Fragmenting the Western American Landscape

The 2006 Colorado College State of the Rockies Report Card

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The Natural Heritage of the American West

West of the 100th meridian, the North American landscape supports vast, biologically rich, and ecologically intact places. The complex natural landscapes of the eight-state Rocky Mountain region—from snow-covered peaks, old growth forests, and wildflower meadows, to endless prairies, and sweetly scented sagebrush shrublands—provide homes for a wealth of biological diversity.

From the east, a tapestry of prairie grasses and shrubs, broken only by lonely buttes and rugged canyons, sweep up and finish their final ascent towards the mountains. Abutting the prairie, the relatively young Rocky Mountains form the rugged and lofty backbone of the West. As the mountains rise up from the plains to heights above 14,000 ft., contrasts in elevation, temperature, and moisture support a number of diverse natural communities. The transition from the piñon-juniper and ponderosa pine woodlands of the foothills, to the higher elevation mixed conifer, spruce, fir, and lodgepole pine forests, and then to the treeless, high alpine tundra, provide habitats for a wide array of plant and animal species. Sweeping down the western slope of the Rockies, the landscape becomes an arid place dominated by dry basins, smaller mountain ranges, and vast expanses of desert and sagebrush shrubland. Approximately 200 years post-settlement, the region still supports this vision of the "West"—a place for biodiversity to persist and for communities and visitors to appreciate, use, and enjoy.

A remarkable array of wildlife exists within these natural places, including wide-ranging populations of bison, ferruginous hawks, pronghorn, Rocky Mountain elk, bald eagles, mountain lions, wolves, and grizzly bear, along with habitat for the smaller but equally important sage grouse, sandhill crane, and prairie dog. These ecosystems also protect clean air and water, provide raw materials, and preserve agricultural and rangelands. The Rocky Mountains are also alluring to people. Prior to European settlement, native people hunted, farmed, and otherwise used the land. Approximately 200 years ago, early European explorers, trappers, miners, and settlers came to make a living managing the resources of the open western territories. Today, the West still entices ranchers, farmers, speculators, developers, and recreationalists to make their home among the region's rich natural resources. Yet, the Rocky Mountain states are changing.

Photo courtesy of The Nature Conservancy photo archives.

How Does Human Settlement Challenge the Biological Diversity of the Rockies?

Rapid growth and development are changing the natural character of the West by altering patterns of land ownership and use.[2] To meet the demands of the region's growing population, farmlands and rangelands are being quickly converted to urban areas, transportation networks are spreading, and many millions of people now leave an impact in what was, until recently, a mostly rural place.[3] The solitude once common is now harder to find (Figure 1). There is little reason to expect that this growth will not continue and, consequently, human pressures on the environment are reasonably predicted to increase.

Human settlement patterns today are more dispersed and require more land per person than in the past.[5] The land-use changes most often associated with human settlement include urban expansion, the subdivision of agricultural and rangelands, and the creation of roads, highways, and other human infrastructure. These patterns and the associated land conversion have wide-ranging regional impacts on the regional character of the West.[6] As the

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Illustrating the Effects of Development on Natural Areas - Monument, Colorado

Rapid growth and development are replacing native ecosystems in some areas at a rapid rate. The two photographs below provide an aerial overview of land use changes in Monument, Colorado (Douglas County in Colorado's Front Range) between 1929 (left) and 2006 (right). As levels of human development begin to dominate the landscape, natural habitat patches become increasingly fragmented by roads and exurban development.[4] The remaining natural areas are disconnected, smaller in size, and may experience ecological conditions outside of the normal range of experience. The species living within the area may face significant difficulty in meeting their life history requirements, including finding food, raising young, and avoiding predation.

Figure 1

Photo courtesy of the Jerry Crail Johnson Earth Sciences and Map Library, University Libraries, University of Colorado at Boulder (BOV 20, Aug. 19, 1927, U.S. Forest Service).

Photo courtesy of GoogleEarth.

demands of an expanding human population and the associated development pressures increase, significant ecological consequences such as habitat loss, landscape fragmentation, and the isolation of populations also increase.[7]

What is the Relationship between Biological Diversity, Human Expansion, and Fragmentation?

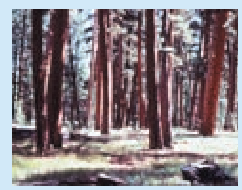
Landscape fragmentation, defined as the breaking up of ecosystems and habitats into smaller and more isolated patches of natural land cover,[8] generally results from land conversion and land use changes that shrink habitat, natural communities, and populations.[9] These changes generally reduce and isolate biodiversity.[10] Conservation science studies indicate that fragmentation, including the loss of ecosystems and habitats, and the separation of large natural blocks of native vegetation, have demonstrable impacts on the distribution and abundance of species and ecological systems.[11] In other words, to the extent that it is occurring, fragmentation could be one of the most pervasive threats to the natural heritage that defines the Rocky Mountain West.

