sedimentary rocks along the range margins. Large areas of unsorted Quaternary deposits of glacial, colluvial, and alluvial origin occur in valleys and on hillslopes (Winters et al. 2003). The San Juan Mountains are the highest elevation range of the entire Rocky Mountain system, with 14 peaks reaching over 4,270 m elevation, and hundreds of peaks over 3,660 m. Glaciated high elevation valleys have broad U-shapes with numerous tarns, cirques, and moraines, while narrow lower elevation valleys have been cut by rivers. Higher elevation areas have snowmelt driven hydrologic regimes, and lower elevations are rainfall driven (Winters et al. 2003).

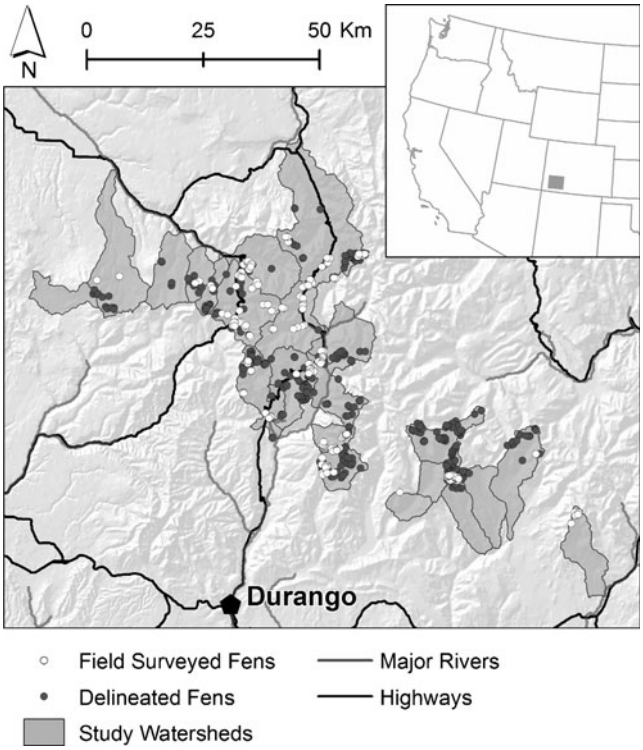


**Fig. 1** Randomly selected watersheds (*grey polygons*), mapped fens (*black circles*), and visited fens (*open circles*) in the San Juan Mountains, Colorado

### Fen Identification and Mapping

We used natural color aerial photograph stereo pairs and digital aerial imagery to identify wetlands with brownish colors and peat generated landforms typical of fens in our region. We mapped and field verified fens in 11 adjacent watersheds in two Colorado counties (San Miguel and Ouray) to perfect methods for fen identification. We then mapped and visited fens in randomly selected watersheds across the entire mountain range, which covers 44,194 km$^2$. We used the National Hierarchical Framework of Aquatic Ecological Units in North America (Maxwell et al. 1995) and the National Watershed Boundary Data sets Federal Standards for Delineation of Hydrologic Unit Boundaries to identify HUB 6$^{th}$ level watersheds. We developed a watershed classification using agglomerative cluster analysis based upon the percent of each bedrock type (calcareous, intrusive igneous, and volcanic), elevation categories, and climate in each watershed (Winters et al. 2003; Wohl et al. 2007). A total of nine watershed types were identified, and two watersheds of each type were randomly selected for inventory. We also added nine additional HUB 6$^{th}$ level watersheds with unique geological characteristics. Within each watershed, the boundary of each fen was delineated with the GIS software package ArcView 9.2 (ESRI 2006). We field verified our image interpretation by investigating

soils and hydrologic regime, and corrected fen polygon boundaries. We determined the ownership, elevation, and exact location of each fen from available GIS layers.

### Field Assessments

In many watersheds, all mapped fens were field verified and sampled. In watersheds with large numbers of fen polygons, we visited a subsample by selecting only a few from areas with large clusters of similar fen types. Subsamples were chosen to maximize the diversity of fens sampled and to not oversample areas with large numbers of fens. A total of 182 fens were field sampled during June–August 2006 and 2007. We defined fens as wetlands with organic soils at least 40 cm thick and used the Natural Resources Conservation Service's Soil Taxonomy to identify organic soils (Soil Survey Staff 2006). In all field verified fens, we determined location and ownership, overall site characteristics, condition and disturbances, and collected stand-level vegetation composition data. All data were entered into a Palm Pilot® using the software program EcoNab (NIISS 2006). Data were downloaded each day into Microsoft Access® creating an easily accessible electronic database.

In each study fen, homogenous stands (usually between 1–5 stands per fen) of vegetation were identified and data were collected within these stands. A 40-cm deep pit was opened with a shovel in each stand, the pH and temperature of groundwater that filled the hole was measured using an YSI 100 handheld pH meter, and water table depth was recorded once it equilibrated. One ground water sample was collected from each fen, stored in a 20-ml scintillation vial, sealed immediately, and kept refrigerated until analyzed by the U.S. Forest Service, Grand Rapids, Minnesota, for major anion and cation concentrations. A soil sample from 30–40 cm depth was collected from each site for analysis of percent organic matter content by loss on ignition (Belyea and Warner 1996). The approximate thickness of the peat body was measured using a tile probe and the level of peat decomposition was determined with the von Post scale (Rydin and Jeglum 2006). Percent slope was measured with a clinometer and each fen was placed into a hydrogeomorphic class of either sloping or depression (Brinson 1993).

Vegetation composition within each stand was analyzed using the relevé method (Mueller-Dombois and Ellenberg 1974). The canopy cover of each vascular plant and bryophyte species was visually estimated and voucher specimens of any unknown species were collected. *Sphagnum* spp. were identified by Richard Andrus (Binghamton University, New York, BING) and all other mosses by William Weber (University of Colorado, Boulder, (COLO), where vouchers were deposited. Taxonomy from the Flora of Western Colorado was followed (Weber and Wittmann 2001).

Vegetation data from homogenous stands were classified using agglomerative cluster analysis with Sørensen distance measure and flexible beta linkages method with $\beta$=-0.25, using the computer program PC-ORD 5.0 (McCune and Mefford 2006). Indicator species analysis was used to prune the dendrogram and optimize the number of clusters (McCune and Grace 2002). We averaged p-values across all species for each cluster level using Monte Carlo Analysis and the cluster level with the lowest average p-value was used as the optimal level. Ordination of vegetation, soil and water chemistry, and environmental variables was conducted using Nonmetric Multidimensional Scaling (NMS) in PC-ORD 5.0 using Sørensen distance measure and 3-axes, as determined by the stress test (McCune and Grace 2002).

### Disturbances and Restoration Potential

We identified disturbances on aerial imagery, topographic maps, and during site visits. The level of severity of each disturbance was assessed by the proportion of fen it impacted and the intensity of the impact. Disturbances were ranked by severity, those that impacted <1% of the fen were ranked as low, 1–5% as moderate, 5–15% as high, and >15% as very high. We also assessed hydrologic disturbances, including headcuts, gullies, ditches, diversions, and road cuts to fens by estimating the proportion of area that was altered. Vegetation disturbance was assessed by identifying the proportion of bare soil or the presence of invasive or non-wetland plant species, and the degree of grazing or browsing. Soil disturbance was the proportion of fen with bare soil, mineral material overlying peat soil, or undergoing erosion.

We assessed each site's restoration priority as very high, high, low, or very low based on the likely ease or difficulty of restoration and the rarity or commonness of the fen type. Sites considered high or very high restoration priorities could easily be restored or were rare fen types. Sites rated as low or moderate restoration priority were slightly impacted or so severely impacted that restoration would be cost prohibitive.

## Results

### Mapping

We preliminarily identified 624 sites as fens on aerial imagery in the 37 study watersheds (Fig. 1). Our field surveys indicate that our delineation had an accuracy of 92% for correctly identifying polygons that were fens. We altered boundaries on a number of polygons in the field, and a few polygons were added. We estimate that

approximately 10% of fens were missed in the image based delineation. Mapped sites ranged from 0.2 to 20.5 ha in area, with a mean of 1.2 ha and a median of 0.8 ha. Site elevations ranged from 2,532 to 3,832 m. Approximately 90% of fens occurred above 3,000 m elevation, with an average elevation of 3,288 m (Fig. 2a).

## Physical and Chemical Characteristics

We visited 182 fens (30% of all mapped fens) and analyzed 309 homogenous stands in these fens (Fig. 1). Mean peat thickness was 1.25 m (std=0.78) and ranged from 0.40 to >4.00 m. We likely underestimated the thickest peat bodies because our soil probe was 4 m long. Mean soil organic matter content was 60% (std=15%), which is approximately 30% organic carbon (Chimner unpublished data). Peat decomposition, as indicated by the von Post scale, averaged 5, moderately decomposed, with *Sphagnum* peat being least decomposed and drained *Carex* peat the most decomposed. Approximately 28% of fens had formed in depression landforms and 78% on slopes. The mean fen slope was 5% and the maximum 21% (Fig. 2b).

Groundwater pH in most fens ranged from 5.0 to 6.5; although, several fens were basic with pH>7.0 and a number were highly acid with pH<4.5 (Fig. 2c). Groundwater pH varied due to watershed bedrock composition and surficial deposit geochemistry (Table 1). Watersheds with some calcareous bedrock had the highest concentrations of $Ca^{+2}$, $Mg^{+2}$, and $Na^{+}$ in ground water. Intrusive igneous watersheds had the highest concentrations of $K^{+}$, while volcanic watersheds had high $Fe^{+3}$.

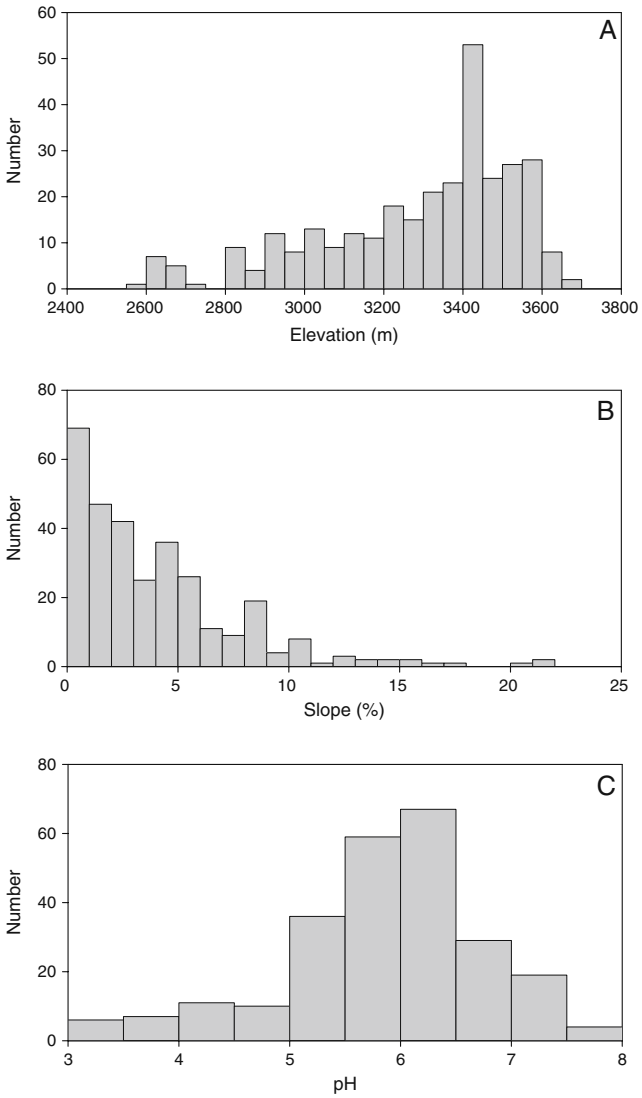


**Fig. 2** Histographs of **a** mapped fen elevations, **b** fen slopes, and **c** fen pH

## Vegetation

We identified 188 vascular and 63 bryophyte species in the study plots (Supplementary Material, Appendix A). A total of 30 species of *Carex* were found (34 in Cyperaceae) and ~80% of the stands were *Carex*-dominated (>50% cover). *Carex aquatilis* was the most common species found, occurring in 65% of plots. *Rhynchospora alba* was found in one fen, and this genus was not previously known for the Rocky Mountains south of Idaho (Flora of North America Editorial Committee 2002). Unlike many regions with peatlands (Rydin and Jeglum 2006), fens in the Rockies have little tree cover (Johnson 1996). Only 5% of the study fens supported any trees, and only one species, *Picea engelmannii*, commonly occurred in fens. Most of the forested fens analyzed occurred at the margins of large fen complexes. Many fens were shrub covered. However, instead of species in the family *Ericaceae*, as is common in most boreal peatlands, southern Rocky Mountain fens are covered by six species of *Salix,* with *Salix planifolia* being most common. Bryophyte cover and diversity was dominated by mosses in the family Amblystegiaceae with 18 species and *Warnstorfia fluitans* was the most common member of this family. Other common brown mosses included *Aulacomnium palustre, Ptychostomum pseudotriquetrum*, and *Climacium dendroides.*

Hierarchal cluster analysis separated the 309 stands into 20 community types (Table 2). The communities are divided into three main groups based on geochemistry (rich, intermediate, and iron fens) and secondarily divided into the hydrogeomorphic classes of sloping and depressional fens (Table 2). We classified vegetation communities with an average pH >6.5 as rich fens. These communities generally also had high ground water $Ca^{+2}$ and $Mg^{+2}$ concentrations, although there were a few with lower concentrations. Fens with pH between 5 and 6.5 were classified as intermediate fens and had low $Ca^{+2}$ and $Mg^{+2}$

**Table 1** Mean (±se) water chemistry (mg/L) of ground water by dominant watershed rock type

Letters denote significant difference ($P<0.05$) between watershed types as tested by ANOVA using Tukey's post-hoc test

| Cation | Calcareous ($n=56$) | Volcanic ($n=156$) | Intrusive Igneous ($n=54$) |
|---|---|---|---|
| $Ca^{+2}$ | 70.7±7.7[a] | 32.6±3.4[b] | 6.0±0.9[c] |
| $Mg^{+2}$ | 9.1±1.1[a] | 6.0±0.1[b] | 1.1±0.4[c] |
| $K^{+}$ | 1.6±0.1[a] | 1.2±0.1[a] | 5.0±1.2[b] |
| $Na^{+}$ | 4.9±0.5[a] | 3.2±0.3[b] | 0.91±0.1[c] |
| $Fe^{+3}$ | 0.1±0.1[a] | 0.4±0.1[b] | 0.1±0.1[a,b] |

concentrations. Fens with low pH (<5) in the study area were iron fens, not ombrotrophic bogs, and occurred in watersheds with outcroppings of highly mineralized iron pyrite that oxidizes to form sulfuric acid, creating ground water with naturally low pH but high $Ca^{+2}$ and $Mg^{+2}$ concentrations. The majority of fens in our study were intermediate fens (66% of total fens sampled), followed by rich fens (23%) with iron fens being rare (1%).

**Table 2** Plant community types grouped by geochemistry (rich, intermediate, and iron) and landform (sloping and depression)

| Group | Plant Community |
|---|---|
| Rich Fens: | |
| Sloping Rich Fens | |
| 1.1: | *Salix monticola*/*Alnus incana* |
| 1.2: | *Salix wolfii*/*Pentaphylloides floribunda* |
| 1.3: | *Carex buxbaumii*/*Eriophorum angustifolium* |
| 1.4: | *Eriophorum angustifolium*/*Juncus albescens* |
| 1.5: | *Psychrophila leptosepala*/*Primula parryi* |
| Depression Rich Fens | |
| 2.1: | *Carex utriculata*/*Galium trifidum* |
| 2.2: | *Carex magellanica*/*Carex utriculata* |
| 2.3: | *Carex limosa*/*Menyanthes trifoliata* |
| Intermediate Fens: | |
| Sloping Intermediate Fens | |
| 3.1: | *Picea engelmannii*/*Calamagrostis canadensis* |
| 3.2: | *Salix planifolia*/*Carex aquatilis* |
| 3.3: | *Eleocharis quinqueflora*/*Carex aquatilis* |
| 3.4: | *Carex illota*/*Pedicularis groenlandica* |
| 3.5: | *Carex aquatilis*/*Psychrophila leptosepala* |
| 3.6: | *Carex aquatilis*/*Pedicularis groenlandica* |
| 3.7: | *Carex saxatilis*/*Scorpidium cossonii* |
| 3.8: | *Eleocharis quinqueflora*/*Warnstorfia fluitans* |
| Depression Intermediate Fens | |
| 4.1: | *Carex canescens*/*Calamagrostis canadensis* |
| 4.2: | *Carex lasiocarpa*/*Drosera anglica* |
| Iron Fens: | |
| 5.1: | *Betula glandulosa*/*Sphagnum russowii* |
| 5.2: | *Carex aquatilis*/*Sphagnum fimbriatum* |

Community types named by a combination of dominant species and indicator species

The most common species in iron fens were *Betula glandulosa, Carex aquatilis*, and a continuous carpet of *Sphagnum* mosses. Ten species of *Sphagnum* were identified in iron fens including *S. obtusum*, which was not been previously known for the Rocky Mountains (Andrus personal communication). We also found additional populations of another rare peat moss *Sphagnum balticum,* which is disjunct from its main range in boreal regions of Canada (Cooper et al. 2002). The most common *Sphagnum* species were *S. russowii, S. fimbriatum*, and *S. angustifolium*.

More intermediate fen communities (10) than rich fen communities (8) or iron fen communities (2) occur in the study area, and more sloping fen (14) than depression fen (6) community types occur (Table 2). Sloping fens had higher total vascular and bryophyte species richness and diversity than depression fens, but there was little difference between rich sloping fens and intermediate sloping fens, or between rich depression fens and intermediate depression fens (Table 3). Iron fens had the lowest number of total and vascular species, although many of their species are regionally rare.

Multivariate Nonmetric Multidimensional Scaling (NMS) analysis had a 3-dimensional solution of 21.45 and a final instability 0.0038 (Fig. 3). Axis 1 had an $r^2$ of 0.19 and was most correlated to elevation ($r^2=0.29$) and $Ca^{+2}$ concentrations in ground water ($r^2=0.14$; Table 4). Axis 2 had an $r^2$ of 0.18 and was most correlated with elevation ($r^2=0.15$) and slope ($r^2=0.12$). Axis 3 had an $r^2$ of 0.16 and was most correlated with pH ($r^2=0.17$).

## Disturbance and Restoration Potential

Forty-two (23%) of the fens visited had some level of disturbance. The most severe disturbances were from ditching, mining, urban development, and roads, with roads being the most common disturbance (Table 5). The least severe disturbances were from native animal use (e.g., elk wallows) and recreational uses (e.g., skiing, biking). Disturbances impacted vegetation, hydrological functions, soil stability, or all three.

Five fens were classified as having very high restoration priority and 13 additional fens as having a high restoration priority (data not shown). Six fens classified as having high or very high restoration priority were rare iron fens (out of

**Table 3** Total number of species (T) present and Simpsons Diversity Index (D) of major fen vegetation types. Separated by all species, vascular species and bryophytes

| | All | | Vascular | | Bryophyte | |
|---|---|---|---|---|---|---|
| | T | D | T | D | T | D |
| 1-Rich Sloping | 149 | 0.54 | 124 | 0.55 | 25 | 0.51 |
| 2-Rich Depression | 75 | 0.15 | 57 | 0.15 | 18 | 0.17 |
| 3-Intermediate Sloping | 155 | 0.59 | 122 | 0.57 | 33 | 0.66 |
| 4-Intermediate Depression | 72 | 0.13 | 54 | 0.12 | 18 | 0.15 |
| 5 Iron Fen | 54 | 0.13 | 36 | 0.11 | 18 | 0.19 |

15 iron fens surveyed). Nineteen fens were ranked as medium and the remaining 145 fens as low restoration priority. All but one of the low restoration priority fens were in good or excellent condition and did not require restoration. However, one fen was in poor condition from a highway bisecting it and was ranked as low restoration priority due to the cost of restoration. Common disturbances ranked as having high or very high restoration priorities were from small roads, mining, and ditching. However, some fens with severe disturbance from roads or mining were ranked as medium or low restoration priorities due to the high cost of restoration required to fix these sites.

## Discussion

### Mountain Fen Characteristics

We estimate that approximately 2,000 fens occur in the subalpine zone (~3,000–4,000 m) of the San Juan Mountains, covering 2,400 ha, or 1% of area. Few studies have estimated fen abundance on the scale of an entire mountain region, but information from this and other studies indicate that fens are numerous in mountain regions of western North American (Chadde et al. 1998; Cooper and Wolf 2006; Lemly 2007; Patterson and Cooper 2007).

Mountain peatlands also occur along the entire length of the Andes, and in tropical and subtropical regions including the pàramo of Colombia, Venezuela, and Ecuador (Samaniego et al. 1998; Chimner and Karberg 2008); the puna in Chile, Peru, and Boliva (Preston et al. 2003; Earle et al. 2003; Cooper et al. 2010); central Andes and Patagonia (Coronato et al. 2006; Chimner et al. 2007); and Tierra del Fuego where peatlands cover large areas (Kleinebecker et al. 2008). Mountain peatlands also occur in other temperate mountain ranges including the Alps, Himalayas, in Japan, and the Southern Alps of New Zealand (Gerdol 1995; Wahren et al. 2001; Dickinson et al. 2002; Chen et al. 2008; Koch et al. 2008; Fujita et al. 2009), as well as Hawaii, Africa and Indonesia (Islebe et al. 1996; Chimner 2004).

Fens in mountain regions are typically small in size because they are limited by steep slopes and the small size of watersheds supporting them (Patterson and Cooper

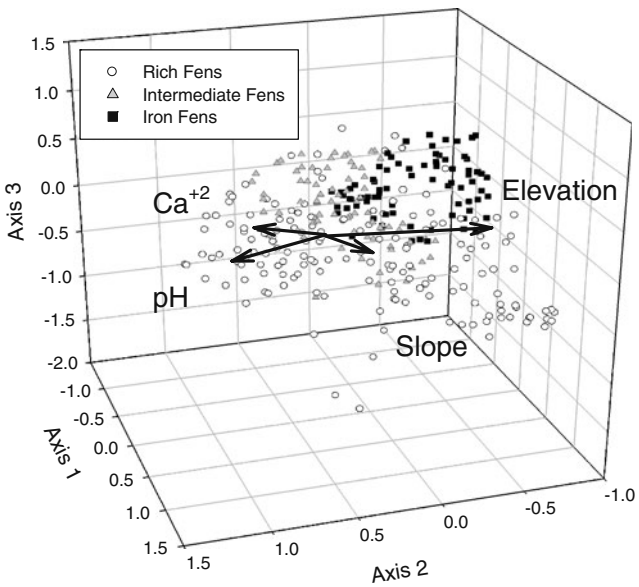


**Fig. 3** NMS diagram of stands and environmental vectors grouped by wetland type

**Table 4** Pearson ($r^2$) and Kendall ranked (tau) correlations of environmental values with ordination axes

| | Axis 1 | | Axis 2 | | Axis 3 | |
|---|---|---|---|---|---|---|
| | $r^2$ | tau | $r^2$ | tau | $r^2$ | tau |
| Elevation | 0.29 | 0.39 | 0.15 | -0.21 | 0.07 | 0.18 |
| Slope | 0.00 | 0.02 | 0.12 | -0.29 | 0.01 | -0.04 |
| Water table | 0.03 | -0.18 | 0.01 | -0.08 | 0.04 | -0.25 |
| von Post | 0.01 | -0.07 | 0.01 | 0.05 | 0.10 | -0.23 |
| Peat thickness | 0.00 | -0.04 | 0.01 | 0.05 | 0.01 | 0.09 |
| pH | 0.03 | 0.05 | 0.06 | 0.19 | 0.17 | -0.28 |
| calcium | 0.14 | -0.33 | 0.06 | 0.15 | 0.04 | -0.24 |
| magnesium | 0.03 | -0.24 | 0.08 | 0.18 | 0.08 | -0.22 |
| potassium | 0.02 | -0.05 | 0.00 | -0.05 | 0.00 | 0.02 |
| sodium | 0.12 | -0.35 | 0.04 | 0.11 | 0.04 | -0.16 |
| iron | 0.02 | 0.02 | 0.02 | -0.05 | 0.00 | 0.05 |

**Table 5** Disturbance categories, number of times disturbance was encountered during field surveys, and average severity level of disturbance (1 = lowest severity and 5 = most severe impact)

| Disturbance | Number of occurrences | Average severity |
|---|---|---|
| Drainage | 7 | 3.9 |
| Mining | 21 | 3.2 |
| Other | 6 | 2.8 |
| Development | 19 | 2.6 |
| Roads | 52 | 2.4 |
| Grazing | 10 | 2.2 |
| Native animals | 23 | 1.8 |
| Recreation | 21 | 1.7 |

Categories ranked by average severity

Numbers are based on stand level data and each site can have more than one disturbance

2007). The average fen in our study was 1.2 ha in area, which is similar to fen size in other mountain ranges in the western U.S., with the largest fens generally being less than 100 ha (Cooper and Wolf 2006; Lemly 2007).

Mountain fen peat bodies are relatively thin, averaging 1–1.25 m thick in the Rockies and Sierra Nevada (Cooper and Wolf 2006; Lemly 2007; this study, Chimner unpublished data). However, some mountain peatlands are >4 m in the Rocky Mountains, and >7 m in the Peruvian Andes (Cooper et al. 2010). Mountain fen soils typically have high mineral and low organic carbon content (Chimner and Karberg 2008). Soils from 419 Colorado fens average 30% organic carbon (60% soil organic matter) (this study, Chimner unpublished data), which is similar to the carbon content of Sierra Nevada fen soils (Cooper and Wolf 2006). However, carbon accumulation rates can be quite high in mountain fens because soil bulk density is typically high (Chimner et al. 2002).

Bogs do not occur in our study area. Mountain bogs occur only in mountain ranges with a hypermaritime climate (e.g., coastal areas of British Columbia, Canada, and southeastern Alaska) that receive ample rain and have high humidity throughout the year (Asada et al. 2003). Mountain regions with dry summers (e.g., Rockies and Sierra Nevada) have fens (Cooper and Andrus 1994; Cooper and Wolf 2006; Lemly 2007). Because most mountain fens are sloping and supported by ground-water discharge, watershed geology exerts a strong influence in ground-water chemical content (Vitt and Chee 1990; Cooper and Andrus 1994; Bedford and Godwin 2002; Bragazza et al. 2003), which strongly influences fen plant community composition (Vitt and Chee 1990; Cooper and Andrus 1994; Cooper 1996; Bedford and Godwin 2002; Bragazza et al. 2003). Hydrogeomorphic landform can also control fen plant community composition (Bridgham et al. 1996; Grootjans et al. 2006). We used well known geochemical fen categories to organize the plant communities into rich, intermediate, and iron fen types. Intermediate fens are common on granite and other intrusive igneous watersheds while rich fens are common in districts with calcareous rocks (e.g., limestone and dolomite) and iron fens are present where iron pyrite rich rocks outcrop (Cooper and Andrus 1994; Cooper 1996; Cooper et al. 2002).

## Disturbances and Fen Restoration

Ten percent of the fens sampled were highly disturbed, and were ranked as having high to very high restoration priorities, indicating that a large number of fens in the San Juan Mountains are in need of restoration. The most common disturbance encountered was roads, which are present in most study watersheds. Roads impact fens by intercepting water flow, bisecting fens, and are commonly a source of mineral sediment that can bury organic soils. Most roads had limited impacts to fens, but a few roads have caused severe impacts, especially where poor culvert placement created channels and erosion. Several fens also showed signs of off-road vehicles driving through or adjacent to them causing erosion.

Many fens were impacted by development other than roads (e.g., golf courses, parking structures, ski runs and structures), especially around the tows of Mountain Village and Telluride. The main impact from these developments was filling or structures that altered ground-water flow supporting fens.

Several fens had drainage ditches or water diversions. Dewatering is a severe disturbance in fens because it lowers the water table allowing peat to oxidize and the ground surface to subside due to increased decomposition (Chimner and Cooper 2003a).

Invasive species and heavy livestock grazing were minor issues. The few non-native species found, including *Breea arvensis, Descurainia sophia*, *Taraxacum officinale*, and *Trifolium repens* occurred in the dried and disturbed portions of a few fens. Relatively little domestic livestock grazing occurs in the study area at present and impacts were minor compared to grazing impacts in other mountain regions (Dull 1999; Preston et al. 2003; Cooper and Wolf 2006; Cooper and Wolf 2006; Chimner et al. 2007). We also found disturbances from native animals, primarily elk wallows and trampling, which caused erosion and gulling.

Two fen types were most likely to be highly disturbed and in need of restoration. Iron fens, which are rare in the western U.S., were frequently in poor condition with 6 out of 15 iron fens surveyed requiring restoration. Metal mines were often located near iron fens, which were used as tailings dumps. Besides the physical factor of tailings covering peat, tailing piles can disrupt surface and

ground-water flow and alter chemical and mineral sediment influx into fens. Some iron fens have been mined for "bog iron ore", which left the fen completely denuded even a century later, with bare soils undergoing severe frost heave and erosion.

Stands of rich sloping fens dominated by *Eleocharis quinqueflora* were disturbed in many areas, and their string and flark patterns and "step-terraces" were eroded by off road vehicles, horses, or elk. Most sites undergoing gully erosion were of this community type.

In summary, fens are an important component of subalpine zone ecosystems in the San Juan Mountains. However, the role mountain fens play in regional water and carbon cycles, and the provision of local and regional habitat for plants and animals is largely unknown (Vitt et al 2001; Bedford and Godwin 2002). Most mountain fens occur on slopes supported by ground-water discharge, which makes them especially vulnerable to disturbances that intercept ground water, for example roads and ditches, or cause erosion, for example mining, vehicle travel, and trampling. Iron fens and *E. quinqueflora* dominated fens are most likely to need protection and restoration.

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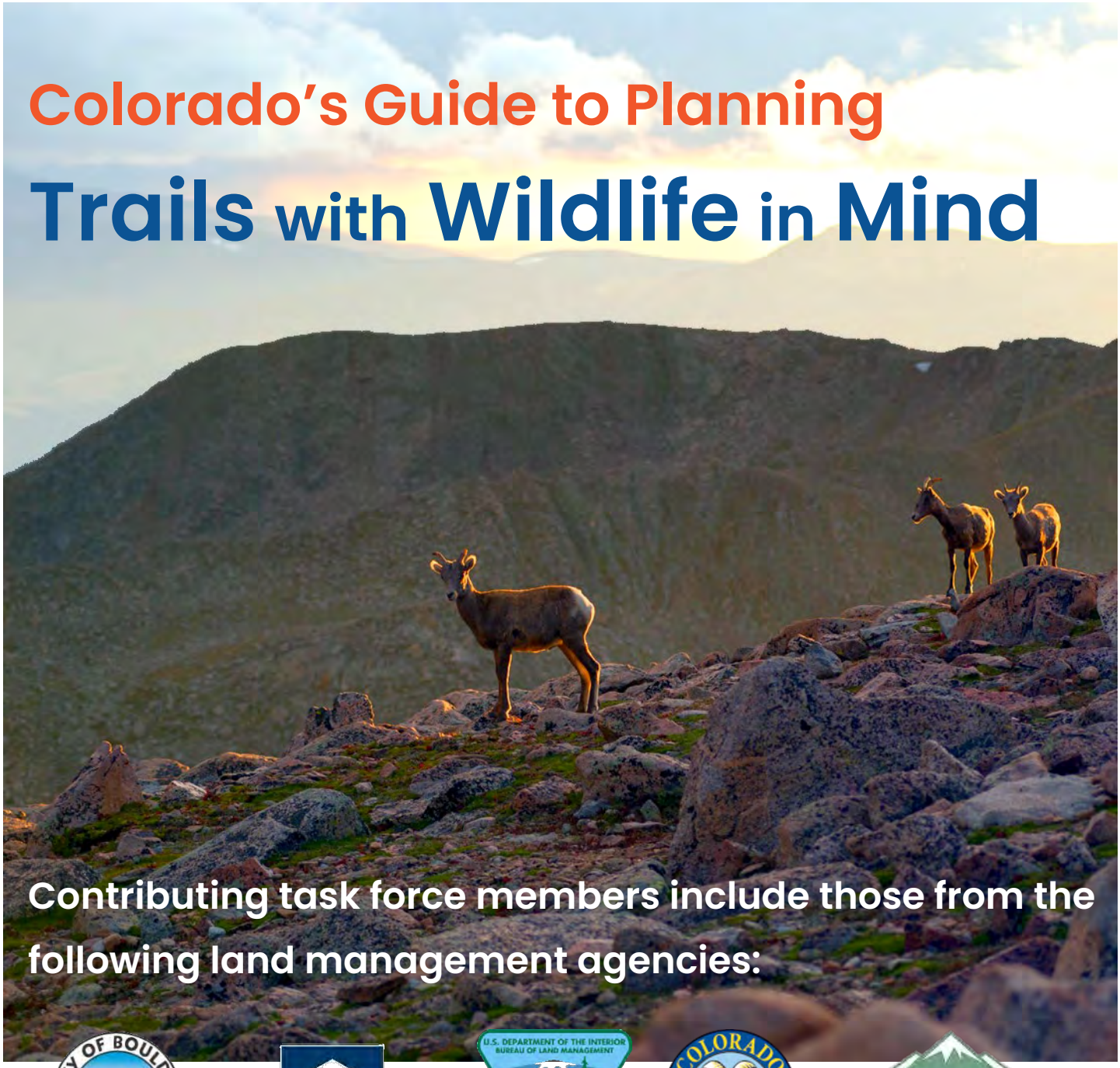
# Colorado's Guide to Planning

# Trails with Wildlife in Mind



**Contributing task force members include those from the following land management agencies:**

CITY OF BOULDER Open Space & Mountain Parks

TOWN OF BRECKENRIDGE OPEN SPACE & TRAILS

U.S. DEPARTMENT OF THE INTERIOR BUREAU OF LAND MANAGEMENT

COLORADO PARKS • WILDLIFE

COLORADO SPRINGS parks · recreation · cultural services

CRESTED BUTTE, COLORADO A National Historic District

JEFFERSON COUNTY COLORADO Open Space

DENVER PARKS & RECREATION

EAGLE COUNTY Open Space

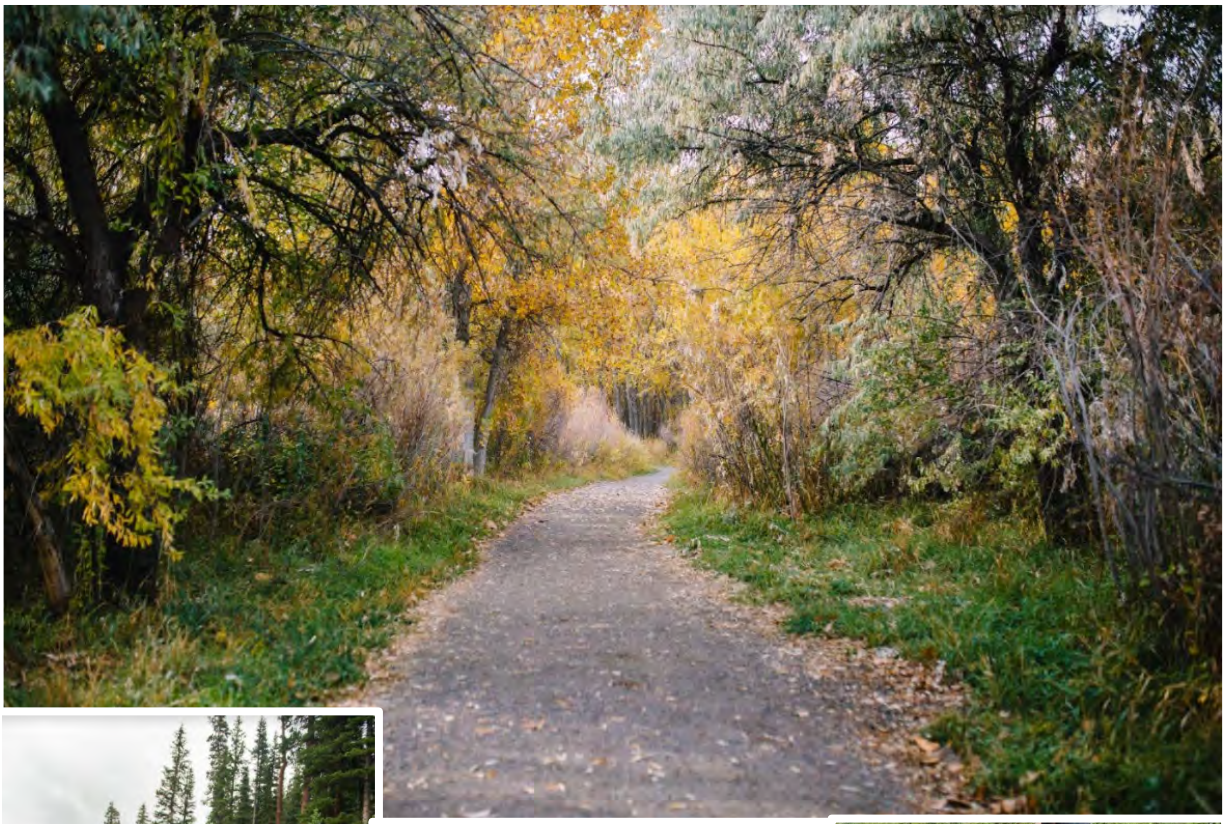
U.S. FISH & WILDLIFE SERVICE

FOREST SERVICE U.S. DEPARTMENT OF AGRICULTURE

CITY of DURANGO

NATIONAL PARK SERVICE

OPEN SPACE & TRAILS PITKIN COUNTY



June 2021

Developed by the

# Colorado Trails with Wildlife in Mind Task Force

with support by:

Wellstone Collaborative Strategies

in partnership with:

rocky mountain innovation lab



COLORADO
Parks and Wildlife
Department of Natural Resources

Director's Office
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June 30, 2021

Dear Fellow Coloradans,

Colorado Parks and Wildlife is tasked with providing wildlife management and world class outdoor recreation opportunities. To deliver on this mission it's important to recognize two facts: first, that recreation and conservation goals can often support each other, and second, that partnerships with other organizations and agencies across the state are critical to accomplish those goals. As our population continues to grow and visitation to our public land increases, it's more important than ever to be proactive and intentional with how we plan for recreation to ensure that wildlife still have the habitat they need to thrive.

