The Geography of Freshwater Habitat Conservation: Roadless Areas and Critical Watersheds for Native Trout.

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ABSTRACT— Inventoried roadless areas on National Forest and Bureau of Land Management (BLM) lands have been the subject of sustained controversy and legal and policy machinations. The importance of presently unprotected roadless areas for conservation has received mention, but little formal analysis. Research from the northern Rocky Mountain Region of the U.S. helps put roadless lands in conservation perspective. We examine how roadless lands spatially integrate with watersheds of known high conservation value for freshwater species and habitats. Roadless areas can be small and fragmented, but can accrue to a large fraction of critical landscape. In the Upper Missouri Basin in Montana, within the 37% of the landscape with watersheds classified as highest value for freshwater conservation, almost one-half occurs within unprotected federal roadless areas; just 7% is inside wilderness and parks. In western Montana, bull trout *Salvelinus confluentus* abundance increases with watershed roadless proportion. Roadless lands tend to occupy middle to lower elevations compared to protected Wilderness, where they more directly interface with high-value fish habitat; a Montana statewide "fine-filter" assessment revealed remarkably high occurrence of native trout populations associated with roadless areas, even within watersheds that are otherwise compromised. Most roadless areas contain steep lands with expanses of erosion-prone soils. We conclude that the value of roadless areas for native trout and biodiversity conservation continues to receive insufficient evaluation and disclosure in roadless policy debates and decisions.

INTRODUCTION

Inventoried roadless areas on National Forest and Bureau of Land Management (BLM) lands, officially recognized in the RARE I and RARE II planning processes of past decades (USDA Forest Service 1972, 1979), continue to be the subject of sustained controversy and extraordinary machinations of policy and law. Scientists and fish and wildlife managers across the West recognize that native fish and high-quality waters are often positively associated with watersheds having low overall road density and large proportions of roadless area (Quigley and Arbelbide 1997; Trombulak and Frissell 2000; WNTC 2001). In public debate, however, the conservation value of roadless areas for native fish and water, while occasionally mentioned, has seldom been the focus of rigorous analysis or thorough consideration and public disclosure when decisions about roadless area or national forest management are made.

The Forest Service commonly prefers to consider roadless area decisions primarily in the context of how roads affect offsetting "motorized versus nonmotorized" recreational values—not their ecological and biological conservation values that are an intrinsic function of the lack of roads and many associated forms of human disturbance of land and water (Forman and Alexander 1998; Jones and Swanson 2000; Trombulak and Frissell 2000). The Clinton Roadless Rule

(USDA Forest Service 2000) was the first forum where the environmental values of Forest Service roadless lands were more broadly accounted for (see also Gucinski et al. 2001 on National Forest roads), and in so doing, it was explicitly in accord with numerous federal court rulings about roadless area significance. However, as a national rule this analysis did not document the case-by-case natural resource values sustained by roadless areas, and more recent agency efforts press for devolution of roadless area decisions to state and local authorities. Hence, it is increasingly important that a full local accounting of the natural resource conservation value of roadless lands be made.

In this paper we examine scientific evidence at three regional scales to illustrate how National Forest roadless lands in their current state contribute to the conservation of freshwater species and habitats, including native trout, in the state of Montana.

ROADLESS AREAS AND FRESHWATER VALUES: STATEWIDE ANALYSIS

We used USDA Forest Service digital mapping of roadless areas as the basis for our analysis. These data were "cleaned up" via adjustment for some errors, detached polygons, and redundant entries. We found the Forest Service inventory rosters 223 uniquely named roadless areas, encompassing a total of 26,359 km^2 in Montana. These areas are mapped statewide in Figure 1.

