WORKING PAPER NO. 40 APRIL 2011

CONSERVATION VALUE OF ROADLESS AREAS FOR VULNERABLE FISH AND WILDLIFE SPECIES IN THE CROWN OF THE CONTINENT ECOSYSTEM, MONTANA

WILDLIFE CONSERVATION SOCIETY

By John L. Weaver

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by John L. Weaver

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To assess the conservation value of remaining roadless areas in the Crown of the Continent Ecosystem in Montana, I compiled and synthesized a sizeable haystack of biological information on a suite of vulnerable fish and wildlife species. Such a synthesis simply would not have been possible without the generous cooperation of many fine biologists.

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SUMMARY

The Crown of the Continent Ecosystem is one of the most spectacular landscapes in the world and most ecologically intact ecosystem remaining in the contiguous United States. Straddling the Continental Divide in the heart of the Rocky Mountains, the Crown of the Continent Ecosystem extends for >250 miles from the fabled Blackfoot River valley in northwest Montana north to Elk Pass south of Banff and Kootenay National Parks in Canada. It reaches from the short-grass plains along the eastern slopes of the Rockies westward nearly 100 miles to the Flathead and Kootenai River valleys. The Crown sparkles with a variety of dramatic landscapes, clean sources of blue waters, and diversity of plants and animals.

Over the past century, citizens and government leaders have worked hard to save the core of this splendid ecosystem in Montana by establishing world-class parks and wildernesses – coupled with conservation of critical wildlife habitat on state and private lands along the periphery. These include jewels such as Glacier National Park, the Bob Marshall-Scapegoat-Great Bear Wilderness, the first-ever Tribal Wilderness in the Mission Mountains, numerous State of Montana Wildlife Management Areas (WMAs), and vital private lands through land trusts such as The Nature Conservancy. Their combined efforts have protected 3.3 million acres and constitute a truly impressive commitment to conservation. It was a remarkable legacy and great gift …but, in the face of new challenges, it may not have been enough.

The melting glaciers of Glacier National Park signal that ecosystems already are experiencing changes in climate that may become even more pronounced in the next century. Climate scientists have documented the following patterns in the western United States (including the Crown): warmer winters and hotter summers, decreasing snowpack and earlier melting in spring, declining stream flows and warmer streams, and longer wildfire season with more severe fires. During warming episodes in past millennia, plants and animals in North America generally shifted north in latitude and (in mountains) upward in elevation. Of course, there were no roads and other human infrastructure back then that posed barriers to shifts by species in response to climate change.

One of the key climate-smart strategies is: *promote resiliency by keeping future options open through an emphasis on ecological variability across space and time*. A broad consensus has emerged on the following actions to promote such resiliency: (1) increase the extent and effectiveness of protected areas,

(2) enhance connectivity within and around large ecosystems, and (3) reduce pressure on species and ecosystems from sources other than climate change. In an ever-changing world where impacts of habitat loss and fragmentation, invasive species, and climate warming are accelerating, vulnerable species will persist longer with well-designed networks of core refugia and connectivity that offer ecological options.

In the Montana portion of the Crown of the Continent Ecosystem, more than 1 million acres of public lands remain roadless. This presents a large-scale opportunity to complete the legacy of conservation in this spectacular and treasured landscape. One of the key land policy questions is: What is the conservation value of these roadless areas for vulnerable fish and wildlife that are important to Montanans and others?

The purpose of this report is to inform discussions and decisions about the remaining roadless areas in the Crown of the Continent Ecosystem, Montana. The goal is to assess the conservation value of 1.33 million acres of roadless areas for a suite of vulnerable species using latest scientific information about their occurrence and conservation needs. Specific objectives are to: (1) determine the geographic occurrence of these species, (2) examine connectivity relative to other Wilderness/Park lands and for movement options in response to climate change, and (3) make recommendations for various levels of wildland protection. The approach involves synthesis of available spatial data into maps of conservation value for vulnerable species and a geographical narrative to draw attention to key areas. For assessing the conservation value of roadless areas in the Crown of the Continent Ecosystem in Montana, I selected the following suite of fish and wildlife species: bull trout (*Salvelinus confluentus*), westslope cutthroat trout (*Oncorhynchus clarki lewisi)*, grizzly bear (*Ursus arctos horribilis*), wolverine (*Gulo gulo*), mountain goat *(Oreamnus americanus*), and Rocky Mountain bighorn sheep (*Ovis canadensis*). These species have limited resiliency to human impacts and thus are vulnerable.

Bull trout and westslope cutthroat trout exhibit high vulnerability. They have a cold-water niche – especially for spawning and rearing – and low resistance to warming water. Both trout have low resistance to invasion by non-native trout, too. Although adult bull trout can move long distances, human fragmentation of streams can have acute impacts on connectivity. Bull trout and westslope cutthroat trout are vulnerable to several detrimental effects of human activities associated with roads. Finally, climate change may diminish the unique thermal niche of these trout and lead to smaller, more isolated and less viable populations. Protection of large and well-connected patches of cold-water habitat remains an important element in the conservation of bull trout and genetically-pure westslope cutthroat trout.

Despite their resourcefulness, grizzly bears exhibit high vulnerability due to low demographic or population resiliency. Bears have very low reproduction and cannot quickly compensate for excessive mortality. Young females do not disperse very far, which makes bear populations susceptible to landscape fragmentation. Protection of large areas of productive habitats with security from human disturbance and mortality are key themes in conservation of grizzly bears.

Wolverines exhibit high vulnerability. Although they have a broad foraging niche, wolverines select areas with persistent snow cover during spring for their reproductive habitat, summer habitat, and dispersal routes. Wolverines have extremely low reproductive rates, too. Consequently, they cannot sustain high mortality rates, which can be exacerbated by trapping pressure – especially in areas of disjunct habitat patches. Trapping may diminish the likelihood of successful dispersal by juvenile wolverines, which could be important to the viability of regional populations. Wolverines appear sensitive to human disturbance near maternal sites. Due to their adaptation for snow environments, wolverines appear particularly susceptible to reductions in suitable habitat as a result of projected climate change.

Mountain goats exhibit high vulnerability. They are constrained to live on or very near cliffs that provide escape terrain from predators and more accessible forage in winter. Female goats have very low reproduction and cannot quickly compensate for excessive mortality (notably hunting). Goats, particularly males, do disperse modest distances which may provide connectivity among some populations. Mountain goats are especially sensitive to motorized disturbance and access.

Bighorn sheep exhibit moderate vulnerability. They have a narrow feeding niche on grasses and are constrained to live on or near cliffs for escape terrain. Female sheep have low to moderate reproduction, but wild sheep are highly susceptible to outbreaks of disease (some carried by domestic sheep) that can decimate a herd quickly. Because Rocky Mountain bighorn sheep have strong fidelity to chosen sites, they do not disperse very readily and have a low capacity for re-colonizing vacant habitats. Bighorn sheep appear less sensitive to motorized disturbance than goats. In terms of climate-smart conservation strategies, maintaining secure access to cliffs and rocky terrain along an elevation gradient could provide options for bighorn sheep on montane winter ranges.

Protected wildlands have a vital role to play in the conservation of such vulnerable fish and wildlife. Protected wildlands: (1) provide secure access to habitat with less risk of human-caused mortality and unsanctioned release of non-native fish, (2) facilitate better connectivity for population and genetic exchange, and (3) afford more room for animals to shift in response to shortfall in key foods or changes in climate. Although some of the detrimental effects of roads can be mitigated with proper design and management (such as permanent or seasonal closure), vulnerable populations of fish and wildlife have a better chance to prosper and persist in large protected areas.

Although a considerable amount of information has been collected for most of these vulnerable species, it had not been fully compiled and displayed. Therefore, I compiled and synthesized the latest available spatial information for these species in Arc GIS 9.3 to produce maps of their present occurrence. To the extent that data spans long periods of varying environmental conditions, maps of occurrence integrate much information about which areas *sustain* these vulnerable species. To supplement the GIS maps, I spent 112 days during 2009-2010 on foot and horseback in field reconnaissance of these roadless areas around the Crown of the Continent Ecosystem in Montana.

To assess the relative importance of roadless areas, I developed a scoring system to quantify the conservation values for vulnerable fish and wildlife species. The scoring system comprised 3 relative ranks: *Moderate* Importance = score of 1, *High* Importance = score of 2, and *Very High* Importance = score of 3. The very high score typically included considerations of likely effects of climate change, with the intention of providing some future options for that species. The purpose of the ranking system was to <u>inform</u> choices about designation of roadless areas.

I recommended the following designations for wildland protection: (1) *Wilderness* for roadless areas that scored high and very high composite conservation values, (2) *Backcountry* for areas that scored lower (moderate) composite conservation values, wherein management would emphasize remote recreation opportunity in roadless areas, and (3) *Wildland Restoration Zone* where certain key roads would be de-commissioned or otherwise permanently closed and returned to more natural condition. Such restoration would increase security value of adjacent lands for vulnerable wildlife and enhance the configuration (less edge exposure to deleterious impacts) of recommended Wilderness areas.

The **Rocky Mountain Front** marks where the Great Plains first meet the dramatic uplift of the Rocky Mountains along the eastern border of the Crown of the Continent Ecosystem. Ranching families, organizations like The Nature Conservancy, and the State of Montana have worked long and hard to conserve private lands and wildlife along the foothills of the Rocky Mountain Front. On its western flank, the Bob Marshall Wilderness and Scapegoat Wilderness protect the high mountain country near the Continental Divide. Between these landmark landscapes, approximately 388,160 acres of *roadless* lands remain – with varying conservation value for vulnerable fish and wildlife species. The most concentrated network of streams with genetically-pure populations of westslope cutthroat trout and potential for restoration occurs in the Badger-Two Medicine area. The Rocky Mountain Front is the last place where grizzly bears still range out onto the prairie as they did in olden times. The northern sector of the Rocky Mountain Front from Highway 2 south to Teton River supports a higher relative density of grizzly bears than the sector south of the Sun River. Primary habitat for resident adult wolverines is widespread along the Rocky Mountain Front, but blocks of maternal habitat for wolverine become smaller and more isolated along the eastern foothills and toward the south end of the Front. The Rocky Mountain Front provides habitat for one of the largest native populations of mountain goats in Montana. The heart of the goat range extends from the high peaks of the Badger-Two Medicine area south to the Deep Creek area. Some of the largest herds of bighorn sheep in America range across the spectacular rocky reefs and wind-swept montane grasslands along the Rocky Mountain Front.

Several roadless areas along the Rocky Mountain Front scored very high or high in composite conservation value for these vulnerable fish and wildlife species. Accordingly, I recommend that 306,288 roadless acres (78.9%) of high-priority lands be designated as **Wilderness**: ✓ most of the Badger-Two Medicine area, ✓ Walling Reef south to Choteau Mountain, ✓ headwaters of

Teton River, ✓ all of Deep Creek watershed, ✓ some areas north of Gibson reservoir, ✓ Renshaw Mountain-Fairview Plateau area between Gibson Reservoir and the Benchmark road, ✓ headwaters of Smith Creek and Elk Creek, and ✓ upper section of the Dearborn River and West Fork of Falls Creek. I further recommend that 81,218 acres (20.9%) of moderate-priority lands be managed in roadless condition as 'Backcountry' with emphasis on non-motorized recreation and security of fish and wildlife populations.

The **Blackfoot – Clearwater River Basin** frames the southern border of the Crown of the Continent Ecosystem. The fabled Blackfoot River threads a glaciated valley of grass-sage, and forests of pine and fir on lower slopes transition to more open forests on the ridges. The Blackfoot Challenge – a group of landowners, business owners, land trusts like the Nature Conservancy, and resource management agencies – are working hard to conserve and enhance natural resources and a rural way of life for present and future generations. A string of glacier-carved lakes grace the Clearwater River valley, where mesic forests rise more sharply to rugged ridges and cirque basins. The Montana Legacy Project has secured protection of thousands of acres of corporate timber land in these watersheds. The Bob Marshall Wilderness and Scapegoat Wilderness protect the high mountain country along the edges of these basins.

Approximately 297,830 acres of *roadless* lands remain in these two watersheds – with varying conservation value for vulnerable fish and wildlife species. The Blackfoot River and Clearwater River plus 17 tributaries have been designated as critical habitat for bull trout. Westslope cutthroat trout occur throughout both river systems, with a wide spectrum of genetic integrity. At present, numerous headwaters streams still harbor genetically-pure populations of these native trout. Relative density of grizzly bears here is lower than in more northerly sectors of the Crown of the Continent Ecosystem, but grizzlies appear to be expanding their range southward through the Blackfoot River basin. For wolverines and mountain goats, the cirque basins and high peaks in the Blackfoot-Clearwater country represent the southern and western edge of an extensive set of large, well-connected blocks of suitable habitat stretching northward across the Bob Marshall and Scapegoat Wildernesses. In addition, the roadless headwaters of Monture Creek provide important summer/fall range for the Blackfoot-Clearwater elk herd.

Several areas in the Blackfoot-Clearwater River basin scored very high or high in composite conservation value for these vulnerable fish and wildlife species. Accordingly, I recommend that 134,159 roadless acres (45.0%) of high-priority lands be designated as **Wilderness:** ✓ Swan Range from Wolverine Peak at the headwaters of the Clearwater River south to Limestone Pass above Monture Creek, ✓ from Limestone Pass southeast along the watershed divide of the Blackfoot River past Arrastra Mountain, then east to the head of Alice Creek basin, and ✓ headwaters of West Fork Clearwater River and Marshall Creek.

I further recommend that 58,930 roadless acres (19.8%) of moderate-priority lands be managed in roadless condition as 'Backcountry' with emphasis on non-motorized recreation and security of fish and wildlife populations. Several isolated blocks of roadless lands totaling 104,742 acres (35.2%) south of Highway 200 are disjunct from the main complex of wilderness and roadless areas and provide lower (moderate) conservation values for these vulnerable fish and wildlife. Consequently, I have not proposed any particular designation for them.

The **Swan River and Southern Flathead River Basin** includes three major tributaries to Flathead Lake on the west side of the Crown of the Continent Ecosystem, Montana – the Swan River, the South Fork of the Flathead River, and the Middle Fork of the Flathead River. Diverse coniferous forests clothe the steep slopes, and jewels of tarn lakes are set among the rugged peaks, a few glaciers, and cirque basins. The Montana Legacy Project has secured protection of thousands of acres of corporate timber land in the Swan Valley. Some of the roadless areas are bordered by Glacier National Park, the Great Bear Wilderness, and the Bob Marshall Wilderness. Substantial roadless lands along the northern part of the Swan Range are not protected by any wildland legislation.

Approximately 376, 594 acres of roadless areas exist currently along the Swan Range and the southern Flathead River basin. Cold-water drainages in the Swan River and Southern Flathead River basins have been deemed a vital stronghold for bull trout in the Columbia River system. About half (18) of the tributaries designated as critical habitat for this threatened native trout have their headwaters in roadless areas. Numerous streams in the Flathead Rivers also have pure populations of westslope cutthroat trout, and the South Fork Flathead River is considered the stronghold for this native species. Suitable primary and maternal habitat for wolverine occurs throughout much of the Swan Range and southern Flathead, where relative density of grizzly bears is also high. The southern crest of the Swan Range and the Flathead Range hold traditional maternal habitat for mountain goats, but goat populations may have been diminished due to ease of hunter access afforded by expanding road system.

Several areas in the Swan River and Southern Flathead River basin scored very high (especially the Swan Range) or high in composite conservation value for these vulnerable fish and wildlife species. Accordingly, I recommend that 253,554 roadless acres (67.3%) of high-priority lands be designated as **Wilderness**: ✓ small areas in Elk Creek and Piper Creek and around upper Lindbergh Lake, ✓ Swan Range from Holland Lake north to Inspiration Point an area and around Spotted Bear Mountain, ✓ higher portions of the Swan Range from Bunker Creek north to Columbia Mountain, ✓ above the east shore of Hungry Horse Reservoir, the basins from Unawah Mountain south to Dry Park Mountain, ✓ Paola Ridge area above the lower Middle Fork Flathead River, and ✓ Slippery Bill Mountain and Patrol Ridge area along the Continental Divide in the Middle Fork of the Flathead River basin. I further recommend that 106,286 roadless acres (28.2%) of moderate-priority lands be managed in roadless condition as 'Backcountry' with emphasis on non-motorized recreation and security of fish and wildlife populations.

A number of primitive, old logging roads extend westward from Hungry Horse Reservoir and penetrate rather deeply into the narrow Swan Range. In recognition of the important fish and wildlife values in the Swan Range, the

Flathead National Forest has closed many of these roads on a permanent or seasonal basis. Nonetheless, some of these roads still receive unauthorized ATV use or may be open to snow machine use in winter which, in some cases, may impact wildlife. To enhance security for vulnerable wildlife and configuration of recommended Wilderness areas, I propose that the upper sections of several primitive roads be considered for wildland restoration (de-commissioned or otherwise permanently closed and returned to more natural condition).

The **North Fork Flathead River Basin and Ten Lakes** roadless area drapes over the Whitefish Range along the western edge of the Crown of the Continent Ecosystem in Montana. The North Fork Flathead River begins in British Columbia and meanders southward through a broad basin and across the international border, marking the west boundary of Glacier National Park. A mix of roadless and logged Forest Service lands occurs west of the Flathead River. International concern and attention to conservation issues in this critical trans-boundary watershed have increased markedly in recent times. The Ten Lakes Scenic Area is the centerpiece of a roadless area on the west side of the Whitefish Range.

Approximately 272, 443 acres of roadless areas exist currently in the North Fork Flathead River Basin and Ten Lakes roadless area. The North Fork Flathead River and 8 major west-side tributaries have been designated as critical habitat for threatened bull trout, which migrate up to 75 miles from Flathead Lake to spawn in their natal streams with unique genetic signatures. Another set of clean and cold streams in the vicinity of Ten Lakes have also been designated as critical habitat for this native species. Most of the genetically-pure populations of westslope cutthroat trout occur in the northern section of the North Fork Flathead River and in a few streams in the vicinity of Ten Lakes. Relative density of grizzly bears is high throughout much of the North Fork Flathead River watershed. Suitable habitat for wolverine occurs throughout much of the Ten Lakes and North Fork Flathead River basin, but blocks of maternal habitat become progressively smaller and less connected toward the south and southeast. A trans-border herd of bighorn sheep with unique genetic composition spends the summer and fall in the Ten Lakes area and winters on a nearby Montana Wildlife Management Area (WMA).

Several roadless areas in the North Fork Flathead River Basin – Ten Lakes area scored high or very high in composite conservation value for these vulnerable fish and wildlife species. Accordingly, I recommend that 193, 460 roadless acres (71.0%) of high-priority lands be designated as a new **Wilderness** area: ✓ Thoma-Mount Hefty area, ✓ Tuchuck area, ✓ Mount Thompson-Seton south to Lake Mountain (including the headwater basins of Williams Creek and Blue Sky Creek on the west side of the Whitefish Divide), ✓ headwaters of Hay Creek and Coal Creek, ✓ south end of Whitefish Range from Haines Pass south to Werner Peak, and ✓ Ten Lakes Scenic Area and the area east of upper Wigwam River including Stahl Peak, Wam Peak, and north nearly to the Canadian border. This complex of wilderness would protect the highest-value habitats, enhance connectivity with both Glacier National Park and the Canadian Flathead, and underscore American commitment to protecting the ecological integrity of the trans-boundary Flathead region.

I further recommend that 63,890 acres (23.5%) be managed in roadless condition as 'Backcountry' with emphasis on non-motorized recreation and conservation of fish and wildlife. To enhance security for vulnerable wildlife and configuration of recommended Wilderness areas, I propose that the upper sections of several primitive roads be de-commissioned or otherwise permanently closed and returned to more natural condition.

Many of the remaining roadless areas in the Crown of the Continent Ecosystem in Montana have high conservation value for vulnerable fish and wildlife species. Based upon a thorough spatial assessment, I recommend that:

- ✓ 887,461 acres (66.5%) be legislated as **Wilderness**,
- ✓ 310,320 acres (23.2%) be designated as Backcountry, and
- ✓ 82 miles of old, primitive logging roads be restored to natural condition for wildlife security.

These actions would protect habitats vital for year-round ranges, safeguard genetic integrity, enhance connectivity, and provide options for movement in response to changing conditions.

Here – where native trout fin their way back to natal streams to spawn in the clean, cold blue waters of the Rockies … where herds of bighorn sheep nibble short grasses with the roar of chinook winds and eagle wings in their ears … where the wild challenge of a bull elk trumpets across a September sunrise – lays an opportunity to complete the legacy of conservation in the Crown of the Continent Ecosystem in Montana and to sustain the wild heartbeat of Life for present and future generations.

Figure 1. Location of the trans-border Crown of the Continent Ecosystem in Alberta, British Columbia and Montana. The boundary of the Montana section for this conservation assessment of roadless areas is delineated in the bolder green. Map courtesy of Misstakis Institute.

1. CROWN OF THE CONTINENT ECOSYSTEM

A Spectacular Landscape, Splendid in its Diversity

The Crown of the Continent Ecosystem is one of the most spectacular landscapes in the world and most ecologically intact ecosystem remaining in the contiguous United States. In 1891, the naturalist George Bird Grinnell coined the name 'Crown of the Continent' to describe the area later designated as Glacier National Park. Today, in recognition that Glacier Park is an integral part of a much larger, trans-boundary ecosystem, the entire region is now called the Crown of the Continent Ecosystem ('Crown').

Straddling the Continental Divide in the heart of the Rocky Mountains, the Crown extends for > 250 miles from the fabled Blackfoot River valley in northwest Montana north to Elk Pass, which is south of Banff and Kootenay National Parks in Canada (Figure 1). It reaches from the short-grass plains along the eastern slopes of the Rockies westward nearly 100 miles on average to the Flathead and Kootenai River valleys. Altogether, the Crown of the Continent Ecosystem encompasses roughly 28,000 square miles (Crown Managers Partnership 2010). The Montana portion covers over 18,000 square miles (65%) of the ecosystem – the size of Vermont and New Hampshire combined. The Crown sparkles with a variety of dramatic landscapes, clean sources of blue waters, and diversity of plants and animals.

The Crown is a rugged mountainous landscape with a great variety of terrain features. The Continental Divide – called *Miistakis* or 'backbone of the world' by the Blackfeet Indians – is a principal feature of the Crown of the Continent Ecosystem. It cleaves the Crown into two very different ecological settings on the wetter west side and the drier east side. In general, the major mountain ranges are oriented south↔north, but there are many ridges and spurs that run in other directions. There is a 10-fold range in elevation across the Crown in Montana from 317 m (1040 ft) to 3190 m (10,466 ft) on Mount Cleveland in Glacier National Park. Moreover, there is tremendous variation in topography at several scales. Additionally, natural disturbances have resulted in diverse patterns at different scales. For example, much of the Crown was covered by ice during the last glacial period about 20,000 years ago (Clark et al. 2009). Importantly, though, several areas were free of ice – including peaks extruding through the ice ('nunataks') as well as lower areas south and east of the ice sheets. These areas provided multiple refugia for both plants and animals and influenced many of the distribution patterns of biota today (Shafer et al. 2010). More recently, disturbances like insects and fire have created new patterns at local scales. All of these factors have set the stage for a diverse assemblage of plant and animal species.

The Crown of the Continent Ecosystem has a large flora composed of 1300-1400 vascular plant species, which is impressive for a small area (Lesica 2002, Hebda 2010). Its geographic position in North America provides a cross-road for plants from many other regional floras. For example, there are species representing mountain, boreal forest, prairie, circumpolar, and Beringian flora. Plant communities are arrayed in 3-6 different zones stacked vertically from prairie to peak. About 240 species of birds and 65 mammals find a rich mix of habitats across the Crown of the Continent Ecosystem (Figure 2).

The Crown is home to a remarkable group of native fish and wildlife. The cold, clear waters of the Crown are a stronghold for bull trout and genetically-pure populations of westslope cutthroat trout. Here is the largest population of Rocky Mountain bighorn sheep found anywhere in the United States, the largest population of mountain goats in Montana, and some of the country's largest elk herds. Here roam the wild hunters – wolf, grizzly bear, cougar, lynx, wolverine and others – that have been vanquished from more settled areas. In fact, the community of carnivores here (17 species) appears unmatched in North America for its variety, completeness, and density of species that are rare elsewhere (Weaver 2001). And here is the only place where grizzly bears still range out onto the open prairie as in times past.

Such an astonishing legacy of vulnerable fish and wildlife did not occur by accident. Rather, it was the direct outcome of concerned citizens – both local and national – who cherished these natural values and acted to protect treasured wildlands and their splendid diversity.

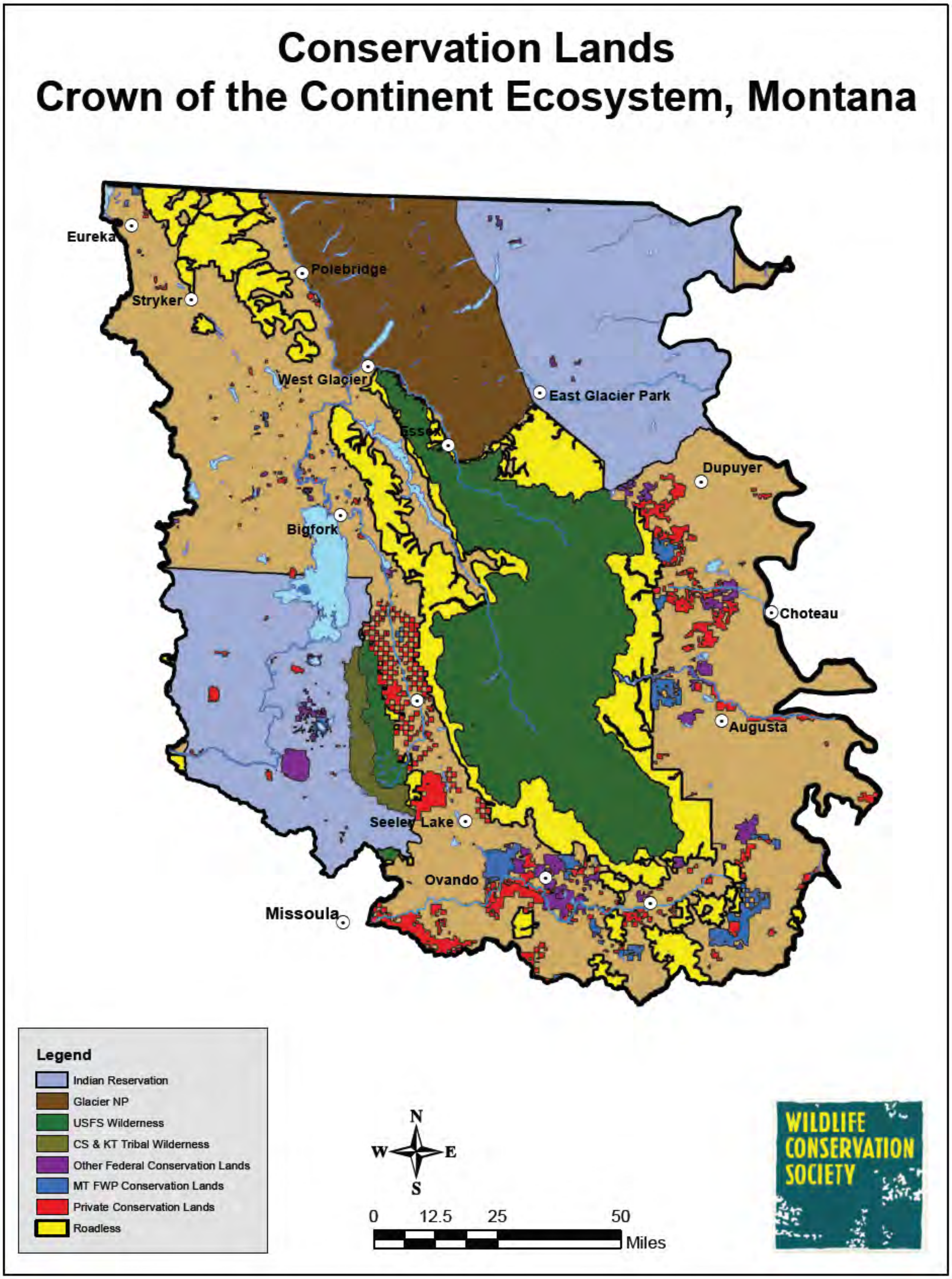
A Century of Conservation Commitment: The Legacy of Protected Lands

For millennia, native people traveled across homelands that we now call the Crown of the Continent Ecosystem. Over the past century spanning 1910-2010, there have been significant conservation investments to protect lands in the Crown of the Continent Ecosystem (Figure 3). Here, I present a chronology of those steadfast efforts that borrows in part from a beautiful and interesting book on Montana's Bob Marshall Country by Rick and Susie Graetz (2004).

Glacier National Park

In 1910, Glacier National Park straddling the Continental Divide in northwestern Montana was established as one of America's earliest investments in a portfolio of spectacular Nationals Parks. Glacier National Park encompasses 1,013,572 acres – with 99.3% essentially wilderness. The park is world renowned for its spectacular scenery of glaciers, fiord-like glacial lakes, serrated peaks and amphitheater cirques dropping off a mile deep into broad U-shaped valleys, countless waterfalls, meadows ablaze with wildflowers, and diverse

Figure 3. Location of conservation lands in the Crown of the Continent Ecosystem, Montana, 2010. Remaining roadless areas are highlighted in yellow.



coniferous forests. The Continental Divide cleaves the Park into two very different ecological worlds. West of the Divide, the high amounts of annual precipitation promotes lush old-growth forests of Douglas fir, western larch, Engelmann spruce and subalpine fir. Even western red cedar, western hemlock and white pine thrive in the McDonald Valley. On the much drier east slopes, short-grass prairie transitions into limber pine and aspen, lodgepole pine and spruce-fir forest. The Park retains nearly all of its native plant and animal species, including notable populations of grizzly bear, wolverine, gray wolf, lynx, mountain goat, and bighorn sheep. Along with its Peace Park sister Waterton Lakes National Park in Canada, Glacier National Park was designated a World Heritage Site in 1995. It anchors the north end of wild country in the Crown of the Continent Ecosystem in Montana.

Figure 2. The Crown of the Continent Ecosystem is one of the most spectacular landscapes in the world, splendid in its diversity of land and waters, plants and animals.

Glacier National Park

Harvey Locke

Rick and Susie Graetz

Bob Marshall Wilderness

During the 1930s, the US Forest Service designated wild lands south of Glacier National Parks as 'primitive areas'. These included the South Fork (Flathead River) area in 1931, the Pentagon area in 1933, and the Sun River area in 1935. Following the premature death of the wilderness visionary Bob Marshall in 1939, the US Forest Service coalesced these primitive areas and designated about 950,000 acres as the Bob Marshall Wilderness Area in 1940 "as a monument to his memory". The 'Bob' (as it is often called) now encompasses 1,009,352 acres and was brought into the national wilderness system in 1964 following passage of the Wilderness Act. This is a vast wild land that straddles the Continental Divide, protecting the headwaters of the South and Middle Forks of the Flathead River as well as the Sun River. Perhaps the most ecologically-intact mountain wilderness in the country, the Bob includes rugged peaks, big river valleys, more than 100 lakes, large meadows and extensive coniferous forests. It transitions sharply from lush, diverse conifer forests on the west side to drier, more open country to the east. The Chinese Wall, an imposing limestone precipice that towers 1,000 feet for 13 miles, is the centerpiece of the Bob Marshall Wilderness (Figure 4). But, the original designation of the Bob Marshall Wilderness left out several significant areas that may people believed warranted protection.

Figure 4. The Chinese Wall is the iconic centerpiece of the vast Bob Marshall Wilderness in Montana.

Rick and Susie Graetz

Scapegoat Wilderness

During the 1960s, Montana citizens challenged the US Forest Service over plans to build roads and harvest timber in the wildlands north of Lincoln, Montana. Eventually, Congress protected 239,936 acres as the Scapegoat Wilderness Area in August 1972. The Scapegoat Wilderness abuts the southeast boundary of the Bob Marshall Wilderness along the east side of the Continental Divide. From the heights of the massive Scapegoat Plateau flow the headwaters of the South Fork Sun River, the Dearborn, and the fabled Blackfoot River. This geologic formation is the southerly extension of the Chinese Wall. Framing this grassy plateau are awesome 1,000-foot limestone cliffs that stretch nearly four miles, with views of the great prairie stretching eastward. In addition to its mountain centerpiece, the Scapegoat has 14 lakes and provides habitat for grizzly bears, mountain goats, elk, and other wildlife. But, this addition to the Nation's wilderness left out an important northern link between the Bob Marshall Wilderness and Glacier National Park – the Middle Fork of the Flathead.

Great Bear Wilderness

During the 1970s, Montana citizens called for greater protection of the wild Middle Fork Flathead River and its larger watershed. In 1978, Montana Senator Lee Metcalf inspired by the notion of room to roam for grizzly bears – led Congressional protection of 286,700 acres known as the Great Bear Wilderness. This wilderness encompasses the entire upper drainage of the Middle Fork Flathead River from the Continental Divide west to the Flathead Range. Its glaciated history reveals itself in the serrated ridges and awesome cirque basins that provide habitat for grizzly bears, mountain goats, and wolverines. Together, these three wildernesses protect 1,535,988 acres in the heart of the Crown of the Continent Ecosystem.

Mission Mountains Wilderness

The Mission Mountains frame the western skyline of the Crown of the Continent Ecosystem and cradle one of the densest concentrations of alpine lakes in the northern Rockies. Intercepting westerly flow of moist Pacific airstreams, the Mission Mountains capture and store tremendous amounts of precious snow and water. With more than 350 lakes, ponds and pools and sparkling clear streams, the Missions are a natural water tower. It's a range of rocky crags, sheer cliffs, jagged ridges, cirques, valleys and active glaciers. The eastern slopes of the Mission Mountains are draped by diverse forests of Engelmann spruce and subalpine fir, lodgepole pine, western red cedar, western larch, and ponderosa pine as they drop down into the Swan Valley. The US Forest Service classified a part of the Missions as a primitive area back in 1931. Finally, in 1975, Congress designated 73,877 acres as the Mission Mountains Wilderness.

Mission Mountains Tribal Wilderness

The western slopes of the Mission Mountains are privately-owned lands of the Confederated Salish and Kootenai Tribes (CSKT) on the Flathead Indian Reservation. On this side, steep slopes rise abruptly from the Mission Valley more than 6,000 feet to the high peaks. Indeed, the view of this west side of the Missions is one of the most dramatic in Montana. From hidden alpine basins and high lakes, Mission Falls and Elizabeth Falls plunge 1000 feet. During the early 1970s, the BIA Flathead Agency proposed to log portions of the coniferous forests on the roadless mountain slopes. Three highly-respected grandmothers (known in Salish as ‘Yayas’) protested before the Tribal Council, which sparked many other Tribal members to call for protection of these lands. In 1982, the Confederated Salish and Kootenai Tribes established the Mission Mountains Tribal Wilderness encompassing 91,778 acres of the Mission Mountains (CSKT 2005). This was the first-ever designation of tribal wilderness by any tribe. The tribes’ leadership demonstrates their cultural and spiritual links to the health and integrity of this wildland.

Together, these two contiguous Wildernesses protect 165,655 acres of the Mission Mountains.

Rattlesnake Wilderness

In 1980, again at citizen behest, Montana’s Congressional delegation led designation of the Rattlesnake Wilderness, comprised of 32,976 acres just north of Missoula, Montana. Only a small portion (<5,000 acres) of this wilderness, however, occurs within the Crown of the Continent Ecosystem.

In addition, the US Forest Service administers another 6,453 acres in conservation easements

BLM Outstanding Natural Areas

Along the Rocky Mountain Front, the Bureau of Land Management (BLM) manages 13,087 acres in 4 separate units as ‘Outstanding Natural Areas’ to protect their wilderness character. These areas showcase examples of native prairie grasslands in a spectacular setting.

US Fish and Wildlife Service Lands

The US Fish and Wildlife Service manages 30,894 acres in National Wildlife Refuges and stewards another 98,604 acres in conservation easements in the Crown of the Continent Ecosystem in Montana.

Altogether, the total acreage of conservation lands within these Federal and Tribal areas in the Crown of the Continent Ecosystem sums to approximately 2,857,162 acres.

Montana Department of Fish, Wildlife and Parks (FWP) Wildlife Management Areas

The State of Montana has made significant investments in conservation lands around the Crown of the Continent Ecosystem during the past century. Most of these lands have the primary purpose of providing critical winter range for ungulates such as elk, bighorn sheep, and deer. Of course, these WMAs provide many other conservation benefits as well.

On the Rocky Mountain Front, Montana FWP has invested in several key areas. Between 1948 and 1974, it acquired 19,771 acres to establish the Sun River WMA. In 1976 -77, the Department bought 3,047 acres to secure the Ear Mountain WMA. During 1979-1985, it purchased 10, 497 acres to protect the Blackleaf WMA.

In the Blackfoot-Clearwater River basin, Montana FWP purchased 10,936 acres of crucial winter range in 1948. Through a series of land transactions over the years, by 1998 the Department had acquired a total of 18,000 acres and leased another 49,000 acres to conserve winter grazing lands for ungulates. Other conservation lands include the Aunt Molly (1184 acres) and Nevada Lake (740 acres) WMAs.

In the Kootenai sector, Montana FWP acquired 1,147 acres of the Woods Ranch in 1982. This WMA protects critical winter range for a genetically-unique herd of bighorn sheep.

These state-owned WMAs protect a total of 54,386 acres of prime habitat. In addition, Montana FWP has received or purchased conservation easements on numerous parcels scattered around the Crown.

Non-governmental Land Trusts

In more recent decades, several land trusts have received or acquired deeded lands and conservation easements for 335,269 acres in the Crown of the Continent Ecosystem, Montana. Much of this private investment has focused on the Rocky Mountain Front, the Blackfoot-Clearwater River basin, and the Swan Valley. The Nature Conservancy leads the way with 71% of the holdings, followed by Montana Land Reliance with 22%. A recent example of this commitment is the Montana Legacy Project – the largest, private conservation land purchase in U.S. history. As part of this bold initiative totaling >300,000 acres, the Nature Conservancy (in partnership with Trust for Public Land) purchased approximately 137,000 acres in the Swan, Clearwater, and Potomac Valleys from Plum Creek Timber Company. This substantial investment prevented unchecked, piecemeal development of vital wildlife habitat in this section of the Crown of the Continent Ecosystem. Most of this land will transfer to US Forest Service, Montana State Trust Lands, and Montana Fish, Wildlife and Parks Department.

This private investment in public conservation values has even extended across the border into Canada. In early 2011, The Nature Conservancy (U.S.) joined with Nature Conservancy of Canada in a commitment of $9.4 million to secure a ban on mining and energy development in the Canadian section of the North Fork of the Flathead River. Because numerous fish and wildlife species move back and forth across the border in this trans-boundary basin (Weaver 2001), this strategic commitment by The Nature Conservancy (U.S.) will help secure protection of habitats vital for many fish and wildlife.

Total Investment in Conservation Lands

Over the past century, the combined investments of federal, tribal, state, and private sectors has protected approximately 3.3 million acres in the Crown of the Continent Ecosystem, Montana. In addition, there have been a number of policy initiatives to protect ecological values in the Crown. One example is withdrawal of the Rocky Mountain Front and North Fork Flathead River areas from new oil and gas and mineral leasing, as well as some private companies volunteering to relinquish their current leases. In sum, this is truly an impressive commitment to conservation.

Previous generations of citizens and government leaders have worked hard to save the core of this splendid ecosystem by establishing these world-class parks and wildernesses, coupled with conservation of critical wildlife habitat on state and private lands along the periphery.

It was a remarkable legacy and great gift … but, in the face of new information and new challenges, it may not have been enough.

The Next Century: The Challenge of Climate Change

One challenge facing conservation of wildlife and wildlands over the past century has been the ever-expanding footprint of humans – urban and rural sprawl, superhighways and forest roads, dams and diversions. But scientists are alerting us to a new challenge for the next century: climate change. What changes in climate can we anticipate over the next 50-100 years? What will be the ecological consequences? What might comprise thoughtful responses to this new challenge?

Over the past 100 years, a new array of instruments has enabled climate scientists to measure trends and variability in temperature, precipitation, snowpack and other climate variables with greater accuracy and better geographic representation. This has provided a strong empirical record for many areas, including the Crown of the Continent Ecosystem.

Attempting to predict future climate conditions, though, is a daunting but important endeavor. Projecting climate change depends, of course, upon the (1) assumed scenario of greenhouse gas (GHG) emissions and (2) variables and relationships used to build any specific climate model. The empirical record of past climate change helps scientists better understand the performance of a model. In an attempt to develop robust projections, researchers increasingly are using ensembles of different climate models to examine implications of different GHG scenarios (Leung et al. 2004). Climate scientists have projected future climate conditions for North America using an ensemble of 22 IPCC climate models and a moderate scenario of greenhouse gas emissions (A1B moderate scenario = rapid economic growth, global population that peaks in mid-century and declines thereafter, and the rapid introduction of new and more efficient technologies).

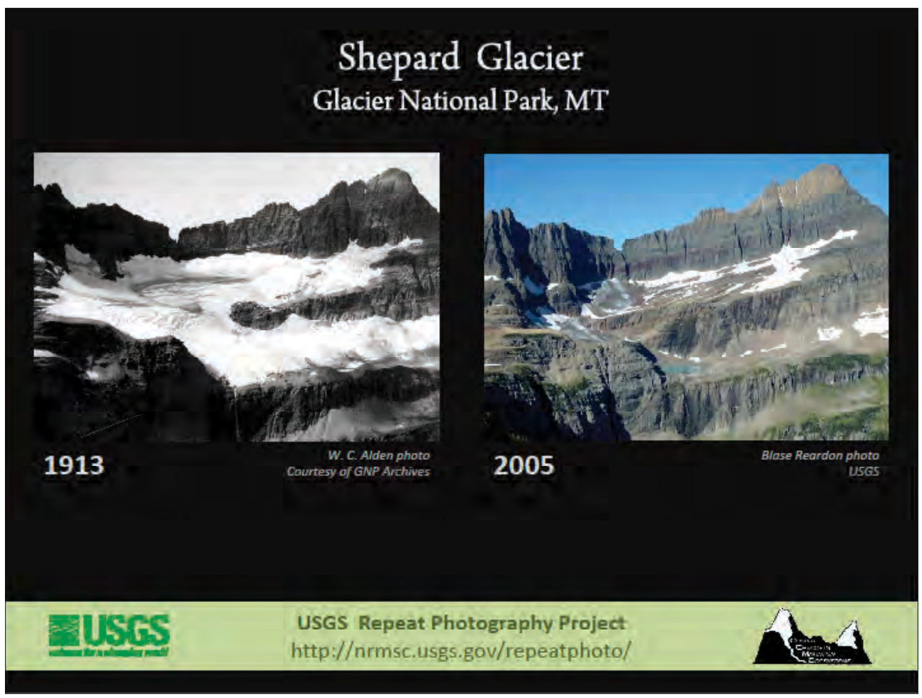
Because most conservation planning and action happens at a regional or local scale, it's important to match global climate-change models to smaller scales (Wiens and Bachelet 2009). That has been a difficult endeavor, however, due to seemingly chaotic behavior of climate systems at these scales. Recently, NOAA scientists downscaled temperature projections from global models to 22 mountain ranges across the western United States (Ray et al. 2010), while the Climate Impacts Group at the University of Washington has completed preliminary projections of April 1 snowpack and potential evapotranspiration at regional scales (*in* McWethy et al. 2011). Taken together, these represent some of the best available projections of future climate conditions in the western United States. Although there is still considerable uncertainty in climate projections (especially for complex environments like mountains), climatologists expect that patterns and trends in climate over the past 50-100 years will continue and perhaps accelerate under even moderate GHG scenarios.

Here, I synthesize the major findings from recent research to describe climate patterns over the past 100 years as well as projected changes over the next 40 years (2011-2050). This lays the foundation for anticipating changes in future environmental conditions that vulnerable fish and wildlife may encounter.

△ Disappearing glaciers

Perhaps the most iconic impact of climate change in western Montana has been the disappearance of glaciers from Glacier National Park (Figure 5). Of 150 glaciers in the Park in1850 (covering 99 km^2 total), only 25 (<16 km^2 total) remain today. Increasing temperature during the critical spring and summer melting season has accelerated the retreat of glaciers. If trends continue, scientists expect glaciers will disappear from Glacier Park by 2030 (Hall and Fagre 2003, McWethy et al. 2010).

Figure 5. Melting of glaciers in Glacier National Park signals an era of changing climate.



△ Warmer winters and hotter summers

Over the past 100 years, average annual temperature in western Montana has increased 1.3° C (2.3° F), nearly twice the rise in global temperature (Pederson et al. 2010). The largest increase has taken place in winter, when minimum temperatures rose +2.4° C and maximum temperatures 1.8° C. The average number of days below-freezing in winter has dropped from 186 days to 170 days, due mostly to warmer days in early spring (Westerling et al. 2006). Temperatures have warmed dramatically since the early 1980s and hot temperatures have occurred longer through the summer (Bonfils et al. 2008, McWethy et al. 2010, Pederson et al. 2010). This increase in summer temperature has been 3x greater at higher elevations (Pederson et al. In Press). Such accelerated warming at high elevations has been reported from many areas across the globe (Pepin and Lundquist 2008).

Climatologists project that by 2050, annual temperatures will be 1.4^{0} – 3.1^{0} C (2.5^{0} – 5.5^{0} F) warmer than now (Barnett et al. 2005, McWethy et al. 2010, Pederson et al. 2010, Running et al. 2010). Both winters and summers will become warmer, with intense heat waves in summer becoming more common and longer in duration. There will be fewer, shorter, and less intense episodes of really cold weather in winter. There still could be large variability between years and decades.

△ Variable precipitation patterns

During the 20^{th} century, there have been periods of drought and periods of greater precipitation in western Montana. Indeed, the high variability in seasonal, annual, and decadal patterns of precipitation overrides any strong century-long trends (Selkowitz et al. 2002). Precipitation patterns are more difficult to predict than temperature, especially in complex terrain of mountains (Solomon et al. 2010). Summers are likely to become even hotter and drier, which could increase evapotranspiration and loss of vulnerable wetlands.

△ Decreasing snowpack and earlier melting in spring

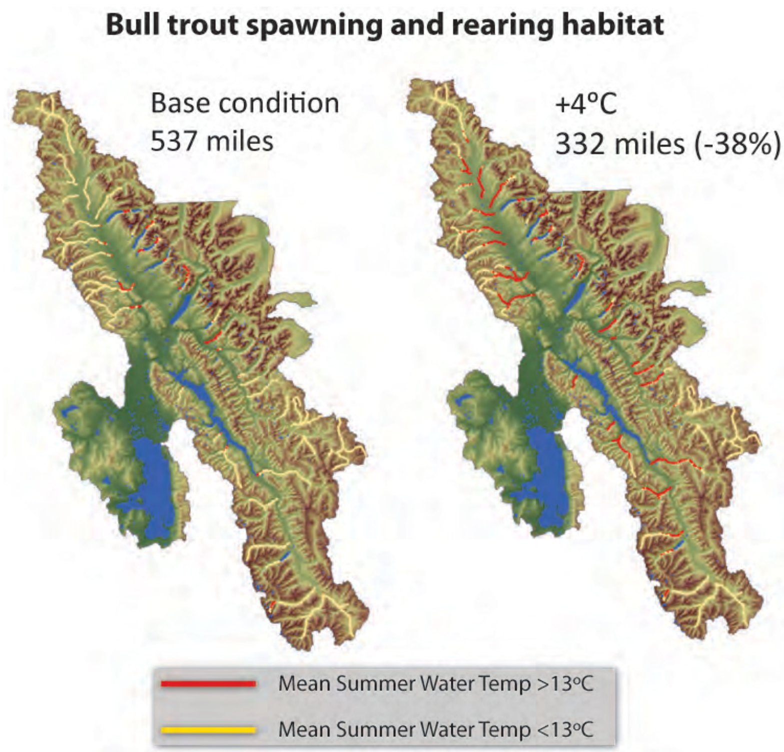
Annual snowpack level (indexed by April 1 Snow Water Equivalent) has declined by 15 to 30 percent throughout the Rocky Mountains during the second half of the 20^{th} century (Hamlet et al. 2005, Mote et al. 2005, Barnett et al. 2008, Pierce et al. 2008) and by approximately 20% in the Crown (Pederson et al. In Press). More of the winter precipitation in the western United States has been falling as rain rather than snow – especially at lower elevations – due to significant increases in number of days when temperatures are above freezing (Mote et al. 2005, Bales et al. 2006, Knowles et al. 2006, McWethy et al. 2010). Rain-on-snow events have become more frequent at low to mid-elevations, increasing the prospects for winter flooding (Hamlet and Lettenmaier 2007). Over the past 50 years, warmer temperatures have led to earlier runoff in the spring (by 1-4 weeks) and reduced base-flow of streams in the summer and autumn across western United States (Stewart et al. 2005, Hildago et al. 2009). In the Crown of the Continent Ecosystem, for example, average snowmelt advanced about 8 days earlier in the spring between 1969 and 2006 (Pederson et al. In Press).

For the future, climatologists project that, due to warmer temperatures during winter, there will be more rain and less snow falling at low and mid elevations. This will result in less snowpack, shorter snow season, and earlier melt in spring (Bales et al. 2006, Knowles et al. 2006, Mote 2006, Running et al. 2010, Pederson et al. In Press). Winter rains may result in more floods out of the mountains (Groisman et al. 2005, Hamlet and Lettenmaier 2007).

△ Declining stream flows and warmer streams, particularly by late summer

Approximately 60-80% of surface water flow in the interior Mountain West is governed by the amount of snowpack (Barnett et al. 2005). Over the past 50 years, there has been a general decline in stream flows associated with reduced snowpack (McCabe and Clark 2005, Barnett et al. 2008). In the Northern Rockies, for example, water flow in August decreased by an average of 31% (range 21-48%) during 1950-2008 (Leppi et al. 2010). In the Crown of the Continent, annual discharge of water declined from historic levels in 21 of 31 river reaches, particularly on the eastern slopes of the Rockies (Rood et al. 2005, Rood et al. 2008). In the Flathead River, summer base flows decreased about 11% between 1978 and 2007 (C. Muhlfeld, USGS, *unpublished data*). The decline in snowpack has reduced recharge of aquifers, which makes less water available for groundwater flow into streams and also decreases the base flow during the key summer period (Rood et al. 2008). In the Crown of the Continent Ecosystem, increased precipitation during spring may have buffered the annual streamflow from more severe declines due to decreased snowpack alone (Pederson et al. In Press). With warmer air temperatures, loss of shading cover along streams due to wildfire, and lower stream flows by August, stream temperatures have also increased (Isaak et al. 2010). Moreover, both the year-to-year variability in stream flow (Pagano and Garen 2005) and multi-year duration of drought conditions are increasing (McCabe et al. 2004). Researchers project that these trends in stream flows will continue in the future (Shepard et al. 2010, Running et al. 2010), with negative consequences for coldwater native trout (Haak et al. 2010) (Figure 6).

Figure 6. Due to smaller snowpack in winter and hotter temperatures in summer, stream flows are declining and becoming warmer - particularly by late summer. This warming has negative consequences for native trout that require cold water. For example, under a projected 4 C° increase in average August air temperatures, critical spawning and rearing habitat for bull trout in the Flathead River basin would decrease by 38% (inset maps: C. Muhlfeld and L. Jones, USGS Glacier National Park, in-review).



Montana Department of Fish, Wildlife, and Parks.

△ Longer season of wildfire, with severe fires across more of the landscape

Wildfires, of course, have long been a feature of landscapes and driver of ecological processes across western North America. Beginning in the mid-1980s, large forest fires have become more frequent and much more severe than in previous decades (Running 2006). Compared to the 1970-1985 period, for example, there has been a 6-fold increase in number of acres burned each year and the fire season is about 78 days longer (Westerling et al. 2006). Notably, much of the increased fire activity has occurred in forests at higher elevations (5500 to 8500 feet), where snowpack levels normally keep wildfire activity low (Westerling et al. 2006). More intense fires have swept across streams, and the loss of critical shading has exacerbated warming of streams (McKenzie et al. 2004, Dunham et al. 2007, Pettit and Naiman 2007).

As temperatures continue to climb in the future accompanied by earlier snowmelt and hotter, drier summers (Cook et al. 2004), there will likely be a longer fire season with severe fires across more of the landscape (Spracklen et al. 2009, McWethy et al. 2010, Running et al. 2010).

△ Spread of insects and invasive weeds

In the wake of milder winter temperatures, populations of mountain pine beetle have exploded in recent years across western North America (Logan et al. 2003, Nordhaus 2009). More than 5 million acres of Montana's forests have been affected by the current infestation. In addition, warmer summers with longer droughts have stressed many coniferous tree species (van Mantgem et al. 2009), enabling bark beetles to expand to higher elevations and new host species – such as the whitebark pine (Logan et al. 2003). The willow stem borer has spread throughout southern British Columbia and attacked up to 75 percent of willows, a keystone shrub with many ecosystem benefits (Pojar 2010). Along with warmer temperatures and prolonged droughts, wildfire and land alterations have promoted spread of invasive plant species such as cheatgrass and spotted knapweed (Bradley 2009).

