United States Department of Agriculture

Forest Service

# Grand Mesa, Uncompahgre, and Gunnison National Forests

## DRAFT Forest Assessments: Aquatic and Riparian Ecosystems

**November 2017**
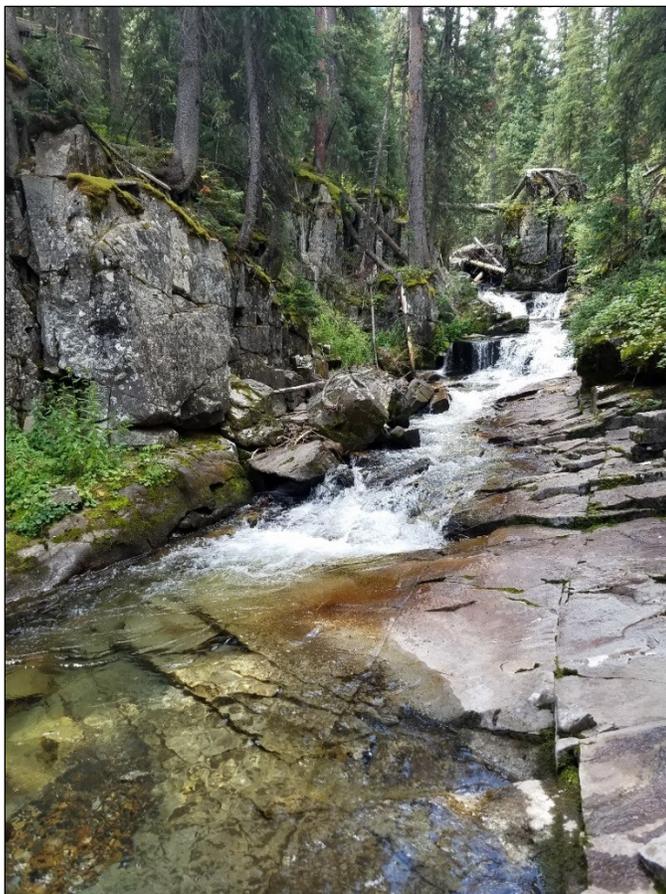
Streams like Bilk Creek in the San Juan Mountains provide high-quality aquatic habitat while supplying pristine water resources.

# Contents

# List of Tables

# List of Figures

# Chapter 1. Introduction

In this assessment, we address the ecosystem integrity of the major aquatic, riparian, and wetland ecosystems on the GMUG NF. We also discuss the drivers, stressors, and threats to their ecosystem integrity on the forest. Given the GMUG's climate, it is likely that most of these ecosystems are groundwater-dependent, with the exception of some intermittent and ephemeral streams (Stroope, pers comm). Complementary additional information is located in the *Watershed, Water and Soil Resources* assessment; cross-references are noted throughout. A separate assessment - *Terrestrial Ecosystems* - addresses the ecosystem integrity of terrestrial ecosystems on the GMUG.

## Key Issues for Aquatic and Riparian Ecosystems on the GMUG

The current Forest Plan includes standards and guidelines that could be revised to allow for more effective management strategies within aquatic ecosystems. One such revision would move away from inventory and monitoring of aquatic macroinvertebrates and focus on fishes and amphibians. Future management direction should capitalize on existing information and the ability of these groups to serve as surrogate species for managing aquatic ecosystems.

Along with a myriad of other factors, increasing population growth and climate change will likely result in increased water demand in the future. Serving as the headwaters for parts of the Upper Colorado River, Dolores River and most of the Gunnison River, water development on the GMUG is and will remain crucial.

## Summary Public Input

The GMUG National Forests conducted eight public comment open houses during the summer of 2017 to encourage input from the public during the Forest Plan Revision Assessment Phase, and also received emails and electronic and hand-written comments.

Issues discussed included instream flow rights, water development, water pollution and instream habitat improvement.

Further concerns were voiced regarding the presence of Threatened or Endangered Species of fishes within any given waterbody and the effect they would have on future water development.

Several users and permittees (fishing outfitters) expressed concern that they would like to see more habitat improvements for stream fishes.

## Use of Best Available Science

The following information was integrated into this assessment: 1) 2004 GMUG Riparian ecosystems spatial dataset; 2) 2014 GMUG Wetland and Fen inventory; 3) 2016 FWS National Wetlands Inventory; 4) GMUG FSVegSpatial data (polygons identified as "riparian"); 5) 2011 GMUG Watershed Condition Framework; 6) 2005 GMUG Subwatershed Condition Assessment; 7) 2012 Species Assessment for native cutthroat trout on the GMUG; 8) 2013 Species Assessment for non-native trout on the GMUG; 9) 2006

Aquatic, Riparian, and Watershed Assessments for GMUG and San Juan NFs. Additional peer-reviewed scientific research was integrated into this assessment.

## Information Gaps

The GMUG would benefit from a comprehensive and consistent GIS effort focused on mapping riparian, wetland, and other groundwater-dependent ecosystems.

Further, we did not have information to assess ecosystem function, which is the output resulting from the structure of the components of an ecosystem. Examples of functions include seasonal variations in stream flow, frequency of disturbances, nutrient cycling, and ecosystem services (such as carbon sequestration or clean water production).

# Chapter 2. Condition and Trends

Conditions and trends for aquatic, riparian and wetland ecosystems on the GMUG NF were assessed by evaluating the following key ecosystem characteristics. As noted above, we did not have information to assess ecosystem function.

## Ecosystem Composition

Ecosystem composition can be defined as the pieces that make up an ecosystem. Examples include geologic characteristics, soils, and species that define an ecosystem. For example, a wetland has specific physical characteristics that result in a specific biological community. The process also works in reverse. For example, beaver "engineer" stream ecosystems through the construction of dams.

## Ecosystem Structure

Ecosystem structure is how the components of an ecosystem are organized on the landscape. The word forest can be defined broadly; however, different forest types (aspen versus Ponderosa pine, for example) are structured differently.

## Ecosystem Connectivity

Specific ecosystems repeat across a landscape. For example, numerous discrete wetlands are found across the GMUG NF. Ecosystem connectivity refers to the extent to which multiple units of a single ecosystem are connected to one another and how a specific ecosystem is connected to the surrounding landscape. Ecosystem connectivity varies with ecosystem type. For example, terrestrial ecosystems, such as forests, connect to one another in at least two dimensions (north-south and east-west), while aquatic ecosystems are one-dimensional (upstream-downstream).

Consequently, human activity and natural processes can affect ecosystem connectivity in different ways. For aquatic ecosystems, connectivity can be affected by placement of roads or culverts that alter stream hydrology and create barriers to aquatic organism movement.

# Aquatic Ecosystems

Aquatic ecosystems on the GMUG include streams (perennial, intermittent, and ephemeral), springs, and lakes and reservoirs. See also the *Watersheds, Water, and Soil Resources Assessment* for complementary additional information. Streams are assessed here.

Life in streams on the GMUG has adapted to relatively low water temperatures and commensurate low productivity. While many streams support 30 or 40 species of invertebrates (e.g. insects) there are few fishes that are native to the area. However, many non-native species, particularly trout, have been introduced to streams on the GMUG and are maintained to support a vibrant recreational fisheries with significant economic impact to surrounding communities.

## Integrity of Aquatic Systems

Aquatic ecosystem integrity for the GMUG was assessed based on several key ecosystem characteristics: 1) distribution of native and non-native fish species, particularly trout (composition); 2) distribution and abundance of aquatic invertebrates and the characteristics of aquatic invertebrate communities across the forest (composition); 3) characteristics of physical habitat in streams (structure); 4) fragmentation of stream habitat caused by human uses, such as dams (connectivity) and 5) distribution and abundance of native amphibians and the distribution of the invasive fungi (*Batrachochytrium dendrobatidis*) (composition). The scale and quality of data for each of these characteristics is variable. For example, information on fish distribution is the result of systematic sampling by Forest Service, Colorado Parks and Wildlife, and BLM personnel. Information on stream habitat characteristics has been collected in particular watersheds, the need for which was often project specific. Each section describes the type of data that served as the basis for an analysis.



**Figure 1. The native threatened, green lineage - Colorado River Cutthroat Trout**

### *Native Fish Distribution*

There are 24 extant populations of green-lineage Colorado River Cutthroat Trout known to exist on the GMUG NF. Research suggests this variety of cutthroat trout is aboriginal to the GMUG NF (Metcalf et al., 2012). At least two green-lineage cutthroat trout populations are

located on each Ranger District. These fish occupy about 90.3 miles of habitat in 24 streams on the GMUG NF.

Bluehead Suckers occupy 12 streams on the GMUG NF; however, they are relatively rare given the habitat preferences of the species reflecting conditions more commonly found in lower elevation streams: warm water temperatures, for example. An estimate of the amount of habitat occupied by this species is not available. Bluehead Suckers occupy somewhat warmer waters of lower gradient seasonally throughout the year and use higher elevation, higher gradient streams in the spring for spawning.

Two species, Flannelmouth Sucker and Roundtail Chub, are known to be present directly downstream from the national forest. These streams are located mainly on the Uncompahgre Plateau. Flannelmouth Sucker and Roundtail Chub are included on the current Region 2 Sensitive Species list. They are associated with Bluehead Sucker as these species have similar habitat preferences. There are four endangered species in the Colorado River and lower Gunnison River: Bonytail Chub, Colorado Pikeminnow, Humpback Chub, and Razorback Sucker. These species occupy habitat several stream miles removed from the national forest boundary; however, a large percentage of the water creating their habitat originates on the national forest.