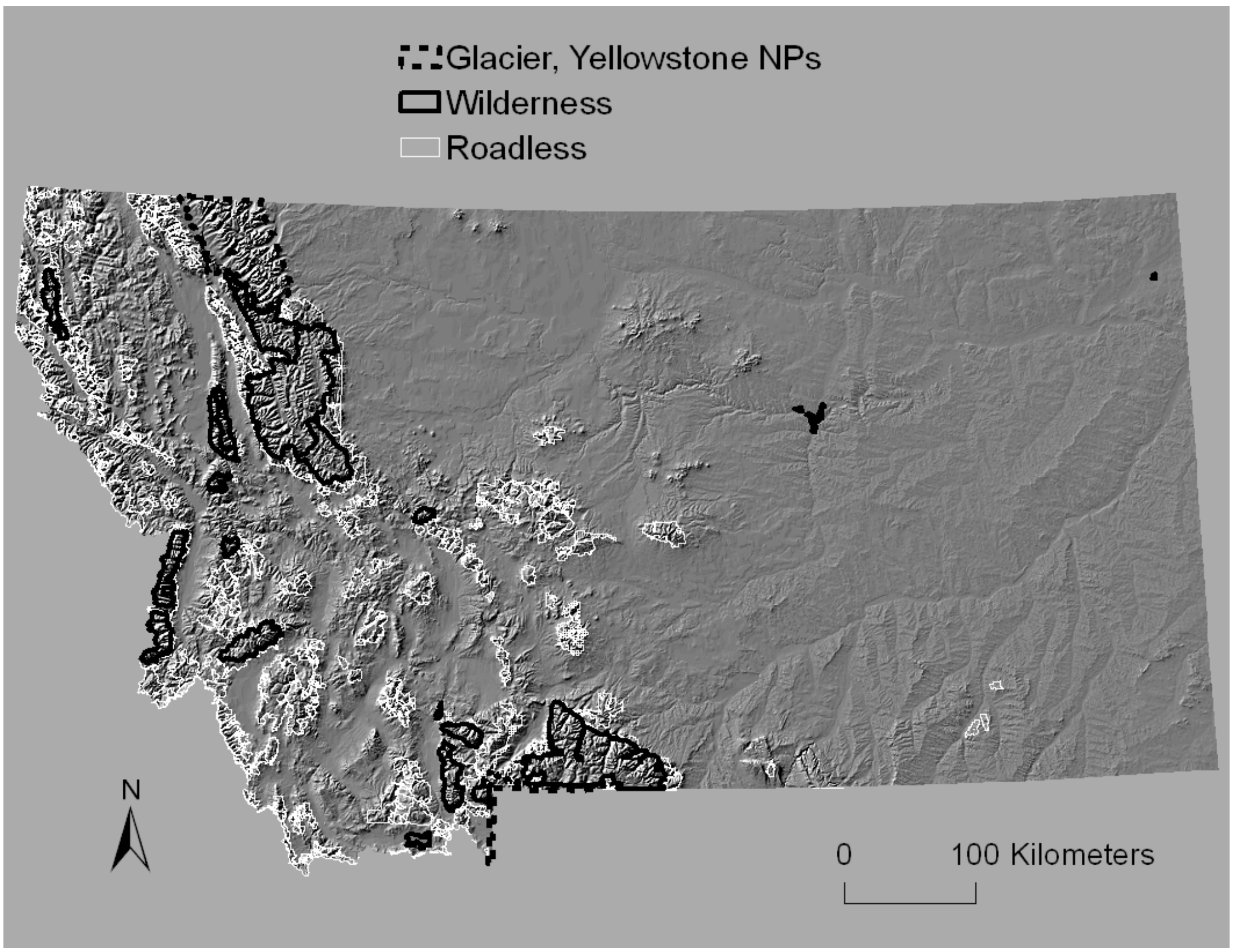


Figure 1. Distribution and relative topographic relationship of inventoried roadless areas (white outlines) on National Forest lands in Montana, USA. Black outlines delimit existing protected lands in congressionally designated Wilderness and National Parks