This need was recognized back in 1997 when a Task Force was convened to draft the first version of Planning Trails with Wildlife in Mind. This guiding document supported land managers over the past two decades as they made decisions about how to best develop and manage trail systems. The 2021 update to Planning Trails brings the original document up to date, and achieved this through a second collaborative Task Force that exemplifies how we need to conduct this work in order to be successful.

CPW believes that deep, long-term partnerships such as the Task Forces convened to develop these documents allow us to work toward shared objectives and ensure delivery of practical solutions both on the ground and at the 30,000-foot strategic level. We believe that the support of our partners enables us to excel at protecting and caring for our most valued and valuable resources in the state, including the many wildlife species that call Colorado home. Our agency continues to seek out opportunities to support and enhance community-level and region-wide efforts to conserve wildlife habitat and accommodate growing demand for outdoor recreation. This document can enhance these efforts to find the common ground between local and statewide priorities by providing a shared language, reinforcing the importance of up-front and intentional collaboration, and driving home the understanding that conservation and recreation are mutually beneficial endeavors foundational to our way of life in Colorado.

I want to express my gratitude and thanks to the Trails with Wildlife in Mind Task Force, as well as the CPW staff and other stakeholders throughout the state that were involved in the development of this important document. Now that it's complete, I hope to see it in use as a tool to engage the public, land managers, and all who recreate to support an outdoor ethic that respects both wildlife and people. Above all, I hope that those using this document view it not as an end to this conversation, but a beginning.

Dan Prenzlow
Director

# Table of Contents

## Acronyms

**AWM:** Area Wildlife Manager

**BLM:** Bureau of Land Management

**BMP:** Best Management Practice(s)

**CODEX:** Colorado Conservation Data Explorer

**COMBA:** Colorado Mountain Bike Association

**COPMOBA:** Colorado Plateau Mountain Bike Trail Association

**COTREX:** Colorado Trail Explorer

**CPW:** Colorado Parks and Wildlife

**ESA:** Endangered Species Act

**FLMA:** Federal Land Management Agency

**FP:** Forest Plan

**GOCO:** Great Outdoors Colorado

**GUSG:** Gunnison Sage-Grouse

**HPH:** High Priority Habitat(s)

**HTA:** Headwaters Trails Alliance

**NEPA:** National Environmental Policy Act

**NOHVCC:** National Off-Highway Vehicle Conservation Council

**NPS:** National Parks Service

**OHV:** Off-Highway Vehicle

**OSMP:** Open Space and Mountain Parks

**RMP:** Resource Management Plan

**SWAP:** State Wildlife Action Plan

**T&E:** Threatened and Endangered Species

**TMP:** Travel Management Plan

**USDA:** United States Department of Agriculture

**USFS:** United States Forest Service

**USFWS:** United States Fish and Wildlife Service

**VVMTA:** Vail Valley Mountain Trails Alliance

**ZOI:** Zone of Influence

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# Introduction: Wildlife and Trails Overview

## Background and Purpose

Few things are loved more by Coloradans than the outdoors. According to the 2019 Statewide Comprehensive Outdoor Recreation Plan, 92% of residents took part in at least one outdoor activity every few weeks, with many engaging in several activities a week. Using trails is the most popular outdoor activity, with an estimated 400 million days spent by Coloradans on trails every year. No matter your favorite recreational pastime – hiking into the Indian Peaks Wilderness to fly-fish, exploring Taylor Park on an OHV, mountain biking at Lake Pueblo State Park, snowmobiling at Rabbit Ears Pass, or going for a walk around Denver's City Park – trails are the way we access Colorado's outdoors. They also enable residents and visitors alike to experience the joy of viewing wildlife: seeing raptors soaring, bighorn sheep on a ridge, a lizard scurrying across the trail, or ducks on an urban pond. However, all trails and trail uses have some impact on wildlife and their habitats. As our population increases by an estimated 36% to 8 million people over the next three decades, land managers must prepare for both more people wanting to enjoy these outdoor spaces and the subsequent increased impact on the environment.

**A trail** is a designated route on land with public access for recreation purposes such as hiking, running, bicycling, OHV riding, horseback riding, mountain biking, snowmobile riding, and backpacking.

In 2020, Colorado Parks and Wildlife (CPW) convened a Task Force made up of 20 representatives from CPW, federal agencies, and local agency partners from across the state. In addition to these representatives, the Task Force worked diligently to include voices and perspectives from a diverse array of stakeholders in conservation and recreation (see Appendix D for a complete list). Finally, a technical advisory team contributed extensively to the scientific aspects of the document. This updated document attempts to address the practical challenges facing trail and wildlife advocates in serving both conservation and recreational needs and values.

The 2021 version of *Planning Trails with Wildlife in Mind* updates the best practices and science for Colorado's land managers, trail advocates, and conservationists engaged in trail planning. This guide focuses extensively on collaborative approaches to problem solving. We believe that when trail users, conservation advocates, government agencies, and other community partners sit at the table together, we

achieve outcomes that are greater than the sum of their parts while maintaining respect for the values of all involved. It should be noted that the terms “user” and “visitor” are used interchangeably throughout the document to describe a single or multiple trail recreationist(s).

## Conservation and Recreation in Colorado

There are many concurrent efforts in Colorado focused on balancing conservation and recreation. **Trail planning is one aspect of the larger landscape-level and regional planning efforts currently underway across the state.**

Colorado has entered an era where land managers face ever-escalating pressure to meet recreation demands while maintaining the land’s natural resources. Landscape-level and regional planning efforts currently underway across the state are one mechanism that land managers are adopting to meet this challenge. Other powerful tools available to managers include adaptation of trails to support multiple uses, increased connectivity between trail systems across land ownership boundaries, and a greater emphasis on maintenance of existing systems. Even with these options, managers still look to develop new trails for a variety of reasons, including increased demand for quality trail experiences, anticipated population growth, improved access for under-served communities, the mental and physical health benefits from being outdoors, and the economic benefits to a local community. In addition to the benefits trails provide to recreationists, they can also act as tools to support wildlife needs and conservation goals, guiding human-use away from sensitive areas and into places less impactful to wildlife.

Both trails and wildlife are incredibly valuable to Coloradans. Valuing both requires that the conservation and recreation communities come together to reconcile supporting wildlife needs with an increased demand for trails. As a community we must plan for increased impacts by utilizing management tools geared to the unique sensitivity of the habitats and wildlife populations. We need to elevate strong regional and local planning early on, long before lines on a map are drawn or volunteer trail building crews put boots on the ground. Trail design guidebooks by both the International Mountain Bicycling Association and the National Off-Highway Vehicle Conservation Council each highlight how early master planning helps to better define trail concepts, concentrate trails, increase restoration opportunities, and protect wildlife without sacrificing the trail experience.

Trails serve dual purposes: Connecting people to the outdoors and managing people on the landscape. This document provides a framework to achieve a vision that recognizes:

*Trails in Colorado connect people with nature and support a high quality of life for all; proper trail planning, design, and management can minimize impacts and can serve as a tool to support resilient landscapes, wildlife, and biodiversity.*

## Core Principles to Guide Outdoor Planning

To help create a strategy towards the future described above, the Task Force adopted the Colorado Outdoor Principles and added an additional equity principle to guide the development of this document.

**Science-based Decisions -** Physical, biological, and social science must inform the management of outdoor recreation. **Management decisions should be grounded in the best available scientific information to ensure the protection of natural areas** and the sustainability of resources and should be applied adaptively to avoid restrictions that are overly or unnecessarily broad. This information is also necessary to maintain and enhance the quality of outdoor recreation experiences.

**Equity and Inclusion –** Actively engage *all* Coloradans to expand recreational access, conserve our ecosystems, and ensure inclusive planning processes. **We are committed to support a welcoming, inclusive, and accessible environment for all visitors to our facilities and public lands.**

**Working Together -** Both recreation and conservation are needed to sustain Colorado's quality of life. Both are beneficial to local economic well-being, for personal health, and for sustaining Colorado's natural resources. **This mutual need exists because outdoor recreation helps people understand the importance of maintaining healthy and intact ecosystems. That understanding builds support for natural resource protection and stewardship. In turn, conservation protects the land, water, and wild places upon which outdoor recreation depends.**

**Minimize Impact -** All recreation has an impact. Coloradans have an obligation to minimize these impacts across the places they recreate and the larger landscape through ethical outdoor behavior. **Ethical outdoor behavior demonstrates respect for land, water, and wildlife. This outdoor ethic is critical and must be developed in current and future users.**

**Management and Education -** Proactive management solutions, combined with public education, are both necessary to care for land, water, and wildlife, and to provide the protections needed to maintain quality recreation opportunities**. Active public engagement in crafting solutions is necessary to ensure that land management decisions reflect a consensus and can be effectively implemented. A broad, landscape approach is necessary in order to meet both conservation and recreation needs.** Collaborative decision-making is needed to decide which activities are best suited for various landscapes.

## Outcome-Based Planning Framework

This document is grounded in the overarching framework of Outcomes-Based Planning. ***Figure 1*** depicts the outcomes-based framework for trail planning, from identifying outcomes and needs to siting and managing a trail. The chapters in this document are organized to reflect the flow through this framework. **Chapter 1** describes the importance of building partnerships through collaborative processes, how to engage the public, and strategies to define desired outcomes (Step A). **Chapter 2** explores how to identify opportunities for trails and assess the needs of wildlife (Steps B and C). **Chapter 3** details the trail management and monitoring practices needed to minimize wildlife impacts after completing trail construction (Step D). **The Appendices** of this document provide multiple resources, including species-specific best management practices, examples of planning frameworks used in different areas of the state, and an extensive list of scientific literature used as the basis for this document.


**Figure 1. Outcomes-based trail planning framework**

## Objectives

It is our intent that this document be easy to share and to reference throughout the collaborative process of trail planning. Informed by Advisory Groups and other stakeholders, the 2021 update to *Planning Trails with Wildlife in Mind* serves the following purposes.

1. Acts as a framework for how we effectively work together in conservation and recreation, providing direction to get collaborative conversations about trails and wildlife started early, and emphasizing the value of communication and collaboration between, and within, communities.
2. Improves communication and collaboration between government agencies regarding trails and wildlife by establishing common language, and by building consensus around best practices.
3. Provides best practices grounded in current, relevant science concerning the impact of trails and trail recreation on wildlife, while remaining accessible as an educational tool for readers of all backgrounds.
4. Offers guidance to groups advocating for new trail construction or maintenance projects, detailing how to factor wildlife impact into their plans. It serves as a starting point for addressing wildlife concerns when submitting State Trail Grants, and provides a framework for how to work collaboratively with government agencies to find solutions that balance wildlife and recreation needs.

## Considerations

Since proper trail management, planning, and design can minimize impacts to natural resources and can serve as a tool to support resilient landscapes, wildlife, and biodiversity, this document offers a process to eliminate poorly managed or unmanaged use. Thus, this document should be viewed through the context of a specific project and the landscape impacted by the project. Not everything in these guidelines applies directly to every specific project, but the information and process proposed here are a great starting point for land managers, recreation groups, and conservation advocates, especially when used and considered in tandem with larger regional and local planning efforts in your area. This document is not meant to advocate for or against new trails, but rather to help determine where trails can be placed on the landscape with the least amount of impact on wildlife.

While there is a desire for this document to achieve many goals and serve many purposes, it remains focused on trails and wildlife. The following includes responses to common expectations voiced by stakeholders that lie **outside** the scope of this document:

1. The document is not intended to supersede agency-specific policies or processes – it is a guide for those who wish to enhance their policies or processes, and an explanation for why certain policies and processes already exist within some agencies.
2. The document is focused on trails as they relate to wildlife and does not focus on the extensive benefits of trails to people, as there are many other resources that serve that purpose.
3. While trails impact wildlife, they are certainly not the only source of adverse impact. Development, natural resource extraction, disease, wildfires, invasive species, roadways, and climate change, to name a few, each impact wildlife in unique ways. A focus on those stressors is outside the scope of this document. **While planning, it is important to remember the cumulative impact of other stressors on wildlife, and to put trail development in that context.**

The Task Force for *Planning Trails with Wildlife in Mind* was intentionally made up of land managers because they are seen as the main audience for this document. Ideally, when trail or wildlife needs are proposed at the local level, land managers can convene a core team as described in Chapter 1 and use this document as the guiding framework for their process. All trail proponents and wildlife advocates should ensure that the local land manager they are working with is starting from the collaborative framework outlined in this document.

# Chapter 1. The Collaborative Process

## *Collaborate early and often*

**Chapter Focus:** Diverse interest groups need to continue coming together to create strategies that work for wildlife, habitat, conservation, and recreation interests through well-facilitated collaborative processes. An extensive increase in collaboration between wildlife management, regional planning, and recreation interests, especially early in the process will result in community buy-in and excitement. It also ensures successful implementation, viable trails for the long-term, and ultimately creates better solutions. *Figure 2* provides a framework that supports collaboration between project proponents, land managers, and CPW staff, and demonstrates how to best engage the public.

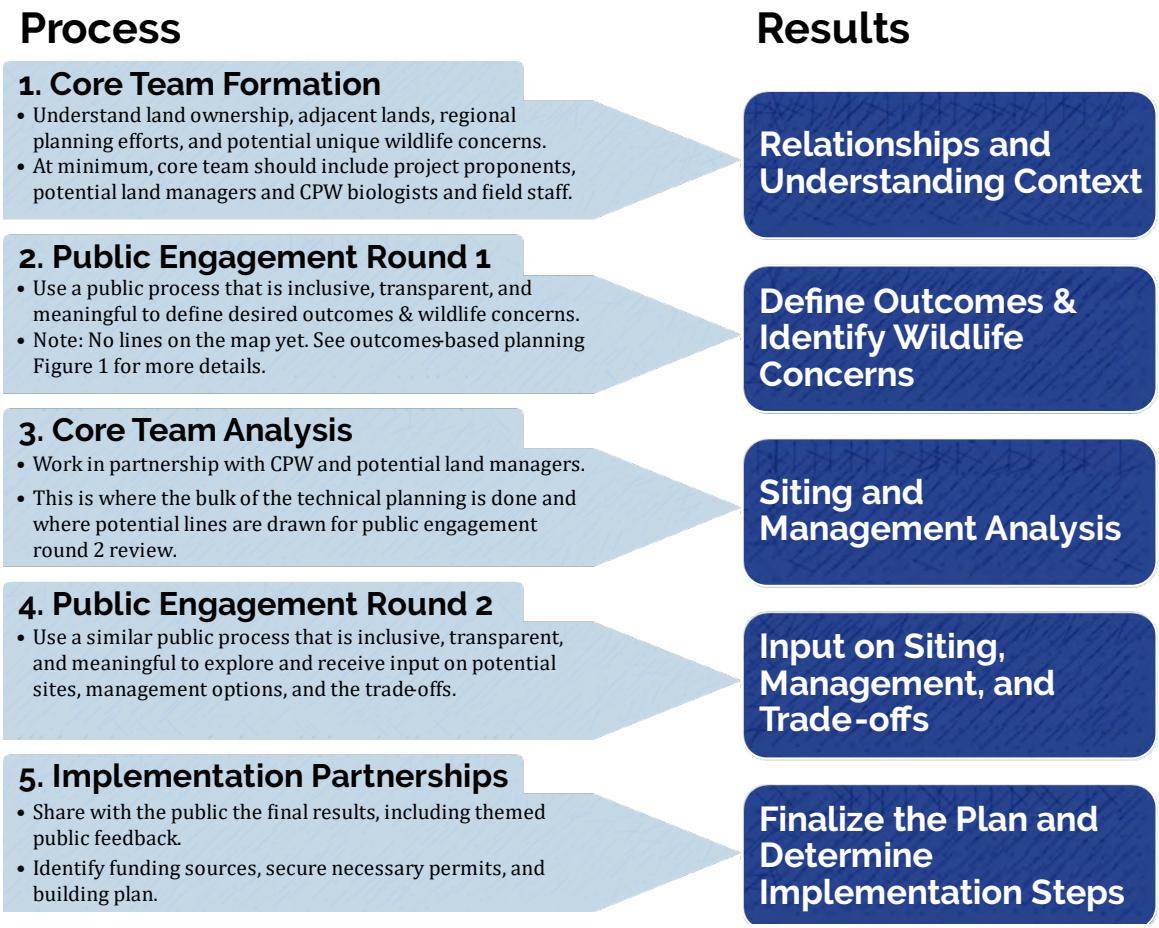



**Figure 2. Framework for collaboration and public engagement**

# Core Team Formation

## Relationships

**Partner with Agency Stakeholders.** At a minimum, project proponents should consult with local CPW biologists and field staff, appropriate land management agencies (federal, state, local, tribal, or private), and/or county or municipal agencies at the beginning of a trail planning process. Ideally, trail project proponents will form a core team that includes these and other partners. This will help project proponents engage in long-term planning partnerships with these agencies and stakeholders. By bringing agency staff and stakeholders into the process early, challenges and solutions can be identified quickly (see Chapter 2).

**Bring Conservation and Recreation Interests Together.** In addition to project proponents and agency representatives, the core team should include a liaison to the area's Regional Partnership (referenced on the next page), conservation and recreation advocates, and other key community stakeholders. Through the Outcomes-Based Planning framework established in Figure 1, this team can work together to define what success means for the project. These conversations contribute to understanding the requirements of the project before too much investment has occurred, because identifying unique wildlife resource concerns early on is the most effective method to avoid and minimize impacts to wildlife from recreational activities (see Appendix A for full list of recommendations). The core team can review data and research together, get feedback, and share interpretations, making it much easier to collaboratively identify potential trail alignments or realignments when the project reaches that step (see Chapter 2).

**Collaborate Case Study:**
Palisade Plunge

The 34-mile singletrack Palisade Plunge trail is the result of ten years of collaboration between a wide array of stakeholders, including the BLM, USFS, Bureau of Reclamation, Town of Palisade, Mesa County, City of Grand Junction, CPW, local ranch operators, private landowners, and Colorado Plateau Mountain Bike Trail Association (COPMOBA). In addition to traversing land managed by federal agencies, the trail crosses City of Grand Junction and Town of Palisade managed watersheds and property, leased ranching and hunting lands, and private property. Given the number of unique stakeholders involved, Scott Winans, long-time President of COPMOBA, noted to the Colorado Sun that "a big project like this could have been killed along the way by any one of these partners. Not out of malice, but just by having a priority that doesn't quite jibe with [everyone else's]." Fortunately, the shared vision for the Plunge was strong enough that when priorities among stakeholders differed, the only thing to shift was the proposed trail alignment.

A major consideration when planning the Plunge was the trail's potential impact on wildlife. At multiple points during the planning process the trail was rerouted to avoid sensitive wildlife areas such as raptor nests, and allowances were incorporated into the management plan to temporarily close sections of the trail near these areas if impacts from trail users were deemed too great. In addition, annual seasonal closures from December 1 – May 1 were established in elk and mule deer winter range habitat. By implementing and enforcing seasonal trail closures on the Palisade Plunge and trails throughout the Grand Valley, regional wildlife managers can provide wildlife the space and time they need to survive.

## Understanding Context

**Consider Land Ownership Implications on the Process.** Additional steps might be determined by who owns the land, how the land was acquired, and who is funding the project. Having this information may also lead to expansion of the core team. Additionally, it's important to understand adjacent land ownership and how that might impact the trail plan and wildlife.

### Specific Considerations for Federal Lands

Federal lands are managed by Federal Land Management Agencies (FLMAs) including the US Forest Service, Bureau of Land Management, National Park Service, and US Fish & Wildlife Service.

- Most FLMAs have Forest Plans (FPs), BLM Resource Management Plans (RMPs), Travel Management Plans (TMPs), or other land use management plans in place. Consult with these agencies early during the planning process to learn about these landscape-level plans.
- FPs, TMPs, & RMPs identify current and future routes, trail uses, closures, and seasonal closures. These planning processes allow advocates to get involved in planning and designing quality trails and systems.
- FLMAs are required to go through the National Environmental Policy Act (NEPA) process prior to making decisions, which, in addition to habitat fragmentation, considers vegetation, soils, air and water quality, and cultural resources. NEPA requires public comment and review opportunities.
- TMP development is a high priority for FLMAs. Many FLMAs have shifted from "open" unrestricted use of public lands to limiting motorized and mechanized travel to designated routes.
- Emphasize early stakeholder and public involvement in the NEPA and TMP processes for Federal lands (as well as state and local).
- TMPs on public lands that change strategies from an open system of travel to limited, generally reduce existing road and trail mileage significantly. New trails or networks located in less impactful areas may be proposed based on local needs with an emphasis on quality over quantity.

### Specific Considerations for Local and State Lands

- County-wide master plans.
- Municipal land-use restrictions.
- State Wildlife Area, Natural Area, and Park Management Plans.
- State Wildlife Action Plan.
- Conservation easements.

### Specific Considerations for Private Lands

- Engage with potential private land partners early in the process.
- Engage with local Land Trust(s) to understand conservation easements, and any site-specific agreements concerning agriculture, ownership, restrictions, habitat protections, ranching and livestock.
- Understand the intention of donor/seller of land or easement to use land.

**Get Involved with Regional Planning Processes.** Planning a specific trail should also be integrated into larger, regional planning processes such as Regional Outdoor Partnerships, GOCO Communities, and/or existing roundtables or other similar initiatives (e.g., Envision Chaffee County). Project proponents should understand the needs of larger regional planning efforts and how their potential project could address those needs. Working with a liaison, or participating directly in regional partnerships, encourages everyone to look at recreational trails at a landscape level versus planning one

trail at a time. Project proponents should also be sure the specific trail project is understood in the context of area recovery, management, and master plans, as well as the State Wildlife Action Plan (SWAP).

**Recognize this as an Ongoing Collaborative Process.** Be aware of the need to revisit some of these collaborative steps again and again. For example, a trail might be planned in close cooperation with a wildlife biologist, but it might not fit with the intent of a management area, a regional plan, or county planning map. It would be useful to know ahead of time whether a land use plan or Resource Management Plan (RMP) allows for trail development in a certain location. If not, alternate locations can be identified. Reviewing and understanding the direction in regional plans and existing zones and designations are important first steps in the collaborative process.

## Public Engagement

**Reach out to the Community Early and Thoughtfully.** Regional planning processes should already include community outreach, but if your trail project is not part of one of these processes, be sure to include community outreach as part of your Outcomes-Based Planning. Having a diversity of opinions and perspectives represented in your outreach and communication plans (e.g., surveys, public meetings, online forums, focus and affinity group conversations) can help achieve successful project outcomes.

**Understand the Complexities of Good Collaboration.**
success of these projects to leave collaboration to chance. Instead, ensure good facilitation, identify conflict resolution processes, and set clear expectations from the outset for both the core team and public engagement. Also recognize that collaboration doesn't always mean full consensus and may often require acceptable compromises. For example, encourage people to come together through shared values, such as the Colorado Outdoor Principles. In addition, productive engagement and collaboration starts with the following:

1. Use a participatory approach: Engage in a participatory approach. Many projects should have at least two windows of engagement. The first typically focuses on unmet needs and the second on solutions. All meetings should be full of engagement and be fully inclusive, relying on adult learning methods. Get the participants talking early and mix up any presentation time every five or ten minutes. Otherwise, people will not be able to pay attention for long.
2. Ensure participant diversity: Find diverse community members by advertising and showing up at locations where they engage the community (e.g., local businesses, the grocery store, local paper, places of worship, etc.). It is critical to bring to the room not just the typical folks who engage but people who represent all interests, and especially those who are most impacted by the effort and those with lived experience. Diversity of opinions ensures that the feedback is truly balanced.
3. Engage community members in the data: While it's important to have community opinions, it's also important that when data is available, this data is clearly communicated to community members. Just as managers and planners each wrestle with data to find the best approach or understand needs, the community can also provide their perspectives after considering the information.
4. Rely on and support community members: When convening focus groups or community meetings, tap into local members who can speak the preferred language, be culturally sensitive, and speak as a member of the community. Work to build local capacity within the community where there is a need.
5. Provide strong accessibility: If hosting meetings or focus groups, find out what the community members need to participate, such as childcare, compensation, certificate of recognition, food, specific meeting times, translation and/or interpretation, transportation, etc.

6. Support community's power: Tap into the community's own power – learn where the community needs support from your group and provide that to augment their work.
7. Follow-up: After the event, communicate on the project's progress to the interested public and describe how they helped shape the effort. Learn from each meeting and improve! Don't be shy to share what you've learned.

*Helpful considerations from the field*

- Do not draw lines on a map or share a specific trail alignment with the public too early. Instead consider using circles to convey general areas of interest.
- Be transparent about the actual cost/benefit modeling so that the community and stakeholders can make informed, intelligent decisions together.
- In the absence of regional planning processes, additional stakeholders to engage with during a trail-planning process might include conservation groups, recreation advocates, local and regional governments, user groups, landowners, and local communities.

**Ensure the Process Incorporates Equity, Diversity, and Inclusivity Values.** When designing a process for regional planning or trail planning, an inclusive and equitable process is critical. This includes direct outreach to bring traditionally under-represented communities into the conversation to ensure diverse participation. This engagement is a critical step in ensuring that the process balances the true range of community and user needs while increasing the possibility of successful outcomes for all parties. One goal should be to get people involved early and keep them engaged throughout the planning effort. The State of Colorado's Community Partnerships Principles Guide is a great resource to support implementation.

**Maximize Data-Informed Decisions During the Collaborative Process.** While projects might be driven locally or by specific recreation interests, scientifically validated tools should be used to help make data-informed decisions. As a reminder, Chapter 2 provides an overview for desktop and field analysis, as well as siting considerations. This guidance is complemented by Chapter 3, which offers recommendations for trail maintenance and management. Appendices A and B of this document dive even deeper into the research.

Questions to answer collaboratively:

- Considering the full community, including those traditionally under-represented in trail conversations, what types of trail opportunities are most needed and missing from the landscape?
- Where do people want to recreate (near water, access to peaks, easy accessibility, etc.)?
- How do they want to recreate (use types based on region)?
- How do they consume information (signage, education, communication methods)?
- What are the intended uses, experiences, and desired recreation opportunities for the trail system?
- What are the prioritized or most abundant recreation types for this area and for this trail? How many users can the trail and the surrounding landscape accommodate? (See the Visitor Capacity Guidebook for a reference.)
- Where can trails be built that minimizes impacts to wildlife? (To be analyzed in processes described in Chapter 2 and for discussion during round 2 of public feedback.)

**Public Engagement Round 2 and Beyond.** Clear public communication and education remains critical throughout the process. After completing desktop and field analysis (see Chapter 2), planners and core team members should reengage the public to discuss alternative trail locations and what the

potential impacts could be on the landscape. Share awareness about wildlife and areas of concern, and keep in mind that when the public thinks about wildlife, they are often only thinking about big game (deer, elk, moose, pronghorn, and bear). Communicating a broader understanding of wildlife and habitat supports the overall transparency of a project.

*Helpful considerations from the field*

- The public outreach process can help the public understand the greater biodiversity of the area, learn how their roles can minimize impacts, and the see the reasoning behind certain planning decisions.
- Transparency is key – It's important to share available information, while making sure the public understands that CPW doesn't have conclusive data on every habitat and species in the state.
- Put the science in context. The available data, science, and literature are very detailed, and wildlife managers or other experts can help interpret and apply the science appropriately.

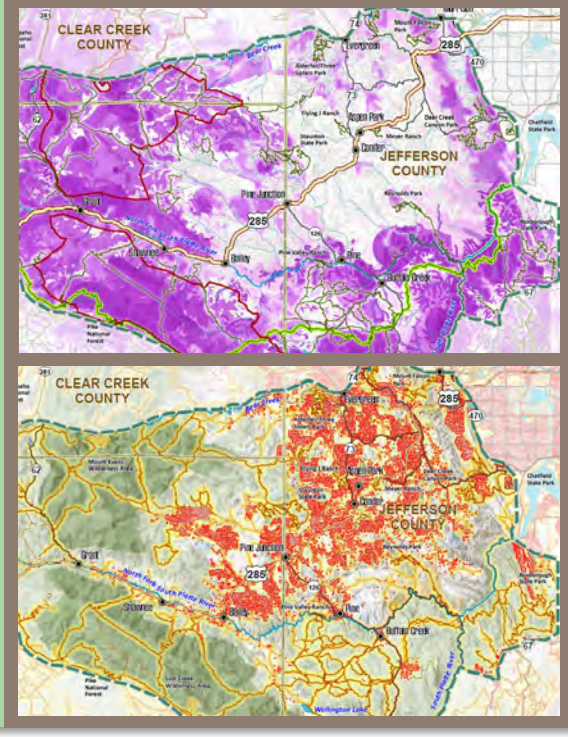
## Outside 285 Case Study

As part of an ongoing process, the Colorado Mountain Bike Association (COMBA), CPW, and the South Platte Ranger District of the Pike National Forest have initiated a regional planning effort focused on identifying opportunities for trail improvements and wildlife habitat conservation within public lands surrounding the US-285 corridor southwest of Denver. Together with a steering committee of 19 other land managers, wildlife biologists, wildlife advocates, and recreation user groups, the group is undertaking a year-long planning process to develop a Master Plan that proposes regional recommendations for conservation, recreation development, management, and maintenance. In the summer of 2020, the group conducted a habitat analysis of the Outside 285 region and created two maps: An Existing Disturbance Map and a Habitat Sensitivity Map.

To generate the Existing Disturbance Map, the planning team considered a variety of existing developments and human uses, ranked from high to low disturbance potential. To make their model as relevant to on-the-ground conditions as possible, they also considered multiple levels of disturbance from a single source. For example, existing trails were given both a medium-disturbance radius of 100m (recognizing that the highest intensity impacts are close to trails) and a low-disturbance radius of 400m (recognizing that lower intensity impacts extend well beyond the immediate trail area). This incorporates into the mapping process the fact that higher intensity disturbance exists on and near trails, but that even wildlife farther away may still be disturbed by recreation.

The Habitat Sensitivity Map highlights those areas within the region with the highest relative sensitivity and conservation priority. The map was created using a collection of publicly available GIS data and first-hand knowledge from CPW and USFS field personnel concerning known or potential habitat for endangered, sensitive, and species of management concern. This data was categorized into three priority levels – A, B, and C – based on the level of sensitivity of each habitat type, their federal listing status, USFS sensitive designation, CPW importance, NatureServe rank, and State Wildlife Action Plan (SWAP) tier.

Used in conjunction with one another, these analyses allowed the planning team to identify focus areas within the region. These included areas with existing issues or habitat impacts, and areas presenting opportunities for new trails, trail linkages, and habitat restoration.



# Chapter 2: Evaluating Wildlife Needs and Trail Opportunities

**Chapter Focus:** This chapter serves two main purposes. First, to enhance trail project planners' and core teams' understanding of wildlife concerns and limitations. Second, to explain how to take these issues into account when considering trail siting opportunities. The chart below outlines the three components of understanding limitations and siting, which are then examined in greater detail throughout the chapter.

**1.** **Evaluate Wildlife Habitat.** Specific considerations include:

- Utilize existing scientific tools and research as references, such as CPW's High Priority Habitat Maps, for evaluating wildlife habitat relative to trail projects.
- Consider threatened, endangered, imperiled, and declining wildlife species.
- Evaluate existing trails, both for potential improvements that might lessen the need for additional trails and for potential closure and restoration opportunities to offset impacts of new trails.
- Complement the desktop analysis by conducting a site visit with local CPW staff.
- Evaluate seasonal wildlife use by life cycle needs.

**2.** **Siting Considerations.** During a site visit, consider the following elements and opportunities with regard to potential trail locations:

- Understand zones of human influence and disturbance.
- Consolidate high-density trail networks in less sensitive wildlife habitats.
- Avoid habitat fragmentation and maintain habitat connectivity.
- Identify potential human-wildlife interactions.
- Identify habitat restoration opportunities.
- Plan for mitigation.

**3.** **Consider human dimensions that impact wildlife and habitat.** These include but are not limited to:

- The driving forces behind people's decisions.
- The human behaviors that lead to change.
- The effects of change on natural resources and quality of life.
- Management strategies to address change.