△ Shifting distribution of plants and animals

As conditions become warmer and more arid in the future, different plant species will become stressed and shift individually in response to changes in temperature and soil moisture (Rehfeldt et al. 2006). Short-grass prairies on the eastern slopes of the Rockies will become less productive and more prone to erosion, fire, and insects (Clark et al. 2002). At lower elevations, forests will decline in density and extent, and some may transition to shrub-dominated sites and grasslands (Fagre 2007). In the middle sections of mountain slopes, the structure and composition of forest communities will change as different species shift mainly upward or to different aspects.

Some species, however, could shift downward depending upon water balances (Crimmins et al. 2011). With warming and longer growing seasons at higher elevations, trees could colonize alpine meadows and fill-in more over time (Klasner and Fagre 2002).

During warming episodes in past millennia, distribution of plants and animals in North America generally shifted north in latitude and upward in elevation (Pielou 1991). In the mountains, various mammals shifted distribution upward in elevation or perhaps to a different aspect (Guralnick 2007) and consequently did not have to shift as far north as those in flatter areas (Lyons et al. 2010). Of course, there were no roads and other human infrastructure back then that posed barriers to shifts by species in response to climate change. In recent years, researchers have documented similar shifts northward and upward (Parmesan 2006, Moritz et al. 2008). But, there may be niche or physiological constraints to such adaptive movements. Alpine animals like pikas may find temperatures too warm even on mountaintops and suffer local extirpation (Beever et al. 2003).

From this litany of past and projected changes in climate, there appears to be strong consensus that western United States, including portions of the Crown of the Continent Ecosystem, will continue to get warmer – perhaps much warmer. It's sobering to see how relatively small changes in average temperature [1^0-2^0 C] and snow-rain thresholds have resulted in large ramifications for water resources such as snowpack and summer stream flow. Projected changes in climate will set many ecological changes cascading into motion, putting increasing pressure upon plants and animals to adapt their niche or move to track preferred environmental conditions. Their responses will be individualistic and complicated due to complex ecological interactions beyond simply their climatic 'envelope'. What does all of this imply for conservation strategies to maintain species, ecosystems, and the critical services they provide society?

One key conservation concept involves *resilience thinking* (Walker and Salt 2006). 'Resilience' can be defined as the capacity of species or system to withstand disturbance and still persist (*sensu* Holling 1973, Folke et al. 2004). Plants and animals evolved in ecosystems where natural disturbances varied in frequency, intensity, duration, and extent – thereby resulting in different spatial and temporal patterns of change (Pickett et al. 1989). Over millennia, animals developed important behaviors and ecological traits that imbued them with resilience to certain kinds and levels of disturbance (Weaver et al. 1996, Lavergne et al. 2010). But as human activities accelerate rates of disturbance across a greater extent of the landscape, the combination of rapid change and simplification can undermine the evolved resiliency of species and render their populations more fragile.

Importantly, the resilience framework does not require an ability to precisely predict the future, but only a qualitative capacity to devise systems that can withstand disturbance and accommodate future events in whatever surprising form they may take (Berkes and Folke 1998). **One of the key messages of resilience thinking is to *keep future options open through an emphasis on ecological variability across space and time***, rather than a focus on maximizing production over a short time (Walker and Salt 2006).

This kind of resilience thinking is reflected in several 'climate-smart' strategies identified by scientists and managers from around the world (Hannah and Hansen 2005, Heller and Zavaleta 2009, Mawdsley et al. 2009, Running and Mills 2009, Graumlich and Francis 2010, Hansen et al. 2010, Hobbs et al. 2010, Turner et al. 2010). A broad consensus has emerged on the following actions to enhance resiliency in the face of climate change:

- Increase the extent and effectiveness of protected areas.
- Enhance connectivity within and around large ecosystems.
- Reduce pressures on species and ecosystems from sources other than climate change.
- Manage/restore ecosystem functions.

In an ever-changing world where impacts of habitat loss and fragmentation, invasive species, and climate warming are accelerating, vulnerable species will persist longer with well-designed networks of core refugia and connectivity that offer ecological options (Carroll et al. 2009, Hodgson et al. 2009, Krosby et al. 2010). Thus, protecting ecologically-diverse roadless areas in legislated Wilderness and other non-motorized categories (e.g., legislated 'Backcountry') is a sound and robust strategy in response to climate change.

Roadless Areas in the Montana Crown: An Opportunity to Complete the Legacy

The core of the Crown of the Continent Ecosystem in Montana has been protected through establishment of Glacier National Park and designation of several large wilderness areas. In addition, the State of Montana and the private sector have worked steadily to protect important habitats along the flanks of the Crown ecosystem. Are there still opportunities to enhance the effectiveness of these conservation investments and build upon the tremendous legacy? What about all the public lands that still remain roadless?

I accessed two sources for an inventory of roadless areas in the Crown of the Continent Ecosystem, Montana (Figure 3). The 'Inventory of Roadless Areas' (IRA) by the US Forest Service tallied 1,229,281 acres, whereas the Montana Wilderness Association (MWA) tallied 1,400,652 acres (including 13,087 acres of BLM Outstanding Natural Area that are essentially roadless). About 56,020 acres of roadless lands occurred on the periphery and outside the sub-region watersheds used for this assessment. Thus, there was agreement between the two inventories on roadless status involving 92% of these un-roaded lands. Some of the remaining difference can be attributed to Forest Service protocols for IRAs that dismissed some un-roaded lands because they lacked (in their interpretation) sufficient solitude, opportunity for primitive recreation, or remoteness (USDA Forest Service 2000). Another discrepancy involved 23,640 roadless acres (in Badger-Two Medicine area) left out of the earlier RARE II inventory by Forest Service – perhaps for its oil and gas potential. Because court cases in the past have ruled against arbitrary interpretations by federal land agencies, I have used the higher inventory of roadless areas. Finally, there were some inevitable 'blank slivers' in edge-matching different GIS data bases.

By this estimation, there are approximately 1,335,000 acres of roadless lands remaining in the Montana portion of the Crown of the Continent Ecosystem (depicted in yellow on the map in Figure 3). **This presents a large-scale opportunity to complete the legacy of conservation in this spectacular and treasured landscape**. One of the key land policy questions is: What is the conservation value of these roadless areas for vulnerable species of fish and wildlife that are important to Montanans and others?

Purpose, Goal and Objectives, and Organization of the Report

The purpose of this report is to inform discussions and decisions about the remaining roadless areas in the Crown of the Continent Ecosystem, Montana. The goal is to assess the conservation value of 1.335 million acres of roadless areas for a suite of vulnerable fish and wildlife species using latest scientific information about their occurrence and conservation needs. Specific objectives are to: (1) determine the geographic occurrence of these species, (2) examine connectivity relative to other Wilderness/Park lands and for movement options in response to climate change, and (3) make recommendations for various levels of wildland protection. The approach involves synthesis of available spatial data into maps of conservation value for vulnerable species and a geographical narrative to draw attention to key areas.

The Wildlife Conservation Society has woven together several lines of contemporary thinking about planning for wildlife conservation into a concept called 'landscape species' (Sanderson et al. 2002, Groves 2003). It is based on the notion that species which use large, ecologically diverse areas can serve as useful 'umbrellas' or surrogates for conservation of other species. Importantly, a <u>suite</u> of species is chosen considering area requirements, heterogeneity of habitats, ecological functionality, and socioeconomic significance. For assessing the conservation value of roadless areas in the Crown of the Continent Ecosystem in Montana, I have selected the following suite of fish and wildlife species: bull trout (*Salvelinus confluentus*), westslope cutthroat trout (*Oncorhynchus clarki lewisi)*, grizzly bear (*Ursus arctos horribilis*), wolverine (*Gulo gulo*), mountain goat *(Oreamnus americanus*), and Rocky Mountain bighorn sheep (*Ovis canadensis*).

In Chapter 2, I develop profiles of these fish and wildlife species that provide an ecological and behavioral basis for understanding why they are so vulnerable today and into the future. Next, I discuss the role of roads in their vulnerability and the role of protected wildlands in their conservation. In chapter 3, I document the types of data, sources and methods for mapping the current occurrence of each species. I describe a scoring system for ranking the relative importance of roadless areas for conservation of these vulnerable species now and in terms of future options. I outline various kinds of wildland protection including Wilderness, Backcountry, and Wildland Restoration Zones (along old intrusive roads).

To provide more detail in this assessment, I divided the Crown of the Continent Ecosystem in Montana into 4 sub-regions: (1) Rocky Mountain Front, (2) Blackfoot - Clearwater River Basin, (3) Swan River - Southern Flathead River Basin (includes the South Fork and Middle Fork of Flathead River), and (4) North Fork Flathead River - Ten Lakes area. I devote a separate chapter (Chapters 4-7) for each sub-region. In each chapter, I describe and map present occurrence of each species, and map the composite conservation score of roadless areas for all species. Finally, I recommend and map specific areas for Wilderness or Backcountry designation, as well as a few Wildland Restoration Zones. Considerable spatial information about these species and these roadless areas is captured in the series of maps.

In the closing Chapter 8, I sum up the conservation value of these roadless areas across the entire Crown of the Continent Ecosystem in Montana. I discuss the tremendous opportunity to complete the legacy of conservation in this treasured landscape. The Literature Cited includes ≈300 citations about these fish and wildlife species, climate change, and conservation. A map of the conservation values for individual species is provided in Appendix I.

2. ROLE OF PROTECTED WILDLANDS IN CONSERVATION OF VULNERABLE FISH AND WILDLIFE

Vulnerability Profiles of Selected Fish and Wildlife Species

Vulnerability refers to the susceptibility of species to disturbances of various kinds. Over millennia, species have persisted by a variety of mechanisms that buffered environmental disturbance at various spatial and temporal scales. Yet some species seem more vulnerable than others. What factors contribute to their vulnerability?

Two concepts – resistance and resilience – can guide our thinking about vulnerability. *Resistance* can be defined as the ability of individuals to remain unchanged by a disturbance (West and Salm 2003, Jen 2005). Resistance can be due to either (1) an intrinsic quality such as physiological tolerance for warmer temperatures, or (2) extrinsic factors that provide some (albeit partial) protection, such as upwelling cooling of water temperature. *Resilience* can be defined as the capacity of species to withstand disturbance and still persist (*sensu* Holling 1973, Folke et al. 2004). Species can be considered as nested hierarchies of individuals, populations, and meta-populations in which the higher levels provide context for mechanisms at lower levels. Persistence may be accomplished by 'spreading the risk' (e.g., separate small herds of bighorn sheep will be less vulnerable than a single large herd to spread of a virulent disease). Because disturbances occur at different spatial and temporal scales, no single level of organization can respond adequately to all disturbances. Hence, the nested structure increases resilience by linking the system across hierarchical levels (Pickett et al. 1989).

Following Weaver et al. (1996), I postulate a basic mechanism of resistance or resiliency at each of three hierarchical levels: individual, population, and metapopulation. At the individual level, an animal can exhibit physiological tolerance to an environmental condition or behavioral flexibility in food acquisition and selection of habitat. For example, in the face of environmental change, an individual may substitute one resource for another in its diet, thereby ameliorating flux in food availability.

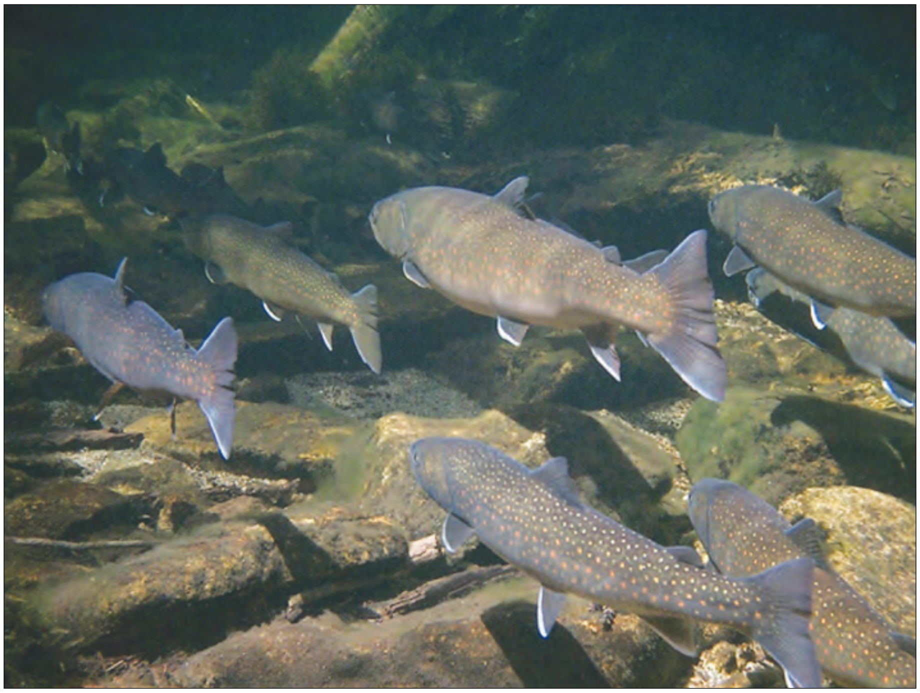
At the population level, native fish may have little resistance to invasion by non-native fish and are vulnerable to hybridization and/or competition. Some mammals compensate for excessive mortality with increased reproduction and/or survivorship, thereby mitigating demographic fluctuations. High survivorship and longevity of adult females typically is critical to the continued well-being of many mammal populations.

At the metapopulation level, dispersal enables animals to augment an existing population or re-colonize an area where a population has been extirpated. Dispersal usually refers to movements by juvenile animals when leaving their natal range after reaching the age of independence (adults occasionally disperse, too). Dispersal is successful only if the individual survives, establishes a home range, finds a mate and reproduces. In landscapes fragmented by human disturbance, successful dispersal is the mechanism by which vanishing local populations are rescued from extirpation and functional connectivity of metapopulations is established (Gilpin and Hanski 1991).

In reference to human disturbance, behavioral flexibility and physiological tolerance address the problem of loss or change in habitat conditions. Capacity for greater productivity enables populations to compensate for overexploitation or to come through a genetic 'bottleneck' more quickly. Dispersal addresses the problem of habitat fragmentation at a landscape scale. Resistance and resiliency, however, have definite limits. As human activities accelerate rates of disturbance across a greater extent of the landscape, the combination of rapid change and simplification can undermine the evolved resistance and resiliency mechanisms of species and render their populations more fragile. Cumulative effects can accrue that threaten their persistence. **One of the key messages of resilience thinking is to *keep future options open through an emphasis on ecological variability across space and time***, rather than a focus on maximizing production over a short time (Walker and Salt 2006).

In this section, I use the concepts of resistance and resilience to assess vulnerability for 6 species of native fish and wildlife. For each of the selected species, I have examined the latest information about its behavior and ecology to sketch a vulnerability profile (with data from the Rocky Mountains as available). Each profile addresses the following factors: (1) niche flexibility, (2) reproductive resistance or reproductive compensation, (3) dispersal, (4) response to human disturbance, and (5) sensitivity to climate change.

Bull Trout



US Fish and Wildlife Service

Populations of bull trout have declined throughout much of their native range (Rieman et al. 1997, USFWS 2002). Currently, the species is federally listed as 'threatened' under the Endangered Species Act and critical habitat has been designated (USFWS 2010). Declines have been attributed to habitat degradation and fragmentation (Fraley and Shepard 1989, Rieman et al. 1997, Baxter et al. 1999) and interactions with non-native salmonids (Kitano et al. 1994, Martinez et al. 2009).

Niche Flexibility: Bull trout have low physiological tolerance for warm water (Selong et al. 2001). Warm but sub-lethal temperatures can alter metabolism, growth, and competitive interactions for cold-water trout, whereas high water temperature can cause direct mortality. Thermal protection standards are typically based on a combination of optimum growth and survival (upper temperature tolerance). Laboratory studies suggest that peak growth in bull trout occurs between 10°-15° C (52°- 60° F), whereas the upper lethal temperature is about 21° C (70° F) (Selong et al. 2001). Across the range of bull trout in northwestern United States, small bull trout (indicative of spawning and rearing habitat) occur mostly in streams where the maximum daily temperature during late July – September is <12° C (<54° F) (Dunham et al. 2003). In the Flathead River system, bull trout migrate up to 250 km upriver from Flathead Lake to spawn in tributaries when water temperatures fall below 9° C (48° F) (Fraley and Shepard 1989). Bull trout select stream reaches for spawning where upwelling of ground water provides cooler and well-oxygenated conditions (Baxter and Hauer 2000, USFWS 2010). Groundwater sources provide cold-water refugia for fish in summer and warm-water refugia in winter (Meisner et al. 1988). In addition, warm groundwater and beaver ponds inhibit formation of anchor ice in winter, which otherwise would cause high mortality as young trout emerge (Jakober et al. 1998).

Resistance to Hybridization: Because fish have external fertilization, hybridization is more common in fishes than in any other vertebrate taxa (Leary et al. 1995). In undisturbed ecosystems, reproductive isolation is maintained by spatial and temporal isolation during the spawning period. Barriers to interbreeding may be lost, however, due to introduction of non-native species and exacerbated by habitat alterations. Non-native fish can also displace native fish through predation and competition.

Non-native brook trout are widely distributed across the range of bull trout (Rieman et al. 1997). Brook trout can reproduce with bull trout, thereby producing mostly sterile hybrids which reduce reproductive potential in populations (Leary et al. 1993, Kitano et al. 1994). In addition, they can depress foraging by bull trout (Nakano et al. 1998) or out-compete them for scarce resources (Gunckel et al. 2002). Brook trout can displace or push bull trout from lower elevations, with greater displacement in streams with smaller patches initially or with lower stream gradients (Rieman et al. 2006). Conversely, they may invade from higher elevation if introduced to a headwater lake (Adams et al. 2001). Brook trout are moving into higher gradient/higher elevation streams that once were considered refugia for bull trout (McMahon et al. 2007).

Competition with non-native lake trout (*Salvelinus namaycush*) in lakes is considered the most significant threat to recovery and conservation of bull trout in several areas (Martinez et al. 2009). Lake trout prey on young bull trout and can completely displace bull trout in mountain lakes due to substantial overlap in their niches (Donald and Alger 1993, Fredenberg 2000). For bull trout that spawn in the North Fork and Middle Fork Flathead River and migrate downstream to winter in Flathead Lake (Fraley and Shepard 1989), lake trout represent a significant threat to their recovery (USFWS 2002). Unfortunately, this threat has emerged for bull trout in Swan Lake watershed, too, where a population of lake trout founded by 2-3 individuals in the late 1990s has grown to approximately 7,000 lake trout by 2008 (Kalinowski et al. 2010).

Dispersal and Connectivity: Connectivity throughout a watershed is critical for bull trout for in terms of migration strategies, population persistence and genetic diversity (USFWS 2002). Bull trout express a variety of life history strategies, depending upon where they migrate after 1-3 years as juveniles in natal streams. Some bull trout remain in their natal streams (*resident*), some migrate into larger tributaries (*fluvial*), and others migrate into lakes (*adfluvials*). In the Flathead River system, bull trout migrate up to 250 km upriver from Flathead Lake to spawn in their natal tributaries (Fraley and Shepard 1989). Most bull trout populations are small in size (even smaller in terms of genetically effective size) and are connected to a larger metapopulation via low rates of dispersal among populations (Dunham and Rieman 1999, Rieman and Allendorf 2001). Bull trout exhibit high fidelity to selected spawning sites, which can be located at specific patches. Much of the genetic variation in bull trout occurs at very fine geographic scales (Spruell et al. 1999, Warnock et al. 2010, Ardren et al. In Press). In the Flathead River drainage, for example, researchers found that adjacent populations were highly isolated in terms of reproduction (Kanda and Allendorf 2001, Meeuwig et al. 2010). Hence, it's vital to maintain local populations to safeguard genetic diversity and to promote long-term persistence of bull trout (Spruell et al. 1999, Spruell et al. 2003). Accordingly, the Recovery Plan identifies 118 'bull trout core areas' for their conservation (USFWS 2010).

Ensuring connectivity in the dendritic or branching structure of stream networks, however, can be challenging for several reasons (Fagan 2002, Meeuwig et al. 2010). First, the linear distance between 2 patches at the head of 2 long streams may be short 'as the crow flies' but very far 'as the trout swims'. Secondly, isolated but nearby patches may suffer the same correlated risk to landscape disturbances such as wildfire. Conversely, in a linear feature like streams, all patches may be at risk regardless of distance when a toxic pollutant enters at the headwaters and flows downstream. Lastly, the effect of fragmentation in a dendritic stream network depends upon the position of the fracture. If it occurs at the trunk, it can affect a much more extensive network than if it happens at a higher branch. Thus, bull trout may appear especially vulnerable to increasing fragmentation of dendritic stream networks.

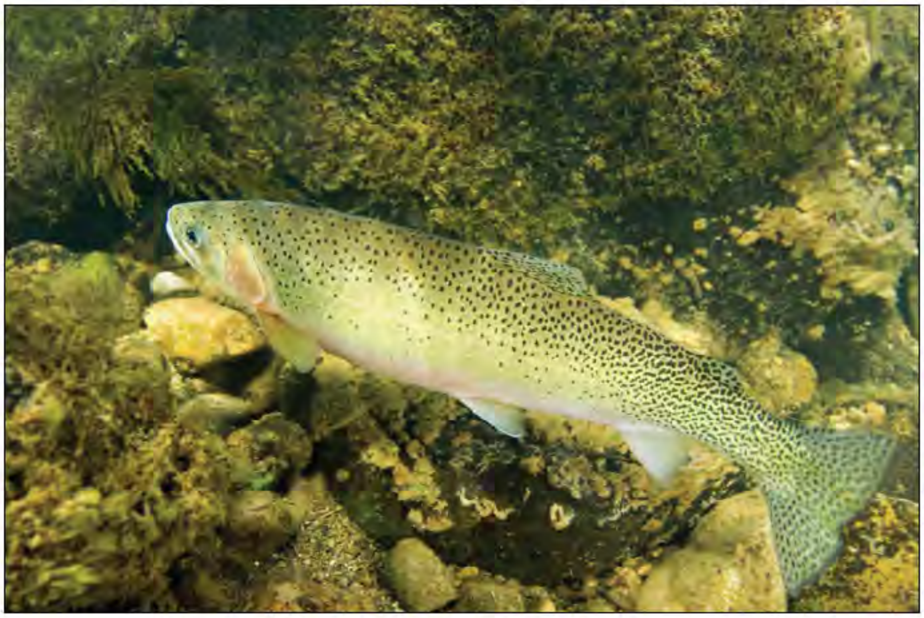
Response to Human Disturbance: Bull trout are vulnerable to a wide range of human disturbances (USFWS 2002). Dams can pose the biggest threat by blocking fish movements, resulting in genetic isolation and loss of migratory populations and altering natural flow regimes and river habitats (Muhlfeld et al. 2011). Such blockage can be detrimental to migratory populations that require diverse, connected habitats for different life stages (Swanberg 1997, Muhlfeld and Marotz 2005). (In the special case of Hungry Horse dam, however, the large reservoir supports abundant forage fish and is connected to high quality spawning and rearing habitat up the South Fork Flathead River.) Timber harvesting and associated roads/culverts can increase sedimentation into spawning streams, block access for trout, remove riparian cover and increase stream temperatures (Baxter et al. 1999, Ripley et al. 2005). Moreover, roads increase ready access for angler mortality and poachers (Long 1997), particularly in small lakes (Parker et al. 2007) and tributary streams (Swanberg 1997) where bull trout are especially vulnerable. Mining and oil and gas activities can cause massive chemical pollution of streams and major mortality of fish (Moore et al. 1991), while associated roads can increase sedimentation and provide access (Ripley et al. 2005). Major highways and railroads can increase the potential for catastrophic spill of toxic substances, too. Agricultural practices can dewater streams, increase water temperature, degrade stream banks and increase sedimentation, and disrupt migrations (USFWS 2002). Finally, purposeful stocking in the past and continued illegal releases of non-native trout have resulted in the most challenging threat to native bull trout in the Flathead River basin (USFWS 2002).

Sensitivity to Climate Change: Bull trout will likely be vulnerable to several manifestations of climate change (see Chapter 1 for fuller discussion of climate change and references). Over the past several decades in western Montana, there has been decreased snowpack and more rain-on-snow events, accelerated melting of snow and earlier runoff in spring, reduced recharge of groundwater and lower base flows, warmer stream temperatures in summer, longer periods of drought, and increased sedimentation due to more wildfires. The net result has been warmer water and lower base flows at low-mid elevations, particularly in late summer and fall when bull trout are migrating and spawning. These changes are projected to continue into the future (McWethy et al. 2010).

Warmer temperatures and drought could render the lower elevation sections thermally unsuitable for these cold-adapted fish to spawn (Pörtner and Farrell 2008, Muhlfeld et al. In Press), thereby raising the lower-elevation limit of suitable natal habitat (Rieman et al. 2007). Some of the most dramatic increases in stream temperatures could occur in areas that are burned severely by wildfire and lose the shading cover of streamside trees and shrubs (Issak et al. 2010). In addition, warmer stream temperatures could enable non-native brook trout to invade higher reaches of streams, conceivably raising the prospects of competition and hybridization (McMahon et al. 2007). The net outcome would be continued shrinkage of the cold-water niche for bull trout, thereby reducing both the size and connectivity of remaining suitable patches and eventually resulting in fewer bull trout (Rieman et al. 2007). Due to its more northerly location and higher elevation, bull trout in the Crown of the Continent Ecosystem may face lower risk than in areas further south (Rieman et al. 2007, Haak et al. 2010). Nonetheless, bull trout in some areas like the Blackfoot River or Upper Clark Fork River basins could be at higher risk from warmer, drier conditions. In addition, diminished recruitment of young bull trout entering Flathead Lake could make the bull trout population there more vulnerable to lake trout.

Conclusion: Bull trout exhibit **high vulnerability** due to low resistance and resiliency to human impacts to their environment. They have a cold-water niche – especially for spawning and rearing – and low resistance to warming water. Bull trout have low resistance to invasion by non-native trout, too. Although adult bull trout can move long distances, human fragmentation of connectivity can have acute effects on dispersal. Bull trout are vulnerable to several detrimental effects of human activities associated with roads. Finally, climate change may impact the unique thermal niche of bull trout and lead to smaller, more isolated populations that could be less viable. Protection of large, well-connected, and undisturbed (by roads) patches of habitat remains an important element in the conservation of bull trout (Dunham and Rieman 1999, Rieman and Allendorf 2001, USFWS 2002).

Westslope Cutthroat Trout



Michael Ready

Westslope cutthroat trout is one of 15 recognized subspecies of native cutthroat trout in western North America (Behnke 2002). At present, genetically pure populations of westslope cutthroat trout occupy only about 10% of their historic range (Shepard et al. 2005). This decline has been associated with introductions of non-native fish, habitat changes, and over-exploitation. In 1972, Montana Department of Fish, Wildlife and Parks (FWP) listed the westslope cutthroat trout as a State 'species of special concern', followed by a statewide Memorandum of Understanding and WCT Conservation Agreement in 1999.

Niche Flexibility: Like bull trout, westslope cutthroat trout also have low physiological tolerance for warm water. Laboratory studies suggest that optimum temperature for growth and long-term persistence in westslope cutthroat trout is about 13-15° C (55-59° F), whereas the upper lethal temperature is about 20° C (68° F) (Bear et al. 2007). Rainbow trout, a nonnative competitor and source of genetic introgression, have a greater capacity for growth at warmer temperatures and a higher upper limit of lethal temperature at 24° C (76° F) in the laboratory. In the North Fork Flathead River in Montana, non-hybridized westslope cutthroats were found in stream reaches where average summer temperatures ranged from 6.6°-11° C (44°-53° F) (Muhlfeld et al. 2009b). Brook trout, another non-native competitor, have similar optimum temperatures as westslope cutthroat trout but can tolerate a wider range of temperatures (Shepard 2010). WCT may grow faster than brook trout at their thermal optima, which would offer some resiliency to invasion within narrow thermal conditions (B. Shepard, WCS, *personal communication*).

Resistance to Hybridization: Westslope cutthroat trout have low resistance to hybridization and genetic introgression by non-native trout. Indeed, interbreeding between westslope cutthroat trout and rainbow trout and the resulting loss of genomic integrity is widely considered the greatest threat to the persistence of pure westslope cutthroat trout throughout their range (Shepard et al. 2005). Rainbow trout produce fertile offspring when crossed with cutthroat trout, resulting in genetic introgression. In early stages, populations may be comprised of admixtures of both hybrids and non-hybridized westslope cutthroats. But, in the absence of barriers, introgression often spreads until a hybrid swarm develops, and the native cutthroat genomes become extinct (Allendorf and Leary 1988).

In the Flathead River drainage in northwest Montana, genetic introgression of native westslope cutthroat trout by rainbow trout spread rapidly between 1984 and 2004 (Hitt et al. 2003, Boyer et al. 2008). The source of rainbow trout appears to have been a singular source in the lower part of the drainage (Abbott Creek), with hybridization spreading upstream (Boyer et al. 2008). The spawning periods of both rainbow trout and especially hybrids overlap with those of native westslope cutthroats (Muhlfeld et al. 2009a). Westslope cutthroat trout migrated greater distances and spawned in headwater streams, whereas rainbow trout and hybrids spawned lower in the drainage. Hybridization was more likely to occur and spread in streams with warmer temperatures at lower elevations, increased number of roads crossing streams, and closer proximity to the main source of hybridization (Muhlfeld et al. 2009b). Although the amount of introgression decreases with greater distance from the source (isolation by distance), the spread of hybridization has been facilitated both by stepping-stone invasion and by long-distance dispersal and straying of hybrids and rainbow trout (Muhlfeld et al. 2009c). Importantly, researchers have documented that as little as 20% hybridization can result in a 50% decline in reproductive success (Muhlfeld et al. 2009c). The conservation implication is that even low levels of genetic introgression may facilitate continued expansion of hybridization and place native cutthroat trout at risk, unless source populations of non-native trout are suppressed or eliminated.

Additionally, brook trout are another widespread non-native species in the western United States (Dunham et al. 2002). They have a similar niche with cutthroat trout and can displace the natives in warmer waters at most elevations (Shepard 2010). Brook trout have excluded native westslope cutthroat trout by competition from headwater streams on the east side of the Continental Divide in Montana. However, the growth and reproductive success of these native trout may suffer if confined to small, very cold headwater reaches (Coleman and Fausch 2007) and jeopardize their long-term viability (Fausch et al. 2009). Hence, barriers to prevent invasion by brook trout has become an important conservation strategy for preserving viable populations of westslope cutthroat trout (Shepard 2010).

Dispersal and Connectivity: The vulnerability of westslope cutthroat trout to genetic hybridization accentuates the trade-off dilemma between connectivity and isolation (Shepard et al. 2005, Fausch et al. 2009). Theoretically, small and isolated populations have a greater likelihood of extirpation due both to systematic and random pressures (Gilpin and Hanski 1991). Consequently, a common conservation strategy is to promote connectivity between populations to facilitate both demographic and genetic exchange. In the case of stream fish, however, such connectivity also enables competition and genetic introgression by non-native species … hence, the dilemma. Fausch et al. (2009) proposed a framework to explicitly examine the trade-offs in specific situations. Where non-native trout do not occur, fish biologists recommend that large areas of interconnected habitats should be maintained to conserve both migratory and resident life histories as well as stream and lake habitats (Shepard 2010).

Response to Human Disturbance: Westslope cutthroat trout are vulnerable to many of the same human disturbances that affect bull trout (Liknes and Graham 1988). Westslope cutthroat are considered highly vulnerable to excessive take by angling (MacPhee 1966) but respond well to catch-and-release and closure regulations (Bjornn and Johnson 1978). Timber harvesting and associated roads and culverts can increase sedimentation into spawning streams, block access for trout, remove riparian cover and increase stream temperatures. Moreover, roads increase ready access for angler mortality. Agricultural practices can de-water streams, increase water temperature, degrade stream banks and increase sedimentation, and disrupt migrations. Mining and oil and gas activities can cause massive chemical pollution of streams and major mortality of fish. The most challenging threat to pure stocks of native westslope cutthroat trout, however, has been genetic introgression by non-native trout, resulting from purposeful stocking in the past and continued illegal releases (Shepard et al. 2005). Natural barriers (waterfalls) and dams have safeguarded some westslope cutthroat trout populations from such unfortunate invasion. Fish managers throughout the American West have constructed small barriers to protect populations of native cutthroat trout from upstream invasion by non-native fish.

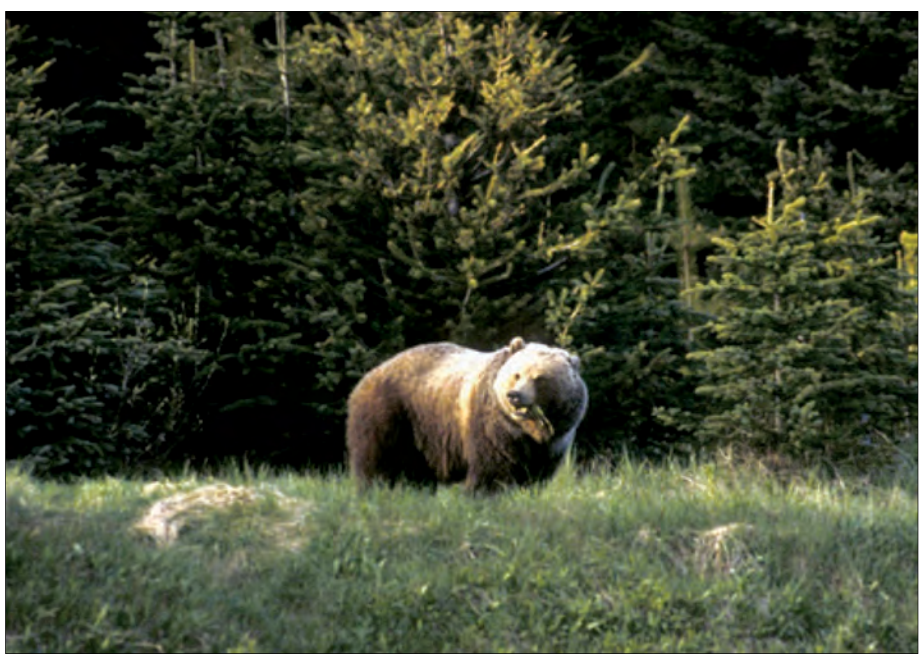
Sensitivity to Climate Change: Like bull trout, westslope cutthroat trout appear quite vulnerable to myriad effects of climate change (Williams et al. 2009, Haak et al. 2010). Climate change is projected to have major effects on the hydrologic regime, including: decreased snowpack and more rain-on-snow events, accelerated melting of snow and earlier runoff in spring, increased flooding, and reduced recharge of groundwater and lower base flows. Increased warming and evapotranspiration will result in warmer stream temperatures in summer, longer periods of drought, as well as loss of shading cover along streams and increased sedimentation due to more wildfires. The net result of such changes will be warmer water and lower stream levels at low-mid elevations, particularly in late summer.

At the more northerly and higher elevation limits of cutthroat trout distribution, a warming climate may gradually improve habitat suitability and promote greater growth and recruitment (Sloat et al. 2005, Coleman and Fausch 2007). However, these warmer stream temperatures likely will enable rainbow trout to invade even further upstream, where they will compete and hybridize with westslope cutthroat trout (Dunham et al. 2003, Rahel and Olden 2008, Fausch et al. 2009, Muhlfeld et al. 2009b). These warmer temperatures may also elevate the lower limits of suitable stream habitat for coldwater trout, thereby squeezing them between lower reaches that are too hot and upper reaches that are too small (Williams et al. 2009, Isaak et al. 2010). The net result would be continued shrinkage in habitat and population numbers, rendering them less resilient (Hilderbrand and Kershner 2000). Intense and widespread wildfires could have greater proportional impacts on these residual habitats and populations (Brown et al. 2001, Dunham et al. 2003, Haak et al. 2010).

Compared to other subspecies of cutthroat trout further south, westslope cutthroat trout populations in the Crown of the Continent region appear to be at less risk (but variable) from climate change. Haak et al. (2010) examined risk of 4 factors: increasing summer temperature, drought, wildfire, and flooding. Based upon their assessment, populations of westslope cutthroat trout at low to mid-elevations (Blackfoot River and North Fork Flathead River basins) could become more vulnerable – especially if warmer and drier scenarios develop. Remnant, isolated populations of genetically-pure westslope cutthroat trout along the Rocky Mountain Front may be at additional risk due to climate change. Stress from climate change is likely to compound existing problems with genetic introgression of non-native trout.

Conclusion: Westslope cutthroat trout exhibit **high vulnerability** due to low resistance and resiliency to human impacts. They have a cold-water niche – especially for spawning and rearing – and low resistance to warming water. Westslope cutthroat have especially low resistance to invasion by non-native trout, too. Many of the genetically-pure populations are confined to headwater streams, where they have low growth and productivity. Westslope cutthroat trout are vulnerable to several detrimental effects of human activities associated with roads. Finally, climate change may counteract the thermal advantage niche of westslope cutthroat trout and lead to further isolation of smaller populations in headwaters. Two strategies appear useful: (1) safeguarding large, well-connected networks that retain genetically-pure populations of westslope cutthroat trout, and (2) stocking streams with natural barriers with genetically-pure specimens and/or installing barriers to protect selected cutthroat populations (Rahel et al. 2008, Mosher et al. 2009).

Grizzly Bear



Milo Burcham

Niche Flexibility: Grizzly bears exhibit considerable flexibility in their foraging and habitat use over space and time (Schwartz et al. 2003). Although grizzly bears in the Crown of the Continent Ecosystem use a wide variety of foods, four main groups compose most of their diet: grasses and sedges, forbs and forb roots, berries, and mammals (including ungulates and rodents) (Craighead et al. 1982, Mace and Jonkel 1983, Aune and Kasworm 1989, McLellan and Hovey 1995). Here, grizzly bears fed on: (1) ungulates (usually carrion of winter-killed elk and moose), grasses and sedges, and hedysarum (*Hedysarum* spp.) roots in spring; (2) grasses, horsetails (*Equisetum arvense*), forbs like cow parsnip (*Heracleum lanatum*), and insects (ants, cutworm moth larvae) in summer; (3) huckleberries (*Vaccinium* spp.) and buffaloberries (*Shepherdia canadensis*) in late summer; and (4) berries, ungulates, and roots in the fall.

Although bears consume a diverse array of foods, they rely upon berries in late summer and fall for weight gain and fat deposition necessary for successful hibernation and reproduction. n the face of a shortfall in nutritious food, bears move widely in search of food – which may increase encounters with humans (Mattson et al. 1996). This substantially increases the risk of immediate human-caused mortality, management capture and translocation with problematic success (Riley et al. 1994), and food-conditioning or habituation which may lead to future problems (T. Manley and J. Jonkel, Montana FWP, *personal communication*). Diversity of foods enables switching by bears, which may contribute toward sustaining a relatively stable and high density grizzly bear population (McLellan and Hovey 1995).

Grizzly bears also appear resourceful in locating key habitats (both old and new) for such foods (R. Mace, Montana FWP, *personal communication*). Some important habitats are found in enduring landscape features such as riparian zones in river valleys and avalanche chutes on mountain slopes (Mace 1986). Other habitats such as huckleberry and buffalo berry patches occur where wildfires burned 50-70 years ago (Waller and Mace 1998, Hamer 1996, McLellan and Hovey 2001a).

Reproductive Compensation: Grizzly bears exhibit very low reproductive potential and cannot readily compensate for high mortality (see Weaver et al. 1996 for synthesis). Females produce their first litters at approximately 5-6 years of age and average 2 cubs per litter, with an average interval between litters of 3.1 years. An adult female grizzly may produce only 0.5 – 0.8 cubs per year, with most productivity occurring between 8 and 20 years. It's estimated that the average female grizzly bear may produce only 3 - 4 daughters during her full lifetime. There is no conclusive evidence of a sharp reproductive response or increased survival of young that would compensate for increased mortality (McLellan 1994, Craighead et al. 1995). Consequently, grizzly bear populations cannot absorb high mortality levels; known mortality rates from human causes should not exceed 4%, with deaths of females not to exceed 30% of that level (US Fish & Wildlife Service 1993). In particular, annual survivorship of female grizzly bears should be >92% to maintain stable populations (Eberhardt 1990), but this is a difficult and expensive metric to measure.

Dispersal and Connectivity: Dispersal by young grizzly bears appears to be a gradual process over months or even years (McLellan and Hovey 2001b). Compared to many other carnivores, young grizzlies do not seem to disperse very far from their natal range. In the trans-boundary Flathead area, the average dispersal distance was 10 km for females (longest = 20 km) and 30 km for males (longest = 67 km) (McLellan and Hovey 2001b). Sub-adult females often establish home ranges that overlap their mother's. The implication is that female grizzly bears are unlikely to colonize disjunct areas even at modest distances and that habitat fragmentation is a real conservation concern.

Response to Human Disturbance: Grizzly bears are vulnerable to human disturbance in several ways (Weaver et al. 1996). Grizzly bears tend to avoid human settlements and busy roads up to 1 km (McLellan and Shackleton 1988, Mace et al. 1996, Apps et al. 2004). Some bears may use the cover of darkness to exploit areas that are disturbed during the day (Aune and Kasworm 1989, Martin et al. 2010). Thus, human activities can alienate grizzly bears from important habitats such as low-elevation spring range. More importantly, areas of human activity can increase mortality risk from direct shooting or subsequent removal by agency personnel if bears become habituated (loss of wariness) or conditioned to human food and garbage (Mattson et al. 1996, McLellan et al. 1999, Gibeau et al. 2002, Nielsen et al. 2004). Across 13 study areas in the interior mountains of western North America, people killed 75% of 77 grizzly bears that died while radio-collared between 1975 and 1997 (McLellan et al. 1999). It was estimated that approximately half of the deaths would not have been detected without the aid of radio-collars. The risk to adult females – the most essential component of the population – can be of special concern near human access because (ironically) females with cubs sometimes use these areas to avoid *male* grizzly bears (Mattson 1990). The distribution and persistence of grizzly bears is a function of habitat quality and the level of human-caused mortality (Nielsen et al. 2010). Provision of 'security areas', where bears can meet their energetic requirements while minimizing contact with people, has emerged as a critical component of contemporary management for grizzly bears (Mace and Waller 1998, Gibeau et al. 2001, Nielsen et al. 2010).

Sensitivity to Climate Change: At a recent workshop of potential impacts of climate change on grizzly bears in the trans-boundary Rocky Mountains, the group of biologists opined that grizzly bears may be comparatively less vulnerable due to their general resourcefulness (Servheen and Cross 2010). Climate change could bring increases in some foods and new areas (wildfire could generate more berry-producing sites, more grass, and more ants over the long-term). More climate variability and extreme events such as multi-year droughts, however, could impact food resources. This could prompt bears to roam widely in search of alternative foods, thereby coming into more contact with humans. Warmer temperatures could delay snowfall in autumn and earlier arrival of spring, which could force bears to enter winter dens later in fall and emerge sooner in spring. This would place additional pressure on grizzly bears to 'fatten up' in the fall and increase potential for bear-human conflicts. The capacity of bears to exercise their resourcefulness will depend upon freedom to move across landscapes without conflict. Humans will likely scramble, however, to gain more resources (energy, water, fiber) and build more roads across more lands, which could exacerbate the likelihood of habitat loss/displacement and mortality risk to bears (Turner et al. 2010). The group noted that one climate-smart strategy would be to secure more 'protected areas' (Wilderness areas, parks, 'backcountry') that span a large range and diversity of environmental gradients (Servheen and Cross 2010).

Conclusion: Despite their resourcefulness, grizzly bears exhibit **high vulnerability** due to low demographic or population resiliency. They need secure access to quality forage in spring and fall. Bears have very low reproduction and cannot quickly compensate for excessive mortality. Young females do not disperse very far, which makes bear populations susceptible to landscape fragmentation. Altogether, this does not provide much resiliency in human-dominated landscapes.

Wolverine

Larry Master

Niche Flexibility: Wolverines are opportunistic, generalist feeders that exhibit broad regional and seasonal flexibility in their diet (Banci 1994, Copeland and Whitman 2003). Comparatively little is known about their summer diet, but they likely use a variety of foods including ground squirrels and marmots, ungulate carrion, microtines, birds, and berries (Magoun 1987). Marmots may stand out as an important prey in late spring and summer for female wolverines raising young kits (Copeland and Yates 2006, Lofroth et al. 2007, R. Inman, Wildlife Conservation Society, *personal communication*). For the remainder of the year, wolverines subsist largely on carrion and occasional kills of ungulates (moose, caribou, mountain goats, elk, and deer) (Hornocker and Hash 1981, Banci 1987, Magoun 1987, Lofroth et al. 2007). Other carnivores such as wolves may be important provisioners of carrion (Banci 1987, Van Dijk et al. 2008).Wolverines range widely in constant search of food, with large home ranges of 311 - 405 km^2 for females and 1,005 - 1,582 km^2 for males (Copeland 1996, Krebs et al. 2007).

In the western U.S., wolverines occur primarily at higher elevations in the subalpine and alpine life zones (Aubry et al. 2007, Copeland et al. 2007, Krebs et al. 2007). Several researchers have pointed out the strong concordance of wolverine occurrence and persistence of snow cover during spring (mid-April thru mid-May), which covers the end of wolverine denning period (Aubry et al. 2007, Inman et al. 2007, Copeland et al. 2010). Female wolverines dig long tunnels in the snow (and under fallen trees/large boulders in the snowpack) for birthing ('natal' dens) and early rearing of kits ('maternal' dens) and may re-use the same sites in subsequent years (Magoun and Copeland 1998, Copeland and Yates 2006). It's postulated that these snow dens provide thermal insulation and refuge from predators, which aids survival of the young (Magoun and Copeland 1998). Later in summer, females 'park' their young at 'rendezvous sites' in talus fields composed of large boulders, often in subalpine cirque basins (Magoun and Copeland 1998, Copeland and Yates 2006). Based upon 3917 radio locations of wolverines recorded from 5 study areas in Montana, Idaho, and Wyoming, about 88% of summer locations and 84% of winter locations fell within areas covered by snow during the spring period (calculated from data in Copeland et al. 2010). With their large plantigrade feet, compact body, and dense fur, wolverines are well adapted to travel and live in snowy environments, which may offer them a competitive advantage over other carnivores.

Reproductive Compensation: Wolverines have a very low reproductive rate, which may reflect the tenuous nutritional regime for this scavenger (Banci 1994). Age at first reproduction varies from 2 to 4 years of age, whereas average litter size *in utero* has varied from 2.2 to 3.5 kits (Rausch and Pearson 1972, Liskop et al. 1981, Magoun 1985, Banci and Harestad 1988). However, the number of kits observed in summer is usually 2. The proportion of adult females pregnant in a given year has ranged from 50% to 92%. Some females may not be successful for 2-3 consecutive years. The net result is low annual production, usually <1.0 offspring per adult female (Magoun 1985, Copeland 1996). Few female wolverines in the wild are likely to reproduce past the age of 8 years (Rausch and Pearson 1972). Given average parameters and assuming annual survivorship of 0.80 for adult females (Krebs et al. 2004, Squires et al. 2007), the average female wolverine may only produce two female offspring during her lifetime. Clearly, wolverines have a very low capacity to compensate for excessive mortality.

Dispersal and Connectivity: Wolverines are capable of dispersing long distances. Juvenile dispersals of 105 to 236 miles have been reported (Magoun 1985, Gardner et al. 1986, Copeland 1996, Vangen et al. 2001, Copeland and Yates 2006). More recently, a young male wolverine left Grand Teton National Park in northwest Wyoming, crossed the Red Desert and Interstate Highway 80 in southern Wyoming, and pulled up in Rocky Mountain National Park in northern Colorado – an astounding distance of 563 miles (Inman et al. 2009). Young wolverines also make extensive exploratory movements >100 miles, which usually precede actual dispersal (Vangen et al. 2001, Inman et al. 2004). Both males and females make long-distance movements, typically during their second year prior to reaching sexual maturity (Vangen et al. 2001, Dalerum et al. 2007). If the territory of a resident adult female becomes vacant, often her daughter will take over that space (Vangen et al. 2001). Using both mitochondrial DNA (maternal-only) and nuclear microsatellite DNA, researchers reported that male gene flow predominated and female gene flow was restricted at the southern portion of their range (Cegelski et al. 2006).

The genetically-effective population size (the number of individuals actually involved in breeding, in contrast to the total number of animals) for wolverines in the northern U.S. Rocky Mountains has been estimated at only 35 individuals (range 28-52) (Schwartz et al. 2009). Due to such low effective population size and the patchy, 'island-like' distribution of suitable wolverine habitat in the Rocky Mountains, maintaining landscape connectivity that facilitates demographic and genetic interchange among sub-populations will be crucial to ensuring the viability of the larger meta-population (Inman et al. 2007, Schwartz et al. 2009). Researchers have found that areas with persistent snow cover during late spring and sparse human footprint (housing density) characterize the least-cost pathways for successful gene flow among sub-populations of wolverines across the northern U.S. Rocky Mountains (Balkenhol et al. 2009, Schwartz et al. 2009). The Crown of the Continent Ecosystem comprises one of the largest contiguous blocks of occupied wolverine habitat in the western United States, with the greatest genetic diversity (Cegelski et al. 2006). With better protection for wolverines, it could provide a source of dispersers to other areas (Cegelski et al. 2003).

Response to Human Disturbance: Wolverines are vulnerable to human disturbance in several ways (Chadwick 2010). They are very susceptible to trapping at bait sites during winter, particularly in years when carrion availability is low. Trapping and hunting accounted for 35% of 62 mortalities recorded during 1972-2001 in 12 telemetry studies of wolverines across western North America (starvation accounted for 29%) (Krebs et al. 2004). Trapping accounted for 21 (88%) of 24 wolverine mortalities recorded during 1972-1977 in the South Fork of the Flathead River basin (Hornocker and Hash 1981). Researchers working in western Montana determined that stability of wolverine populations was most sensitive to adult survival (Squires et al. 2007). Numerous wolverine researchers have cautioned that trapped populations will likely decline in the absence of immigration from un-trapped populations (Krebs et al. 2004, Squires et al. 2007). Small populations in isolated mountain ranges are especially vulnerable to over-harvest. Refugia – such as Glacier National Park <u>or</u> those created by restricting/eliminating trapping quotas – appear important in the overall conservation of wolverine (Weaver et al. 1996, Krebs et al. 2007, Squires et al. 2007).

Maternal female wolverines seem sensitive to human activity near maternal dens and rendezvous sites (Magoun and Copeland 1998). With the advent of more powerful snow machines as well as heli-skiing, one concern is that such motorized access could disturb maternal females and young during the critical late winter and spring period. Major highways can have a significant impact on wolverine movements, too. In winter, wolverines avoided areas within 100 m of the Trans Canada Highway between Yoho and Banff National Parks and preferred areas >1100 m away from the highway (Austin 1998). Wolverines made repeated approaches and retreats and only crossed 3 of 6 times. Obviously, such major highways may fragment habitat and restrict movements and associated gene flow.

Sensitivity to Climate Change: Wolverines may be especially sensitive to climate change. As noted, the broad distribution of wolverines, their reproductive ecology, and travel routes associated with successful dispersal seem strongly linked to areas characterized by persistent snow cover during spring (Aubry et al. 2007, Inman et al. 2007, Schwartz et al. 2009, Copeland et al. 2010). Moreover, 90% of 1474 wolverine locations during summer in the northern U.S. Rocky Mountains occurred in areas with average maximum temperatures during August <73° F (22.8° C) (calculated from data in Copeland et al. 2010). This is consistent with the hypothesis that wolverines select cooler habitats at higher elevations during hot summer months in the southern sector of their range. Finally, climate change (warming) could impact the ecology and populations of wolverines' alpine prey such as hoary marmots (Lofroth et al. 2007) and reduce the abundance of ungulate carrion due to milder winter conditions (Wilmers and Post 2006). Some of the biggest changes wrought by global warming may be alterations to mountain snowpack (Jones et al. 2001). Recent warming has already led to substantial reductions in spring snow cover in the mountains of western North America (Mote et al. 2005). Future projections under various scenarios through the year 2040 suggest this trend will continue, notably at low to mid-elevations (Pederson et al. 2010). Some researchers estimate that the extent of persistent snow cover in spring could decrease by 23% (J. Copeland, USFS, *personal communication*). Wolverines will be quite vulnerable to such changes, with likely reductions in the size of suitable habitat patches and loss of connectivity (Peacock 2011).

Conclusion: Wolverines exhibit **high vulnerability** due to low resiliency. Although they have a broad foraging niche, their selection for reproductive habitat, summer habitat, and dispersal routes is closely linked to areas characterized by persistence of snow cover during spring. Wolverines have extremely low reproductive rates. Consequently, they cannot sustain high mortality rates, which can be exacerbated by trapping pressure – especially in areas of disjunct habitat patches. Trapping also may obviate the likelihood of successful dispersal by juvenile wolverines, which could be important to the viability of regional populations. Wolverines appear sensitive to human disturbance near maternal sites. Due to their multi-faceted adaptation to snow environments, wolverines appear particularly vulnerable to reductions in suitable habitat as a result of projected climate change.