Native Fishes

By spatially intersecting Forest Service roadless area maps with stream and fish species data obtained from Montana Fish, Wildlife and Parks (Frissell et al. In Preparation; statewide fish distribution data with genetics for some species, Natural Resource Information System, Montana State Library, Helena, MT; note these data were adjusted by eliminating occurrences outside the native range of each species) with ArcInfo software, we identified a total of 1,282 occurrences of fish populations from the seven target taxa within inventoried roadless areas (IRAs) state-wide. Native westslope cutthroat trout *Oncorhynchus clarkii lewisi*, Montana's official state gamefish, occurred in 1,220 records, occupying 138, or 62% of the total list of IRAs. Known genetically pure populations (free of hybrid contamination from introduced rainbow trout *Oncorhynchus mykiss* or other trout) occurred in 92 IRAs. In other words, 41% of roadless areas support known pure populations of westslope cutthroat trout—an extraordinary figure because pure populations are thought to occupy far less than 10% of the present range of this subspecies (Allendorf et al. 2004). Bull trout *Salvelinus confluentus* occurred in 286 locations occupying 80, or 36% of IRAs statewide, with known genetically pure populations in 19 of these IRAs (many populations have not been tested). Yellowstone cutthroat trout *Oncorhynchus clarkii bouvieri* were found in 54 occurrences within 26 IRAs statewide, and eight of these areas support populations known to be free of hybridization. Columbia River redband trout *Oncorhynchus mykiss gairdneri* occurred in 20 places within 15 roadless areas, with two IRAs supporting known genetically pure populations. Arctic grayling *Thymallus arcticus* had 28 occurrences in 16 IRAs, and native lake trout *Salvelinus namaycush* occupied two IRAs in the Upper Missouri River basin.

Although the spatial extent of the native range of these species within Montana varies, within their ranges all species appear to show a substantial affinity for watersheds with a high proportion of roadless area. Native trout populations within roadless areas tend to be more frequently free of hybrization influence and demographically robust enough to be considered "strong" in population status (e.g., Quigley and Arbelbide 2000). Comparatively many streams in designated Wilderness and National Parks drain headwater lake basins that were historically targeted for introduction of nonnative trout; hence, native trout in some Wilderness and National Parks are more extensively hybridized or displaced by nonnative species (Hitt and Frissell 1999; Adams et al. 2001) than are those in many National Forest roadless areas.

Elevation and Slope Hazards in Roadless Areas

To examine how roadless areas relate to the remainder of the landscape with regard to general geomorphic features and landscape setting, we sought a range of data sets concerning soils and slope stability. Ultimately, within the time available and with a need for statewide coverage, the primary source we found to be useful was a digital elevation model (DEM), which we used to characterize the elevation and slope of roadless areas relative to other parts of the landscape. Our source of DEM data for this analysis was the USDA Forest Service Region 1's 200-m grid Digital Elevation Model (http://www.fs.fed.us/r1/gis/thematic_data/dem_region1_200m.zip). DEM data were processed and related to roadless areas and other land categories using ArcEditor mapping and GIS software. Slopes were derived from the DEM using ArcGIS's Slope tool, then classified with the desired class breaks using the Reclassify tool. Inventoried roadless areas were downloaded from http://roadless.fs.fed.us/documents/feis/data/gis/coverages/, as were Forest Service lands boundary data (nfsland_us_dd.zip). Then IRAs and FS lands within Montana were extracted using a state boundary polygon dataset. We used Montana designated Wilderness areas mapped by the Montana Natural Heritage Program (http://nris.mt.gov/nsdi/nris/shape/wild.zip), masked with the Forest Service lands layer to extract only Forest Service Wilderness areas for these slope and elevation comparison analyses.

Figure 2 compares the elevation distributions of inventoried roadless areas, roaded portions of the National Forests, and National Forest lands protected as Wilderness. The graph clearly shows that the previously managed, roaded portions of the National Forests are concentrated at lower elevations. This is important because soils, climate, growing seasons, and other elevation-related factors often confer resilience to disturbance that is lacking in higher-elevation ecosystems. Roadless areas comprise a large proportion of high-elevation lands, as do existing Wilderness areas, but also clear in Figure 2 is that roadless areas contain a higher-than average concentration of land within the middle elevation range from 2000-6000 meters. Land in this elevation range receives relatively high snowpack, but tends to have shorter growing seasons and less resilient soils than lower-elevation terrain. A geographer might characterize lands in this elevation range as the hydrologic "bread and butter" of watersheds across the region.