## Overview

There are often multiple competing priorities in open space that land managers, stakeholders, and the public need to understand. Sometimes limited resources, competing priorities, critical wildlife values, and conflicting stakeholder needs require trade-offs to maintain collaborative conservation and recreation relationships over the long-term. This chapter is not meant to advocate for or against new trails. Instead, it is meant to help determine where trails can be placed on the landscape with the least amount of impact on wildlife.

As land managers seek to accommodate recreational demand, it's important to recognize how trails can function as a tool to manage where people go on the landscape. **Trail design should minimize the impacts that people have on the natural resources of a given landscape, including both wildlife and their habitat. Good trail design also enhances the visitor experience and provides opportunities to enjoy the natural world, which includes viewing wildlife.**

The decision to add a new trail means you are introducing a new use, and any associated impacts, onto the landscape. *Figure 3* provides a framework for understanding the decision process of where a trail might be sited relative to habitat. In some cases, such as for threatened and endangered species, if impacts cannot be avoided, and minimization and mitigation efforts cannot sufficiently protect the species, a trail may not be able to be built in that location. Doing an evaluation of the existing site conditions at the beginning of this process can help a land manager or trail planner decide where those trails belong on the landscape and what areas it would be best to avoid.

NOTE: This decision tree does not take the place of a site visit or consultation with land managers; nor does it account for exceptions to the rule (e.g., developing a trail instead of more impactful development). Trails may also need to avoid any impact to federally threatened or endangered species or if avoidance is the only acceptable strategy to prevent wildlife impacts. As such, a trail planning process may need to pause prior to "minimize." See the following page for definitions of terms.

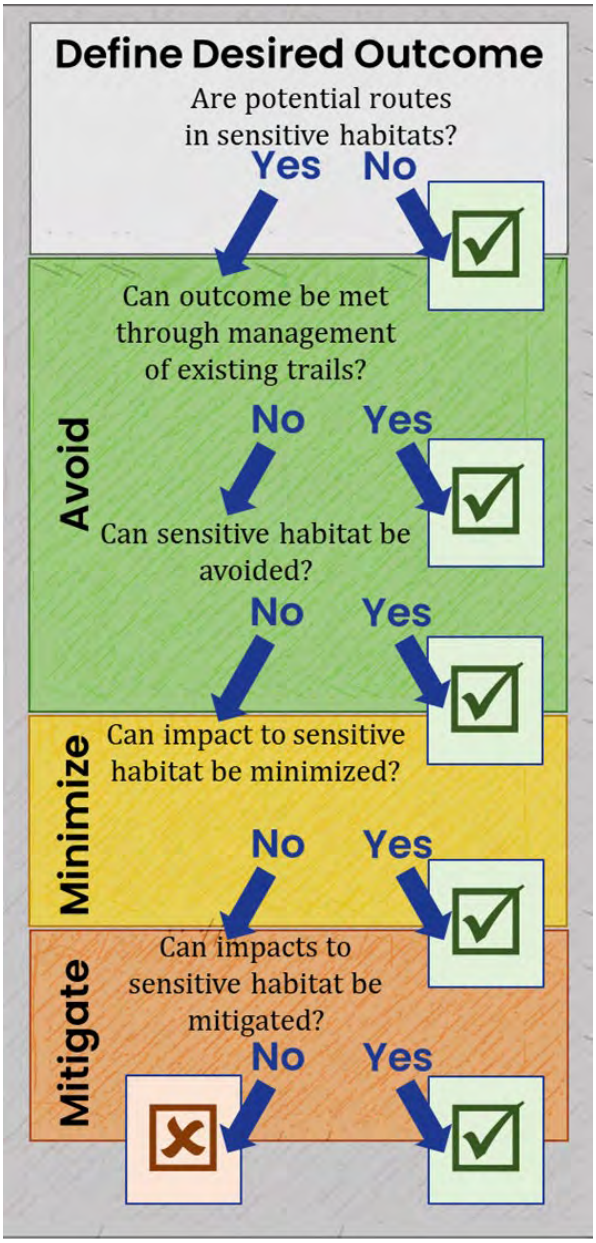



**Figure 3. Simplified decision tree for trail siting with wildlife in mind.** *Sensitive Habitat is used as a catch-all term for specific habitats in which avoid-minimize-mitigate measures may be necessary. Checked boxes indicate that a trail may be possible based on its potential impact to wildlife or habitat. A box with an X indicates that trail approval is unlikely based on its potential impact to wildlife or habitat.*

*Helpful considerations from the field*

- Data needs to include human dimensions (see overview, Chapter 2) and the user experience; the purpose, goals, and capacity of the trail or trail system; and a nuanced understanding of the flora and fauna and its needs in their area.
- Data does not automatically determine decisions but does highlight sensitive wildlife habitats and provides a scientific basis for project planning.
- Scientific information referenced in this process should be sound and peer reviewed.
- Consider the concept of a "sliding scale for data needs." Not every project needs extensive data collection. For example, a project in low-quality habitat may require less data to feel confident in moving forward. In contrast, a project in a sensitive habitat would likely need more data. Working collaboratively from the outset ensures that the wildlife biologists, recreation interests, and planners are working together to decide what data is needed and how it can best be used.

## Key Terms and Concepts

*The following terms and concepts are used throughout this chapter and are explained here:*

- Habitat. A place where an organism makes its home, and that meets all the environmental conditions an organism needs to survive. The components of a habitat are water, food, cover, and space, all in a suitable arrangement. For a wild animal, essential habitat includes water, forage, cover, breeding, and reproduction areas, as well as movement and migration corridors to connect all of these components daily and throughout the year. Habitat management is an essential aspect of wildlife management, and it ensures the essential needs of wildlife species are met.
- Avoid Impacts. Strategies that place trails or sites for ancillary facilities (e.g., parking lots, trailheads) outside of biologically sensitive habitat types.
- Minimize Impacts. Strategies that reduce biological impacts through the application of Best Management Practices to reduce the extent, severity, significance, or duration of unavoidable impacts.
- Mitigate Impacts. Strategies that compensate for unavoidable adverse impacts to wildlife and habitat, including habitat replacement, on- or off-site habitat enhancement, or contribution to larger scale conservation projects.
- Seasonal Timing Restrictions. A restriction on trail use during defined date ranges that captures an important and sensitive life history stage for a given species. Examples include reproduction and wintering periods when animals are in a vulnerable state.
- Buffer Zone. A defined distance (radius) surrounding a sensitive wildlife location, such as bird nest sites or grouse lek sites, where human activities should be limited to protect the given wildlife resource from disturbance. Disturbance within the buffer could cause a decline in wildlife reproduction or survival. Each recommended buffer distance is based on the best available science and CPW's field staff expertise.
- Production Area. That part of a species' overall range where production (calving, fawning, nesting, etc.) and rearing of young occurs. This activity often occurs in the spring of each year for most species.
- Migration Corridor. A specific mappable site through which large numbers of animals migrate and loss of which would change migration routes.

- Migration Pattern. A subjective indication of the general direction of the movements of migratory ungulate herds.
- Habitat Connectivity. The degree to which the landscape facilitates or impedes animal movement and other ecological processes.
- Habitat Effectiveness. The relative amount of habitat that is fully usable by a given wildlife species, compared to the total amount of potential habitat.
- Sensitive Habitat. Any distinguishable habitat that either exists in a limited quantity relative to the broader landscape (e.g., riparian), and/or those that are very difficult to restore once they've been damaged (e.g., tundra).
- Sensitive Species. Any species whose habitat, distribution, population size, and population condition is adversely affected by pressures arising from human activities.
- Zone of Influence (ZOI). The area beyond a route's physical footprint in which on-trail activities affect wildlife behavior and habitat use.
- Winter Concentration Area. That part of the winter range where densities were at least 200% greater than the surrounding winter range density in the majority of the previous ten years.
- 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.
- Route Density. A measurement to assess the number of given roads and trails within a defined geographic area. For the sake of this document, densities are indicated as the number of road/trail miles per square mile. This can be calculated across different scales depending on the scope of a proposed project and wildlife habitats present.

# Evaluating Wildlife Habitat

**Use Desktop Analysis Tools.** Prior to visiting potential trail sites, planning teams should conduct a desktop analysis, or analysis using previously collected data, to understand opportunities for trail alignments. Extensive scientific tools and research exist as references for evaluating wildlife habitat relative to trail projects, such as CPW's High Priority Habitats and Species Activity Mapping. By using one of these tools, such as CPW Species Activity Mapping tool, CPW species layers, Colorado Conservation Data Explorer (CODEX), forest-wide models of potentially suitable habitat for Canada lynx or Mexican spotted owl, USFWS critical habitat units, and the Colorado Hunting Atlas, the core team can review many of the habitats that a trail may intersect when considering a new route (additional tools in Appendix C). The team can then create a list of species and habitats with which the potential trail might overlap. While these tools are effective to understand large-scale wildlife presence, they are less effective at a local level and cannot replace consultation with local CPW staff. This chapter's best management practices chart and the Appendices can be used to better understand concerns and begin potential avoidance, minimization, and mitigation efforts early on in the planning process.

Questions to ask:

- Where are the important habitat and resources on the landscape that should be avoided?
- Can trails avoid fragmenting large blocks of intact habitat?
- Can trails be concentrated with a higher density in areas with lower value for wildlife?
- Can low trail density be maintained in areas that have high value for wildlife?
- Where can trails or other habitat disturbances be rehabilitated, consolidated, or reclaimed to mitigate potential trail impacts?

> *Helpful consideration from the field:* The tools referenced here can help planners and advocates who don't have an extensive scientific background understand the outer limits of trail development in a specific area. The tools can also reduce a planner's frustration by helping them learn about wildlife management or science considerations earlier in the process, rather than after much effort has been put into shaping the specifics of a potential project.

**Conduct an Evaluation of Existing Impacts.** It is important at this stage for the core team to understand the geographic context of existing trails and other uses on the landscape that impact wildlife. This includes evaluating cumulative impacts to wildlife from factors other than trails, such as grazing leases, oil and gas operations, and climate change. Existing trails can be evaluated for potential improvements or maintenance work, such as new design features to enhance the user experience, trail connections, or reroutes to address resource damage. Similarly, illegal user-created routes (often called social or rogue trails) or poorly designed trails that fall within sensitive wildlife habitat should be evaluated for potential decommissioning and restoration to improve habitat and compensate for new trail disturbance.

Questions to ask:

- What is the trail density in the area surrounding the planned trail?
- What other trails are in the area? How can they connect? (see Regional Planning referred to in the Introduction and Chapter 1).
- Where are the user-created trails? What is causing them to occur (i.e., are people traveling on an undesignated path as a shortcut to the desired destination)? How can this issue be addressed?
- Can you improve access to a desired destination and decommission the unsustainable user-created trail(s)?

**Consider Threatened & Endangered (T&E), Imperiled, & Declining Species.** Areas with T&E species and species of national and local concern need further consideration, especially if the project doesn't require a NEPA analysis. A few useful resources for considering T&E species include CPW's T&E species list, CODEX, the USFWS tool to map federally designated critical habitat, and CPW sensitive species map.

> *Helpful considerations from the field:*
>
> - Work to keep common species common.
> - Be sensitive to overall biodiversity, taking into consideration diverse flora and fauna.

**Conduct a Site Visit.** Desktop analysis should be followed by a site visit to verify habitat and wildlife concerns. Conduct the site visit and evaluation with core team stakeholders, local CPW staff, a land or natural resource manager, and/or biologist to ground truth the desktop analysis information and discuss potential recreation impacts to wildlife species in the area. This analysis is more important than trying to

apply broad ecological concepts that may be true in some places, but not in others. **Use the summary checklist found at the beginning of this chapter and the chart at the end for the site visit.**

> *Helpful consideration from the field:* While on site, discuss known and anticipated habitat conditions and year-round species use of the area. Also discuss existing user impacts to establish baseline data for future monitoring. Consider if baseline ecological surveys exist or are needed for your trail site. Plan for ongoing monitoring and potential enforcement needs as part of the project development.

### Points to keep in mind during the site visit:

- Identify opportunities to consolidate high-density trail networks and recreation facilities in less sensitive wildlife habitats in order to maintain recreational access, while minimizing new impacts to wildlife species and their habitats.
- Avoid fragmenting large blocks of intact habitat with new trails, such as open meadows, forest stands, riparian areas, or wetlands.
- Maintain or rehabilitate native vegetation (i.e., trees, willows, shrubs, etc.) between trails, open areas, and other sensitive sites. Consider how disturbance from trail construction might introduce non-native vegetation, and plan for the implementation of weed control as necessary. Try to use existing vegetation as a screen to reduce the distance that animals perceive recreational users to be a threat.
- Identify potential human-wildlife interactions and plan trails accordingly. Route trails away from potential high conflict areas, such as high-quality bear forage or moose habitat. Provide signage in areas of existing or potential conflict between people, dogs, and wildlife species. Monitor wildlife encounters for adaptive management (example: Jefferson County Open Space Human-Wildlife Interactions)
- Understand zones of influence and disturbance, and plan for necessary wildlife mitigation practices. Trail management can greatly reduce the zone of influence of a trail by reducing density or intensity of trails in sensitive areas.
- Recognize potential opportunities to enhance and rehabilitate degraded landscapes through restoration during trail development and construction.
- Anticipate the impacts of off-trail features like rest spots, views, water sources, and shade, and the impacts those might cause. Consideration of areas that people naturally gravitate to early in the design stage is critical. If they aren't considered early on, users may create illegal trails to gain access to these places, potentially damaging habitat.
- Identify wildlife impacts caused by dogs on- or off-leash. In addition to expanding their human's zone of influence, dogs can chase, harass, and kill wildlife, or become prey for carnivores. Consider restrictions to dogs if necessary, and leash laws to keep pets safe and minimize impacts to wildlife.
- Consider the effects of trails in the absence of recreation. Trails themselves can be a conduit for modified species travel, including invasive species, and in other cases can act as a barrier to movement for some smaller species.
- Consider which types of existing and emerging recreation are appropriate for a given trail. Technology for trail-based recreation is constantly evolving, and new types of trail use, such as E-bikes, are important to consider in the trail planning process.

# Siting Considerations: Avoid, Minimize, Mitigate

## Overview

The following contains best management practices (BMPs) for recreational trail planning and construction, which are intended to avoid and minimize adverse impacts to Colorado's wildlife species and their habitats. **There are no "one size fits all" rules, but this section shares effective practices that should be considered and incorporated as appropriate.** These recommendations are based on peer-reviewed scientific research focused on impacts to wildlife from human disturbance, including recreation. A full list of BMP recommendations can be found in Appendix A, and additional documents from the published literature can be found in Appendix B.

The BMP recommendations are aligned on a continuum of actions that follow the mitigation hierarchy of Avoid, Minimize, and Mitigate. Where possible, development should avoid impacts to biologically sensitive habitats. If avoidance is not possible, then measures should be taken to minimize impacts. Finally, impacts that are unavoidable or cannot be minimized should be mitigated. To balance the needs of multiple wildlife species, many trails use BMPs across the spectrum of avoid, minimize, and mitigate. For example, the trail might avoid the most threatened species, while minimizing impacts to big game, and mitigating impacts on other sensitive species.

## Avoiding Sensitive Habitats

It should be noted that not all trails are built in pristine habitats, and recreational opportunities should be commensurate with the environment. Considerations should be taken for whether the potential trail sites are in urban or "primitive" settings as described in the Recreation Opportunities Spectrum. This spectrum is described in this U.S. Forest Service Primer and the Adaptation for State Lands Planning. The reality is that many land managers have jurisdiction over property that falls into multiple zones between urban and designated wilderness. One of the first outcomes for any planning process should be to decide which areas should allow human use on the landscape and which should be conserved for the protection of resources.

**Minimize Impacts Case Study:**
Ben's Down 'N Out, Durango

Surrounded by incredible terrain, Durango is known for its vast array of trails near town. Mountain bike trail proponents approached the City of Durango with a desire for more advanced trails, which could also serve to connect trails in the popular Horse Gulch trail system. Several potential alignments were evaluated, including creating a new trail across an undisturbed hillside. The final alignment repurposed a historic fire break, which minimized new impacts to the surrounding habitat. This met mountain bikers' desire for a different user experience while minimizing the need for additional habitat disturbance. The project is now a favorite among the area's downhill mountain bikers.

With that in mind, some sensitive species, such as certain amphibians and nesting songbirds, require minimum buffers of approximately 300 feet. Other species, such as nesting raptors or grouse, require buffer distances that range from a quarter to one full mile, or greater. *Figure 4* depicts the buffers recommended to avoid impacting certain sensitive species.

It is also recommended that trail planners and core teams establish adequate buffers between new trails and riparian or wetland habitat types. A large portion of Colorado's wildlife species utilize riparian habitat for some portion of their life history. Minimizing disturbance within these areas remains of high importance.

## A Note: Small Parcel Sizes

City and County open space programs often acquire parcels that are relatively small (0.5 acres-100 acres). These are often strategic acquisitions to protect wildlife habitat and open space from fragmentation and development, or to connect and provide access to other public lands. The framework outlined in this document can be used to appropriately plan land management activities and recreational use on these parcels to accommodate wildlife habitat needs. Property-specific management plans may be the most appropriate place to outline the wildlife values that the community is interested in conserving. It may be necessary to conduct site-specific inventories and monitoring to gather data to inform implementation decisions and determine the appropriate scale for protective measures. If wildlife habitat extends to adjoining lands, this connectivity should be taken into consideration and management should be coordinated with the adjoining land managers.

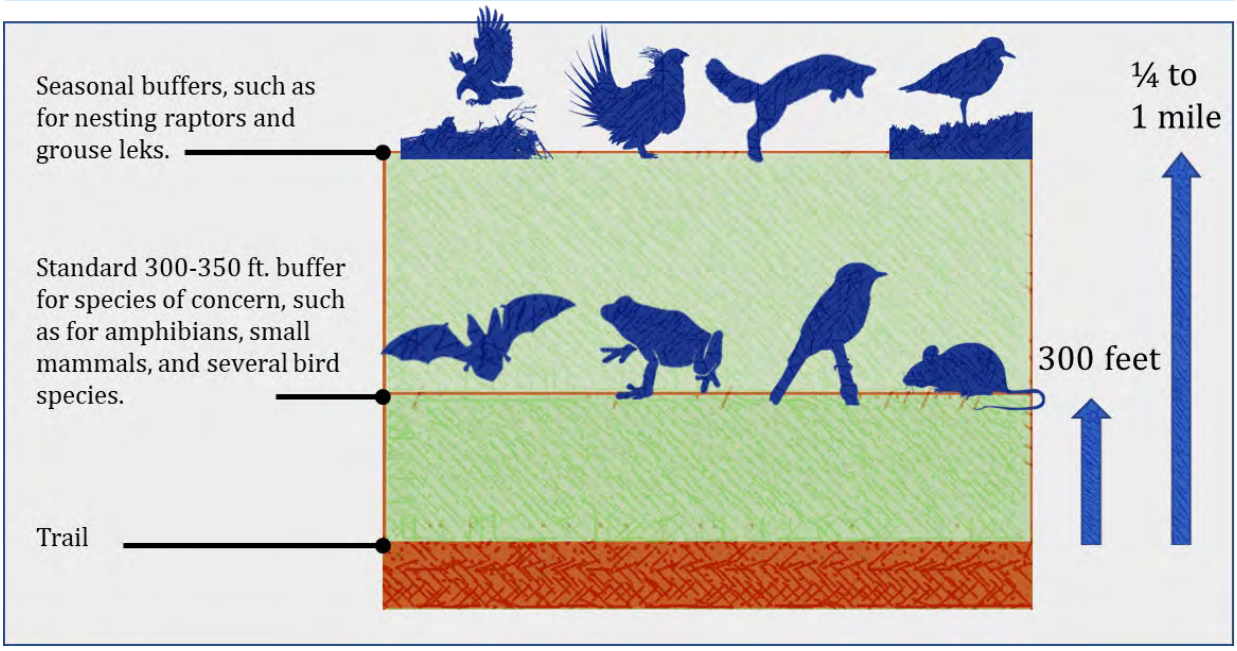



**Figure 4. Buffer zones vary depending on species type.**

## Minimizing Wildlife Impacts

If impacts from trails cannot be avoided, consider minimization strategies. When reviewing potential trail alignments, strive to minimize habitat fragmentation by maintaining large blocks of undisturbed core habitat in the project area. One way is to redirect trails around, rather than through, areas of intact habitat (*Figure 5*). To achieve the goal of minimizing habitat fragmentation, there are three strategies to consider:

- Consolidate high density trail networks and recreation facilities in less sensitive or already disturbed habitats.
- Limit route densities within high priority habitats to an average of 1 linear mile of road or trail per total square mile for the species indicated in the best management practices table.

- **Restrictions** may also be needed, such as seasonal trail closures or dog limitations.

Depending on the existing levels of disturbance, habitat type, wildlife sensitivity, and intended trail use(s), one strategy may be more applicable than the others. For example, higher route densities may be appropriate in areas already impacted by development or located outside of high priority habitats; whereas low route density may be appropriate, or required, to maintain the effectiveness of large blocks of unfragmented or sensitive habitat areas.

To minimize wildlife impacts, it is critical to account for how proposed trails interact with blocks of habitat. Habitat is directly lost due to the development of infrastructure (e.g., roads, trails, trailheads, parking areas), and additionally through avoidance of these areas by wildlife (Sawyer et al. 2017). As route densities increase, buffer zones (zones of influence) may increasingly overlap with each other, severely reducing habitat effectiveness or eliminating wildlife habitat altogether. In other words, the cumulative effects of multiple trails and other routes with overlapping buffer zones can impact a substantially larger area compared with the habitat
loss from the routes themselves. The strategies listed above work toward minimizing buffer zone overlap to maintain functional blocks of habitat and connectivity of movement corridors.

There are two important considerations to keep in mind with route density:

- Site-specific factors, such as topography, may influence the quality of habitat, and are not accounted for in the calculation for route density.
- Route density calculations do not necessarily account for how trails are spatially distributed across the landscape (*Figure 6*).

**Seasonal Wildlife Closures Case Study:** Jefferson County Open Space

Jefferson County uses seasonal wildlife closures in their parks to protect species at sensitive times in their life cycles. Seasonal wildlife closures apply to all park visitors and all types of visitation. Jeffco Open Space staff use applicable Federal, State, and local laws and guidelines, as well as knowledge of wildlife populations to delineate closure areas and time periods. Closures are put into place in response to conditions on the ground to protect sensitive species, especially considering the high levels of use on Front Range trails. Jeffco Open Space Natural Resources staff and wildlife monitoring volunteers monitor local conditions during closures and adjust as needed.

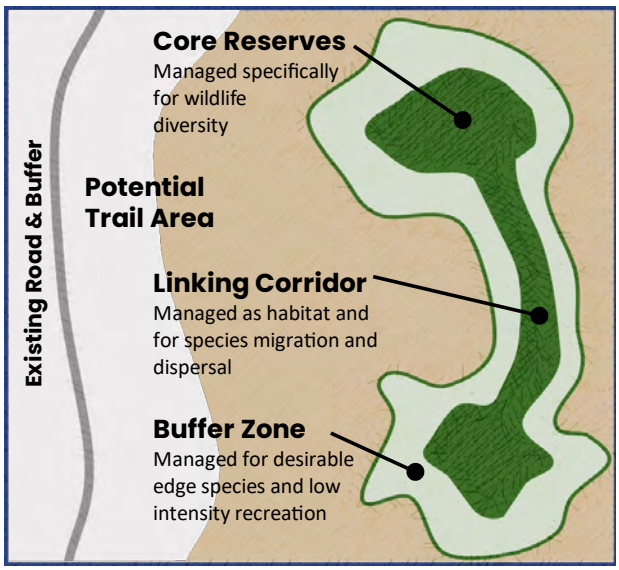



**Figure 5.** *An example of unfragmented habitat. Core habitat is farthest away from any disturbance and is typically managed for wildlife. Buffer zones surround core habitat and may be managed for low-intensity recreation. Whenever possible, medium to high-intensity disturbance should be located beyond the buffer zone. (Adapted from NRCS.)*

The overarching intent of the route density consideration is to minimize habitat fragmentation and loss of habitat functionality for wildlife. It is important to note that this consideration is meant as a starting point for conversation about how to minimize wildlife impacts, and is not regulatory in nature. Also, route density only applies to specific high priority and sensitive habitats and species – there are many areas in the state where it isn't (see Appendix B for more detail). Consultation with local agency staff and on the ground evaluation of the habitat are important to avoid any misapplications of route density. Remember that these strategies are part of a larger suite of BMP recommendations; it's always important to consider how other strategies can be applied to minimize and/or mitigate impacts on wildlife.

**Figure 6.** *The spatial component of trail density. These two images have identical trail densities. The image on the right shows how consolidating trails can be an important consideration to achieve the goal of minimizing habitat fragmentation.*

## Mitigating Wildlife Impacts

Not all impacts to wildlife from a proposed project can be avoided. For unavoidable residual impacts, consider working with local CPW staff to design and implement habitat mitigation strategies. If impacts to T&E species are unavoidable, further consultation with USFWS will most likely be required. Options to restore or enhance wildlife habitat may include:

- Decommissioning and reclaiming illegal user-created trails to enhance and/or reconnect habitat.
- Enhancing habitat through mechanical vegetation treatments, noxious weed management, wetland restoration, and reseeding and planting native vegetation.
- Removing unnecessary fencing within or near the project area that pose a threat to wildlife, such as abandoned grazing fences. When new fencing is necessary, such as around new parking areas or trailheads, use the CPW's Fencing with Wildlife in Mind specifications.
- Contributing to a larger scale habitat project or land acquisition to protect and conserve wildlife habitat.

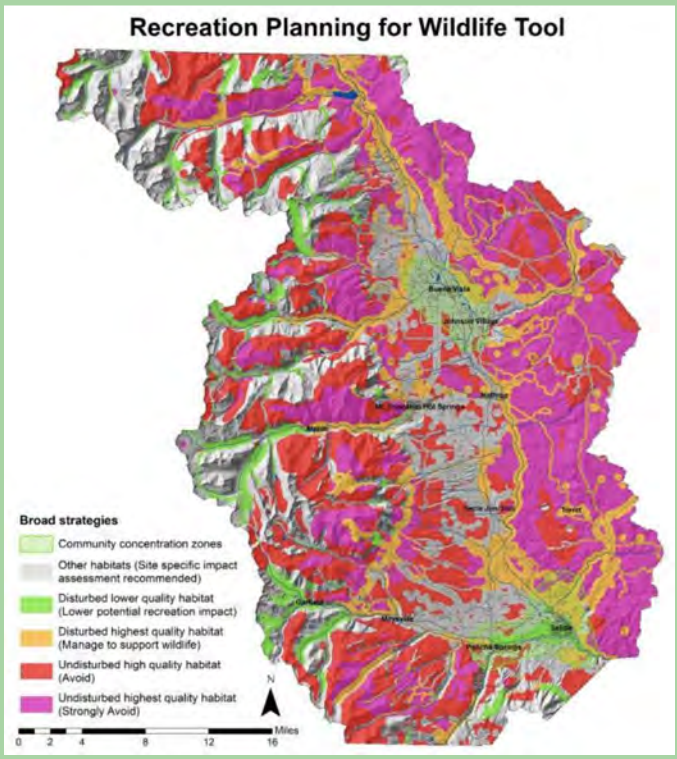
### Enhance Wildlife Habitat Case Study: Denver's Central Park Westerly Creek

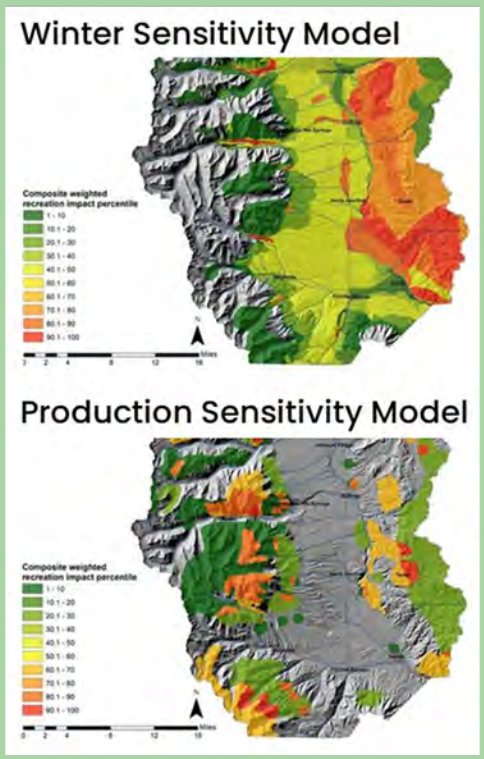
Even in an urban setting, wildlife habitat can be improved. One approach is for trail planners to seek out opportunities to restore or enhance habitat in already impacted areas during the planning process. Planners in Denver's Central Park neighborhood planted native vegetation. In addition, "large concrete chunks [from the former Stapleton International Airport] were used like stones to line the hike and bike trails and retain the soil of low rolling slopes around the bridge. The concrete slabs look amazingly 'natural' — almost like stone rockfalls…. The beauty of the Westerly Creek Trail makes it a local favorite" (Westword, 2010). This created habitat is featured along the creek in the urban park and is popular for birding. Although this area will never be a pristine habitat, the park allows visitors to experience a direct connection to nature in the middle of Colorado's largest metro area.

## Envision Chaffee County Case Study

Envision Chaffee County and the Chaffee Recreation Council created an all-lands management plan to address the community-identified need of balancing the health of the natural environment with the abundant opportunities for recreation that the area offers. To inform this plan, the two groups designed and implemented a recreation survey, which indicated broad support from both residents and visitors for prioritizing environmental health over the recreation experience, and for land managers to implement new management actions to support the needs of wildlife and their habitat. After assessing current wildlife trends and finding 65% of indicator species populations to be in decline, the Council and community set a goal to stabilize, and ideally reverse, these trends.

To start, they asked, "Can we create a recreation suitability tool that helps to protect wildlife as recreation grows, and will it be useful to groups in the community as they plan management actions and potential new recreation development?" Using a framework similar to their community wildfire protection plan, they compiled species and habitat data and used geospatial modeling to get a picture of the cumulative potential impacts of recreation on 44 species of wildlife and their unique habitats. Data was adjusted for species lacking precise or up-to-date mapping to maximize the tool's efficacy. Envision also evaluated and mapped existing disturbance intensity from recreation and development. By combining these two maps created a Recreation Planning for Wildlife Tool (below). This tool won't replace site-specific analysis but will help identify the following: undisturbed sensitive habitats that should be avoided; important habitat with existing disturbance in which management can help minimize or mitigate any further impacts; and low sensitivity or highly disturbed areas in which recreation development would be most suitable.



## Summary of Avoid-Minimize-Mitigate Recommendations

The recommendations within this chart represent suggested best management practices for avoidance, minimization, and mitigation actions to protect wildlife, wildlife habitats, and the safety of recreationists during the trail siting, design, and approval processes. The species included below do not capture all of the wildlife species that may be impacted by trails. Refer to Appendix A for more detailed species-specific recommendations.

| | Avoidance | Minimization | Mitigation |
|---|---|---|---|
|  **Big Game Species** Bighorn Sheep, Elk, Deer, Pronghorn, and Mountain Goats | • Avoid locating new trails within CPW-mapped production areas, migration corridors, and winter range habitats. | • Limit trail densities (including existing trails) to less than one linear mile of trail per total square mile, within production areas, migration corridors, and winter range habitats.<br>• For trails within production areas or winter range habitats, implement seasonal timing restrictions for all trail users.<br>• For trails within winter range, production areas, summer concentration areas, and in moose habitat, restrict dogs or implement and enforce year-round dog-on-leash restrictions.<br>• Post signage to prohibit feeding and harassment of big game.<br>• Within moose habitat, post signage to protect human safety. | • Decommission and reclaim routes in sensitive habitats<br>• Perform habitat enhancement projects.<br>• Remove and/or replace old fencing that is hazardous to wildlife. |

| | Avoidance | Minimization | Mitigation |
|---|---|---|---|
|  **Grouse Species** Greater Sage-Grouse, Gunnison Sage-Grouse, and Columbian Sharp-Tailed Grouse | • Avoid locating new trails within 0.6 miles of Columbian Sharp-tailed Grouse lek sites, and within 1 mile of Sage Grouse (Greater and Gunnison) lek sites.<br>• Avoid trails in priority habitat for Greater Sage Grouse. | • Limit trail densities (including existing trails) to less than one linear mile of trail per square mile on average.<br>• Columbian Sharp-Tailed Grouse: For trails within winter range, implement seasonal timing restrictions for all trail users from Nov. 15 – Mar. 15. For trails within production areas, implement seasonal timing restrictions for all trail users from March 15 through July 30.<br>• Greater Sage-Grouse: For trails within priority habitat management areas, general habitat management areas, and production habitat, implement seasonal timing restrictions for all trail users from March 1 through July 15.<br>• Gunnison Sage-Grouse: For trails within production areas and within 4 miles of a lek site, implement seasonal timing restrictions for trail users from March 1 through June 30. | • Avoidance is recommended for grouse leks; Mitigation of impacts has proven to be unsuccessful.<br>• Trail/route decommissioning and rehabilitation in grouse production habitat.<br>• Fence removal or marking to reduce collisions in grouse priority, production, and winter range habitats.<br>• Habitat enhancement, including pinyon-juniper mastication, planting sage brush, and weed control in grouse habitats. |

| | Avoidance | Minimization | Mitigation |
|---|---|---|---|
|  **Large Carnivores** Black Bears, Lynx, Coyotes, Mountain Lions | • Avoid trail/route placement and habitat fragmentation within identified lynx linkages to maintain landscape connectivity.<br>• Discourage the introduction and expansion of snow compaction activities within high quality lynx habitat.<br>• Locate winter trailheads, parking areas, access roads, and other facilities outside of high-quality lynx habitat. | • Limit trail/route densities to less than one linear mile of trail per square mile on average within high-quality Canada lynx habitat.<br>• Implement seasonal trail closure of winter-based recreation trails (skiing, snowmobiling) on May 1 annually within high-quality lynx habitat to protect denning areas.<br>• Limit tree thinning and removal of trees and/or woody debris to protect snowshoe hare habitat within lynx habitat.<br>• Discourage the introduction and expansion of motorized off-trail over-the-snow activities within high-quality lynx habitat.<br>• Install certified bear-proof trash receptacles at trailheads, campgrounds and other recreation facilities within black bear habitat.<br>• Implement CPW Camping and Hiking in Bear Country recommendations and practices.<br>• For new and existing trails within areas that have known human-coyote interactions, implement year-round dog-on-leash regulations.<br>• For trails within mountain lion habitat, post signage to inform trail users *and* implement and enforce year-round dog-on-leash regulations. | • Reduce route density by obliterating and reclaiming redundant routes, and by consolidating routes where possible. |

| | Avoidance | Minimization | Mitigation |
|---|---|---|---|
|  **Raptors and Other Avian Species** | • Avoid new trail construction and human activity within designated buffers of known raptor nest locations and production areas, in T&E or special concern species production areas, and in USFWS designated critical habitats.<br>• Avoid removal or disturbance of key plants such as willow patches, boxelder, and cottonwood stands important to specific species. | • For any project within designated critical habitat, or with potential impact to species protected under the Migratory Bird Treaty Act, consult with the U.S. Fish and Wildlife Service to obtain necessary approvals for federally listed species.<br>• Implement seasonal trail closures between specific dates (see Appendix A) in nesting and production areas for raptors, threatened & endangered, or species of special concern.<br>• Implement weed control measures to prevent invasive species establishing in riparian areas.<br>• Consult with local CPW field staff to determine if pre-construction field surveys are needed to identify breeding and production area habitats for threatened and endangered species. | • Avoidance of nests is recommended; mitigation for nesting raptors and other avian species is typically unsuccessful.<br>• Consult with CPW and USFWS regarding impacts and potential mitigation for federally listed threatened and endangered species.<br>• Implement dog-on-leash rules and utilize signage to keep users and dogs on trails to avoid disturbance to ground nesting birds. |

| | Avoidance | Minimization | Mitigation |
|---|---|---|---|
|   **Small Mammals** Bats, Black-footed Ferrets, Prairie Dogs, Foxes, Mice | • New Mexico and Preble's meadow jumping mouse: Prohibit new trail construction within 300 feet of the ordinary high-water mark of any stream within their overall range.<br>• Townsend's Big-eared Bat, Mexican Free-tailed Bat, *Myotis* species: Prohibit new trail construction within 350 feet of the cave or mine entrance for any known winter hibernacula (site where hibernation activity occurs).<br>• Black-footed Ferret: Prohibit dogs entirely within known black-footed ferret habitat or release sites. Dogs can transmit diseases that are lethal to ferrets. | • Gunnison's and white-tailed prairie dog: Implement seasonal timing restrictions for all recreational users from March 1 through June 15 within their overall range.<br>• Black-footed Ferret: Consult with local CPW field staff for trail projects within mapped ferret release sites. Where deemed necessary, implement seasonal timing restrictions for all recreational users from May 1 through September 1.<br>• Swift Fox: Implement seasonal timing restrictions for all users from March 15 through June 15 within 0.25 miles of active swift fox den sites. | • Habitat enhancements. |

| | Avoidance | Minimization | Mitigation |
|---|---|---|---|
|  <br>**Riparian and Aquatic Species**<br>Boreal Toads, Leopard Frogs, Native Fish | • Boreal Toad: Consult with local CPW field staff to identify and avoid specific breeding sites. Prohibit trail construction within 300 foot of breeding sites and wetland ponds.<br>• Avoid native grass removal and clear-cutting of trees in wet meadows and riparian areas.<br>• Avoid touching or handling amphibian species to prevent spread of disease among populations.<br>• Avoid trail construction within 300 feet of the ordinary high-water mark of any reservoir, lake, wetland, or natural perennial or seasonally flowing stream or river.<br>• Avoid work or disturbance in any perennial stream or river during fish spawning timeframes. Consult with the local CPW aquatic biologist to determine species present and spawning times. | • Boreal Toad: Limit tree removal and minimize trail width, winter grooming, and snow compaction in boreal toad range.<br>• Northern Leopard Frog: Maintain a 300-foot buffer around Northern Leopard Frog breeding sites (emergent marshes).<br>• To prevent the spread of disease organisms and aquatic nuisance species during construction in wet waterbodies or riparian/wetland habitats, disinfect all equipment (e.g., waders, boots, shovels, etc.) before *and* after commencing work. Use a CPW-approved disinfectant and cleaning method (see "Quaternary Ammonia Compound Disinfection Protocols").<br>• Consider signage to educate about sensitive species in area.<br>• Where fishing access is the primary purpose of a new trail, construct specific access points to the intended waterway to avoid unnecessary damage to riparian plant communities or bank/shoreline erosion.<br>• For trails adjacent to wetlands, implement year-round dog-on-leash regulations.<br>• Consider installing foot bridges, log stringers, or stepping stones to cross streams. This will avoid stream bank erosion and stream sedimentation that is typically associated with fords.<br>• Construct all crossings at right angles to the stream. | • Habitat enhancements. |

# Considering Human Dimensions

## Overview

What do we mean by "human dimensions"? The term human dimensions refers to how and why humans value natural resources, how humans want resources managed, and how humans affect or are affected by natural resource management decisions. Human dimensions inquiries strive to understand human traits and how to incorporate that understanding into management planning and actions. Work from the National Park Service discussing wildlife habituation near National Parks highlights the critical importance of integrating human dimensions and biological research to effectively manage this and similar issues.