Mountain Goat

John Weaver

Niche Flexibility: Mountain goats have broad flexibility in their diet (Brandborg 1950, Côté and Festa-Bianchet 2003). They will feed on grasses, sedges, lichens, herbs, mountain shrubs, and conifer needles – sometimes, all on the same cliff. Indeed, they are masters of the opportunistic foraging microniche (Chadwick 1983). In contrast, mountain goats have very narrow habitat preferences based upon topography (Gross et al. 2002, Poole et al. 2009). Simply put, they select cliff faces – the steeper, the better because steep cliffs shed snow that buries the rest of the high country (Chadwick 1983). Most of the time, mountain goats are found on or within 750 feet of cliffs that serve as escape terrain (Gross et al. 2002), and females typically stay within 250 feet of escape terrain (Hamel and Côté 2007). Thus, the broad foraging niche of mountain goats may have evolved to compensate for their narrow habitat niche among the cliffs (Geist 1971). Due to their strong affinity and perhaps physiological dependence on mineral licks during late spring-summer, goats may travel several miles even through forests to visit such sites (Poole et al. 2010). In areas with dry, shallow snow conditions, mountain goats may winter on the same mountain top where they spent the summer, too. In other areas with deep moist snow, goats may move to bands of cliffs at lower elevations (Chadwick 1983, Rice 2008, Poole et al. 2009).

Reproductive Compensation: Compared to other ungulates, native populations of mountain goats have very low reproductive potential (Côté and Festa-Bianchet 2003). Young goats grow more slowly than juvenile bighorn sheep and do not reach age of first reproduction until 4 or 5 years, or even older (Festa-Bianchet and Côté 2008). Prime reproductive age for female mountain goats is from 8 to 12 years of age. A nanny typically carries only a single kid, but up to a 1/3 of adult females (>3 years old) may not produce offspring in a given year. These parameters may improve initially for females in *introduced* populations (Swenson 1985). The longer a female goat lives, the more offspring she is likely to produce. Hence, longevity of female mountain goats is paramount to their lifetime reproductive success (Festa-Bianchet and Côté 2008). Consequently, native populations of mountain goats have extremely limited capacity to compensate for excessive mortality. The history of mountain goat populations harvested by hunters is strewn with case studies of excessive kill rates, often facilitated by new road access (Chadwick 1983, Côté et al. 2001, Hamel et al. 2006 and references therein). Fortunately, many wildlife managers in Montana have embraced this realization and reduced harvest quotas for mountain goats.

Dispersal and Connectivity: Young mountain goats appear to disperse more commonly and further distance than bighorn sheep (Stevens 1983, Festa-Bianchet and Côté 2008). In the population of goats introduced to the Olympic National Park, young individuals of both genders (but mostly 2-3 year-old males) dispersed an average of 25 miles (maximum >60 miles). Thus, goats appear to have moderate capacity for re-colonization through dispersal.

Response to Human Disturbance: Mountain goats appear particularly sensitive to disturbance from certain human activities (Côté and Festa-Bianchet 2003). Several studies have documented behavioral responses of goats to helicopters ranging from short movements (<100 m) and brief bouts of nervous activity to panicked goats running at full speed over precipitous terrain resulting in at least 1 case of a broken leg (Côté 1996, Goldstein et al. 2005). The closer the helicopter, the stronger the behavioral reaction by goats. It does not appear that mountain goats habituate over time to helicopter activity. Goats likely would be vulnerable to disturbance to a variety of helicopter-supported activities: including backcountry skiing, fishing, biking and hiking, sightseeing, exploration for minerals/oil and gas, and wildlife research. Consequences of helicopter harassment could include abandonment of critical habitat, which could result in a decline in local goat populations (Festa-Bianchet and Côté 2008). Researchers have recommended no-fly buffer zones ranging in size from 0.6 mile (Goldstein et al. 2005) to 1.25 miles (Foster and Rahs 1983, Côté 1996). Of course, mountain goats likely are susceptible to land-based industrial activities in alpine areas or on winter range such as seismic exploration and mountain-top removal mining of coal.

Sensitivity to Climate Change: Vulnerability of mountain goats to climate change is not well understood at present (Festa-Bianchet and Côté 2008). Conceivably, warmer daytime temperatures and more intense solar radiation in the alpine during summer could force a reduction in foraging time for mountain goats, whose tolerance for heat does not seem high. Researchers have documented such heat discomfort and reduced feeding time for male Alpine ibex in the mountains of Italy (Grignolio et al. 2004, Aublet et al. 2009). Adequate foraging in summer is important for female ungulates that must bear and nurse young and acquire good body condition to survive the following winter. On the other hand, warmer winters with less snow could result in milder conditions for goats during that season. In wintering sites where deep, moist snow is more common, rain-on-snow events could create crusted snow conditions. This would be especially tough on young goats that have not reached full body size and cannot paw as well as adults (Chadwick 1983). For these mountain-top denizens, perhaps the best conservation strategy for now is to provide stress-free security on a variety of cliff aspects where they can move in response to changing conditions.

Conclusion: Mountain goats exhibit **high vulnerability**. They are constrained to live on or very near cliffs that provide escape terrain from predators and more accessible forage in winter. Female goats have very low reproduction and cannot quickly compensate for excessive mortality (notably hunting). Goats, particularly males, do disperse modest distances which may provide connectivity among some populations. Mountain goats are especially sensitive to motorized disturbance. In terms of climate-smart conservation strategies, maintaining secure access to a variety of aspects among cliffs could provide options.

Rocky Mountain Bighorn Sheep

John Weaver

Niche Flexibility: Rocky Mountain bighorn sheep have relatively low flexibility in their foraging niche (Geist 1971). Along the Rocky Mountain Front, bighorn sheep feed primarily on grasses (especially bunchgrasses and fescues), though they will occasionally consume palatable forbs and shrubs (Schallenberger 1966, Erickson 1972, Frisina 1974, Andryk 1983). During the short summer season, bighorn sheep range in the open, high country (6000-9000 feet elevation). Due to their strong affinity and perhaps physiological dependence on mineral licks during late spring-summer, sheep may travel several miles (even through forests) to visit such sites (Geist 1971). During the longer winter season (8 months), bighorn sheep along the Rocky Mountain Front find available food plants in the bunchgrass, rocky reef, and old burn habitats predominantly along south-facing slopes at lower elevations (range 4000-7000 feet). Fire suppression can result in encroachment of open slopes by dense stands of conifers, which compromises the size and quality of these habitat patches (Schirokauer 1996). Deep snow can hinder movements of bighorn sheep (especially ewes and lambs) and their access to grass forage, particularly if snowfall lasts for several days and/or becomes hard crusted (Geist 1971). Thus, in winter, sheep usually select sites where deep snow does not accumulate due to low elevation, south exposure, and/or wind. Moreover, bighorn sheep usually occur within 400-500 feet of rocky terrain and cliffs (Erickson 1972) that provide escape habitat (defined as slopes > 27°) from terrestrial predators. Cliffs also provide available forage when snow events preclude use of other sites. This close interspersion of rocky terrain/cliffs with south-facing grassy slopes delimits suitable habitat during winter for Rocky Mountain bighorn sheep (Dicus 2002). Consequently, sheep also have low flexibility in their selection of habitat.

Reproductive Compensation: Compared to other ungulates, Rocky Mountain bighorn sheep have low reproductive potential. A ewe does not reach reproductive age until 3 years and typically carries only a single lamb each year thereafter (Geist 1971). Early survival of lambs can vary substantially, depending upon maternal nutrition and spring weather. Adult survivorship is usually high between ages 2 and 8 years. Bighorn sheep are notoriously susceptible, however, to virulent outbreaks of disease that can decimate a herd rather quickly (see Bunch et al. 1999). Bighorn sheep populations recover slowly from such reductions, depending upon the quality of the range. Hence, bighorn sheep exhibit low resistance to disease and possess low capacity to compensate for excessive mortality.

Dispersal and Connectivity: Bighorn sheep find their niche in patches of montane and alpine grassland that remain stable through time. In undisturbed situations, most suitable patches are already occupied by sheep. Dispersing into unknown areas where there is a low likelihood of finding suitable habitat would not be a good strategy. Instead, juveniles inherit home ranges from adults and pass them on as a living tradition to their offspring (Geist 1971). Male bighorns occasionally move upwards of 20-30 miles between herds, which could maintain some genetic connectivity (Geist 1971, DeCesare and Pletscher 2006). Nonetheless, bighorn sheep have been perceived as poor dispersers with low potential for natural re-colonization of distant, vacant habitat (Shackleton et al. 1999).

Response to Human Disturbance: Bighorn sheep appear less sensitive to disturbance from human activities compared to mountain goats (Geist 1971, Shackleton et al. 1999). For example, sheep tolerate industrial activities and readily use open-pit coal mines that have been re-claimed (McCallum and Geist 1992). Sheep also seem to habituate to predictable, repeated activities including highway traffic and even helicopter overflights beyond 0.25 miles (MacArthur et al. 1982, Stockwell et al. 1991). On the other hand, vehicle traffic and human activity impacted use of a nearby mineral lick by bighorn sheep (Keller and Bender 2007). Additionally, bighorn sheep do react negatively to approaching humans on foot, especially when accompanied by a dog (MacArthur et al. 1982). Chronic disturbances at critical sites (i.e., mineral licks) and/or of sensitive groups (ewes and lambs) could compromise the health and productivity of bighorn sheep populations.

Sensitivity to Climate Change: Potential effects of climate change on Rocky Mountain bighorn sheep are not clear at present (K. Keating, USGS, *personal communication*). Conceivably, with warmer temperature in the subalpine/alpine realm, conifer trees could encroach upon meadows and reduce some foraging opportunity in summer. But, the winter season is widely considered to be the most challenging for bighorn sheep survival (Shackleton et al. 1999, Montana FWP 2009). Warmer winters with less snow could result in milder conditions and more expansive range for bighorn sheep. Following periods of deep snowfall, however, rain-on-snow events could create a hard-crusted snow that would reduce access to ground forage. Perhaps the best conservation strategy for now is to provide stress-free security along an elevation gradient of south-facing slopes interspersed with cliffs. This would allow bighorn sheep options for moving in response to changing conditions.

Conclusion: Bighorn sheep exhibit **moderate vulnerability**. They have a narrow feeding niche on grasses and are constrained to live on or near cliffs for escape terrain. Female sheep have low to moderate reproduction, but wild sheep are highly susceptible to outbreaks of disease (some carried by domestic sheep) that can decimate a herd quickly. Because Rocky Mountain bighorn sheep have strong fidelity to chosen sites, they do not disperse very readily and have a low capacity for re-colonizing vacant habitats. Bighorn sheep seem less sensitive to motorized disturbance than goats. In terms of climate-smart conservation strategies, maintaining secure access to cliffs and rocky terrain along an elevation gradient could provide options for bighorn sheep on montane winter ranges.

Role of Protected Wildlands in Conservation of Vulnerable Fish and Wildlife

Roads can have a variety of substantial effects upon species and ecosystems (see reviews of research findings by Trombulak and Frissell 2000, Gucinski et al. 2001, Forman et al. 2003, Coffin 2007, Fahrig and Rytwinski 2009 and references therein). These authors concluded that roads and associated activities can have a negative effect on behavior and abundance of animals and ecological processes. Protected wildlands without roads have the following positive role in conservation of fish and wildlife, especially for the more vulnerable species.

- **Protected wildlands have more natural ecological functioning**. Road construction destroys soil biota, plants and slow-moving organisms within the road alignment. During the construction phase, fine sediments may be deposited in adjacent waters, which can kill aquatic organisms and impair aquatic productivity. Roads and road crossings can reroute surface water or shallow groundwater and nutrient flow, cause collapse of unstable hill slopes and formation of new gullies resulting in sedimentation, and pose barriers to movement of fish and other aquatic organisms. Such effects may show up years later and/or miles downstream. Bull trout and westslope cutthroat trout are vulnerable to these impacts. Some of these effects can be mitigated effectively by proper design and construction of roads.

- **Protected wildlands have cleaner air and water**. Many chemicals are introduced into the local environment due to road maintenance and vehicles. For example, a variety of heavy metals are deposited from gasoline additives and de-icing salts. These contaminants can pollute nearby soils, plants, and waterways. Ungulates such as mountain goats and bighorn sheep are attracted to salt applied to highways and are killed in vehicular collisions.

- **Protected wildlands are less prone to spread of invasive plants (weeds) and introduction of nonnative fish**. Road construction inevitably disturbs soils, which can stress or eliminate native plants and favor establishment of nonnative 'weeds'. Nonnative plants, spores of exotic diseases, and mollusks can 'hitchhike' on vehicles and spread to new sites. Roads into remote areas also facilitate unsanctioned introduction of nonnative fish into lakes and streams, leading to profound effects on native fish such as bull trout and westslope cutthroat trout and aquatic ecosystems.

- **Protected wildlands enable more access to habitat without disturbance**. Roads are typically built for extraction of commodity resources, which often alters habitats for variable periods of time. The loss of habitat depends upon the type and extent of the development. Some wildlife species avoid roads and associated human activity during both the extraction phase and subsequent use of open roads by people. Depending upon the type, volume of traffic, and duration of traffic, animals can be displaced from 100 m to 2 km from a road or facility. This displacement results in the loss of available habitat, which can result in less productivity in some cases. Some animals can habituate to road traffic that is predictable in space and time. Even when animals are not displaced from roadside habitats, human activity/vehicles on roads can elevate their metabolic rate and costly expenditure of energy.

- **Animals in protected wildlands have more natural behavior, with less habituation and less chance of getting accustomed to food/garbage left by people**. Habituation along roadways can result in loss of wariness for species like grizzly bears, or the animals become conditioned to receiving rewards of available food or garbage at campgrounds. This prompts managers to capture and relocate them to more remote areas (but the bears often return to the original site) or kill the animal after repeat episodes. In protected wildlands, wildlife can be wild.

- **Protected wildlands provide more security and less risk of human-caused mortality**. Collisions with vehicles along roads kill many animals every year, including large and small mammals, birds, amphibians and reptiles, and countless insects. This mortality may be nonselective in terms of age, sex, or condition of the animal. In general, mortality increases with traffic volume. New roads also open up access into remote areas, which can lead to increased mortality from poaching, incidental killing, and excessive harvest. Grizzly bears, wolverines, mountain goats, and bighorn sheep are vulnerable to the effects of new access and inadequate regulations. If excess harvest of fish remains chronic, this can give rise to public demand for artificial stocking to compensate for unsustainable harvest … at the further expense of native trout populations and ecosystem integrity.
- **Protected wildlands provide better connectivity for population and genetic exchange, and more freedom for animals to move in response to shortfall in key foods or changes in climate**. Roads may pose an impermeable barrier to some small organisms, and a partial barrier to larger species. This fragmentation can lead to smaller populations and greater isolation, which increases the risk of local extirpation. Animals also move on a daily or seasonal basis in response to severe weather events or a shortfall in key foods. As climate changes in the future, fish and wildlife will need to move to find new sites and foods for sustaining their ecological needs. Because the exact location of new habitats will be difficult to predict, animals will need room to roam in their search. Better connectivity benefits many species in most circumstances.
- **At the larger scale of landscapes, protected wildlands provide a safety net or refuge from the cumulative effects of industrial activities**. A single road arguably may have little detrimental effect upon fish and wildlife populations. But the cumulative impacts of a spidery network of many roads can result in substantial and cascading effects upon animal populations and ecological processes.

In conclusion, protected wildlands have a vital role to play in the conservation of vulnerable fish and wildlife. Construction of roads into new country results in a complex of detrimental co-effects upon fish and wildlife and ecosystems, not just a single kind of effect. Some of the detrimental effects of roads can be mitigated with proper design and management (such as permanent or seasonal closure), and some effects (such as mortality of food-conditioned bears) can happen at backcountry sites, too. Yet – in the big picture – vulnerable populations of fish and wildlife will have a better chance to prosper and persist in large roadless areas. Hence, as a greater proportion of the natural landscape continues to be modified by human infrastructure and activities, protected wildlands become even more critical and valuable.

3. METHODS FOR ASSESSING CONSERVATION VALUES OF ROADLESS AREAS

Occurrence of Vulnerable Fish and Wildlife Species

As a first step in assessing the conservation value of roadless areas, I compiled and synthesized the latest available spatial information for the selected fish and wildlife species in Arc GIS 9.3 to produce maps of their present occurrence. The one exception was the wolverine for which I applied a model of habitat suitability to map their likely occurrence. Of course, the utility of occurrence maps depends upon the extent of available records. Fortunately, a considerable amount of information has been collected on the occurrence of most of these vulnerable species across the Crown of the Continent Ecosystem in Montana – often encompassing several years to even decades. (Inevitably, there was some variation in the quality and quantity of available data within and between species.) To the extent that available data spans long periods of varying environmental conditions, maps of occurrence integrate much information about which areas *sustain* these vulnerable species. Moreover, maps of present occurrence depict the areas from which species will respond to climate change. Here, I present details on the type and sources of available information for each species. With the preceding vulnerability profiles as context, I describe a system for scoring and ranking the conservation value of roadless areas for vulnerable fish and wildlife species.

Bull Trout

The U.S. Fish and Wildlife Service designated critical habitat for bull trout on October 18, 2010 (USFWS 2010). Critical habitat included (1) occupied streams where spawning and rearing occurred or migratory connections existed, and (2) downstream lakes and reservoirs where bull trout foraged and overwintered. For occurrence of bull trout in this report, I used the map of critical habitat designated by U.S. Fish and Wildlife Service. Abundant populations of bull trout also occupy a few streams not designated as critical habitat because, for example, spawning had not been documented there.

Westslope Cutthroat Trout

In Montana, westslope cutthroat trout occupy the upper Missouri River drainages east of the Continental Divide and the upper Columbia River drainages west of the divide. At present, genetically-pure populations of WCT occupy about 8-10% of entire historic range and <3% of its historic range in Montana, mainly confined to headwater streams (Shepard et al. 2005). For this report, I used information in the most recent update (2009) of the multi-state assessment on the status and conservation needs of westslope cutthroat trout (Shepard et al. 2005). I distinguished two levels of 'conservation populations' of westslope cutthroat trout: (1) ***Core** Conservation Populations* = >99% genetic purity and (2) *Conservation Population* = 90%-99% genetic purity. I also differentiated streams where genetic integrity had been tested from those where genetic integrity had been assumed (mostly within Wilderness areas).

Grizzly Bear

In 2004, interagency biologists conducted the first-ever systematic survey of grizzly bear density across their occupied range in the Crown of the Continent Ecosystem of Montana (a.k.a. 'Northern Continental Divide Ecosystem') (Kendall et al. 2009). Field personnel established 2,558 scent stations in 641 'cells' (cell size = 49 km^2) across a 31,410-km^2 grid. Although this effort was exemplary in terms of design and analysis, the vagaries of sampling resulted in no detection of grizzlies in numerous areas – even though grizzly bears were known to occur there. Some of these cells with no grizzly bears detected had neighboring cells with up to 12 individual grizzlies recorded.

To derive a map that depicted the distribution of *relative* grizzly bear density, I carried out the following steps. Montana FWP provided a raster map (cell size = 25 km^2) of recent grizzly occurrence across the NCDE that was based on >162,000 grizzly bear locations recorded during the past 10 years (R. Mace, Montana FWP, *unpublished data*). Visual inspection of the underlying data revealed that many of these coarse grid cells had locations distributed throughout the cell. Nearly all cells in the NCDE grizzly bear density grid were occupied. For all <u>occupied</u> cells with no grizzly bears detected in the 2004 survey, I assumed a minimum number of 1 bear. For those few cells without recent records of grizzly occupancy, I assumed 0 bear. Next, I used a fixed-kernel estimator in Hawth's Analysis Tools© with a LSCV smoothing factor (10,000) to estimate the relative density across the landscape (Beyer 2004). I used a 'natural breaks' algorithm in Arc GIS 9.3 to re-classify the map into 3 classes of relative density. Although the resulting map was not always satisfactory at fine scale, I believe that it provides a better picture of relative density across the Crown of the Continent Ecosystem.

In addition, I examined plotted locations of grizzly bears from earlier studies along the Rocky Mountain Front (Aune and Kasworm 1989), the Swan Range (Waller and Mace 1998), and Glacier Park-North Fork Flathead (Kendall et al. 2008). Finally, I interviewed regional grizzly bear biologists with Montana FWP for their local knowledge and perspective based upon many years in the field.

Wolverine

To map likely occurrence of wolverine across the Crown of the Continent Ecosystem in Montana, I relied on a model developed by Robert Inman with the Wildlife Conservation Society that delineates suitable habitat for adult wolverines across the western United States (Brock et al. 2007, updated Inman 2010). Based upon results from a long-term field study of wolverines in the Greater Yellowstone Ecosystem (Inman et al. 2007) and information in the literature, the 'Inman' model addresses 5 key aspects of wolverine ecology: food, competition, escape cover for young wolverines, dispersal, and human disturbance.

To delineate primary habitat used by resident adult wolverines, the researchers used logistic regression to compare habitat characteristics associated with 2,257 telemetry locations collected from 18 resident wolverines (12F, 6 M) with those of random locations. They also analyzed habitat characteristics for 31 natal den and rendezvous sites to identify maternal habitat used by female wolverines with young kits. Their final model included 2 snow variables (April 1 snow depth, distance to snow on April 1), 3 topographic variables (latitude-adjusted elevation, terrain ruggedness index, distance to high-elevation talus), 1 vegetation variable (distance to treecover), and 2 human variables (human population density, road density). To evaluate the model, researchers used 3 independent datasets: 1575 other locations of wolverine from the GYE, 321 wolverine mortality records in Montana, and 31 historical records of wolverine in Utah. The model performed well against the independent datasets (see Brock et al. 2007 and Inman 2010 for further details). In addition, Howard Hash kindly provided original records from the pioneering field study of wolverines that he conducted with Maurice Hornocker in the late 1970s in the South Fork of the Flathead River basin (Hornocker and Hash 1981).

Mountain Goat

To map occurrence of mountain goats, I compiled data from a number of original sources. For areas along the Rocky Mountain Front, I used maps of general goat range and maternal goat range (nannys and kids during summer) developed by Joslin (1986) based upon 8,290 observations that she compiled. For the Badger-Two Medicine area down to Teton River, I mapped 369 locations (1234 goats) recorded during 15 years of aerial surveys (1990-2008) (kindly provided by G. Olson, Montana FWP, *unpublished data*). Also, I mapped records of 428 goats observed during aerial surveys July 1994-2008, mostly along the Continental Divide (kindly provided by B. Lonner, Montana FWP, *unpublished data*). For occurrence of mountain goats west of the Continental Divide, I mapped locations of 1,282 records from 1980-2009 (kindly provided by J. Vore and E. Wenum, Montana FWP, *unpublished data*). I plotted additional locations of mountain goats in the upper Blackfoot River basin (kindly provided by J. Kolbe, Montana FWP, *unpublished data*), as well as locations of goats trans-located to the Red Mountain area (B. Henderson, Montana FWP, *unpublished data*).

During the late 1940s, MT FWP biologists carried out field surveys to map general distribution of mountain goats on Forest Service lands across the Crown of the Continent Ecosystem (Casebeer et al. 1950). Because mountain goats typically exhibit fidelity to selected ranges, this map provided a useful baseline reference.

Rocky Mountain Bighorn Sheep

I mapped seasonal ranges of bighorn sheep along the Rocky Mountain Front based upon maps in several theses (Schallenberger 1966, Erickson 1972, Frisina 1974, Andryk 1983, Schirokauer 1996) and the Ten Lakes area east of Eureka, Montana (Johnson 1993). In addition, local biologists updated and vetted these maps (B. Lonner, G. Olson, and T. Thier, Montana FWP, *personal communication*).

Scoring System for Ranking Conservation Values of Roadless Areas

To assess the relative importance of roadless areas across the Crown of the Continent Ecosystem, I developed a scoring system to quantify the conservation values for vulnerable fish and wildlife species. The scoring system comprised 3 relative ranks: *Moderate* Importance = score of 1; *High* Importance = score of 2; and *Very High* Importance = score of 3. The scoring system started with Moderate Importance (rather than Low Importance) for two reasons: (1) the Crown of the Continent Ecosystem is one of the most ecologically intact and important areas for native fish and wildlife in the lower 48 states, and (2) each of the vulnerable species has national importance due to federal listing (e.g., bull trout, grizzly bear), listing warranted (e.g., wolverine), and/or iconic prominence (mountain goat, bighorn sheep).

I customized the scoring criteria for each vulnerable species to reflect attributes that are important to the long-term persistence of that species (Table 1) (see below for further details). The moderate and high scores addressed current key conditions. The very high score typically included considerations of likely effects of climate change, with the intention of providing some future options for that species.

Bull Trout

The primary challenge in conservation of bull trout is to maintain viable populations with genetic integrity in suitable aquatic habitats that are cold, complex, and connected (USFWS 2002). In October 2010, the U.S. Fish and Wildlife Service designated critical habitat for bull trout in the northwest United States (USFWS 2010). A few streams with abundant populations of bull trout were not designated. Critical habitat designations included lakes, main stems of rivers, and tributaries to capture all the various life history stages and full range of migration/resident strategies. As climate change unfolds, however, waters at lower elevations may become too warm for bull trout, especially for spawning and rearing (Rieman et al. 2007, Isaak et al. 2010). Tributaries may provide important future options (refugia) due to higher elevation and the input of cooler groundwater.

Accordingly, I assigned the following importance scores for bull trout:

Moderate = Non-critical habitat but abundant population
High = Critical Habitat
Very High = Critical Habitat (tributaries)

Table 1. Scoring system for ranking relative value of roadless areas for conservation of vulnerable fish and wildlife species, Crown of the Continent Ecosystem, Montana.

Species	Importance	Criterion	Score
Bull Trout	Very High	Critical Habitat – higher elevation tributaries	3
	High	Critical Habitat	2
	Moderate	Other streams with abundant populations	1
Westslope Cutthroat Trout	Very High	Persistence of genetic purity at watershed scale	3
	High	>99 % genetic purity	2
	Moderate	>90 % but <99% genetic purity	1
Grizzly Bear	Very High	High Density + High Security	3
	High	High Density + Moderate Security	2
	Moderate	Low Density + Varying Security	1
Wolverine	Very High	Maternal Habitat	3
	High	Future Primary Habitat	2
	Moderate	Primary Habitat	1
Mountain Goat	Very High	Traditional Maternal Range	3
	High	Maternal Range	2
	Moderate	Occasional Occurrence	1
Bighorn Sheep	Very High	Current Winter Range	3
	High	Winter Range – Future Options	2
	Moderate	Summer Range	1
Range-of-Elevation	Very High	High Range-of-Elevation	3
	High	Moderate Range-of-Elevation	2
	Moderate	Low Range-of-Elevation	1
Maximum Possible Score			**21**

Westslope Cutthroat Trout

Maintaining genetic integrity of westslope cutthroat trout in suitable cold-water habitat is widely considered to be a primary challenge in their conservation (Shepard et al. 2005).The status assessment of westslope cutthroat trout designated populations with ≤10% genetic introgression as 'conservation populations' (Shepard et al. 2005). Although including hybridized populations is subject to debate, some fish managers argue that elimination of any genetically-contaminated population might result in loss of unique phenotypic, genotypic, and behavioral variations (Dowling and Childs 1992). Others have recommended that only genetically pure populations of westslope cutthroat trout should be protected because this would best safeguard their evolutionary legacy, protect local adaptations presumed important for long-term persistence, and minimize opportunity for spread of introgression (Allendorf et al. 2004). Moreover, the best prospects for conservation of pure westslope cutthroat trout most likely involve watersheds (or upper portions) where pure populations dominate or reside at considerable distance from sources of hybrids (M. Deleray, Montana FWP, *personal communication*).

Accordingly, I assigned the following importance scores for westslope cutthroat trout:

(1) Moderate = ≥90 % but <99% genetic integrity
(2) High = ≥99 % genetic integrity
(3) Very High = Persistence of ≥99 % genetic purity at watershed scale

Grizzly Bear

Over the long-term, grizzly bears have fared better in productive habitats with security from human-caused disturbance and low mortality risk (Mattson and Merrill 2002). I used various combinations of relative density and security to determine importance values. First, I buffered all forest roads by 500 m on each side to delineate a low security zone (Mace et al. 1996, Flathead National Forest 1999); all other areas were considered high security. Next, I multiplied the 3 levels of relative density by the 2 levels of habitat security. Then, I reclassified the resulting groups into 3 levels of importance for grizzly bear as follows:

(1) Moderate = Low Density + Low or High Security
Moderate Density + Low Security
(2) High = Moderate Density + High Security
High Density + Low Security
(3) Very High = High Density + High Security

Wolverine

To score importance values for wolverine, I relied upon the model developed by Robert Inman of the Wildlife Conservation Society to map and score primary and maternal habitats. Persistent snow cover during winter and spring is characteristic of both habitats but may serve different ecological functions (R. Inman, WCS, *personal communication*). Because primary habitats occur at lower elevations, they may be more susceptible to loss of snow anticipated at low to mid-elevations in future projections of climate change (see Chapter 1). To estimate future options for wolverine in response to climate change, I developed 2 different approaches. First, I assumed a warming scenario of 2.0^0 C (3.5^0 F) for the Crown of the Continent Ecosystem by the year 2050 (per McWethy et al. 2009). Using a mid-point for moist and dry adiabatic lapse rates of 3.5^0 F/ 1000 ft elevation yielded an upslope shift of 1000 feet for the projected scenario. Secondly, I assumed a projected reduction of 25% in April 1 snow depth. R. Inman kindly re-ran his wolverine model using these scenarios and parameters. The elevation adjustment seem to provide a more sensitive and reasonable change, so I used it to map primary habitat in the future. This resulted in an estimated 27% loss of primary habitat. Maternal habitat is a subset at higher elevations used by adult females for denning and rearing kits. These maternal habitats are crucial because successful reproduction by adult females is so critical for the viability of wolverine populations. Maternal habitat was above the zone affected by the climate-change scenario that extended to the year 2050.

Accordingly, I assigned the following importance scores for wolverine:

(1) Moderate = Primary Habitat
(2) High = Future Primary Habitat
(3) Very High = Maternal Habitat

Mountain Goat

Mountain goats have a narrow habitat niche centered on cliff faces that provide escape terrain and shed snow during winter. Because female mountain goats have very low reproductive rates, maternal ranges are very important to well-being of the population. Due to matrilineal traditions, goats exhibit strong fidelity to core maternal ranges, which may be revealed by periodic surveys over time.

Accordingly, I assigned the following importance scores for mountain goats:

(1) Moderate = Occasional Occurrence
(2) High = Maternal Range
(3) Very High = Traditional (Core) Maternal Range

Bighorn Sheep

Bighorn sheep have a narrow habitat niche centered on cliff faces and rocky terrain interspersed with alpine and montane grasslands. Winter ranges are widely considered the most important for bighorn sheep survival. Providing winter range along a wider range of elevation gradient of south-facing slopes could provide robust options during vagaries of climate change, but this remains more speculative at present. Traditional winter ranges are especially important because they reflect consistent use during varying winter conditions over long periods of time.

Accordingly, I assigned the following importance scores for bighorn sheep:

(1) Moderate = Summer Range
(2) High = Winter Range – Future Options
(3) Very High = Traditional Winter Range

Range-of-Elevation

A variety of species – including these vulnerable fish and mammals – will be affected by climate change. Some species will move upward in elevation while others may move down if that takes them closer to more mesic habitats. Some may track changing environmental conditions by spending more time on different aspects. Maximizing the range of ecological heterogeneity or variation is one way of providing future options for many species. Because so much of the Crown of the Continent Ecosystem in Montana is very rugged, I chose range-of-elevation within a 10-km radius of a moving 90-m^2 window as a simple metric of ecological heterogeneity.

Accordingly, I assigned the following importance scores for range-of-elevation:

(1) Moderate = Low Range-of-Elevation
(2) High = Moderate Range-of-Elevation
(3) Very High = High Range-of-Elevation

Recommendations for Wildland Protection

I devised the following set of management categories for conserving roadless wildlands in the Crown of the Continent Ecosystem, Montana: (1) Wilderness, (2) Backcountry, (3) Wildland Restoration Zone, and (4) Other Roadless (no recommended designation).

I recommend *Wilderness* designation for those roadless areas that scored high and very high composite values for the suite of vulnerable species. Ideally, these areas would become legislated Wilderness under the Wilderness Act of 1964 as either additions to existing Wilderness or a new unit in the national system.

I recommend a *Backcountry* designation for areas that scored lower (moderate) composite values for these fish and wildlife species. Backcountry is a management designation commonly used by National Forests for roadless areas to emphasize remote recreation opportunity with less strict standards than in Wilderness areas. In the context of the Crown of the Continent Ecosystem as a national treasure, protection for backcountry areas could be legislated to ensure permanent protection.

In some areas of the Crown of the Continent Ecosystem, primitive roads penetrate rather deeply into narrow mountain ranges – notably in the Swan Range and the Whitefish Range on the Flathead National Forest. Most of these roads were constructed for timber harvest back during the 1960-1970s. In recognition of the important fish and wildlife values in the Swan and Whitefish Range, the Flathead National Forest has closed several of these roads on a year-round or seasonal basis. Nonetheless, some of these roads still receive unauthorized use by ATVs and/or snowmobiles which, in some cases, may impact wildlife. I proposed a category called *Wildland Restoration Zone* where certain key roads would be de-commissioned or otherwise permanently closed and returned to more natural condition. Such restoration would increase security value of adjacent lands for vulnerable wildlife and enhance the configuration (less edge exposure to deleterious impacts) of recommended Wilderness areas.

Subsequently, these restored zones could be designated as backcountry trails for non-motorized use or added to the Wilderness system.

Finally, there are some blocks of roadless areas that are disjunct from other roadless and wilderness areas and across state highways or major roads. They scored uniformly moderate in conservation value for this suite of fish and wildlife species, too. I left their status as simply *Other Roadless* pending future management decisions based upon other criteria.

The purpose of the ranking system is to inform choices about designation of roadless areas, not to automatically render an outcome. For example, a very high composite score across all species would strongly indicate that a roadless area should be recommended for Wilderness. On the other hand, a lower composite score might suggest a 'Backcountry' designation. If a very high score for a particular species, however, was embedded in the low overall score, then that might warrant consideration for Wilderness.

Field Reconnaissance of Roadless Areas

Although synthesis of existing information was central to this assessment, I believe strongly in the value of field reconnaissance. Therefore, I spent 112 days during 2009-2010 exploring these roadless areas around the Crown of the Continent Ecosystem in Montana. I hiked and rode horseback hundreds of miles on and off trails. On many occasions, I followed trails up to existing or abandoned lookout sites; on other days, I simply headed up to the nearest high point in a roadless area. The trek upward allowed me to examine different ecological communities and conditions, including specific habitats for the focal species. From the high vantage point, I obtained a broad view of the surrounding landscape and its geographic context in terms of connectivity. This field reconnaissance provided vital on-the-ground perspective that complemented the GIS maps.

4. ROCKY MOUNTAIN FRONT

Rick and Susie Graetz

The Rocky Mountain Front marks where the Great Plains first meet the dramatic uplift of the Rocky Mountains. Reef formations from ancient sea beds frame the eastern border of the Crown of the Continent Ecosystem for 150 miles along the Front from Rogers Pass north to the Canadian border. Montanans know the Front as the place where mighty chinook winds have warmed winter temperatures from 15^0F to 50^0F in minutes and swept the foothills and plains clean of snow. Considerable physical and habitat diversity is compacted in a short distance from the grasslands westward to alpine plateaux on the Continental Divide. Here is the last place in America where one might see a grizzly bear roaming out onto the prairie as in olden times.

Ranching families, organizations like The Nature Conservancy, and the State of Montana have been working hard to conserve private lands and wildlife along the foothills of the Rocky Mountain Front. On its western flank, the Bob Marshall Wilderness and Scapegoat Wilderness protect the high mountain country near the Continental Divide. Between these landmark landscapes remain about 388,000 acres that is still roadless and unprotected in legislation. What is the conservation value of these roadless lands, especially for vulnerable species that Montanans and other people treasure?

Bull Trout

Bull trout do not occur along the east side of the Continental Divide south of Glacier National Park.

Westslope Cutthroat Trout

Westslope cutthroat trout are the native trout of the Rocky Mountain Front. Unfortunately, recent genetic sampling reveals that many of the westslope cutthroat trout populations along the Front have been hybridized by non-native rainbow trout or Yellowstone cutthroat trout (Moser et al. 2009, D. Yerks, Montana FWP, *personal communication*). Nearly all remaining streams on the Rocky Mountain Front known to sustain conservation populations of westslope cutthroat trout occur in designated wilderness or roadless areas. An active program to restore genetically pure populations is underway on the Front (Moser et al. 2009).

The most concentrated network of streams with conservation populations and potential for restoration occurs in the Badger-Two Medicine area (Figure 7). The headwaters of Badger Creek (North Badger Creek, Lee Creek, Lonesome Creek, and Muskrat Creek) and South Fork Two Medicine River (Sidney Creek) contain populations of pure westslope cutthroat trout. Populations of westslope cutthroat with minor genetic introgression occur lower down in the Two Medicine River and its tributaries. Streams identified for possible restoration of pure westslope cutthroat trout include tributaries to the South Fork Two Medicine River and upper reaches of the South Fork of Badger Creek.

Another core conservation population of pure westslope cutthroat trout occurs in the South Fork Birch Creek and its tributaries. The only other known populations of pure westslope cutthroat trout occur in the following roadless areas: South Fork Dupuyer Creek, Green Gulch Creek (tributary to South Fork Teton River), North Fork Ford Creek and Petty Creek (a tributary to Smith Creek).

Core populations of westslope cutthroat trout populations with minor genetic introgression (<10%) occur in the following roadless areas: North Fork Dupuyer Creek, North Fork Teton River and tributaries (Middle Fork Teton, South Fork Waldron Creek) and a tributary to South Fork Teton River (Rierdon Gulch Creek). South of the Sun River, only two small streams harbor relatively pure strains (Little Willow Creek and Moudess Creek). Pure strains of westslope cutthroat trout are being restored to Lange Creek, a tributary to Gibson Reservoir. Other potential sites for restoration include: South Fork Deep Creek, upper Elk Creek, and Falls Creek of the Dearborn.

Grizzly Bear

I base the following discussion of grizzly bear occurrence not only on the map of relative density of grizzly bears but also on telemetry data and field observations collected 1976-1987 (Aune and Kasworm 1989) and 1988-present (M. Madel, Montana FWP, *unpublished data*).

The Rocky Mountain Front is the last place where grizzly bears still range out onto the prairie as they did in olden times. Some of these bears den in the higher terrain of the Bob Marshall Wilderness and adjacent roadless areas, move out to the prairie in spring, then back into the roadless mountains for summer and fall. Other bears are residing longer each year along prairie stream bottoms. Grizzly bears occur throughout the Rocky Mountain Front and well out onto the prairie.

In general, the northern sector of the Rocky Mountain Front from Highway 2 south to Teton River supports a higher relative density of grizzly bears than the southern sector (Figure 8). The Badger-Two Medicine roadless area has a high relative density of grizzly bears and offers the potential for a large block of secure habitat for bears. Smaller home ranges of female grizzly bears there suggest rich, well-distributed habitat (Aune and Kasworm 1989). Home ranges for some female grizzlies overlap with Glacier National Park and the Blackfeet Indian Reservation (Waller 2005). The roadless area from Split Mountain south to Blackleaf Canyon offers the richest montane grassland (spring habitat) along the Front and sustains a concentration of adult female grizzly bears. Similarly, the grassland foothills from Blackleaf south to Choteau Mountain (including BLM lands) provide excellent spring habitat. Grizzly bears roam much of the higher, roadless country in the North and South Forks of Teton River and in both forks of Deep Creek; some locales there are notable for the concentration of grizzly bear dens. Relative density of grizzly bears, average body weight of individual bears, and reproduction by adult females are highest from Birch Creek south to the Teton River (M. Madel, Montana FWP, *unpublished data*).

Grizzly bears are comparatively sparse south of the Sun River. Nonetheless, the Elk Creek-Smith Creek area stands out as a key area (M. Madel, Montana FWP, *unpublished data*). Grizzly bears use the roadless wildlands around Renshaw Mountain-Patricks Basin-Sheep Shed Mountain, too. At the south end of the Rocky Mountain Front, Falls Creek of the Dearborn (including Cuniff Basin) is another roadless area used by grizzly bears. Bears have denned along the Continental Divide there and traveled to adjacent roadless basins at the head of the Blackfoot River.

Wolverine

Suitable habitat for wolverine encompasses ridges and basins in the subalpine zone. Primary habitat for resident adult wolverines is widespread along the Rocky Mountain Front. Maternal wolverine habitat is restricted more to the higher elevations and strongly oriented in a north-south direction due to the structure of the mountains. In general, blocks of suitable habitat for wolverine (especially maternal habitat) become less expansive and less closely connected going from north to south along the Front and from the higher mountains east to the prairie edge (Figure 9).

Roadless areas with larger, more connected blocks of wolverine habitat include: western and southern portion of the Badger-Two Medicine area, Mount Werner south to Choteau Mountain, upper reaches of the North and South Forks of the Teton River, the divide between Teton and Deep Creek drainages, and the headwaters of North and South Forks of Deep Creek. These blocks of suitable habitat taper to a peninsula north of Gibson Reservoir, bounded on the west by the montane valley of the North Fork Sun River and by the prairie on the east.

South of the Sun River, there is considerable primary habitat but maternal habitat becomes more restricted (Figure 9). The largest block of suitable wolverine habitat includes the complex of upper Patricks Basin-Allan Mountain-Renshaw Mountain-Fairview and Ford Plateaus. Another block includes the high ridge and basins south of the Benchmark Road from Patrol Mountain to Crown Mountain. Finally, the high ridge at the headwaters of the west fork of Falls Creek (Dearborn) is part of a larger complex of wolverine habitat straddling the Continental Divide.

Mountain Goat

The Rocky Mountain Front provides habitat for one of the largest native populations of mountain goats in Montana (Joslin 1986; G. Olson, Montana FWP, *unpublished data*). The heart of the goat range extends from the high peaks of the Badger-Two Medicine area south to the Deep Creek area (Figure 10). Many of these areas have been documented as maternal ranges for at least 60 years – indicating their critical importance as traditional ranges for birthing and rearing of young (Casebeer et al. 1950, Joslin 1986; G. Olson, Montana FWP, *unpublished data*). Goats occupy most of these peaks year-round.

Several roadless areas along the Rocky Mountain Front contain notable herds of mountain goats. In the Badger-Two Medicine area, a large connected complex of traditional maternal range includes: Running Owl-Goat Mountain, Curly Bear Mountain-Spotted Eagle Mountain, Scarface Mountain-Morningstar Mountain-Mount Poia, and Family Peak (G. Olson, Montana FWP, *unpublished data*).

In the Dupuyer-Blackleaf Creek area, the Wilderness boundary runs along the crest of Old Man of the Hills, Mount Frazier, and Mount Werner. Goats use cliffs on the non-Wilderness but roadless side of these peaks, too. Home ranges of female goats captured in the Blackleaf area extend from south of Choteau Mountain north to Mount Frazier and west to the headwaters of the North Fork Teton River (Thompson 1982).

The high peaks encircling the Teton River basin comprise extensive maternal range for mountain goats. On the east, goats occupy the roadless ridge running from Choteau Mountain north to the head of Jones Creek. Along the high ridge marking the Bob Marshall Wilderness boundary, goats use the cliffs on the roadless side from Mount Wright west to Teton Pass. Continuing south along this boundary ridge, goats inhabit the roadless side from Mount Lockhart south to Old Baldy, above Our Lake and on to Rocky Mountain. Further west, mountain goats remain in historic areas along or near the Continental Divide from Scapegoat Mountain north along the Chinese Wall to the headwaters of the Middle Fork of the Flathead River (Montana FWP, *unpublished data*). The ridge between Mount Wright and Switchback Pass may provide an important landscape linkage for occasional exchange between goat herds.

Twenty-five goats were trans-located to Ear Mountain west of Choteau by Montana FWP in 2008 and 2009. Subsequent monitoring found these goats scattered during summer – some slightly north of Ear Mountain, others around Chute Mountain, and some at the headwaters of South Fork Deep Creek (B. Lonner, Montana FWP, *unpublished data*).

Goat numbers appear to have declined in the roadless Deep Creek area, likely due to excessive removal for translocation elsewhere (114 goats removed 1941-1950: Picton and Lonner 2008) and excessive harvest during the 1940-1960s (Joslin 1986). Mountain goats have been slow to recover from the removal during that era. Currently, they occur sparsely along the north-south ridges between South Fork Teton River and South Fork Deep Creek. A few goats still inhabit canyon cliffs in the lower roadless sections of the North and South Forks of Deep Creek (B. Lonner, Montana FWP, *unpublished data*).

Historically, some isolated cliffs south of the Benchmark road were mapped as occupied goat range in the late 1940s (Casebeer et al. 1950), but few goats (if any) occur there at present.

Bighorn Sheep

The spectacular rocky reefs and wind-swept, montane grasslands along the Rocky Mountain Front provide idea habitat for bighorn sheep. Some of the largest herds of bighorn sheep in America occur in discrete patches of suitable habitat on the Front (Montana FWP 2009). Bighorn sheep often have traditional seasonal ranges to which they migrate during the year. Because winter can be the most challenging season for bighorn sheep, traditional winter ranges are particularly critical. Sheep winter ranges are well mapped along the foothills of the Rocky Mountain Front, with some information also on lambing habitat and summer range (Figure 11) (Schallenberger 1966, Erickson 1972, Frisina 1974, Andryk 1983).

Winter and spring range for the large Sun River herd of bighorn sheep (≈1000 animals) extends along the north side of Gibson Reservoir and Sun River from Medicine Springs east to Castle Reef. Lambing habitat (as mapped by Lewis and Clark National Forest) occurs on slopes above Arsenic Creek, Big George Gulch, Mortimer Gulch, and lower Castle Reef. Known summer ranges include the head of Cabin Creek, Grass Hill at the head of Hannan Gulch, and the north end of Castle Reef. Much of this annual range is roadless.

Another important winter and spring range includes the roadless area of the North Fork Ford Creek and Ford Plateau. Sheep there migrate northwest to spend the summer and early fall on Fairview Plateau, Red Hills, and Sheep Shed Mountain.

Other roadless areas with wintering and lambing sites favored by bighorn sheep include Lime Ridge, lower canyons of Deep Creek, Ear Mountain, Jones Creek, and Wailing Reef. Bighorn sheep spend the summer and early fall in these roadless areas: southeast corner of the Wailing Reef, Choteau Mountain north to headwaters of west and main Jones Creek, Route Creek Pass south to Rocky Mountain, Ear Mountain south to Chute Mountain, and South Fork Deep Creek (Figure 11).

Figure 7. Conservation populations of westslope cutthroat trout, Rocky Mountain Front, Crown of the Continent Ecosystem, Montana.

Figure 8. Relative density of grizzly bears, Rocky Mountain Front, Crown of the Continent Ecosystem, Montana.

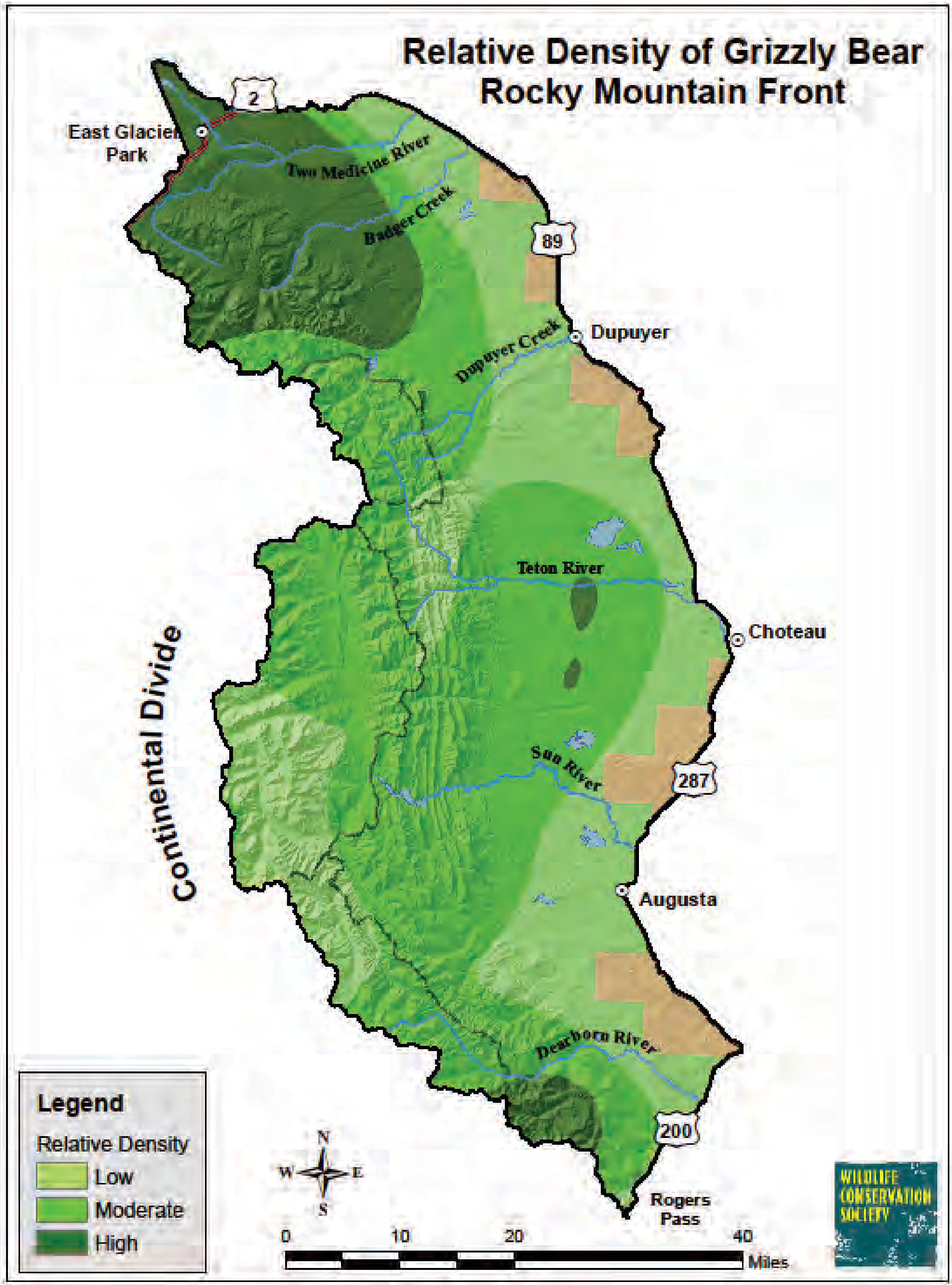


Figure 9. Primary and maternal habitat for wolverine, Rocky Mountain Front, Crown of the Continent Ecosystem, Montana.

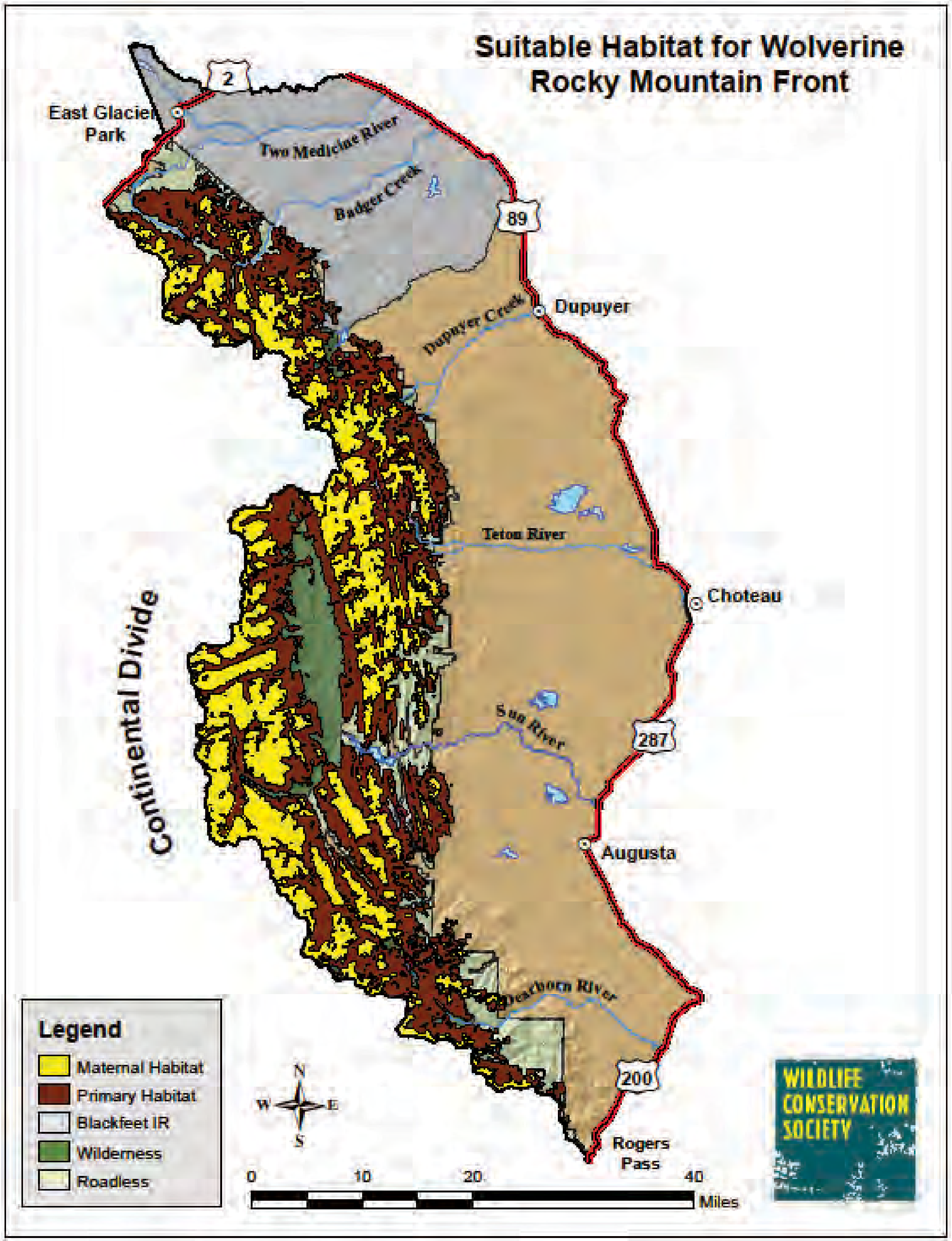


Figure 10. Ranges of mountain goat, Rocky Mountain Front, Crown of the Continent Ecosystem, Montana.