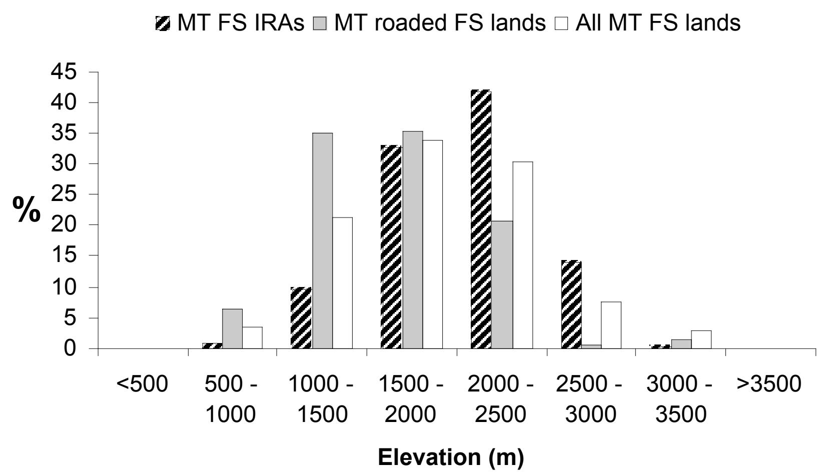


Figure 2. Elevation distribution of aggregated inventoried national forest roadless areas statewide (crosshatched bars, left), roaded national forest lands (gray shaded, middle bars), and all national forest lands in Montana (wilderness, roadless, and roaded, open bars).

Steep hillslopes are prone to mass failure, channelized debris flows, increased vulnerability to surface erosion and gully incision, and longer transport distances of detached sediments, yielding a greatly increased probability of delivery of sediments to streams compared to gentler slopes. All of these erosion types are significantly aggravated and sometimes initiated by disturbance of vegetation and soil surfaces through logging, grazing, mining, fire suppression activities, and other management practices that are supported by roads, as well as by construction, maintenance, drainage alteration by, and use of the roads themselves. We could not find direct and integrated metrics of soil surface erosion and landslide hazard, but the comparison of land categories by slope steepness distribution is revealing (Figure 3).

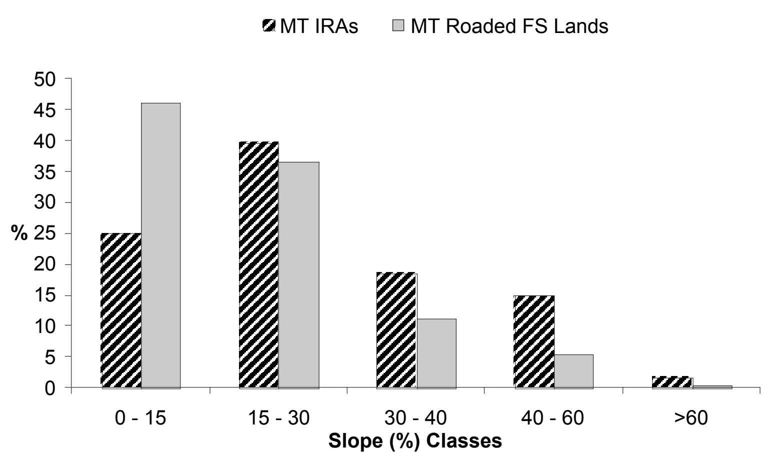


Figure 3. Distribution of slope steepness in Montana inventoried national forest roadless areas in aggregate (crosshatched) and roaded national forest land (shaded).

First, note that the roaded landscape of the national forests in Montana—sometimes referred to as "the working landscape" is dominated by gently sloping terrain. Using an arbitrary slope threshold of 40% for comparison, just under 6% of the managed, roaded landscape exceeds 40% slope angle; 94% is comparatively gentle or moderate in slope. By contrast, almost 17% of the area of inventoried roadless lands exceeds 40% in slope. Keep in mind, slope classifications based on DEMS of this resolution are biased downward for steep slopes, and the bias increases with average landscape slope. Hence, the difference is likely greater than depicted in these data. In simple terms, hazardous conditions are at least three times more prevalent in remaining roadless areas than they are on the already-roaded portion of the national forests. This is but one piece of evidence that risk of incremental harm to watersheds and fish habitat caused by management disturbance is severely elevated compared to that in the portion of the landscape where Forest Service managers have previous experience. In fact, the history of nearly every national forest and ranger district in Montana is fraught with one or more incursions of roads and logging projects into steeper portions of the landscape that led to immediate, disastrous consequences, followed by formal or informal decision to halt further development on those lands. This history is precisely the origin of the majority of inventoried roadless areas today.