The human dimensions of natural resource management include:

- The driving forces behind people's decisions.
- The human behaviors that lead to change.
- The effects of change on natural resources and quality of life.
- The management strategies to address change.

Specific to trail use, some research has documented that recreationists' perception of the intensity of their own impacts is low compared to studies quantifying their actual impacts. Surveys have shown recreationists held members of other user groups responsible for stress or negative impacts to wildlife rather than holding themselves and other members of their own recreational user group responsible (Taylor and Knight 2003). This belief that their own personal use is benign and that wildlife impacts are caused by other user groups can lead to a resistance to supporting wildlife related trail management measures. Signage, education programs, and personal interactions between staff/volunteers and trail users can foster understanding of and appreciation for natural resources, as well as encourage visitor behavior that protects wildlife, habitat, and the trail. Appropriate messaging for communication with trail users should be positive to increase user buy-in and to create a welcoming experience for visitors both at the trailhead and on the trail. Messages should include actions users can make to be part of the solution to protect our resources (e.g., stay on the trail, pack out your trash, leave no trace). The human dimension needs to be explored and understood during regional planning processes to inform potential trail projects at both a trail/site-specific and landscape scale.

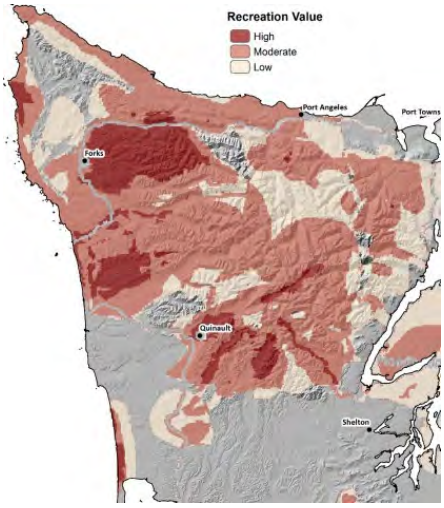
### Questions to ask:

- How can potential projects both meet the recreational desires of a community and enhance their understanding of the importance of wildlife and conservation measures?
- What specific efforts can be undertaken with members of the public to help them understand their impact on wildlife when they recreate?
- How can that understanding be utilized to improve compliance with management strategies such as seasonal closures?

As the NPS points out, human values regarding wildlife interactions change over time and will continue to evolve. Human dimensions should be considered alongside biological considerations. They should be conveyed to the public during the outreach and communication phase.

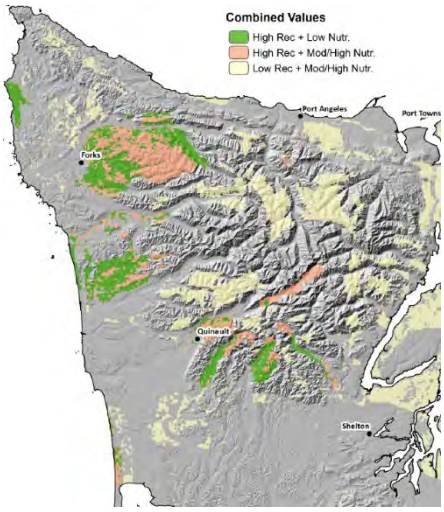
## Examining Opportunities and Trade-Offs

How can the two values of wildlife and recreation be evaluated across the landscape? One approach comes from Mike Wisdom, a wildlife biologist from the USFS Pacific NW Research Station, who suggests utilizing spatial mapping tools to compare the two values directly. Wisdom suggests mapping recreational values in terms of desires for new trails, then ranking them by importance – High, Moderate, and Low Value – based on the consensus of the community. Wildlife areas can be mapped similarly and ranked as High, Moderate, and Low Value based on the importance of the habitat to a species. In this study, nutritional value, or the potential of any given habitat to provide adequate food resources, was used to assess the value of habitat.




When putting those two data sets together, planners can begin to compare them by looking at the combined values of recreation and habitat. Areas with high recreation and low habitat value are potential opportunities for trail systems with a high mileage density. Areas with low recreation and high habitat value provide opportunities to protect wildlife habitat by avoiding sensitive areas, limiting trail use to existing systems, and identifying areas to expand or enhance habitat through restoration projects. Areas with high-moderate values of both recreation and wildlife require more attention to determine where trails might be compatible with wildlife and where they should be avoided. These determinations can be assessed by performing site specific analysis using the best practices in this document.


This model can provide a powerful initial overview of the landscape to find easy areas of compatibility that may already exist. It does not identify definitive answers in every case, but it can highlight areas where a win-win situation exists for both recreation and wildlife, as well as the areas where a more focused discussion is needed. It also allows planners to visually express the information to stakeholders, thus increasing the opportunity for collaboration as discussed in Chapter 1.

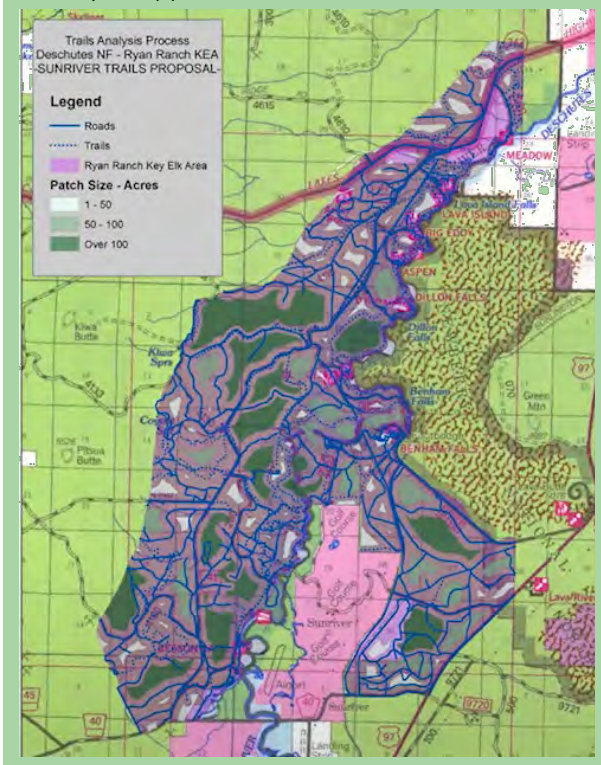


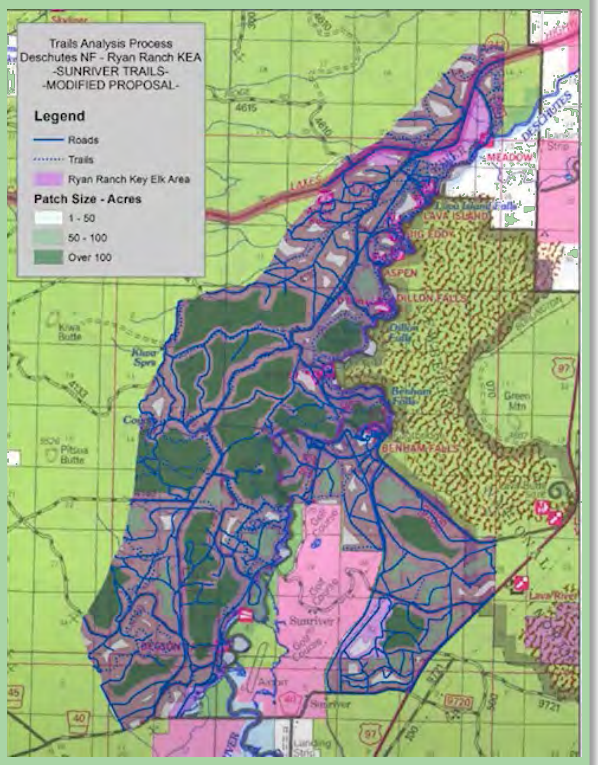
## Ryan Ranch Key Elk Area - Sunriver Trails

A real-world example of land managers using this type of data to find solutions comes from the Deschutes National Forest. The Forest Service was asked to evaluate a proposed 10-15 miles of new mountain bike trails about eight miles southwest of Bend, OR. This area has both a high wildlife value (elk habitat) and a high recreational value (established mountain bike trail system). Forest Service wildlife biologists conducted an analysis of the existing habitat and proposed trail alignment, and submitted an alternative alignment proposal focusing on three things:

1. Maintain large patches of core habitat.
2. Consolidate new disturbance into existing disturbance corridors.
3. Reconnect small and medium patches to build larger patches of habitat with some additional restoration work to improve those patches.

After modifying the proposed alignments to better achieve these goals, the result was a 40% increase to core elk habitat and the construction of 10 miles of new trails. These trails provide connections between the local community and the broader mountain bike trail system. They also enhance the variety of opportunities for different skill levels.



# Chapter 3: Plan for Trail Management and Monitoring

**Chapter Focus:** Once a decision is made about where to locate a trail, it is time to address management of use on the trail. This chapter (like the others) does not seek to offer a prescription, but instead provides resources, recommendations, and the overall guidance land managers need to further protect wildlife through trail management and monitoring. *Figure 7* provides a summary of trail management types. Chapter 3 covers Visitor Education, Adaptive Management Techniques, and Enforcement. Use Limitations and Infrastructure, Design, and Maintenance were covered in Chapter 2.


**Figure 7. Wildlife trail management types:** *Different management techniques can be used, depending on species and proximity to sensitive wildlife.*

# Monitoring

**Establish Wildlife Baselines When Feasible.** For ecological monitoring to be effective, baselines must be established prior to trail construction. Monitoring only at the end of the planning process greatly reduces its efficacy. This starts with an effective initial evaluation (see Chapter 2) by the core team to establish baselines, and a plan for ongoing monitoring to ensure resources remain in a healthy state. Baselines in this case refer to current conditions, including existing impacts, and not to conditions that would exist without any human impacts.

**Be Discerning About Who Completes Monitoring.** To increase buy-in from all stakeholders, monitoring should be driven by an interdisciplinary group of agency staff and wildlife and recreation interests. This process can encourage mutual trust between stakeholders and allow groups to verify monitoring data. Not all agencies have a funding source for extensive monitoring, so establishing monitoring partnerships with appropriately trained local volunteers may be a key to achieving success.

# Visitor Education

**Incorporate Visitor Education Needs.** Where feasible, choose easy to understand management strategies and/or align with nearby strategies. This knowledge should complement messages that might come from a user's own advocacy group. The following sources can provide additional messaging guidance: Leave No Trace, Stay the Trail, Tread Lightly, NOHVCC Great Trails, and International Mountain Bicycling Association. Consider education and outreach methods that can adapt with changing management strategies (such as the trails application COTREX). It's also important to consider diverse learning styles. As such, planners should consider how to use accessible and diverse modes of visitor education.

**Anticipate Conflicts Between Users.** Understanding potential types of conflict between recreational users may help address requests to create more trails. It may also help to address trail density concerns. Education of users on multiple use can sometimes remedy conflicts and reduce the public requests for additional trails. Trail users perceive that other user groups have more of an impact on the environment and wildlife, whereas studies suggest that all users have similar impacts when they stay on formal trails. According to Hennings (2017), **actions that may decrease user conflicts include**:

- Encourage positive interaction among trail users; their values are likely more similar than different. Positive interactions both on and off the trail can break down barriers and stereotypes and build

### Stay the Trail Case Study

The idea for Stay the Trail first came about in 2003 after a group of Off-Highway Vehicle (OHV) enthusiasts recognized a need to educate the public on responsible OHV use and to develop a sense of stewardship for public lands among OHV recreationists. They released their first brochure in 2005. Since then, they have greatly expanded their education and outreach capacity, reaching users throughout the year and across the state through educational programs, stewardship projects, direct user contacts, and trail map services. Stay the Trail operates in partnership with a wide spectrum of stakeholders, from individual OHV enthusiasts and local clubs to state and federal land management agencies like BLM and USFS. Their traveling trailers are the cornerstone of their program and can be found throughout the state during the summer months at trailheads. The trailers help spread their message to always stay on designated routes to protect surrounding habitat, and to respect wildlife when encountering them by slowing down to allow animals plenty of room.

understanding, good will and cooperation. One example is to bring the different types of visitors together for joint trail building or maintenance projects.

- Use the most "light-handed" management approaches possible that will still achieve objectives. This is essential to providing choices in natural environments, which are so important to trail-based recreation.
- Actively and vigorously promote trail etiquette; target the audience, get the information into users' hands as quickly as possible, and present etiquette in simple, interesting, understandable and sometimes lighthearted or humorous ways.
- Monitor the ongoing effectiveness of programs implemented. It is essential to evaluate the effectiveness of the actions designed to minimize conflicts; provide for safe, high-quality trail experiences; and protect natural resources. Conscious, deliberate monitoring is the only way to determine if conflicts are indeed being reduced and what changes in programs might be needed. This is only possible within the context of clearly understood and agreed-upon objectives for each trail area.
- Understand the needs of present and likely future users of each trail. This is critical for anticipating and managing conflicts and requires patience, effort, and sincere active listening.
- Work with affected users (all parties involved) to reach mutually agreeable solutions. Users who are not involved as part of the solution are likely to be part of the problem now and in the future.
- Plan and act locally – whenever possible, address issues regarding multiple use trails at the local level. This allows for greater sensitivity to local needs and provides better flexibility for addressing difficult issues on a case-by-case basis. This also facilitates involvement of the people most affected by any decisions, and most able to assist in their successful implementation.
- Recognize conflict as one visitor interfering with another visitor's reasons for visiting the natural area.
- Identify potential user groups and involve them as early as possible.
- Identify actual sources of conflicts – get beyond emotions and stereotypes as quickly as possible and get to the root of any problems that exist.

**Reduce Impacts on Agriculture and Ranching.** Many trails in Colorado pass through private working lands and/or public land with grazing leases. Conflict can be reduced by posting signage at recreation facilities that informs users about fencing, cattle guards, and the risk of dogs-off-leash in these areas.

### Vail Valley Wildlife Ambassadors and COPMOBA: Peer Education Initiatives

Trail users are becoming increasingly involved in conducting outreach surrounding seasonal trail closures. Two prominent examples of this come from the Colorado Plateau Mountain Bike Trail Association (COPMOBA) and Vail Valley Mountain Trails Alliance. In their fall newsletter, COPMOBA reminds recreationists which trails are subject to seasonal closures and why it is so important that they observe these closures. They explain the needs of wildlife, address common questions (e.g., Why is this trail closed if there's no snow? Why do closures last until spring?), and direct users to other trails in the area that are still open.

In Eagle County, recent trail development reinvigorated conversations about trails and their impact on local wildlife populations. This led to the creation of the Wildlife Trail Ambassador Program. The Vail Valley Mountain Trails Alliance (VVMTA) launched the ambassador program in the spring of 2018 after recognizing the need to proactively educate and communicate with trail users and the community about seasonal trail closure. Volunteer Ambassadors are placed at seasonally closed trailheads to enforce and educate trail users about the closure, along with *Leave **No Trace*** principles, trail etiquette, and options of where trail users can recreate during these times. Additionally, the program includes social ambassadors. These are community members who frequently interact with and inform the public of the importance of seasonal closures at events and meetings, such as hotel conferences, community groups, at outdoor retailers, and within their social networks. The VVMTA in partnership with the Eagle-Holy Cross Ranger District has installed and managed over 10 game cameras on seasonally closed trails to provide data and inform the direction and decisions of the ambassador program. From its inception through 2019, the program has logged 346 hours of volunteer time, made contact on trails and in the community with over 2,000 people. The program has expanded its coverage of seasonally closed trails to include both the spring calving and winter seasons. While the ambassadors have been beneficial by increasing user awareness around closures, it is not a complete solution itself; additional techniques still need to be employed to educate users and enforce violations.

## Maintenance

As alluded to earlier in the document, the maintenance of existing trails is an important consideration for all land managers when thinking about how to provide additional capacity for statewide recreation. Properly managed and maintained trails should provide safe and appropriate use levels and can help provide additional capacity for recreation. Trail maintenance can include both trail reroutes and realignments to help avoid or mitigate resource issues as well as address visitor safety issues. New reroutes should be done in conjunction with reclamation and restoration of the old trail to encourage regrowth of native vegetation.

Trail maintenance can be needed for a number of reasons, including poor construction, poor alignment, overgrowth, and weather-related damage. These minor modifications and improvements do not need to go through the same process as new trail construction. New trails should be constructed following current best practices; this will reduce the amount of future maintenance needed.

# Adaptive Management Techniques

Adaptive management is a learning process that emphasizes monitoring and flexible decision-making. Adaptive management is not an end in itself, but rather a means to achieve more effective management outcomes for both wildlife and trail users. As new research continues to come out on impacts to wildlife and effective recreation strategies, the core team should include adaptive management practices from the outset and consider monitoring plans early in the process. For example, planners can employ methods to track the use of newly constructed trails and facilities, which may include counting devices to track daily and seasonal timing of use, total number of users, and different types of recreational users. This data, based on real-time information, can be helpful in constructing a spectrum of restrictions that can be applied when necessary and can help avoid overly restrictive or not-restrictive-enough management. It's important to note that the responsiveness of adaptive management can vary, and that the planning team should consider this limitation. The Interagency Monitoring Guidebook goes into much greater depth on how to evaluate the effectiveness of visitor use management.

### Trail Construction Best Practices

To limit impacts to habitat and wildlife during the trail building phase, consider Boulder OSMP's BMPs: Save topsoil for restoration, limit the import of soil with invasive seeds, consider appropriate equipment to limit impacts, use native seeds to restore disturbed areas, don't use straw erosion control (which often contains non-desirable plant species), use equipment to set up erosion control and limit sedimentation in aquatic habitat, and limit the spread of invasive species by washing equipment.

*Helpful considerations from the field*

- Trail counters are incredibly important to better understand the timing, frequency, and volume of use on specific trails. This data can go a long way in informing management practices.
- Where available, consider methods to track potential wildlife impacts and reactions. Track wildlife use and responses through collar data, human conflict reporting, and general observations to help discern trends through time.
- Consider monitoring and recording violations concerning trail use compliance surrounding restrictions (e.g., seasonal closures) and the creation of illegal user created trails.

## Enforcement Planning

Enforcement and education planning might include responses to closure violations, illegal off-trail use, dogs off leash, and other infractions within the trail plan. It's critical to establish clear expectations for trail use, and how patterns of illegal or damaging use will lead to new levels of enforcement or adaptive management practices. Enforcement and education planning should consider current and future capacity. Planners should consider how rules and regulations will be enforced on newly proposed trails in perpetuity, for regulations, such as seasonal closures, designed during the planning process are only effective if there are adequate levels of education and enforcement.


*Helpful considerations from the field*

- Most conflict, impact, and damage stems from users' lack of knowledge. Education and communication are critical.
- Self-policing and reporting can be very effective methods of increasing user compliance with rules and regulations. One of the most effective methods to curb violations and illegal trail use is to create an informed public and instill a resource-friendly etiquette. Two examples of how to go about this are provided in the case studies.
- Human presence (staff, volunteer, ranger) is most important. Direct communication regarding wildlife and an outdoor etiquette/ethic, goes a lot farther than signage. You can get creative with volunteers to expand capacity.

### Good OHV Management Trail Crew Projects

Funded by user registration fees from OHV users, Colorado Parks and Wildlife's OHV Good Management Program is an agreement between USFS, BLM, and CPW that was born out of a need to proactively maintain high-use, motorized recreation areas on federal lands. Good Management trail crews include two or three full-time crew members that are deployed during the summer and fall recreation seasons to take a holistic management approach that preserves riding opportunities while protecting sensitive resources. These trail crews use "best practices" to maintain and restore OHV riding areas through trail maintenance, monitoring, signing, education, and mapping. Crews also promote public safety by checking OHV operators for registration and required equipment. Although enforcement is not the main part of their job, crews working on USFS land can also cite operators and issue warnings for off-route use and other resource damage violations.

# Conclusion

The land manager Task Force convened to update this document in 2020. Colorado land managers saw a glimpse into the future that summer, reporting record use numbers as people sought the outdoors as a safe outlet for mental and physical relief during the COVID-19 shutdown. A common refrain from government agencies was that weekday use looked like a typical weekend and weekend use looked like a Fourth of July holiday weekend. These unprecedented levels of use and interest by the public underscored the importance and urgency of this update.

Trails are only one piece of the puzzle, but as the most popular form of outdoor recreation in the state, we know that trails are how many Coloradans and visitors to our state connect to nature and wildlife. Land managers use trails as a tool to help them manage human use on the landscape. A mentor to well-known trail building professional Tony Boone said simply: “People don't need trails. The land needs trails.” In other words, left to their own devices, people will find a way to recreate on the landscape. Trails help us to focus on areas that can be designed to handle high usage, shifting use away from sensitive or valuable habitat.

The Task Force's goal was to create a resource for other land managers, recreational trails groups, and the public at large, providing guidance, based on our knowledge, on how to develop trail systems that meet recreational needs and address wildlife impacts. While we acknowledge that the material herein may not be perfect, it is a collection of our best practices and a document we will all strive to use within our agencies. We have created a framework for collaboration between groups, sharing ways that solutions can be found. We have provided examples from case studies that describe how trails can be designed to minimize the impacts that people have on wildlife and wildlife habitat. We hope the information can help us all make better and more informed decisions based on the sensitivity of habitat and wildlife populations.

We must continue to work cooperatively to find successful solutions that achieve a balance between protection of wildlife habitat and providing outdoor recreation opportunities. Good trail design can enhance the visitor experience, provide opportunities to enjoy the natural world, and minimize impacts on wildlife. By providing sustainable trails for recreationists to enjoy outdoor experiences, users are more likely to become advocates in our efforts to protect our state’s natural resources.

“The most important thing is getting rid of the myth that increasing visitors and protecting resources are incompatible,” said Dale Blahna, former USFS research social scientist in an article in The Wildlife Professional (Learn 2020, p. 25). “That belief actually hinders creative applications that could meet both goals – allowing public access and protecting resources simultaneously.” This document represents our attempt to ask Coloradans to work together on the mutually dependent goals of recreation and conservation.

# National Forest Socioeconomic Indicators

## Grand Mesa, Uncompahgre and Gunnison National Forests

**Selected Geographies:**

**San Miguel County, CO**

**Benchmark Geography:**

**Delta County, [1]**

**Report Date:**

**October 26, 2023**

## Headwaters Economics

### National Forest Socioeconomic Indicators

The National Forest Socioeconomic Indicators reporting tool makes socioeconomic data accessible and useful for Forest Service planning. The reporting tool is free and an ideal solution for Forest NEPA project documentation at all levels, from forest plans to categorical exclusions to large landscapes. The tool delivers county and Forest-level socioeconomic indicators that are defensible (accurate, relevant, and reliable) and establish appropriate context for monitoring National Forest contributions and impacts on surrounding communities.

For more detailed reports, try these other tools by Headwaters Economics:

### Populations at Risk

Populations at risk are more likely to experience adverse social, health, and economic outcomes due to their race, age, gender, poverty status, and other socioeconomic measures.

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Quickly create reports of current socioeconomic data in convenient formats, including Excel and PDF.

**Available nation-wide**
Build reports for geographies from states to census tracts. Aggregate multiple geographies into custom study areas.

**Updated continuously**
Make use of reliable, published government data. The Populations at Risk report always shows the latest available data and trends.

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### Economic Profile System

The Economic Profile System (EPS) generates reports on a range of topics including local economics, demographics, and income sources while providing historic context and trends.

**Free and easy-to-use**
Like Populations at Risk, EPS is free, updated continuously, and easy-to-use.

**Integrates federal data sources**
Access data from many sources, including the Census, Bureaus of Economic Analysis, Labor Statistics, and others.

**Widely used**
For more than a decade, EPS has been used by researchers, economic developers, grant writers, elected officials, cities, planners, federal agencies, reporters, and others.

**headwaterseconomics.org/eps**

# National Forest Socioeconomic Indicators

## County Region

## Table of Contents



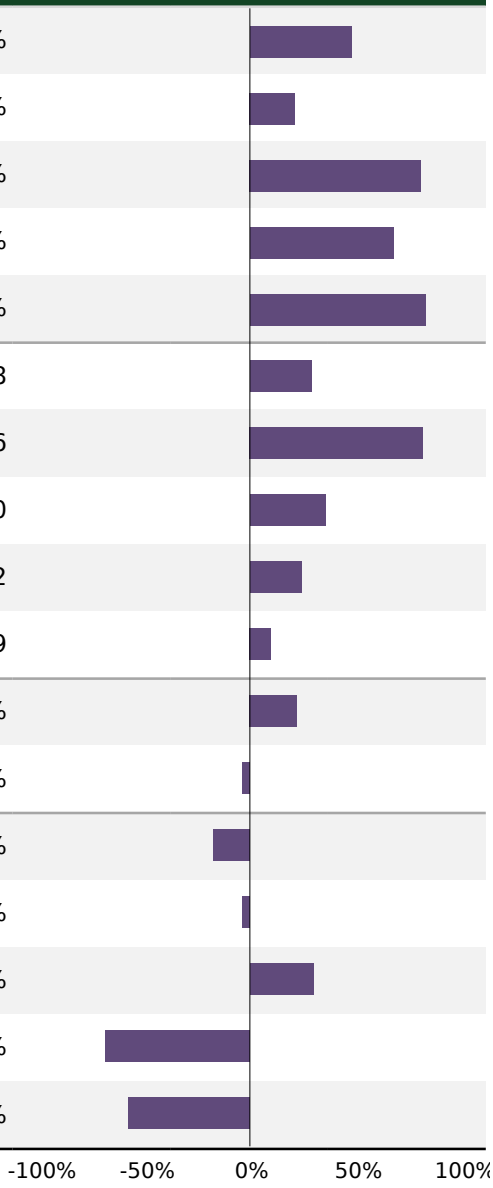
*Click the links above for quick access to report sections.*

# National Forest Socioeconomic Indicators

## Grand Mesa, Uncompahgre and Gunnison National Forests

## Region Benchmarks

| | Indicators | San Miguel County, CO | Delta County, CO | Percent Difference San Miguel County, CO vs. Delta County, CO |
|---|---|---|---|---|
| Trends | Population,% change, 2000-2021 | 22.2% | 13.6% | |
| | Employment, % change, 2000-2021 | 27.0% | 21.8% | |
| | Personal Income, % change, 2000-2021 | 126.8% | 53.9% | |
| | Avg. Earnings per Job, % change, 2000-2021 | 18.5% | 9.1% | |
| | Per Capita Income, % change, 2000-2021 | 85.7% | 35.5% | |
| Prosperity | Avg. Earnings per Job, 2021 | $55,269 | $41,208 | |
| | Per Capita Income, 2021 | $118,383 | $49,726 | |
| | Services, Avg. Annual Wages, 2021 | $53,807 | $37,490 | |
| | Non-Services, Avg. Annual Wages, 2021 | $62,549 | $49,052 | |
| | Government, Avg. Annual Wages, 2021 | $55,779 | $50,509 | |
| Stress | Unemployment Rate, change 2000-2021 | 2.5% | 2.0% | |
| | Unemployment Rate, 2021 | 5.5% | 5.7% | |
| Structure | Proprietors, % of Jobs, 2021 | 37.1% | 44.0% | |
| | Non-Labor Income, % of Pers. Income, 2021 | 55.8% | 57.9% | |
| | Services, % of Jobs, 2021 | 77.2% | 57.0% | |
| | Non-Services, % of Jobs, 2021 | 12.7% | 25.8% | |
| | Government, % of Jobs, 2021 | 9.5% | 17.2% | |




CITATION: U.S. Department of Commerce. 2022. Bureau of Economic Analysis, Regional Economic Accounts, Washington, D.C.; U.S. Department of Labor. 2023. Bureau of Labor Statistics, Local Area Unemployment Statistics, Washington, D.C.; U.S. Department of Labor. 2023. Bureau of Labor Statistics, Quarterly Census of Employment and Wages, Washington, D.C.

# Region Benchmarks

## What do we measure on this page?

This page shows a quick comparison for indicators of economic performance that highlight how the region differs from the selected benchmark geography.

The percent, or relative, difference between the selected geography and the benchmark is calculated by dividing the difference between the values by the arithmetic mean of the values.

The term "benchmark" in this report should not be construed as having the same meaning as in the National Forest Management Act (NFMA).

## Why is it important?

These indicators can be analyzed to get a comprehensive view of the economy.

When considering the benefits of growth, it is important to distinguish between standard of living (such as earnings per job and per capita income) and quality of life (such as leisure time, crime rate, and sense of well-being).

In some cases it may be appropriate to compare a local economy to the U.S. economy. In most cases, however, it will be more useful to compare county or regional economies with other similar county or regional economies. For example, if the region being analyzed is rural, it should be compared to similar regions because comparing against the U.S. will include data from large metropolitan areas.

# National Forest Socioeconomic Indicators

## Grand Mesa, Uncompahgre and Gunnison National Forests

## County Benchmarks

| Indicators | San Miguel County, CO | Delta County, CO |
|---|---|---|
| Population, 2021 | 8,074 | 31,661 |
| **Trends** | | |
| Population % change, 1970-2021 | 311.9% | 107.0% |
| Employment % change, 1970-2021 | 1066.2% | 171.7% |
| Personal Income % change, 1970-2021 | 2171.5% | 327.9% |
| **Prosperity** | | |
| Unemployment rate, 2022 | 3.1% | 3.6% |
| Average earnings per job, 2021 (2022 $s) | $55,269 | $41,208 |
| Per capita income, 2021 (2022 $s) | $118,383 | $49,726 |
| **Economy** | | |
| Non-Labor % of personal income, 2021 | 55.8% | 57.9% |
| Services % of employment, 2021 | 77.2% | 57.0% |
| Government % of employment, 2021 | 9.5% | 17.2% |
| **Use Sectors*** | | |
| Timber % of private employment, 2020 | 0.0% | ~1.7% |
| Mining % of private employment, 2020 | 0.4% | 0.1% |
| Fossil fuels (oil, gas, & coal), 2020 | ~0.2% | ~0.1% |
| Other mining, 2020 | ~0.2% | ~0.0% |
| Agriculture % of employment, 2021 | 1.9% | 9.8% |
| Travel & Tourism % of priv. emp., 2020 | ~43.7% | 10.9% |
| **Federal Land** | | |
| Federal Land % total land ownership | 59.6% | 55.3% |
| Forest Service % | 21.1% | 25.7% |
| BLM % | 38.5% | 29.5% |
| Park Service % | 0.0% | 0.0% |
| Military % | 0.0% | 0.0% |
| Other % | 0.0% | 0.1% |
| Fed. payments % of gov. revenue, 2017 | 0.0% | |
| **Development** | | |
| Residential land area % change, 2000-2010 | 16.8% | 12.5% |
| Wildland-Urban Interface % developed, 2010 | 0.0% | 0.0% |

Estimates for data that were not disclosed are indicated with tildes (~) and gray text.

*Data for timber, mining, and travel and tourism-related are from County Business Patterns which excludes proprietors. Data for agriculture are from Bureau of Economic Analysis which includes proprietors.

# County Benchmarks

## What do we measure on this page?

This page shows a quick comparison for indicators of economic performance and land characteristics. The table allows you to compare performance and characteristics between counties that make up the region and selected comparison geography.

Trends: Refers to general indicators of economic well-being (population, employment, and real personal income) measured over time.