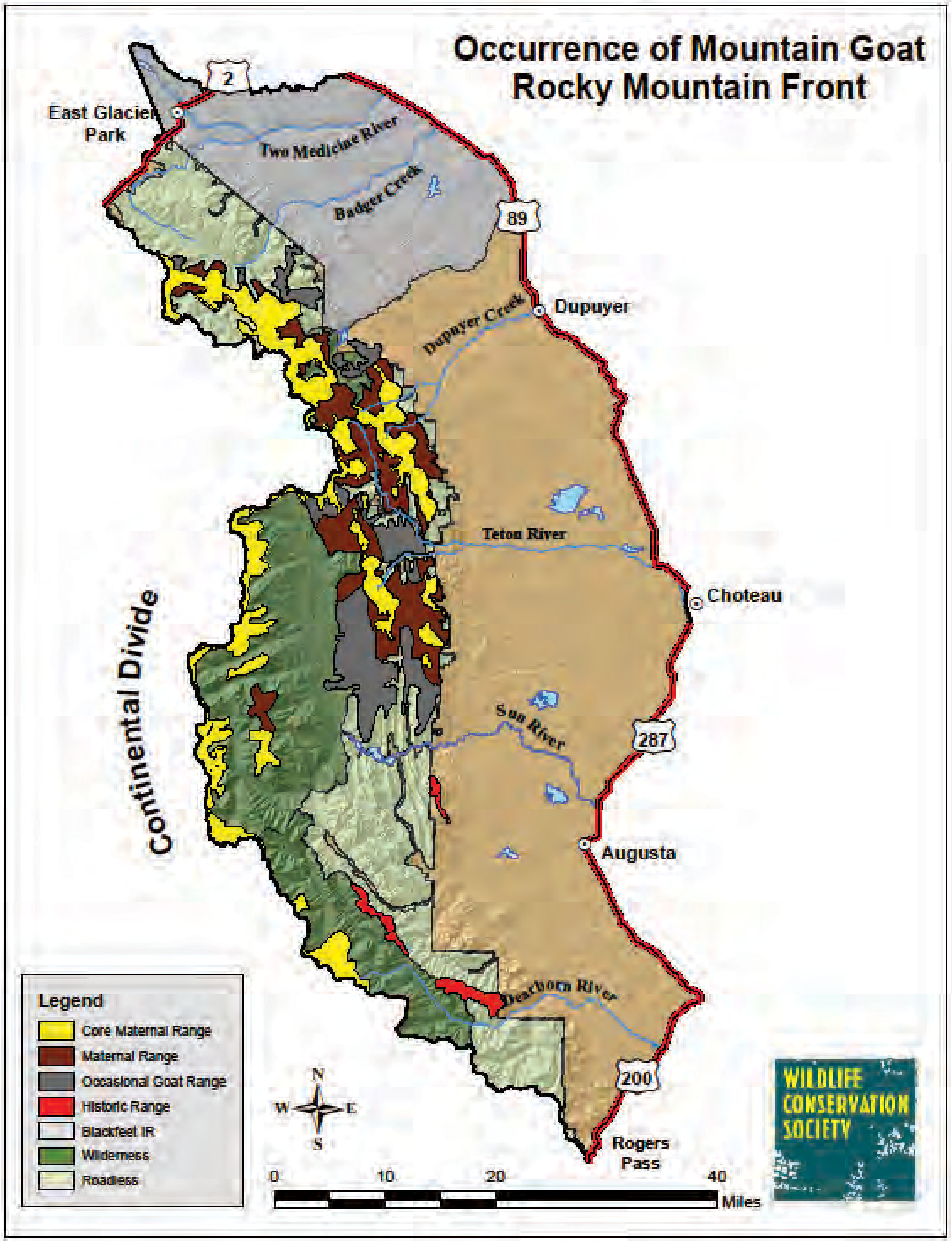
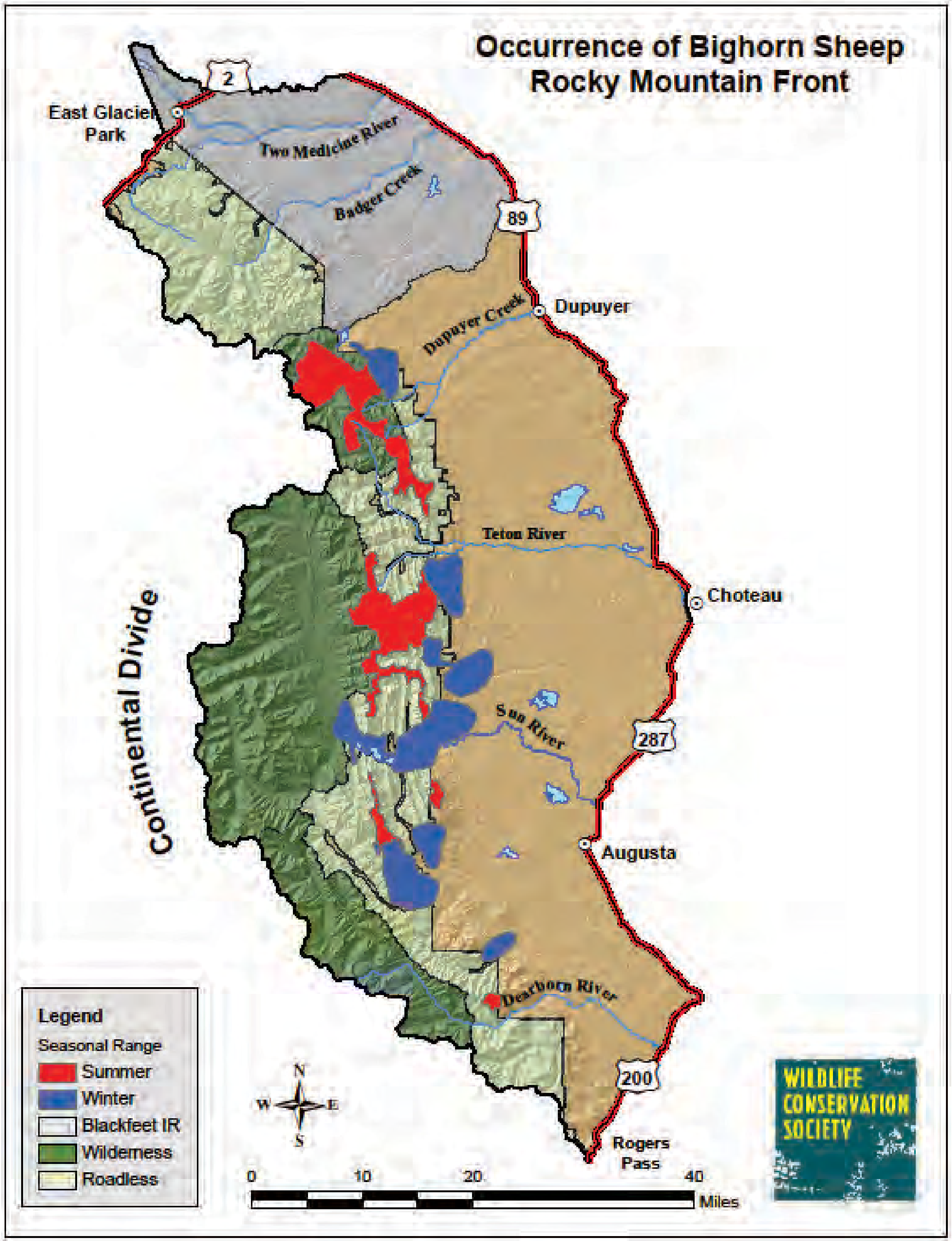


Figure 11. Seasonal ranges of bighorn sheep, Rocky Mountain Front, Crown of the Continent Ecosystem, Montana



Synthesis of Conservation Values

In this section, I synthesize pertinent information about the occurrence of vulnerable fish and wildlife species, terrain options for response to climate change, and connectivity to other important landscapes. The Lewis and Clark National Forest has developed planning documents for 2 major roadless units along the Rocky Mountain Front that comprise approximately 375,000 acres (USDA Forest Service 2007, USDA Forest Service 2009). In addition, there are 13,087 acres of adjacent BLM lands designated as 'Outstanding Natural Areas' (ONAs), where no motorized use is allowed to 'protect their wilderness character'. To provide more detail, I discuss features of several roadless units along the Front.

Badger-Two Medicine Unit

The Badger-Two Medicine comprises approximately 130,000 acres at the north end of the Rocky Mountain Front. It is bounded on the northwest by Glacier National Park, on the east by the Blackfeet Indian Reservation, and on the south by the Bob Marshall Wilderness and the Great Bear Wilderness. Approximately 5,000 acres are in private ownership – mainly at the north end near Hwy 2. Most of the Badger-Two Medicine is roadless as only a few roads penetrate the periphery of the north and east borders for access to private lands and trailheads. The determination of roadless area varies from 102,000 acres by the USDA Forest Service to about 126,000 acres by the Montana Wilderness Association. The difference occurs in the northern corner north of Two Medicine Ridge – which is un-roaded but was not recognized as roadless in the Forest Service RARE II many years ago.

- Much of the Badger-Two Medicine scored as **very high** or **high** *composite* conservation value for the five vulnerable species (Figure 12).
- The Badger-Two Medicine is the best remaining stronghold for genetically-pure westslope cutthroat trout along the Rocky Mountain Front, with several streams suitable for additional restoration as well.
- Relative density of grizzly bears and habitat security appears very high in the South Fork Two Medicine drainage and high in the upper reaches of North and South Fork Badger Creek. Only a small proportion (32%) of crucial spring habitat for grizzly bears along the Rocky Mountain Front exists within borders of the National Forest. Much of this important but limited habitat occurs in the Badger-Two Medicine (22%), primarily in the valley and adjacent hills of Two Medicine River (USDA Forest Service 2009).
- Large, well-connected blocks of primary and maternal wolverine habitat occur in the higher, more rugged terrain of the Badger-Two Medicine – especially south of Two Medicine Ridge.
- Mountain goats occur on many peaks throughout the western and southern sections of the Badger-Two Medicine (bighorn sheep do not occur in this area).

- In addition, ≈250 elk use the area around Lubec Ridge-Mettler Coulee for winter range and roadless upper basins and ridges of Two Medicine Ridge, South Fork Two Medicine River and South Fork Badger Creek for summer range (G. Olson, Montana FWP, *personal communication*). Some of the ≈800 elk that winter on the Blackleaf WMA and/or the Theodore Roosevelt Memorial Ranch also migrate to the upper Badger-Two Medicine drainages for summer range (Olson et al. 1994).
- The Badger-Two Medicine offers considerable options for shifts in response to climate change, too. The landscape goes from grassland plains (4500 feet elevation) on the east up to subalpine basins and alpine plateaus (8300 feet elevation) along the Continental Divide on the west – all within a distance of 8 to10 miles.. Range of elevation and terrain ruggedness is very high in the Badger Creek basin. Finally, the northern part of the Rocky Mountain Front is wetter and typically more productive than the southern part.
- The Badger-Two Medicine lies in a very strategic position in the context of the Crown of the Continent Ecosystem. Its proximity to Glacier National Park and the adjoining Wildernesses enhances prospects for long-term connectivity and security from industrial developments, which is vital for wide-ranging species. In recognition of the ecological values of the Badger-Two Medicine and its cultural significance to the Blackfeet Nation, the Lewis and Clark National Forest closed nearly all of the area to motorized travel (including snowmobiling) in March 2009. In accordance with the Forest Service new travel plan, 9 miles of designated routes would remain open for motorized travel, which will also enable Blackfeet Tribal members to exercise their treaty rights.
- Thus, the Badger-Two Medicine roadless unit has outstanding ecological value.

Birch Creek South Unit

The Birch Creek South roadless unit encompasses ≈250,000 acres of Forest Service roadless lands along the Rocky Mountain Front. Adjacent to the Forest border are four BLM ‘Outstanding Natural Areas’ (Blindhorse, Ear Mountain, Chute Mountain, and Deep Creek-Battle Creek ONAs) totaling 13,087 acres. This unit is bounded on the northwest by the Badger – Two Medicine roadless area and on the west by the Bob Marshall Wilderness and Scapegoat Wilderness. On the east, there are numerous private conservation holdings (e.g., Boone and Crockett Club Theodore Roosevelt Memorial Ranch and The Nature Conservancy’s Pine Butte Reserve) and three large Montana FWP Wildlife Management Areas. In addition, there are numerous private ranches that have a long history of land stewardship. This unit terminates at Rogers Pass on Highway 200 at the south end.

In October 2007, the Lewis and Clark National Forest released a travel management plan for the Birch Creek South area of the Rocky Mountain Front (USDA Forest Service 2007). In recognition of the prominent ecological values and public comments favoring traditional non-motorized travel, the Forest Supervisor wrote:

> "My conclusion is this area provides the highest quality opportunities on the Lewis and Clark National Forest for non-motorized types of outdoor recreation. For these reasons, I have decided to increase our emphasis on the Rocky Mountain Ranger District as a primary place to enjoy solitude, wildlife viewing, hiking, backcountry hunting, fishing, horseback riding, and pack trips".

Teton River - Deep Creek Roadless Areas:

This roadless area includes ≈109,000 acres from Dupuyer Creek south to the Sun River and Gibson Reservoir.

- Much of the Teton River and Deep Creek roadless area scored as **high** or **very high** *composite* conservation value for the five vulnerable species (Figure 12).
- The area includes several of the remaining streams along the Rocky Mountain Front with genetically-pure westslope cutthroat trout, and Deep Creek may have potential for restoration.
- Relative density of grizzly bears and habitat security is high throughout the area. A high density of grizzly bears occurs from upper Dupuyer Creek south toward Choteau Mountain where montane grasslands provide crucial spring habitat in the foothills. The four BLM Outstanding Natural Areas also provide important spring range and security for grizzly bears. There is a notable concentration of known denning sites in the Deep Creek area.
- Large, well-connected blocks of primary wolverine habitat occur throughout the area, with extensive maternal habitat in the higher, more rugged terrain of upper Teton River and Deep Creek basins.
- Traditional maternal range for mountain goats occurs on many cliffs and peaks at the headwaters of Dupuyer Creek, Blackleaf Creek, and the Teton River. Goats have declined markedly in the Deep Creek area but still occur there in the lower canyons of Deep Creek. Recently, mountain goats have been released in historic range around Ear Mountain.
- Nationally-renown herds of bighorn sheep winter and have their lambs in spring on the slopes just north of Gibson Reservoir and Sun River. Some migrate northward to summer range near the divide with Deep Creek. Other important winter/spring ranges occur around Ear Mountain and lower Deep Creek. The BLM ONAs between the Teton River and Deep Creek provide winter range for bighorn sheep, too. Bands of bighorn sheep have been observed during summer in the high country of upper Deep Creek and west of Ear Mountain.
- In addition, the roadless area in upper Dupuyer and Blackleaf Creeks is used by elk from the Theodore Roosevelt herd year-round and also for calving range and seasonal migration routes (Olson et al. 1994).

Subalpine basins and ridges at the roadless headwaters of North Fork Teton River provide summer range for elk, too.

- The landscape goes from grassland plains on the east to subalpine basins and alpine plateaus along the Continental Divide on the west – all within a distance of 2 to10 miles. The east↔west connectivity from the plains and foothills to the high country is vital for seasonal movements of several wildlife species. In addition, south→north orientation of the front ranges and valleys may facilitate latitudinal shifts in distribution in response to climate change. Proximity of these roadless areas to adjoining Wildernesses enhances prospects for long-term connectivity and security from industrial developments, which is vital for wide-ranging species.
- To summarize: much of the Teton River and Deep Creek roadless units have outstanding conservation value for these vulnerable fish and wildlife species.

Renshaw Mountain, Sawtooth, Benchmark- Elk Creek, Silver King – Falls Creek Roadless Areas:

This area encompasses ≈141,000 acres of roadless lands from Sun River south to the Falls Creek of the Dearborn River near Highway 200 (Figure 12). It is bounded along the west and southwest by the Bob Marshall and Scapegoat Wildernesses and on the east by the Sun River WMA and private ranches and some State lands.

- Several sections of the roadless area south of the Sun River scored as **high** *composite* conservation value for the five vulnerable species (Figure 12). Compared to areas further north along the Front, however, a greater proportion of this area scored as moderate conservation value.
- The area includes a few isolated streams with genetically-pure westslope cutthroat trout. Active restoration is underway at one site in the Renshaw roadless area (Lange Creek), and Falls Creek may have potential for restoration.
- Relative density of grizzly bears is moderate throughout much of the area, but lower than areas north of the Sun River. Relative density of grizzly bears is high in the Smith Creek, Elk Creek, and Falls Creek area. The Sawtooth area (Beaver-Willow road east to Forest boundary) has less conservation value for grizzly bears.
- Relatively large blocks of primary wolverine habitat occur south of the Sun River, but blocks of maternal habitat are smaller and less connected. The Renshaw Mountain roadless area (Allan Mountain south to Fairview Plateau and Red Hill) provides the largest and best connected complex of wolverine habitat in this part of the Front. The Sawtooth area provides some primary habitat but little maternal habitat for wolverines. Wolverine habitat around Caribou Peak at the head of Falls Creek is part of a larger block extending into the Scapegoat Wilderness.

- Roadless areas south of the Sun River have little conservation for mountain goats.
- The Renshaw Mountain roadless area provides excellent year-round range for bighorn sheep from Allan Mountain-Sheep Shed Mountain south to the lower slopes around the North Fork Ford Creek. Some winter and spring range for bighorn sheep occurs at both the south end (Lime Ridge) and the north end (Home Gulch) of the Sawtooth roadless area. Steamboat Mountain provides summer range for some bighorn sheep.
- In addition, elk from the renowned Sun River herd use the roadless areas just south of Gibson Reservoir for seasonal migrations. In the Renshaw Mountain roadless area, elk use the Patricks Basin-Renshaw Mountain-Fairview Plateau for summer range.
- Considerable terrain options for shifts in response to climate change exist across these roadless areas. The section from Sun River south to the Dearborn River, however, is drier and less productive than northern sections of the Front. Proximity of these roadless areas to adjoining Wildernesses enhances prospects for long-term connectivity and security from industrial developments, which is vital for wide-ranging species.
- To summarize: composite conservation value for vulnerable fish and wildlife drops south of the Sun River. Nonetheless, there are still some roadless places that are important – including Renshaw Mountain-Fairview Plateau, and the upper sections of Elk Creek, Dearborn River, and west fork of Falls Creek.

Recommendations for Wildland Protection

For the Rocky Mountain front, I recommend that 306,288 roadless acres (78.9%) be designated as **Wilderness** (Table 2, yellow highlight areas in Figure 13). These areas have high and very high conservation value for vulnerable fish and wildlife species. Their protection would enhance habitat security and connectivity with the Bob Marshall and Scapegoat Wildernesses, and provide topographic options in the face of climate change.

As additions to the Bob Marshall Wilderness, I recommend 261,259 acres:

✓ most (97%) of the Badger-Two Medicine area,

✓ Walling Reef south to Choteau Mountain (including some BLM Outstanding Natural Area adjacent to Blackleaf WMA),

✓ headwaters of Teton River (including some BLM ONA adjacent to Ear Mountain WMA),

✓ all of Deep Creek watershed (including some adjacent BLM ONA),

✓ Big George Gulch, Arsenic Creek, and Castle Reef north of Gibson reservoir, and

Figure 12. Composite conservation values for suite of vulnerable fish and wildlife species, Rocky Mountain Front, Crown of the Continent Ecosystem, Montana.

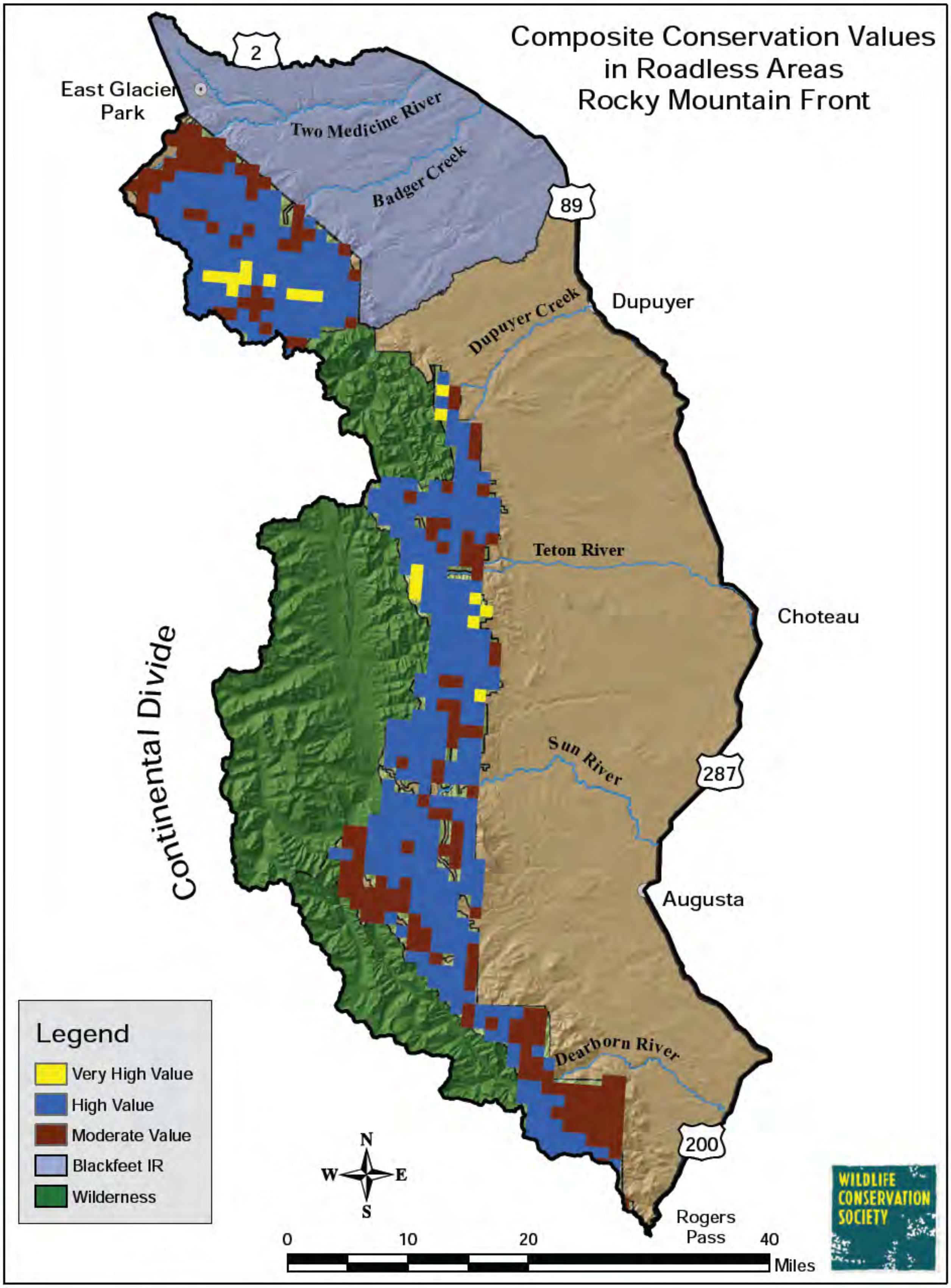
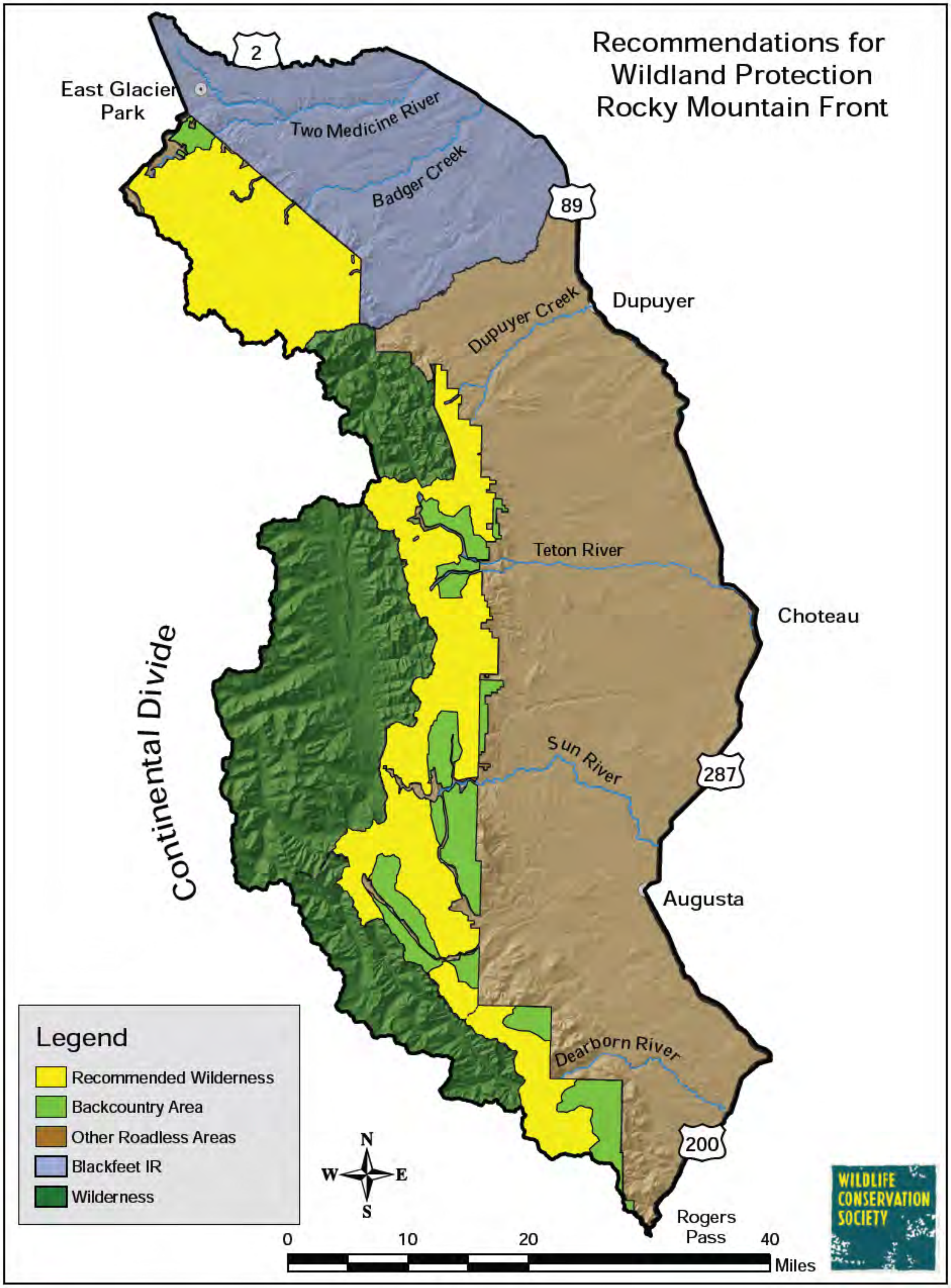


Figure 13. Recommendations for wildland protection, Rocky Mountain Front, Crown of the Continent Ecosystem, Montana.



- ✓ Allan Mountain, Renshaw Mountain, Fairview Plateau and Ford Plateau between Gibson Reservoir and the Benchmark road.

As additions to the Scapegoat Wilderness, I recommend 45,029 acres:

- ✓ strip of roadless area west of the South Fork Sun River and west of lower Straight Creek,
- ✓ headwaters of Smith Creek and Elk Creek from Crown Mountain to Steamboat Mountain at the Forest boundary,
- ✓ upper roadless section of the Dearborn River, and
- ✓ West Fork of Falls Creek.

I further recommend that 81,218 acres (20.9%) be managed in roadless condition as 'Backcountry' with emphasis on non-motorized recreation and conservation of fish and wildlife (Table 2, green areas in Figure 13). These are mostly lower elevation sites that have lesser (moderate) conservation value; nonetheless, they would enhance security for these vulnerable species. Roadless areas recommended for Backcountry include (north→south):

- small area on Lubec Ridge at north end of Badger-Two Medicine area,
- lower slopes of Teton River drainage,
- Blacktail Gulch and Hannan Gulch north of Gibson Reservoir,
- Sawtooth unit between Sun River and Willow Creek, west of the Sun River WMA,
- lower slopes along both sides of Benchmark road,
- lower section of Elk Creek, and
- East Fork of Falls Creek (tributary of the Dearborn River).

Table 2. Number of acres recommended for Wilderness, Backcountry, Other Roadless, and Wildland Restoration Zone, Rocky Mountain Front, Crown of the Continent Ecosystem, Montana.

Roadless Unit	Wilderness		Backcountry		Other Roadless		WRZ[1]		Total
	Ac	%	Ac	%	Ac	%	Ac	%	
Badger – Two Medicine	122,037	96.9	3,929	3.1	–	–	–	–	125,966
Birch – Teton	175,391	70.4	73,426	29.5	–	–	290	0.1	249,107
BLM ONAs (4)	8,860	67.7	3,863	29.5	364	0.1	–	–	13,087
TOTAL	306,288	78.9	81,218	20.9	364	0.1	290	0.1	388,160

5. BLACKFOOT – CLEARWATER RIVER BASIN

Bitterroot

The Blackfoot-Clearwater River basin frames the southern section of the Crown of the Continent Ecosystem. The fabled Blackfoot River threads a glaciated valley of grass-sage, and forests of pine and fir on lower slopes transition to more open forests on the ridges. The Blackfoot Challenge – a group of energetic landowners, business owners, land trusts like the Nature Conservancy, and resource management agencies – are working hard to conserve and enhance natural resources and a rural way of life for present and future generations. A string of glacier-carved lakes grace the Clearwater River valley, where mesic forests rise more sharply to rugged ridges and cirque basins. The shining Mission Mountains frame the west side of the Clearwater River basin. The Montana Legacy Project has secured protection of thousands of acres of corporate timber land in these watersheds. The Bob Marshall Wilderness, Mission Mountains Wilderness (USFS/CSKT), and South Fork Jocko Tribal Primitive Area, and Scapegoat Wilderness protect the high mountain country along the edges of these basins.

Between these treasured landscapes lay ≈300,000 acres that are still *roadless* and unprotected in legislation. What is the conservation value of these roadless lands for vulnerable fish and wildlife species?

Bull Trout

A number of streams and rivers in the Blackfoot-Clearwater River basin have been designated as critical habitat for bull trout (Figure 14) (USFWS 2010). In the Blackfoot section, those designated streams pertinent to the roadless assessment include Cottonwood Creek, Monture Creek and its tributaries Lodgepole and Dunham Creeks, North Fork of the Blackfoot River, Copper Creek, and Landers Fork. Bull trout also occur in Snowbank Creek, a tributary to Copper Creek. In the Clearwater section, pertinent streams include both forks of Marshall Creek and Marshall Lake, Clearwater Lake and East Fork Clearwater River, and Morrell Creek.

Westslope Cutthroat Trout

Westslope cutthroat trout occur throughout the Blackfoot and Clearwater River systems, with a wide spectrum of genetic integrity (Figure 15). Many populations are compromised with introgression of rainbow trout and Yellowstone cutthroat trout. Nonetheless, several streams (or headwater reaches) still have pure strains of westslope cutthroat trout. Montana FWP has led a cooperative effort by many groups and agencies to implement a model conservation effort to restore stream health and conserve native fish in the Blackfoot River drainage (Pierce et al. 2008). Montana FWP is developing a similar plan for the Clearwater River watershed (L. Knotek, Montana FWP, *personal communication*).

In the western section of the upper Blackfoot River watershed near Ovando, pure strains of westslope cutthroat trout appear confined to the upper reaches of occupied streams. Genetic integrity of populations in the lower reaches has been compromised. Pure populations of westslope cutthroat trout occur in the very headwaters of Monture Creek and upper tributaries (Cottonwood Creek, Dunham Creek, and McCabe Creek). Further east up the Blackfoot River basin near Lincoln, nearly all of the tributary streams north of Highway 200 flowing into the main river retain westslope cutthroat populations with intact genetic integrity. Examples include Arrastra Creek, Stonewall and Park Creeks, Copper Creek and Snowbank Creek, Landers Fork, and Alice Creek. Copper Creek is especially important because its cold waters provides spawning and rearing conditions for pure populations of westslope cutthroats and migratory, fluvial bull trout (Pierce et al. 2008).

In the Clearwater section, the genetic integrity of westslope cutthroat trout is more compromised (Figure 15). Known pure populations of westslope cutthroat trout are confined to the upper reaches of North Fork Placid Creek and perhaps Deer Creek, a short reach of West Fork Clearwater River, Richmond Creek, Camp Creek, Findell Creek, Murphy Creek, upper Morrell Creek, and upper Trail Creek (L. Knotek, Montana FWP, *unpublished data*). Few headwaters on the east side of the Clearwater River basin contain westslope cutthroats due to the steep gradient coming off the crest of the Swan Range.

Nearly all reaches occupied by pure westslope cutthroat trout, however, have non-native or hybridized trout downstream. Rainbow trout have been released directly into the tributary (sometimes surreptiously) or have moved upstream from the main Blackfoot or Clearwater River. It's likely that warmer temperatures in these lower waters have facilitated the competitive advantage of rainbow trout over the native westslope cutthroat. Without natural or man-made barriers, these remnant populations of pure westslope cutthroat trout are quite vulnerable to hybridization by non-native trout. To the extent that climate changes favor the upstream movement of non-native trout, higher (but still suitable) reaches isolated by waterfalls may provide a critical refugium for protecting genetic integrity of westslope cutthroat trout.

Grizzly Bear

The inter-agency survey of grizzly bears in 2004 suggests a lower density of grizzlies in the Blackfoot-Clearwater River basin, compared to more northerly sectors of the Crown of the Continent Ecosystem (Kendall et al. 2009). Nonetheless, there has been increasing documentation of grizzly bears in the Blackfoot-Clearwater basin over the past 10 years. Most of the area north of the Blackfoot River and east of the Clearwater River appears occupied, and grizzly bears are showing up in places further south (R. Mace and J. Jonkel, Montana FWP, *unpublished data*). The map of relative grizzly bear density suggests a high to moderate density in the upper Blackfoot River basin (North Fork and Landers Fork) and moderate density in the upper Clearwater River north of Seeley Lake (Figure 16). Red Mountain in the upper Blackfoot is a notable concentration area for grizzly bears in late summer. Home ranges of grizzly bears living in the southern end of the Rocky Mountain Front extend across the Continental Divide and into the upper Blackfoot River basin (M. Madel, Montana FWP, *unpublished data*). The Continental Divide at the head of the Blackfoot River (Alice Creek basin) may be one conduit for the southerly expansion of grizzly bears (J. Jonkel, Montana FWP, *personal communication*).

Wolverine

The high ridges and cirque basins in the Blackfoot-Clearwater country comprise the southern and western edges of an extensive set of large, well-connected blocks of suitable wolverine habitat across the Bob Marshall and Scapegoat Wildernesses (Figure 17). In the roadless Blackfoot section, primary and maternal wolverine habitat extends from Monture Mountain eastward to Arrastra Mountain, Stonewall Mountain and Silver King Mountain. Little maternal habitat for wolverine exists south of Highway 200.

In the roadless Clearwater section, a strip of suitable habitat for wolverine extends continuously along the crest of the Swan Range from Wolverine Mountain south to Morrell Mountain (Figure 17). A block of suitable wolverine habitat (maternal) occurs in the upper west fork of the Clearwater River south to upper Marshall Creek and Lake Dinah next to the Mission Mountains Wilderness (USFS/ CSKT).

Mountain Goat

Mountain goats occur in the high peaks in roadless areas adjacent to the Bob Marshall and Scapegoat Wildernesses. In the Blackfoot River basin, mountain goats occur from Monture Mountain eastward around the headwaters of Monture Creek to Limestone Pass (Figure 18). Core maternal ranges include the Monture Mountain-Nome Point-Dunham Creek area where goat numbers appear to have declined in recent decades (J. Kolbe, Montana FWP, *unpublished data*). Another traditional maternal range for mountain goats is the southern edge of the Scapegoat massif (Casebeer et al. 1950). Historically, a disjunct band of mountain goats occurred on Red Mountain north of Lincoln, Montana, but they were extirpated by 1980 due to excessive mortality from legal and illegal hunting. More recently, goats were transplanted there in 2002 and 2005 (B. Henderson, Montana FWP, *unpublished data*). Some of these goats have used the Stonewall Mountain area, too.

In the Clearwater River basin, mountain goats occur along the crest of the Swan Range from Wolverine Peak south to Devine Peak (Figure 18). This represents the western edge of a large block of mountain goat range extending into the Bob Marshall Wilderness. The section from Wolverine Peak south to Sunday Mountain is traditional maternal goat range.

Bighorn Sheep

Bighorn sheep do not occur in the upper reaches of the Blackfoot-Clearwater area.

Figure 14. Critical habitat for bull trout, Blackfoot – Clearwater River Basin, Crown of the Continent Ecosystem, Montana.

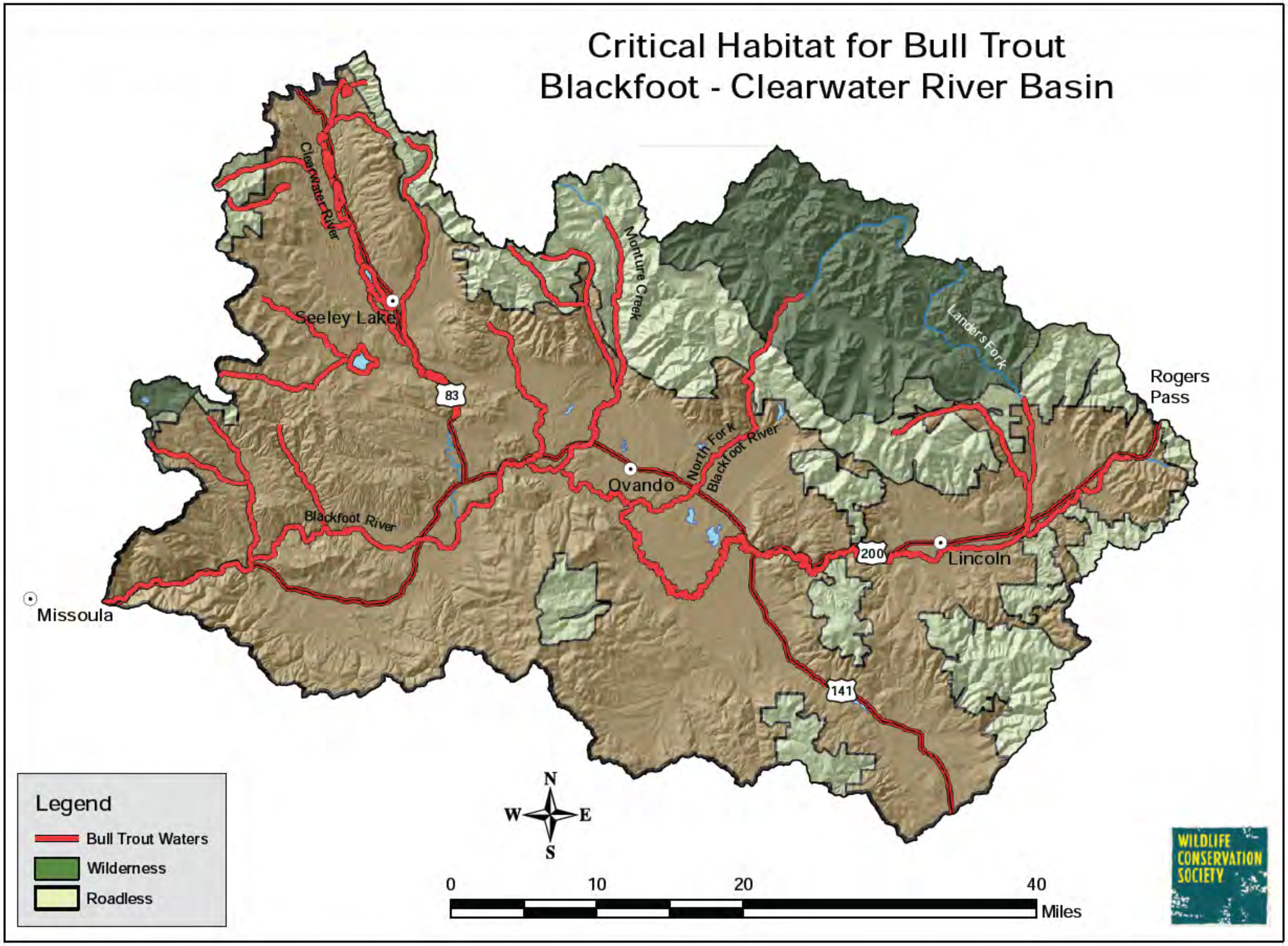


Figure 15. Conservation populations of westslope cutthroat trout, Blackfoot – Clearwater River Basin, Crown of the Continent Ecosystem, Montana.

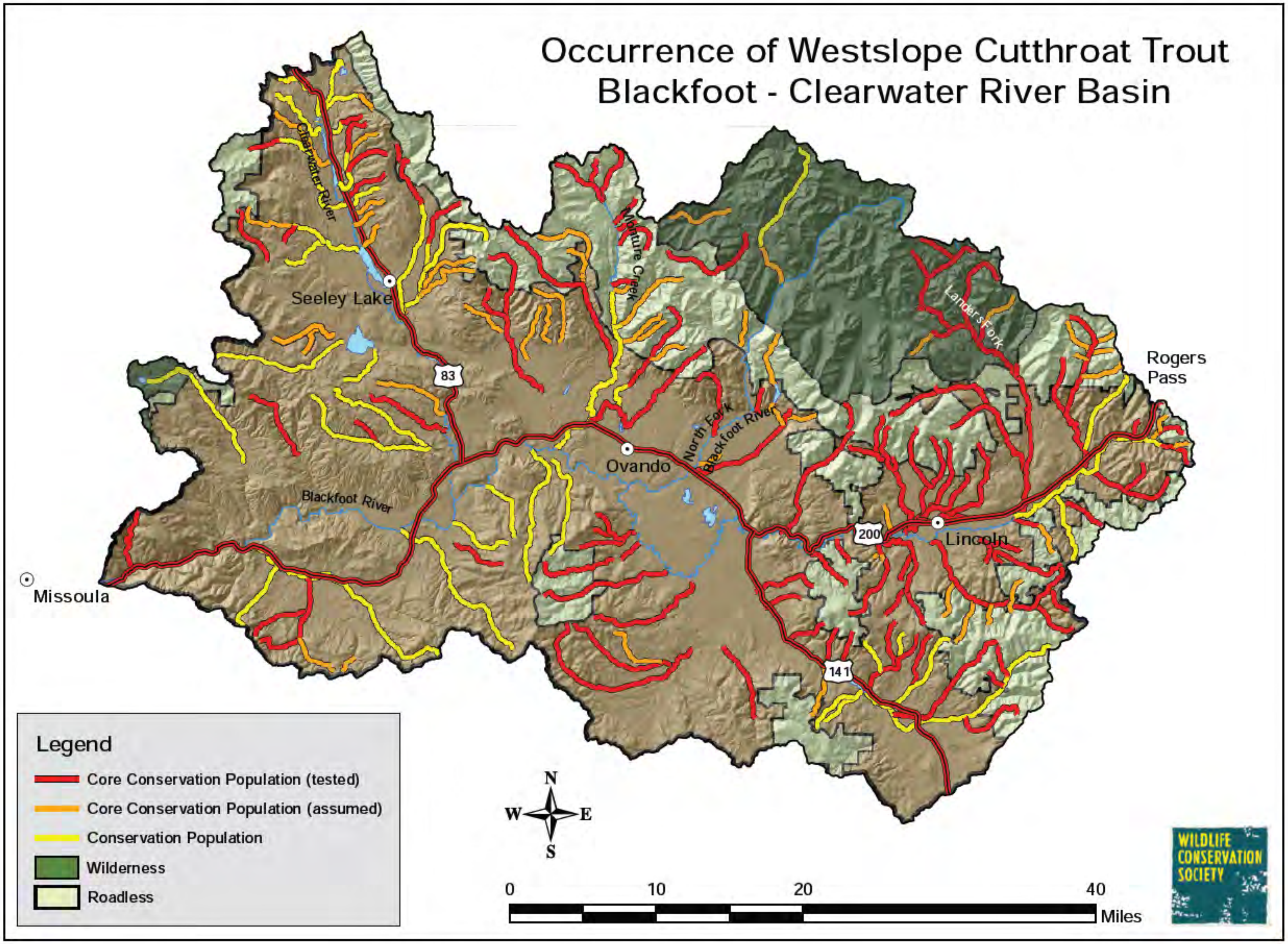


Figure 16. Relative density of grizzly bears, Blackfoot – Clearwater River Basin, Crown of the Continent Ecosystem, Montana.

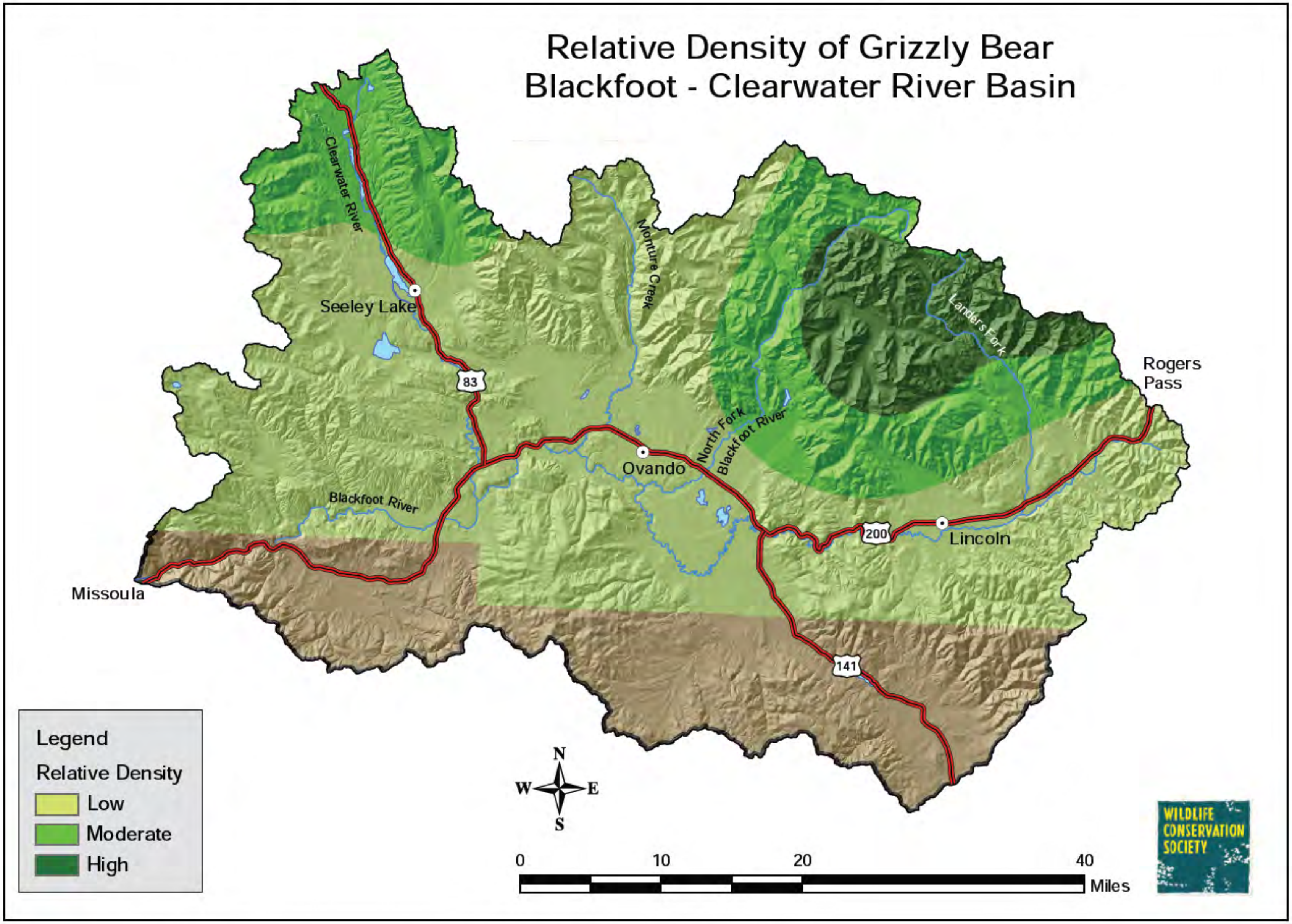


Figure 17. Primary and maternal habitat for wolverine, Blackfoot – Clearwater River Basin, Crown of the Continent Ecosystem, Montana.

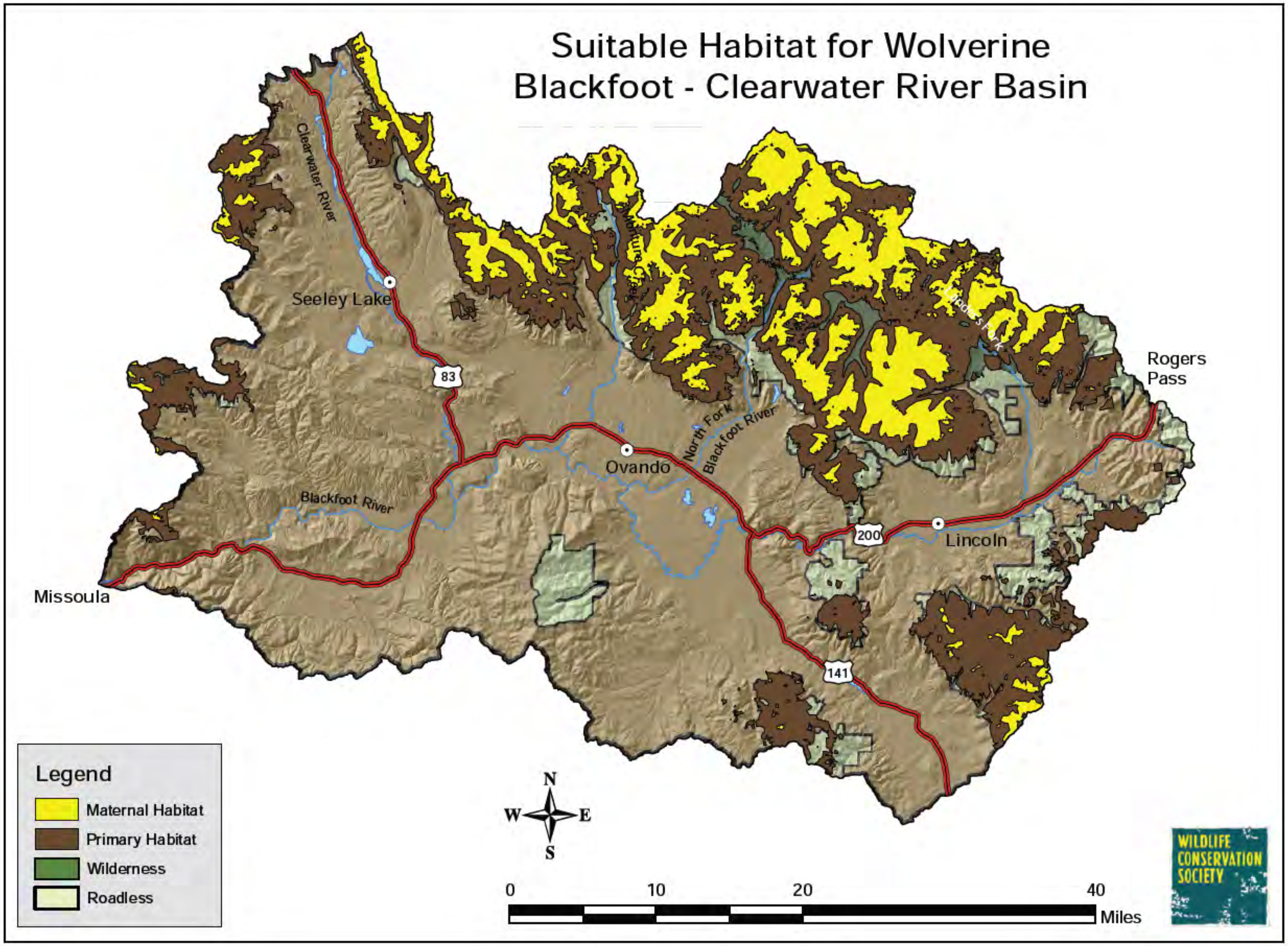
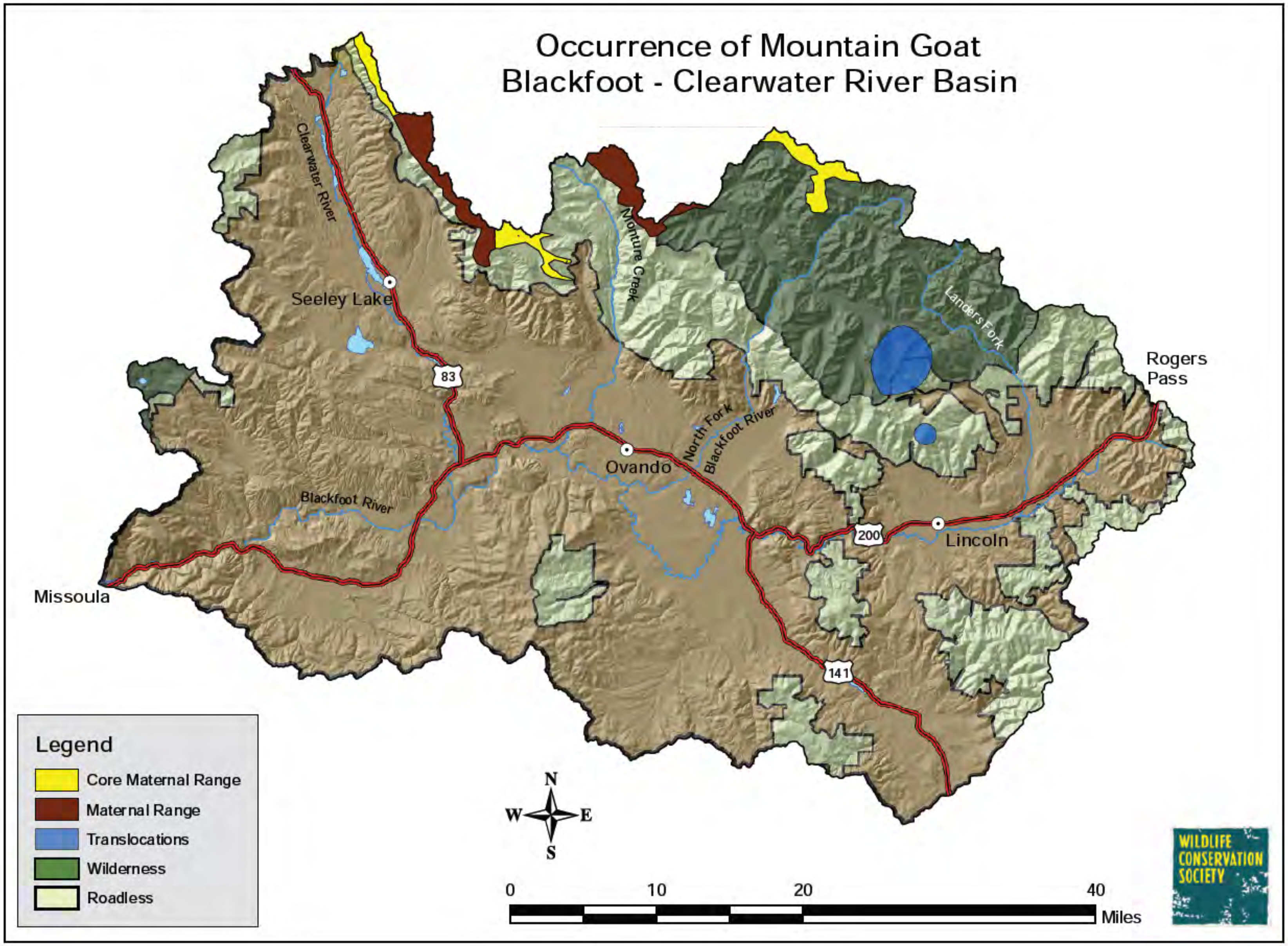


Figure 18. Ranges of mountain goat, Blackfoot – Clearwater River Basin, Crown of the Continent Ecosystem, Montana.