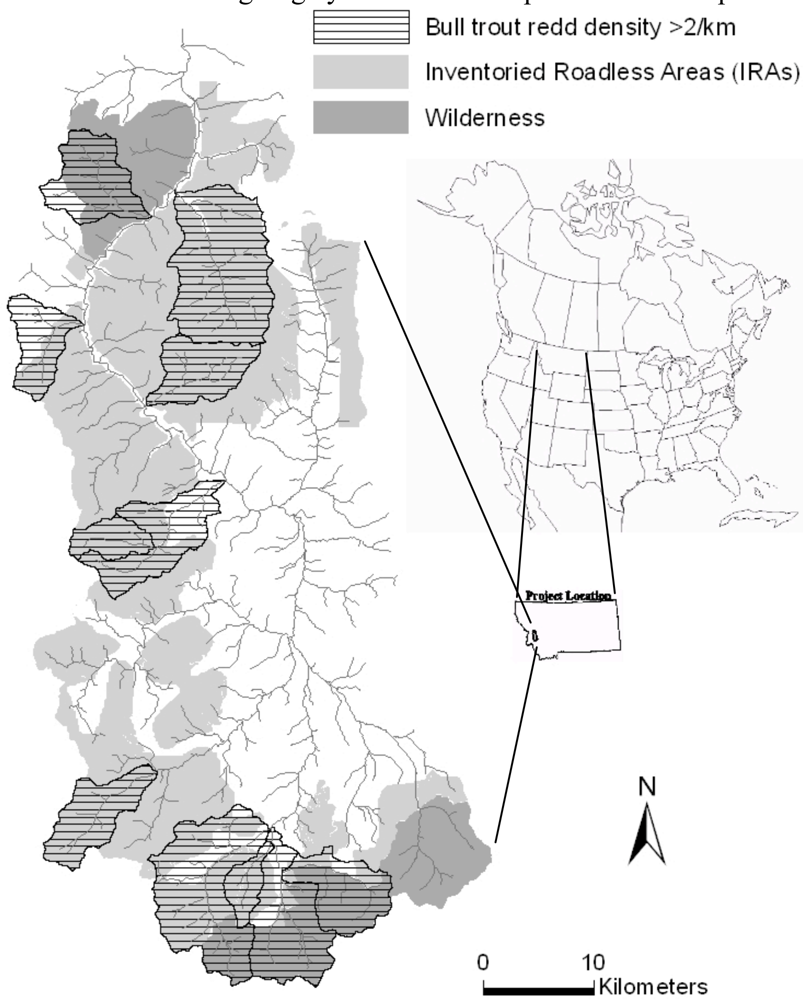
Roadless Areas at the Basin Scale: the Upper Missouri

In 2002 a consortium of nongovernmental organizations sponsored a region-wide assessment of watersheds in the Upper Missouri drainage of Montana, spanning most of the Rocky Mountain Front and the headwaters of the Big Hole, Beaverhead, Jefferson, Madison, and Gallatin rivers (Oechsli and Frissell 2002). In the assessment process, we compiled comprehensive spatial data on native fish species distribution and status, nonnative species introduction and fish stocking, Montana Natural Heritage Program occurrences of aquatic-, riparian-, and wetland-dependent plant and animal species, and road networks as an indicator of landscape and habitat disturbance. All sub-watersheds were scored and ranked across these factors using different models, with the final result based on behavior across multiple models. The result is a map of this large region of central and southwest Montana showing variation in the relative ecological integrity of its streams, rivers, and watersheds (http://www.y2y.net/science/aia/AIA_UMfinal.pdf).

For this analysis, using data from Oechsli and Frissell (2002) we selected the highest-ranked 37% of the landscape where watersheds were classified as highest value for freshwater conservation and evaluated its land management status relative to national forest roadless areas. We found that just under one-half of this high-value acreage occurs within unprotected federal roadless areas. By contrast just 7% of this highest-priority area lies inside designated Wilderness and National Parks that can be considered to afford comprehensive watershed protection (Oechsli and Frissell 2002). This case analysis shows the extreme importance of roadless areas in maintaining the integrity of watersheds that support high conservation value. These are the watersheds needed to serve as the cornerstones of effective regional species recovery and aquatic restoration programs (Moyle and Sato 1991; Frissell and Bayles 1996; Frissell 2000).