Prosperity: Refers to common indicators of individual well-being or hardship (unemployment, average earnings per job, and per capita income).

Economy: Refers to three significant areas of the economy: non-labor income (e.g., government transfer payments, and investment and retirement income), and services and government employment.

Use Sectors: Refers to components of the economy (commodity sectors including timber, mining and agriculture, and industries that include travel and tourism) that have the potential for being associated with the use of public lands.

Federal Land: Refers to the amount and type of federal land ownership, and the dependence of county governments on payments related to federal lands. Federal land payments (e.g., PILT) compensate state and local governments for non-taxable federal lands within their borders, and can be an important source of government revenue.

Development: Refers to the residential development of private lands, including the wildland-urban interface. The wildland-urban interface data are available and reported only for the 11 western public lands states (not including Alaska and Hawaii).

Some data are withheld by the federal government to avoid the disclosure of potentially confidential information. Headwaters Economics uses uses a starndardized method to estimate these data gaps.[1, 2] Estimated values are indicated with tildes (~) and gray text.

## Why is it important?

Land management actions may affect areas differently, depending on demographics, the makeup of the economy, and land use characteristics.

Use of this table is to explore similarities and differences within the counties that make up the region.

# National Forest Socioeconomic Indicators

## Grand Mesa, Uncompahgre and Gunnison National Forests

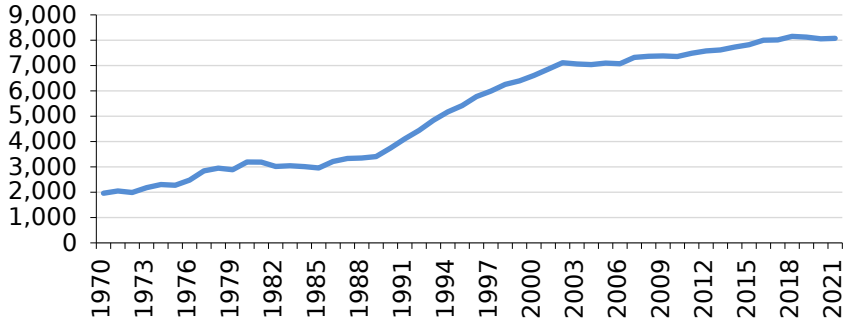
## Trends in Population, Employment, and Personal Income

| | 1970 | 1980 | 1990 | 2000 | 2021 | Change 2000-2021 |
|---|---|---|---|---|---|---|
| Population | 1,960 | 3,192 | 3,741 | 6,609 | 8,074 | 1,465 |
| Employment (full & part-time jobs) | 786 | 1,840 | 3,613 | 7,218 | 9,166 | 1,948 |
| Personal Income (thous. of 2022 $s) | 42,079 | 80,208 | 158,225 | 421,383 | 955,821 | 534,438 |

Population and personal income are reported by place of residence, and employment by place of work on this page.

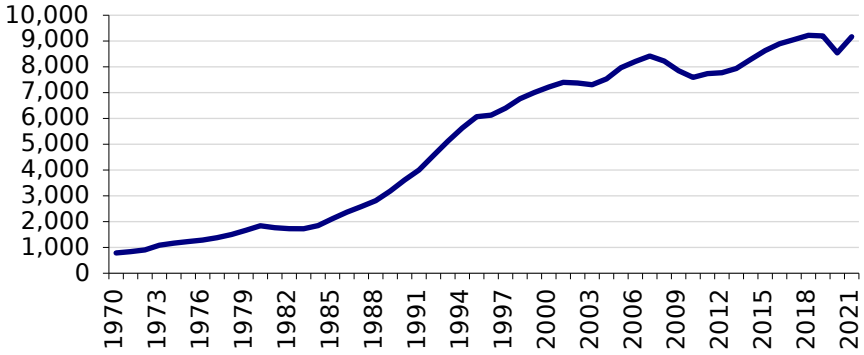
### Population Trends, San Miguel County, CO

- From 1970 to 2021, population grew from 1,960 to 8,074 people, a 312% increase.



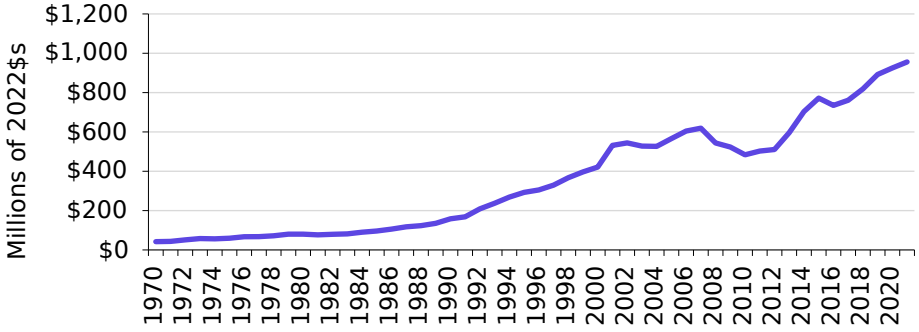

### Employment Trends, San Miguel County, CO

- From 1970 to 2021, employment grew from 786 to 9,166, a 1,066% increase.




### Personal Income Trends, San Miguel County, CO

- From 1970 to 2021, personal income grew from $42.1 million to $955.8 million, (in real terms), a 2,171% increase.




Data Sources: U.S. Department of Commerce. 2022. Bureau of Economic Analysis, Regional Economic Accounts, Washington, D.C.

# Trends in Population, Employment, and Personal Income

## What do we measure on this page?

This page describes trends in population, employment, and real personal income.

Population: The total number of people by place of residence.

Employment: All full and part-time workers, wage and salary jobs (employees), and proprietors (the self-employed) reported by place of work.

Personal Income: Income from wage and salary employment and proprietors' income (labor earnings), as well as non-labor income (dividends, interest, and rent, and transfer payments) reported by place of residence. All income figures in this report are shown in real terms (i.e., adjusted for inflation). Subsequent sections of this report define labor earnings and non-labor income in more detail.

## Why is it important?

Long-term, steady growth of population, employment, and real personal income is generally an indication of a healthy, prosperous economy. Erratic growth, no-growth, or long-term decline in these indicators are generally an indication of a struggling economy.

Growth can benefit the general population of a place, especially by providing economic opportunities, but it can also stress communities, and lead to income stratification. When considering the benefits of growth, it is important to distinguish between standard of living (such as earnings per job and per capita income) and quality of life (such as leisure time, crime rate, and sense of well-being).

Data Sources: U.S. Department of Commerce. 2022. Bureau of Economic Analysis, Regional Economic Accounts, Washington, D.C.

## Components of Population Change

| | Change 2010-2022 |
|---|---|
| Population Growth, 2010-2022 | 645 |
| Avgerage Annual Population Change (Natural Change & Net Migration) | 54 |
| From Natural Change | 37 |
| Births | 62 |
| Deaths | 25 |
| From Net Migration | 18 |
| International Migration | 19 |
| Domestic Migration | -2 |
| From Residual | -1 |

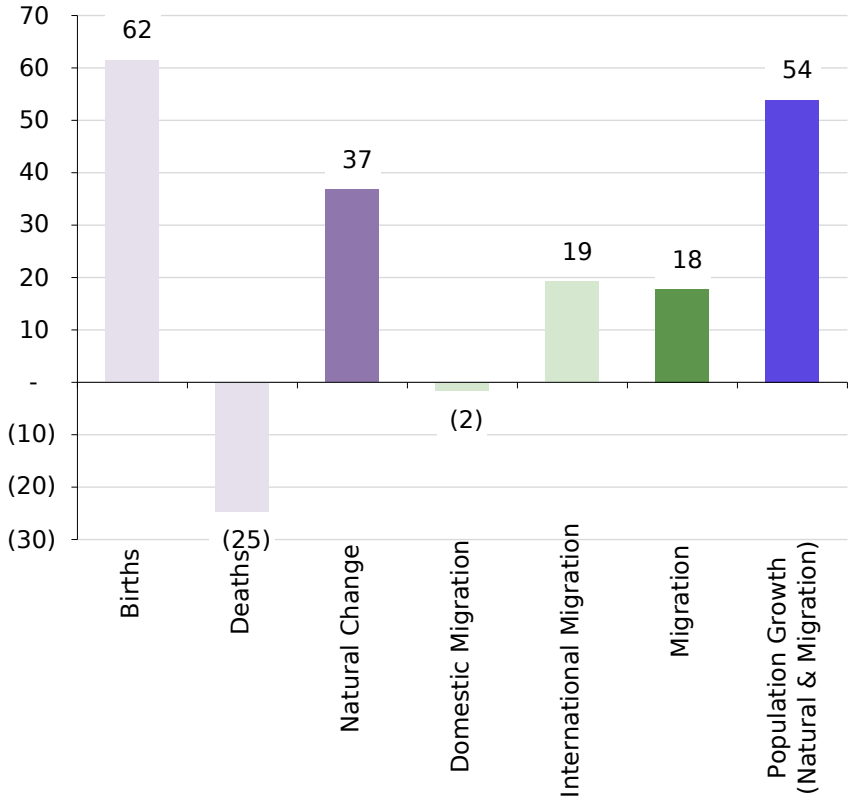
### Factors Contributing to Population Change*, 2010-2022

| | |
|---|---|
| Natural Change | 66.6% |
| Net Migration | 32.2% |
| Residual | 1.2% |

* The absolute value of the individual component of population change divided by the sum of the absolute values of the three components (natural change, net migration, and the residual).

Average Annual Components of Population Change, San Miguel County, CO, 2010-2022

- From 2010 to 2022, population grew by 645 people, a 9% increase.
- From 2010 to 2022, natural change contributed to 67% of population growth.
- From 2010 to 2022, migration contributed to 32% of population growth.




The Census Bureau makes a minor statistical correction, called a "residual" which is shown in the table above, but omitted from the figure. Because of this correction, natural change plus net migration may not add to total population change in the figure.

Data Sources: U.S. Department of Commerce. 2023. Census Bureau, Population Division, Washington, D.C.

# Components of Population Change

## What do we measure on this page?

This page describes various components of population change and total population growth (or decline). Total population growth (or decline) is the sum of natural change (births & deaths) and migration (international & domestic).

The Bureau of the Census makes a minor statistical correction, called a "residual." This is defined by the Bureau of the Census as resulting from "two parts of the estimates process: 1) the application of national population controls to state and county population estimates and 2) the incorporation of accepted challenges and special censuses into the population estimates. The residual represents change in the population that cannot be attributed to any specific demographic component of population change."

## Why is it important?

It is useful to understand the components of population change because it offers insight into the causes of growth or decline and it helps highlight important areas of inquiry. For example, if a large portion of population growth is from in-migration, it would be helpful to understand what the drivers are behind this trend, including whether people are moving to the area for jobs, quality of life, or both. If a large portion of population decline is from out-migration, it would similarly be important to understand the reasons, including the loss of employment in specific industries, youth leaving for education or new opportunities, and elderly people leaving for better medical facilities.[3, 4]

Data Sources: U.S. Department of Commerce. 2023. Census Bureau, Population Division, Washington, D.C.

# National Forest Socioeconomic Indicators

## Grand Mesa, Uncompahgre and Gunnison National Forests

## Employment by Industry

| | 2001 | 2005 | 2010 | 2021 | Change 2010-2021 |
|---|---|---|---|---|---|
| Total Employment (number of jobs) | 7,399 | 7,966 | 7,591 | 9,166 | 1,575 |
| Non-services related | ~1,543 | ~1,521 | ~1,239 | ~1,160 | -~79 |
| Farm | 135 | 123 | 144 | 175 | 31 |
| Forestry, fishing, & ag. services | na | na | na | na | na |
| Mining (including fossil fuels) | 43 | ~32 | ~79 | ~48 | -~31 |
| Construction | 1,219 | 1,218 | 884 | 756 | -128 |
| Manufacturing | 146 | 148 | 132 | 181 | 49 |
| Services related | ~5,110 | ~5,721 | ~5,510 | 7,080 | ~1,570 |
| Utilities | ~13 | 12 | 15 | 10 | -5 |
| Wholesale trade | ~47 | 45 | 39 | 53 | 14 |
| Retail trade | 584 | 567 | 546 | 655 | 109 |
| Transportation and warehousing | ~29 | 73 | 62 | 94 | 32 |
| Information | 101 | 160 | 118 | 78 | -40 |
| Finance and insurance | 216 | 236 | 241 | 413 | 172 |
| Real estate and rental and leasing | 902 | 980 | 963 | 1,245 | 282 |
| Professional and technical services | 435 | 496 | 492 | 618 | 126 |
| Management of companies and enterprises | ~23 | 30 | ~27 | 65 | ~38 |
| Administrative and waste services | ~335 | 339 | ~341 | 475 | ~134 |
| Educational services | 54 | 112 | 143 | 187 | 44 |
| Health care and social assistance | 150 | 243 | 251 | 316 | 65 |
| Arts, entertainment, and recreation | 574 | ~684 | 676 | 927 | 251 |
| Accommodation and food services | 1,174 | ~1,226 | 1,069 | 1,409 | 340 |
| Other services, except public administration | 473 | 518 | 527 | 535 | 8 |
| Government | 753 | 789 | 832 | 874 | 42 |
| **Percent of Total** | | | | | % Change 2010-2021 |
| Total Employment | | | | | 20.7% |
| Non-services related | ~20.9% | ~19.1% | ~16.3% | ~12.7% | -~6.4% |
| Farm | 1.8% | 1.5% | 1.9% | 1.9% | 21.5% |
| Forestry, fishing, & ag. services | na | na | na | na | na |
| Mining (including fossil fuels) | 0.6% | ~0.4% | ~1.0% | ~0.5% | -~39.2% |
| Construction | 16.5% | 15.3% | 11.6% | 8.2% | -14.5% |
| Manufacturing | 2.0% | 1.9% | 1.7% | 2.0% | 37.1% |
| Services related | ~69.1% | ~71.8% | ~72.6% | 77.2% | ~28.5% |
| Utilities | ~0.2% | 0.2% | 0.2% | 0.1% | -33.3% |
| Wholesale trade | ~0.6% | 0.6% | 0.5% | 0.6% | 35.9% |
| Retail trade | 7.9% | 7.1% | 7.2% | 7.1% | 20.0% |
| Transportation and warehousing | ~0.4% | 0.9% | 0.8% | 1.0% | 51.6% |
| Information | 1.4% | 2.0% | 1.6% | 0.9% | -33.9% |
| Finance and insurance | 2.9% | 3.0% | 3.2% | 4.5% | 71.4% |
| Real estate and rental and leasing | 12.2% | 12.3% | 12.7% | 13.6% | 29.3% |
| Professional and technical services | 5.9% | 6.2% | 6.5% | 6.7% | 25.6% |
| Management of companies and enterprises | ~0.3% | 0.4% | ~0.4% | 0.7% | ~140.7% |
| Administrative and waste services | ~4.5% | 4.3% | ~4.5% | 5.2% | ~39.3% |
| Educational services | 0.7% | 1.4% | 1.9% | 2.0% | 30.8% |
| Health care and social assistance | 2.0% | 3.1% | 3.3% | 3.4% | 25.9% |
| Arts, entertainment, and recreation | 7.8% | ~8.6% | 8.9% | 10.1% | 37.1% |
| Accommodation and food services | 15.9% | ~15.4% | 14.1% | 15.4% | 31.8% |
| Other services, except public administration | 6.4% | 6.5% | 6.9% | 5.8% | 1.5% |
| Government | 10.2% | 9.9% | 11.0% | 9.5% | 5.0% |

All employment data are reported by *place of work*. Estimates for data that were not disclosed are indicated with tildes (~) and gray text.

Data Sources: U.S. Department of Commerce. 2022. Bureau of Economic Analysis, Regional Economic Accounts, Washington, D.C.

# Employment by Industry

## What do we measure on this page?

This page describes recent employment change by industry from 2001 to 2008. Industries are organized according to three major categories: non-services related, services related, and government. Employment includes wage and salary jobs and proprietors. The employment data are organized according to the North American Industrial Classification System (NAICS) and reported by place of work.[5]

Some data are withheld by the federal government to avoid the disclosure of potentially confidential information. Headwaters Economics uses a standardized method to estimate these data gaps. Estimated values are indicated with tildes (~) and gray text.[1,2]

## Why is it important?

In most geographies the majority of new job growth in recent years has taken place in services related industries.[6, 10]

Services related industries encompass a wide variety of high and low-wage occupations ranging from jobs in accommodation and food services to professional and technical services.

It can be useful to ask what factors are driving a shift in industry makeup and competitive position. It may be the case that the economic role and contribution of public lands have changed along with broader economic shifts in many geographies.[7, 8, 9]

The terms non-services related and services related are not terms used by the U.S. Department of Commerce. They are used in these pages to help organize the information into easy-to-understand categories.[11]

Data Sources: U.S. Department of Commerce. 2022. Bureau of Economic Analysis, Regional Economic Accounts, Washington, D.C.

# National Forest Socioeconomic Indicators

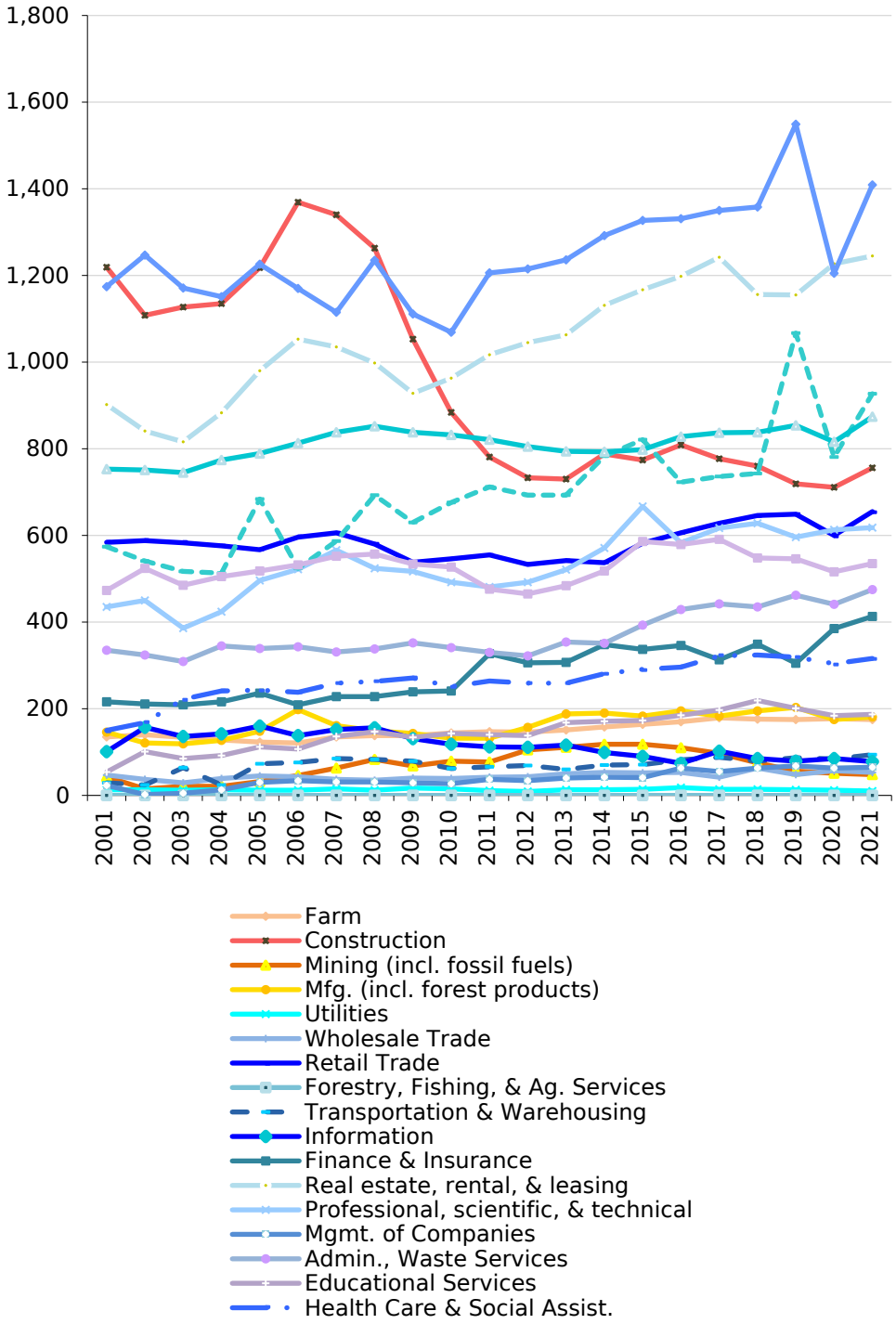
## Grand Mesa, Uncompahgre and Gunnison National Forests

## Employment by Industry

Employment by Industry, San Miguel County, CO

- In 2021 the three industry sectors with the largest number of jobs were accommodation and food services (1,409 jobs), real estate and rental and leasing (1,245 jobs), and arts, entertainment, and recreation (927 jobs).

- From 2001 to 2021, the three industry sectors that added the most new jobs were arts, entertainment, and recreation (353 new jobs), real estate and rental and leasing (343 new jobs), and accommodation and food services (235 new jobs).




Data Sources: U.S. Department of Commerce. 2022. Bureau of Economic Analysis, Regional Economic Accounts, Washington, D.C.

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Data Sources: U.S. Department of Commerce. 2022. Bureau of Economic Analysis, Regional Economic Accounts, Washington, D.C.

# National Forest Socioeconomic Indicators

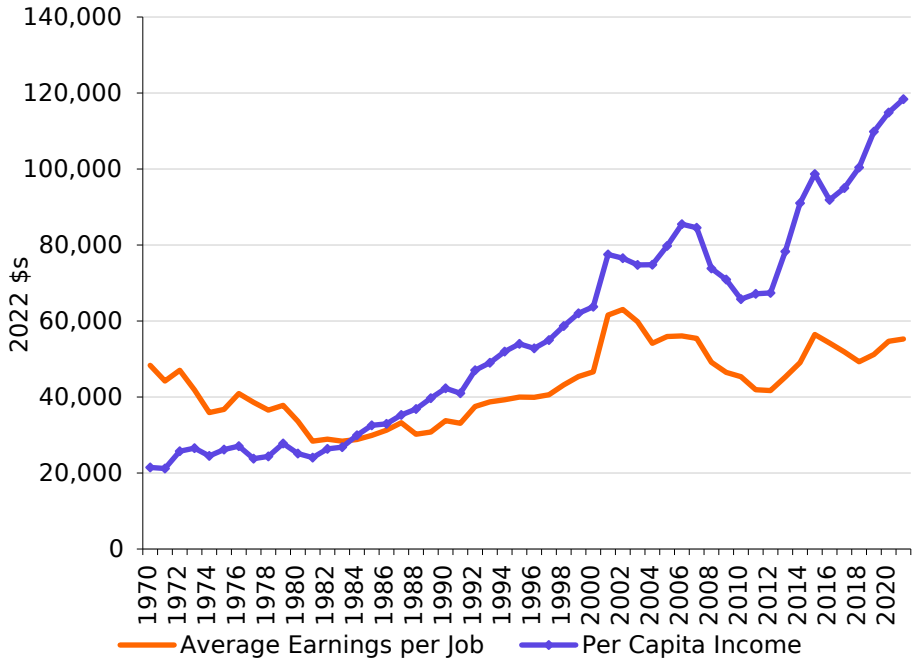
## Grand Mesa, Uncompahgre and Gunnison National Forests

## Average Earnings per Job and Per Capita Income

| | 1970 | 1980 | 1990 | 2000 | 2021 | Change 2000-2021 |
|---|---|---|---|---|---|---|
| Average Earnings per Job, 2022 $s | $48,332 | $33,626 | $33,779 | $46,633 | $55,269 | $8,636 |
| Per Capita Income, 2022 $s | $21,469 | $25,128 | $42,295 | $63,759 | $118,383 | $54,624 |
| **Percent Change** | | | | | | % Change 2000-2021 |
| Average Earnings per Job | | | | | | 18.5% |
| Per Capita Income | | | | | | 85.7% |

Average Earnings per Job & Per Capita Income, San Miguel County, CO

- From 1970 to 2021, average earnings per job grew from $48,332 to $55,269 (in real terms), a 14% increase.
- From 1970 to 2021, per capita income grew from $21,469 to $118,383 (in real terms), a 451% increase.




Data Sources: U.S. Department of Commerce. 2022. Bureau of Economic Analysis, Regional Economic Accounts, Washington, D.C.

# Average Earnings per Job and Per Capita Income

## What do we measure on this page?

This page describes how average earnings per job and per capita income (in real terms) have changed over time.

Average Earnings per Job: This is a measure of the compensation of the average job. It is total earnings divided by total employment. Full-time and part-time jobs are counted at equal weight. Employees, sole proprietors, and active partners are included.

Per Capita Income: This is a measure of income per person. It is total personal income (from labor and non-labor sources) divided by total population.

## Why is it important?

Average earnings per job is an indicator of the quality of local employment. A higher average earnings per job indicates that there are relatively more high-wage occupations. It can be useful to consider earnings against local cost of living indicators.[12, 13]

There are a number of reasons why average earnings per job may decline. These include: 1) more part-time and/or seasonal workers entering the workforce; 2) a rise in low-wage industries, such as tourism-related sectors; 3) a decline of high-wage industries, such as manufacturing; 4) more lower-paid workers entering the workforce; 5) the presence of a university with increasing an enrollment of relatively low-wage students; 6) an influx of workers with low education levels that are paid less; 7) the in-migration of semi-retired workers who work part-time and/or seasonally; and 8) an influx of people who move to an area for quality of life rather than profit-maximizing reasons.[14]

Per capita income is considered one of the most important measures of economic well-being. However, this measure can be misleading. Per capita income is total personal income divided by population. Because total personal income includes non-labor income sources (dividends, interest, rent and transfer payments), it is possible for per capita income to be relatively high due to the presence of retirees and people with investment income.[15] And because per capita income is calculated using total population and not the labor force as in average earnings per job, it is possible for per capita income to be relatively low when there are a disproportionate number of children and/or elderly people in the population.

Data Sources: U.S. Department of Commerce. 2022. Bureau of Economic Analysis, Regional Economic Accounts, Washington, D.C.

## Non-labor Income

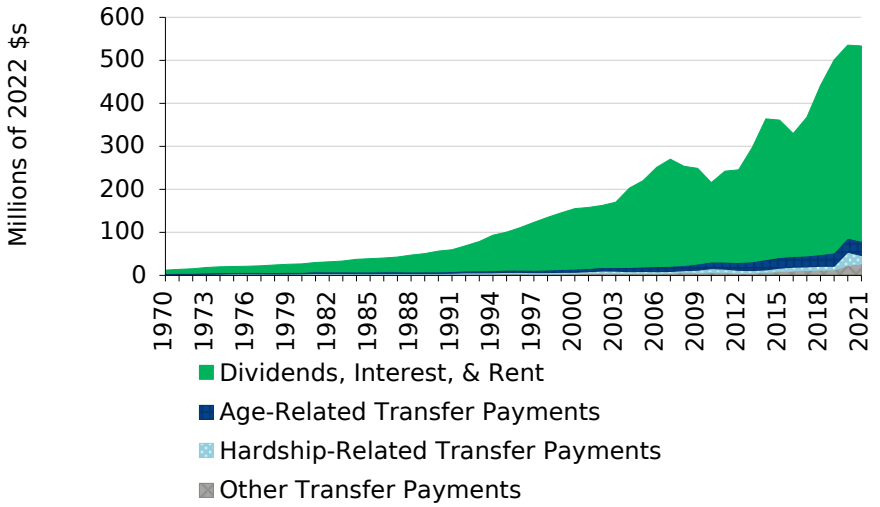
| | San Miguel County, CO | Delta County, CO |
|---|---|---|
| Total Personal Income (thous. of 2022 $s) | 955,821 | 1,574,362 |
| Total Non-Labor Income | 533,512 | 910,781 |
| Dividends, Interest, Rent | 454,175 | 347,397 |
| Age-Related Transfer Payments | 33,155 | 273,055 |
| Social Security | 21,994 | 168,035 |
| Medicare | 11,161 | 105,020 |
| Hardship-Related Payments | 20,105 | 163,272 |
| Medicaid | 7,010 | 93,396 |
| Income maintenance ("welfare") | 4,266 | 47,004 |
| Unemployment ins. compensation | 8,829 | 22,872 |
| Other Transfer Payments | 26,078 | 127,057 |
| Veterans benefits | 1,177 | 29,376 |
| Education and training assistance | 1,706 | 6,903 |
| All other, incl. Workers' comp. | 23,194 | 90,777 |

### Percent of Total Personal Income

| | | |
|---|---|---|
| Total Non-Labor Income | 55.8% | 57.9% |
| Dividends, Interest, Rent | 47.5% | 22.1% |
| Age-Related Transfer Payments | 3.5% | 17.3% |
| Social Security | 2.3% | 10.7% |
| Medicare | 1.2% | 6.7% |
| Hardship-Related Payments | 2.1% | 10.4% |
| Medicaid | 0.7% | 5.9% |
| Income maintenance ("welfare") | 0.4% | 3.0% |
| Unemployment ins. compensation | 0.9% | 1.5% |
| Other Transfer Payments | 2.7% | 8.1% |
| Veterans benefits | 0.1% | 1.9% |
| Education and training assistance | 0.2% | 0.4% |
| All other, incl. Workers' comp. | 2.4% | 5.8% |

**Components of Non-Labor Income, San Miguel County, CO**

- From 1970 to 2021, dividends, interest, and rent grew from $8 million to $454 million, an increase of 5,447 percent.
- From 1970 to 2021, age-related transfer payments grew from $2 million to $33 million, an increase of 1,333 percent.
- From 1970 to 2021, income maintenance transfer payments grew from $1 million to $20 million, an increase of 2,624 percent.




Data Sources: U.S. Department of Commerce. 2022. Bureau of Economic Analysis, Regional Economic Accounts, Washington, D.C.

# Non-labor Income

## What do we measure on this page?

This page describes the components of non-labor income, how they have changed over time (in real terms).

Dividends, Interest, and Rent: This includes personal dividend income, personal interest income, and rental income of persons with capital consumption adjustment that are sometimes referred to as "investment income" or "property income."

Age-Related Transfer Payments: This measures Medicare and Social Security benefits.

Hardship-Related Transfer Payments: These payments are associated with poverty and include Medicaid, Food Stamps (SNAP), Supplemental Security Income (SSI), Unemployment Insurance, and other income maintenance benefits.

Other Transfer Payments: All other components of transfer payments not identified in age and hardship-related categories including veterans benefits, education and training, Workers' Compensation Insurance, railroad retirement and disability, other government retirement and disability, and other receipts of individuals and non-profits.

## Why is it important?

In some geographies, non-labor income has grown rapidly over the last three decades, while in others it has not. Also, some geographies are more dependent on non-labor sources of income than others.[15, 16]

Because non-labor income is often so significant, it is important to understand component details. Some places may rely more on investment income, others on retirement benefits, and still others on welfare-related income streams. The table shows absolute values and percent of total non-labor income, while the figure shows key long-term trends.

Some important metrics include the largest components of non-labor income, whether non-labor income is growing, which components are growing the fastest, whether investment earnings are significant and growing, and whether age-related components of transfer payments are significant and growing. Also worth considering is whether the growth in non-labor income stems from new investment and age-related income and whether poverty-related components of transfer payments are significant and growing.[17, 18]

If age-related transfer payments are significant and growing, it may be important to consider whether public lands resources are meeting the needs of an aging population. If poverty-related transfer payments are significant and growing, it may be important to consider whether there are environmental justice issues related to public lands management.

Data Sources: U.S. Department of Commerce. 2022. Bureau of Economic Analysis, Regional Economic Accounts, Washington, D.C.

# National Forest Socioeconomic Indicators

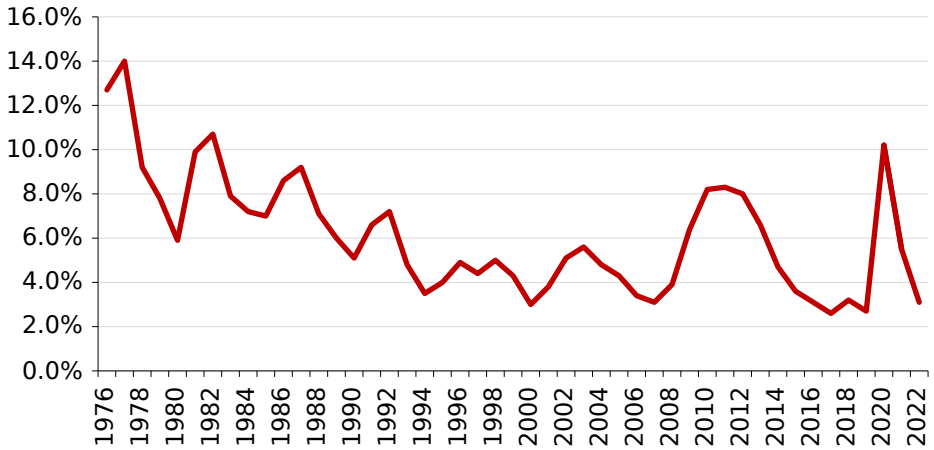
## Grand Mesa, Uncompahgre and Gunnison National Forests

## Unemployment Rate

| | 1976 | 1990 | 2000 | 2010 | 2022 | Change 2010-2022 |
|---|---|---|---|---|---|---|
| Unemployment Rate (Average Annual) | 12.7% | 5.1% | 3.0% | 8.2% | 3.1% | -5.1% |

Unemployment Rate (Average Annual), San Miguel County, CO

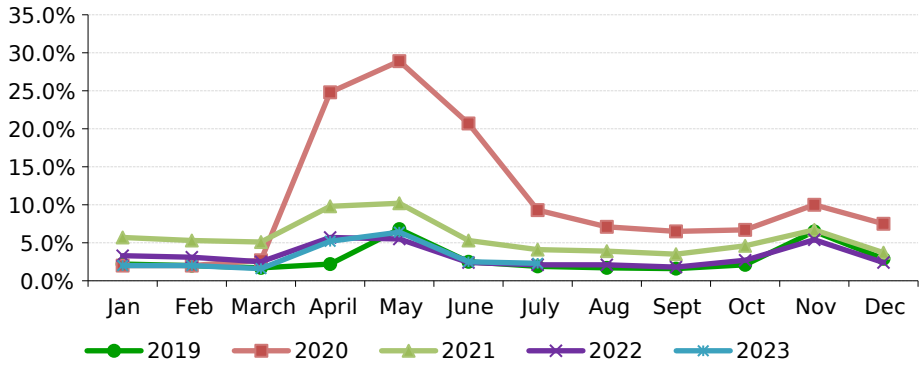
- Since 1976, the annual unemployment rate ranged from a low of 2.6% in 2017 to a high of 14% in 1977.




| | Jan. | Feb. | March | April | May | June | July | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2019 | 2.2% | 2.0% | 1.7% | 2.2% | 6.8% | 2.5% | 1.9% | 1.7% | 1.6% | 2.1% | 6.5% | 2.9% |
| 2020 | 2.0% | 2.0% | 2.7% | 24.8% | 28.9% | 20.7% | 9.3% | 7.1% | 6.5% | 6.7% | 10.0% | 7.5% |
| 2021 | 5.7% | 5.3% | 5.1% | 9.8% | 10.2% | 5.3% | 4.1% | 3.9% | 3.5% | 4.6% | 6.7% | 3.7% |
| 2022 | 3.3% | 3.1% | 2.5% | 5.7% | 5.5% | 2.4% | 2.1% | 2.1% | 1.8% | 2.7% | 5.4% | 2.4% |
| 2023 | 2.0% | 2.0% | 1.6% | 5.2% | 6.4% | 2.5% | 2.3% | | | | | |

Unemployment Rate (Monthly), San Miguel County, CO

- The lowest monthly unemployment rate was Sept of 2019. The highest monthly unemployment rate was May of 2020.