Synthesis of Conservation Values

Here, I synthesize pertinent information about the occurrence of vulnerable fish and wildlife species, terrain options for response to climate change, and connectivity to other important landscapes. To provide more details, I discuss features of the Blackfoot and Clearwater roadless units separately.

In the Blackfoot River roadless unit:

- much of the roadless area in this unit scored as **high** *composite* conservation value for the five vulnerable species (Figure 19). Lower composite values (moderate) characterized the southern edge of roadless areas north of Highway 200 and nearly all the areas south of Highway 200.
- several streams have been designated as critical habitat for bull trout and their headwaters also contain populations of genetically-pure westslope cutthroat trout – Cottonwood Creek, Monture Creek and its tributaries Dunham Creek and Lodgepole Creek, as well as Landers Fork and its tributary Copper Creek. The North Fork Blackfoot River is critical habitat for bull trout, too. Alice Creek has a pure population of westslope cutthroat trout at present.
- for grizzly bears, the roadless area from the North Fork Blackfoot River east to the Continental Divide above Alice Creek scores high to very high in conservation value and augments the habitat and security value of the Scapegoat Wilderness.
- subalpine basins and ridges in the Blackfoot roadless area north of Highway 200 provide maternal habitat (present and future) and thus score very high conservation value for wolverines. These sites augment the conservation value of adjacent areas in the Bob Marshall and Scapegoat Wildernesses for wolverines.
- Monture Peak and the cliff bands in Dunham-Nome Peak score high as core maternal habitat and anchor the south end of an extensive block of goat habitat along the Swan Crest.
- the roadless basin and ridges at the head of Monture Creek provide important summer/fall range for the Blackfoot-Clearwater elk herd of 1100 animals (Hurley 1994).
- roadless areas from Monture Peak over to Stonewall Mountain score high for range of elevation and terrain ruggedness, which will provide some options for response to climate change.

In the Clearwater River roadless unit:

- much of the roadless area in this unit scores **high** in *composite* conservation value for the five vulnerable species, with a **very high** score in Grizzly Basin at the head of Morrell Creek (Figure 19).
- headwaters of Morrell Creek score very high in conservation value for bull trout and high for pure westslope cutthroat trout. Other streams in roadless area with very high scores for bull trout include an east tributary to Clearwater Lake, upper west fork Clearwater River and upper Marshall Creek. Several high-gradient streams flowing off the crest of the Swan Range provide cold water to downstream areas occupied by native trout.
- the roadless west slopes of the Swan Range from Wolverine Peak south to Devine Peak score high for grizzly bears due to a mixture of key habitats (avalanche chutes, cirque basins, and berry patches) and high security. The roadless block in the upper west fork of Clearwater River south to Lake Dinah also scores high and connects to a larger block of valuable grizzly bear habitat in the Mission Mountains Wilderness (USFS and CSKT).
- the narrow strip of roadless on the western slope of the Swan Range scores very high for wolverine from Wolverine Peak south to Crescent Mountain and also around Morrell Mountain. It is contiguous with a large block in the Bob Marshall Wilderness that scores very high in conservation value for wolverine. The roadless area in the upper west fork Clearwater River and upper Marshall Creek provide primary and some maternal habitat for wolverine, too.
- cliffs and rocky ridges along the western slope of the Swan Range from Wolverine Peak south to Sunday Mountain score very high for mountain goat as part of a larger connected population extending into the Bob Marshall Wilderness. Roadless sections of the Swan Range further south score high for goats.
- The entire roadless stretch along the western slopes of the Swan Range scores high for range of elevation and terrain ruggedness and accumulates considerable snowpack. These features will provide some options for response to climate change.

Recommendations for Wildland Protection

For the Blackfoot - Clearwater River basin, I recommend that 134,162 roadless acres (45.0%) be designated as Wilderness (Table 3, yellow highlight areas in Figure 20). These areas have high and very high conservation value for vulnerable fish and wildlife species, provide topographic options in the face of climate change, and enhance habitat security and connectivity with the Bob Marshall and Scapegoat Wildernesses.

As an addition to the Bob Marshall Wilderness, I recommend 73,009 acres in:

- ✓ roadless portion of the Swan Range from Wolverine Peak at the headwaters of the Clearwater River south to Omar Mountain along the watershed divide of the Blackfoot River to Camp Pass and thence Spread Mountain (upper Monture Creek watershed).

As an addition to the Scapegoat Wilderness, I recommend 53,899 acres in:

- ✓ roadless area continuing from Omar Mountain (described above) southeast along the watershed divide of the Blackfoot River past Arrastra Mountain, then east to nearly Red Mountain at the head of Alice Creek basin.

As an addition to the Mission Mountains Wilderness (USFS) but also contiguous with the Mission Mountains Tribal Wilderness (CSKT), I recommend 7,254 acres in:

- ✓ roadless headwaters of West Fork Clearwater River and Marshall Creek.

The southern edge of the roadless area north of Highway 200 has lower conservation value (moderate) for these vulnerable species, so I recommend approximately 58,930 acres (19.8 %) there be managed in roadless condition as 'Backcountry' with emphasis on non-motorized recreation and conservation of fish and wildlife (Table 3, green areas in Figure 20). Areas recommended for Backcountry designation include:

- in the Blackfoot River basin, area north of Ovando Mountain, lower sections of Arrastra Creek basin, lower slopes around Stonewall Mountain, and lower slopes of Silver King Mountain and Alice Creek basin.
- In the upper Clearwater River basin, a small patch around Lake Elsina.

I did not recommend any particular designation for several roadless blocks south of Highway 200 in the Blackfoot unit that comprise 104,742 acres in total (35.2%) because they (1) are disjunct from other roadless and wilderness areas, and (2) scored uniformly moderate in conservation value for this suite of fish and wildlife species (Figure 20). Rather, I mapped their status as simply 'other roadless' pending other management decisions.

Table 3. Number of acres recommended for Wilderness, Backcountry, and Other Roadless, Blackfoot – Clearwater River Basin, Crown of the Continent Ecosystem, Montana.

Roadless Unit	Wilderness		Backcountry		Other Roadless	
	Ac	%	Ac	%	Ac	%
Blackfoot River Basin	108,368	42.7	58,930	23.2	86,703	34.1
Clearwater River Basin	25,794	58.8	–	–	18,041	41.2
TOTAL	134,162	45.0	58,930	19.8	104,744	35.2

Figure 19. Composite conservation values for suite of vulnerable fish and wildlife species, Blackfoot – Clearwater River Basin, Crown of the Continent Ecosystem, Montana.

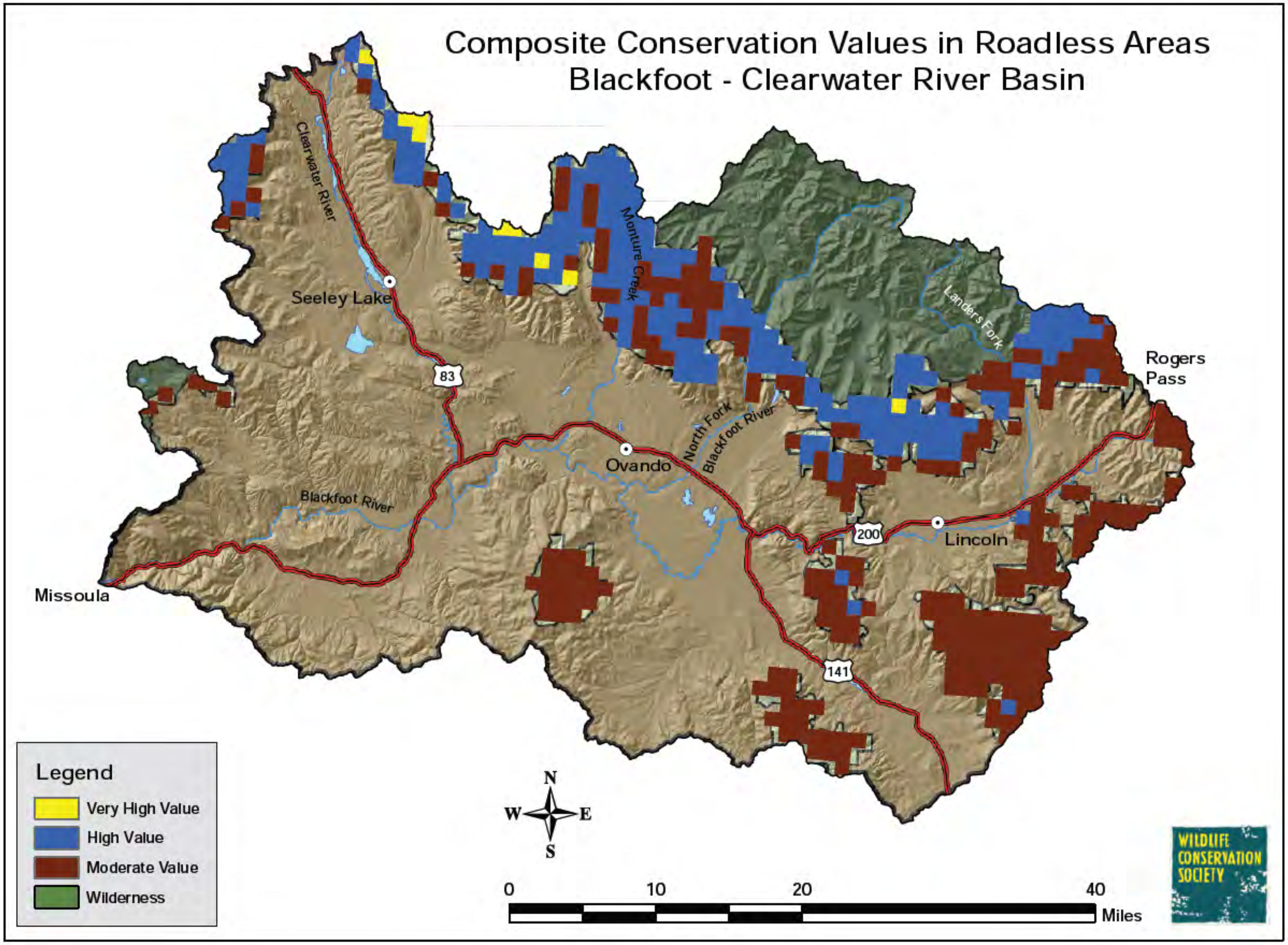
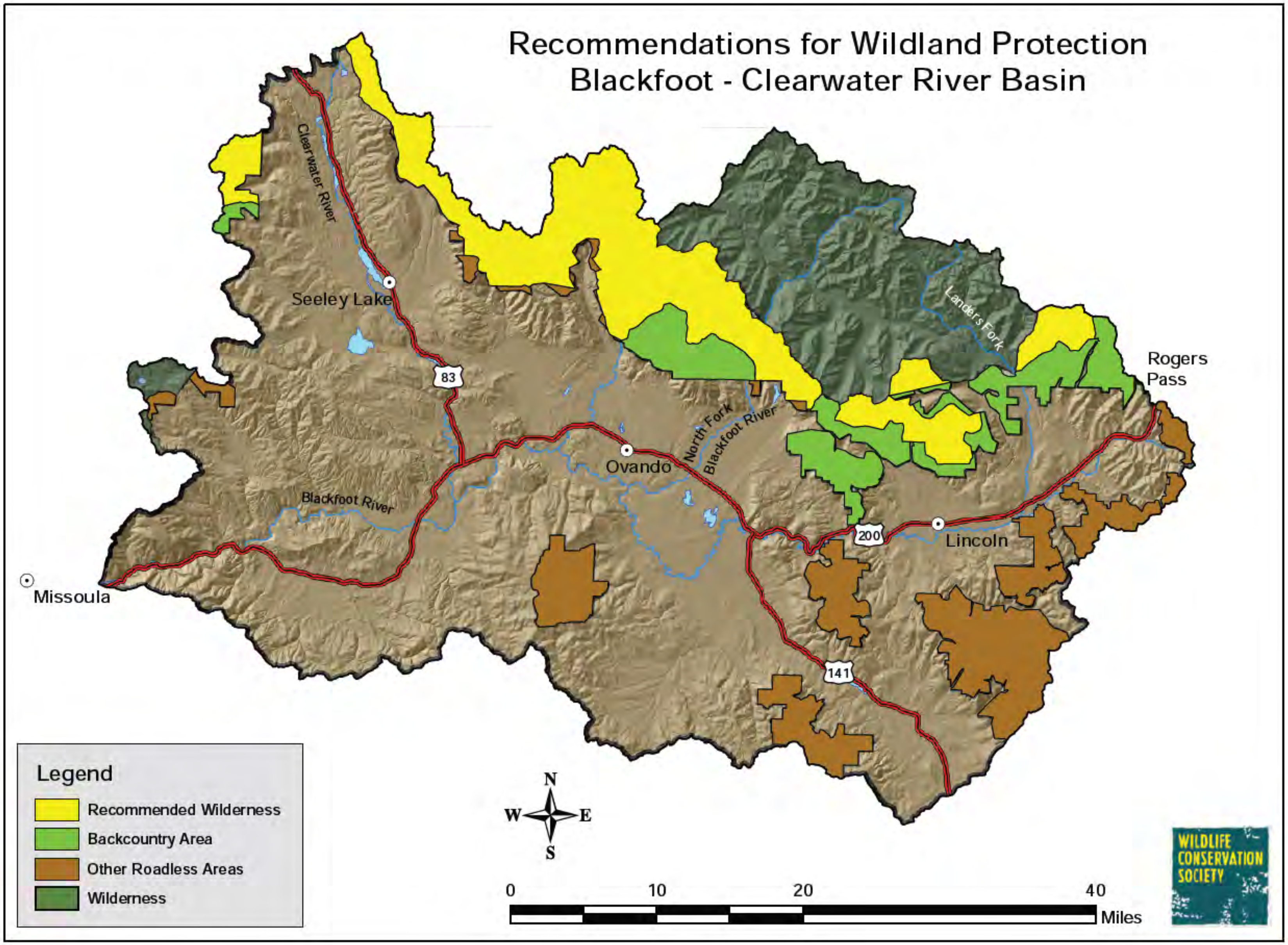


Figure 20. Recommendations for wildland protection, Blackfoot – Clearwater River Basin, Crown of the Continent Ecosystem, Montana.



6. SWAN RIVER AND SOUTHERN FLATHEAD RIVER BASINS


Montana FWP

The Swan River and Southern Flathead River Basin includes three major tributaries to Flathead Lake on the west side of the Crown of the Continent Ecosystem, Montana – the Swan River, the South Fork of the Flathead River, and the Middle Fork of the Flathead River. Diverse coniferous forests clothe the steep slopes, and exquisite jewels of tarn lakes are set among the rugged peaks and cirque basins. The Montana Legacy Project has secured protection of thousands of acres of corporate timber land in the Swan Valley. Agencies and citizens have been working hard to conserve key lands and vital connectivity across the valleys in this region. Some of the roadless areas are bordered by Glacier National Park, the Great Bear Wilderness, and the Bob Marshall Wilderness. But roadless lands along the narrow northern crest of the Swan

Range are perched between the agricultural Flathead Valley and Hungry Horse Reservoir. About 376, 594 acres of roadless areas exist currently along the Swan Range and in the Southern Flathead River basin. What is the conservation value of these roadless lands for vulnerable fish and wildlife species?

Bull Trout

Cold-water drainages in the Swan River and Southern Flathead River basins have been deemed a stronghold for bull trout in the Columbia River system (Rieman et al. 1997, USFWS 2010). Numerous rivers and streams have been designated as critical habitat for bull trout (USFWS 2010) (Figure 21).

The entire Swan River, including Swan Lake, has been designated as critical habitat. Designated waters with their source in the roadless Swan Range include: Holland Lake, Lion Creek, Squeezer Creek, Goat Creek, Soup Creek, and both South Fork and North Fork Lost Creek. Several tributaries descending from the Mission Mountains Wilderness on the west side of the Swan Valley have been designated as critical habitat for bull trout. North Fork Elk Creek and Piper Creek flow through small roadless areas, as well as upper Lindbergh Lake.

The entire South Fork of the Flathead River, including Hungry Horse Reservoir, has been designated as critical habitat. Designated waters with their source in the roadless Swan Range include: Bunker Creek, Sullivan Creek, Quintonkon Creek, Wheeler Creek, Graves Creek, and Wounded Buck Creek. Spotted Bear River has been designated as critical habitat, too.

The upper Middle Fork of the Flathead River and its major tributaries within the Great Bear Wilderness and Bob Marshall Wilderness has been designated as critical habitat. Designated streams within roadless areas include headwaters of Granite Creek and Morrison Creek.

Westslope Cutthroat Trout

Westslope cutthroat trout occur throughout the Swan River and South and Middle Fork Flathead River systems, albeit with a wide spectrum of genetic integrity (Figure 22). Numerous streams in the Flathead Rivers still have pure populations of westslope cutthroat trout. Some populations of genetically-pure westslope cutthroat trout also persist in the Swan River system, but many have been compromised by introgression of non-native trout.

In the Swan River drainage, streams with genetically-intact populations of westslope cutthroat trout in roadless areas include Cooney Creek, Cat Creek, Lion Creek, and South Fork Lost Creek.

The South Fork Flathead River is considered a stronghold for pure populations of westslope cutthroat trout (M. Deleray, Montana FWP, *personal communication*). All of the east-side tributaries to Hungry Horse Reservoir and Spotted Bear River contain genetically-intact WCT populations (majority have been tested), with sections of their headwaters flowing through roadless areas. Most of the west-side streams descending from the roadless Swan Range have genetically-pure populations, including: Bruce Creek, Tin Creek, Sullivan Creek and tributaries, Quintonkon Creek, Jones Creek, upper Graves Creek, Clayton Creek, and Doris Creek. Montana FWP has an active program to eliminate non-native trout in some headwater lakes, where they are causing genetic introgression downstream (Montana FWP 2005).

In the upper Middle Fork Flathead River drainage (above Bear Creek), westslope cutthroat trout have tested as genetically-pure in the main stem and assumed pure in the vast network of tributaries. They are found in the following streams in roadless areas: Challenge Creek (tested), Puzzle Creek, Morrison Creek, Granite Creek, Dodge Creek and Skyland Creek. In the lower section of the Middle Fork Flathead River, Essex Creek and Tunnel Creek contain genetically-pure populations of westslope cutthroat trout.

Grizzly Bear

Relative density of grizzly bears is high throughout much of the Swan Range and Flathead Headwaters and moderate in other sections (Figure 23).

In the Swan Range, relative density of grizzly bears is high in roadless areas from Holland Lake and Bunker Creek north to Doris Mountain. Concentrated activity by radio-collared female grizzly bears has been documented in the northern Swan Range from Bunker Creek north to Wounded Buck Creek (Mace et al. 1996). Grizzly bears are also spending more time on the roadless west slopes of the Swan Range adjacent to the Flathead Valley in the vicinity of Blaine Mountain (R. Mace, Montana FWP, *unpublished data*).

In the Swan Valley and Mission Mountains, relative density of grizzly bears is moderate (Figure 23). In recent years, numerous radio-collared grizzly bears have been documented using the mixed-ownership lands in the central valley floor of the Swan Valley during spring, summer, and fall and crossing from the Swan Range to the Mission Range (R. Mace, Montana FWP and others, *unpublished data*). Some individual bears have made literally hundreds of crossings of Highway 83 at specific sites, including near Holland Creek, Barber Creek, and Cold Creek. Ten of 11 known mortalities during 2000-2005, however, occurred in the valley bottom.

In the narrow roadless area along the east side of Hungry Horse Reservoir, relative density of grizzly bears is high at the north and south ends and moderate in the central sector (Figure 23). In the roadless section between upper Middle Fork Flathead River and Marias Pass, relative density of grizzly bears appears high, too. In the lower roadless section of the Middle Fork west of Highway 2, relative density of grizzlies seems high in the Nyack area.

Wolverine

Suitable habitat for wolverine occurs throughout much of the Swan Range and Flathead Headwaters (Figure 24). In the roadless section of the Swan Range from Wolverine Peak north to Inspiration Point, blocks of primary and maternal wolverine habitat are part of a large, connected complex that extends into the Bob Marshall Wilderness. In the northern section of the Swan Range from Lost Creek-Bunker Creek north to Columbia Mountain, primary habitat is extensive but patches of maternal habitat become comparatively smaller and rather more isolated. This area was the focus of the first field study of wolverine in North America conducted by Maurice Hornocker and Howard Hash during the late 1970s (Hornocker and Hash 1981). Those researchers estimated the density to be 1 wolverine per 65 km^2, and home ranges (MCP) averaged 388 km^2 for females and 422 km^2 for males (Hornocker and Hash 1981). Locations of radio-collared wolverine occurred primarily in the roadless and wilderness areas of the South Fork Flathead River basin, especially in Bunker Creek and from Jewel Basin north to Doris Mountain (Figure 25). Most (62 %) of these locations fell within the primary habitat predicted by the Inman wolverine model. Of the remaining locations, most (28%) occurred at lower elevations along remote tributary valleys during winter, often within 1 mile of primary habitat. Some wolverines initially radio-collared in Bunker Creek were legally trapped by commercial trappers in Lost Creek in the Swan Valley.

Primary wolverine habitat occurs throughout the narrow roadless area along the east side of Hungry Horse Reservoir, whereas maternal habitat occurs at higher elevations mostly inside the Great Bear Wilderness (Figure 24). Some maternal habitat occurs in the roadless stretch from Logan Creek south to Crossover Mountain. Radio-collared wolverines used the Hungry Horse drainage northeast of the reservoir during summer and winter (Figure 25) (Hornocker and Hash 1981). In the roadless section of the lower Middle Fork Flathead River, Paola Ridge - Tunnel Ridge provides both primary and maternal habitat for wolverines, and several wolverines have been trapped there (Figure 24). All of the roadless area in the upper Middle Fork Flathead River basin comprises primary wolverine habitat. Maternal habitat for wolverines occurs there in the roadless section along the Continental Divide, Slippery Bill Mountain, and in upper Twentyfive Mile Creek.

Mountain Goat

The crest of the Swan Range from Wolverine Peak above Holland Lake north to Con Kelly Mountain is traditional maternal habitat for mountain goats (Figure 26). Goats range across both the Wilderness and roadless sides of the crest. This important goat range extends further eastward into the Bob Marshall Wilderness to form an extensive complex. Tributary basins and banded cliffs in roadless sections above Bunker Creek provide key maternal range for mountain goats (Chadwick 1983, Montana FWP *unpublished data*).

A narrow ribbon of habitat along the crest of the Swan Range from Con Kelly Mountain north to Doris Mountain was mapped as occupied by goats during the late 1940s (Casebeer et al. 1950). At present, though, only a few goats still persist on isolated peaks in Jewel Basin. Historically, goats used cliffs at lower elevation for crucial winter range in places such as lower Bond Creek and Lion Creek (Chadwick 1983). Extensive road building for timber harvest and liberal hunting seasons during the 1960s and 1970s, however, likely facilitated excessive harvest of goats in the Swan Range (Chadwick 1983).

Most of the maternal goat range high above the east shoreline of Hungry Horse Reservoir lies inside the Great Bear Wilderness (Figure 26). A section from Unawah Mountain south to Circus Peak, however, laps over into the roadless area. In the upper reaches of the Middle Fork of the Flathead River, mountain goats occur along the Continental Divide between Running Crane Mountain and Big Lodge Mountain (Figure 26). These animals represent the northern extent of a stronghold of mountain goats in the rugged peaks of the Badger-Two Medicine area at the north end of the Rocky Mountain Front (see Figure 10 in Chapter 4). A few goats occur on roadless Slippery Bill Mountain, too.

Bighorn Sheep

Bighorn sheep do not occur in the Swan Range or in the South Fork and Middle Fork of the Flathead River basins.

Figure 21. Critical habitat for bull trout, Swan River and Southern Flathead River Basin, Crown of the Continent Ecosystem, Montana.

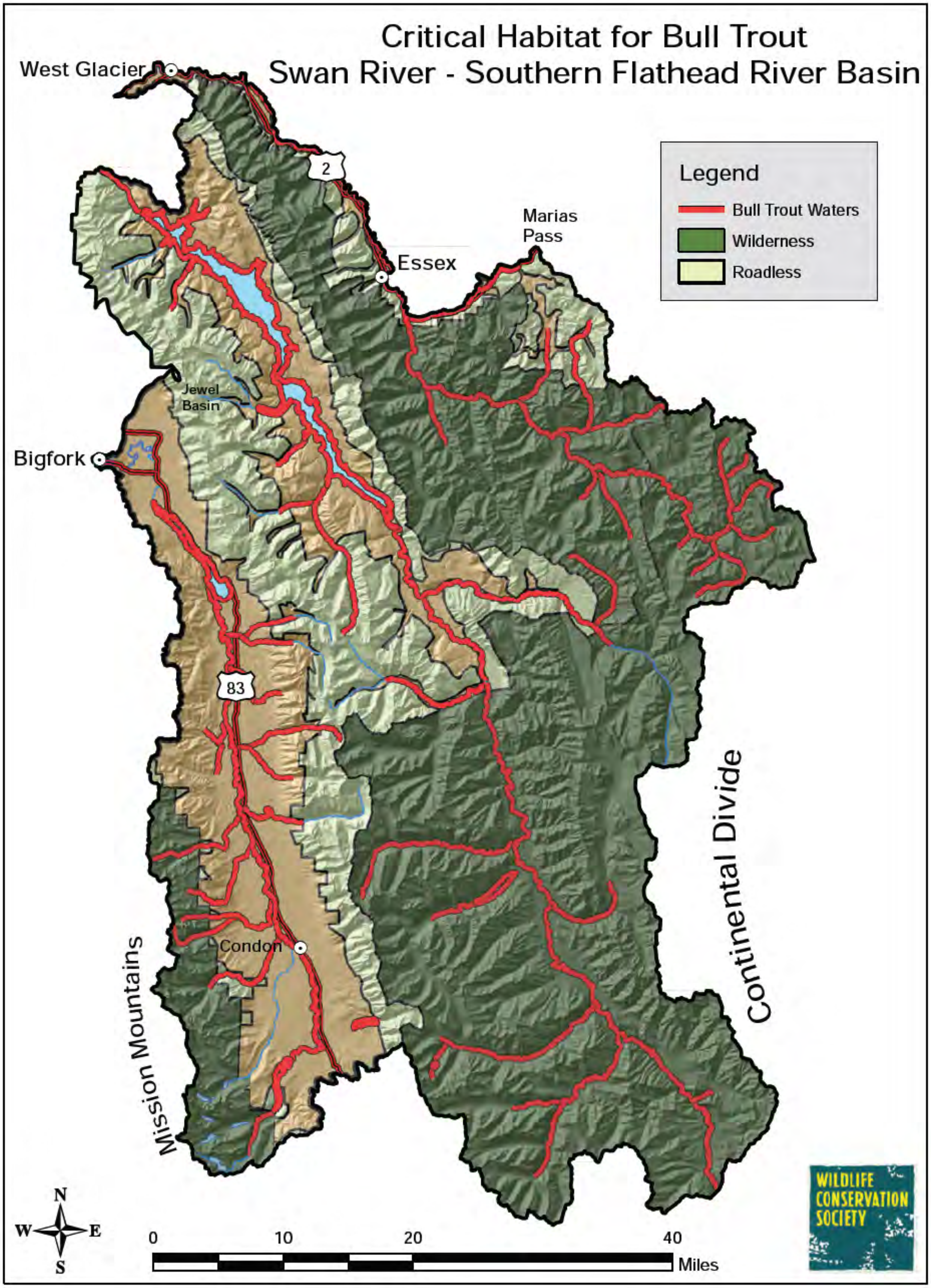


Figure 22. Conservation populations of westslope cutthroat trout, Swan River and Southern Flathead River Basin, Crown of the Continent Ecosystem, Montana.

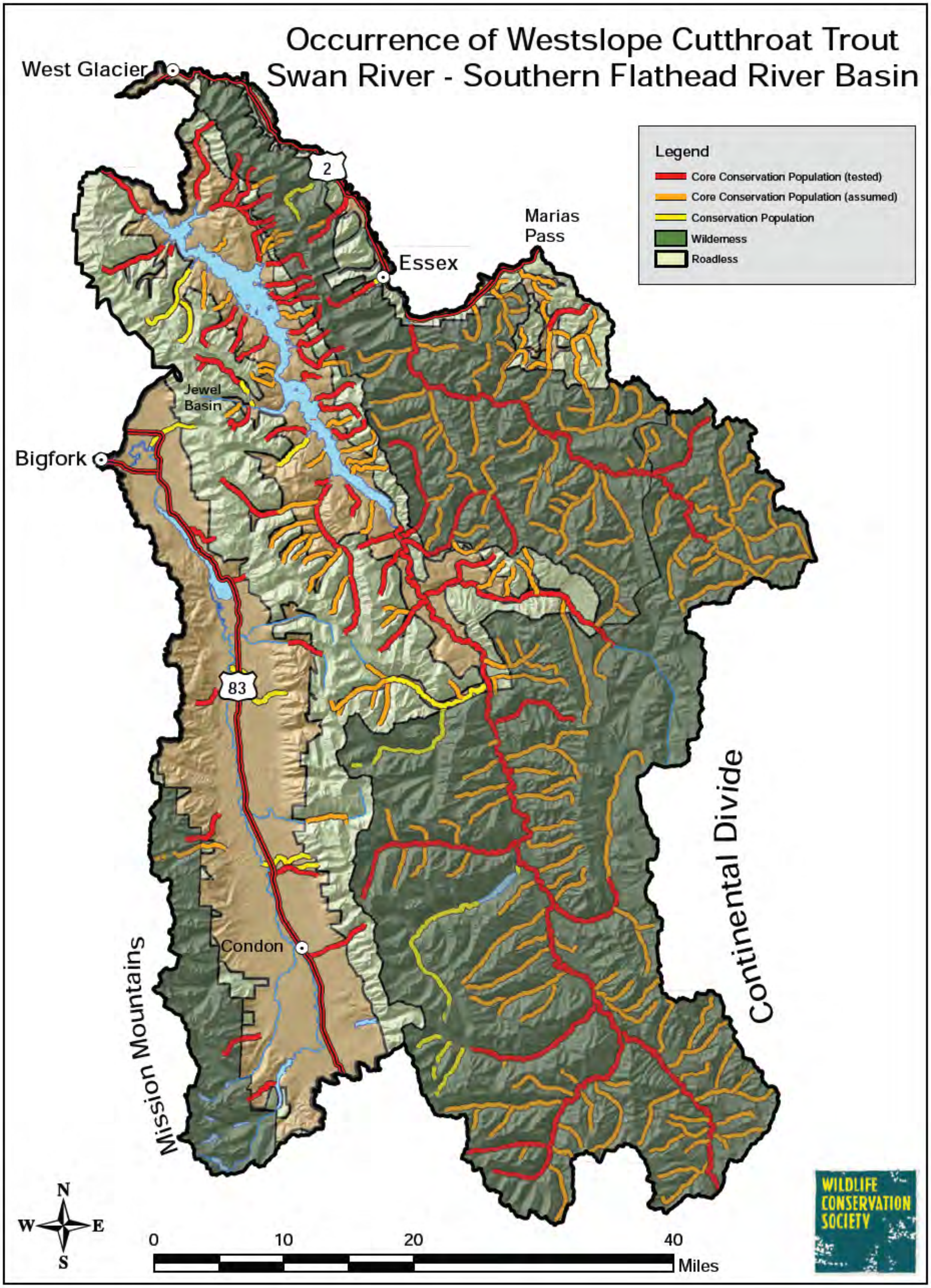


Figure 23. Relative density of grizzly bears, Swan River and Southern Flathead River Basin, Crown of the Continent Ecosystem, Montana.

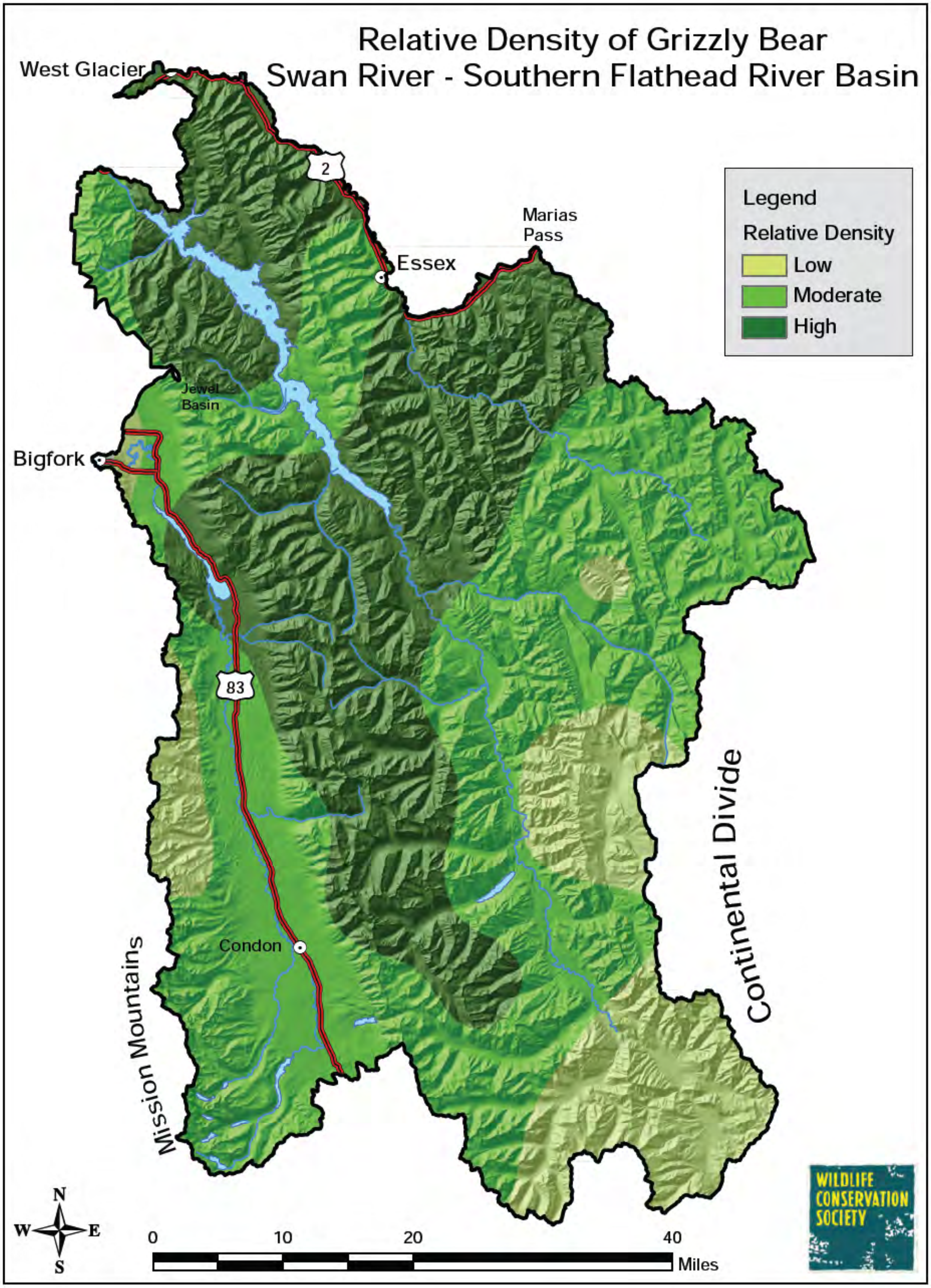


Figure 24. Primary and maternal habitat for wolverine, Swan River and Southern Flathead River Basin, Crown of the Continent Ecosystem, Montana.

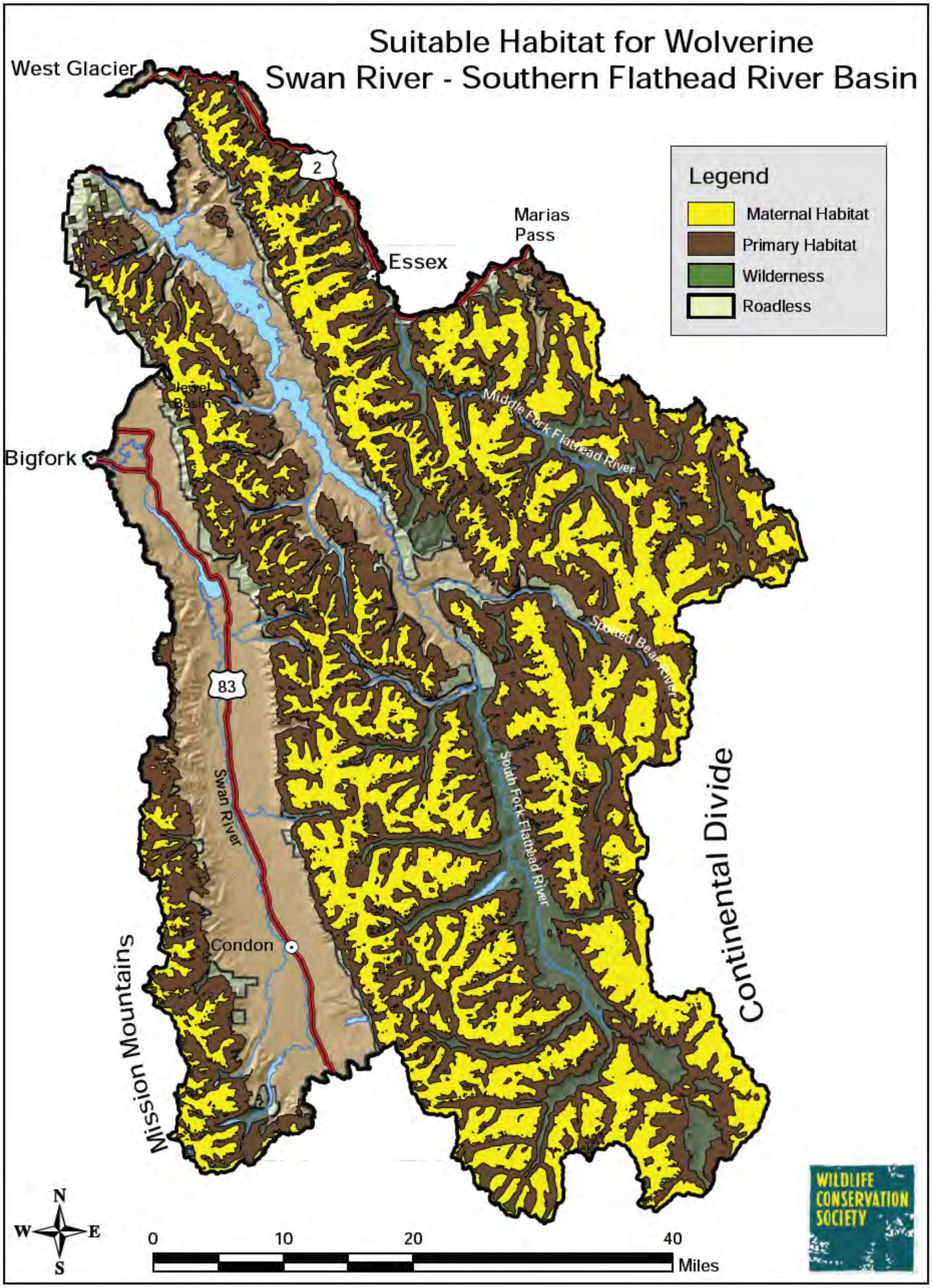


Figure 25. Seasonal telemetry locations of wolverines, Swan River and Southern Flathead River Basin, Crown of the Continent Ecosystem, Montana. Data from study by Hornocker and Hash (1981).

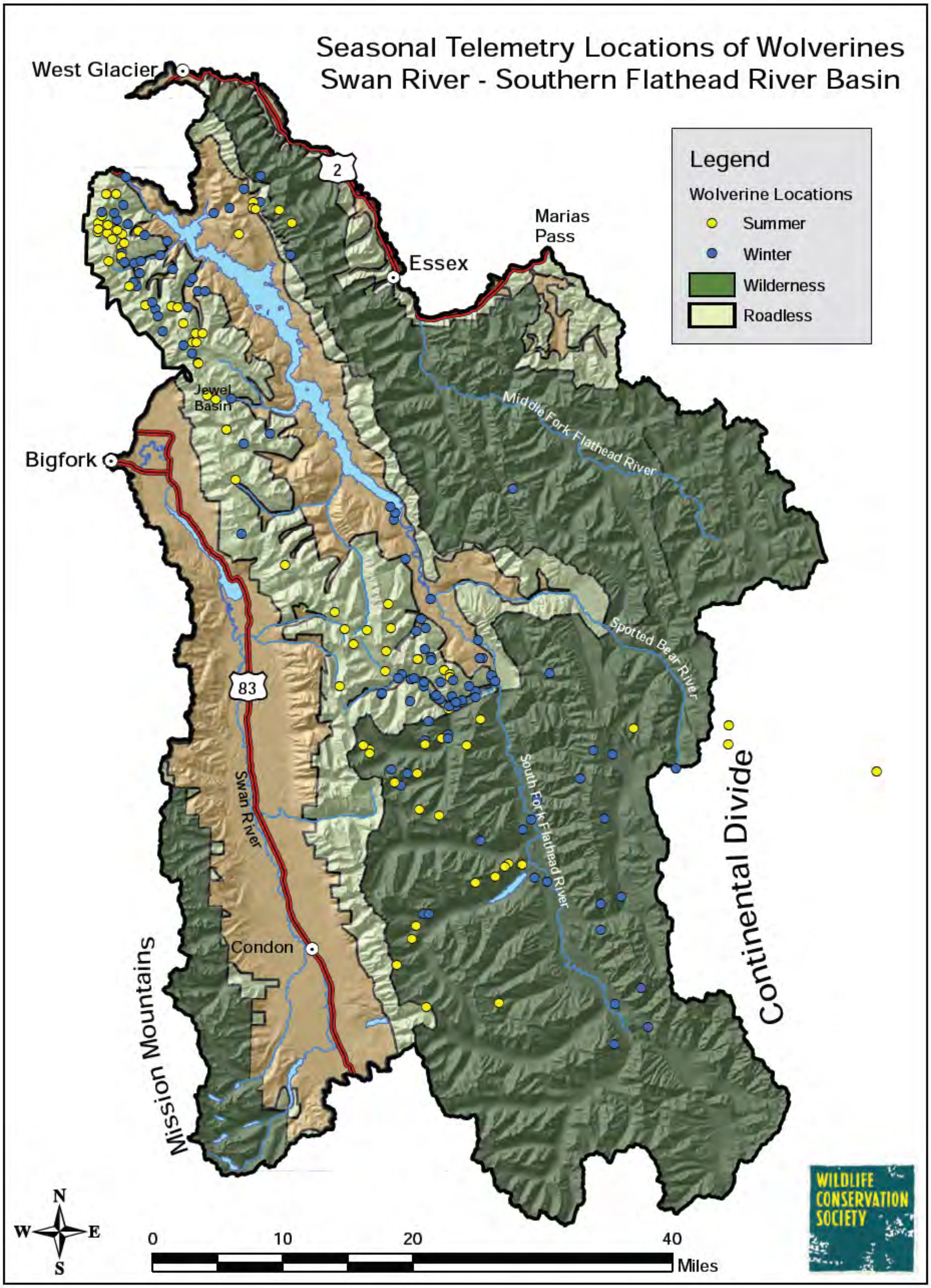
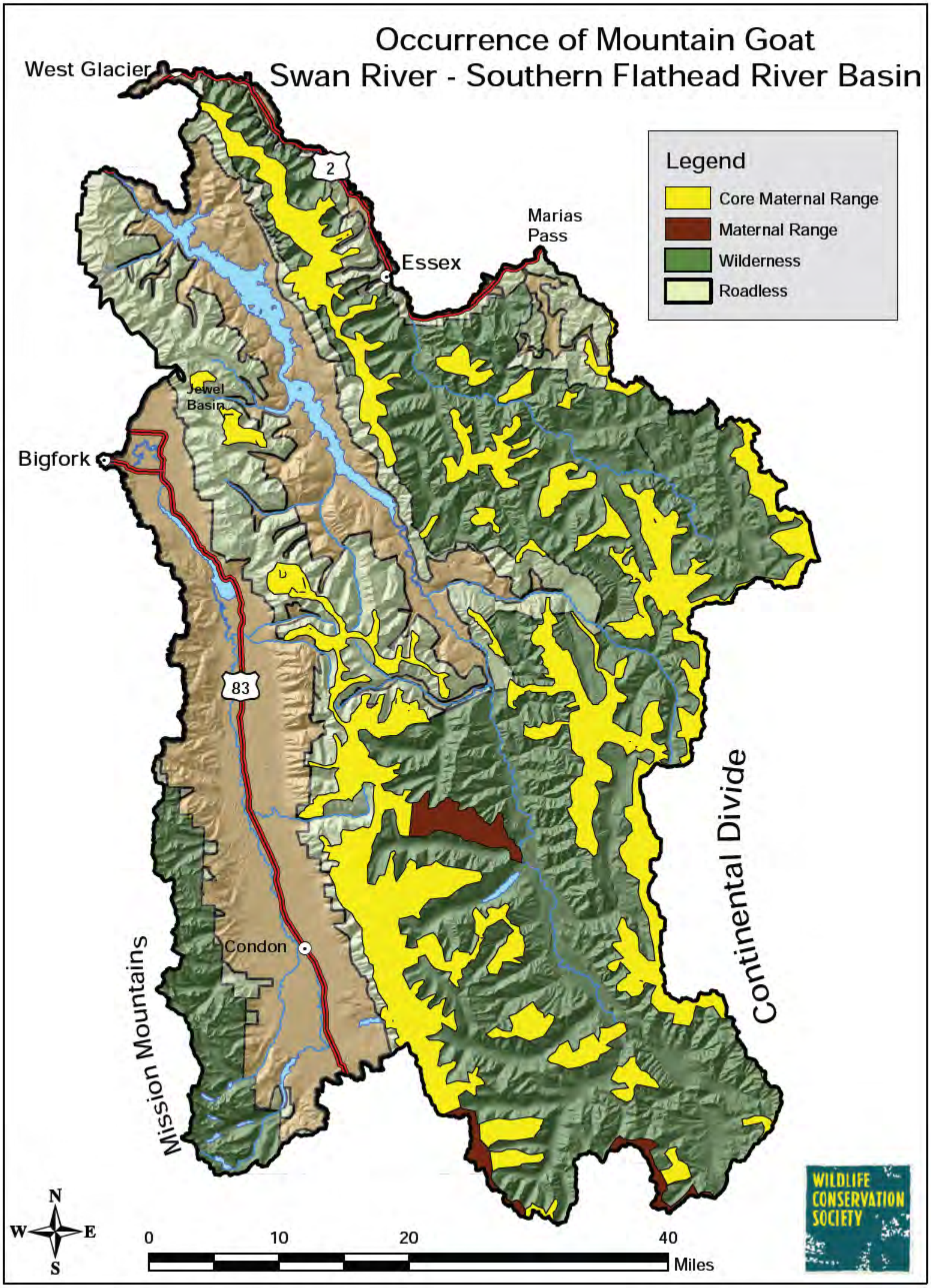


Figure 26. Ranges of mountain goat, Swan River and Southern Flathead River Basin, Crown of the Continent Ecosystem, Montana.



Synthesis of Conservation Values

In this section, I synthesize pertinent information about the distribution of vulnerable fish and wildlife species, terrain options for response to climate change, and connectivity to other important landscapes. To provide more nuanced assesssment, I discuss the composite conservation values and features of several roadless units within the Swan River-Southern Flathead River basin. I have organized this discussion and recommendations according to the geographic areas used in the proposed Forest Plan for the Flathead National Forest (2006).

Swan Valley roadless unit

The roadless area in the southern Swan Valley (west of Swan Range crest) from above Holland Lake north to Bond Creek has *outstanding* value for conservation of vulnerable fish and wildlife.

- Compared to other roadless areas in the Crown of the Continent Ecosystem in Montana, a larger portion of this roadless unit (and adjacent roadless areas in Bunker Creek) scored **very high** in *composite* conservation value for the five vulnerable species (Figure 27). Most of these very high composite values were concentrated in the southern section of the Swan Range, from Holland Lake north to North Fork Lost Creek and many lay adjacent to the Bob Marshall Wilderness. A small roadless block in Elk Creek along the edge of the Mission Mountains Wilderness scored high in composite conservation value, too
- The southern section of the Swan Valley roadless unit has very high conservation value for bull trout, whereas a few streams scored high for westslope cutthroat trout. Most of the area scored very high for grizzly bears due to relatively high density, productive habitats and high security. This section also scored very high in conservation value for wolverine because of the extent, connectivity, and likely persistence of maternal habitat in this snowy area. The crest of the Swan Range in this section scored very high in conservation value for mountain goats, too. In addition, subalpine basins and ridges in the roadless portion of the southern Swan Range provide summer/fall range for elk that winter in the Swan Valley.
- This same section of the Swan Range also was the only roadless area in the Crown of the Continent Ecosystem in Montana to attain a score of very high in elevation and terrain variation, which may provide critical options in the face of climate change.
- Much of this roadless area that is so valuable for vulnerable fish and wildlife is an integral part of a larger block of habitat that extends eastward into the Bob Marshall Wilderness.

The roadless area in the northern Swan Valley unit (west of Swan Range crest) from Bond Creek north to above Blaine Lake has important values for conservation of vulnerable fish and wildlife.

- Most of the remaining roadless area in the Swan Range has **high** composite conservation value (Figure 27). Moderate composite values were found along the lower elevation edge of roadless areas in the Swan and Flathead valleys.

- The northern section of the Swan Valley roadless unit does not contain streams of direct conservation value for bull trout or westslope cutthroat trout. Of course, water from these streams flows west eventually into Swan Lake or Flathead Lake, which have been designated as critical habitat for bull trout. Thus, maintaining capacity of these streams to provide clean, cold water remains important. For grizzly bears, this roadless area scored very high (Jewel Basin) or high. It provides productive habitats and high security for adult female grizzlies. While considerable primary habitat for wolverines occurs in this northern section of the Swan Range, patches of maternal wolverine habitat become smaller in size and less connected. Few locations of instrumented wolverines were obtained during the 1970s on the west side of the Swan Range crest in this section. Also, few occurrences of mountain goats have been recorded on this side of the Swan Crest. This area scored uniformly high in variation of elevation and terrain ruggedness. In conclusion, the western slope of this northern roadless section of the Swan Range has relatively lower composite conservation value compared to the southern section.