Roadlesss Areas and Fish Abundance within Basins: Rock Creek

Bull trout are less likely to use highly roaded basins for spawning and rearing, and if present, were likely to be at lower population levels (Quigley and Arbelbide 1997, USFWS 1999). Baxter et al. (1999) reported an inverse correlation of bull trout abundance and roads in the Swan River Basin that strongly implicated the importance of protecting remaining roadless areas. Similarly, extensive habitat and population surveys on the Clearwater National Forest, Idaho, found that with few exceptions, native salmonid abundance was higher and nonnative brook trout *Salvelinus fontinalis* were scarce or absent in streams draining largely un-roaded compared to road-impacted landscapes (Huntington 1995). Baxter et al. (1999) found that bull trout population trend over time was strongly negatively associated with road density.



In Rock Creek, tributary to the Clark Fork River in western Montana, we first indexed bull trout spawner abundance from redd survey counts made in 19 tributary sub-basins within the Rock Creek drainage (Frissell and Carnefix 2002). We compared response metrics of spawner abundance against a large suite of environmental variables, including measures of geomorphology, summer stream temperature, and land management. We used pairwise correlation of environmental variables with redd density to select 44 candidate predictor (independent) variables across 11 major categories such as geology, basin relief, channel slope, climate, size, and land use/management disturbance, for entry into stepwise and backward model selection routines.

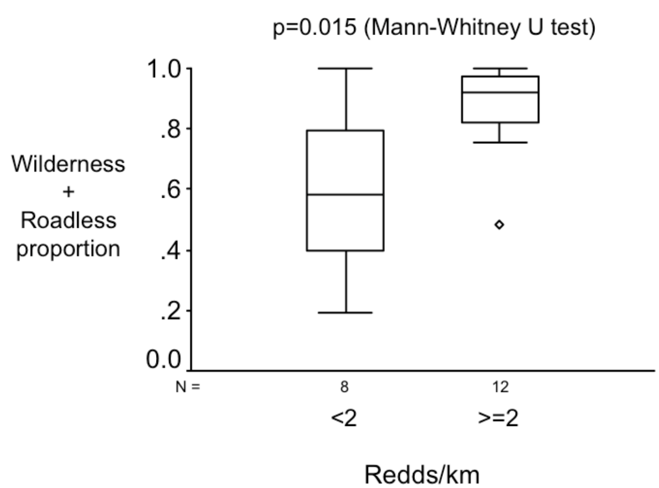


Figure 5. Top: Map of Rock Creek, Clark Fork Basin, Montana, showing the association between national forest Inventoried Roadless Areas (gray shading), designated Wilderness (black shading), and subwatersheds with high bull trout spawner density (crosshatched). Unshaded (white) portions of the basin are roaded areas and a small area of non-Forest Service land. Bottom: Box plot of proportion of un-roaded land area (Wilderness plus roadless) within basins of low (left) and high (right) bull trout spawning density.

We iterated multivariate analyses to compare effects of alternate aggregation and stratification methods for both response and environmental variables. Across iterations, significance tests revealed several robust results: spawner abundance increased with channel or sub-basin slope and extent of bounded alluvial valley geomorphology, and declined with maximum stream temperature. Abundance increased with increasing proportion of sub-basin comprised by wilderness and roadless areas, and the roadless variable was not significantly correlated with the other environmental correlates. Surprisingly, catchment road density did not correlate with bull trout spawning, but the range of road density among Rock Creek sites was far lower than regional average and one order of magnitude lower than in a previously published analysis for Swan River tributaries (Baxter et al. 1999).

Based on the Rock Creek results, we hypothesize that proportional roadless area, a variable that reflects the dispersion of road disturbance within a catchment, is an important measure of human disturbance at lower road density, but at moderate and higher road densities prevailing across the bull trout's range, total road density tends to saturate or override the effect of spatial distribution of roads within the catchment. These results are highly consistent with contention that undeveloped roadless areas are of special importance for sustaining, among other regional biological values, bull trout populations of relatively high abundance. In other words, even in landscapes marked by relatively limited road development, roadless areas appear to provide a critical and prominent function as refugia to sustain robust local populations of native fish. Protecting roadless areas will be a key element determining the success of any recovery or restoration plan.

Acknowledgements

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