### Non-native Cold-Water Fish Distribution

Since 2001 Brook Trout have been observed in 63 streams, Brown Trout in 24 streams, and Rainbow Trout in 38 streams. Self-sustaining populations of all three species can be found across the GMUG and CPW maintains Rainbow Trout populations through stocking in a number of streams, lakes, and reservoirs. Unless there are site-based data to the contrary, we assume all perennial streams on the GMUG NF are occupied by at least one species of native or non-native trout. However, natural barriers do exist in numerous locations (i.e., waterfalls), creating fishless reaches of stream. Fishless portions of stream may be important for other aquatic fauna such as toads and frogs that would otherwise be predated by trout.

There are 11 known populations of blue-lineage Colorado River Cutthroat Trout on the GMUG NF. This type of cutthroat trout is native to Colorado but is not native to the watersheds of the GMUG NF (Metcalf et al., 2012). Blue-lineage cutthroat trout occupy 33.5 miles of habitat in 10 streams and about 15 acres of habitat in one reservoir.

### Amphibians and Chytrid

Native amphibians to the GMUG National Forests include barred tiger salamander (*Ambystoma mavortium*), boreal chorus frog (*Pseudacris maculata*), northern leopard frog (*Lithobates [Rana] pipiens*) and western (boreal) toad (*Anaxyrus boreas boreas*). Because amphibians require aquatic environments at some point in their life cycle and respire through their skin they are very susceptible to changes in the aquatic environment. Worldwide there has been a drastic decline in amphibian populations and distribution. In part this decline has been attributed to the spread of invasive diseases and pollution.

Historically, boreal toad (BOR) and northern leopard frog (NLF) were widely distributed, abundant and considered ubiquitous in Colorado (Corn 1994). Some of the earliest documentation cited observations of BOR and NLF in road side puddles and around Taylor

Park Reservoir on the Gunnison National Forest (Burger and Bragg 1947). The same account observed young BOR swarming in the shallow water and in vegetation near Cement Creek.

Disease outbreak has been the single largest contributing factor to the decline of BOR and NLF in Colorado. Most mass mortality events in the western U.S. have been attributed to chytridiomycosis (chytrid, Carey *et al.* 1999, Green *et al.* 2002, Voordouw *et al.* 2010). A fungal infection, chytrid is caused by the flagellated zoospore *Batrachochytrium dendrobatidis* (*Bd*, Daszak *et al.* 2000). Thought to have originated from Africa and transported by pet trade, *Bd* is characteristically aquatic and unique from other fungi because it is capable of moving through water using a single flagellum.

Not only is it motile but it can be transmitted from host to host through direct contact (territorial or breeding encounters), movement of surface water, in damp or moist soil and in laboratory tests it has been found to live on the feathers of birds, especially waterfowl, long enough to be transported between waterbodies (Johnson and Speare, 2003; 2005). Although mammalian body temperatures preclude *Bd* infection both migrating aquatic and terrestrial mammals may serve as vectors of this disease.

Formerly common in the West Elk Mountains (Burger and Bragg, 1947), Carey (1993) observed that eleven populations of BOR found there during 1971-1973 were all extinct by 1982. All eleven of these populations were within the boundaries of GMUG administered lands. Currently the GMUG National Forests has only fifteen (15) known occurrences of boreal toad, with less than half of those (7) exhibiting successful breeding.

The full extent of NLF distribution within the Grand Mesa, Uncompahgre and Gunnison National Forests (GMUG) has yet to be established. There have been considerable occupancy surveys conducted within the North Fork of Gunnison River (North Fork) watershed. At lower elevations along the periphery of the GMUG, NLF is considered abundant in the North Fork (Dennis Garrison, personal com). Unfortunately within the rest of the GMUG where NLF was once known to exist there are no positive sightings of the frog. As addressed above, disease is a possible cause of local extirpation. However, since frogs have an innate immune response that renders them less susceptible to chytrid, there may be other factors in play.

One such factor has been documented in the decline of NLF in the Sierra Nevada Mountains of California; the volatilization of persistent organic pollutants (POP). Termed orographic cold trapping, volatile organic compounds used in pesticide application can evaporate during application in agricultural areas and become suspended in the atmosphere. Regional weather patterns then transport the dissolved particles to areas of higher elevation where heavier moisture laden air-masses must cool adiabatically to pass over mountain ranges. Termed orographic lifting, these air masses drop their moisture and heavier elements including POPs over high elevations. Further confounding the problem, research (Taylor *et al.* 1999) suggests that immunosuppression due to POPs could have aided in the mass dies offs of NLF and BOR caused by red leg disease and chytrid observed in the West Elk Mountains in the 1970s (Carey 1993).

### *Aquatic Macroinvertebrates*

Between 1992 and 2007 288 samples of macroinvertebrates were collected in streams on and adjacent to the GMUG NF. Samples were collected by USFS and BLM personnel. Streams on the GMUG NF contain invertebrate communities that are typical of streams in the

southern Rocky Mountains, including stoneflies, mayflies, and caddisflies. Additionally, aquatic beetles, aquatic flies (dipterans), and a few species of mollusks are relatively common.

The number of identified taxa within these samples varied considerably. The Montrose Field Office of the BLM collected 219 samples from 1992 through 2006 and observed an average 20 different invertebrates in those samples. A graduate research study conducted on the GMUG in 2004 and 2005 included the collection of 61 invertebrate samples. An average of 33 different invertebrates were observed in those samples. The most diverse sample was collected in the Clear Fork of East Muddy Creek in 2005. Forty-eight different invertebrates were identified in that sample. A common index of species diversity, Shannon's H, was applied to both of these datasets. The average diversity value for the BLM dataset was 1.8, whereas the average value in the national forest sample was 2.2.

A Benthic Index of Biological Integrity was applied to 49 invertebrate samples collected on the GMUG NF (Figure 2). Samples are ranked from 1, which indicates a strong deviation from expected conditions, to 5, which is equivalent to undisturbed conditions. Thirty-five of the 49 samples scored 4 or 5 and only three samples scored 1. These data, which were collected in a representative sample of GMUG streams, indicate macroinvertebrate communities and the streams they inhabit on the forest are not experiencing broad-scale negative changes resulting from human use of the surrounding environment.
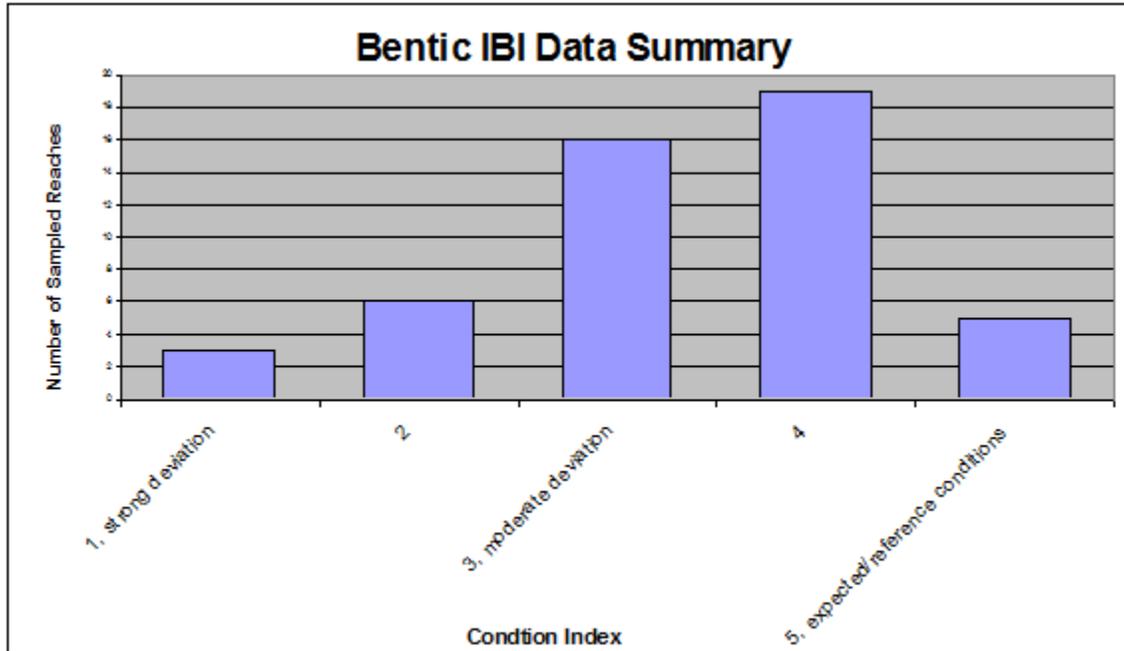


**Figure 2. Benthic Index of biological integrity values for macroinvertebrates collected in 49 streams on the GMUG NF**

### *Stream Habitat Characteristics and Variation*

The number of extant native Cutthroat Trout populations and the ubiquity of all three common trout species in GMUG watersheds suggests the Forest contains ample habitat for cold-water species. There is no evidence to suggest that current or future land management activities or other human impacts will affect the amount of habitat available to cold-water fishes at the Forest scale. However, 23 streams on the GMUG are affected by historic mining, and most of these do not support viable populations of native or non-native fishes.

Stream habitat quality is variable on the GMUG. In 2006 GMUG personnel completed a broad-scale assessment of stream and riparian habitat conditions using the PACFISH/INFISH Biological Opinion (PIBO) protocol (Adams 2006). Habitat data were collected in 19 reference watersheds. Reference watersheds were those exhibiting the least human influence and represented the most "natural" conditions on the Forest. Within each watershed a variety of abiotic and biotic data were collected in a response reach, which was defined as having a gradient of less than 4% (Table 1).