South Fork (Flathead River) and Hungry Horse roadless unit

Both the west and east sides of South Fork Flathead River /Hungry Horse Reservoir have roadless areas (Figure 27). On the west side, substantial roadless lands extend westward up to the Swan Crest. Roads of various age and condition, however, extend up along many of the drainages, with various types of vehicle use/non-use and seasonal dates. Along the east shore of Hungry Horse Reservoir, a relatively narrow strip of roadless area occurs between the west boundary of the Great Bear Wilderness and roaded lands. I present the conservation values of the west side and east side roadless areas separately.

West Side of South Fork Flathead/Hungry Horse roadless unit:

Most of the roadless area along the west side of Hungry Horse Reservoir from Bunker Creek north to Columbia Mountain has *outstanding* value for conservation of vulnerable fish and wildlife.

- Nearly all of this roadless area scored **very high** or **high** in *composite* conservation value for the five vulnerable species; some lower elevation sites had moderate value (Figure 27). Very high values were concentrated in Bunker Creek and upper Sullivan Creek.

- The South Fork Flathead River is a stronghold for both bull trout and genetically-pure populations of westslope cutthroat trout. Several tributaries scored very high in conservation value for bull trout, and nearly all streams scored very high for westslope cutthroat trout. Most of the area scored very high value for grizzly bears due to relatively high density, productive habitats and high security. Other areas (e.g., vicinity of Doris Mountain) scored high in conservation value and appear to be receiving increased use by grizzly bears. Subalpine basins and ridges scored very high in conservation value for wolverine because of the extent, connectivity, and likely persistence of maternal habitat in this snowy area. The wolverine study during the 1970s documented wolverine use in nearly every drainage. Cliff bands in Bunker Creek and rugged peaks in Jewel Basin scored very high in conservation value for mountain goats, too. In addition, subalpine basins and ridges in Bunker Creek and Bruce Ridge provide summer/fall range for some of the elk that winter along the South Fork Flathead River in the vicinity of Spotted Bear (Simmons 1974, Biggins 1975, Fuller 1976). This area scored uniformly high in range-of-elevation and terrain ruggedness.

East Side of South Fork Flathead/Hungry Horse roadless unit:

- The Great Bear Wilderness boundary extends down to mid-slope along the east side of Hungry Horse Reservoir. In the narrow strip of remaining roadless lands, there is a mix of very high, high, and moderate composite conservation values for the five vulnerable species (Figure 27).
- Although the amount of roadless area is small, key sections in Spotted Bear and near Mt Baptiste have high to very high conservation values. Nearly all streams draining into the east side of Hungry Horse Reservoir and the Spotted Bear River scored very high in conservation value for westslope cutthroat trout, and the Spotted Bear River also scored very high for bull trout. The roadless section from Logan Creek (Unawah Mountain) south to Baptiste Creek (Circus Peak) scored very high for grizzly bear, wolverine and mountain goats and is part of a larger block of connected habitat for these species.
- Other areas on the east side have high to moderate values for these vulnerable species. In addition, the roadless high country from Margaret Creek south to Canyon Creek provide summer/fall range for the Firefighter Mountain elk herd that winters along the east shore of Hungry Horse Reservoir (Vore et al. 1995). This narrow roadless unit is steep, with substantial range of elevation and terrain variation.

Middle Fork (Flathead River) roadless unit

Much of the Middle Fork Flathead River watershed is protected within the Great Bear Wilderness and the Bob Marshall Wilderness. Of the remaining roadless areas, the most substantial acreage occurs in the Skyland-Slippery Bill Mountain area south of Marias Pass (termed the ‘upper section’) and downstream of Bear Creek/Essex (termed the ‘lower section’).

- The upper section has important values for the conservation of vulnerable fish and wildlife, especially around Slippery Bill Mountain (including Puzzle Creek) which scored **very high** in *composite* conservation value (Figure 27). The headwaters of Morrison and Granite Creeks scored very high for bull trout and westslope cutthroat trout. Slippery Bill Mountain has numerous avalanche chutes – and riparian zones extend along Puzzle Creek, Crescent Creek, and Morrison Creek – that provide excellent habitat for grizzly bears. Slippery Bill Mountain and Crescent Cliff also scored very high in conservation value for wolverine and mountain goat and connect to habitat across the Continental Divide into the Badger-Two Medicine roadless area.
- In addition, a herd of elk winters along the Middle Fork of the Flathead River between Granite Creek and Vinegar Creek (McDonald 1980). In spring, many of these elk migrated north and east following Twenty-five Mile, Granite, and Morrison Creek drainages (Smith 1978). Calving and summer ranges centered on the high country along the Continental Divide, including the headwater areas of Puzzle Creek and Crescent Creek east of Slippery Bill Mountain and north of Skyland Creek. Both elk and mountain goats made extensive use of a large mineral lick at the head of Puzzle Creek. Smith (1978) recommended that the Puzzle Creek area so critical to elk be closed permanently.
- Other sites within this upper section had high composite value– primarily for grizzly bear, wolverine, and westslope cutthroat trout.
- The lower section of the Middle Fork Flathead River roadless unit has important values for the conservation of vulnerable fish and wildlife, particularly in the Paola-Tunnel Ridge area. The Middle Fork has been designated as critical habitat for bull trout, and some tributaries (Essex and Tunnel Creek) have very high value for westslope cutthroat trout. Paola-Tunnel Ridge has very high value for grizzly bears and wolverines and may serve as a connector to the east side of Hungry Horse Reservoir.

Recommendations for Wildland Protection

For the Swan River – Southern Flathead River basin, I recommend that 253,554 roadless acres (67.3%) be designated as Wilderness (Table 4, yellow highlight areas in Figure 28).

As additions to the Bob Marshall Wilderness, I recommend 72,815 acres in:

✓ the Swan Range from Holland Lake north to Inspiration Point, and

✓ an area around Spotted Bear Mountain.

As additions to the Mission Mountains Wilderness (USFS), I recommend 7,137 acres in:

✓ small areas in Elk Creek and Piper Creek and around upper Lindbergh Lake.

As additions to the Great Bear Wilderness, I recommend 173,602 acres in:

✓ higher portions of the Swan Range from Bunker Creek north to Columbia Mountain,

✓ above the east shore of Hungry Horse Reservoir, the basins from Unawah Mountain south to Dry Park Mountain,

✓ Paola Ridge area above the lower Middle Fork Flathead River, and

✓ Slippery Bill Mountain and Patrol Ridge area along the Continental Divide in the Middle Fork of the Flathead River basin.

These additions would protect the highest-value habitats and connectivity for these vulnerable fish and wildlife, provide options for future responses to climate change, and add value to existing Wilderness.

I further recommend that 106,286 acres (28.2%) be managed in roadless condition as 'Backcountry' with emphasis on non-motorized recreation and conservation of fish and wildlife (Table 4, green areas in Figure 28). These are mostly lower elevation sites that have lesser (moderate) conservation value for these vulnerable fish and wildlife. Areas recommended for Backcountry designation include:

- lower slopes along the west side of the Swan Range from Swan Lake north above Lake Blaine (note: an argument could be made that because the northern part of the Swan Range is fairly narrow, wilderness designation for this roadless section along the western slope would augment recommended wilderness on the east side),

- smaller blocks on the north side of Columbia Mountain, Jimmy Ridge, and upper Jungle Creek basin along the west shore of Hungry Horse Reservoir, all of the remaining roadless area above the east shore of Hungry Horse Reservoir from

- all of the remaining roadless area above the east shore of Hungry Horse Reservoir from head of Emery Creek south to Horse Ridge_and north side of Spotted Bear River (arguably some of the north end could be considered for Wilderness), and

- the narrow strip of roadless along the Middle Fork of the Flathead River from West Glacier east to Marias Pass (these areas along Highway 2 may be very important to ensure connectivity between Glacier National Park and the Great Bear Wilderness).

A number of primitive roads extend westward from Hungry Horse Reservoir and penetrate rather deeply into the narrow Swan Range. Most of these were constructed for timber harvest back during the 1960-1970s. In recognition of the important fish and wildlife values in the Swan Range, the Flathead National Forest has closed many of these roads on a permanent or seasonal basis. Nonetheless, some of these roads still receive unauthorized ATV use or may be open to snow machine use in winter which, in some cases, may impact wildlife.

I recommend that 65 miles of primitive roads be considered for wildland restoration (de-commissioned or otherwise permanently closed and returned to more natural condition). These include roads in the following headwater drainages (north to south along the west side of Hungry Horse Reservoir/shown in blue in Figure 28):

- Silver Run Creek in upper Doris Creek,
- upper end of Lost Johnny Creek,
- middle and upper sections of Wildcat Creek,
- Aeneas Creek,
- upper end of Wheeler Creek,
- upper end of Quintonkon Creek and Posey Creek,
- upper end of west tributaries to Sullivan Creek, and
- north and middle forks of Bunker Creek (especially important).

Assuming a displacement effect of 150 m on each side of these roads, the total acreage would sum to 1,569 acres (0.4%).

Finally, a few lower-elevation blocks of roadless areas totaling 15,185 acres (4.0%) along the west shore of Hungry Horse Reservoir have little value for this particular suite of species, and I have left them as 'other roadless area' pending other management decisions (Table 4, shown in brown in Figure 28).

Table 4. Number of acres recommended for Wilderness, Backcountry, Other Roadless, and Wildland Restoration Zone (WRZ), Swan River – Southern Flathead River basin, Crown of the Continent Ecosystem, Montana.

Roadless Unit	Wilderness		Backcountry		Other Roadless		WRZ	
	Ac	%	Ac	%	Ac	%	Ac	%
Swan River Valley	74,248	74.8	19,534	19.7	5,291	5.3	167	0.2
South Fork/Hungry Horse	157,845	67.7	64,558	27.7	9,894	4.2	1025	0.4
Middle Fork	21,461	48.7	22,194	50.4	–	–	377	0.9
TOTAL	253,554	67.3	106,286	28.2	15,185	4.0	1,569	0.4

Figure 27. Composite conservation values for suite of vulnerable fish and wildlife species, Swan River and Southern Flathead River Basin, Crown of the Continent Ecosystem, Montana.

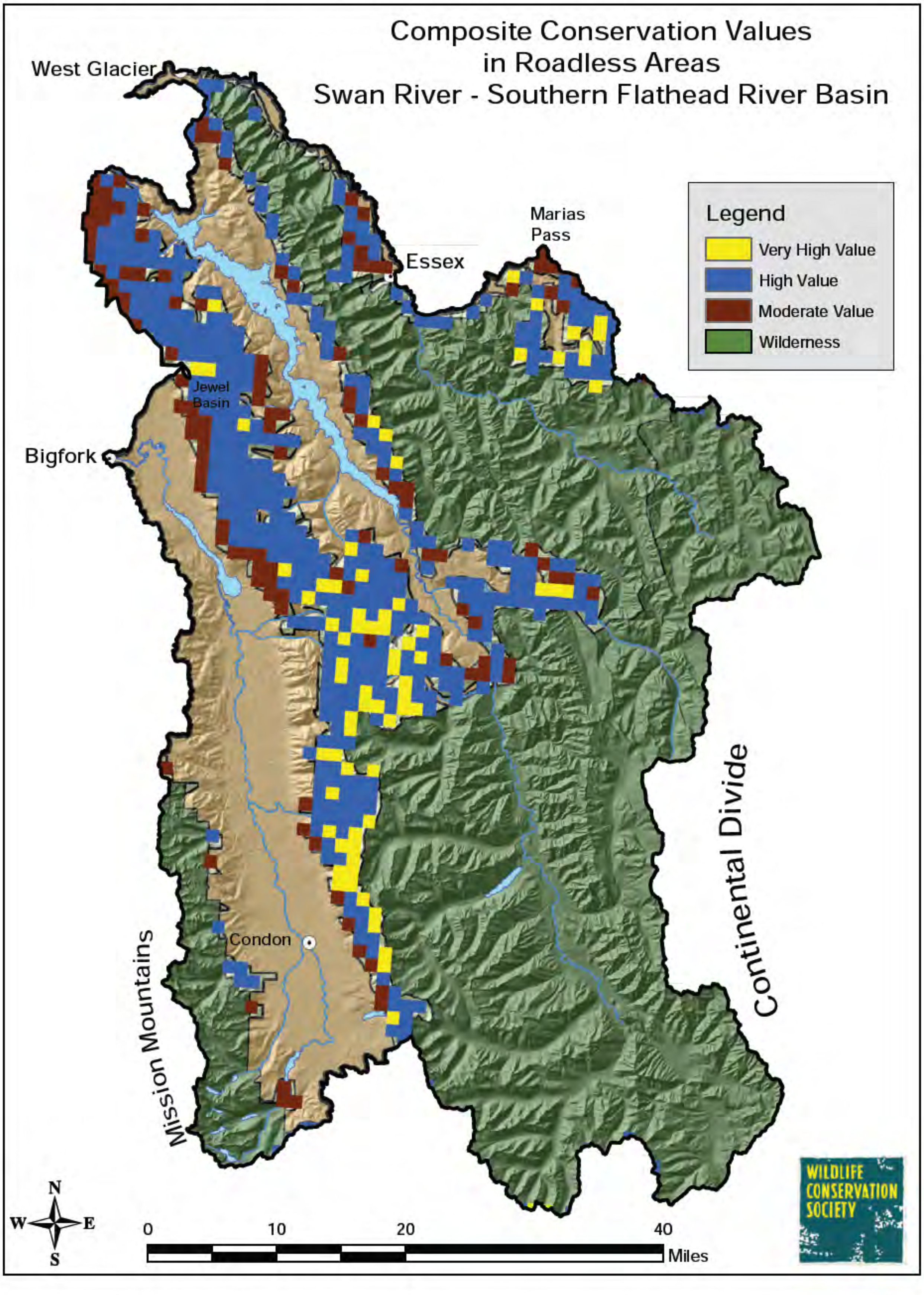
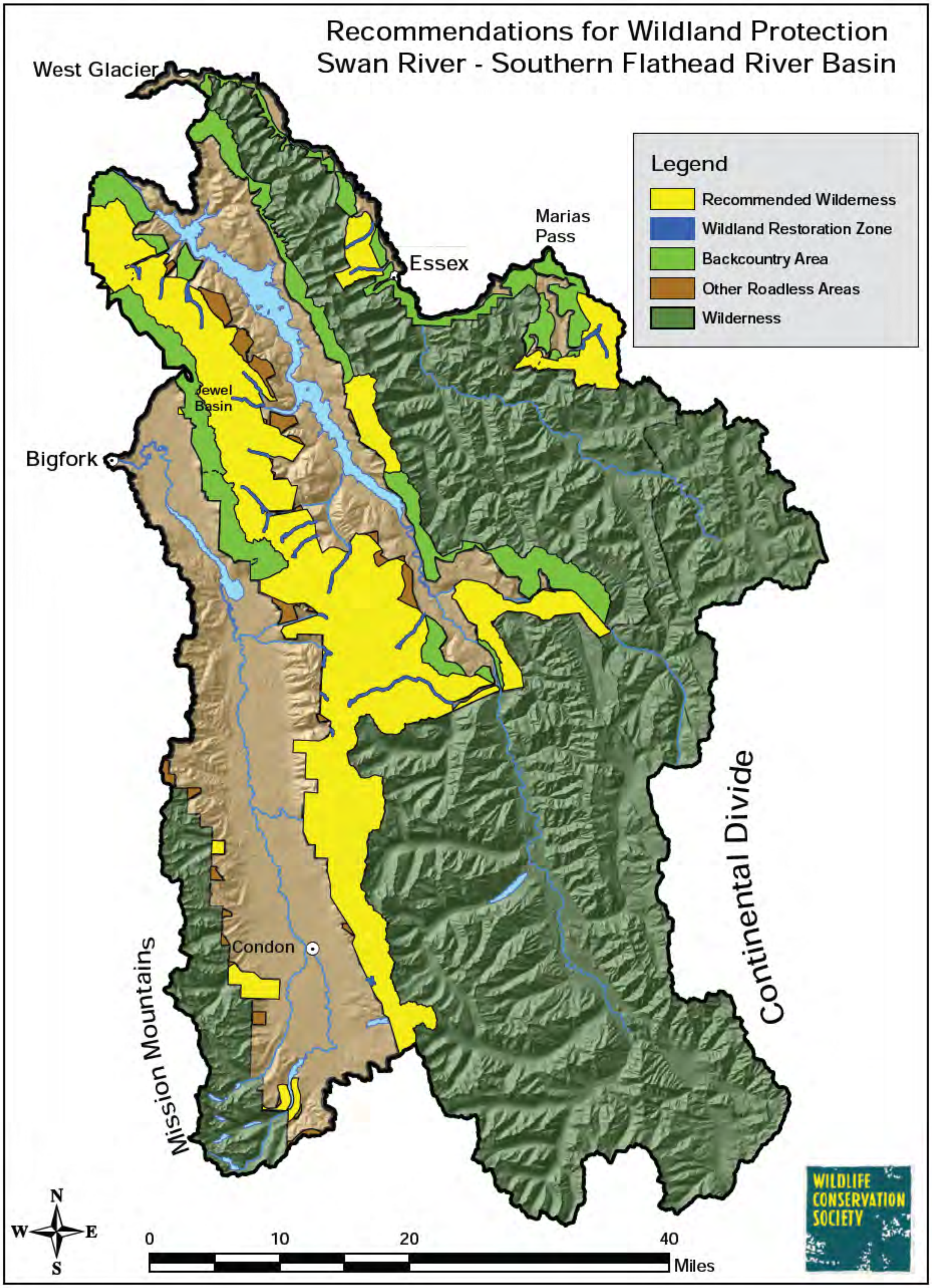


Figure 28. Recommendations for wildland protection, Swan River and Southern Flathead River Basin, Crown of the Continent Ecosystem, Montana.



7. NORTH FORK FLATHEAD RIVER BASIN AND TEN LAKES AREA

John L. Weaver

The North Fork Flathead River Basin and Ten Lakes roadless area drapes over the Whitefish Range along the western edge of the Crown of the Continent Ecosystem in Montana. The North Fork Flathead River begins in British Columbia and meanders southward through a broad basin and across the international border, marking the west boundary of Glacier National Park. A mix of roadless and logged Forest Service lands occurs west of the Flathead River. International concern and attention to conservation issues in this critical trans-boundary watershed have increased markedly in recent times. The Ten Lakes Scenic Area is the centerpiece of a roadless area on the west side of the Whitefish Range. Approximately 272, 443 acres of *roadless* lands exist currently in the North Fork Flathead River Basin and Ten Lakes area. What is their conservation value for vulnerable fish and wildlife species?

Bull Trout

The entire North Fork Flathead River and many of its tributaries have been designated as critical habitat for bull trout (USFWS 2010). Designated tributaries on the west side of the North Fork (Flathead National Forest) with their source in the roadless Whitefish Range include: Trail Creek, Whale Creek and Shorty Creek, Red Meadow Creek, North Fork and South Fork Coal Creek, and Big Creek and its upper tributary Hallowat Creek (Figure 29). Bull trout using different tributaries have unique genetic differences (Kanda and Allendorf 2001). Thus, maintaining local populations is vital to safeguard genetic diversity and to promote long-term persistence of bull trout (Spruell et al. 1999, Spruell et al. 2003). Bull trout migrate upwards of 250 km between Flathead Lake and upper tributaries during their long life history (Fraley and Shepard 1989, Muhlfeld and Marotz 2005). A major concern in conservation and recovery of bull trout in the Flathead River basin is competition and predation by non-native lake trout (Martinez et al. 2009, USFWS 2010).

In the Grave Creek drainage of the Kootenai River basin, critical habitat for bull trout has been designated for the following streams: Grave Creek, Clarence Creek, lower section of Blue Sky Creek, above Frozen Lake, and upper Wigwam River (Figure 29). Bull trout also have been mapped as 'abundant' in Lewis Creek, Rich Creek, Stahl Creek, and Williams Creek where some rearing may take place. A resident population of bull trout may spawn in a lake at the head of Williams Creek near Krinklehorn Mountain (M. Hensler, Montana FWP, *personal communication*).

Westslope Cutthroat Trout

Westslope cutthroat trout occur throughout the North Fork Flathead River watershed, albeit with a wide spectrum of genetic integrity (Figure 30). Most of the genetic introgression by non-native rainbow trout has occurred in the lower-elevation, warmer streams in the lower section of the drainage, which are closer to the main source of hybridization (Boyer et al. 2008, Muhlfeld et al. 2009b). Nonetheless, numerous streams in the North Fork Flathead River still have pure strains of westslope cutthroat trout. Those streams with either headwaters and/or occupied reaches in roadless areas include: Colts Creek, Trail Creek and several tributaries, Whale Creek and several tributaries, Moose Creek, Red Meadow Creek (but Red Meadow Lake may becoming a source of introgression), upper Hay Creek, Moran Creek, and upper sections of Big Creek and tributaries (Muhlfeld et al. 2009a, Muhlfeld et al. 2009b).

In the Grave Creek drainage of the Kootenai River basin, westslope cutthroat trout occur in the following streams: Williams Creek, upper section of Blue Sky Creek, upper Stahl Creek, Foundation Creek, above Frozen Lake, and Rich Creek (Figure 30) (M. Hensler, Montana FWP, *personal communication*). According to the most recent assessment of westslope cutthroat trout in 2009, these are assumed to be pure (<1% introgression) and thus are considered core conservation populations.

Grizzly Bear

Relative density of grizzly bears is high throughout much of the North Fork Flathead River basin (Fig. 31). For areas near the Canadian border such as Trail Creek, the apparent low/moderate relative densities may represent an artifact due to constraining effects of the edge of the study area on computer modeling. Locations of radio-collared grizzly bears are certainly common in the Trail Creek area, with some home ranges spanning the international border (R. Mace, Montana FWP, *unpublished data*). It's likely that this area supports moderate to high relative densities to the border. Indeed, the highest densities of grizzly bears reported for interior North America have been documented in this trans-border area (McLellan 1989, Hovey and McLellan 1996). Importantly, much of the North Fork Flathead River basin supports family groups of grizzly bears, whereas the Smoky Range in the south end seems to be dominated by male grizzlies (R. Mace and T. Manley, Montana FWP, *unpublished data*).

In the Grave Creek drainage of the Kootenai River basin, relative density of grizzly bears appears moderate or high (Figure 31). Again, the apparent low density shown for a portion of the Ten Lakes Scenic Area near the Canadian border may be an artifact of modeling, and the actual density may be higher.

Wolverine

Suitable habitat for wolverine occurs throughout much of the North Fork Flathead River basin (Figure 32). Large blocks of primary wolverine habitat are rather ubiquitous across all of the roadless sections on the west side of the river. Blocks of maternal wolverine habitat are large and well-connected in the northern roadless sector of the North Fork Flathead River basin but become progressively smaller and less connected toward the south and southeast.

This same general pattern characterizes wolverine habitat in the Grave Creek drainage of the Kootenai River basin (Figure 32). East of Grave Creek, blocks of both primary and maternal habitat are part of larger complexes that extend across the Whitefish Range into the North Fork Flathead River basin. These become smaller and less connected at the south end near Mount Marston. West of Grave Creek, there are large and well-connected blocks from the Mount Wam area south to Gibralter Ridge and northwest up through the Ten Lakes Scenic Area.

Mountain Goat

According to Casebeer et al. (1950), upwards of 40-50 mountain goats occurred during the late 1940s in three areas in the North Fork Flathead River basin: (1) Mount Thompson Seton – Hornet Mountain – Cleft Rock Mountain north of Whale Creek (est. 15 goats), (2) Nasukoin – Mount Young – Lake Mountain north of Red Meadow Creek (est. 30 goats), and (3) Smoky Range between Big Creek and Canyon Creek (est. 5 goats). The Nasukoin complex provided the largest expanse of suitable habitat at that time. It is doubtful if any goats occur in any of these areas at this time (T. Thier, Montana FWP, *personal communication*).

Bighorn Sheep

A herd of approximately 100 bighorn sheep spends the summer and fall in the Ten Lakes area and winter and spring on the Woods Ranch Wildlife Management Area (Montana FWP) and Kootenai National Forest lands near the Canadian border at Roosville (Figure 33) (Johnson 1993; Montana FWP 2009; T. Thier, Montana FWP, *personal communication*). This trans-boundary herd is known as the 'Ten Lakes' herd in Montana and the 'Phillips Creek' herd in British Columbia, where it has summer range and some winter range (Johnson 1993). It may be the only hunted herd of bighorn sheep that is shared between the United States and Canada (≈ 1-2 rams taken per year). Notably, this is one of only two herds native to northwest Montana, and these sheep possess a different genotype than bighorn sheep elsewhere in Montana (Montana FWP 2009). Montana FWP has invested considerable effort and funds toward the conservation of this herd.

Synthesis of Conservation Values

In this section, I synthesize pertinent information about the distribution of vulnerable fish and wildlife species, terrain options for response to climate change, and connectivity to other important landscapes. Then, I make recommendations for Wilderness (high-priority lands) and Backcountry (medium-priority lands) designation in remaining roadless areas. I have organized this discussion and recommendations according to the: (1) North Fork Flathead River geographic area used in the proposed Land Management Plan for the Flathead National Forest (2006), and (2) Tobacco geographic area used in the proposed Land Management Plan for the Kootenai National Forest (2006).

North Fork Flathead River roadless unit

Several roadless areas in the North Fork Flathead River basin have *outstanding* value for conservation of vulnerable fish and wildlife.

- Much of the roadless area in the North Fork Flathead River basin scored **high** in *composite* conservation value for the five vulnerable species (Figure 34). A few places – notably in the Mount Thompson Seton-Akinkoka Peak area – scored **very high**.
- The section of the North Fork Flathead River roadless unit from Red Meadow Creek north to the Canadian border has larger blocks with high composite value that are connected across the Whitefish Divide to other high-value areas on the Kootenai National Forest (Figure 34). Moreover, this section connects with important wildlife areas across the Canadian border in British Columbia (Weaver 2001). This northern section has very high conservation value for bull trout and westslope cutthroat trout, very high and high values for grizzly bears, and very high value in terms of maternal wolverine habitat. High values for range-of-elevation and terrain ruggedness provide options for movement in response to climate change, too.

Figure 29. Critical habitat for bull trout, North Fork Flathead River Basin and Ten Lakes area, Crown of the Continent Ecosystem, Montana.

Figure 30. Conservation populations of westslope cutthroat trout, North Fork Flathead River Basin and Ten Lakes area, Crown of the Continent Ecosystem, Montana.

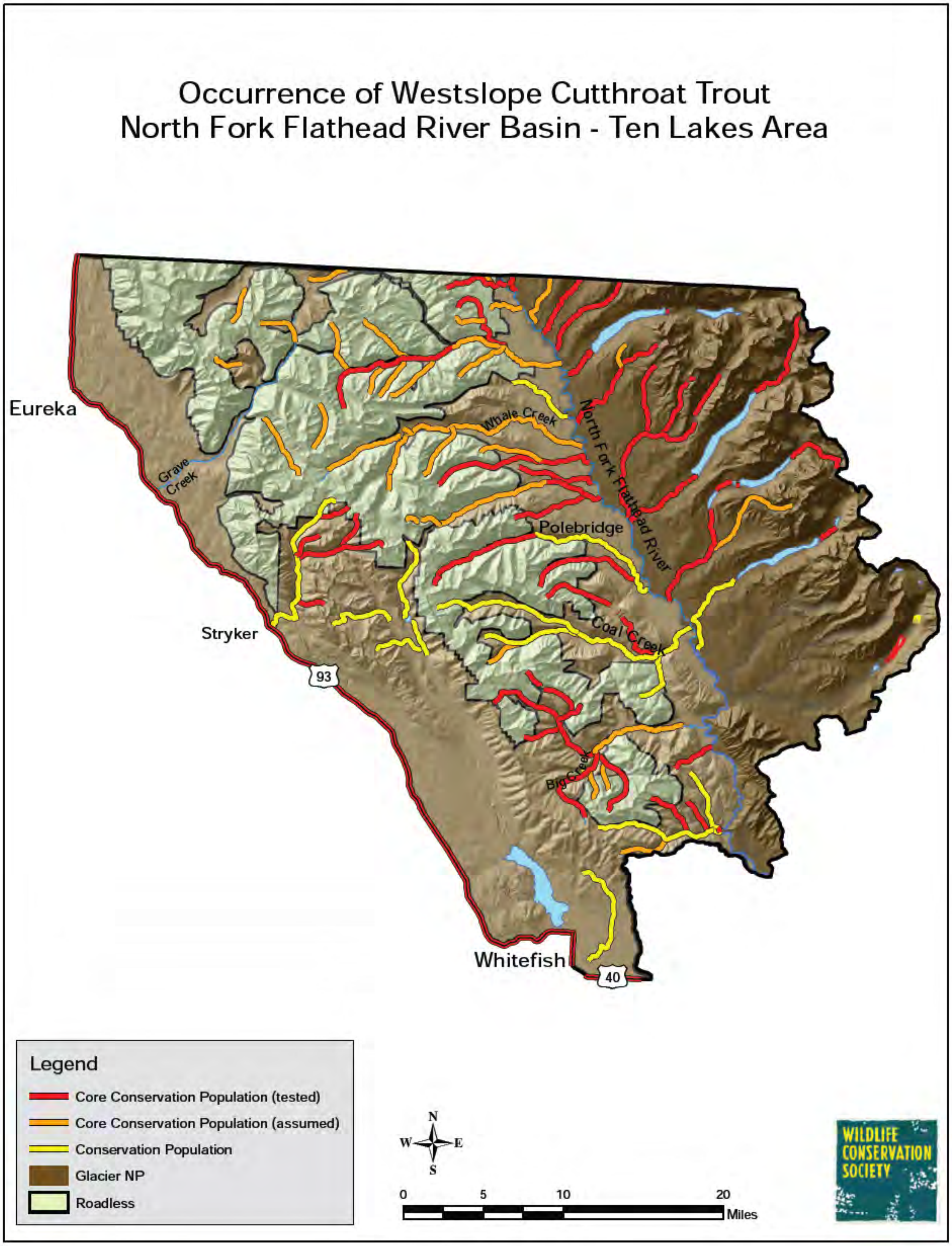


Figure 31. Relative density of grizzly bears, North Fork Flathead River Basin and Ten Lakes area, Crown of the Continent Ecosystem, Montana.

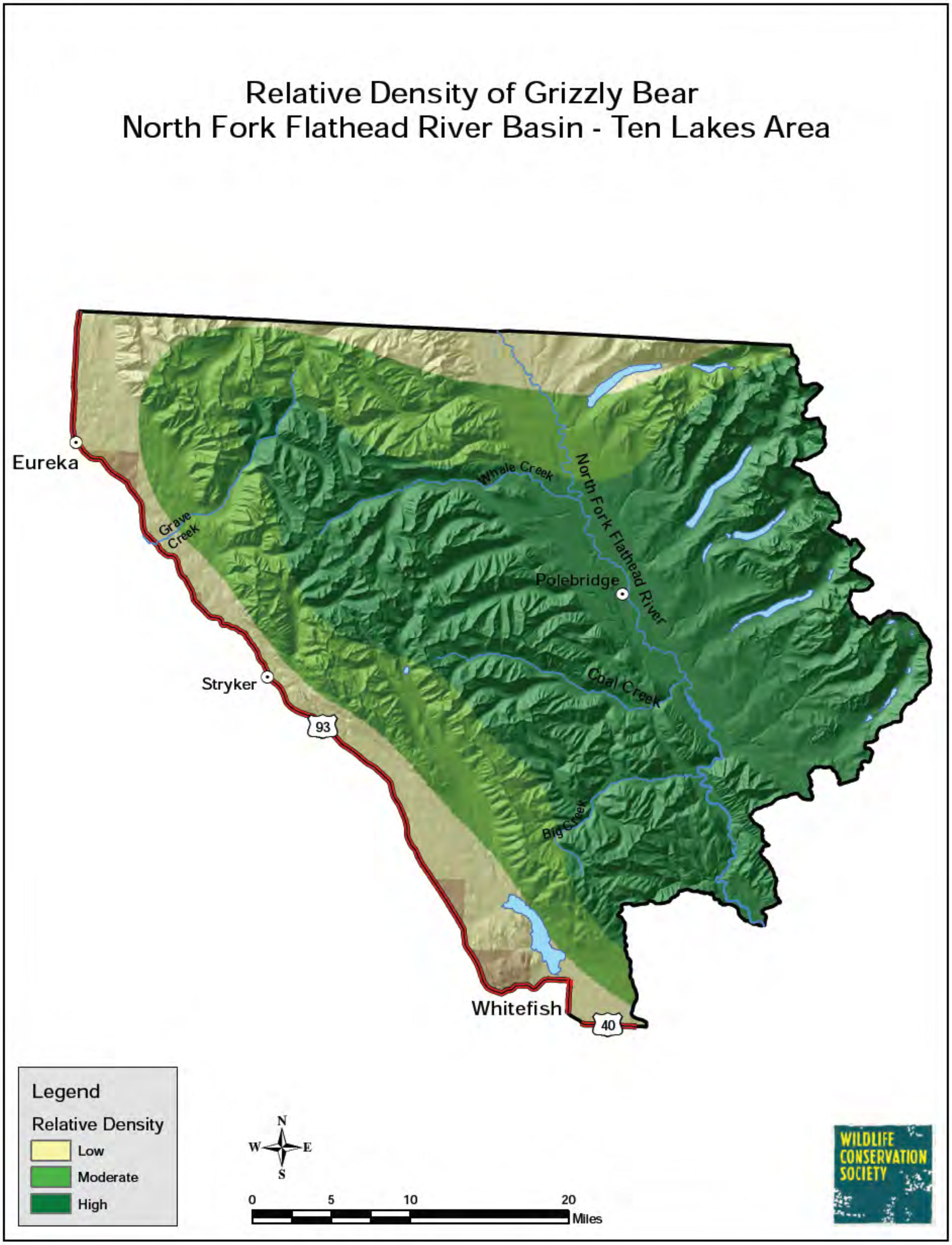


Figure 32. Primary and maternal habitat for wolverine, North Fork Flathead River Basin and Ten Lakes area, Crown of the Continent Ecosystem, Montana.

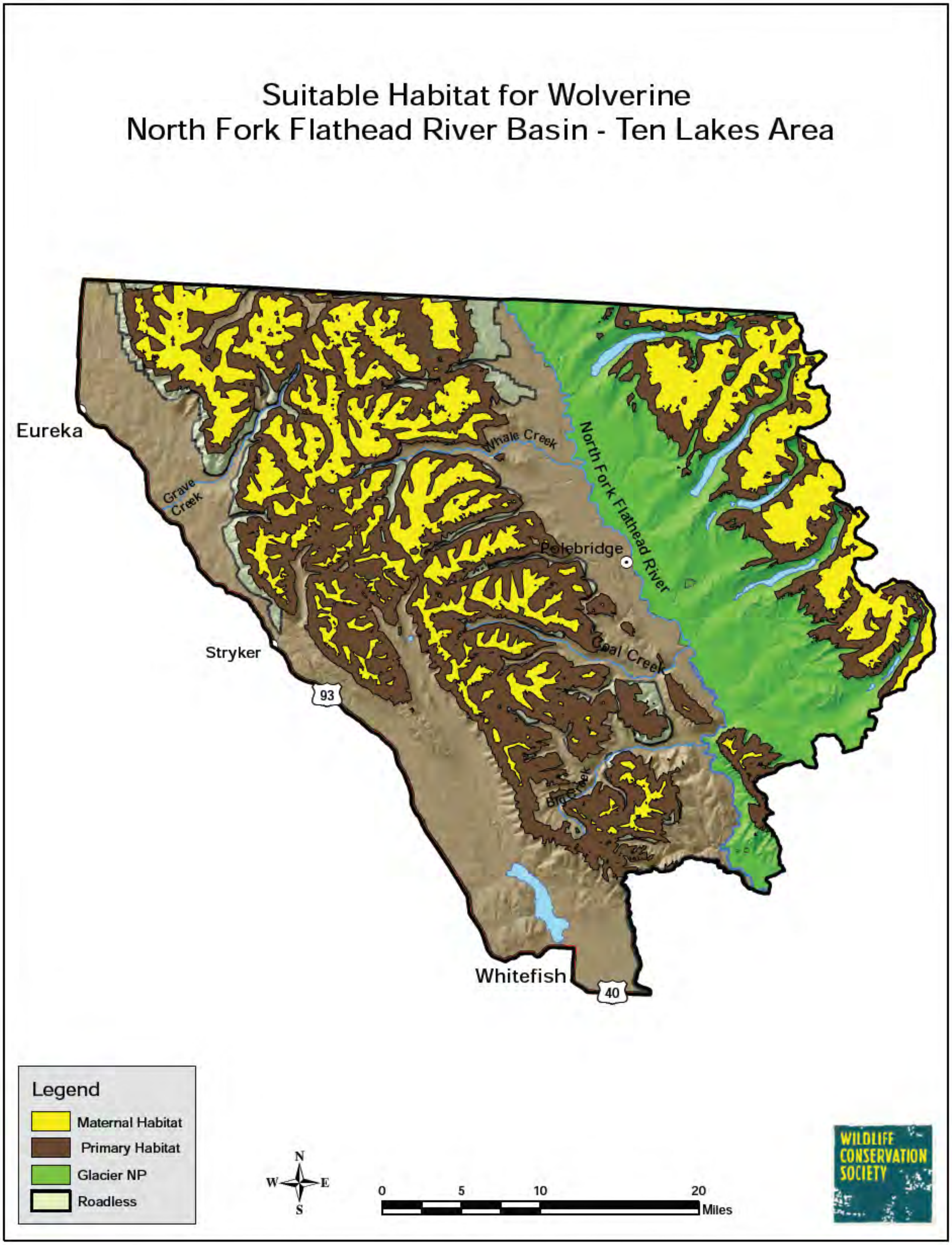


Figure 33. Seasonal ranges of bighorn sheep, North Fork Flathead River Basin and Ten Lakes area, Crown of the Continent Ecosystem, Montana.

- The southern section of roadless areas in the North Fork Flathead River basin also has patches of high conservation value but they are smaller in size, less well-connected, and closer to areas with intensive resource extraction and/or non-native species (Figure 34). This southern section has some very high conservation streams for bull trout, but westslope cutthroat trout are more compromised by genetic introgression from rainbow trout. Some areas have productive habitat for grizzly bears, but extensive roads penetrate further westward and compromise habitat security. Blocks of maternal wolverine habitat become smaller and more isolated at the southern tip of roadless areas. These may shrink even further in the future if warming winter temperatures reduce critical snowpack at low to mid-elevations. In this southern section of the North Fork Flathead River basin, comparatively more of the conservation value for these vulnerable species is found in the roadless headwaters of drainages closer to the Whitefish Divide.

Ten Lakes roadless unit

Several roadless areas in the Ten Lakes area and along the Whitefish Divide have *outstanding* value for conservation of vulnerable fish and wildlife.

- The heart of the roadless area around the Ten Lakes Scenic Area and along the Whitefish Divide_scored **high** in *composite* conservation value for the five vulnerable species (Figure 34). The western and southern edges of these roadless areas at lower elevations mostly scored lower (moderate) in composite conservation value.
- Graves Creek and Wigwam River scored very high conservation value for bull trout, and some of their tributaries scored high for westslope cutthroat trout as well. Much of the Whitefish Divide scored very high in conservation value for grizzly bear, whereas most of the Ten Lakes area scored high. Both of these areas scored very high in conservation value for wolverines (attested by trapping of 24 wolverines in the Ten Lakes area 1985-1996: Weaver 2001). The Ten Lakes area provides important spring, summer, and fall range for a trans-border bighorn sheep herd with unique genetic composition, too. In addition, high values for range-of-elevation and terrain ruggedness will provide future options for movement in response to climate change. Finally, both the Ten Lakes and Whitefish Divide areas connect to important habitats across the Canadian border in British Columbia.
- The western and southern slopes of the roadless Ten Lakes area that drain into the Tobacco River and along Gibralter Ridge have lower conservation values for this suite of vulnerable species.
- The block of roadless area around Mount Marston adjacent to the western boundary of the Stillwater State Forest also has lower conservation values for them.

Recommendations for Wildland Protection Designation

For the North Fork Flathead River basin and Ten Lakes area, I recommend that 193,460 roadless acres (71.0%) be designated as **Wilderness** (Table 5, yellow highlight areas in Figure 35).

I recommend the following areas be designated as part of a new wilderness area (some suggest it be called the Winton Weydemeyer Wilderness):

- ✓ Thoma-Mount Hefty area,
- ✓ Tuchuck area,
- ✓ Mount Thompson-Seton south to Lake Mountain, including the head-water basins of Williams Creek and Blue Sky Creek on the west side of the Whitefish Divide,
- ✓ headwaters of Hay Creek and Coal Creek,
- ✓ south end of Whitefish Range from Haines Pass south to Werner Peak, and
- ✓ Ten Lakes Scenic Area and the area east of upper Wigwam River including Stahl Peak, Wam Peak, and north nearly to the Canadian border.

These additions would protect the highest-value habitats for these vulnerable fish and wildlife species, enhance connectivity with both Glacier National Park and the Canadian Flathead, and provide options for future responses to climate change. It would underscore a strong American commitment to protecting the ecological integrity of the trans-boundary Flathead region.

I further recommend that 63,890 acres (23.5%) be managed in roadless condition as 'Backcountry' with emphasis on non-motorized recreation and conservation of fish and wildlife (Table 5, green areas in Figure 35). These are sites that have lesser (moderate) conservation value for these vulnerable fish and wildlife. Areas recommended for Backcountry designation include:

- lower elevation sites between Trail Creek and the Canadian border,
- ridges between lower reaches of Hay Creek
- upper basin of Dead Horse Creek,
- the Smoky Range,
- Mount Marston-Patrick Ridge, and
- lower roadless slopes south and west of Ten Lakes Scenic Area from Gibralter Ridge northwest to the Canadian border.

Several primitive roads extend westward from main road up the North Fork Flathead River and penetrate deeply into the Whitefish Range. Most of these were constructed for timber harvest back during the 1960-1970s. In recognition of the important fish and wildlife values in the North Fork Flathead River basin, the Flathead National Forest has closed many of these roads on a year-round or seasonal basis. Nonetheless, some of these roads still receive unauthorized use by ATV and/or snowmobiles which, in some cases, may impact wildlife. I recommend that 17 miles of primitive roads in the following headwater drainages be considered for wildland restoration (de-commissioned or otherwise permanently closed and returned to more natural condition) (north to south along the west side of North Fork Flathead River/shown in blue in Figure 35):

- Trail Creek – Thoma Creek past Frozen Lake,
- Antley Creek (tributary to Yakinikak Creek),
- upper Hay Creek and south tributary,
- headwaters of South Fork Coal Creek and Mathias Creek, and
- upper Hallowat Creek.

Assuming a displacement effect of 150 m on each side of these roads, the total acreage would sum to 2,025 acres (0.7%). These measures would enhance habitat security for several species, as well as the spatial integrity (less fragmentation) of lands recommended for Wilderness designation.

Finally, a few peripheral blocks of roadless lands totaling 13,068 acres (4.8%) along the west side of the North Fork Flathead River have little value for these particular species, and I have depicted them as 'other roadless area' pending other management decisions (Table 5, shown in brown in Figure 35).

Table 5. Number of acres recommended for Wilderness, Backcountry, Other Roadless, and Wildland Restoration Zone (WRZ), North Fork Flathead River Basin and Ten Lakes area, Crown of the Continent Ecosystem, Montana.

Roadless Unit	Wilderness		Backcountry		Other Roadless		WRZ	
	Ac	%	Ac	%	Ac	%	Ac	%
North Fork Flathead River	127,160	71.0	37,400	20.9	12,433	7.0	2025	1.1
Ten Lakes area	66,300	71.0	26,490	28.4	635	0.6	–	–
TOTAL	**193,460**	**71.0**	**63,890**	**23.5**	**13,068**	**4.8**	**2,025**	**0.7**

Figure 34. Composite conservation values for suite of vulnerable fish and wildlife species, North Fork Flathead River Basin and Ten Lakes area, Crown of the Continent Ecosystem, Montana.

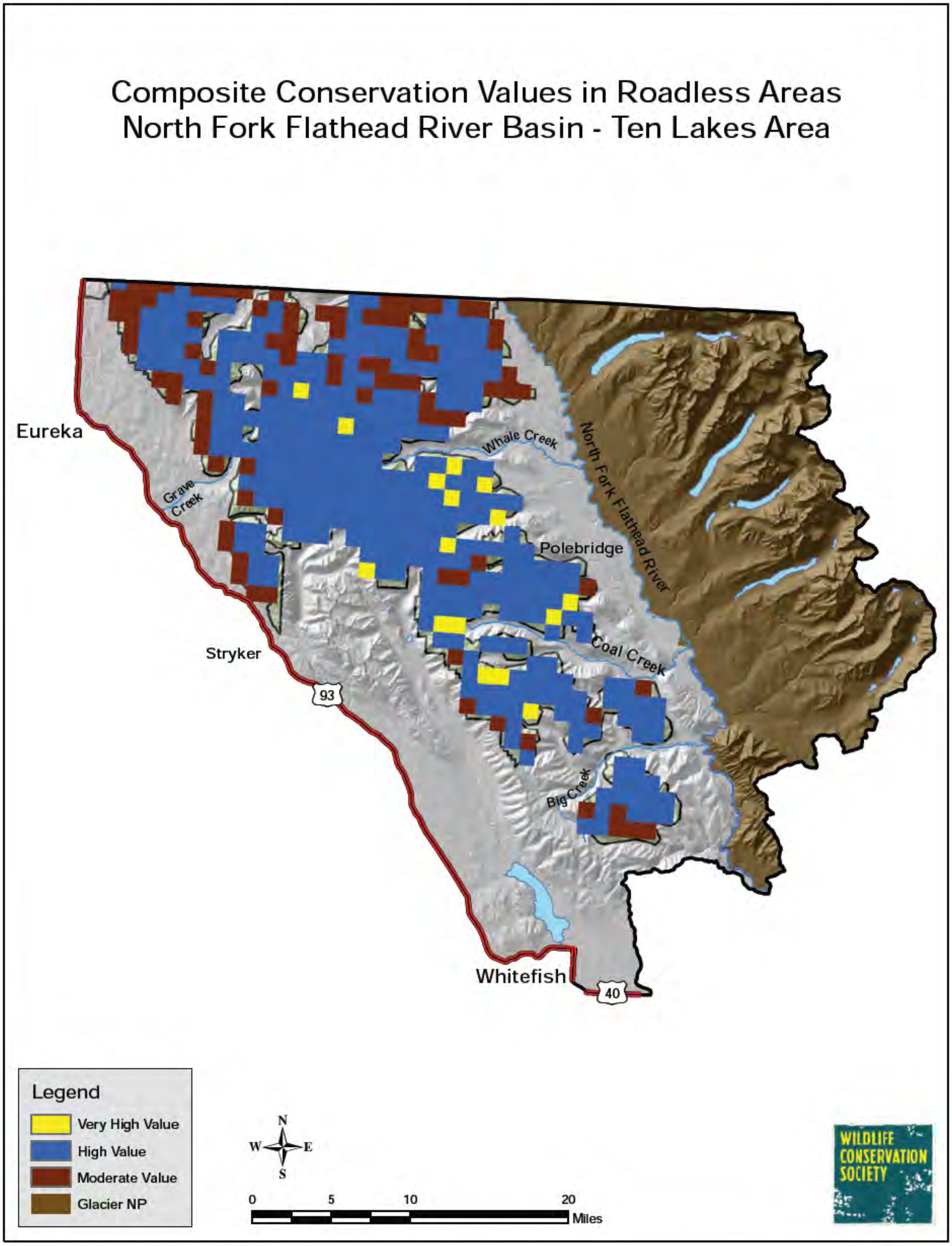
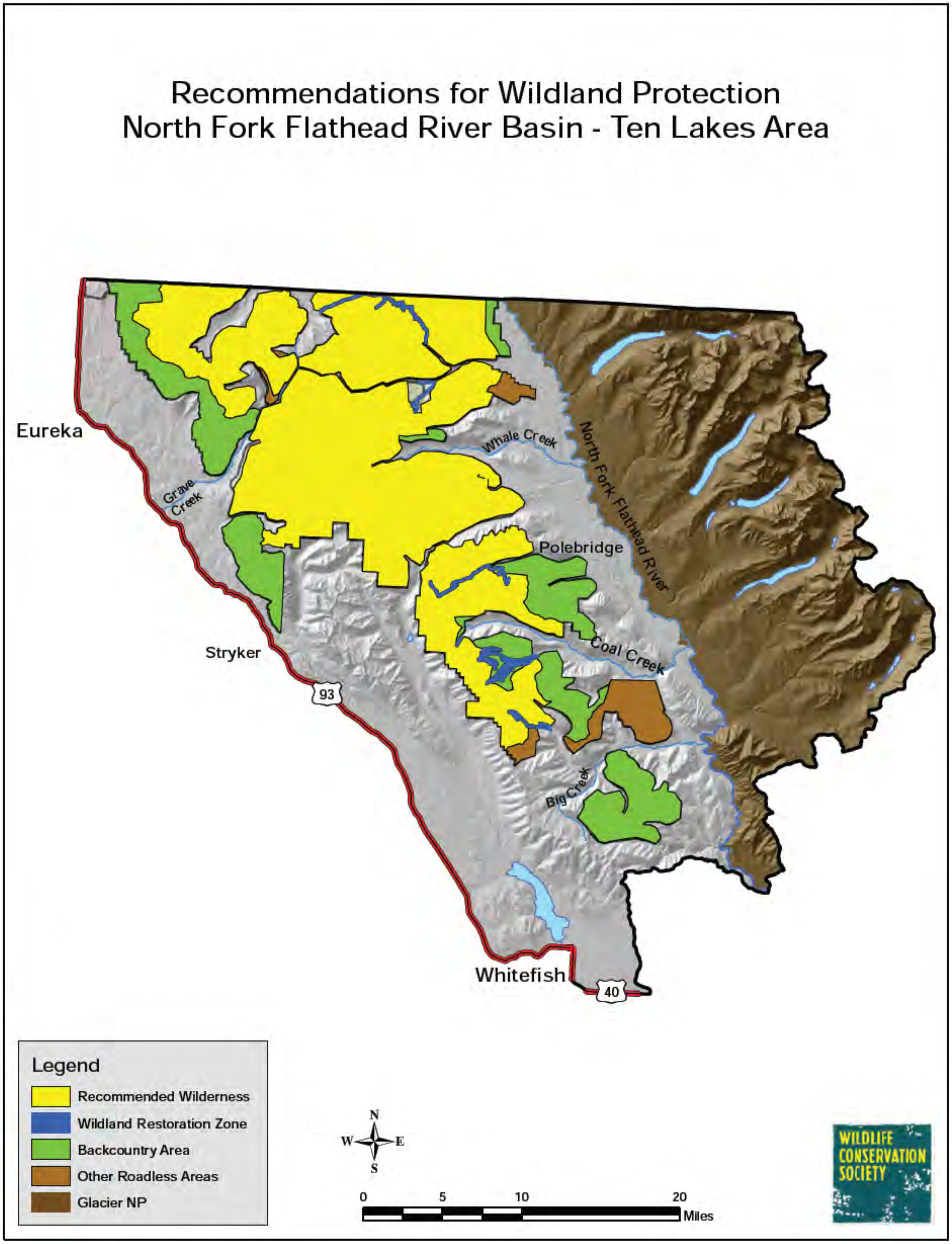


Figure 35. Recommendations for wildland protection, North Fork Flathead River Basin and Ten Lakes area, Crown of the Continent Ecosystem, Montana.



8. CROWN OF THE CONTINENT ECOSYSTEM: COMPLETING THE LEGACY OF CONSERVATION

Synthesis of Conservation Values across the Crown of the Continent Ecosystem, Montana

In this assessment, I have examined the conservation value of remaining roadless areas for vulnerable fish and wildlife species in various regions around the Crown of the Continent Ecosystem in Montana. Now, let's zoom out a bit and view these roadless lands and waters from the vantage of the entire Crown ecosystem for a larger perspective (see Appendix A for maps of conservation values for each species).

The waters of the Flathead River basin provide the cold, clean, complex and connected habitat that is critical for native bull trout, a threatened species (Appendix A1). Indeed, the Flathead River basin is widely acknowledged to be a stronghold for bull trout in the American West. Although several of these critical waters occur in existing Wilderness or Glacier National Park, many other streams designated as critical habitat begin or flow through roadless areas. As the Crown's climate continues to warm, tributaries will provide the best likelihood of remaining sufficiently cold for bull trout – especially those in the roadless headwaters of the Swan Range, Whitefish Range, and upper Blackfoot River basin.

The status assessment for native westslope cutthroat trout in the western United States revealed that 49% of the remaining 'conservation populations' occur in roadless areas on US Forest Service lands (Shepard et al. 2005). The network of cold-water streams throughout the Crown of the Continent Ecosystem provide a stronghold for remaining genetically-pure populations of westslope cutthroat trout, too (Appendix A2). Hybridization with non-native trout (particularly rainbow trout), however, threatens the genetic integrity of many westslope cutthroat populations. Because climate warming will favor the spread of non-native trout at lower elevations, the higher tributaries will offer the most likely refugia for this cold-water native species. In the larger perspective, cold and clean streams in the South Fork, Middle Fork, and upper North Fork of the Flathead River will become even more important for westslope cutthroat trout.