Data Sources: U.S. Department of Labor. 2023. Bureau of Labor Statistics, Local Area Unemployment Statistics, Washington, D.C.

# Unemployment Rate

## What do we measure on this page?

This page describes the average annual unemployment rate and the seasonality of the unemployment rate over time.

The figure Average Annual Unemployment Rate shows the rate of unemployment since 1990. The figure Seasonal Unemployment Rate shows the rate of unemployment for the last five years, for each month of the year. This figure is useful to see if there are higher rates of unemployment during certain months of the year, and whether this has changed over time.

Unemployment Rate: The number of people who are jobless, looking for jobs, and available for work divided by the labor force.

Data begin in 1990 because prior to that the Bureau of Labor Statistics used a different method to calculate the unemployment rate.

## Why is it important?

The rate of unemployment is an important indicator of economic well-being.[19] This figure can go up during national recessions and/or when more localized economies are affected by area downturns. There can also be significant seasonal variations in unemployment.

It is important to know how the unemployment rate has changed over time[20], whether there are periods of the year where the rate is higher or lower, and if this seasonality of unemployment has changed over time. Geographies that are heavily dependent on the tourism industry, for example, may show higher rates of unemployment during Spring and Fall "shoulder seasons." Places that rely heavily on the construction industry, for example, may have lower unemployment rates during the non-winter months.

As the economy of a place diversifies, it can become more resilient and less affected by downturns and rising unemployment rates. This is particularly true of places that are able to attract in-migration, retain manufacturing, and support a high-tech economy.[21]

Public land agencies sometimes provide seasonal employment and may have an effect on the local rate of unemployment.

Data Sources: U.S. Department of Labor. 2023. Bureau of Labor Statistics, Local Area Unemployment Statistics, Washington, D.C.

# National Forest Socioeconomic Indicators

## Grand Mesa, Uncompahgre and Gunnison National Forests

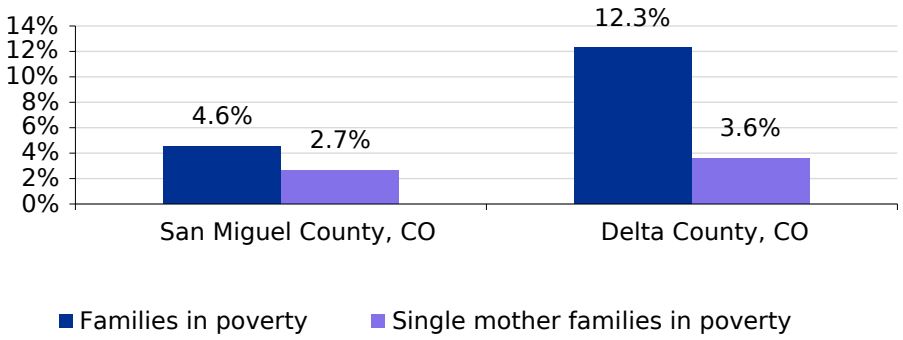
## Families in Poverty

| | San Miguel County, CO | Delta County, CO |
|---|---|---|
| Total families for whom poverty status is determined, 2021* | 1,996 | 7,559 |
| Families in poverty | 91 | 928 |
| Families with children in poverty | **62** | 645 |
| Single mother families in poverty | **53** | 272 |
| **Percent of Total, 2021*** | | |
| Families in poverty | 4.6% | 12.3% |
| Families with children in poverty | **3.1%** | 8.5% |
| Single mother families in poverty | **2.7%** | 3.6% |
| **Change in Percentage Points, 2010*-2021*** | | |
| For example, if the value is 3% in 2010* and 4.5% in 2021*, the reported change in percentage points is 1.5. | | |
| Families in poverty | -2.4 | 2.5 |
| Families with children in poverty | -2.1 | 0.9 |
| Single mother families in poverty | 0.3 | -0.9 |

**High Reliability**: Data with coefficients of variation (CVs) < 12% are in black to indicate that the sampling error is relatively small.
**Medium Reliability**: Data with CVs between 12 & 40% are in orange to indicate that the values should be interpreted with caution.
**Low Reliability**: Data with CVs > 40% are displayed in red to indicate that the estimate is considered very unreliable.

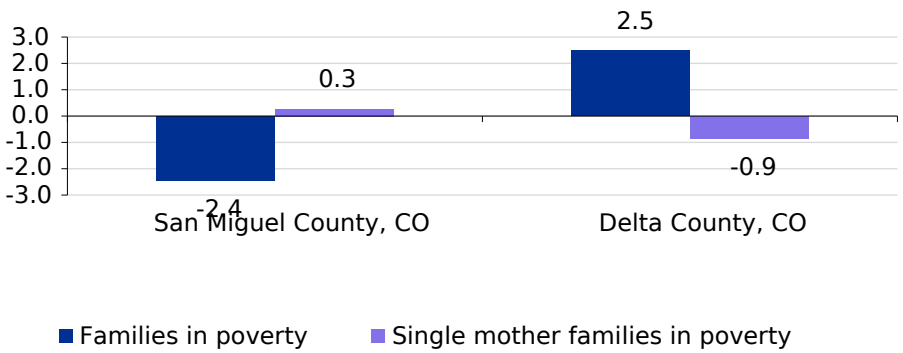
**Families in Poverty, Percent of Total, 2021***

- Delta County, CO has the largest share of single mother families in poverty (3.6%).




**Families in Poverty, Change in Percentage Points, 2010*-2021***

- The largest change in the share of single mother familes in poverty occurred in Delta County, CO, which went from 4.5% to 3.6%.




* ACS 5-year estimates used. 2021 represents average characteristics from 2017-2021; 2010 represents 2006-2010.

CITATION: U.S. Department of Commerce. 2022. Census Bureau, American Community Survey Office, Washington, D.C.

# Families in Poverty

## What do we measure on this page?

This page describes the number of families living below the poverty line, and separately reports families with children and single mother families with children.

The Census defines a family as a group of two or more people who reside together and who are related by birth, marriage, or adoption.

The Census Bureau uses a set of income thresholds that vary by family size and composition to define who is poor. If the total income for a family or an unrelated individual falls below the relevant poverty threshold, then the family or an unrelated individual is classified as being "below the poverty level."

## Why is it important?

Families in poverty may lack the resources to meet their basic needs. Their challenges cross the spectrum of food, housing, health care, education, vulnerability to natural disasters, and emotional stress.

To save money, families with low incomes often have to make lifestyle compromises such as unhealthy foods, less food, substandard housing, or delayed medical care.[22]

Lack of financial resources makes families in poverty more vulnerable to natural disasters. This is due to inadequate housing, social exclusion, and an inability to re-locate or evacuate.[21, 23, 24]

Inadequate shelter exposes occupants to increased risk from storms, floods, fire, and temperature extremes.[23] Households with low incomes are more likely to have unhealthy housing such as leaks, mold, or rodents.[24]

The expense of running fans, air conditioners, and heaters makes low-income people hesitant to mitigate the temperature of their living spaces.[22, 23] Furthermore, those in high-crime areas may not want to open their windows.[23]

Families in poverty are disproportionately affected by higher food prices, which are expected to rise in response to climate change.[22]

Children in poor families, on average, receive fewer years of education compared to children in wealthier families.[25, 26]

Low-income residents are less likely to have adequate property insurance, so they may bear an even greater burden from property damage due to natural hazards.[23]

Living in poverty can lead to a lack of personal control over potentially hazardous situations such as increased air pollution or flooding. Impoverished families may be less likely to take proactive measures to prevent harm.[24]

CHANGES IN BOUNDARIES: Data describing change over time can be misleading when geographic boundaries have changed.
The Census provides documentation about changes in boundaries at this site: www.census.gov/geo/reference/boundary-changes.html

# National Forest Socioeconomic Indicators

## Grand Mesa, Uncompahgre and Gunnison National Forests

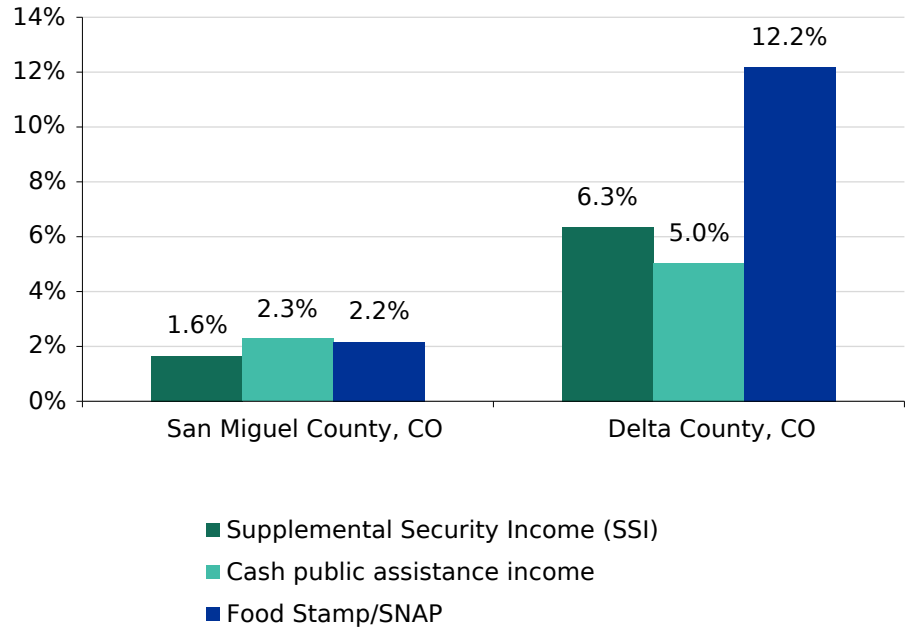
## Households Receiving Public Assistance

| | San Miguel County, CO | Delta County, CO |
|---|---|---|
| Total Households, 2021* | 3,594 | 12,143 |
| Households receiving: | | |
| Supplemental Security Income (SSI) | 59 | 771 |
| Cash public assistance income | 82 | 612 |
| Food Stamp/SNAP | 78 | 1,480 |
| **Percent of Total, 2021*** | | |
| Supplemental Security Income (SSI) | 1.6% | 6.3% |
| Cash public assistance income | 2.3% | 5.0% |
| Food Stamp/SNAP | 2.2% | 12.2% |
| **Change in Percentage Points, 2010*-2021*** | | |
| For example, if the value is 3% in 2010* and 4.5% in 2021*, the reported change in percentage points is 1.5. | | |
| Supplemental Security Income (SSI) | 0.7 | 3.5 |
| Cash public assistance income | 2.0 | 3.4 |
| Food Stamp/SNAP | -1.6 | 4.4 |
| Median Household Income (MHI), 2021* (2022 $s) | $76,642 | $55,947 |
| Change in MHI, 2010*-2021* (2022 $s) | **-$12,465** | **$1,662** |

**High Reliability**: Data with coefficients of variation (CVs) < 12% are in black to indicate that the sampling error is relatively small.
**Medium Reliability**: Data with CVs between 12 & 40% are in orange to indicate that the values should be interpreted with caution.
**Low Reliability**: Data with CVs > 40% are displayed in red to indicate that the estimate is considered very unreliable.

**Percent of Households Receiving Earnings, by Source, 2021***

- Delta County, CO has the largest share of households receiving Supplemental Security Income (6.3%).
- Delta County, CO has the largest share of households receiving cash pubic assistance (5.0%).
- Delta County, CO has the largest share of households receiving Food Stamps/SNAP (12.2%).




* ACS 5-year estimates used. 2021 represents average characteristics from 2017-2021; 2010 represents 2006-2010.

CITATION: U.S. Department of Commerce. 2022. Census Bureau, American Community Survey Office, Washington, D.C.

# Households Receiving Public Assistance

## What do we measure on this page?

This page describes the number of households receiving public assistance.

Supplemental Security Income, or SSI, provides financial assistance to people with limited income who are aged, blind, or disabled. Unlike Social Security benefits, which are determined by the recipient's lifetime earnings, SSI benefits are not based on prior work.[27]

Cash public assistance can be from the Federal program, Temporary Assistance for Needy Families (TANF), or various state-level cash assistance programs. It does not include separate payments received for hospital or other medical care (vendor payments) or SSI or noncash benefits such as the Supplemental Nutrition Assistance Program.

The Supplemental Nutrition Assistance Program, or SNAP, (formerly known as food stamps), provides benefits to those who are unemployed, have no or low incomes, are elderly, are disabled with low incomes, or are homeless. The income threshold for SNAP varies with household size and other factors. SNAP benefits can be used to purchase grocery items such as breads, cereals, fruits, vegetables, meats, and dairy products.[28]

Median income can be used to identify areas of high or low income, but care should be taken to consider regional differences in cost of living.

## Why is it important?

The number of households receiving public assistance are indicative of households living in poverty or with insufficient resources.

In 2011, families receiving public assistance spent 77 percent of their household budget to meet the basic necessities of housing, food, and transportation.[29]

Payments associated with economic hardship are associated with lower household income and educational attainment, higher poverty and unemployment. They are often high in communities that are losing population.[15]

CHANGES IN BOUNDARIES: Data describing change over time can be misleading when geographic boundaries have changed.
The Census provides documentation about changes in boundaries at this site: www.census.gov/geo/reference/boundary-changes.html

# National Forest Socioeconomic Indicators

## Grand Mesa, Uncompahgre and Gunnison National Forests

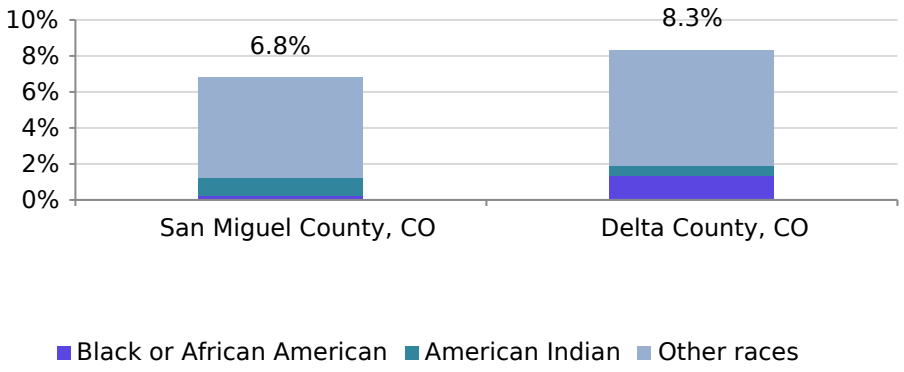
## Race & Ethnicity

| | San Miguel County, CO | Delta County, CO |
|---|---|---|
| Total Population, 2021* | 8,084 | 31,133 |
| White alone | 7,535 | 28,539 |
| All other races | 549 | 2,594 |
| Black or African American | **19** | 418 |
| American Indian | **79** | 173 |
| Other races | 451 | 2,003 |
| Hispanic ethnicity | 903 | 4,809 |
| Non-Hispanic ethnicity | 7,181 | 26,324 |
| **Percent of Total, 2021*** | | |
| White alone | 93.2% | 91.7% |
| All other races | 6.8% | 8.3% |
| Black or African American | **0.2%** | 1.3% |
| American Indian | **1.0%** | 0.6% |
| Other races | 5.6% | 6.4% |
| Hispanic ethnicity | 11.2% | 15.4% |
| Non-Hispanic ethnicity | 88.8% | 84.6% |

**High Reliability**: Data with coefficients of variation (CVs) < 12% are in black to indicate that the sampling error is relatively small.
**Medium Reliability**: Data with CVs between 12 & 40% are in orange to indicate that the values should be interpreted with caution.
**Low Reliability**: Data with CVs > 40% are displayed in red to indicate that the estimate is considered very unreliable.

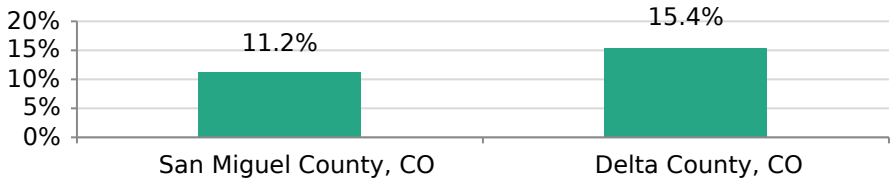
### People of Color, Percent of Total, 2021*

- Delta County, CO has the largest share of people of color (8.3%).




### Hispanic Population, Percent of Total, 2021*

- Delta County, CO has the largest share of Hispanics (15.4%).




* ACS 5-year estimates used. 2021 represents average characteristics from 2017-2021; 2010 represents 2006-2010.

CITATION: U.S. Department of Commerce. 2022. Census Bureau, American Community Survey Office, Washington, D.C.

# Race & Ethnicity

## What do we measure on this page?

Race is self-identified by Census respondents who choose the race or races with which they most closely identify. Included in "Other Races" are "Asian," "Native Hawaiian or Other Pacific Islander," and respondents providing write-in entries such as multiracial, mixed, or interracial.

Ethnicity has two categories: Hispanic or Latino, and Non-Hispanic or Latino. The federal government considers race and Hispanic origin to be two separate and distinct concepts. Hispanics and Latinos may be of any race.

## Why is it important?

Race and ethnicity are strongly correlated with disparities in health, exposure to environmental pollution, and vulnerability to natural hazards.[22]

Research consistently has found race-based environmental inequities across many variables, including the tendency for minority populations to live closer to noxious facilities and Superfund sites, and to be exposed to pollution at greater rates than whites.[22, 30]

Many health outcomes are closely related to the local environment. Minority communities often have less access to parks and nutritious food, and are more likely to live in substandard housing.[22]

Minorities tend to be particularly vulnerable to disasters and extreme heat events. This is due to language skills, housing patterns, quality of housing, community isolation, and cultural barriers.[31, 32]

Blacks and Hispanics, two segments of the population that are currently experiencing poorer health outcomes, are an increasing percentage of the US population.[22, 33]

Research has identified measurable disparities in health outcomes between various minority and ethnic communities.

Across races, the rates of preventable hospitalizations are highest among black and Hispanic populations. Preventable hospital visits often reflect inadequate access to primary care. These types of hospital visits are also costly and inefficient for the health care system.[25]

Relative to other ethnicities and races, Hispanics and blacks are less likely to have health insurance, but rates of uninsured are dropping for both groups.[34]

Compared to other races, blacks have higher rates of infant mortality, homicide, heart disease, stroke, and heat-related deaths.[25]

Hispanics have higher rates of diabetes and asthma.[25]

American Indians have a distinct pattern of health effects different from blacks and Hispanics. Native populations are less likely to have electricity than the general population.[23] They have high rates of infant mortality, suicide and homicide, and nearly twice the rate of motor vehicle deaths than the U.S. average.[25]

# National Forest Socioeconomic Indicators

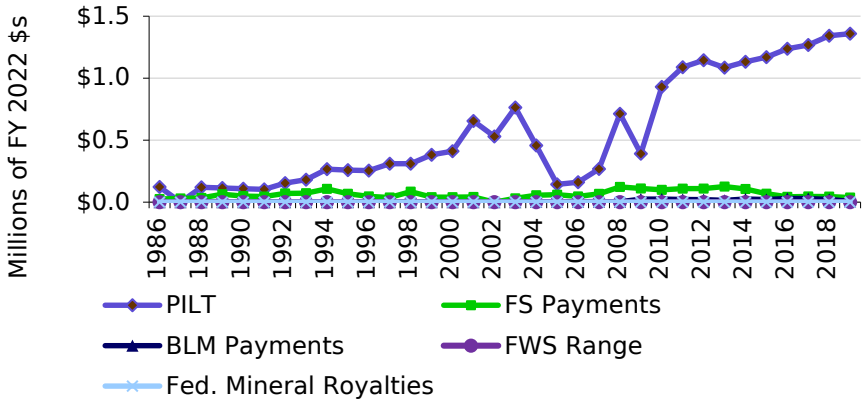
## Grand Mesa, Uncompahgre and Gunnison National Forests

## Federal Land Payments by Geography of Origin

| | San Miguel County, CO | Delta County, CO |
|---|---|---|
| Total Federal Land Payments to State and Local Gov., FY 2019 (FY 2022 $s) | 1,403,222 | 1,222,204 |
| PILT | 1,359,107 | 1,015,433 |
| Forest Service Payments | 37,312 | 202,172 |
| BLM Payments | 6,803 | 3,994 |
| USFWS Refuge Payments | 0 | 605 |
| Federal Mineral Royalties | 0 | 0 |
| **Percent of Total** | | |
| PILT | 96.9% | 83.1% |
| Forest Service Payments | 2.7% | 16.5% |
| BLM Payments | 0.5% | 0.3% |
| USFWS Refuge Payments | 0.0% | 0.0% |
| Federal Mineral Royalties | 0.0% | 0.0% |

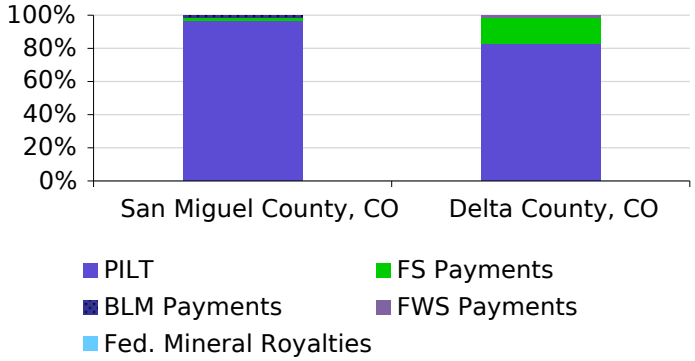
**Components of Fed. Land Payments per FY, San Miguel County, CO**

- From FY 1986 to FY 2019, Forest Service revenue sharing payments grew from $25,379 to $37,312, an increase of 47 percent.
- From FY 1986 to FY 2019, BLM revenue sharing payments grew from $0 to $6,803.




**Components of Fed. Land Payments, FY 2019**

- In FY 2019, PILT made up the largest percent of federal land payments in San Miguel County, CO (96.9%), and USFWS Refuge Payments made up the smallest (0%).




Data Sources: U.S. Department of Interior. 2020. Payments in Lieu of Taxes (PILT), , Washington, D.C.; U.S. Department of Agriculture. 2020. Forest Service, , Washington, D.C.; U.S. Department of Interior. 2018. Bureau of Land Management, , Washington, D.C.; U.S. Department of Interior. 2020. U.S. Fish and Wildlife Service, , Washington, D.C.; U.S. Department of Interior. 2020. Office of Natural Resources Revenue, , Washington, D.C.

# Federal Land Payments by Geography of Origin

## What do we measure on this page?

Federal land payments: These are federal payments that compensate state and local governments for non-taxable federal lands within their borders. Payments are funded by federal appropriations (e.g., PILT) and from receipts received by federal agencies from activities on federal public lands (e.g., timber, grazing, and minerals).
Payments in Lieu of Taxes (PILT): These payments compensate county governments for non-taxable federal lands within their borders. PILT is based on a maximum per-acre payment reduced by the sum of all revenue sharing payments and subject to a population cap.
Forest Service Revenue Sharing: These are payments based on USFS receipts and must be used for county roads and local schools. Payments include the 25% Fund, Secure Rural Schools & Community Self-Determination Act, and Bankhead-Jones Forest Grasslands.
BLM Revenue Sharing: The BLM shares a portion of receipts generated on public lands with state and local governments, including grazing fees through the Taylor Grazing Act and timber receipts generated on Oregon and California (O & C) grant lands.
USFWS Refuge: These payments share a portion of receipts from National Wildlife Refuges and other areas managed by the USFWS directly with the counties in which they are located.
Federal Mineral Royalties: These payments are distributed to state governments by the U.S. Office of Natural Resources Revenue. States may share, at their discretion, a portion of revenues with the local governments where royalties were generated.
Federal Fiscal Year: FY refers to the federal fiscal year that begins on October 1 and ends September 30.

## Why is it important?

State and local government cannot tax federally owned lands the way they would if the land were privately owned. A number of federal programs exist to compensate county governments for the presence of federal lands. These programs can represent a significant portion of local government revenue in rural counties with large federal land holdings.[35, 36]

Before 1976, federal payments were linked directly to receipts generated on public lands. Congress funded PILT with appropriations beginning in 1977 in recognition of the volatility and inadequacy of federal revenue sharing programs. PILT was intended to stabilize and increase federal land payments to county governments. More recently, the Secure Rural Schools and Community Self-Determination Act of 2000 (SRS) decoupled USFS payments from commercial receipts. SRS received broad support because it addressed several major concerns around receipt-based programs--volatility, the payment, and the incentives provided to counties by linking federal land payments directly to extractive uses of public lands.

PILT and SRS each received a significant increase in federal appropriations in FY 2008 through the Emergency Economic Stabilization Act of 2008. Despite the increased appropriations, SRS is authorized only through FY 2011, PILT only through FY 2012, and federal budget concerns are creating uncertainty for the future of both.[37]

Data Limitations: Local government distributions of federal land payments may be underreported due to data limitations from USFWS, ONRR, and some states that make discretionary distributions of mineral royalties and some BLM payments. USFWS data limitations are relatively insignificant at the federal level, but may be important to specific local governments with significant USFWS acreage. Federal mineral royalties represent a more significant omission in states that share a portion of royalties with local governments.

Data Sources: U.S. Department of Interior. 2020. Payments in Lieu of Taxes (PILT), , Washington, D.C.; U.S. Department of Agriculture. 2020. Forest Service, , Washington, D.C.; U.S. Department of Interior. 2018. Bureau of Land Management, , Washington, D.C.; U.S. Department of Interior. 2020. U.S. Fish and Wildlife Service, , Washington, D.C.; U.S. Department of Interior. 2020. Office of Natural Resources Revenue, , Washington, D.C.

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# Emissions from prescribed burning of timber slash piles in Oregon

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## Abstract

Emissions from burning piles of post-harvest timber slash (Douglas fir) in Grande Ronde, Oregon were sampled using an instrument platform lofted into the plume using a tether- controlled aerostat or balloon. Emissions of carbon monoxide, carbon dioxide, methane, particulate matter ($PM_{2.5}$), black carbon, ultraviolet absorbing PM, elemental/organic carbon, filter-based metals, polycyclic aromatic hydrocarbons (PAHs), polychlorinated dibenzodioxins/dibenzofurans (PCDD/PCDF), and volatile organic compounds (VOCs) were sampled to determine emission factors, the amount of pollutant formed per amount of biomass burned. The effect on emissions from covering the piles with polyethylene (PE) sheets to prevent fuel wetting versus uncovered piles was also determined. Results showed that the uncovered ("wet") piles burned with lower combustion efficiency and higher emission factors for VOCs, $PM_{2.5}$, PCDD/PCDF, and PAHs. Removal of the PE prior to ignition, variation of PE size, and changing PE thickness resulted in no statistical distinction between emissions. Results suggest that dry piles, whether covered with PE or not, exhibited statistically significant lower emissions than wet piles due to better combustion efficiency.

### Keywords

Emission factors; timber slash; pile cover; moisture; polyethylene

## INTRODUCTION

To reduce wildfire risk and to improve timber forest productivity and health, woody biomass fuels from selective thinning and timber harvests are mechanically treated and piled for burning[1, 2] This practice is becoming more prevalent as prescribed fire complexity and risk

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SUPPORTING INFORMATION

Additional material as noted in text. This material is available free at charge via the Internet at [*Editor to add*].

associated with elevated fuel levels (proximity to the wildland/urban interface, smoke effects on air quality and respiratory health) limit the use of broadcast prescribed burning[3]. Pile burning mitigates concerns about fire safety and air quality as it allows managers to burn under optimal weather conditions and with reduced staffing levels[3]. Biomass pile burns are often the most economical way to dispose or utilize the biomass due to collection, transportation, and end-product processing costs[4]. Depending on the season and rainfall history, burn piles can smolder for days after they are lit resulting in significant quantities of air pollution[4]. To promote pile combustion, the biomass is preferably dry, resulting in faster, hotter, and more efficient burns, presumably with less pollutants. Common practice involves covering these large piles with polyethylene (PE) film until burn conditions are optimal to prevent moisture saturation during the rainy season. This has raised some questions about emissions from the burning plastic film. The Oregon Department of Forestry (ODF) has used small amounts of PE film sheeting (9.3 $m^2$) per pile through administrative rulemaking (OAR 629–048-0210)[5]. Often this is not enough to keep piles dry for efficient consumption after significant rainfall. Because of this limitation, ODF is seeking data to determine whether or not larger and thicker coverings of PE have deleterious effects on burn emissions.

Only a few studies[6] have investigated pile burn emissions in the field and often the number of pollutants characterized was limited [6, 7] Laboratory burns of pinus ponderosa slash (twigs, needles, and small branches) by Yokelson et al.[8] characterized emissions from burn piles (1 m x 2 m) using FTIR analysis. Their work determined emission factors for smoldering/ flaming phase as partitioned by modified combustion efficiency. Other work[9] examined emissions from 2 kg mixtures of manzanita stick wood *(Arctostaphylos* sp.) with 0, 5, and 50 g of shredded low density PE but found no statistical effect of increase PE content on over 190 compounds.

To complement the laboratory scale work previously done on assessing potential contribution of PE to biomass emissions, this work aimed to characterize and compare emissions from burning woody biomass piles, including dried PE-covered piles and wetted piles, in a large-Scale Field Application

## METHODS

### Biomass piles

Tests were conducted during mid-October in western Oregon, on a timber-harvested Douglas fir (Pseudotsuga menziesii) stand (45° 0’ 44.14” N, −123° 41’ 6.49” W) located about 8 km southwest of Grand Ronde, Oregon and 30 km east of the Pacific coast. The site is at 880 m elevation on a ridge top with an about 10 m change in elevation in the test area. After timber harvesting, the piled material was primarily small branches and limbs of size less than 20 cm in diameter.

Biomass piles approximately 2.5 m high and 5 m in diameter and spaced at least 15 m apart were constructed by the landowner (Figure 1). Three pile types were tested nominally: Dry, Wet, and Dry Polyethylene (PE) covered. Polyethylene sheeting covered eight of the piles throughout the summer to comprise the Dry and PE-covered test piles for the October tests. The PE was removed from four piles prior to testing and were designated Dry piles. The

remaining four covered piles were left with the PE in place and were designated Dry PE piles. PE-covered piles had two film thicknesses, 0.10 mm (4 mil) and 0.15 mm (6 mil), and two area sizes, 3.0 m by 3.0 m (10 ft by 10 ft), and 6.1 m by 6.1 m (20 ft by 20 ft) (Table 1). The remaining four piles were uncovered throughout the summer and designated as Wet piles.

Terrain constraints to pile access, a desire to prevent the emissions from upwind smoldering fires from impinging on new burn piles, and effects of week-long meteorological conditions prohibited true random pile testing. The resultant “ordered” testing affects randomness and may have introduced bias into the measurements as a result of dynamic meteorological variables (conditions present at the end of the testing may be different than those at the beginning) confounding the comparisons. Four days of sampling were conducted in later October. Meteorological data for these dates are reported in Supporting Information (SI). The order and notation for the tests are presented in Table 1.

## Sampling method

Fires were initiated by drip torch immediately after which emissions were sampled using an aerostat-lofted sampler system (Figure 2) detailed more fully elsewhere[10, 11]. Briefly, the system consists of a 5 m diameter, helium-filled aerostat, connected with two tethers to all-terrain vehicle (ATV)-mounted winches, upon which is mounted a sampler/sensor system termed the “Flyer”. The Flyer was maneuvered into the burn pile plume by controlling tether length and the location of the ATV-mounted tether winches. Sampling periods consisted of both active flaming and smoldering emissions

## Instrumentation on the Flyer

Emission samples were analyzed for carbon monoxide (CO), methane ($CH_4$), carbon dioxide ($CO_2$), particulate matter equal to or less than 2.5 μm ($PM_{2.5}$), black carbon (BC), ultraviolet absorbing (UVPM), elemental/organic/total carbon (EC, OC, TC), polyaromatic hydrocarbons (PAHs), polychlorinated dibenzodioxins/dibenzofurans (PCDDs/PCDFs), filter-based metals, and volatile organic compounds (VOCs). Targeted emission constituents and their sampling methods are listed in Table 2.

The flyer was equipped with a data acquisition and control program allowing emission samplers to be turned on and off at $CO_2$ levels above ambient levels (trigger settings: 800 ppm for VOCs and 450 ppm $CO_2$ for all other emission samplers). The control program was also transmitted to the ground permitting the operator full control of the emission samplers.

The $CO_2$ analyzer and the CO sensor was calibrated daily in accordance with EPA Method 3A [12] A precision gas divider Model 821S (Signal Instrument Co. Ltd., England) was used to dilute the high-level span gases for acquiring the mid-point concentrations for $CO_2$ analyzer and CO sensor calibration curves. The precision gas divider was evaluated in the field as specified in U.S. EPA Method 205 [13]. The $PM_{2.5}$ and EC/OC/TC sample pumps as well as the AE51/AE52 were calibrated with a Gilibrator Air Flow Calibration System (Sensidyne LP, USA) before and after the field campaign. SUMMA canisters were equipped with a manual valve, metal filter (frit), pressure gauge, pressure transducer, and an electronic

solenoid valve which enabled the SUMMA to be opened remotely by the ground-based software to maximize desired sample collection and minimize sampling of ambient air.

PCDD/PCDF samples were cleaned and analyzed using an isotope dilution method based on U.S. EPA Method 23[14]. Concentrations were determined using high resolution gas chromatography/high resolution mass spectrometry (HRGC/HRMS) with a Hewlett-Packard gas chromatograph 6890 Series coupled to a Micromass Premier mass spectrometer (Waters Corp., Milford, MA, USA) with an RTX-Dioxin 2, 60 m x 0.25 mm x 0.25μm film thickness column (Restek Corp., Bellefonte, PA, USA). For analysis of tetra- through octa-CDDs/Fs, Method 8290A [15] was followed. The standard used for PCDD/PCDF identification and quantification is a mixture of standards containing tetra-to octa-PCDD/F native and 13C-labeled congeners designed for modified U.S. EPA Method 23 [14] Not all of the seventeen PCDD/PCDF toxic equivalent factor (TEF) weighted congeners were detected in all samples. The congeners that were not detected (ND) were set to zero in the text, however SI Tables S6-S9 show values both ND = 0 and ND = limit of detection (LOD). The PCDD/PCDF toxic equivalent (TEQ) emission factors were determined using the World Health Organization (WHO) 2005 toxic equivalent factors (TEF) [16]. Only four PCDD/PCDF congeners were detected in all samples (1,2,3,4,6,7,8 - HpCDD, 1,2,3,4,6,7,8,9 - OCDD, 2,3,7,8 - TCDF, 1,2,3,4,6,7, 8- HpCDF) these emission factors were used for intercomparison purposes. These emission factors represent the low end of the absolute emission factor but are the most reliable for intercomparison.