**Table 1. Reach-scale stream habitat characteristics collected in response reaches of 19 reference watersheds on the GMUG NF**

[Data were collected using the PACFISH/INFISH Biological Opinion (PIBO) protocol (Kershner et al., 2004).]

| Attribute | Mean (SD) | Range |
|---|---|---|
| Residual pool depth (m) | 0.28 (0.13) | 0.12 – 0.69 |
| Undercut depth (m) | 0.68 (0.60) | 0.19 – 3.02 |
| Undercut banks (%) | 30.30 (15.13) | 4.76 – 60.00 |
| Bank angle | 107.45 (14.05) | 76.00 – 132.31 |
| Bank stability (%) | 95.95 (5.04) | 78.57 – 100.00 |
| Width to depth ratio | 22.03 (4.99) | 8.02 – 36.34 |
| Pool fines, < 2 mm (%) | 14.20 (24.14) | 0.00 – 99.33 |
| Pool fines, < 6 mm (%) | 16.20 (24.31) | 0.00 – 99.43 |
| D50 (mm) | 61.29 (40.49) | 2 – 134 |
| D85 (mm) | 143.66 (100.00) | 6.84 – 350 |
| Conductivity | 97.90 (74.58) | 30 – 270 |
| Alkalinity | 90.79 (45.54) | 20 – 240 |

The data in Table 1 represent baseline microhabitat information for streams on the Forest. Future management activities may impact stream and riparian habitat conditions in streams supporting aquatic species. It is likely that stream habitat surveys will be prompted by project proposals that include management activities which may affect streams and riparian areas. Baseline information is necessary to insure best-management practices (BMPs) and mitigation measures are effective in maintaining habitat conditions conducive to healthy stream fish populations.

### *Instream Flow Water Rights*

See the *Watersheds, Water, and Soil Resources* assessment.

### *Fragmentation of Aquatic Habitat*

On the GMUG, habitat fragmentation and isolation result from poorly designed road crossings and water diversion structures. In streams where these structures are present fish are often able to move downstream but are precluded from returning by the structure. There are no watersheds on the GMUG NF that are not affected by human-caused aquatic fragmentation. See the Watershed, Water and Soil Resources assessment for quantitative information about stream connectivity and fragmentation on the GMUG.

The effects of habitat fragmentation and isolation on stream fish populations are well documented (Dunham et al., 1997). Habitat fragmentation reduces the long-term persistence probability of a population by reducing the population size and restricting life history diversity. Habitat fragmentation also increases the probability that a single disturbance event (e.g., fire or debris flow) could eliminate an entire population (Dunham et al., 2003). However, recent research on inland Cutthroat Trout suggests this species can persist for long periods in relatively small habitat patches when the quality of instream habitat is high (Peterson et al., 2013). These results suggest that native Cutthroat Trout could be translocated into habitat patches on the GMUG NF, upstream of existing fish passage barriers.

In a study of fragmentation and isolation of streams that supported native Cutthroat Trout, GMUG fisheries biologists determined that while 25 of 39 populations of native Cutthroat Trout were isolated by barriers, only eight of these were fragmented by barriers located within occupied reaches (Dare et al., 2012). These data suggest native Cutthroat Trout occupy stream reaches for which connectivity is relatively high. The presence of native Cutthroat trout in these watersheds should be an important consideration when planning road-stream crossings or other instream infrastructure. A second insight is that instream barriers are likely contributing to persistence of native Cutthroat Trout in watersheds in which non-native, invasive species, such as Brook Trout are present, which suggests not every fish passage barrier should be removed in favor of more passage- friendly infrastructure.

# Riparian and Wetland Ecosystems

Classification of riparian and wetland ecosystems on the GMUG is closely based on the classification framework used by the Colorado Natural Heritage Program (CNHP). Final ecosystems identified for assessment are fens, montane-alpine wet meadows and marshes, montane-subalpine riparian shrublands, montane-subalpine riparian woodlands, and cottonwood riparian woodlands. Spatial location and extent for each ecosystem is estimated based on a compilation of GIS data, including a GMUG Riparian inventory, GMUG Wetland and Fen inventory, FSVegSpatial polygons identified as "Riparian," and National Wetlands Inventory data. GMUG-specific datasets (e.g. GMUG Riparian and Wetland and Fen inventories) were given precedence over national datasets in ecosystem identification, and polygon slivers were incorporated into larger neighboring polygons as needed. The final spatial dataset has some limitations, and likely overestimates the area for riparian ecosystems where river corridors for one dataset did not correspond precisely to the corridor for another dataset.

Riparian shrubland systems make up the majority area (over half) of all riparian and wetland ecosystems in the plan area (Table 2). Many ecosystems are distributed disproportionately

across geographic areas; for example the Grand Mesa and Gunnison Basin contain the bulk of fens found on the GMUG, while the Uncompahgre Plateau has the largest percentage of cottonwood riparian woodlands.

**Table 2. Riparian/wetland ecosystems on the GMUG carried forward for assessment**

| Ecosystem | Acres | Percentage by Geographic Area | | | | |
|-----------|-------|-------------|-------------|-----------------|------------|--------------------------|
| | | Grand Mesa | North Fork Valley | Gunnison Basin | San Juans | Uncompahgre Plateau |
| Fen | 4,082 | 25 | 6 | 55 | 14 | 0 |
| Montane-alpine wet meadow and marsh | 45,144 | 19 | 6 | 56 | 11 | 8 |
| Montane-subalpine riparian shrubland | 112,655 | 7 | 15 | 67 | 7 | 4 |
| Montane-subalpine riparian woodland | 32,369 | 8 | 19 | 52 | 5 | 17 |
| Cottonwood riparian | 3,520 | 12 | 23 | 14 | 11 | 40 |

## Fens

Fens are a type of wetland defined by groundwater inflows and peat accumulation of at least 40 cm in the upper 80 cm. In order to accumulate peat, water tables must remain within 30 cm of the surface through July and August. These areas remain saturated primarily as a result of discharging groundwater, seasonal and/or perennial surface water input, or due to their location on the fringes of lakes and ponds. Fens often form in glaciated, relatively level mountain valleys due to large alluvial aquifers and nearby springs supplied by snowmelt from adjacent hillsides. Soil and water chemistry are among the most important factors in the development and structure of peatland ecosystems. Fens have organic soils, classified as histosols. Factors such as pH, mineral concentration, available nutrients, and cation exchange capacity influence fen vegetation types and their productivity. Extremely rich fens occur where water pH is basic (7.6 – 8.3) and there are high concentrations of Ca++ (Cooper 1996). Transitional rich fens occur on acid soils (Cooper and Andrus 1994), and iron fens occur on strongly acidic sites. In the Southern Rocky Mountains, fens receive much of their nutrients from surface and groundwater inputs. Fens are carbon sinks (Chimner et al. 2002) important filters of water, sources of forage for native mammals, and can have shallow pools that support aquatic invertebrates and amphibians.



**Figure 3. A high quality fen within the San Juan Mountains. Note the floating peat mass on the right center**

Fen vegetation can be woody or herbaceous, and usually occurs as a mosaic of several plant associations dominated by water sedge (*Carex aquatilis*), beaked sedge (*C. utriculata*), mud sedge (*C. limosa*), woollyfruit sedge (*C. lasiocarpa*), bog birch (*Betula nana*), Bellardi's bog sedge (*Kobresia myosuroides*), simple bog sedge (*K. simpliciuscula*), and Rolland's bulrush (*Trichophorum pumilum*). Peat moss (*Sphagnum spp.*) is indicative of iron fens while calcareous mosses occur in extremely rich fens, consequently basin fens with floating mats support many rare wetland plants.



**Figure 4. Montane-alpine marsh near Bilk Creek, San Juan Mountains**

## Montane-Alpine Wet Meadows and Marshes

Wet meadows are herbaceous wetlands associated with a high water table or overland flow that typically lack standing water. Sites are usually associated with snowmelt or groundwater and not subjected to high disturbance events such as flooding, though wet meadows may be found adjacent to a stream channel (particularly common for montane wet meadows) and connected to overbank flooding for the channel. At montane elevations, soils are usually clays or silt loams, which occasionally includes hydric soils. Subalpine and alpine wet meadows are typically found on rocky, gravelly soils with good drainage but also a well-developed organic layer. Upstream wet meadows release water throughout the growing season and are an important contribution to streamflow during late summer and drought periods.

Wet meadows often occur in small patches, found in mosaics within woodlands, dense shrublands, or just below alpine communities. Vegetation is dominated by short herbaceous monocots, including species of grass, sedge, and rush. Common graminoids in this system include tufted hairgrass (*Deschampsia caespitosa*), showy oniongrass (*Melica spectabilis*), mountain brome (*Bromus carinatus*), blue wildrye (*Elymus glaucus*), awned sedge (*Carex atherodes*), and small wing sedge (*Carex microptera*).

Marshes are also herbaceous wetlands, but unlike wet meadows they have a permanent water source throughout all or most of the year, with water consistently at or above the surface during the growing season. Marshes form in depressions, and can occur around ponds, as

fringes around lakes, and along low gradient streams and rivers. Maximum water depth ranges from 20 to 200 cm, though marshes may be dry in late summer or in drought years.