The largest population of grizzly bears in the lower 48 states thrives on a variety of foods in habitats that reach from valley to mountain peak across the Crown of the Continent Ecosystem. Relatively higher densities of grizzlies occur in the northern and central sections of the Crown where habitats are most productive (Appendix A3). Roadless areas provide additional security for grizzly bears from human disturbance and mortality to support a robust population. Roadless lands along the Rocky Mountain Front (including Badger-Two Medicine), Swan Range, and Whitefish Range are integral for sustaining the wide-ranging movements of grizzly bears, now and into a future of varying conditions.

The largest population of the rare wolverine in the conterminous United States roams the rugged terrain of the high country across the Crown of the Continent Ecosystem in Montana. Primary habitat appears to be widespread across the Crown, but maternal habitat is more limited to the higher ridges and cirque basins (Appendix A4). Because the distribution and ecology of wolverines appears strongly linked to areas characterized by persistent snow cover (Copeland et al. 2010), climate warming may diminish suitability of habitats at lower elevations. Many of the remaining roadless areas in the Crown provide habitat in the high country that will help sustain the unique niche of this elusive carnivore.

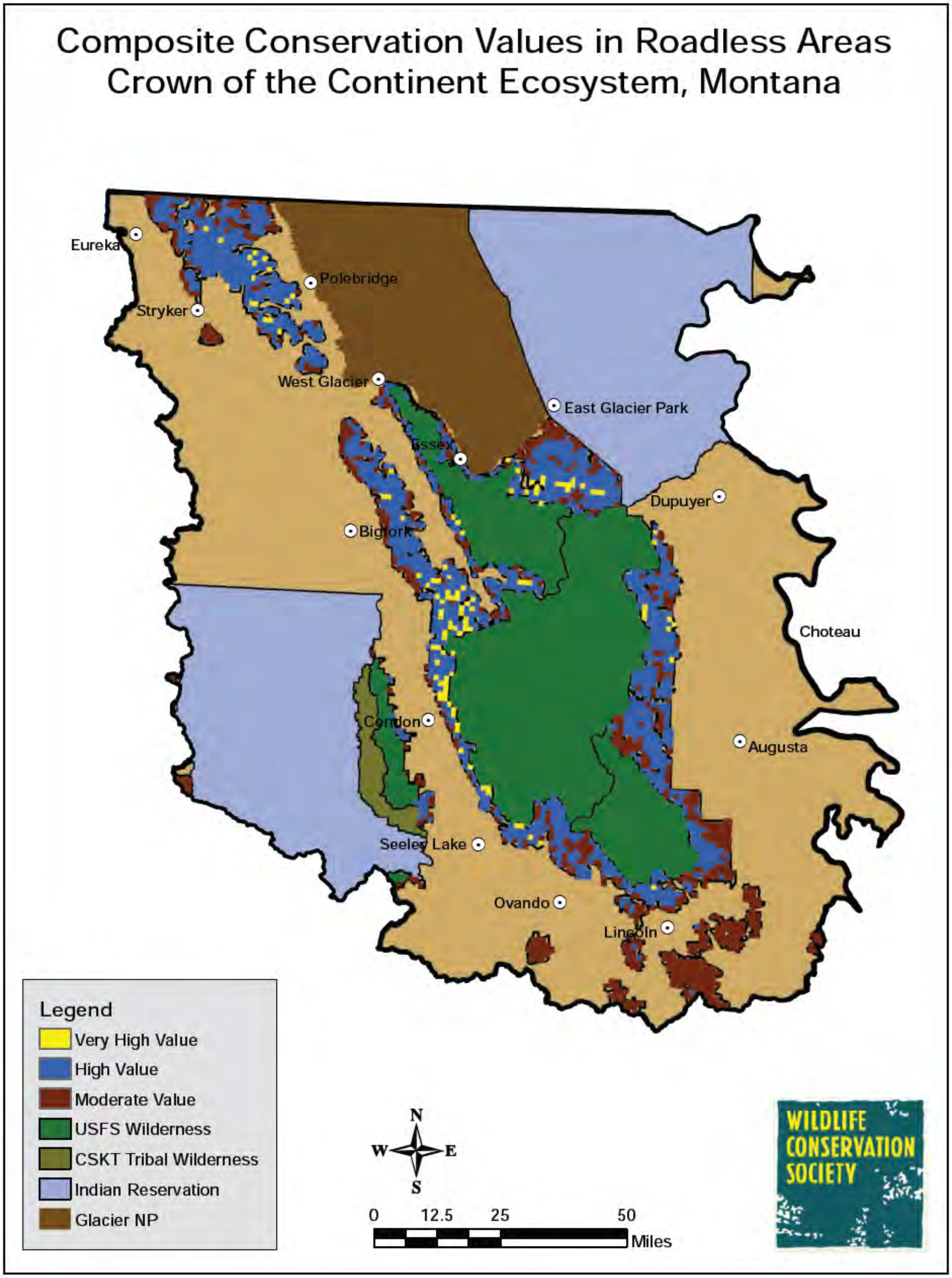
Mountain goats still occupy the same bands of remote cliffs where their ancestors stood sentinel in the past (Appendix A5). In some areas, goat populations have decreased due (in part) to excessive hunting facilitated by new roads and easier access. On many of the narrow crests and peaks, goats may rest on ledges inside a Wilderness area but find their scant forage on the roadless side of the ridge. Roadless areas with traditional maternal goat range, particularly in the Badger-Two Medicine and along the southern Swan Range, have high conservation value for this vulnerable species.

Some of the largest herds of bighorn sheep in America inhabit the spectacular rocky reefs and wind-swept, montane grasslands along the Rocky Mountain Front (Appendix A6). Much of their traditional winter range and summer range occurs in roadless areas there.

Several roadless areas serve as traditional summer range where elk birth and raise their calves, including: the Badger-Two Medicine area along the Rocky Mountain Front, upper Monture Creek in the Blackfoot River basin, upper Bunker Creek-Sullivan Creek and east of Hungry Horse Reservoir in the South Fork of the Flathead, and upper Granite Creek in the Middle Fork of the Flathead River basin.

The majority of remaining roadless lands in the Crown of the Continent Ecosystem scored **very high** (5.2%) or **high** (61.0%) in *composite* conservation value for this suite of vulnerable fish and wildlife species (Figure 36). Very-high conservation values were concentrated in the Badger-Two Medicine area on

Figure 36. Composite conservation values in roadless areas for suite of vulnerable fish and wildlife species, Crown of the Continent Ecosystem, Montana.



the Rocky Mountain Front, central and southern sections of the Swan Range, and a few places in the North Fork Flathead River basin. High conservation values were found in roadless areas throughout the Crown. Roadless lands with moderate value (33.8%) occurred at lower elevations closer to roads and in the isolated blocks south of Hwy 200 in the Blackfoot River basin.

The Crown of the Continent Ecosystem in Montana is truly one of the last, best places for these vulnerable fish and wildlife species. Moreover, the Crown ecosystem offers a notable range of future options for plants and animals to shift and persist during climate change due to: (1) its tremendous range-of-elevation, (2) diverse topography and aspect, and (3) 150-mile latitudinal distance south to north. Hence, the Crown of the Continent Ecosystem has the potential for robust resiliency to climate change compared to other areas. But such advantageous resiliency can be fully realized only if fish and wildlife have room to move unfettered across large, connected landscapes.

Summary of Recommendations for Wildland Protection

Based upon a thorough spatial assessment of conservation values for vulnerable fish and wildlife species on remaining roadless lands in the Crown of the Continent Ecosystem, I recommend that (Table 6, Figure 37):

- ✓ 887,461 acres (66.5%) be legislated as Wilderness,
- ✓ 310,320 acres (23.2%) be designated as Backcountry, and
- ✓ 82 miles of old, primitive logging roads be restored to natural condition for wildlife security.

Table 6. Amount of roadless areas (ac) recommended for Wilderness and other conservation designation for each of the sub-regions across the Crown of the Continent Ecosystem, Montana.

Category	Rocky Mountain Front		Blackfoot-Clearwater River Basin		Swan River and Southern Flathead River Basin		North Fork Flathead River Basin		TOTAL	
	Ac	%	Ac	%	Ac	%	Ac	%	Ac	%
Wilderness	306,288	78.9	134,159	45.0	253,554	67.3	193,460	71.0	887,461	66.5
Backcountry	81,218	20.9	58,930	19.8	106,286	28.2	63,890	23.5	310,324	23.2
WRZ[1]	290	0.1	–	–	1,569	0.4	2,025	0.7	3,884	0.3
Other	364	0.1	104,742	35.2	15,185	4.0	13,068	4.8	133,359	10.0
TOTAL	388,160	100.0	297,831	100.0	376,594	99.9	272,443	100.0	1,335,028	100.0

[1]Wildland Restoration Zone

For roadless lands recommended for Wilderness, I propose the following additions to existing units:

≈ 407,083 acres would be added to the Bob Marshall Wilderness,

≈ 173,602 acres to Great Bear Wilderness,

≈ 98,928 acres to Scapegoat Wilderness, and

≈ 14,391 acres to Mission Mountains Wilderness.

The 193,460 acres recommended for wilderness in the North Fork Flathead River basin and Ten Lakes area would comprise a separate unit, which some have suggested be named the 'Winton Weydemeyer Wilderness' after an early advocate of wildland protection for that area.

In conclusion, I have examined the conservation value of remaining roadless areas in the Crown of the Continent Ecosystem through the lens of a set of vulnerable fish and wildlife species. And I have found that the majority of these lands provide high to very high conservation values. Protecting these wildlands will secure habitats for year-round ranges, safeguard genetic integrity, enhance connectivity, and provide options for movement in response to changing conditions for these vulnerable species.

Completing the Legacy

Why is protecting more wildlands important?

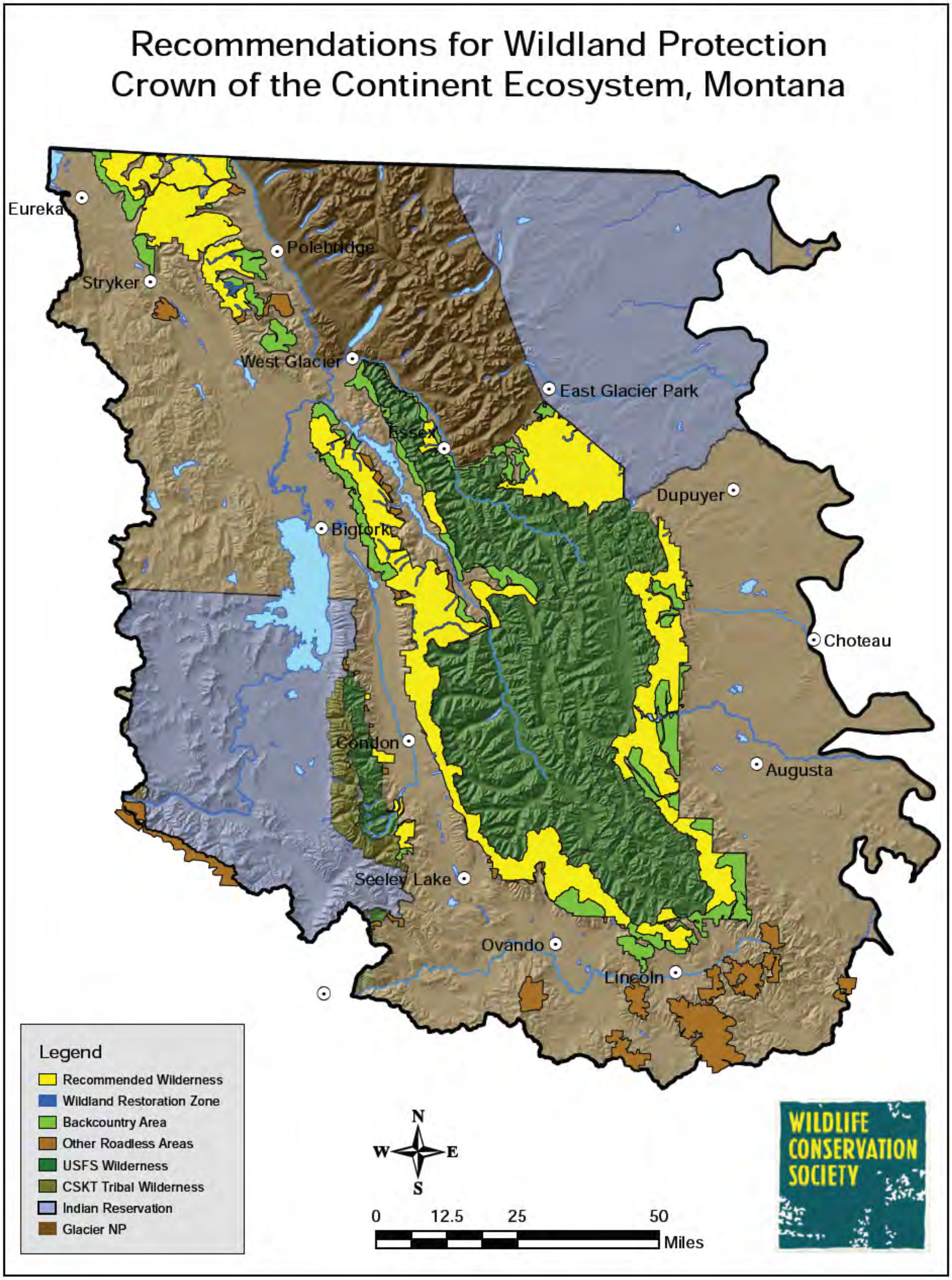
In the view of the eminent ecologist Aldo Leopold, the overall goal of conservation was to preserve the *health of the land* (Leopold 1949). By `land', Leopold meant the soils, waters, plants, and animals - in other words, the ecosystem. By `health', he meant the capacity of the land for self-renewal … its resiliency in the face of change. Leopold believed that health of the land depended upon its ecological integrity … its *wholeness* in terms of native species, collective functioning of integral parts, and intact complexity of ecological interactions. Leopold saw a beauty in the glow of healthy land … especially lands that retained their natural integrity. Here, the scientist Leopold reflected the poetry of Robinson Jeffers (1938):

> "Integrity is wholeness,
>   the greatest beauty is organic wholeness,
> The wholeness of Life and things, the divine beauty of the universe."

Thus, Leopold – as one of the original founders of the wilderness movement in America – envisioned the role of protected wilderness as critical in the larger concept of conservation. Wilderness was one strategic asset in a larger portfolio of conservation investments that ranged from farms to parks.

Leopold also believed that wilderness possessed great cultural value for people. In a deep sense, wild lands remind us of the natural environments that comprised the ancient crucible of humanity. In the modern scene, wilderness offers quiet respite from the pressures and adsorption of contemporary living … a place that yields a cultural harvest of things "natural, wild and free" (Leopold 1949).

Figure 37. Recommendations for wildland protection, Crown of the Continent Ecosystem, Montana.



Many people – past and present, young and old, Montanans and others – share a similar feeling about things natural, wild and free. Over the past century, citizens and government leaders have worked hard to protect the splendid Crown of the Continent Ecosystem in Montana. It was a remarkable legacy and great gift. Yet, in the face of new information and new challenges, it may not have been enough. Today, more than 1.3 million acres remain roadless … wild places where

> **native trout fin the way back to their birth stream to spawn in the clean, cold waters of the Rockies …**
>
> **a mountain goat climbs the narrow ledges of a cliff that cleaves the sky …**
>
> **herds of bighorn sheep nibble short grasses with the roar of chinook winds and eagle wings in their ears …**
>
> **a mother grizzly bear and her cubs savor sweet huckleberries sprouted in soils enriched by the ashes of a wildfire half a century ago …**
>
> **a wolverine lopes across a snow-filled subalpine basin in its undaunted search for something to eat along the ragged edge of Nature's food web …**
>
> **the wild challenge of a bull elk trumpets across a September sunrise.**

Milo Burcham

Rick and Susie Graetz

Here lays a rare opportunity to complete the legacy of conservation in the Crown of the Continent Ecosystem in Montana and to sustain the wild heartbeat of Life for present and future generations.

LITERATURE CITED

Adams, S.B., C.A. Frissell, and B.E. Rieman. 2001. Geography of invasion in mountain streams: consequences of headwater lake introductions. Ecosystems 4:296-307.

Allendorf, F.W., and R.F. Leary. 1988. Conservation and distribution of genetic variation in a polytypic species: the cutthroat trout. Conservation Biology 2:170-184.

Allendorf, F.W., R.F. Leary, N.P. Hitt, K.L. Knudsen, L.L. Lundquist, and P. Spruell. 2004. Intercrosses and the U.S. Endangered Species Act: should hybridized populations be included as westslope cutthroat trout? Conservation Biology 18:1203-1213.

Andryk, T.A. 1983. Ecology of bighorn sheep in relation to oil and gas development along the east slope of the Rocky Mountains, north-central Montana. Thesis, Montana State University. Bozeman, Montana.

Apps, C.D, B.N. McLellan, J.G. Woods, and M.F. Proctor. 2004. Estimating grizzly bear distribution and abundance relative to habitat and human influence. Journal of Wildlife Management 68:138-152.

Ardren, W.R., P.W. DeHaan, S.T. Smith, E.B. Taylor, R. Leary, C. Kozfkay, L. Godfrey, M. Diggs, W. Fredenberg, J. Chan, C.W. Kilpatrick, M.P. Small, and D.K. Hawkins. In Press. Genetic structure, evolutionary history, and conservation units of bull trout in the conterminous United States. Transactions of the American Fisheries Society.

Aublet, J-F., M. Fest-Bianchet, D. Bergero, and B. Bassano. 2009. Temperature constraints on foraging behavior of male Alpine ibex (*Capra ibex*) in summer. Oecologia 159:237-247.

Aubry, K.B., K.S. McKelvey, and J.P. Copeland. 2007. Distribution and broadscale habitat relations of the wolverine in the contiguous United States. Journal of Wildlife Management 71:2147-2158.

Aune, K.W., and W.F. Kasworm. 1989. Final report on East Front grizzly bear study. Montana Fish, Wildlife, and Parks Department. Helena, Montana.

Austin, M. 1998. Wolverine winter travel routes and response to transportation corridors in Kicking Horse Pass between Yoho and Banff National Parks. Thesis, University of Calgary. Calgary, Alberta.

Bales, R.C., N.P. Molotch, T.H. Painter, M.D. Dettinger, R. Rice, and J. Dozier. 2006. Mountain hydrology of the western United States. Water Resources Research. 42:W08432.

Balkenhol, N., L.P. Waits, M.K. Schwartz, J. P. Copeland, R.M. Inman, and N.J. Anderson. 2009. Scale-dependent landscape genetics of wolverines (*Gulo gulo*) in the contiguous United States. Chapter 3 *in* N. Balkenhol. Evaluating and improving analytical approaches in landscape genetics through simulations and wildlife case studies. Dissertation. University of Idaho, Moscow.

Banci, V. 1987. Ecology and behavior of wolverine in Yukon. Thesis, Simon Fraser University. Victoria, British Columbia.

Banci, V. 1994. Wolverine. Pages 99–122 *in* L.F. Ruggiero, K.B. Aubry, S.W. Buskirk, L.J. Lyon, and W.J. Zielinski, editors. The scientific basis for conserving forest carnivores in the western United States. U.S. Forest Service, General Technical Report RM-254.

Banci, V.A., and A.S. Harestad. 1988. Reproduction and natality of wolverine (*Gulo gulo*) in Yukon. Annals Zoologica Fennici 25:265-270.

Barnett, T.P., J C. Adam, and D.P. Lettenmaier. 2005. Potential impacts of a warming climate on water availability in snow-dominated regions. Nature 438:303–309.

Barnett, T.P., and coauthors. 2008. Human-induced changes in the hydrology of the western United States. Science 319:1080-1083.

Baxter, C.V., and F.R. Hauer. 2000. Geomorphology, hyporheic exchange, and selection of spawning habitat by bull trout (*Salvelinus confluentus*). Canadian Journal of Fishery and Aquatic Science 57:1470-1481

Baxter, C.V., C.A. Frissell, and F.R. Hauer. 1999. Geomorphology, logging roads, and the distribution of bull trout spawning in a forested river basin: implications for management and conservation. Transactions of the American Fisheries Society 128:854-867.

Bear, E.A., T.E. McMahon, and A.V. Zale. 2007. Comparative thermal requirements of westslope cutthroat trout and rainbow trout: implications for species interactions and development of thermal protection standards. Transactions of the American Fisheries Society 136:1113–1121.

Beever, E.A., P.F. Brussard, and J. Berger. 2003. Patterns of apparent extirpation among isolated populations of pikas (*Ochotona princeps*) in the Great Basin. Journal of Mammalogy 84:37-54.

Behnke, R.J. 2002. Trout and salmon of North America. Chanticleer Press. New York, New York.

Berkes, F., and C. Folke, editors. 1998. Linking social and ecological systems: management practices and social mechanisms for building resilience. Cambridge University Press. Cambridge, UK.

Beyer, H.L. 2004. Hawth's Analysis Tools for ArcGIS. Available at http://www.spatialecology.com

Biggins, D.E. 1975. Seasonal habitat selection and movements of the Spotted Bear elk herd. Thesis, University of Montana. Missoula, Montana.

Bjornn, T.C., and T.H. Johnson. 1978. Wild trout management, an Idaho experience. Pages 31-39 *in* K. Hashagen, editor. Proceedings of Wild trout Management Symposium. American Fisheries Society. San Jose, California.

Bonfils, C., B.D. Santer, D.W. Pierce, H.G. Hidalgo, G. Bala, T. Das, T.P. Barnett, D.R. Cayan, C. Doutriaux, A.W. Wood, A. Mirin, and T. Nozawa. 2008. Detection and attribution of temperature changes in the mountainous western United States. Journal of Climate 21:6404–6424.

Boyer, M.C., C.C. Muhlfeld, and F.W. Allendorf. 2008. Rainbow trout (*Oncorhynchus mykiss*) invasion and the spread of hybridization with native westslope cutthroat trout (*Oncorhynchus clarkii lewisi*). Canadian Journal of Fisheries and Aquatic Sciences 65:658-669.

Bradley, B.B. 2009. Regional analysis of the impacts of climate change on cheatgrass invasion shows potential risk and opportunity. Global Change Biology 15:196-204.

Brandborg, S.M. 1950. The life history and ecology of the mountain goat in Idaho and Montana. Thesis, University of Idaho. Moscow, Idaho.

Brock, B.L., R.M. Inman, K.H. Inman, A. J. McCue , M.L. Packila, and B. Giddings. 2007. Broad-scale wolverine habitat in the conterminous Rocky Mountain states. Pages 21-53 *in* Greater Yellowstone Wolverine Program. Cumulative Report May 2007. Wildlife Conservation Society, Bozeman, Montana.

Brown, D.K., A.A. Echelle, D.L. Propst, J.E. Brooks, and W.L. Fischer. 2001. Catastrophic wildfire and number of populations as factors influencing risk of extinction for Gila trout (*Oncorhynchus gilae*). Western North American Naturalist 61:139-148.

Bunch, T.D., W.M. Boyce, C.P. Hibler, W.R. Lance, T.R. Spraker, and E.S. Williams. 1999. Diseases of North American wild sheep. Pages 209–237 *in* R. Valdez and P.R. Krausman, editors. Mountain sheep of North America. University of Arizona Press. Tucson, Arizona.

Carroll, C., J.R. Dunk, and A. Moilanen. 2009. Optimizing resiliency of reserve networks to climate change: multispecies conservation planning in the Pacific Northwest, USA. Global Change Biology1365-2486.

Casebeer, R., M. Rognrud, and S. Brandborg. 1950. The Rocky Mountain goat in Montana. Bulletin No. 5. Montana Fish and Game Commission. Helena, Montana.

Cegelski, C., L. Waits, and N. Anderson. 2003. Assessing population substructure and gene flow in Montana wolverines (*Gulo gulo*) using assignment-based approaches. Molecular Ecology 12:2907–2918.

Cegelski, C.C., L.P. Waits, N.J. Anderson, O. Flagstad, C. Strobeck, and C.J. Kyle. 2006. Genetic diversity and population structure of wolverine (*Gulo gulo*) populations at the southern edge of their current distribution in North America with implications for genetic viability. Conservation Genetics 7:197–211.

Chadwick, D.H. 1983. A beast the color of winter: the mountain goat observed. Sierra Club Books, San Francisco, California.

Chadwick, D.H. 2010. The wolverine way. Patagonia Books, Ventura, California.

Clark, J.S., E.C. Grimm, J.J Donovan, S.C. Fritz, D.R. Engstrom, and J.E. Almendinger, 2002. Drought cycles and landscape responses to past aridity on prairies of the northern Great Plains, USA. Ecology 83: 595-601.

Clark, P.U., A.S. Dyke, J.D. Shakun, A.E. Carston, J. Clark, B. Wohlfarth, J.X. Mitrovica, S.W. Hostetler, and A.M. McCabe. 2009. The last glacial maximum. Science 325:710-714.

Coffin, A.W. 2007. From roadkill to road ecology: A review of the ecological effects of roads. Journal of Transport Geography 15:396-406.

Coleman, M.A., and K.D. Fausch. 2007. Cold summer temperature limits recruitment of age-0 cutthroat trout in high-elevation Colorado streams. Transactions of the American Fisheries Society 136:1231-1244.

Confederated Salish and Kootenai Tribes. 2005. Mission Mountains Tribal Wilderness: a case study. Confederated Salish and Kootenai Tribes. Pablo, Montana.

Cook, E.R., C.A. Woodhouse, C.M. Eakin, D.M. Meko, and D.W. Stahle. 2004. Long-term aridity changes in the western United States. Science 306:1015–1018.

Copeland, J.P. 1996. Biology of the wolverine in central Idaho. Thesis, University of Idaho. Moscow, Idaho.

Copeland, J.P., and J.S. Whitman. 2003. Wolverine (*Gulo gulo*). Pages 672-682 *in* G.A. Feldhamer, B.C. Thompson, and J.A. Chapman, editors. Wild mammals of North America: biology, management, and conservation. The Johns Hopkins University Press, Baltimore, Maryland.

Copeland, J.P., and R.E. Yates. 2006. Wolverine population assessment in Glacier National Park. Spring 2006 Progress Report. USDA Forest Service, Rocky Mountain Research Station, Missoula, Montana.

Copeland, J.P., J. Peak, C. Groves, W. Melquist, K.S. McKelvey, G.W. McDaniel, C.D. Long, and C E. Harris. 2007. Seasonal habitat associations of the wolverine in Central Idaho. Journal of Wildlife Management 71:2201–2212.

Copeland, J.P., K.S. McKelvey, K.B. Aubry, A. Landa, J. Persson, R.M. Inman, J. Krebs, E. Lofroth, H. Golden, J.R. Squires, A. Magoun, M.K. Schwartz, J. Wilmot, C.L. Copeland, R.E. Yates, I. Kojola, and R. May. 2010. The bioclimatic envelope of the wolverine (*Gulo gulo*): do climatic constraints limit its geographic distribution? Canadian Journal of Zoology 88:233-246.

Côté, S.D. 1996. Mountain goat responses to helicopter disturbance. Wildlife Society Bulletin 24:681-685.

Côté, S.D., and M. Festa-Bianchet. 2003. Mountain goat. Pages 1061-1075 682 *in* G.A. Feldhamer, B.C. Thompson, and J.A. Chapman, editors. Wild mammals of North America: biology, management, and conservation. The Johns Hopkins University Press, Baltimore, Maryland.

Côté, S.D., M. Festa-Bianchet, and K.G. Smith. 2001. Compensatory reproduction in harvested mountain goat populations: a word of caution. Wildlife Society Bulletin 29:726-730.

Craighead, J.J., J.S. Sumner, and J.A. Mitchell. 1995. The grizzly bears of Yellowstone: their ecology in the Yellowstone Ecosystem, 1959-1992. Island Press. Washington, DC.

Craighead, J.J., J.S. Sumner, and G.B. Scaggs. 1982. A definitive system for analysis of grizzly bear habitat and other wilderness resources. Monograph No. 1. Wildlife-Wildlands Institute. Missoula, Montana.

Crimmins, S.M., S.Z. Dobrowski, J.A. Greenberg, J.T. Abatzoglou, and A.R. Mynsberge. 2011. Changes in climatic water balance drive downhill shifts in plant species' optimum elevations. Science 331:324-327.

Dalerum, F., J. Loxterman, B. Shults, K. Kunkel, and J.A. Cook. 2007. Sex-specific dispersal patterns of wolverines: insights from microsatellite markers. Journal of Mammalogy 88:793-800.

DeCesare, N.J., and D.H. Pletscher. 2006. Movements, connectivity, and resource selection of Rocky Mountain bighorn sheep. Journal of Mammalogy 87:531-538.

Dicus, G.H. 2002. An evaluation of GIS-based habitat models for bighorn sheep winter range in Glacier National Park, Montana. Thesis, University of Montana. Missoula, Montana.

Donald, D.B., and D.J. Alger. 1993. Geographic distribution, species displacement, and niche overlap for lake trout and bull trout in mountain lakes. Canadian Journal of Zoology 71:238-247.

Dowling, T.E., and M.R. Childs. 1992. Impact of hybridization on a threatened trout of the southwestern United States. Conservation Biology 6:355-364.

Dunham, J.B., and B.E. Rieman. 1999. Metapopulation structure of bull trout: influences of physical, biotic, and geometrical landscape characteristics. Ecological Applications 9:642-655.

Dunham, J.B., B.E. Rieman, and G. Chandler. 2003. Influences of temperature and environmental variables on the distribution of bull trout within streams at the southern margin of its range. North American Journal of Fisheries Management 23:894-904.

Dunham, J.B., S.B. Adams, R.E. Schroeter, and D.C. Novinger. 2002. Alien invasions in aquatic ecosystems: toward an understanding of brook trout invasions and potential impacts on inland cutthroat trout in western North America. Reviews in Fish Biology and Fisheries 12:373-391.

Dunham, J.B., A.E. Rosenberger, C.H. Luce, and B.E. Rieman. 2007. Influences of wildfire and channel reorganization on spatial and temporal variation in stream temperature and the distribution of fish and amphibians. Ecosystems 10:335-346.

Dunham, J.B., M.K. Young, R.E. Gresswell, and B.E. Rieman. 2003. Effects of fire on fish populations: landscape perspectives on persistence of native fishes and nonnative fish invasions. Forest Ecology and Management 178:183-196.

Eberhardt, L. 1990. Survival rates required to sustain bear populations. Journal of Wildlife Management 54:587-590.

Erickson, G.L. 1972. The ecology of Rocky Mountain bighorn sheep in the Sun River area of Montana with special reference to summer food habits and range movements. Thesis, Montana State University. Bozeman, Montana.

Fagan, W.F. 2002. Connectivity, fragmentation, and extinction risk in dendritic metapopulations. Ecology 83:3243-3249.

Fagre, D.B. 2007. Ecosystem responses to global climate change. Pages 187-200 *in* T. Prato and D. Fagre, editors. Sustaining Rocky Mountain Landscapes: Science, policy, and management for the Crown of the Continent Ecosystem. Resources for the Future. Washington D.C.

Fahrig, L., and T. Rytwinski. 2009. Effects of roads on animal abundance: an empirical review and synthesis. *in* Effects of roads and traffic on wildlife populations and landscape function. Ecology and Society 14. http://www.ecologyandsociety.org/vol14/iss1/art21/

Fausch, K.D., B.E. Rieman, J.B. Dunham, M.K. Young, and D.P. Peterson. 2009. Invasion versus isolation: trade-offs in managing native salmonids with barriers to upstream movement. Conservation Biology 23:859-870.

Festa-Bianchet, M. and S. Côté. 2008. Mountain goats: Ecology, behavior, and conservation of an alpine ungulate. Island Press, Washington, D.C.

Folke, C., S.R. Carpenter, B. Walker, M. Scheffer, T. Elmqvist, L. Gunderson, and C.S. Holling. 2004. Regime shifts, resilience and biodiversity in ecosystem management. Annual Review in Ecology, Evolution and Systematics 35:557-581.

Forman, R.T.T., D. Sperling, J.A. Bissonette, A.P. Clevenger, C.D. Cutshall, V.H. Dale, L. Fahrig, R. France, C.R. Goldman, K. Heanue, J.A. Jones, F.J. Swanson, T. Turrentine, and T.C. Winter. 2003. Road ecology: science and solutions. Island Press. Washington, D.C.

Foster, B.R., and E.Y. Rahs. 1983. Mountain goat response to hydroelectric exploration in northwestern British Columbia. Environmental Management 7:189-197.

Fraley, J.J., and B.B. Shepard. 1989. Life history, ecology, and population status of migratory bull trout (*Salvelinus confluentus*) in the Flathead Lake and river system, Montana. Northwest Science 63:133-143.

Fredenberg, W. 2002. Further evidence that lake trout displace bull trout in mountain lakes. Intermountain Journal of Sciences 8:143-152.

Frisina, M.R. 1974. Ecology of bighorn sheep in the Sun River area of Montana during fall and spring. Thesis, Montana State University. Bozeman, Montana.

Fuller, P.R. 1976. Browse production and utilization on the Spotted Bear Mountain winter range and seasonal movements of the Spotted Bear elk herd. Thesis, University of Montana. Missoula, Montana.

Gardner, C.L., W.B. Ballard, and R.H. Jessup. 1986. Long distance movement by an adult wolverine. Journal of Mammalogy 67:603.

Geist, V. 1971. Mountain sheep: a study in behavior and evolution. The University of Chicago Press. Chicago, Illinois.

Gibeau, M.L., A.P. Clevenger, S. Herrero, and J. Wierzchowski. 2002. Grizzly bear response to human development and activities in the Bow River watershed, Alberta. Biological Conservation 103:227-236.

Gibeau, M.L., S. Herrero, B.N. McLellan, and J.G. Woods. 2001. Managing for grizzly bear security areas in Banff National Park and the Central Canadian Rocky Mountains. Ursus 12:121-130.

Gilpin, M., and I. Hanski, editors. 1991. Metapopulation dynamics: empirical and theoretical investigations. Academic Press. New York, New York.

Goldstein, M.I., A.J. Poe, E. Cooper, D. Youkey, B.A. Brown, and T.L. McDonald. 2005. Mountain goat response to helicopter overflights in Alaska. Wildlife Society Bulletin 33:688-699.

Graetz, R., and S. Graetz. 2004 (revised). Montana's Bob Marshall country. Northern Rockies Publishing. Helena, Montana.

Graumlich, L., and W.L. Francis, editors. 2010. Moving toward climate change adaptation: the promise of the Yellowstone to Yukon Conservation Initiative for addressing the region's vulnerabilities. Yellowstone to Yukon Conservation Initiative. Canmore, Alberta.

Grignolio, S., I. Rossi, B. Bassano, F. Parrini, and M. Apollonio. 2004. Seasonal variations of spatial behavior in female Alpine ibex (*Capra ibex ibex*) in relation to climatic conditions and age. Ethology, Ecology, and Evolution 16:255-264.

Groisman, P.Y., R.W. Knight, D.R.Easterling, T.R. Karl, G.C. Hegerl, and V.N. Razuvaev. 2005. Trends in intense precipitation in the climate record. Journal of Climate 18:1326–1350.

Gross, J.E., M.C. Kneeland, D.F. Reed, and R.M. Reich. 2002. GIS-based habitat models for mountain goats. Journal of Mammalogy **83**:218-228.

Groves, C.R. 2003. Drafting a conservation blueprint: a practitioner's guide to planning for biodiversity. Island Press. Washington, D.C.

Gucinski, H., M.J. Furniss, R.R. Ziemer, and M.H. Brookes. 2001. Forest roads: a synthesis of scientific information. USDA Forest Service, Pacific Northwest Research Station. Portland, Oregon.

Gunckel, S.L., A.R. Hemmingsen, J.L. Li. 2002. Effect of bull trout and brook trout interactions on foraging habitat, feeding behavior, and growth. Transactions of the American Fisheries Society 131:1119-1130.

Guralnick, R. 2007. Differential effects of past climate warming on mountain and flatland species distributions: a multispecies North American mammal assessment. Global Ecology and Biogeography 16:14-23.

Haak, A.L., J.E. Williams, D. Issak, A. Todd, C.C. Muhlfeld, J.L. Kershner, R.E. Gresswell, S.W. Hostetler, and H.M. Neville. 2010. The potential influence of changing climate on the persistence of salmonids of the Inland West. U.S. Geological Survey Open File Report 2010-1236.

Hall, M.P., and D.B. Fagre. 2003. Modeled climate-induced glacier change in Glacier National Park, 1850-2100. Bioscience 53:131-140.

Hamel, S., and S.D. Côté. 2007. Habitat use patterns in relation to escape terrain: are alpine ungulate females trading off better foraging sites for safety? Canadian Journal of Zoology 85:933-943.

Hamel, S., S.D. Côté, K.G. Smith, and M. Festa-Bianchet. 2006. Population dynamics and harvest potential of mountain goat herds in Alberta. Journal of Wildlife Management 70:1044-1053.

Hamer, D. 1996. Buffaloberry [*Shepherdia canadensis* (L.) Nutt.] fruit production in fire-successional bear feeding sites. Journal of Range Management 49:520-529.

Hamlet, A.F., and D.P. Lettenmaier. 2007. Effects of 20th century warming and climate variability on flood risk in the western U.S. Water Resources Research 43:W06427.

Hamlet, A.F., P.W. Mote, M.P. Clark, and D.P. Lettenmaier. 2005. Effects of temperature and precipitation variability on snowpack trends in the western United States. Journal of Climate 18:4545–4561.

Hannah, L., and L. Hansen. 2005. Designing landscapes and seascapes for change. Pages 329-341 *in* T.E. Lovejoy and L. Hannah, editors. Climate change and biodiversity. Yale University Press, New Haven, Connecticut.

Hansen, L., J. Hoffman, C. Drews, and E. Mielbrecht. 2010. Designing climate-smart conservation: guidance and case studies. Conservation Biology 24:63-69.

Hauer, F.R., and C.C. Muhlfeld. 2009. Compelling science saves a river valley. Science 327:1576.

Hebda, R.J. 2010. The future of flora: the impacts of climate change on the flora of the Canadian Southern Rocky Mountain region and its value to conservation. Report to Canadian Parks and Wilderness Society.

Heller, N. and Zavaleta, E. 2009. Biodiversity management in the face of climate change: 20 years of recommendations. Biological Conservation 142: 14-33.

Hidalgo, H.G., T. Das, M.D. Dettinger, D.R. Cayan, D.W. Pierce, T.P. Barnett, G. Bala, A. Mirin, A.W. Wood, C. Bonfils, B.D. Santer, and T. Nozawa 2009. Detection and attribution of streamflow timing changes to climate change in the western United States. Journal of Climate 22:3838–3855.

Hilderbrand, R.H., and J.L. Kershner. 2000. Conserving inland cutthroat trout in small streams: how much stream is enough? North American Journal of Fisheries Management 20:513-520.

Hitt, N.P., C.A. Frissell, C.C. Muhlfeld, and F.W. Allendorf. 2003. Spread of hybridization between native westslope cutthroat trout, *Oncorhynchus clarkii lewisi*, and nonnative rainbow trout, *Oncorhynchus mykiss*. Canadian Journal of Fisheries and Aquatic Sciences 60:1440-1451.

Hobbs, R.J., D.N. Cole, L. Yung, E.S. Zavaleta, G.H. Aplet, F.S. Chapin, P.B. Landres, D.J. Parsons, N.L. Stephenson, P.S. White, D.M. Graber, E.S. Higgs, C.I. Millar, J.M. Randall, K.A. Tonnessen, and S. Woodley. 2010. Guiding concepts for park and wilderness stewardship in an era of global environmental change. Frontiers in Ecology 8:483-490.

Hodgson, J.A., C.D. Thomas, B.A. Wintle, and A. Moilanen. 2009. Climate change, connectivity and conservation decision-making: back to basics. Journal of Applied Ecology 46:964-969.

Holling, C.S. 1973. Resilience and stability of ecological systems. Annual Review Ecology and Systematics 4:1-23.

Hornocker, M.G., and H.S. Hash. 1981. Ecology of the wolverine in northwestern Montana. Canadian Journal of Zoology 59:1286–1301.

Hovey, F.W., and B.N. McLellan. 1996. Estimating population growth of grizzly bears from the Flathead River drainage using computer simulations of reproductive and survival rates. Canadian Journal of Zoology 74:1409–1416.

Hurley, M.A. 1994. Summer-fall ecology of the Blackfoot-Clearwater elk herd of western Montana. Thesis, University of Idaho. Moscow, Idaho.

Inman, R.M. 2010. Wolverine habitat in Colorado's San Juan Mountains. Unpublished report. Wildlife Conservation Society, North America Program. Bozeman, Montana.

Inman, R.M., K.H. Inman, A.J. McCue, M.L. Packila, G.C. White, and B.C. Aber. 2007. Greater Yellowstone Wolverine study, Cumulative Report. Wildlife Conservation Society, North America Program. Bozeman, Montana.

Inman, R.M., M. Packila, K. Inman, B. Aber, R. Spence, and D. McCauley. 2009. Greater Yellowstone Wolverine Program. Progress Report – December 2009. Wildlife Conservation Society, North America Program. Bozeman, Montana.

Inman, R.M., R.R. Wigglesworth, K.H. Inman, M.K. Schwartz, B.L. Brock, and J.D. Rieck. 2004. Wolverine makes extensive movements in the Greater Yellowstone ecosystem. Northwest Science 78:2761-266.

Isaak, D.J., C. Luce, B.E. Rieman, D. Nagel, E. Peterson, D. Horan, S. Parkes, and G. Chandler. 2010. Effects of climate change and wildfire on stream temperatures and salmonids thermal habitat in a mountain river network. Ecological Applications 20:1350-1371.

Jacober, M.J., T.E. McMahon, R.F. Thurow, and C.G. Clancy. 1998. Role of stream ice on fall and winter movements and habitat use by bull trout and cutthroat trout in Montana headwater streams. Transactions of the American Fisheries Society 127:223-235.

Jeffers, R. 1938. The selected poetry of Robinson Jeffers. Random House. New York, New York.

Jen, E. editor. 2005. Robust design: a repertoire of biological, ecological, and engineering case studies. Santa Fe Institute, Studies in the Science of Complexity. Oxford University Press, England.

Johnson, S.H. 1993. Evaluation of bighorn sheep in the Ten Lakes Scenic Area. Thesis. University of Montana. Missoula, Montana.

Jones, H.G., J.W. Pomeroy, D.A. Walker, and R.W. Hoham, editors. 2001. Snow ecology: an interdisciplinary examination of snow-covered ecosystems. Cambridge University Press, Cambridge, UK.

Joslin, G. 1986. Montana mountain goat investigations: Rocky Mountain Front. Montana Department of Fish, Wildlife, and Parks. Helena, Montana.

Kalinowski, S.T., C.C. Muhlfeld, C.S. Guy, and B. Cox. 2010. Founding population size of an aquatic invasive species. Conservation Genetics 11:2049-2053.

Kanda, N., and F.W. Allendorf. 2001. Genetic population structure of bull trout from the Flathead River basin as shown by microsatellites and mitochondrial markers. Transactions of the American Fisheries Society 130:92-106.

Keller, B.J., and L.C. Bender. 2007. Bighorn sheep response to road-related disturbances in Rocky Mountain National Park, Colorado. Journal of Wildlife Management 71:2329-2337.

Kendall, K.C., J.B. Stetz, J. Boulanger, A.C. MacLeod, D. Paetkau, and G.C. White. 2009. Demography and genetic structure of a recovering grizzly bear population. Journal of Wildlife Management 73:3-17.

Kendall, K.C., J.B. Stetz, D.A. Roon, L.P. Waits, J.B. Boulanger, and D. Paetkau. 2008. Grizzly bear density in Glacier National Park, Montana. Journal of Wildlife Management 72:1693-1705.

Kitano, S., K. Maekawa, S. Nakano, and K.D. Fausch. 1994. Spawning behavior of bull trout in the upper Flathead drainage, Montana, with special reference to hybridization with brook trout. Transactions of the American Fisheries Society 123:988-992.

Klasner, F.L., and D.B. Fagre. 2002. A half century of change in alpine treeline patterns at Glacier National Park, Montana, USA. Journal of Arctic, Antarctic and Alpine Research 34:53-61.

Knowles, N., M.D. Dettinger, and D.R. Cayan. 2006. Trends in snowfall versus rainfall in the western United States. Journal of Climate 18:4545–4559.

Krebs, J., E.C. Lofroth, and I. Parfitt. 2007. Multiscale habitat use by wolverines in British Columbia, Canada. Journal of Wildlife Management. 71: 2180-2192.

Krebs, J.R., E. Lofroth, J. Copeland, V. Banci, D. Cooley, H. Golden, A. Magoun, R. Mulders, and B. Shults. 2004. Synthesis of survival rates and causes of mortality in North American wolverines. Journal of Wildlife Management 68:493-502.

Krosby, M., J. Tewksbury, N.M. Haddad, and J. Hoekstra. 2010. Ecological connectivity for a changing climate. Conservation Biology 24: 1686–1689.

Lavergne, N. Mouquet, W. Thuiller, and O. Ronce. 2010. Biodiversity and climate change: integrating evolutionary and ecological responses of species and communities. Annual Review of Ecology, Evolution, and Systematics 41:321-350.

Leary, R.F., F.W. Allendorf, and S.H. Forbes. 1993. Conservation genetics of bull trout in the Columbia and Klamath river drainages. Conservation Biology 7:856-865.

Leary, R.F., F.W. Allendorf, and G.K. Sage. 1995. Hybridization and introgression between introduced and native fish. American Fisheries Society Symposium 15:91-101.

Leopold, A. 1949. A Sand County almanac, and sketches here and there. Oxford University Press. New York, New York.

Leung, L.R., Y. Qian, X. Bian, W.W. Washington, J. Han, and J.O. Roads. 2004. Midcentury ensemble regional climate change for the western United States. Climatic Change 62:75-113.

Leppi, J., T.H. DeLuca, S.W. Running, J.T. Harper, and S. Harrar. 2010. Influence of climate change on August stream discharge in the Northern Rockies. Journal of Hydrology.

Lesica, P. 2002. A Flora of Glacier National Park, Montana. Oregon State University Press. Corvallis, Oregon.

Liknes, G.A., and P.J. Graham. 1988. Westslope cutthroat trout in Montana: life history, status, and management. American Fisheries Society Symposium 4:53-60.

Liskop, K.S., R.M.F.S. Sadleir , and B.P. Saunders. 1981. Reproduction and harvest of wolverine (*Gulo gulo* L.) in British Columbia. Pages 469-477 *in* J.A. Chapman and D. Pursley, editors. Proceedings of the Worldwide Furbearer Conference. Frostburg, Maryland.

Lofroth, E.C., J.A. Krebs, W.L. Harrower, and D. Lewis. 2007. Food habits of wolverine *Gulo gulo* in montane ecosystems of British Columbia, Canada. Wildlife Biology 13 (Suppl. 2):31-37.

Logan, J.A., J. Regniere, and J.A. Powell. 2003. Assessing the impacts of global warming on forest pest dynamics. Frontiers in Ecology and the Environment 1:130–137.

Long, M.H. 1997. Sociological implications of bull trout management in northwest Montana: illegal harvest and game warden efforts to deter. Pages 71-74 *in* W.C. MacKay, M.K. Brewin, and M. Monita, editors. Proceedings of Friends of the Bull Trout Conference. Trout Unlimited. Calgary, Alberta.

Lyons, S.K., P.J. Wagner, and K. Dzikiewicz. 2010. Ecological correlates of range shifts of Late Pleistocene mammals. Philosophical Transactions Royal Society B 365:3681-3693.

MacArthur, R.A., V. Geist, and R.H. Johnston. 1982. Cardiac and behavioral responses of mountain sheep to human disturbance. Journal of Wildlife Management 46:351-358.

MacCallum, B.N. and V. Geist. 1992. Mountain restoration: soil and surface wildlife habitat. Geojournal 27:23–46.

MacPhee, C. 1966. Influence of differential angling mortality and stream gradient on fish abundance in a trout-sculpin biotope. Transactions of the American Fisheries Society 95:381-387.

Mace, R.D. 1986. Analysis of grizzly bear habitat in the Bob Marshall Wilderness, Montana. General technical report INT-207. USDA Forest Service. Ogden, Utah.

Mace, R.D., and C.J. Jonkel. 1983. Local food habits of the grizzly bear in Montana. International Conference on Bear Research and Management 6:105-110.

Mace, R.D., and J.S. Waller. 1998. Demography and population trend of grizzly bears in the Swan Mountains, Montana. Conservation Biology 12:1005-1016.

Mace, R.D., J.S. Waller, T.L. Manley, L.J. Lyon, and H. Zurring. 1996. Relationship among grizzly bears, roads and habitat in the Swan Mountains, Montana. 1996. Journal of Applied Ecology 33:1395-1404.

Magoun, A.J. 1985. Population characteristics, ecology, and management of wolverines in northwestern Alaska. Dissertation, University of Alaska. Fairbanks, Alaska.

Magoun, A.J. 1987. Summer and winter diets of wolverine, *Gulo gulo*, in arctic Alaska. Canadian Field-Naturalist 101:392-397.

Magoun, A.J., and J.P. Copeland. 1998. Characteristics of wolverine reproductive den sites. Journal of Wildlife Management 62:1313–1320.

Martin, J., M. Basille, B. Van Moorter, J. Kindberg, D. Allainé, and J.E. Swenson. 2010. Coping with human disturbance: spatial and temporal tactics of the brown bear (*Ursus arctos*). Canadian Journal of Zoology 88:875-883.

Martinez, P.J., P.E. Bigelow, M.A. Deleray, W.A. Fredenberg, B.S. Hansen, N.J. Horner, S.K. Lehr, R.W. Schneidervin, S.A. Tolentino, and A.E. Viola. 2009. Western lake trout woes. Fisheries 34:424-442.

Mattson, D.J. 1990. Human impacts on bear habitat use. Ursus 8:33-56.

Mattson, D.J., and T. Merrill. 2002. Extirpations of grizzly bears in the contiguous United States, 1850-2000. Conservation Biology 16:1123-1136.

Mattson, D.J., S. Herrero, R.G. Wright, and C.M. Pease. 1996. Science and management of Rocky Mountain grizzly bears. Conservation Biology 10:1013-1025.

Mawdsley, J.R., R. O'Malley, and D. Ojima. 2009. A review of climate-change adaptation strategies for wildlife management and biodiversity conservation. Conservation Biology 23:1080-1089.

McCabe, G.J., and M.P. Clark. 2005. Trends and variability in snowmelt runoff in the western United States. Journal of Hydrometeorology 6:476–482.

McCabe, G.J., M.A. Palecki, and J.L. Betancourt. 2004. Pacific and Atlantic Ocean influences on multidecadal drought frequency in the United States. Proceedings of the National Academy of Sciences 101:4136-4141.

McDonald, M. 1980. Winter range utilization and movements of elk along the Middle Fork of the Flathead River, Montana. Thesis, University of Montana. Missoula, Montana.

McKenzie, D., Z. Gedalof, D.L. Peterson, and P. Mote. 2004. Climatic change, wildfire, and conservation. Conservation Biology 18:890-902.

McLellan, B.N. 1989. Dynamics of a grizzly bear population during a period of industrial resource extraction. I. Density and age-sex structure. Canadian Journal of Zoology 67:1856-1860.

McLellan, B.N. 1994. Density-dependent population regulation of brown bears. Ursus 3:15-24.

McLellan, B.N., and F.W. Hovey. 1995. The diet of grizzly bears in the Flathead River drainage in southeastern British Columbia. Canadian Journal of Zoology 73:704-712.

McLellan, B.N., and F.W. Hovey. 2001a. Habitats selected by grizzly bears in multiple use landscapes. Journal of Wildlife Management 65:92-99.

McLellan, B.N., and F.W. Hovey. 2001b. Natal dispersal by grizzly bears. Canadian Journal of Zoology 79:838-844.

McLellan, B.N., and D.M. Shackleton. 1988. Grizzly bears and resource extraction industries: effects of roads on behavior, habitat use and demography. Journal of Applied Ecology 25:451-460.

McLellan, B.N., F.W. Hovey, R.D. Mace, J.G. Woods, D.W. Carney, M.L. Gibeau, W.L. Wakkinen, and W.F. Kasworm. 1999. Rates and causes of grizzly bear mortality in the interior mountains of British Columbia, Alberta, Montana, Washington, and Idaho. Journal of Wildlife Management 63:911-920.

McMahon, T.E., A.V. Zale, F.T. Barrows, J.H. Selong, and R.J. Danehy. 2007. Temperature and competition between bull trout and brook trout: a test of the elevation refuge hypothesis. Transactions of the American Fisheries Society 136:1313-1326.

McWethy, D.B., S.T. Gray, P.E. Higuera, J.S. Littell, G.S. Pederson, A.J. Ray, and C. Whitlock. 2010. Climate and terrestrial ecosystem change in the U.S. Rocky Mountains and Upper Columbia Basin: historical and future perspectives for natural resource management. Natural Resource Report NPS/GRYN/NRR—2010/260. National Park Service. Fort Collins, Colorado.

Meeuwig, M.H., C.S. Guy, S.T. Kalinowski, and W.D. Fredenberg. 2010. Landscape influences on genetic differentiation among bull trout populations in a stream-lake network. Molecular Ecology 19:3620-3633.

Meisner, J.D., J.S. Rosenfeld, and H.A. Regier. 1988. The role of groundwater in the impact of climate warming on stream salmonines. Fisheries 13:2-8.