A portion of the methylene chloride extract from the PCDD/PCDF/PAH sample was used for the PAH analysis using a modified EPA Method 8270D [17] Labeled standards for PAHs were added to the XAD-2 trap before the sample was collected and internal standards were added before mass analysis. The PAHs TEQ emission factors were determined using TEFs by Larsen and Larsen [18].

Ambient air background samples were collected for each of the target pollutants. Only the VOC emissions were background corrected. PCDD/PCDF, PAH and PM burn samples had over 20, 170, and 200 times higher concentrations than the ambient air background sample, respectively.

## Calculations

Emission factors, expressed as mass of pollutant per mass of biomass burned, were based on the carbon balance method[25]. This method concurrently measures the target analyte along with the amount of fuel burned, the latter assumed to be determined by the $\Delta CO + \Delta CO_2$ measurements and assuming a 50% carbon concentration in the biomass fuel. The minor carbon mass emitted as hydrocarbons and PM is ignored without significant effect on the emission factor. The resultant emission factors are expressed as mass of pollutant per mass of biomass consumed ($B_c$).

The modified combustion efficiency (MCE), $\Delta CO_2/(\Delta CO_2+\Delta CO+\Delta CH_4)$ (with $CH_4$ included in VOC samples only), was calculated for each of the emission samples. Custom photometric calibration factors were derived for each burn conducted for the DustTrak 8520

by simultaneous collection of $PM_{2.5}$ mass on a filter (averaged continuous $PM_{2.5}$ concentration divided by $PM_{2.5}$ by filter mass).

Single factor one-way analysis of variance (ANOVA) with a level of significance a = 0.05 was used to determine any differences in air pollution emissions between PE covered and uncovered biomass piles. To establish significant difference the ANOVA-returned p value (significant value) has to be less than level of significance (0.05) and the F-distribution value ($F/F_{crit}$) has to be greater than 1.0.

## RESULTS AND DISCUSSION

Eleven pile burns were sampled over a five day period with emission factor results summarized in Table 3. The plumes were sampled with the aerostat/Flyer in close proximity to the fires to maximize the sample collection mass without placing operators or instruments at risk. Typical aerostat heights above the pile burn were 20–70 m. Pile emission sampling averaged 45 minutes. Ambient temperatures ranged from 2–13°C, winds 0–32 km/h, and humidity ranged from 100% for the first two days of testing to 35–40% on the last two days. Additional meteorological data are presented in the Supporting Information.

The potential effect of day-of-testing on the results due to, for example meteorological condition changes through the week, were examined by the chronological examination of the emission factors for all targeted pollutants. This analysis is of limited utility due to the non-random order in which the tests were run. Nonetheless, no effects related to testing date, or time of day were found on the Wet/Dry $PM_{2.5}$, PAH, and PCDD/PCDF emission factors were found including the Dry PE PCDD/PCDF results. However, an effect of the testing date was found for Dry PE on the $PM_{2.5}$ emission factors and was inconclusive on the PAH results.

### CO, $CH_4$, and $CO_2$

Typical concentration results throughout the duration of a Dry and Wet burns are shown in Figure 3. Fluctuations in the concentrations are typical and reflect wind shifts moving the Flyer in an out of the plume. The CO and $CH_4$ emission factors were almost twice as high for the wet piles as the dry (Table 3). Hardy [6] estimated 1.64 and 5.52 g/kg for $CH_4$ from flaming and smoldering, respectively. Our work resulted in whole-burn values of 1.1 g/kg (DRY) to 5.7 g/kg (WET). The $CO_2$, CO and $CH_4$ emission factors in this study str also in the same range as found in the literature of open burning of Douglas fir 1,601–1,772 g/kg, 74–138 g/kg, 0.3–7.9 g/kg[26, 27], respectively.

### $PM_{2.5}$

The $PM_{2.5}$ results show a statistically significant (F = 2.7, p= 0.004) increase in the Wet (18±11 g/kg $B_c$) versus the Dry uncovered + Dry PE covered (4.9±1.8 g/kg) emission factor (Figure 4 Inset). Individual emission factors (Figure 4) show no distinction between the Dry uncovered and Dry PE covered piles. The $PM_{2.5}$ emission factors compare with a value of 6.75 g/kg consumed estimated from hand-pile biomass burns by Wright et al.[28]. The Wet emission factor (18±11 g/kg $B_c$) derived at a MCE of 0.839±0.057 is in the same range as

found in the literature of open burning of Douglas fir 15.7±5.2 g/kg dry fuel consumed[27] at a MCE of 0.916±0.016.

Examination of the relationship between $PM_{2.5}$ and the MCE showed that lower combustion efficiencies were correlated with higher $PM_{2.5}$ loads. Figure 5 shows that comparison of same-day WET and DRY samples (Day 2 and Day 3) continue to verify the distinction with the passage of time, suggesting that the non-random testing did not affect the conclusions. The distinction in the $PM_{2.5}$ emission factors occurs in the initial half of the burns. Figure 6 shows that the early portion of the WET pile burns when the fire is getting started is responsible for the high $PM_{2.5}$ emissions. This distinction with the DRY burns persists until the second half of the burn when smoldering was more prevalent.

## Black Carbon, UVPM, Elemental/Organic Carbon

BC, EC, OC, and TC values were all higher for the WET burns as compared to all of the DRY and PE burns (Figure 7). No statistical distinctions in these values were observed for the varying sizes and thicknesses of PE. BC showed approximately a factor of two higher values than EC and they did not correlate strongly with each other (R2 of 0.49, SI Figure S1) which may be due to the low number of data points. The EC emission factor, 0.10–0.18 g/kg $B_c$, is in the same range as found in the literature, 0.19±0.41 g/kg dry fuel, from laboratory burns of Douglas fir[26]. The relationship between EC and BC emission factors and MCE is shown in Figure 8.

The OC/EC values, a surrogate for comparison of optical reflectance/warming properties, indicates values ranging between 14 and 45, the latter being the WET burns (Table 3). Values greater than unity are common and anticipated for biomass burns. These values are the opposite of what is observed with, for example, crude oil combustion [29], where the OC/EC ratio is about 1/15.

## Volatile Organic Compounds (VOCs)

VOC results for the most concentrated species are shown in Table 4. The full set of VOC emission factors are summarized in Supporting Information, Tables S11-S13. ANOVA analysis (Figure 9) of acrolein, benzene, styrene and 1,3-butadiene showed statistical differences between WET and DRY piles, (Benzene $F = 1.6$, $p = 0.0208$; Acrolein $F = 3.3$, $p = 0.004$; Styrene $F = 1.9$, $p = 0.015$; 1,3-Butadiene $F = 1.4$, $p = 0.026$). Benzene is a common VOC associated with incomplete combustion. Acrolein is a toxic, irritant, 3-C carbonyl and is not listed as a carcinogen on EPA or international lists. 1,3-butadiene is listed as a human carcinogen. Styrene is “reasonably anticipated to be a human carcinogen” [30]. The relationship between emission factors for these select VOCs and MCE is shown in Figure 10.

## PCDD/PCDF

Results for PCDD/PCDF emission factors for Dry, Wet, and PE are summarized in Table 3. Figure 11 presents data for four of the 17 congeners that comprise the PCDD/PCDF TEQ value [16] that were present in all 11 samples (complete data are shown in SI Tables S5-S10). As such, these emission factors represent the low end of the absolute emission factor but are

the most reliable in terms of intercomparisons. Wet PCDD/PCDF values are higher than Dry uncovered piles [F = 2.0, p = 0.017]. Dry and PE values show no statistical difference between them [F = 0.01, p = 0.814]. Within the PE grouping, no distinction was observed between the PE sheet size and thickness, although the limited number of tests limits the statistical power of this test. Figure 12 examines the effect of combustion quality as measured by MCE on the PCDD/PCDF emission factors. Three distinct groupings of emission factors for Dry, Wet, and PE are indicated. While Wet results show no apparent trend with MCE, PE results suggest that PCDD/PCDF emission factors decline with increased MCE ($r^2 = 0.93$). This is similar to observations for both $PM_{2.5}$ and select VOCs. Evaluation of the whole data set shows an $r^2 = 0.82$ with declining emission factor and MCE. Additional data are necessary to verify these MCE indications, although this trend is consistent with historical observations that equate improved combustion conditions with decreased PCDD/PCDF emissions.

These PCDD/PCDF emission factors are approximately ten times lower than literature values of 0.11–0.22 ng TEQ/kg $B_c$ from open burning of pine savannas[10, 32]

### PAHs

Individual PAH emission factors (for the 16 EPA PAHs) are shown in Table 5 and Sum of the 16 EPA PAHs are shown in Figure 13. Similar to observations of $PM_{2.5}$, select VOCs, and PCDD/PCDF, Wet piles resulted in greater emissions (statistically significant, F = 14.3, $p < 0.0001$), by a factor of 4–5. No distinction was observed, however, between any of the Dry (cover and uncovered) PAH emission factors. These emission factors compared to a value of 28 mg/kg burning Douglas fir in a laboratory setting[33].

The PAH measurements reflect both gas phase and particle-bound PAH compounds. The relationship between the emission factors for $PM_{2.5}$ and PAHs were examined in Figure 14. Predictably higher $PM_{2.5}$ is associated with higher PAHs.

The relationship between PAHs and combustion quality (MCE) is shown in Figure 15. As with previous emissions, lower combustion quality (MCE) is associated with higher PAH emissions. All of the Wet results have the lowest MCE and highest PAH levels.

## COMPARISON WITH OTHERS' DATA

Comparison of our results with previously compiled data on open pile burning of woody biomass from twelve sources[4] places our data within the range of reported results. Literature values for PM (total) ranged from 3–22 kg/kg dry biomass burned whereas our results were 3–18 kg/kg $B_c$ (these units are similar but derived differently). Likewise, reported CO emission factors were 17–164 g/kg in comparison to our results of 22–82 g/kg $B_c$. $CH_4$ values were reported at 0.9–11 g/kg versus ours at 1–6 g/kg $B_c$. Few other pollutants for field pile burns are characterized in the literature

## CONCLUSION

Field sampling of eleven biomass pile burns determined emission factors for a wide range of pollutants. Comparison of piles that were naturally wetted versus those that were dry showed statistically higher emission factors for $PM_{2.5}$, PAHs, VOCs, and PCDD/PCDF for the wet piles. Emission levels were negatively correlated with combustion quality as represented by MCE. Variation of PE cover size and thickness showed no statistically significant difference in emission factor for any of the pollutants suggesting that the PE was not contributing significantly to any of the measured pollutants. Time-resolved $PM_{2.5}$ emissions were highest at the beginning of the burns; for the Dry pile tests, this startup period lasted for less than 4 min; for the Wet pile tests, it was four times longer, about 16 min. For the Wet pile tests, $PM_{2.5}$ emission factors were higher than those of the Dry pile tests for at least half of the burn durations, after which they were similar. These tests suggest that use of PE as a biomass pile cover results in lower emission factors than those from piles exposed to moisture, reducing pollutant levels during slash pile burns. These emission factors, together with estimates of burn pile numbers, size, and fuel consumption, can be used by management and regulatory communities to minimize smoke impacts while limiting the potential hazard of biomass fuel loading.

## Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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**Figure 1.**
Typical burn pile, uncovered.

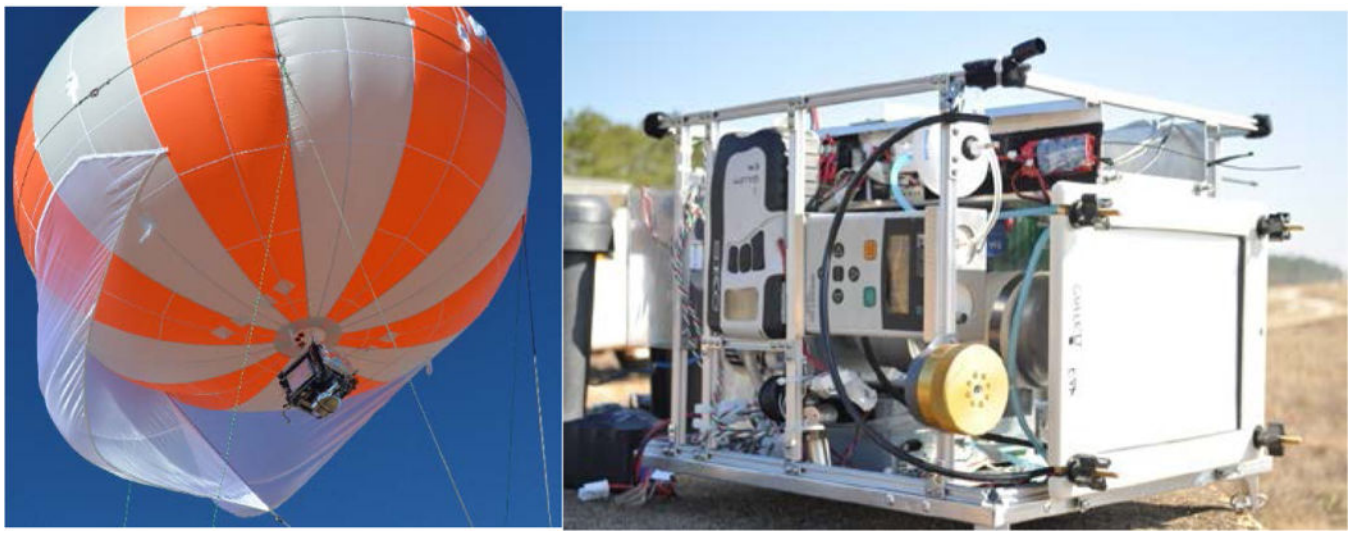

**Figure 2.**
Aerostat with Flyer (Left) and Flyer close up (Right).

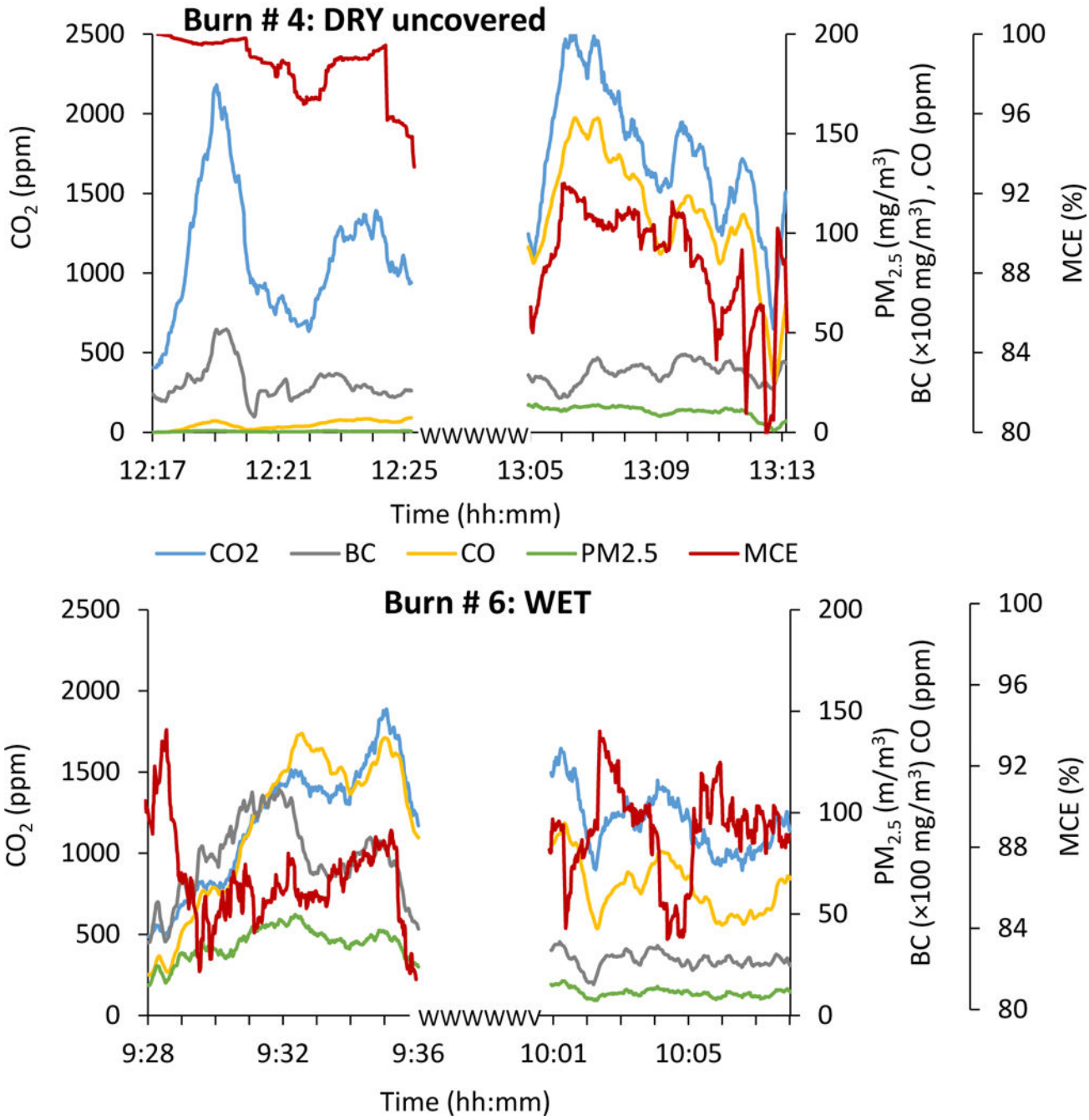


**Figure 3.**

Typical concentration traces of $CO_2$, CO, BC, $PM_{2.5}$ and modified combustion efficiency (MCE) for Dry and Wet burns. Traces displayed in 60 seconds moving average.

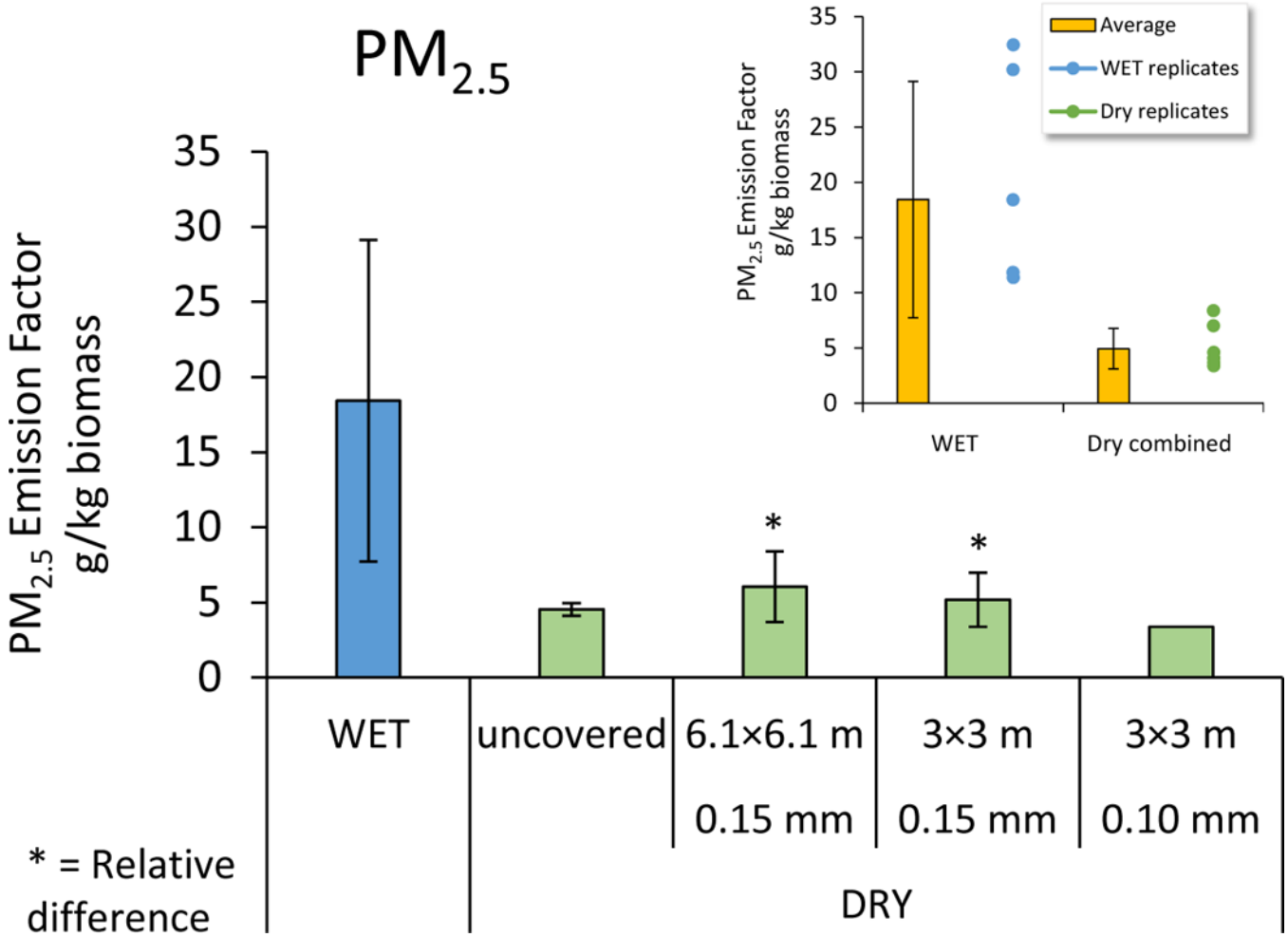


**Figure 4.**

$PM_{2.5}$ results. Inset chart shows Wet versus DRY (PE-covered and uncovered). Error bars represents 1 standard deviation if nothing else stated.

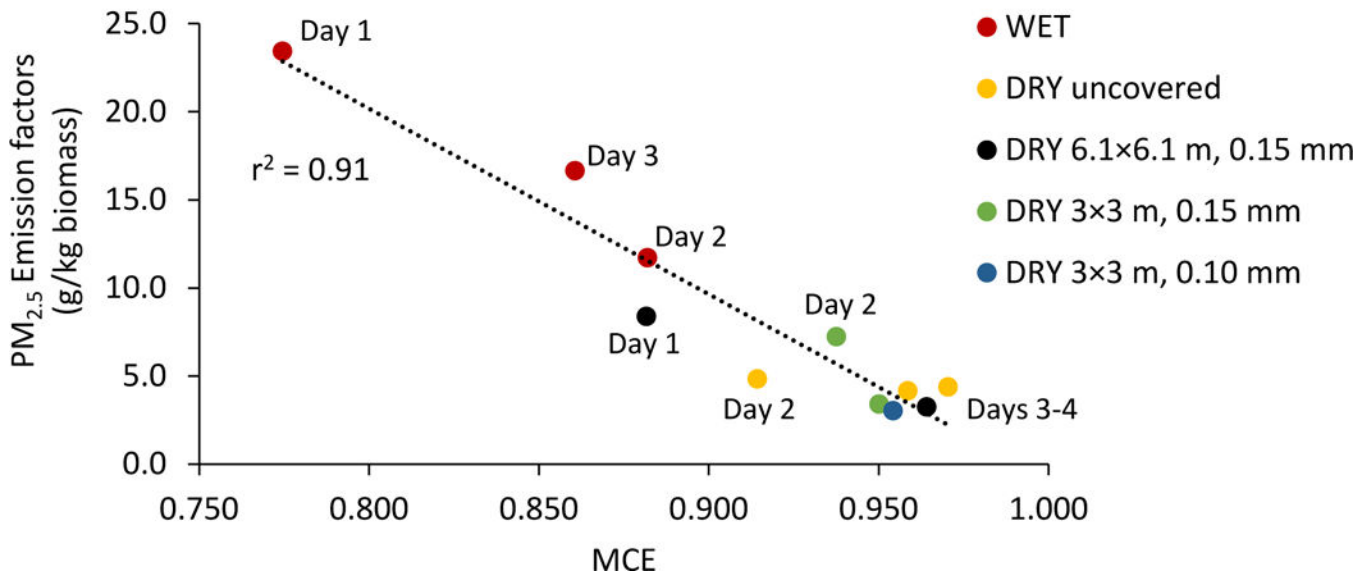


**Figure 5.**
The relationship between $PM_{2.5}$ emission factor and combustion quality (modified combustion efficiency, MCE).

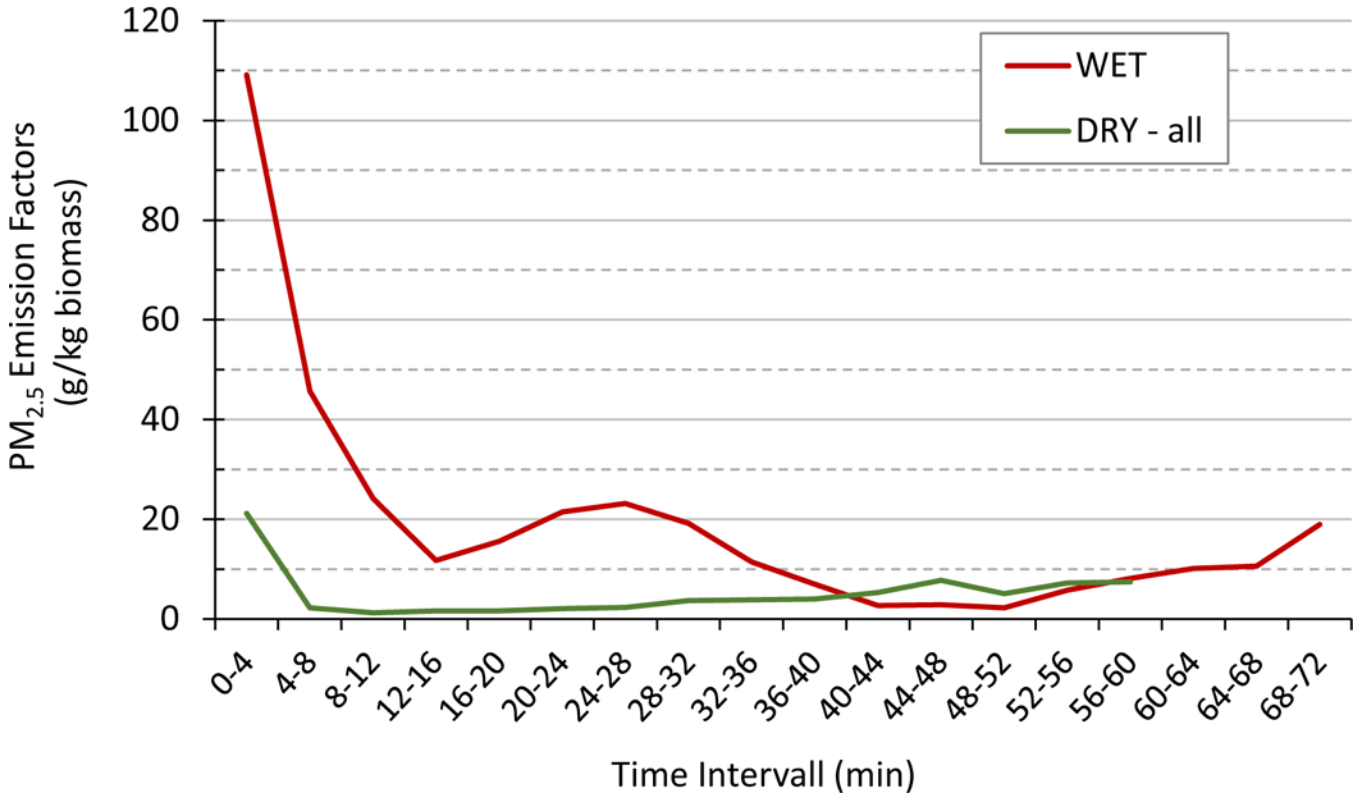


**Figure 6.**

Comparison of $PM_{2.5}$ emission factors at 4 min intervals throughout the burn durations, comparing the combined WET and combined DRY results.

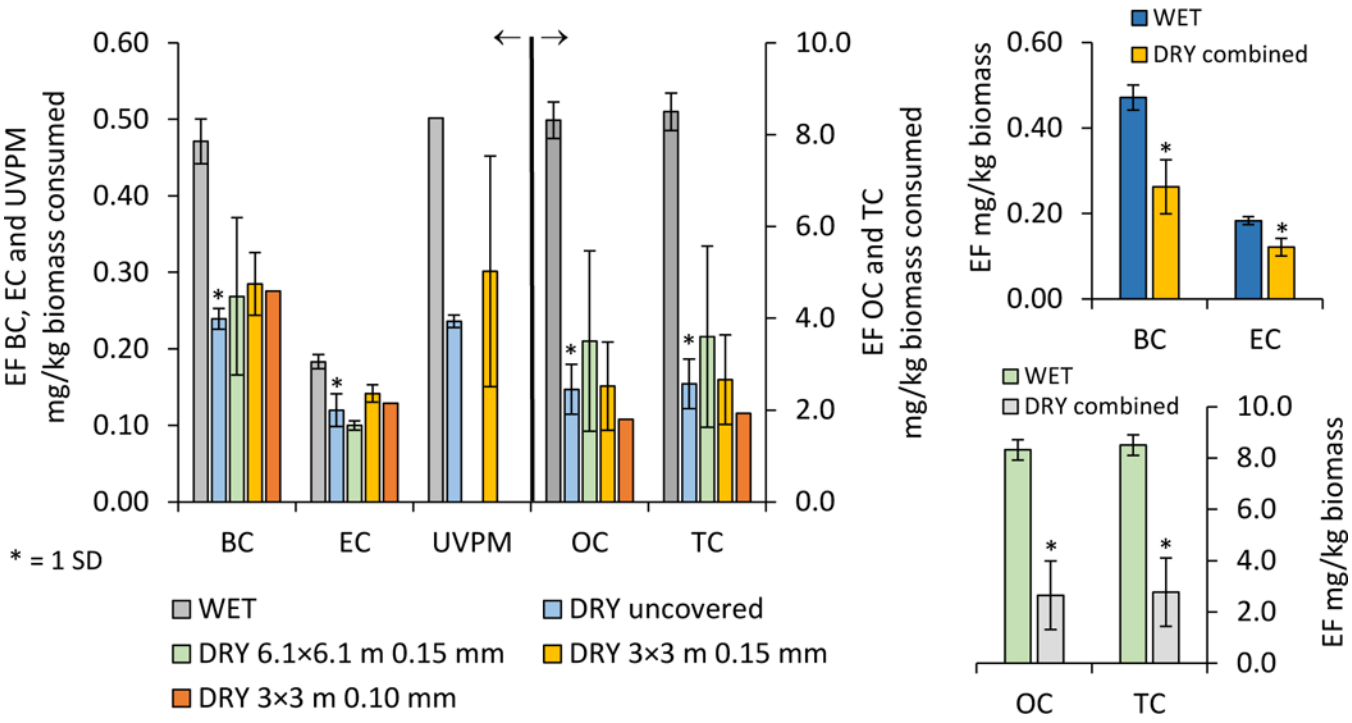


**Figure 7.**

BC, EC, UVPM, OC and TC results. Inset chart shows Wet versus DRY (PE- covered and uncovered). Error bars represents relative difference if nothing else stated.

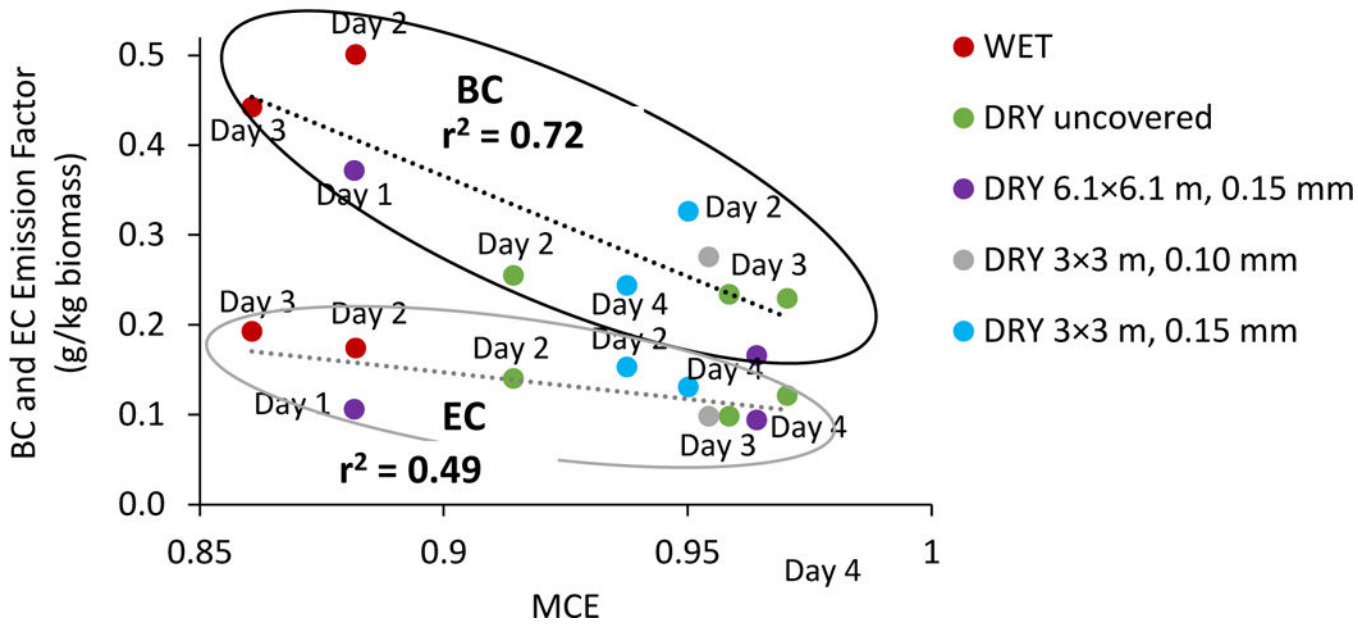


**Figure 8.**
BC and EC in relationship to modified combustion efficiency (MCE).

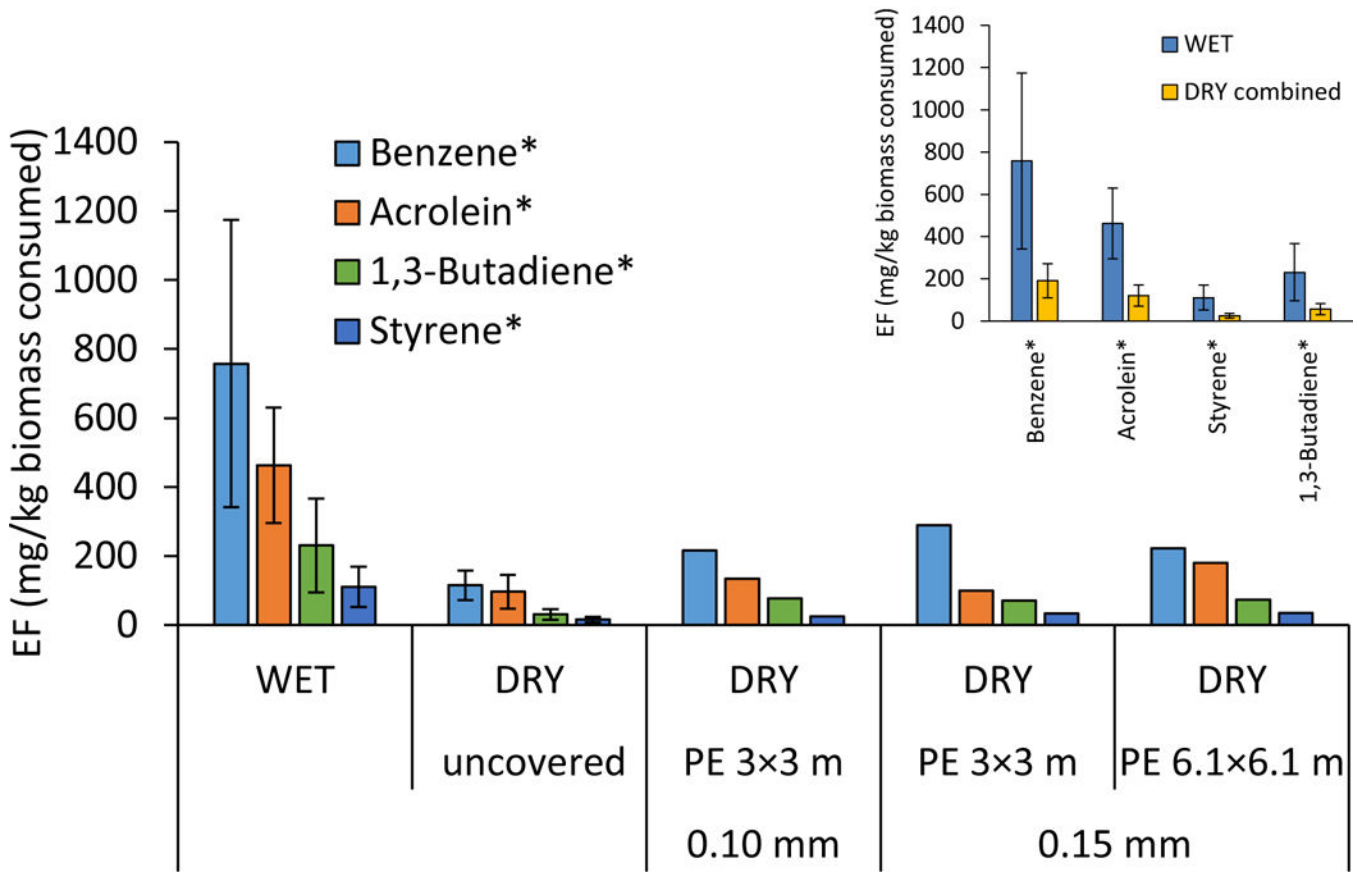


**Figure 9.**

VOC results. Error bars represent one standard deviation for WET burns and DRY combined burns, and relative difference for DRY uncovered burns. * = On U.S EPA's list of hazardous air pollutants.