Marshes typically have very high primary production of both plants and animals (Kantrud et al. 1989). Dominant vegetation includes emergent and floating herbaceous species including species of *Scirpus*, *Schoenoplectus*, *Typha*, *Juncus*, *Carex*, *Potamogeton*, *Polygonum*, and *Nuphar*.



**Figure 5. A montane – subalpine riparian shrubland near Ophir, Colorado**

## Montane - Subalpine Riparian Shrublands

These shrub-dominated wetlands are most often associated with streams, occurring as either a narrow band of shrubs lining streambanks of steep V-shaped valleys, or as a wide shrub stand on alluvial terraces in low-gradient valley bottoms. This ecosystem can also occur around the edges of fens, lakes, seeps, and springs on slopes away from valley bottoms, or within a mosaic of shrub- and herb- dominated communities within snowmelt-fed basins. Riparian shrublands are important nutrient sources for aquatic invertebrates as they provide particulate and dissolved carbon (e.g., detritus) to the stream channel.

On the GMUG, riparian shrublands are typically dominated by willows (*Salix spp.*), with significant components of alder (*Alnus spp.*) and birch (*Betula spp.*). Understories are comprised of a diverse layer of forbs and herbs. Surface water is an essential factor in the formation of riparian shrublands; flooding inundates vegetation, can physically dislodge seedlings/saplings, and alters channel morphology through erosion and deposition of sediment.

**Figure 6. Montane – subalpine riparian woodland in the Raggeds Wilderness**

## Montane - Subalpine Riparian Woodlands

This is a linear, tree-dominated ecosystem that occurs as a narrow streamside forest alongside small, confined low- to mid- order streams. Dominant tree species include subalpine fir (*Abies lasiocarpa*), douglas-fir (*Pseudotsuga mentziesii*), blue spruce (*Picea pungens*), quaking aspen (*Populus tremuloides*), and Rocky Mountain juniper (*Juniperus scopulorum*). Community composition may be determined by a combination of factors including floodplain width and steepness, stream discharge and flooding patterns, and adjacent upland vegetation.



**Figure 7. The Uncompahgre Plateau has the highest percentage of cottonwood riparian woodlands**

## Cottonwood Riparian Woodlands

Cottonwood riparian systems are dependent on a hydrologic regime that includes annual to episodic flooding. Flooding erodes and deposits sediment, influencing the distribution of riparian vegetation and providing a bare alluvium substrate which is critical for the germination of cottonwood and willow seedlings. This ecosystem is found within the flood zone of rivers, on islands, sand or cobble bars, and stream banks. It is frequently found in narrow, linear bands, but in broader valleys cottonwood stands can be as wide as they are long, and are known to move laterally as river channels migrate. Soils in this ecosystem tend to be well-drained sands including mixtures of cobbles and gravels throughout the profile.

On the GMUG, narrowleaf cottonwood (*Populus angustifolia*) is the dominant vegetation for riparian woodlands however it is often associated with a variety of shrubs, including Pacific willow, Geyer willow, alder, serviceberry, red-osier, maple, chokecherry, and currants. Cottonwood stands in good condition are structurally very diverse and are exceptionally valuable habitat for large game animals, songbirds, small mammals, raptors, beaver, and waterfowl.

## Integrity of Riparian and Wetland Systems

Riparian and wetland ecosystems on the GMUG are assessed for ecosystem integrity based on the condition of four key ecosystem characteristics: vegetation condition and function, hydrologic regime and floodplain connectivity, lack of anthropogenic stressors, and physical sensitivity. All key characteristics were assessed at a subwatershed (6th level HUC) scale, and cannot be correlated precisely at the ecosystem level. Subwatershed assessments were completed in 2005 in support of an earlier plan revision effort, and also in 2011 as part of a national effort. These two assessments used different methods and considered different variables; here we present results from both assessments as applicable. One major methodological difference is that the 2005 assessments are GMUG-specific and provide scores from 1-4 (1 = low, 4 = high) for *relative* ranking of the attribute in question, while the 2011 assessments were based on a natural framework that assigns *absolute* scores (functioning properly, functioning at risk, impaired function). Although subwatershed condition classifications are not directly tied to specific ecosystems, here we use area-weighted subwatershed key characteristic ratings to estimate current conditions by ecosystem type.

### *Vegetation Condition and Function*

Healthy and diverse riparian and wetland vegetation is critical to ecosystem integrity, and provides for flood control, floodplain and streambank stability, water quality protection, and wildlife and aquatic habitat. Root masses stabilize streambanks, slow floods, filter sediment, and prevent erosion, and above-ground vegetation provides essential habitat for terrestrial and aquatic organisms as well as nutrient input into aquatic ecosystems. Vegetation can also shade streams, moderating water temperature and impacting the structure of in-stream communities. Moreover, riparian and wetland systems are crucial for floral diversity; in Colorado, more than 40 percent of all plant species occur in wetlands (D. Cooper, unpub. data 2003). As riparian and wetland areas are the interface between terrestrial and aquatic ecosystems, the health of these ecosystems is closely interrelated to the surrounding watershed (Debano and Schmidt 1989, Hornbeck and Kochenderfer 2000).

Table 3 displays subwatershed indicator ratings (from the 2011 GMUG watershed condition classification) for vegetation condition and function by ecosystem. 'Functioning properly' means that plant communities are dominated by healthy and vigorous native mid-to-late seral vegetation appropriate to the site, and native species and reproducing sufficiently to ensure that conditions are sustainable. 'Functioning at risk' indicates that native vegetation shows light to moderate losses in vigor and greater proportions of early seral species. 'Impaired function' occurs when vigorous native vegetation covers less than 25% of riparian/wetland areas, and cover and composition is strongly reflective or early seral species. Much of the area in 'impaired function' subwatersheds have water tables that are disconnected from the riparian area, and the vegetation reflects this loss of available soil water (Polytondy and Geier 2011).

**Table 3. Functional condition of five ecosystem types on the GMUG NF**

| Ecosystem | Percent of ecosystem by subwatershed indicator rating | | |
|---|---|---|---|
| | Functioning properly | Functioning at risk | Impaired |
| Fen | 71 | 29 | 0 |
| Montane-alpine wet meadow and marsh | 58 | 39 | 3 |
| Montane-subalpine riparian shrubland | 59 | 41 | 1 |
| Montane-subalpine riparian woodland | 58 | 39 | 3 |
| Cottonwood riparian | 32 | 64 | 4 |

Results indicate that the majority of most riparian and wetland ecosystems on the GMUG have properly functioning vegetation, with the exception of cottonwood riparian systems, which have a majority of their area in "functioning at-risk" subwatersheds. A significant minority of fens, wet meadows and marshes, and riparian shrublands and woodlands are departed from reference conditions and described as "functioning at-risk" for vegetation condition.

### Hydrologic Regime and Floodplain Connectivity

The hydrologic regime is defined by the magnitude, frequency, and timing of runoff from a watershed, and is a critical component in the ecological integrity of riparian and wetland ecosystems. In riparian systems, the most important aspect of the hydrologic regime is flooding, including annual and inter-annual variability in flooding, as well as sediment erosion and deposition. Conversely, in fens, the presence of stable perennially high water tables and the absence of physical disturbances is crucial. Marshes and wet meadows are driven by periodically deep water along with periodic drought.

A properly functioning hydrologic regime insures floodplain connectivity. Flooding is a natural part of the hydrologic cycle; streams have a low-flow channel, a bank-full channel, and a floodplain to handle above bank-full flows (floods). These flood pulses promote species diversity and biological productivity in the riparian zone, and provide stream channels with a large influx of nutrients in the form of decaying organic matter or small invertebrates.

Human alteration of the natural flow regime (e.g. dam construction, water diversions, ditches, peat mining, groundwater pumping) disrupts the dynamic equilibrium between the movement of water and the movement of sediment that exists in free-flowing rivers (Dunne and Leopold 1978), which can change the composition, structure, and/or function of riparian and wetland ecosystems (Bain et al. 1988).

Table 4 displays sub-watershed indicator ratings (GMUG watershed condition classification 2011) for water quantity ratings by ecosystem. 'Functioning properly' describes sub-watersheds that have primarily free-flowing rivers and streams, unmodified lakes, and limited groundwater withdrawals. Sub-watersheds that are functioning at risk contain dams and diversions that partially mimic natural hydrographs, maintaining peaks and base flows, though patterns of mid-range discharges may occur. Sub-watersheds with impaired function contain dams and diversions that do not mimic natural hydrographs, with significant departures that don't correlate with typical seasonal changes.

**Table 4. Water quantity ratings for four ecosystems on the GMUG NF**

| Ecosystem | Percent of ecosystem by sub-watershed indicator rating | | |
|---|---|---|---|
| | Functioning properly | Functioning at risk | Impaired |
| Fen | 58 | 20 | 22 |
| Montane-alpine wet meadow & marsh | 63 | 27 | 10 |
| Montane-subalpine riparian shrubland | 81 | 13 | 6 |
| Montane-subalpine riparian woodland | 66 | 27 | 8 |
| Cottonwood riparian | 59 | 26 | 15 |

We see similar patterns across ecosystems in terms of properly functioning hydrologic regimes. The majority area for every ecosystem type is in sub-watersheds with properly functioning hydrologic regimes, with a significant minority functioning at risk, and a small proportion that have impaired function. In terms of hydrologic regimes, riparian shrublands are least departed from proper functioning condition, while fens and cottonwood riparian areas are most departed. Atypical hydrologic regimes in cottonwood riparian systems are of particular concern because these ecosystems depend on annual to episodic flooding to provide a bare alluvium substrate necessary for the germination of cottonwood seedlings.