Montana Fish, Wildlife and Parks Department. 2005. South Fork Flathead Watershed Westslope Cutthroat Trout Conservation Program. Final Environmental Impact Statement. Montana Fish, Wildlife, and Parks Department. Helena, Montana.

Montana Fish, Wildlife and Parks Department. 2009. Montana bighorn sheep conservation strategy. Montana Fish, Wildlife and Parks Department. Helena, Montana.

Moore, J.N., S.N. Louma, and D. Peters. 1991. Downstream effects of mine effluent on an intermontane riparian system. Canadian Journal of Fisheries and Aquatic Sciences 48:222-232.

Moritz, C., J.L. Patton, C.J. Conroy, J.L. Parra, G.C. White, and S.R. Beissinger. 2008. Impact of a century of climate change on small-mammal communities in Yosemite National Park, USA. Science 322.

Moser, D., A. Tews, D. Yerk, G. Grisak, G. Liknes, M. Enk, and A. Harper. 2009. Status and conservation needs for westslope cutthroat trout in northcentral Montana. Unpublished report. Montana Fish, Wildlife, and Parks. Lewis and Clark National Forest. Great Falls, Montana.

Mote, P.W., A.F. Hamlet, M.P. Clark, and D.P. Lettenmaier. 2005. Declining mountain snowpack in western North America. Bulletin of the American Meteorological Society 86:39-49.

Muhlfeld, C.C., and B. Marotz. 2005. Seasonal movement and habitat use by subadult bull trout in the upper Flathead River system, Montana. North American Journal of Fisheries Management 25:797-810.

Muhlfeld, C.C., T.E. McMahon, D. Belcer, and J.L. Kershner. 2009a. Spatial and temporal spawning dynamics of native westslope cutthroat trout, *Oncorhynchus clarkii lewisi*, and introduced rainbow trout, *Oncorhynchus mykiss*, and their hybrids. Canadian Journal of Fisheries and Aquatic Sciences 66:1153-1168.

Muhlfeld, C.C., T.E. McMahon, M.C. Boyer, and R.E. Gresswell. 2009b. Local habitat, watershed, and biotic factors influencing the spread of hybridization between native westslope cutthroat trout and introduced rainbow trout. Transactions of the American Fisheries Society 138:1036-1051.

Muhlfeld, C.C., L. Jones, D. Kotter, W.J. Miller, D. Geise, J. Tohtz, and B. Marotz. 2011. Assessing the impacts of river regulation on native bull trout (*Salvelinus confluentus*) and westslope cutthroat trout (*Oncorhynchus clarkii lewisi*) habitats in the upper Flathead River, Montana, USA. River Research and Applications. Published online in at www.wileyonlinelibrary.com DOI:10,1002/rra.1494.

Muhlfeld, C.C., S.T. Kalinowski, T.E. McMahon, M.L. Taper, S. Painter, R.F. Leary, and F.W. Allendorf. 2009c. Hybridization rapidly reduces fitness of a native trout in the wild. Biology Letters 5:328-331.

Nakano, S., S. Kitano, K. Nakai, and K.D. Fausch. 1998. Competitive interactions for foraging microhabitat among introduced brook charr, *Salvelinus fontinalis*, and native bull charr, *Salvelinus confluentus*, and westslope cutthroat trout, *Oncorhynchus clarki lewisi*, in a Montana stream. Environmental Biology of Fishes 52:345-355.

Nielsen, S.E., G. McDermid, G.B. Stenhouse, and M.S. Boyce. 2010. Dynamic wildlife habitat models: seasonal foods and mortality risk predict occupancy-abundance and habitat selection in grizzly bears. Biological Conservation 143:1623-1634.

Nielsen, S.E., S. Herrero, M.S. Boyce, R.D. Mace, B. Benn, M.L. Gibeau, and S. Jevons. 2004. Modelling the spatial distribution of human-caused grizzly bear mortalities in the Central Rockies ecosystem of Canada. Biological Conservation 120:101-113.

Nordhaus, H. 2009. Bark beetle outbreaks in western North America: Causes and consequences. Edited by B. Bentz. University of Utah Press, Salt Lake City, Utah, USA.

Olson, G., L. Marcum, and T. Baumeister. 1994. Movement patterns and habitat use of bull elk that winter on and near the Theodore Roosevelt Memorial Ranch, Montana. Final Report: Part I. Theodore Roosevelt Memorial Ranch Elk Study. Montana Department of Fish, Wildlife, and Parks and the University of Montana.

Pagano, T., and D. Garen. 2005. A recent increase in western U.S. streamflow variability and persistence. Journal of Hydrometerology 6:173-179.

Parker, B.R., D.W. Schindler, F.M. Wilhelm, and D.B. Donald. 2007. Bull trout population responses to reductions in angler effort and retention limits. North American Journal of Fisheries Management 27:848-859.

Parmesan, C. 2006. Ecological and evolutionary responses to recent climate change. Annual Review of Ecology, Evolution and Systematics 37:637-669.

Paul, A.J., and J.R. Post. 2001. Spatial distribution of native and nonnative salmonids in streams of the eastern slopes of the Canadian Rocky Mountains. Transactions of the American Fisheries Society 130:417-430.

Peacock, S. 2011. Projected 21st century climate change for wolverine habitats within the contiguous United States. Environmental Research Letters 6. doi:10.1088/1748-9326/6/1/014007.

Pederson, G.T., L.J. Graumlich, D.B. Fagre, T. Kipfer, and C.C. Muhlfeld. 2010. A century of climate and ecosystem change in Western Montana: what do temperature trends portend? Climatic Change 98:133-154.

Pederson, G.T., S.T. Gray, T.R. Ault, W. Marsh, D.B. Fagre, A.G. Bunn, C.A. Woodhouse, and L.J. Graumlich. In Press. Climatic controls on snowmelt hydrology of the Northern Rocky Mountains, USA. Journal of Climate. Early Online edition, December 8, 2010. doi: 10.1175/2010JCLI3729.1

Pepin, N. C., and J. D. Lundquist. 2008. Temperature trends at high elevations: Patterns across the globe. Geophysical Research Letters 35:L14701.

Peterson, D.L., E.G. Schreiner, and N.M. Buckingham. 1997. Gradients, vegetation and climate: spatial and temporal dynamics in the Olympic Mountains, USA. Global Ecology Biogeography Letters 6:7-17.

Pettit, N.E., and R.J. Naiman. 2007. Fire in the riparian zone: characteristics and ecological consequences. Ecosystems 10:673-687.

Pickett, S.T.A., J. Kolasa, J.J. Armesto, and S.L. Collins. 1989. The ecological concept of disturbance and its expression at various hierarchical levels. Oikos 54:129-136.

Picton, H.D. 1960. Migration patterns of the Sun River elk herd, Montana. Journal of Wildlife Management 24:279-290.

Picton, H.D., and T.N. Lonner. 2008. Montana's wildlife legacy: decimation to restoration. Media Works Publishing. Bozeman, Montana.

Pielou, E.C. 1991. After the Ice Age: the return of life to glaciated North America. The University of Chicago Press. Chicago, Illinois.

Pierce, D.W., T.P., Barnett, H.G. Hidalgo. T. Das, C. Bonfils, B. Sander, G. Bala, M. Dettinger, D. Cayan and A. Mirin. 2008. Attribution of declining western US snowpack to human effects. Journal of Climate 21:6425–6444.

Pierce, R., C. Podner, M. Davidson, L. Knotek, and J. Thabes. 2008. The Big Blackfoot River fisheries and restoration investigations for 2006 and 2007. Montana Fish, Wildlife and Parks. Missoula, Montana.

Poole, K.G., K.D. Bachman, and I.E. Teske. 2010. Mineral lick use by GPS radio-collared mountain goats in southeastern British Columbia. Western North American Naturalist 70:208-217.

Poole, K.G., K. Stuart-Smith, and I.E. Teske. 2009. Wintering strategies by mountain goats in interior mountains. Canadian Journal of Zoology 87:273-283.

Pörtner, H.O., and A.P. Farrell. 2008. Physiology and climate change. Science 32:690-692.

Rahel, F.J., and J.D. Olden. 2008. Assessing the effects of climate change on invasive species. Conservation Biology 22:521-533.

Rahel, F.J., B. Bierwagen, and Y. Taniguchi. 2008. Managing aquatic species of conservation concern in the face of climate change and invasive species. Conservation Biology 22:551-561.

Rausch, R.A., and A.M. Pearson. 1972. Notes on the wolverine in Alaska and Yukon Territory. Journal of Wildlife Management 36:249-268.

Ray, A. J., J. J. Barsugli, K. Wolter, and J. K. Eischeid. 2010. Rapid-response climate assessment to support the FWS status review of the American pika. NOAA Earth Systems Research Laboratory, Boulder, Colorado, USA. http://www.esrl.noaa.gov/psd/news

Rehfeldt, G.E., N.L. Crookston, M.V. Warwell, and J.S. Evans. 2006. Empirical analyses of plant-climate relationships for the western United States. International Journal of Plant Sciences 167: 1123-1150.

Rice, C.G. 2008. Seasonal altitudinal movements of mountain goats. Journal of Wildlife Management 72:1706-1716.

Rich, C.F., T.E. McMahon, B.E. Rieman, and W.L. Thompson. 2003. Local habitat, watershed, and biotic features associated with bull trout occurrence in Montana streams. Transactions of the American Fisheries Society 132:1053-1064.

Rieman, B.E., and F.W. Allendorf. 2001. Effective population size and genetic conservation criteria for bull trout. North American Journal of Fisheries Management 21:756-764.

Rieman, B.E., D.C. Lee, and R.F. Thurow. 1997. Distribution, status, and likely future trends of bull trout within the Columbia River and Klamath River basins. North American Journal of Fisheries Management 17:1111-1125.

Rieman, B.E., J.T. Peterson, and D.L. Myers. 2006. Have brook trout (*Salvelinus fontinalis*) displaced bull trout (*Salvelinus confluentus*) along longitudinal gradients in central Idaho streams? Canadian Journal Fishery and Aquatic Science 63:63-78.

Rieman, B.E., D. Isaak, S. Adams, D. Horan, D. Nagel, C. Luce, and D. Myers. 2007. Anticipated climate warming effects on bull trout habitats and populations across the interior Columbia River Basin. Transactions of the American Fisheries Society 136:1552-1565.

Riley, S.J., K. Aune, R.D. Mace, and M. Madel. 1994, translocation of nuisance grizzly bears in northwestern Montana. International Conference on Bear Research and Management 9:567-574.

Ripley, T., G. Scrimgeour, and M.S. Boyce. 2005. Bull trout (*Salvelinus confluentus*) occurrence and abundance influenced by cumulative industrial developments in a Canadian boreal forest watershed. Canadian Journal of Fisheries and Aquatic Sciences 62:2431-2442.

Rood, S.B, G.M. Samuelson, J.K. Weber, and K.A. Wywrot. 2005. Twentieth -century declines in streamflows from the hydrographic apex of North America. Journal of Hydrology 306: 215-233

Rood, S.B., J. Pan, K.M. Gill, C.G. Franks, G.M. Samuelson, and A. Shepherd. 2008. Declining summer flows of Rocky Mountain streams – changing seasonal hydrology and probable impacts on floodplain forests. Journal of Hydrology 349:397-410.

Running, S.W. 2006. Is global warming causing more, larger wildfires? Science 313:927-928.

Running, S.W., and L.S. Mills. 2009. Terrestrial ecosystem adaptation. A report for Resources for the Future. Adaption: An Initiative of the Climate Policy Program at Resources for the Future.

Running, S.W., C. Boisvenue, R. Anderson, and T. Power. 2010. Impacts of climate change on forests of the Northern Rocky Mountains. University of Montana.

Sanderson, E.W., K.H. Redford, A. Vedder, P.B. Coppolillo, and S.E. Ward. 2002. A conceptual model for conservation planning based upon landscape species requirements. Landscape and Urban Planning 58:41-56.

Schallenberger, A.D. 1966. Food habits, range use and interspecific relationships of bighorn sheep in the Sun River area, west-central Montana. Thesis, Montana State University. Bozeman, Montana.

Schirokauer, D. 1996. The effects of 55 years of vegetative change on bighorn sheep habitat in the Sun River area of Montana. Thesis, University of Montana. Missoula, Montana.

Schmetterling, D.A. 2001. Seasonal movements of fluvial westslope cutthroat trout in the Blackfoot River drainage, Montana. North American Journal of Fisheries Management 21:507-520.

Schwartz, C.C., S.D. Miller, and M.A. Haroldson. 2003. Grizzly bear. Pages 556-586 *in* G.A. Feldhamer, B.C. Thompson, and J.A. Chapman, editors. Wild mammals of North America: biology, management, and conservation. The Johns Hopkins University Press, Baltimore, Maryland.

Schwartz, M.K., J.P. Copeland, N.J. Anderson, J.R. Squires, R.M. Inman, K.S. McKelvey, K.L. Pilgrim, L.P. Waits, and S.A. Cushman. 2009. Wolverine gene flow across a narrow climatic niche. Ecology 90:3222-3232.

Selkowitz, D.J., D.B. Fagre, and B.A. Reardon. 2002. Annual variations in snowpack in the Crown of the Continent Ecosystem. Hydrological Processes 16:3651-3665.

Selong, J.H., T.E. McMahon, A.V. Zale, and F.T. Barrows. 2001. Effect of temperature on growth and survival of bull trout, with application of an improved method for determining thermal tolerance in fishes. Transactions of the American Fisheries Society 130:1026-1037.

Servheen, C., and M. Cross, compilers. 2010. Climate change impacts on grizzly bears and wolverines in the Northern U.S. and Trans-boundary Rockies: Strategies for conservation. Report on a workshop held Sept.13-15, 2010 in Fernie, British Columbia.

Shackleton, D.M., C.C. Shank, and B.M. Wikeem. 1999. Natural history of Rocky Mountain and California bighorn sheep. Pages 78-138 *in* R. Valdez and P.R. Krausman, editors. Mountain sheep of North America. University of Arizona Press. Tucson, Arizona.

Shafer, A.B.A., C.I. Cullingham, S.D. Côté, and D.W. Coltman. 2010. Of glaciers and refugia: a decade of study sheds new light on the phylogeography of northwestern North America. Molecular Ecology 19:4589-4621.

Shepard, A., K.M. Gill, and S.M. Rood. 2010. Climate change and future flows of Rocky Mountain rivers: converging forecasts from empirical trend projections and down-scaled global circulation modeling. Wiley Interscience online (www.wileyinterscience.com) DOI: 10.1002/hyp.7818.

Shepard, B.B. 2010. Evidence of niche similarity between cutthroat trout (*Oncorhynchus clarkii*) and brook trout (*Salvelinus fontinalis*): implications for displacement of native cutthroat trout by nonnative brook trout. Dissertation. Montana State University. Bozeman, Montana.

Shepard, B.B., B.E. May, and W. Urie. 2005. Status and conservation of westslope cutthroat trout within the western United States. North American Journal of Fisheries Management 25:1426-1440.

Simmons, C.A. 1974. Seasonal movements and migrations of the Spotted Bear elk herd. Thesis. University of Montana. Missoula, Montana.

Sloat, M.R., B.B. Shepard, R.G. White, and S. Carson. 2005. Influence of stream temperature on the spatial distribution of westslope cutthroat trout growth potential within the Madison River Basin, Montana. North American Journal of Fisheries Management 25:225-237.

Smith, C.S. 1978. Summer-fall movements, migrations, seasonal ranges, and habitat selection of the Middle Fork elk herd. Thesis, University of Montana. Missoula, Montana.

Solomon, S., K.H. Rosenlof, R.W. Portmann, J.S. Daniel, S.M. Davis, T.J. Sanford, and G.K. Plattner. 2010. Contributions of stratospheric water vapor to decadal changes in the rate of global Warming. Science 327:1219–1223.

Spracklen, D.V., L.J. Mickley, J.A. Logan, R.C. Hudman, R. Yevich, M.D. Flannigan, and A.L. Westerling. 2009. Impacts of climate change from 2000 to 2050 on wildfire activity and carbonaceous aerosol concentrations in the western United States. Journal of Geophysical Research 114, D20301.

Spruell, P., A.R. Hemmingsen, P.J. Howell, N. Kanda, and F.W. Allendorf. 2003. Conservation genetics of bull trout: geographic distribution of variation at microsatellite loci. Conservation Genetics 4:17-29.

Spruell, P., B.E. Rieman, K.L. Knudsen, F.M. Utter, and F.W. Allendorf. 1999. Genetic population structure within streams: microsatellite analysis of bull trout populations. Ecology of Freshwater Fish 8:114-121.

Squires, J.R., M.K. Schwartz, J.P. Copeland, L.F. Ruggiero, and T.J. Ulizio. 2007. Sources and patterns of wolverine mortality in western Montana. Journal of Wildlife Management 71:2213–2220.

Stevens, V. 1983. The dynamics of dispersal in an introduced mountain goat population. Dissertation, University of Washington. Seattle, Washington.

Stewart, I.T., D.R. Cayan, and M.D. Dettinger. 2005. Changes toward earlier streamflow timing across western North America. Journal of Climate 18:1136-1155.

Stockwell, C.A., G.C. Bateman, and J. Berger. 1991. Conflicts in national parks: a case study of helicopters and bighorn sheep time budgets at the Grand Canyon. Biological Conservation 56:317-328.

Swanberg, T.R. 1997. Movements and habitat use by fluvial bull trout in the Blackfoot River, Montana. Transactions of the American Fisheries Society 126:735-746.

Swenson, J.E. 1985. Compensatory reproduction in an introduced mountain goat population in the Absaroka Mountains, Montana. Journal of Wildlife Management 49:837-843.

Thompson, M.J. 1981. Mountain goat distribution, population characteristics and habitat use in the Sawtooth Range, Montana. Thesis, Montana State University. Bozeman, Montana.

Trombulak, S.C., and C.A. Frissell. 2000. Review of ecological effects of roads on terrestrial and aquatic communities. Conservation Biology 14:18-30.

Turner, W.R., B.A. Bradley, L.D. Estes, D.G. Hole, M. Oppenheimer, and D.S. Wilcove. 2010. Climate change: helping nature survive the human response. Conservation Letters 00:1-9.

U.S. Fish and Wildlife Service. 2002. Bull trout recovery plan (draft). U.S. Fish and Wildlife Service. Boise, Idaho.

U.S. Fish and Wildlife Service. 2010. Revised designation of critical habitat for bull trout in the conterminous United States – Final Rule. Federal Register V. 75, No. 200. Monday, October 18, 2010. 75 FR 63898-64070. U.S. Fish and Wildlife Service. Boise, Idaho.

USDA Forest Service. 2000. Forest Service Roadless Area Conservation – Final Environmental Impact Statement. USDA Forest Service. Washington, DC.

USDA Forest Service. 2006. Proposed Land Management Plan, Flathead National Forest. USDA Forest Service, Northern region. Missoula, Montana.

USDA Forest Service. 2007. Rocky Mountain Ranger District Travel Management Plan: Record of Decision for Birch Creek South. Lewis and Clark National Forest. Great Falls, Montana.

USDA Forest Service. 2009. Rocky Mountain Ranger District Travel Management Plan: Record of Decision for Badger-Two Medicine. Lewis and Clark National Forest. Great Falls, Montana.

Van Dijk, J., T. Andersen, R. May, R. Andersen, R. Andersen, and A. Landa. 2008. Foraging strategies of wolverines within a predator guild. Canadian Journal of Zoology 86:966-975.

Vangen, K.M., J. Perrson, A. Landa, R. Andersen, and P. Segerström. 2001. Characteristics of dispersal in wolverines. Canadian Journal of Zoology 79:1641-1649.

Van Mantgem, P.J., N.L Stephenson, J. C. Byrne, L.D. Daniels, J.F. Franklin, P.Z. Fulé, M.E. Harmon, A.J. Larson, J.M. Smith, A.H. Taylor, and T.T. Veblen. 2009. Widespread increase of tree mortality rates in the western United States. Science 323:521-524.

Vore, J., P.R. Malta, and E. Schmidt. 1995. Hungry Horse habitat mitigation report. 1994 annual report. Montana Department of Fish, Wildlife and Parks. Helena, Montana.

Walker, B., and D. Salt. 2006. Resilience thinking: sustaining ecosystems and people in a changing world. Island Press, Washington, DC.

Waller, J.S. 2005. Movements and habitat use of grizzly bears along U.S. Highway 2 in northwestern Montana 1998-2001. Dissertation. University of Montana. Missoula, Montana.

Waller, J.S., and R.D. Mace. 1998. Grizzly bear habitat selection in the Swan Mountains, Montana. Journal of Wildlife Management 61:1032-1039.

Warnock, W.G., J.B. Rasmussen, and E.B. Taylor. 2010. Genetic clustering methods reveal bull trout (*Salvelinus confluentus*) fine-scale population structure as a spatially nested hierarchy. Conservation Genetics. DOI 10.1007/s10592-009-9969-y.

Weaver, J.L. 2001. The transboundary Flathead: a critical landscape for carnivores in the Rocky Mountains. Working Paper No. 18. Wildlife Conservation Society. Bronx, New York.

Weaver, J.L., P.C. Paquet, and L.F. Ruggiero. 1996. Resilience and conservation of large carnivores in the Rocky Mountains. Conservation Biology 10:964-976.

West, J.M., and R.V. Salm. 2003. Resistance and resilience to coral bleaching: implications for coral reef conservation and management. Conservation Biology 17:956-967.

Westerling, A.L., H.G. Hildago, D.R. Cayan, and T.W. Swetnam. 2006. Warming and earlier spring increase western U.S. forest wildfire activity. Science 313:940-943.

Wiens, J.A., and D. Bachelet. 2009. Matching the multiple scales of conservation with the multiple scales of climate change. Conservation Biology 24:51-62.

Williams, J.E., A.L. Haak, H.M. Neville, and W.T. Colyer. 2009. Potential consequences of climate change to persistence of cutthroat trout populations. North American Journal of Fisheries Management 29:533-548.

Wilmers, C.C., and E. Post. 2006. Predicting the influence of wolf-provided carrion on scavenger community dynamics under climate change scenarios. Global Change Biology 12:403-409.

APPENDIX A.
CONSERVATION VALUES OF LANDS FOR VULNERABLE FISH AND WILDLIFE SPECIES

Figure A1. Conservation values for bull trout, Crown of the Continent Ecosystem, Montana.

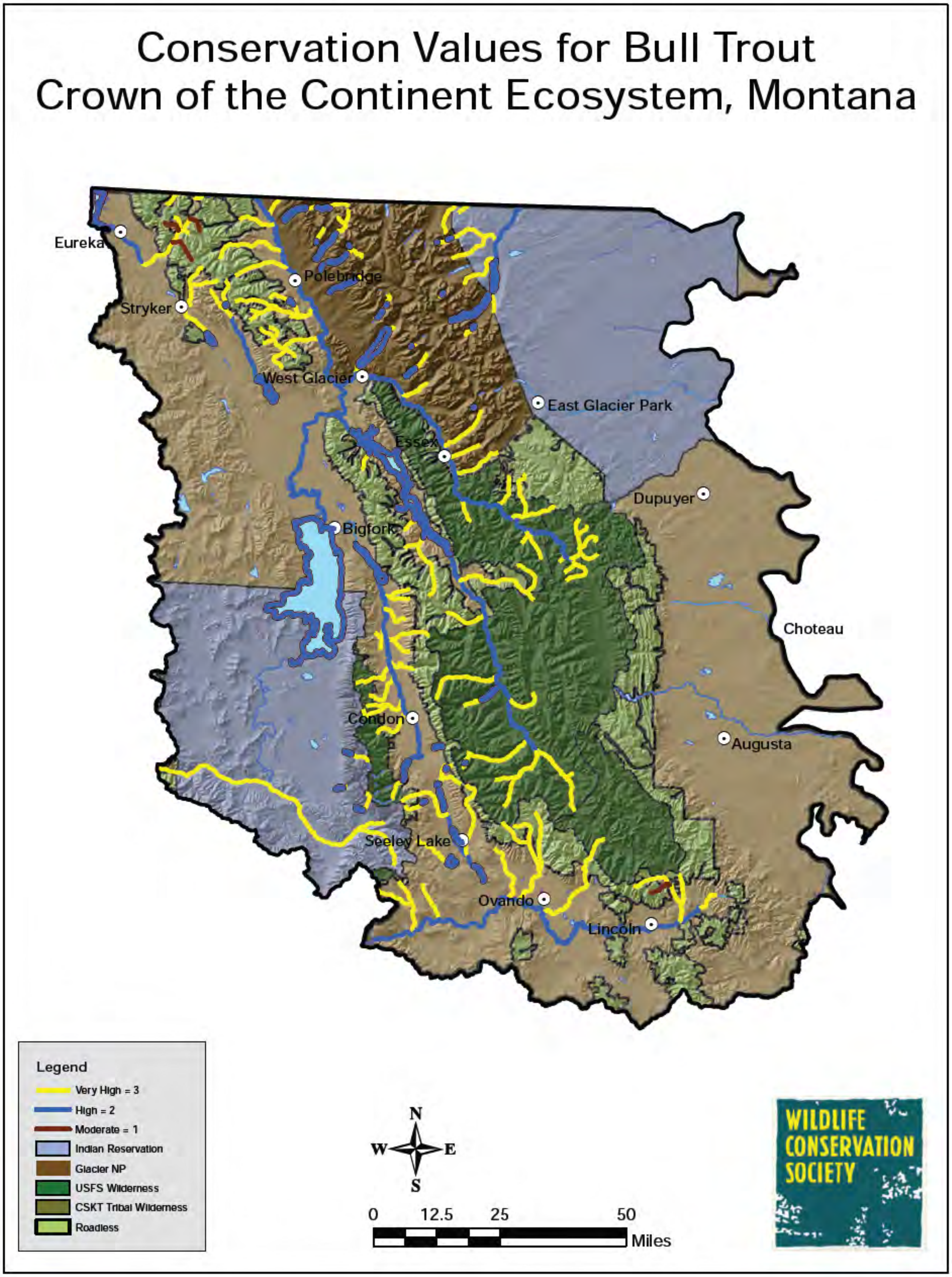


Figure A2. Conservation values for westslope cutthroat trout, Crown of the Continent Ecosystem, Montana.

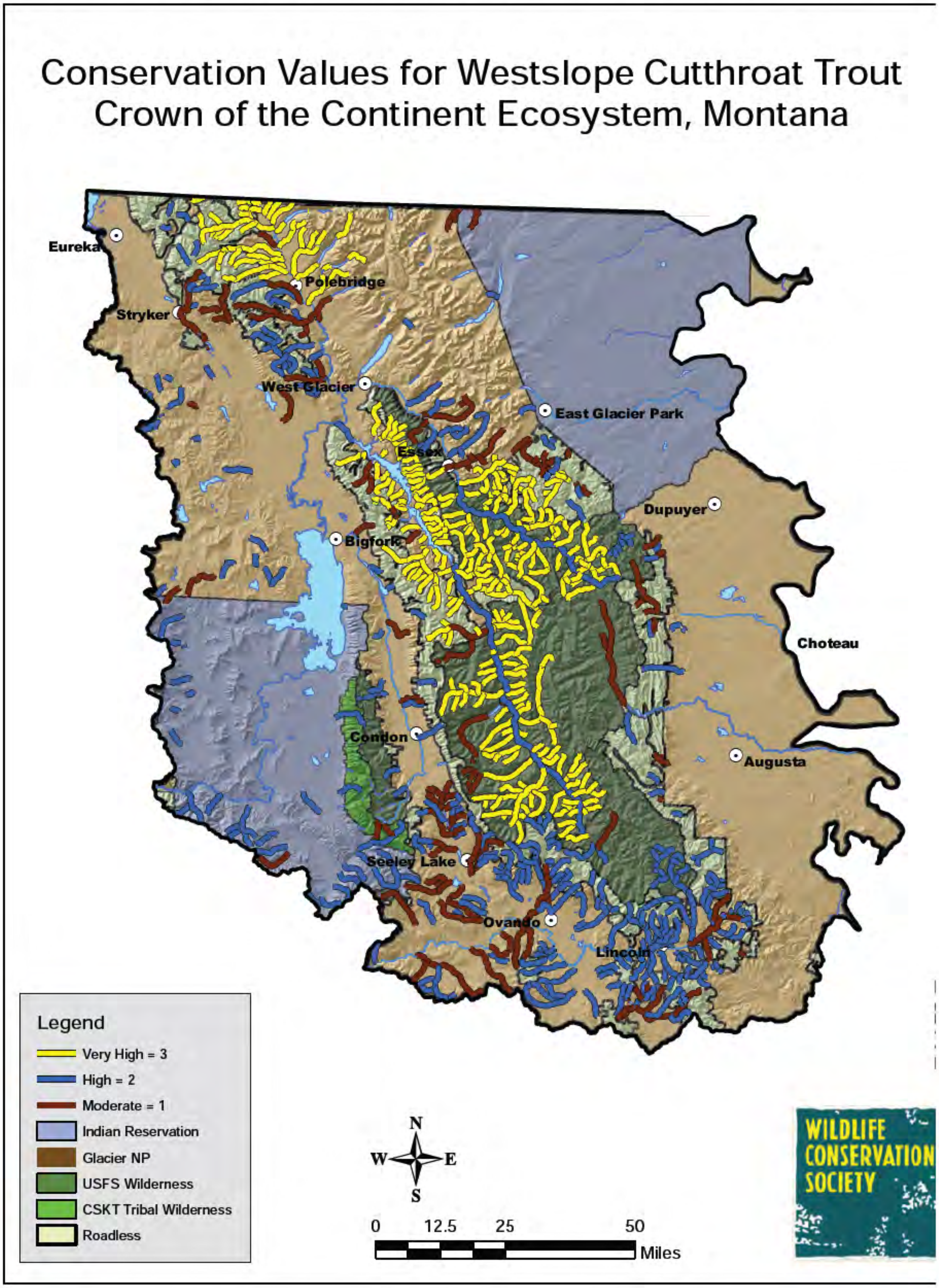


Figure A3. Conservation values for grizzly bears, Crown of the Continent Ecosystem, Montana.

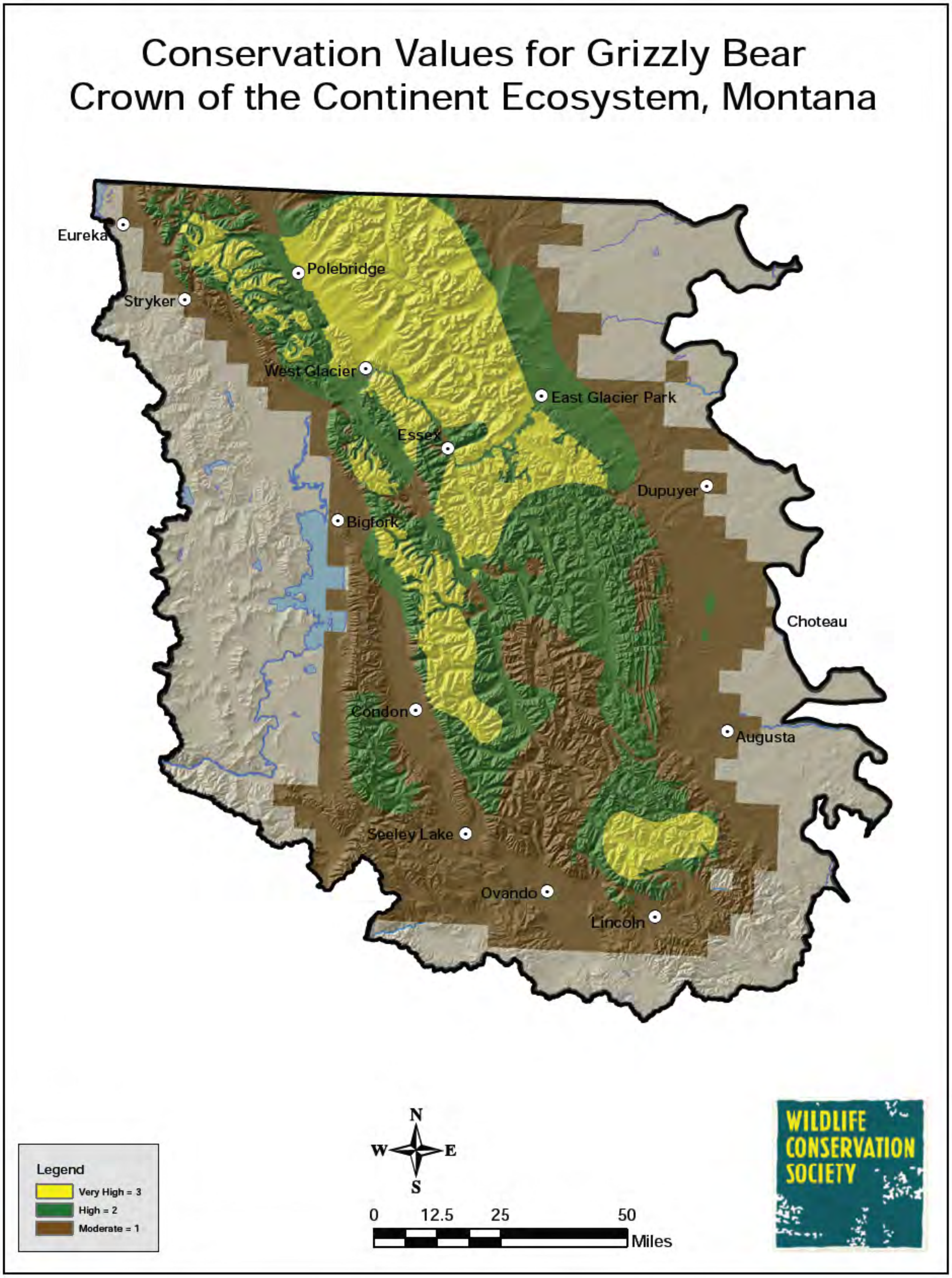


Figure A4. Conservation values for wolverine, Crown of the Continent Ecosystem, Montana.

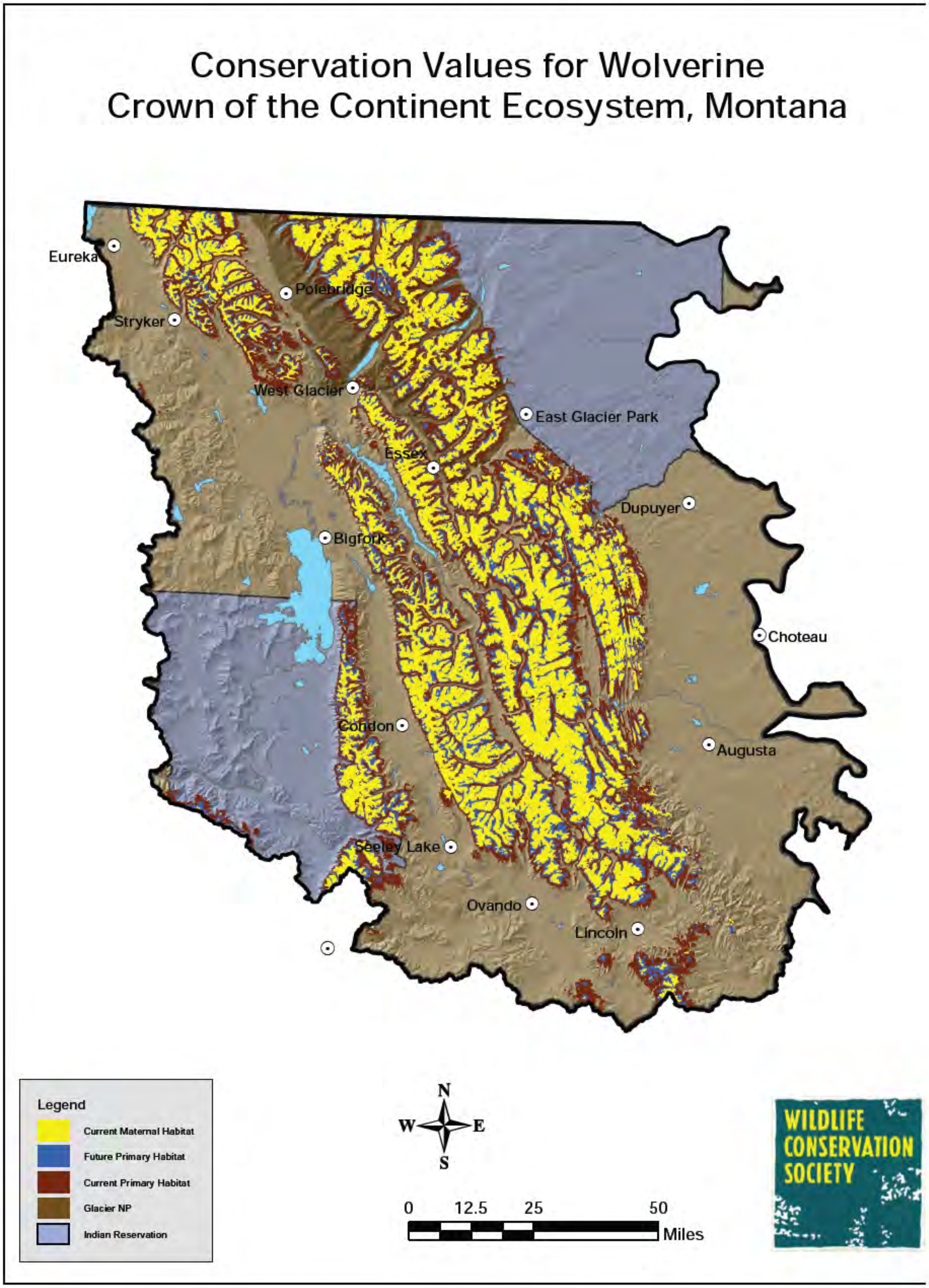


Figure A5. Conservation values for mountain goat, Crown of the Continent Ecosystem, Montana. (No data shown for mountain goat in Glacier National Park.)

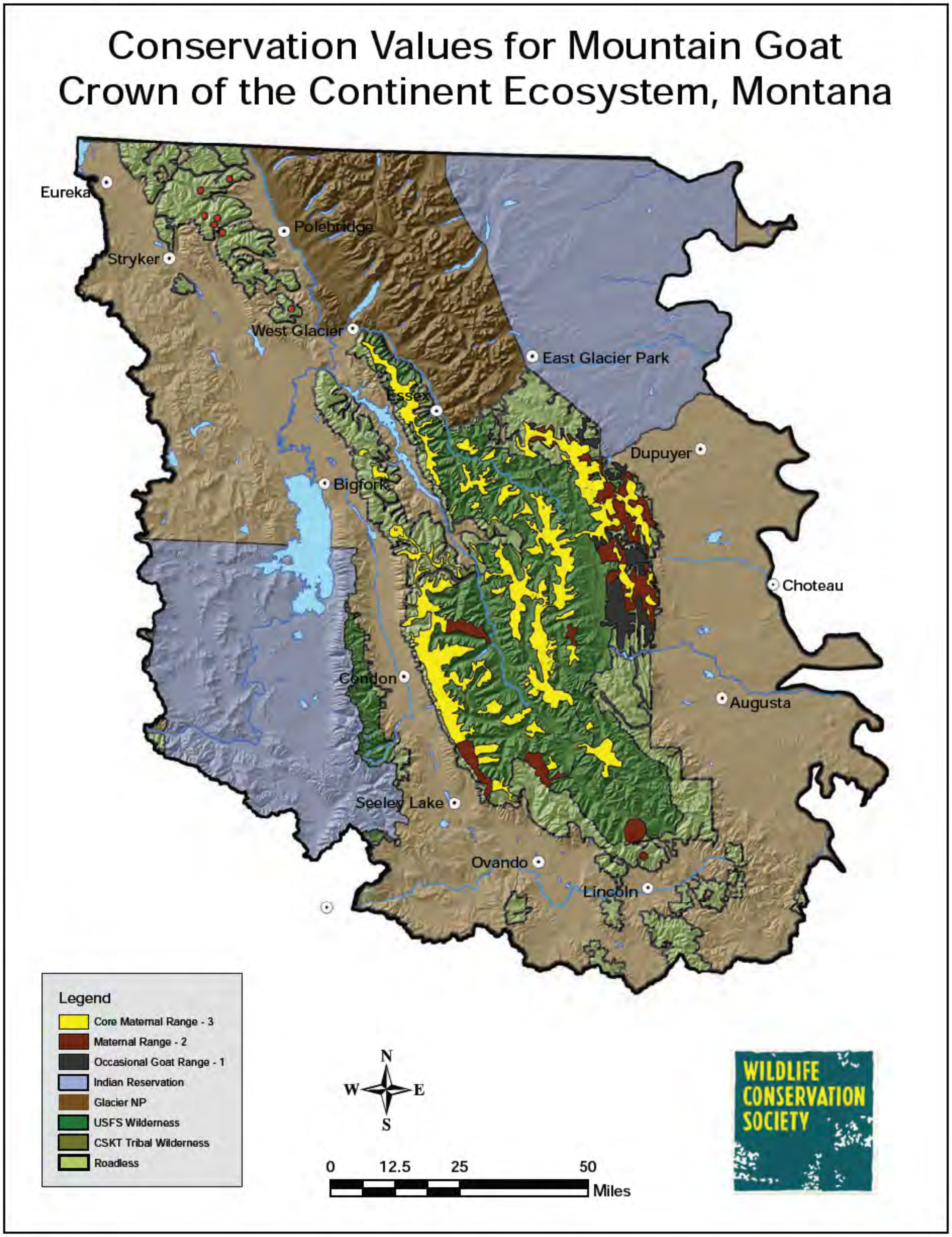


Figure A6. Conservation values for bighorn sheep, Crown of the Continent Ecosystem, Montana. (No data shown for bighorn sheep in Glacier National Park.)

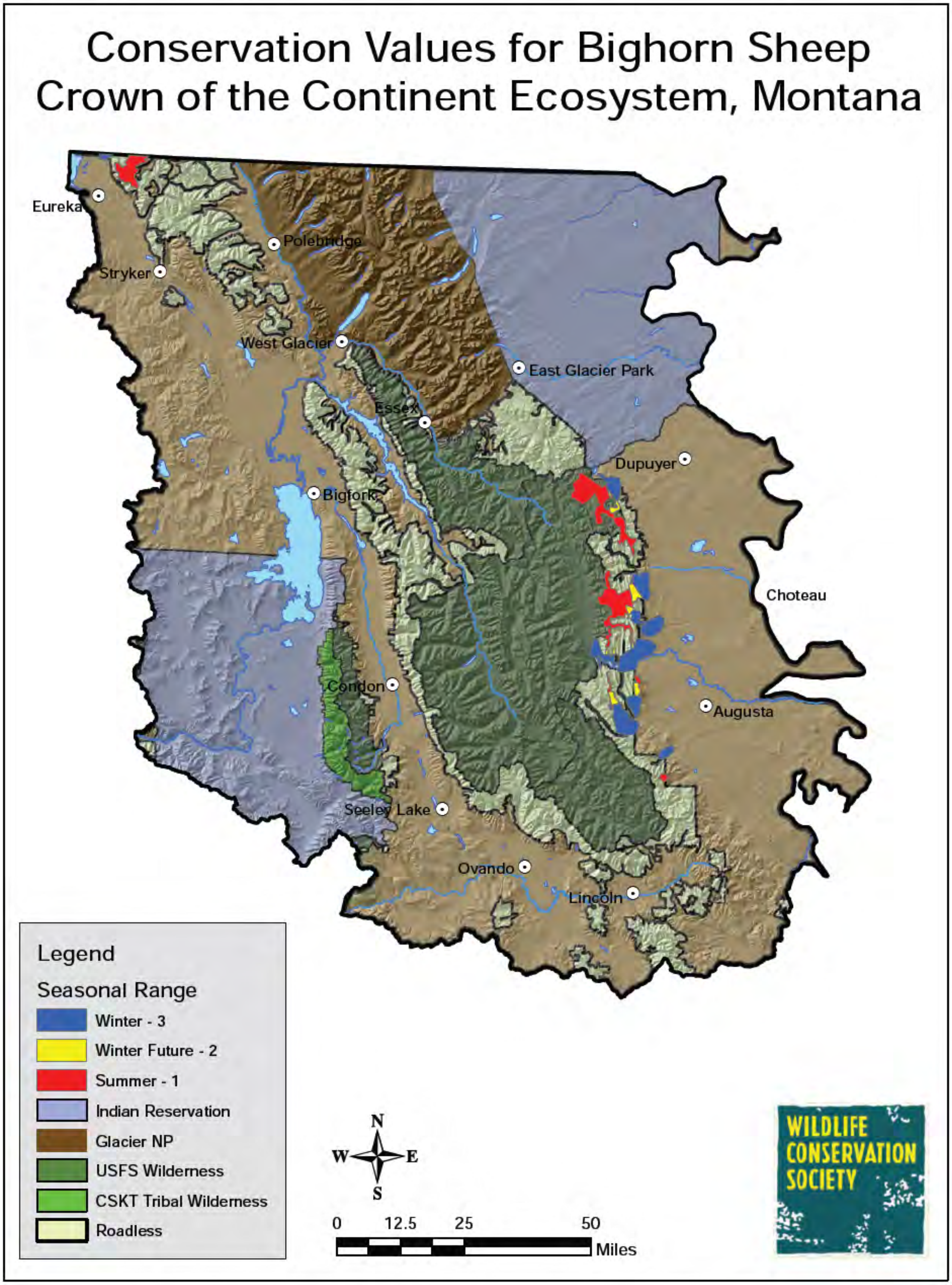
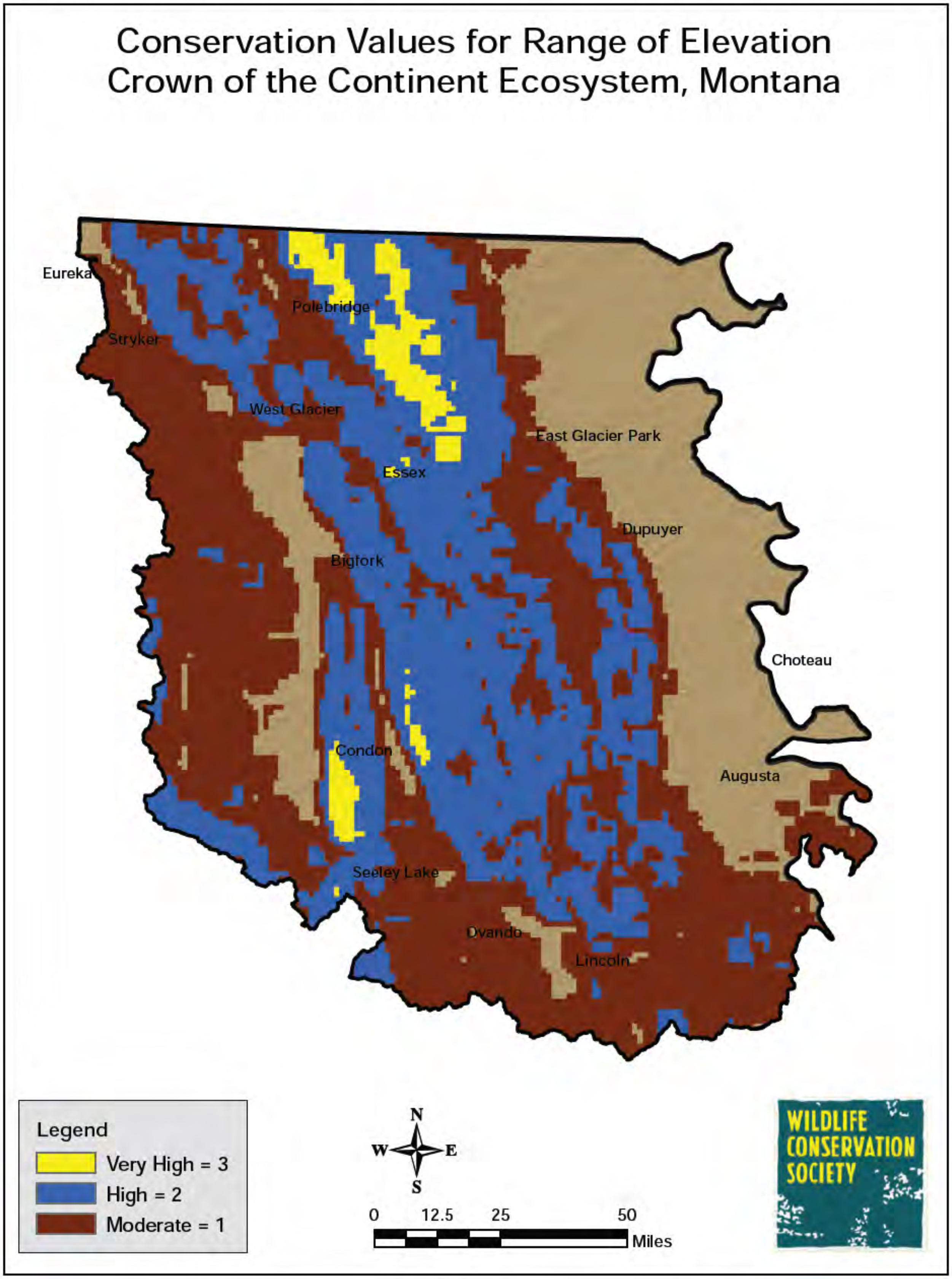


Figure A7. Conservation values for range-of-elevation, Crown of the Continent Ecosystem, Montana.



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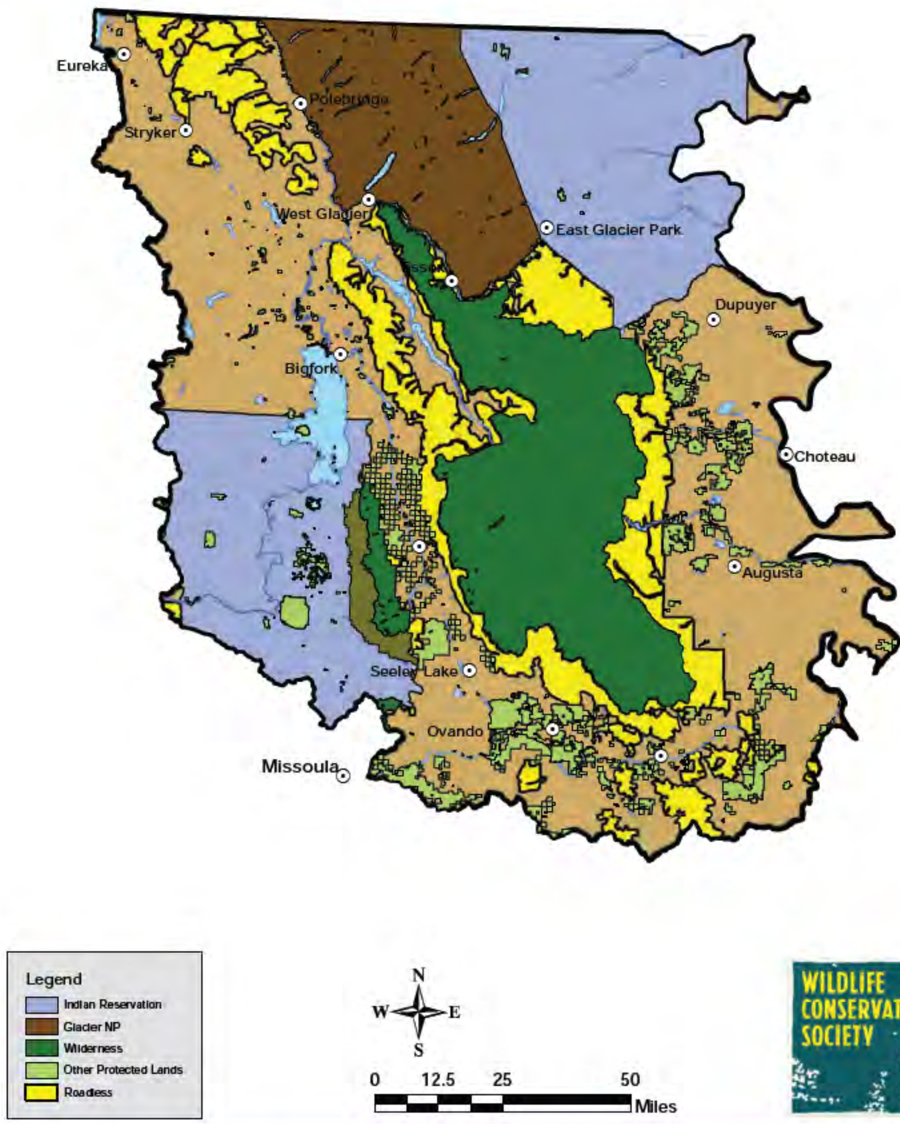
Crown of the Continent Ecosystem, Montana

Let's Complete the Conservation Legacy



Over the past 100 years, previous generations of citizens and Congressional leaders worked hard to protect the central wildlands of the spectacular Crown of the Continent Ecosystem in Montana as National Parks and Wilderness. Private landowners, conservation organizations, and the State of Montana have also teamed up to safeguard crucial habitat for fish and wildlife on surrounding lands. This was a great gift and remarkable legacy. Yet, 1.3 million acres (shown in yellow) remain roadless today. Many of these lands and waters have very high conservation value for a suite of vulnerable fish and wildlife -- including bull trout, westslope cutthroat trout, grizzly bear, wolverine, mountain goat, and bighorn sheep. This is a rare opportunity to complete the legacy of conservation for present and future generations.

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Working Paper No. 40 April 2011 CONSERVATION VALUE OF ROADLESS AREAS IN THE CROWN OF THE CONTINENT ECOSYSTEM, MONTANA By John L. Weaver