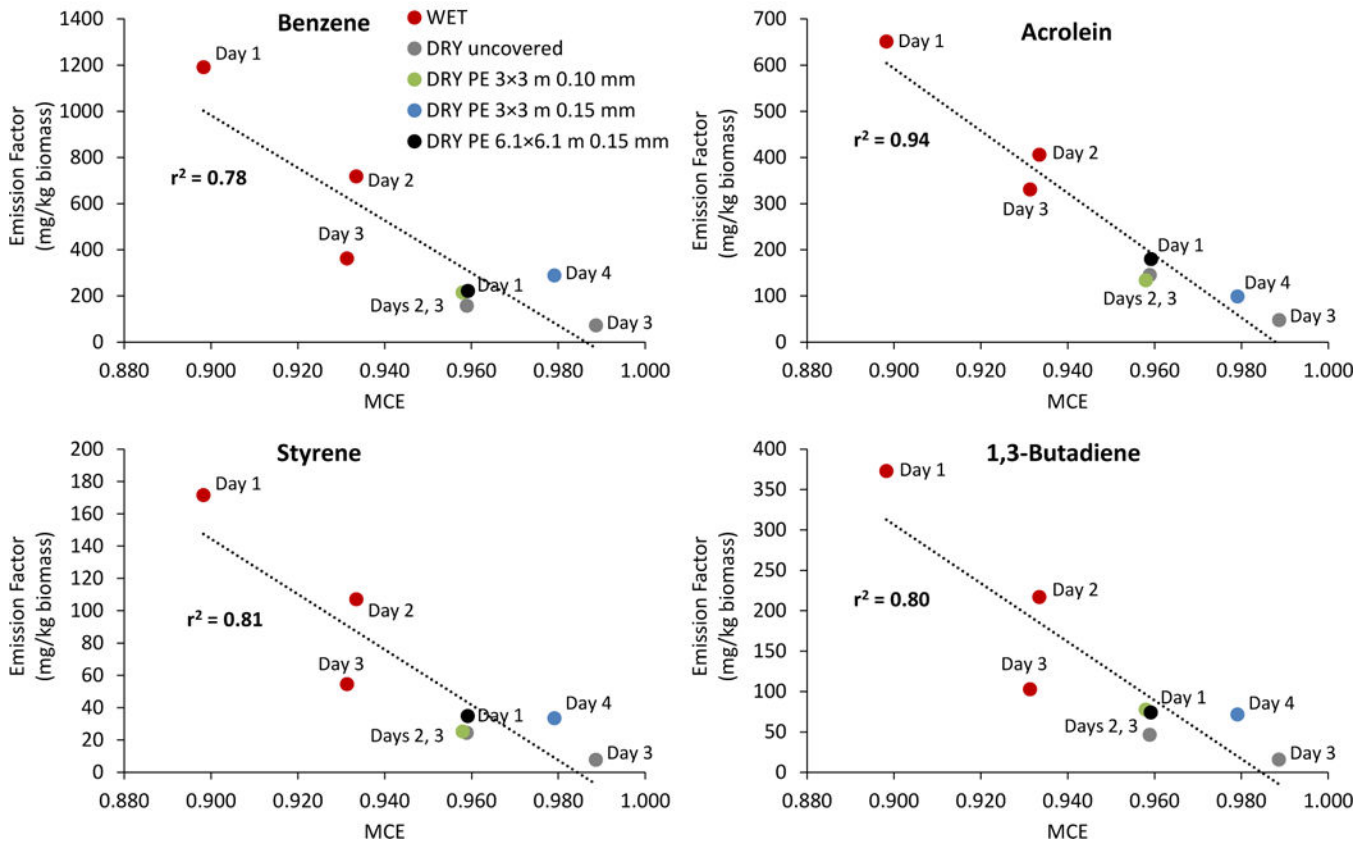


**Figure 10.**
The effect of modified combustion efficiency (MCE) on select VOC emission factors.

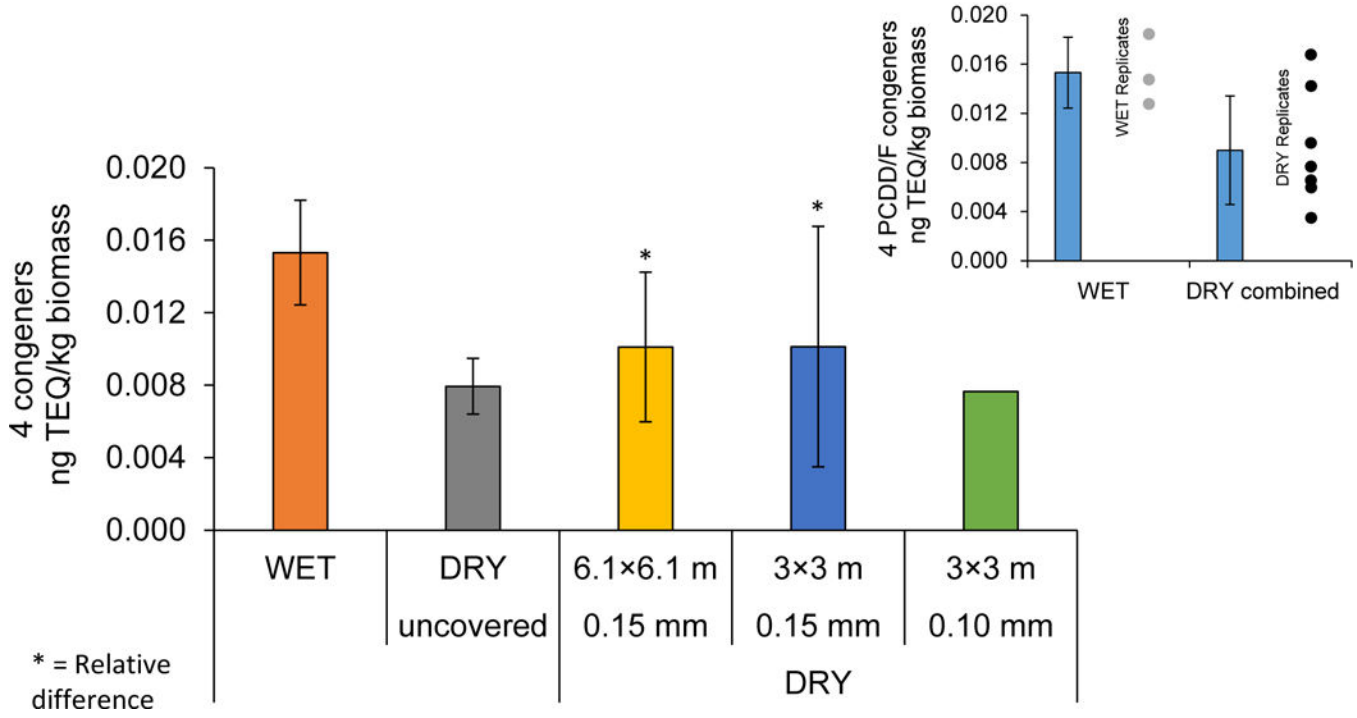


**Figure 11.**

PCDD/PCDF emission factors in ng TEQ/kg biomass consumed. Error bars represent 1 standard deviation if nothing else stated.

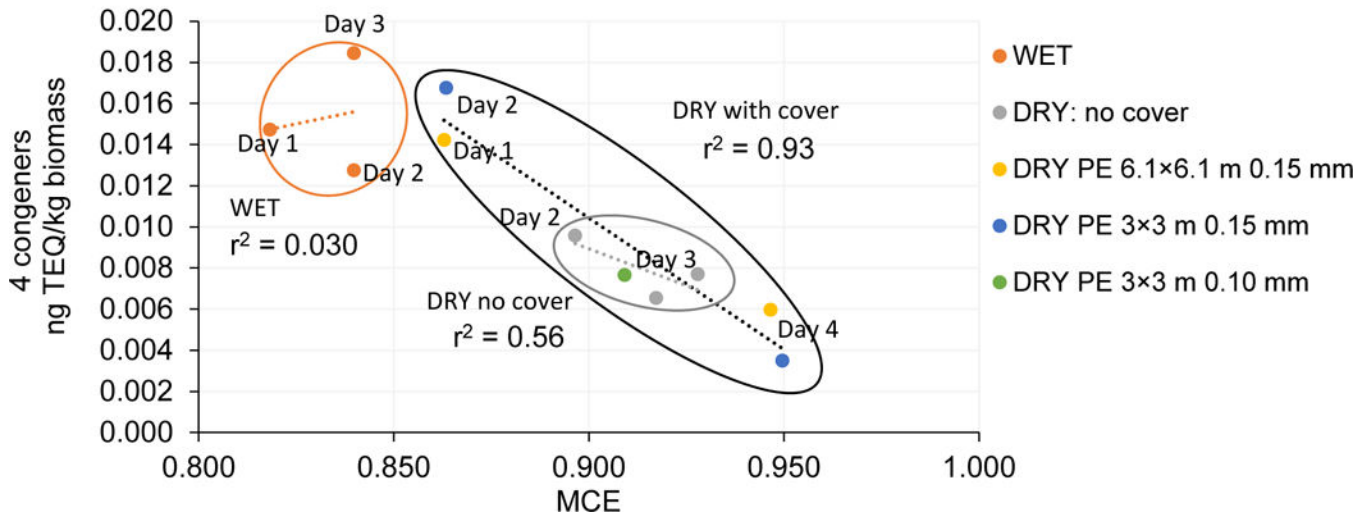


**Figure 12.**
PCDD/PCDF emission factors in ng TEQ/kg biomass consumed by group versus MCE.

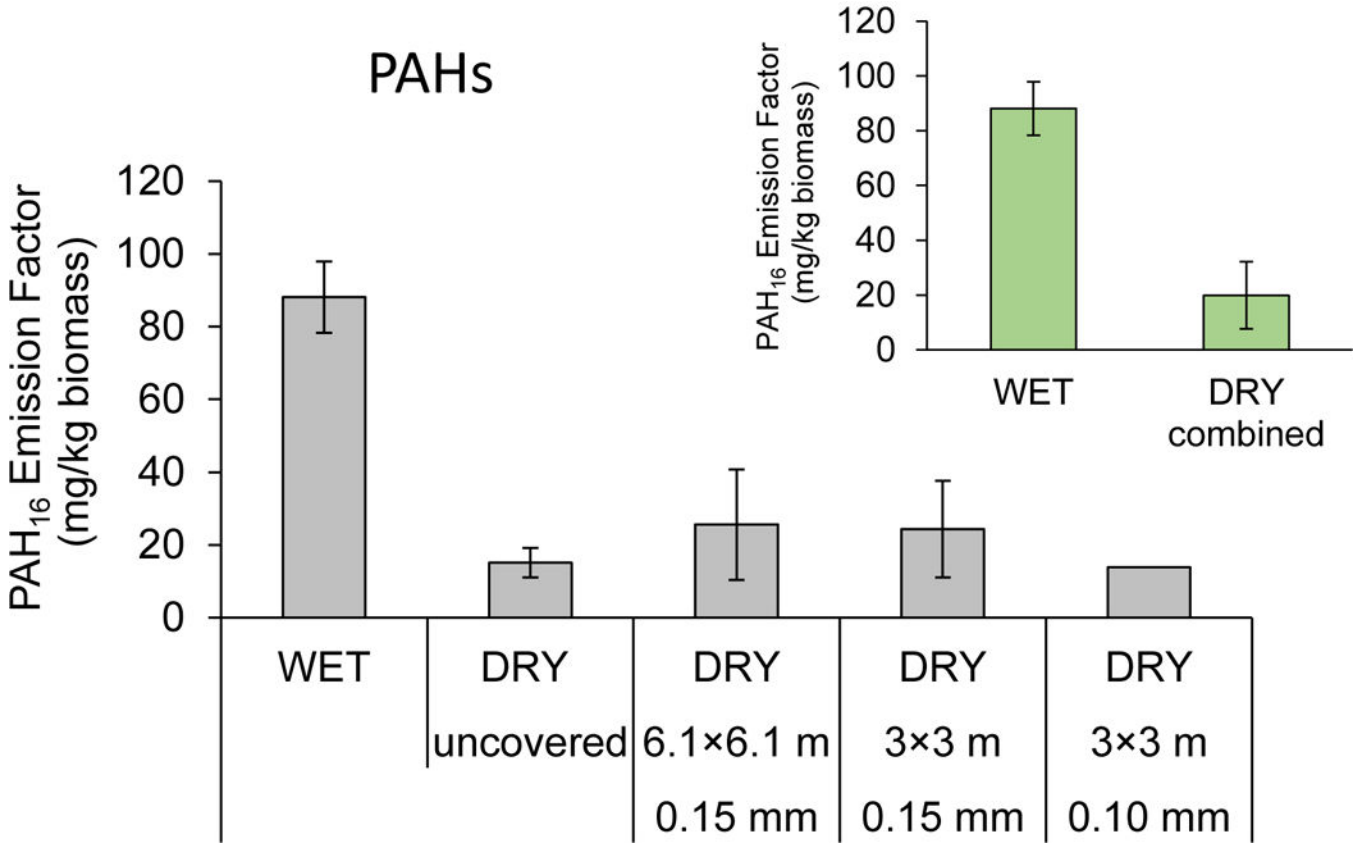


**Figure 13.**
Average PAH emission factors for each category.

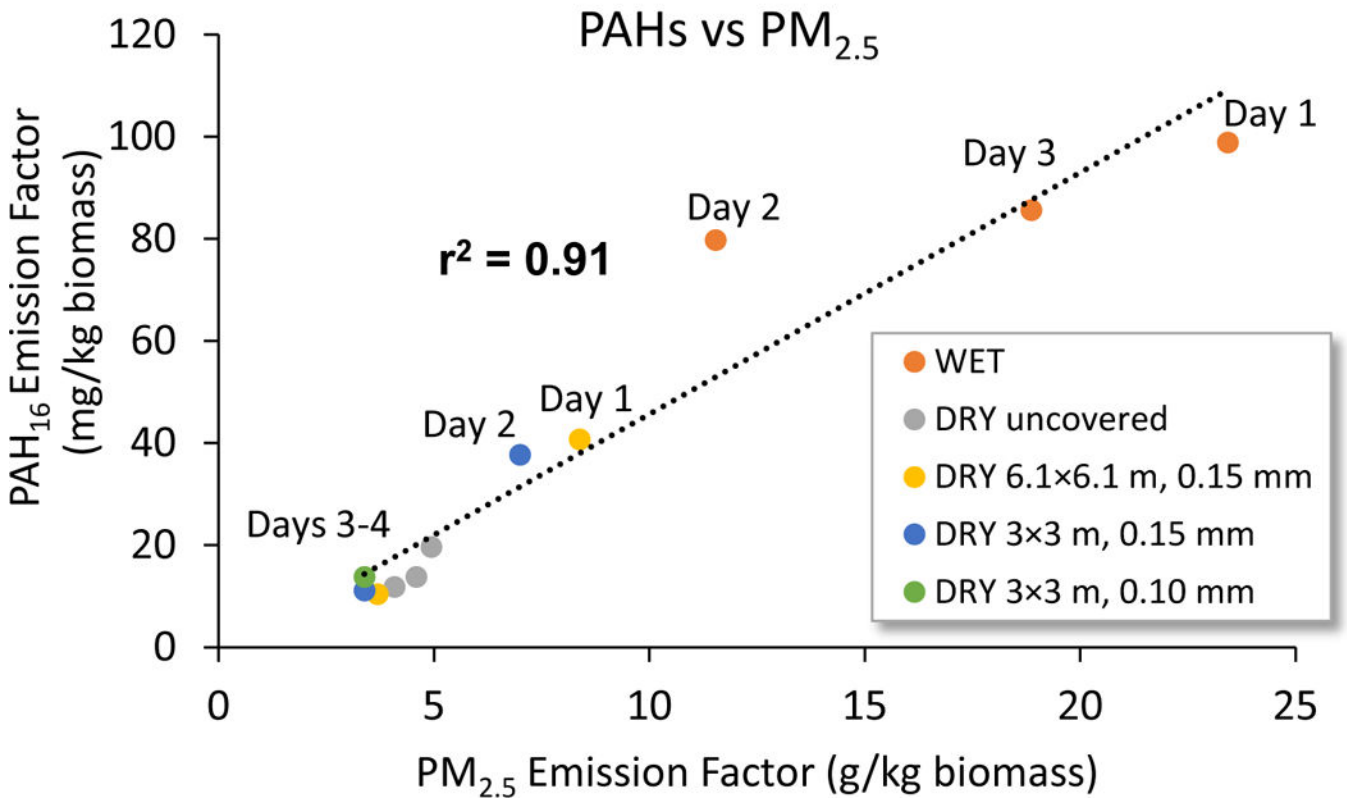


**Figure 14.**
Comparison of PAH emission factors and $PM_{2.5}$ emission factors.

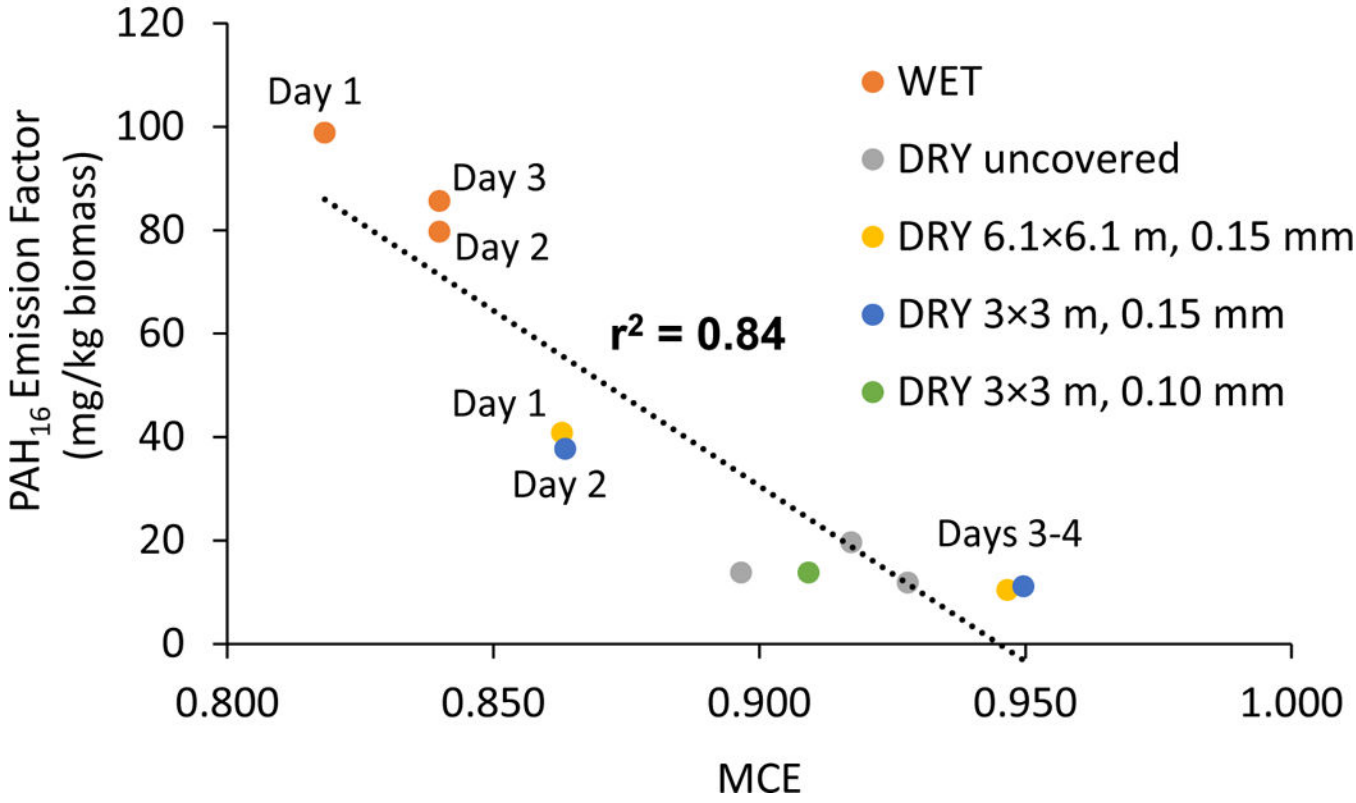


**Figure 15.**
Comparison of PAH emission factors with modified combustion efficiency (MCE).

**Table 1.**

Test order and type.

| Test Day | Test Order, Type, PE Size[a] (if applicable) |
|---|---|
| Day 1 | Burn 1: WET 01 |
| | Burn 2: DRY, PE 6.1×6.1 m, 0.15 mm |
| Day 2 | Burn 3: WET 02 |
| | Burn 4: DRY, uncovered |
| | Burn 5: DRY, PE 3×3 m, 0.15 mm |
| Day 3 | Burn 6: WET 03 |
| | Burn 7: DRY, uncovered |
| | Burn 8: DRY, PE 3×3 m, 0.10 mm |
| | Burn 9: DRY, uncovered |
| Day 4 | Burn 10: DRY, PE 6.1×6.1 m, 0.15 mm |
| | Burn 11: DRY, PE 3×3 m, 0.15 mm<br>Ambient background |

[a]PE = Polyethylene, area in m x m, thickness in mm

**Table 2.**

Target pollutants and sampling methods.

| Analyte | Method/Instrument | Frequency | Method Reference |
|---|---|---|---|
| $CO_2$ | NDIR LICOR-820[a] | Continuous 1 Hz | U.S. EPA Method 10A[19] |
| CO | Electrochemical cell e2V EC4–500-CO[b] | Continuous 1 Hz | U.S. EPA Method 10A[19] |
| $PM_{2.5}$ | SKC Impactor, 47 mm filter 2 μm pore size/gravimetric | Batch - 10 L/min[c] constant flow | 40 CFR 50, Appendix J[20] |
| $PM_{2.5}$ | DustTrak 8520[d] | Continuous 1 Hz | Laser optical, factory calibration |
| PCDD/PCDF/PAHs | Quartz filter/PUF/ XAD/PUF[e] | Batch - 650 L/min nominal flow[f] | Modified U.S. EPA Method TO-9A[21] |
| VOCs | 6 L SUMMA canister | 30–60 min integrated sample | U.S. EPA Method TO-15[22] |
| CO, $CO_2$, $CH_4$ | 6 L SUMMA canister | 30–60 min integrated sample | Modified U.S. EPA Method 25C[23] |
| Black carbon | Aethalometer, AE51[g]/AE52[g] | Continuous 1 Hz/0.1 Hz | 880 nm by light absorption, factory calibration |
| UVPM | Aethalometer, AE52[g] | Continuous 0.1 Hz | 370 nm by light absorption, factory calibration |
| Elemental, organic and Total carbon | SKC Impactor, 47 mm quartz filter | Batch - 10 L/min[c] constant flow | Modified NIOSH Method 5040[24] |

[a] LI-COR Biosciences, USA.

[b] SGX Sensortech, United Kingdom.

[c] Leland Legacy sample pump, SKC Inc., USA.

[d] TSI Inc., USA.

[e] Filter size 20.3×25.4 cm, Polyurethane foam (PUF) size 7.6×3.8 cm.

[f] Windjammer brushless direct current blower AMETEK Inc., USA.

[g] AethLabs, USA.

**Table 3.**

Results.[a]

| Pollutant | Unit | WET[b] | DRY[b] uncovered | DRY PE[c] 6.1×6.1 m 0.15 mm | DRY PE[c] 3×3 m 0.15 mm | DRY PE[d] 3×3 m 0.10 mm |
|---|---|---|---|---|---|---|
| **$CO_2$**[e] | g/kg $B_c$ | 1,689 (36%) | 1,785 (1.5%)[c] | 1,758[d] | 1,795[d] | 1,756[d] |
| **CO**[e] | g/kg $B_c$ | 82 (20%) | 29 (56%)[c] | 43[d] | 22[d] | 46[d] |
| **$CH_4$**[e] | g/kg $B_c$ | 5.7 (2.1%) | 1.1 (67%)[c] | 2.6[d] | 1.5[d] | 2.0[d] |
| **$PM_{2.5}$** | g/kg $B_c$ | 18 (58%) | 4.5 (9.5%) | 6.0 (39%) | 5.2 (35%) | 3.4 |
| **BC** | g/kg $B_c$ | 0.47 (6.2%[C]) | 0.24 (5.7%) | 0.27 (38%) | 0.28 (14%) | 0.28 |
| **UVPM** | g/kg $B_c$ | 0.50[d] | 0.24 (3.5%[C]) | NS | 0.30[d] | NS |
| **EC** | g/kg $B_c$ | 0.18 (4.1%[C]) | 0.12 (18%) | 0.10 (6.0%) | 0.14 (7.9%) | 0.13 |
| **OC** | g/kg $B_c$ | 8.2 (2.9%[C]) | 2.5 (22%) | 3.5 (56%) | 2.5 (38%) | 1.8 |
| **TC** | g/kg $B_c$ | 8.4 (2.9%[C]) | 2.6 (21%) | 3.6 (55%) | 2.7 (37%) | 1.9 |
| **OC/EC** | Ratio | 45 (6%) | 21 (32%) | 34 (52%) | 17 (31%) | 14 |
| **$BC/PM_{2.5}$** | Ratio | 0.033 (30%[C]) | 0.052 (9.4%) | 0.045 (0.6%) | 0.066 (47%) | 0.081 |
| **$EC/PM_{2.5}$** | Ratio | 0.013 (19%[C]) | 0.027 (22%) | 0.021 (34%) | 0.030 (28%) | 0.029 |
| **Σ VOCs**[f] | mg/kg $B_c$ | 4,106 (50%) | 612 (48%)[c] | 1,266 | 1,036 | 1,255 |
| **Σ PAH16** | mg/kg $B_c$ | 88 (10%) | 15 (27%) | 26 (59%) | 24 (54%) | 14 |
| **Σ PAH - TEQ** | mg B[a]$P_{eq}$/kg $B_c$ | 2.7 (11%) | 0.27 (32%) | 0.48 (62%) | 0.55 (50%) | 0.24 |
| **Σ PCDD/PCDF** | ng/kg $B_c$ | 15 (37%) | 5.8 (7.2%) | 8.0 (69%) | 7.6 (73%) | 5.1 |
| **Σ PCDD/PCDF TEQ**[g] | ng TEQ/kg $B_c$ | 0.18 (11%) | 0.077 (59%) | 0.14 (96%) | 0.066 (95%) | 0.057 |
| **Σ 4 PCDD/PCDF congeners**[h] | ng TEQ/kg $B_c$ | 0.015 (19%) | 0.0079 (19%) | 0.010 (41%) | 0.10 (65%) | 0.0077 |

[a] Units in mass of pollutant per mass of biomass consumed ($B_C$). NS = No sample. Relative standard deviation (RSD) and relative percent difference (RPD) within parentheses.

[b] RSD within parentheses.

[c] RPD within parentheses.

[d] Single sample.

[e] Derived from SUMMA Canisters.

[f] Sum of 74 VOCs analyzed via U.S. EPA Method TO-15 [22].

[g] Not detected congeners set to zero, results for each congener and homologue is presented in SI Table S5-S10.

[h] For intercomparison purpose only, PCDD/PCDF congeners detected in all samples: 1,2,3,4,6,7,8 - HpCDD, 1,2,3,4,6,7,8,9 - OCDD, 2,3,7,8 - TCDF, 1,2,3,4,6,7,8 - HpCDF.

**Table 4.**

VOC result.

| Compound | WET[a] | DRY uncovered[b] | DRY PE 3×3 m 0.10 mm | DRY PE 3×3 m 0.15 mm | DRY PE 6.1×6.1 0.15 mm |
|---|---|---|---|---|---|
| | mg/kg biomass consumed | | | | |
| Benzene[c] | 757±416 | 115 (37%) | 216 | 289 | 222 |
| Propene | 682±373 | 119 (53%) | 252 | 199 | 250 |
| Acetone | 668±280 | 32 | 163 | 78 | ND |
| Acrolein[c] | 463±168 | 97 (50%) | 134 | 99 | 180 |
| Vinyl Acetate[c] | 309±133 | 52 (58%) | 78 | 51 | 134 |
| Toluene[c] | 297±172 | 52 (55%) | 100 | 98 | 116 |
| 1,3-Butadiene | 231±136 | 31 (50%) | 78 | 71 | 74 |
| 2-Butanone (MEK) | 156±76 | 27 (69%) | 49 | 21 | 72 |
| Styrene[c] | 111±59 | 16 (52%) | 25 | 33 | 35 |
| Acetonitrile | 69±40 | 17 (60%) | 34 | 12 | 38 |
| m,p-Xylenes[c] | 68±41 | 13 (68%) | 22 | 15 | 27 |
| Ethylbenzene | 43±26 | 7.5 (53%) | 14 | 12 | 15 |
| alpha-Pinene | 41±31 | 8.7 (60%) | 17 | 17 | 14 |
| d-Limonene | 31±21 | 6.7 (3.9%) | 8.7 | 12 | 13 |
| Acrylonitrile[c] | 27±14 | 6 (25%) | 12 | 7.0 | 11 |
| o-Xylene[c] | 23±14 | 4.4 (73%) | 8.0 | 4.5 | 9.1 |
| 1,2,4-Trimethylbenzene | 12±5.8 | 2.4 (1.7%) | 3.8 | 1.9 | 4.2 |
| 1,3,5-T rimethylbenzene | 3.5±1.6 | 1.2 | 1.2 | 0.49 | 1.2 |

[a]Range of data equal one standard deviation.

[b]Range of data equals relative percent difference.

[c]On U.S. EPA's list of hazardous air pollutants[31]. The VOCs shown here were selected based on the number of samples detectable above three times the detection limit and their relevance to the EPA's list of hazardous air pollutants list and their role as greenhouse gas/ozone precursors. Full list of the 74 analyzed VOCs and their emission factors are presented in SI Tables S11-S12.

**Table 5.**

PAH emission factors.

| PAHs | WET[a] | DRY[a] uncovered | DRY PE[b] 6.1×6.1, 6 mm | DRY PE[b] 3×3, 6 mm | DRY PE[c] 3×3, 4 mm |
|---|---|---|---|---|---|
| | mg/kg biomass consumed | | | | |
| Naphthalene | 17 (3.4%) | 4.4 (37%) | 8.1 (50%) | 7.4 (54%) | 5.0 |
| Acenaphthylene | 16 (14%) | 2.5 (24%) | 4.6 (65%) | 4.1 (53%) | 2.3 |
| Acenaphthene | 1.6 (21%) | 0.34 (24%) | 0.60 (67%) | 0.46 (59%) | 0.27 |
| Fluorene | 6.4 (35%) | 0.97 (27%) | 1.7 (66%) | 1.5 (61%) | 0.75 |
| Phenanthrene | 19 (20%) | 3.3 (26%) | 4.8 (64%) | 4.5 (57%) | 2.5 |
| Anthracene | 4.1 (15%) | 0.65 (28%) | 1.0 (63%) | 0.98 (56%) | 0.50 |
| Fluoranthene | 6.9 (3.4%) | 0.90 (30%) | 1.4 (59%) | 1.6 (54%) | 0.76 |
| Pyrene | 6.2 (10%) | 0.78 (31%) | 1.3 (59%) | 1.5 (51%) | 0.68 |
| Benzo(a)anthracene | 2.1 (10%) | 0.24 (28%) | 0.43 (64%) | 0.44 (54%) | 0.20 |
| Chrysene | 2.5 (10%) | 0.38 (24%) | 0.61 (62%) | 0.58 (55%) | 0.30 |
| Benzo(b)fluoranthene | 1.3 (14%) | 0.13 (28%) | 0.24 (61%) | 0.25 (51%) | 0.11 |
| Benzo(k)fluoranthene | 1.7 (6.9%) | 0.16 (35%) | 0.29 (61%) | 0.34 (47%) | 0.15 |
| Benzo(a)pyrene | 1.7 (12%) | 0.16 (33%) | 0.29 (62%) | 0.34 (49%) | 0.14 |
| Indeno(1,2,3-cd)pyrene | 0.84 (12%) | 0.073 (38%) | 0.13 (60%) | 0.17 (47%) | 0.067 |
| Dibenz(a,h)anthracene | 0.20 (14%) | 0.021 (28%) | 0.037 (63%) | 0.041 (51%) | 0.022 |
| Benzo(ghi)perylene | 0.98 (14%) | 0.086 (38%) | 0.15 (58%) | 0.21 (45%) | 0.079 |
| **SUM 16-EPA PAH** | **88 (11%)** | **15 (27%)** | **26 (59%)** | **24 (54%)** | **13.8** |

[a]Range of data within parentheses equals relative standard deviation.

[b]Range of data within parentheses equals relative percent difference.

[c]Single sample.