### *Lack of Anthropogenic Stressors*

Human activities have had a huge impact on riparian and wetland ecosystems in the western U.S. Colorado lost 50% of its natural wetlands between Euro-American settlement and the 1980s (Dahl 1990), and a significant portion of riparian woodland and shrublands have been converted to un-vegetated and herbaceous ecosystems. There has been a shift towards more ecologically sound management and use of riparian and wetland ecosystems in recent years but these areas continue to see levels of use that are disproportionate to their extent on the landscape. As mentioned earlier, these areas are particularly sensitive to human impacts due to their ecosystem dynamics.

Anthropogenic stressors to riparian and wetland systems on the GMUG include water use and developments (diversions, ditches, reservoirs), roads and trails, recreation, livestock

grazing, vegetation treatments, mineral extraction, and invasive species. More information on specific impacts of these stressors can be found in the 'System Stressors' section. Table 5, Table 6, Table 7, and Table 8 display sub-watershed indicator ratings (GMUG watershed condition classification 2011) for roads and trails, rangeland vegetation, and terrestrial invasive species condition by ecosystem. Table 8 presents overall activity impact ratings from the 2005 sub-watershed condition assessments. These ratings were calculated based on a number of factors, including flow modification, roads and motorized trails, streamside recreational use, vegetation treatments, and active and abandoned mine adits and tailings. The roads and trails condition rating is defined based on four factors, including open road density, best management practices for maintenance, the percentage of roads/trails within 300 feet of water bodies, and the potential for mass wasting. Rangeland vegetation condition ratings are defined based on the presence of native or desirable non-native vegetation and its contribution to soil condition, nutrient cycling, and hydrologic regimes at near-natural levels. Terrestrial invasive species ratings are based on the percentage and rate of spread of invasive species that could necessitate removal.

**Table 5. Current roads and trails functional condition for five ecosystems on the GMUG NF**

| Ecosystem | Percent of ecosystem by subwatershed indicator rating | | |
|---|---|---|---|
| | Functioning properly | Functioning at risk | Impaired |
| Fen | 27 | 71 | 3 |
| Montane-alpine wet meadow & marsh | 38 | 58 | 4 |
| Montane-subalpine riparian shrubland | 26 | 67 | 7 |
| Montane-subalpine riparian woodland | 35 | 59 | 7 |
| Cottonwood riparian | 47 | 49 | 4 |

**Table 6. Current rangeland functional ratings for five ecosystems on the GMUG NF**

| Ecosystem | Percent of ecosystem by subwatershed indicator rating | | |
|---|---|---|---|
| | Functioning properly | Functioning at risk | Impaired |
| Fen | 82 | 18 | 0 |
| Montane-alpine wet meadow & marsh | 82 | 17 | 1 |
| Montane-subalpine riparian shrubland | 83 | 16 | 1 |
| Montane-subalpine riparian woodland | 82 | 17 | 1 |
| Cottonwood riparian | 76 | 24 | 0 |

**Table 7. Current terrestrial invasive species functional ratings for five ecosystems on the GMUG NF**

| Ecosystem | Percent of ecosystem by subwatershed indicator rating | | |
|---|---|---|---|
| | **Functioning properly** | **Functioning at risk** | **Impaired** |
| Fen | 96 | 2 | 2 |
| Montane-alpine wet meadow & marsh | 91 | 5 | 3 |
| Montane-subalpine riparian shrubland | 95 | 4 | 1 |
| Montane-subalpine riparian woodland | 88 | 9 | 3 |
| Cottonwood riparian | 84 | 6 | 10 |

**Table 8. Activity ratings for five ecosystems on the GMUG NF**

| Ecosystem | Percent of ecosystem by subwatershed activity rating | | | |
|---|---|---|---|---|
| | **Low (1)** | **2** | **3** | **High (4)** |
| Fen | 8 | 33 | 36 | 22 |
| Montane-alpine wet meadow & marsh | 4 | 16 | 46 | 34 |
| Montane-subalpine riparian shrubland | 11 | 43 | 28 | 18 |
| Montane-subalpine riparian woodland | 19 | 40 | 27 | 14 |
| Cottonwood riparian | 23 | 42 | 25 | 10 |

Of the anthropogenic stressors evaluated individually, roads and trails have the greatest impact by far. All ecosystems have a majority of their area functioning at-risk for this attribute, while a majority of areas are functioning properly for both rangeland vegetation condition and terrestrial invasive species. The latter two stressors show the biggest impact on cottonwood riparian ecosystems, and similar areas of impact for all other systems. The anthropogenic stressor of water use and development is reflected in the previous section on hydrologic regime, though we will note here that those results indicate that while water use and development is a stressor, roads and trails are much more impactful to ecosystems on the GMUG.

### *Physical Sensitivity*

The physical sensitivity of riparian and wetland ecosystems is an estimation of potential response to current or future disturbances (natural or anthropogenic), calculated based on inherent physical factors that dictate sediment and runoff generation, including geologic parent materials, landforms, and topography. As it is determined by physical factors, physical sensitivity is essentially a static characteristic, with the potential for significant change only over geologic time scales (e.g. millions of years). However, it is still a key ecosystem characteristic as it has major implications for management of many anthropogenic stressors. Subwatersheds that have higher sensitivity will show greater impacts on riparian and wetland ecosystems from both natural and anthropogenic disturbances.

Results indicate that fens and riparian shrublands have the greatest proportion of their area in high sensitivity subwatersheds (Table 9), though all ecosystems have significant areas of high sensitivity, reflecting the prevalence of rugged headwaters on the GMUG. Physical

sensitivity is not departed from reference conditions for any ecosystem, and is expected to remain fairly static on the GMUG for the foreseeable future. Nonetheless, management actions (both those that mitigate disturbance and cause disturbance) should take this relatively high physical sensitivity into consideration.

**Table 9. Current riparian, wetland vegetation functional condition for five ecosystems on the GMUG NF**

| Ecosystem | Percent of ecosystem by subwatershed sensitivity rating | | | |
|---|---|---|---|---|
| | Low (1) | 2 | 3 | High (4) |
| Fen | 0 | 21 | 32 | 46 |
| Montane-alpine wet meadow & marsh | 4 | 16 | 46 | 34 |
| Montane-subalpine riparian shrubland | 2 | 9 | 47 | 42 |
| Montane-subalpine riparian woodland | 4 | 17 | 54 | 25 |
| Cottonwood riparian | 1 | 33 | 54 | 12 |

## Overall Trends

The quantitative information we have regarding the status and trends of riparian and wetland systems on the GMUG is limited, and not spatially specific to the ecosystem level. The current available information suggests these ecosystems and their key characteristics generally maintain high integrity. However, roads and trails are a significant stressor in all ecosystems, and lower-elevation ecosystems in general have lower ecosystem integrity on the GMUG. Due to a lack of quantitative historical data regarding these ecosystems, trends in key ecosystem characteristics cannot be assessed with any certainty. We can speculate on a few possible trends given projected future climate conditions. The North Central Climate Science Center recently published a report on southwestern Colorado Spruce-Fir forests that included three climate change scenarios for the year 2035. Briefly these scenarios are 1) Hot/Dry – a 5 °F increase in air temperature and a 10 percent reduction in precipitation; 2) Hot – a 3 °F air temperature increase with no change in precipitation volume; and 3) Warm/Wet – a 2 °F increase in air temperature and increase a 10 percent increase in precipitation with all of that coming as rain (Rondeau et al., 2017). Despite uncertainty, each of these scenarios involves changes in annual precipitation patterns resulting from either changes in air temperature or a reduction in precipitation that could create or exacerbate drought conditions in southwestern Colorado. In addition to the impacts of changing climate, forecasted population growth may impact riparian and wetland ecosystems on the plan area through increased demand for water, increased exurban development and road density, and increased visitor use and recreation impacts.

The Forest Service's Rocky Mountain Research Station has built predictive stream temperature models for the state of Colorado. These models were based on stream temperature data collected throughout the state, including the GMUG NF. The GMUG NF began collecting stream temperature data in 2011 and continues to collect data at more than 40 locations on the forest. These data were an important contribution to the station's model-building efforts. The models are publicly available and described in detail at https://www.fs.fed.us/rm/boise/AWAE/projects/NorWeST.html. Model outputs are available

for several climate change scenarios including 1, 2, and 3 °C stream temperatures increases (approximately 2, 4, and 6 °F) as well as a down-scaled AIB global climate change model applied to Colorado streams. Model outputs suggest that many of the GMUG NF's high-elevation streams are too cold for native fishes (Cutthroat Trout and Bluehead Sucker) currently, but could become suitable for Cutthroat Trout in the future if stream temperatures rose as much as 3 °C. The model's down-scaled AIB model predictions suggest that all but the highest elevation streams on the GMUG NF would become too warm for native Cutthroat Trout. There is uncertainty as to which trajectory stream temperature will follow; however, insights from these models have caused Colorado Parks and Wildlife and Forest Service biologists to begin exploring high-elevation streams in order to identify candidates for refuge sites for native Cutthroat Trout.

# Chapter 3. System Drivers, Stressors, and Management Influences

Ecosystem drivers are factors or processes that affect ecosystem characteristics and contribute to the natural range of variation. Stressors are defined as factors that may directly or indirectly degrade or impair ecosystem composition, structure, or ecological process in a manner that may impair its ecological integrity (36 CFR 219.19). Many system drivers can be stressors if they are operating in atypical ways, outside of their natural range of variability. Management influences can be drivers or stressors, and typically operate at a more local scale than natural drivers and stressors do.

## Drivers and Stressors

### Climate and Climate Change

Climate is a system driver for riparian and aquatic ecosystems. Influencing all ecological processes, climate is the major determining factor in quantity and distribution of available water. Although changes in climate over geologic time is a normal process, it becomes a stressor when average climate, climatic variability, or rate of change shifts outside of its historic range.

It has direct impacts on ecosystems through changes in precipitation and temperature, in addition to indirect effects from its influence on the frequency, extent, and severity of landscape disturbances and extreme weather events.

The exact effect of climate change on the aquatic and riparian ecosystems on the GMUG is unknown, but potential direct effects include reduced precipitation, earlier and shorter periods of snowmelt runoff, attenuated base flows in streams, and increased stream temperatures (Reiman and Isaak 2010). Potential indirect effects include increases in invasive species, increased erosion and sedimentation after uncharacteristic wildfires, changes in the hydrologic regime due to extensive and severe insect outbreaks, and impacts associated with more frequent extreme weather events including droughts and floods (Vose et al. 2012).

## Annual Precipitation Patterns

Most precipitation falls on lands in and around the GMUG NF as snow. Each winter snow accumulates in high elevation areas and melts throughout the spring and summer providing water for stream channels as well as plants across the landscape. The source of perennial streamflow for the vast majority of perennial streams on the GMUG NF is snowmelt, which begins about April of each year and ends with the onset of winter. Many of the streams on the Uncompahgre Plateau, which doesn't have a large annual snowpack, are perennial on the national forest but dry up at lower elevations. The pattern of perennial at higher elevation and intermittent at lower elevation occurs in other areas, including the western end of the Grand Mesa.

Monsoonal rainstorms occur in late summer, which cause a small spike in the annual hydrograph for many perennial streams. The volume of water associated with these storms can cause flash floods in low elevation areas.

## Groundwater

Groundwater is an integral part of watershed function and supports an array of groundwater dependent ecosystems (GDEs), including all of the relevant aquatic and riparian systems identified in this assessment. GDEs also include springs, seeps, areas of shallow groundwater, cave and karst systems, hyporheic and hypolentic zones, some terrestrial vegetation such as phreatophytes, as well as the many species that rely on groundwater to meet part or all of their water requirements. In these ecosystems, groundwater may provide water with physical and chemical characteristics that differ from surface water supplies, and this has important consequences for their structure and function. Owing to their unique water and chemical characteristics, GDEs often support rare and endemic species, as well as provide critical ecosystem services including water storage, supply and purification. Impacts to the quantity, timing and quality of groundwater discharge to these ecosystems have significant consequences to their persistence and viability.

## Wildfire

Fire is an integral part of many ecosystems on the GMUG and across the western United States. Aquatic systems and the terrestrial landscapes that encompass them are recognized as being intricately linked and structured by the disturbance processes associated with particular fire regimes (Bisson et al. 2003). Characteristic fire (similar in size, intensity, and frequency to historical fire regimes) is an ecosystem driver for aquatic and riparian ecosystems, but uncharacteristic fire (dissimilar to historical fire frequency, size, and intensity) can be a stressor (Savage and Mast 2005; Roccaforte et al. 2012).

Following moderate to high severity fire, watershed impacts include accelerated erosion and sediment delivery to stream channels, increased peak flow and stream power, changes in stream channel geometry, gradient and elevation, removal of riparian vegetation, changes in the quantity and distribution of large wood in streams, and water quality impacts. Riparian areas also see an increased risk of invasive plant populations becoming established or expanding. While the immediate post-fire effects on aquatic and riparian ecosystems can be extreme, within intact systems post-fire recovery is relatively fast (Minshall 2003). Moreover, it is generally thought that the long-term impacts of disturbances associated with

fire-related flooding, sedimentation, and large wood inputs are important to ecosystem integrity of aquatic systems (Bisson et al 2003, Minshall 2003).

Wildfire can however also be an ecosystem stressor on aquatic and riparian ecosystems. This may occur if the fire is more extensive, severe, or frequent than is characteristic, or if pre-fire watershed conditions lack ecosystem integrity due to sensitive soils, high road density, or fragmented habitat. Conversely, well-distributed beaver populations can help minimize initial fire event impacts and alleviate post-fire effects related to flooding and soil erosion (Decker et al. 2003).

Past management actions including fire suppression and historic overgrazing (leading to a lack of fine fuels) have resulted in fewer fires in the plan area since the late-1800s. The subsequent accumulation of fuels in some ecosystems has created the potential for larger and more severe fires. Tree mortality from drought or insect and disease outbreaks changes fuel structures and can affect fire behavior. In the future, changing climate is expected to continue to lengthen the fire season and lead to more large fires (Westerling et al. 2006).

## Invasive Plant Species and Aquatic Nuisance Species

Invasive species are defined by Executive Order 13112 (1999) as those species that are non-native to the ecosystem under consideration and whose introduction causes or is likely to cause economic or environmental harm or harm to human health. As such, they are an ecological stressor. Invasive plant species generally are species that have been introduced into ecosystems in which they did not evolve, and consequently, tend to have no natural enemies to limit their reproduction and expansion. They also tend to be more vigorous, taller, and more productive than native species (Mitchell 2000). As a result they can out-compete and displace native plant species, even completely taking over a site.

Areas where vegetative cover is disturbed and bare soil becomes exposed are most susceptible to noxious weed invasions. Invasive plant species can be spread or introduced into unoccupied areas by vehicles, humans, and animals along travel routes and waterways. Most invasive plant species require large amounts of sunlight, warm temperatures and relatively long growing seasons. In arid western environments like the Uncompahgre Plateau, riparian and wetland areas are susceptible because of the available water.

Invasive plant species infestations are increasing exponentially throughout the western United States, including within the plan area, and can have serious ecological impacts. Natural plant community composition can be altered, greatly reducing biodiversity, eliminating habitat and forage for wildlife and livestock, and potentially altering fire regimes. Ecosystem functions such as nutrient cycling and energy flow can be altered. Invasive plants can change soil textures by reducing soil moisture holding capacity or lowering water tables, leading to decreased soil stability and increased surface runoff and sediment yield (Mitchell 2000).

There are two aquatic nuisance species present in and around aquatic ecosystems on the GMUG NF: *Myxobolus cerebalis*, the myxosporean parasite which causes whirling disease and can harm trout populations, and the chytrid fungus (*Batrachochytrium dendrobatidis*) that results in mortality to amphibians, particularly toads and frogs. Other aquatic nuisance species that are not known to occur on the GMUG include zebra and quagga mussels, New Zealand mud snails and invasive aquatic plants. State and federal personnel who work on the

GMUG NF use decontamination protocols to minimize the chance of spreading aquatic nuisance species, such as *M. cerebalis*, New Zealand mudsnails, and invasive aquatic plants. Decontamination protocols are also effective at limiting the spread of Chytrid fungus, an organism known to contribute to the decline of Boreal Toad in Colorado.

GMUG personnel do not monitor water bodies for the presence of aquatic nuisance species; however, all boats entering Taylor Park Reservoir, a popular destination for boaters on the Gunnison Ranger District, are inspected by Colorado Parks and Wildlife staff. The Forest Service is a partner in this inspection effort.

# Management Influences

## Water Development

Of the 235 sub-watersheds (6th level HUC) on the GMUG, approximately 70 percent of them have some level of water development. See also the Watersheds, Water and Soil Resources Assessment.

### *Water Diversions*

Water diversions are used to divert water from National Forest Lands for a variety of agricultural, industrial, and municipal purposes. According to the 2006 assessment, there are approximately 1,600 private water rights and 2,400 federal water rights on the GMUG. These water rights are located in 158 sub-watersheds. The Colorado Water Conservation Board holds instream flow water rights on approximately 1,100 stream miles in 77 sub-watersheds. About 208,500 acre-feet of water is diverted on forest each year, approximately 7.5% of the Forest's total water yield.

The water gained from these diversions are valued beyond measure for the dependents of these rights. Thousands of people in the surrounding communities rely on water diverted from the national forest for their municipal water supply. It is extremely valuable for the local agricultural industry as it allows for millions of dollars' worth of agricultural products to be cultivated. A list of the highest-yielding water diversions on the GMUG is collected in Table 10.

**Table 10. Subwatersheds on the GMUG NF diverting the greatest volumes of water**

| HUC | Watershed | Acre-Feet Diverted | Diversion as Percent of Total Yield of Sub-watershed |
|---|---|---|---|
| 140200039103 | Upper Tomichi Creek | 14,017 | 32.04 |
| 140200019907 | Mid-East River Comp. | 13,303 | 66.3 |
| 140200039301 | Lower Quartz Creek Comp. | 9,146 | 29.3 |
| 140200020501 | Smith Fork | 8,097 | 26.9 |
| 140200025401 | Gunnison River Comp. | 7,505 | Not Available |
| 140200038901 | Mid Tomichi Creek Comp. | 6,152 | 32.8 |
| 140200038702 | Los Pinos Creek | 5,616 | 18.6 |
| 140200028502 | Upper Cebolla Creek | 4,439 | 32.5 |
| | TOTAL | 68,275 | |

### Dams and Reservoirs

Dams and reservoirs have different hydrologic effects than stream diversions. According to the 2006 assessment, reservoirs impact aquatic systems by storing water year round and, therefore, reduce winter flows and eliminate hydrologic peaks and floods. Dams collect sediment at the base of the structure which prevents it from flowing downstream and eliminates sedimentary impacts of steams and floodplains below the facility.

There are hundreds, perhaps thousands of dams on streams and wetland areas on the GMUG NF. The age and utility of water development infrastructure varies greatly within the planning area. There are several large, relatively modern dams on national forest lands; however, a large proportion of dams on the forest are old, earthen structures created to impound relatively small volumes of water. The primary use of reservoirs created by dams is agriculture; however, several water storage facilities exist for providing water for municipal uses in surrounding communities.

The Forest Service plays a role in managing existing dams on forest lands through the permission and administration of annual operating plans for water development companies and individual water right holders, and this will continue to be the primary role during the life of a new Forest Plan. New water developments (of varying sizes) are proposed regularly, and increased water development is anticipated in the future (see also the Watersheds, Water, and Soil Resources assessment); the revised Forest Plan should consider strategic direction for such proposals.

## Roads

Roads and motorized trails have three primary effects on hydrologic processes. They intercept rainfall and subsurface water, they concentrate flow on the road surface or in an adjacent ditch/channel, and they divert water from natural flow paths. Roads can also contribute large amounts of sediment to aquatic ecosystems, impacting fish and invertebrate habitat, altering stream bank width and structure, and lowering primary productivity in the riparian zone. Roads may help facilitate introductions of invasive species, pathogens, and diseases into aquatic and riparian systems.

Specific road-related stressors on aquatic and riparian ecosystems that have been documented on the GMUG include roads parallel to streams constricting natural floodplains; roads across floodplains that disrupt floodplain function; roads constructed through geologically unstable areas; and restriction of flood flows due to insufficient culvert size, subsequently leading to flood flows that overtop roads, floodplains filling up upstream of the culvert, and recurring problems with beaver building dams on culvert inlets.

## Recreation

Many recreation-related stressors to aquatic and riparian ecosystems are addressed under other stressor categories; for example ski areas clearing vegetation would be considered as part of vegetation management. In addition to these wide-ranging secondary impacts, the direct effects of both developed and dispersed recreation sites can be a stressor to aquatic and riparian ecosystems. Developed recreation sites are often located in valley bottoms for aesthetic reasons and to offer easy access to water-related activities. These sites can impinge on riparian areas, causing erosion and increased sedimentation in the stream channel.

Concentrated human use can cause soil compaction and vegetation loss in the riparian zone, resulting in root exposure, stream bank shearing, and loss of organic matter. As levels of recreation use continue to increase on the GMUG, dispersed recreation sites are beginning to show greater importance as a potential ecosystem stressor. Like developed sites, repeated and/or abusive use of dispersed recreation sites can disturb important riparian and wetland vegetation communities and lead to increased levels of sedimentation and contamination of aquatic systems.

## Grazing

Livestock grazing can significantly influence riparian, wetland, and aquatic ecosystems if it is not managed properly (Binkley and Brown 1993). The removal of vegetative cover, and soil compaction that result from excessive grazing reduces water infiltration, increases runoff, and accelerates erosion (Belsky and Blumenthal 1997). On the GMUG, livestock pressure was especially high from 1874 through the 1940s. Animals concentrated in preferred areas, resulting in overgrazing of valley bottoms, and significant impacts on riparian and wetland ecosystems. Some of these impacts persist to this day, and are evident in down cut stream channels and altered riparian vegetation, particularly in low-gradient cottonwood riparian systems. Current levels and management of livestock grazing on the GMUG are much improved, , however localized impacts to riparian and wetland systems still occur.

Aquatic and riparian ecosystems/groundwater-dependent ecosystems exist in most rangeland settings and include springs, fens and other groundwater-fed wetlands. In some areas, these small aquatic ecosystems support a large proportion of the biodiversity in a watershed. Livestock watering facilities commonly exploit these sources of water. Localized livestock impacts to these systems can cause a reduction in ecological integrity and species diversity.

## Forest Vegetation Management

Vegetation treatments and associated activities (including road construction) can have significant impacts on aquatic and riparian systems, with sedimentation of particular concern. Site disturbance associated with mechanized operations can lead to an increase in sediment production and delivery, potentially affecting aquatic and riparian habitat quality. Erosion-related impacts are typically short-lived, lasting 3-10 years after treatment. Changes in runoff and water yield due to vegetative type conversion or reductions in biomass depend on specifics of the management activity, but may persist from 20 to 60 years. Timber management can also affect recruitment of downed logs and woody material into streams and along floodplains. Many undesirable side effects of vegetation management can be mitigated or avoided with implementation of BMPs or project level design criteria associated with the water influence zone (e.g. streamside buffers).

## Mining

There are approximately 900 mineral development sites on the GMUG; less than 2% of these are considered active, with the vast majority classified as historic or unknown status. Consequently, the current ecological impacts of mining across the GMUG are largely related to legacies of historic mineral development. Much of these historic activities were concentrated in the southern San Juans, northwest of Crested Butte, and east of Gunnison.

A total of 63 sub-watersheds of the GMUG include abandoned mine land (AML) sites, with variable impacts on surface water quality and aquatic habitat. The four sub-watersheds with the highest density of AML sites contain all state-listed impaired waters due to water quality impacts from historic mining activities found on the GMUG.

Potential effects of mining on aquatic and riparian ecosystems include changes in hydrologic regimes due to physical channel modifications, interception and rerouting of groundwater, decreases in base flow with accompanying increases in runoff, and consumptive water use. Surface and groundwater quality can be decreased due to contamination from acid runoff, dissolved metals, and sediment production, which in turn can impact aquatic community composition and structure. Wetland and riparian areas may be lost due to mine operations or groundwater interception, and can show changes in structure and function due to water contamination.

# Chapter 4. Sustainability

## Environmental Sustainability of Riparian and Wetland Ecosystems

Environmental sustainability of riparian and wetland ecosystems on the GMUG NF implies the ability of these natural features to support biological communities and the bio-geo-chemical processes that sustain them. In their current states, the riparian and wetland ecosystems within the GMUG NF have the ability to meet the needs of the present generation without compromising the ability of future generations to meet their needs.

However, water demand is anticipated to increase. Combined with the outlook for a possible shift to a warmer drier climate, with less input and more drawdown, the sustainability of riparian and wetland ecosystems will be impacted. The need for change section below discusses how future monitoring and management strategies could better ensure sustainability. Paramount among these are smart growth principles for water development while maintaining flood plain connectivity.

## Social and Economic Sustainability of Riparian and Wetland Ecosystems

Social and economic sustainability of riparian and wetland ecosystems on the GMUG NF implies these systems can support biological communities and bio-geo-chemical processes that sustain them, provide goods and services that feature in local, regional, and national economies, and support the social fabric of local communities.. The challenge for future management will be to administer federal lands and resources in a way that meets current and future growth of water demand (agricultural and domestic) while providing sustainable ecosystem functions for aquatic and riparian systems.

# Chapter 5. Current Forest Plan and its Context within the Broader Landscape

## Existing Forest Plan Management Direction for Aquatic and Riparian Ecosystems

Forest plan direction for aquatic ecosystems can be summarized as 1) maintain streams and aquatic populations; and 2) improve stream habitat characteristics where possible. At the time the existing forest plan was completed, there were not reams of data on stream habitat characteristics and aquatic populations on the GMUG. In response, the forest plan articulated several standards and guidelines related to inventory and monitoring of both aquatic ecosystems and aquatic populations. Over the last 25 years, Forest Service staff and partners, such as Colorado Parks and Wildlife aquatic biologists, have completed intensive surveys of stream habitat, aquatic insect, and fish populations and these data have informed management activities. In particular, a tremendous amount of work has been devoted to documenting the distribution of native cutthroat trout in and around the GMUG.

The existing forest plan directs the Forest Service to "maintain all riparian ecosystems in at least an upper-mid-seral successional stage based upon the R2 Riparian Ecosystem Rating System." It is unclear whether the Forest Service still relies on the R2 Riparian Ecosystem Rating System, what the R2 Riparian Ecosystem Rating System says, or how that system defines "upper-mid-seral successional stage." This aspect of the forest plan, therefore, seems ripe for revision.

# Chapter 6. Potential Need for Plan Changes to Respond to Riparian and Wetland Ecosystem Issues

## Aquatic

The existing Forest Plan includes standards and guidelines that should be changed in a revised plan. For example, there are several guidelines related to the collection of macroinvertebrate data. Several data collection efforts for aquatic macroinvertebrates have occurred in the last 20 years (see above). While aquatic macroinvertebrates are sensitive to changes in a variety of habitat conditions, systematic monitoring of stream insects results in data that creates a degree of separation between what is being monitored and the focus of management efforts: fishes. The Forest will continue to take opportunities to monitor stream insects; however, it may be more valuable to maintain the focus of systematic Forest-level monitoring on fish populations. Furthermore, existing fish datasets are considered a "living" dataset and maintained by multiple agencies (USFS, BLM, CPW).

Historically, little or no amphibian monitoring has been conducted on the GMUG. Because amphibians require aquatic environments at some point in their life cycle and respire through their skin, they are very susceptible to changes in the aquatic environment. Future Forest Plan direction should capitalize on amphibians as detection mechanisms for ecosystem change and the extent and amount of pollution (e.g. persistent organic pollutants).

The existing Forest Plan contains the following standard: "Maintain habitat capability at a level at least 40 percent of potential capability." This standard applies to both terrestrial and aquatic habitats. Unfortunately, the vagueness of this standard undercuts its value. For example, at what scale is 40 percent measured and what is "potential capability?"

Although the current Forest Plan directs the Forest Service to "manage habitat for needs of macroinvertebrates and fish indicator species on *all* (emphasis added) perennial streams which provide potential fisheries," this guideline is vague and doesn't provide strategic direction. Consider identifying priorities for habitat improvement such as stream reaches with native fishes or heavily used recreational fisheries (e.g. Taylor River or the Cimarrons).

## Riparian and Wetland

The existing forest plan directs the Forest Service to "maintain all riparian ecosystems in at least an upper-mid-seral successional stage based upon the R2 Riparian Ecosystem Rating System", a statement which is both too prescriptive and too vague.

Consider revised direction for riparian management that is more site-specific and more flexible, with a focus on maintaining ecosystem processes rather than specific end states. For example, direction to "maintain floodplain connectivity in riparian ecosystems where it is present, and restore floodplain connectivity when possible" would be preferable to "maintain all riparian ecosystems in at least an upper-mid-seral successional stage". Note that vegetation indicators would still be needed to determine riparian health.

## Water Development

Population growth along with other factors, such as climate change, will likely increase water demand placed on the GMUG NF. The new plan should consider incorporating smart growth principles for water development infrastructure that include high-elevation water development to minimize water losses due to evaporation and identifying opportunities to combine water developments and expand existing ones with the goal of having fewer, larger reservoirs in the future. See also the *Infrastructure Assessment*.

Any water development on the national forest is likely to impact stream fishes that reside in medium and large rivers downstream of the national forest. Consider plan direction to continue coordination with the USFWS regarding the impact of water development on the four endangered Colorado River fishes, the Bonytail Chub, Colorado Pikeminnow, Humpback Chub, and Razorback Sucker.

## References Cited

36 CFR 219.19. Forest Service, Department of Agriculture. Part 219 - Planning. Subpart A - National Forest System Land Management Planning. 219.19 Ecological, social, and economic sustainability. 1 pp.

Bain, M.B.; Finn, J.T.; Booke, H.E. 1988. Stream flow regulation and fish community structure. Ecology. 69: 382–392.

Belsky, A.J. and Blumenthal, D.M., 1997. Effects of livestock grazing on stand dynamics and soils in upland forests of the Interior West. Conservation Biology, 11(2), pp.315-327.

Binkley, D., and T.C. Brown, 1993. Management impacts on water quality of forests and rangelands. USDA General Technical Report RM-239.

Bisson, P.A., B.E. Rieman, C. Luce, P.F. Hessburg, D.C. Lee, J.L. Kershner, G.H. Reeves, and R.E. Gresswell. 2003. Fire and aquatic ecosystems of the Western USA: current knowledge and key questions. Forest Ecology and Management.

Burger, W.L., Bragg, A.N., (1947). Notes on *Bufo boreas* (B. and G.) from the Gothic region of Colorado. Proc. Okla. Acad. Sci. 27, 61–65.

Carey, C., Cohen, N., & Rollins-Smith, L. (1999). Amphibian declines: an immunological perspective. *Developmental & Comparative Immunology*, *23*(6), 459-472.

Chimner, R.A., Cooper, D.J. and Parton, W.J., 2002. Modeling carbon accumulation in Rocky Mountain fens. Wetlands, 22(1), pp.100-110.

Cooper, D.J., 1996. Water and soil chemistry, floristics, and phytosociology of the extreme rich High Creek fen, in South Park, Colorado, USA. Canadian Journal of Botany, 74(11), pp.1801-1811.

Cooper, D.J. and Andrus, R.E., 1994. Patterns of vegetation and water chemistry in peatlands of the west-central Wind River Range, Wyoming, USA. Canadian Journal of Botany, 72(11), pp.1586-1597.

Corn, P. S. (1994). What we know and don't know about amphibian declines in the West. *USDA Forest Service, General Technical Report RM-247 (May 1994).*

Dahl, T.E., 1990. Wetlands losses in the United States, 1780's to 1980's. U.S. Department of the Interior, Fish and Wildlife Service, Washington, DC.

Daszak, P., Cunningham, A. A., & Hyatt, A. D. (2000). Emerging infectious diseases of wildlife--threats to biodiversity and human health. *Science*, *287*(5452), 443.

DeBano, L.F. and Schmidt, L.J., 1989. Improving southwestern riparian areas through watershed management. Fort Collins, CO: US Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station.

Decker, L.M., Kershner, J.L. and Winters, D., 2003. Ecological effects of the Hayman Fire-Part 5: Historical aquatic systems.

Dunne, T.; Leopold, L.B. 1978. Water in environmental planning. San Francisco: W.H. Freeman. 818 p.

Green, D., Converse, K. A., & Schrader, A. K. (2002). Epizootiology of sixty-four amphibian morbidity and mortality events in the USA, 1996-2001. *Annals of the New York Academy of Sciences*, *969*(1), 323-339.

Hornbeck, J.W. and Kochenderfer, J.N., 2000. Linkages between forests and streams: a perspective in time. Riparian management in forests of the eastern United States. CRC Press, New York, pp.89-98.

Johnson, M. L., & Speare, R. (2003). Survival of *Batrachochytrium dendrobatidis* in water: quarantine and disease control implications. *Emerging infectious diseases*, *9*, 922-925.

Johnson, M. L., & Speare, R. (2005). Possible modes of dissemination of the amphibian chytrid *Batrachochytrium dendrobatidis* in the environment. *Diseases of aquatic organisms*, *65*, 181-186.

Kantrud, H.A., Millar, J.B. and Van Der Valk, A.G., 1989. Vegetation of wetlands of the prairie pothole region.

Miller, M. P., Susong, D. D., Shope, C. L., Heilweil, V. M., and Stolp, B. J. (2014). Continuous estimation of baseflow in snowmelt-dominated streams and rivers in the Upper Colorado River Basin: A chemical hydrograph separation approach. *Water Resources Research*, *50*(8), 6986-6999.

Miller, M. P., Buto, S. G., Susong, D. D., & Rumsey, C. A. (2016). The importance of base flow in sustaining surface water flow in the Upper Colorado River Basin. *Water Resources Research*, *52*(5), 3547-3562.

Minshall, G.W., 2003. Responses of stream benthic macroinvertebrates to fire. Forest Ecology and Management, 178(1), pp.155-161.

Mitchell J.E. 2000. Rangeland resource trends in the United States: A technical document supporting the 2000 USDA Forest Service RPA Assessment. Gen. Tech. Rep. RMRS-FTR-68. Fort Collins, CO. USDA Forest Service, Rocky Mountain Research Station. 84 p.

Peterson, D. P., B. E. Rieman, D. L. Horan, M. K. Young. 2013. Patch size but not short-term isolation influences occurrences of westslope cutthroat trout above human-made barriers. Ecology of Freshwater Fish 23(4). DOI 10.1111/eff.12108.

Potyondy, J.P. and Geier, T.W., 2011. Watershed condition classification technical guide. FS-978, United States Department of Agriculture, Forest Service, Washington, DC.

Rieman, B.E.; and D.J. Isaak. 2010. Climate change, aquatic ecosystems, and fishes in the Rocky Mountain West: implications and alternatives for management. General Technical Report RMRS-GTR-250. USDA Forest Service, Rocky Mountain Research Station. Fort Collins, CO. 46 pp.

Roccaforte, J.P.; P.Z. Fulé; W.W. Chancellor; and D.C. Laughlin. 2012. Woody debris and tree regeneration dynamics following severe wildfires in Arizona ponderosa pine forests. Canadian Journal of Forest Research 42(3): 593-604.

Rondeau, R., B. Neely, M. Bidwell, I.Rangwala, L. Yung, K. Clifford, and T. Schulz. 2017. Spruce-Fir Landscape: Upper Gunnison River Basin, Colorado. Social-Ecological Climate Resilience Project. North Central Climate Science Center, Ft. Collins. Colorado. Available at http://www.cnhp.colostate.edu/download/documents/2017/SECR_Spruce-Fir_Landscape_Report_4-30-2017_Final_with_Appendices.pdf. Accessed May 16, 2017.

Savage, M., and J.N. Mast. 2005. How resilient are southwestern ponderosa pine forests after high-severity fires? Can. J. For. Res. 35: 967–977.

Stroope, T. Pers. comm. 9 Sept 2017.

Taylor, S. K., Williams, E. S., & Mills, K. W. (1999). Effects of malathion on disease susceptibility in Woodhouse's toads. *Journal of Wildlife Diseases*, *35*(3), 536-541.

USDA Forest Service. 2012. Groundwater-Dependent Ecosystems: Level I Inventory Field Guide Inventory Methods for Assessment and Planning.

Voordouw, M. J., Adama, D., Houston, B., Govindarajulu, P., & Robinson, J. (2010). Prevalence of the pathogenic chytrid fungus, *Batrachochytrium dendrobatidis*, in an endangered population of northern leopard frogs, *Rana pipiens*. *BMC ecology*, *10*(1), 6.

Vose, J. M., D. L. Peterson, T. Patel-Weynand, eds. 2012. Effects of climatic variability and change on forest ecosystems: a comprehensive science synthesis for the U.S. forest sector. Gen. Tech. Rep. PNW-GTR-870. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 265p.

Westerling, A.L., Hidalgo, H.G., Cayan, D.R. and Swetnam, T.W., 2006. Warming and earlier spring increase western US forest wildfire activity. Science, 313(5789), pp.940-943.

**United States Department of Agriculture**
**Forest Service**

Grand Mesa, Uncompahgre, and Gunnison
National Forests
2250 South Main Street
Delta, CO 81416
www.fs.usda.gov/gmug/