The biological diversity of the West originated with complex interactions of geology, climate, and ecological processes. The structure and composition of the resulting ecosystems influence where a species can live, what it eats and how it avoids being eaten, the size of its population, and its home range and migratory patterns.[12] The survival of a species is dependent on its ability to constantly fine-tune its interactions with the surrounding environment. The loss of ecosystem components, and the resulting landscape fragmentation, can stress this relationship.[13]

Landscape conversion drastically changes the amount and quality of plant and animal habitat.[14] Where roads, fences, and neighborhoods divide a natural landscape, they limit species movement in the region, restricting populations to small and/or isolated pockets of habitat.[15] In the most severe cases, populations of flora and fauna become fragmented and isolated to a level that prohibits individuals from moving within and between their normal habitats.[16] For example, a 15,000-acre grassland, isolated by a major interstate and surrounded by urban centers, will be too small and isolated to support wide-ranging species such as pronghorn. The carrying capacity (i.e., the number of species and individuals that can be maintained) of these disconnected habitat patches is greatly reduced[17] and the species may no longer be able to survive as a functional member of its community.[18]

Habitat Fragmentation and Biodiversity

Ponderosa Pine



The ponderosa pine ecosystem is one of the West's hallmark fire-adapted forests. In the foothills of the southern Rocky Mountains, ponderosa pine woodlands and savannas are found on gentle slopes and valley bottoms below 7,500 ft (2,300 m).[46] The ecosystem was historically characterized by frequent, low-intensity surface fires that typically burn through ponderosa pine stands every eight to fifteen years.[47] The process usually removes understory vegetation and downed material. With periodic fire, these areas will support mature ponderosa pine trees in an open woodland setting and an understory of grasses such as big bluestem and blue grama. The disruption of this process can be disastrous.

Fragmentation often alters the pattern of fire in the ponderosa pine ecosystem. Given the overlap of these woodlands with preferred areas for human development, naturally occurring fires are not allowed to occur at the level necessary to maintain ecosystem processes. Without this periodic disturbance, fire-adapted ecosystems lose an important control mechanism. Today, heavy accumulations of fuel and abundant regeneration of understory species greatly increase the chances for high-intensity, stand-replacing crown fires.[48] The risk to human safety and property, and the potential loss of key elements of biodiversity, challenge us to maintain or restore natural fire regimes in this increasingly less natural and highly fragmented landscape.

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Habitat Fragmentation and Biodiversity

Greater Sage Grouse

Around the world many species of grouse are in decline, including the greater sage grouse. Once occurring in large numbers throughout the sagebrush country of the western United States, this species is now a candidate for listing as a threatened species throughout its range. Although extensive areas of sagebrush remain, the species does not appear to be thriving. Recent research (as summarized in Rowland 2004) suggests that some disturbances in the Western landscape that are relatively small in area (such as roads, water tanks, human residences, and agricultural lands) have large-scale impacts on the ability of the species to successfully reproduce.[45] The effective habitat for the grouse may be much smaller than what would be expected based on the total acreage of habitat.

These shifts from naturalness can also alter fire regimes, riparian corridors and nutrient cycling, shift species composition, and increase the likelihood of nonnative species appearing in rangelands, forests, and riparian ecosystems.[19] The introduction of nonnative species can modify plant composition (e.g., sagebrush systems may be replaced by exotic-dominated grasslands). Without the appropriate kind of disturbance, the vegetation structure of a forest can shift (e.g., without ground fires, ponderosa pine savannas and woodlands may become dense and susceptible to catastrophic crown fire). As a result, some native species of the Rocky Mountain West may find the network of places they depend on for food and habitat to be remote or to no longer exist.[20] Given that ecosystems are interconnected, if enough pieces of an ecosystem are lost, our natural places will be hard to reconstruct.[21]

How We Assess Habitat Fragmentation in the Rockies

Given the significant adverse impacts of fragmentation on the individual species and ecological systems of the Rocky Mountains, the loss or decreases of this biodiversity could forever alter the character of the West. Recognizing this, The Nature Conservancy embarked on a research effort to explore the current patterns of habitat loss and land fragmentation in the Rocky Mountain region and to consider the conservation costs and opportunities of these trends. We identified land cover patterns across the region and completed a per-county comparison of habitat fragmentation using a set of key indicators.[22]

Specifically, we sought to define:

1. The current amount and distribution of natural habitat patches across the region;
2. The current patterns of landscape fragmentation on a per-county basis; and
3. The conservation costs and opportunities of these trends.

Through this research, we hope to provide interested parties, particularly those responsible for land-use planning, with information for examining trends in the regional land use. An enhanced understanding of regional land-cover patterns will provide information that can be used to evaluate ecosystem changes over time.[23] Our results are important for land use, land management, and conservation planning efforts.

Data Collection

This research applies advancements in satellite imagery and landscape modeling to develop the most up-to-date habitat fragmentation assessment for the region. Our analysis is based on data derived from the Multi-Resolution Land Characteristics (MRLC) Consortium's 2001 National Land Cover Database,[24] 2004 Southwest Regional Gap (REGAP) Assessment,[25] and current commercially available road data. REGAP is based on National Land Cover data derived from 1996; it provides the most current and accurate fine-resolution (30m pixels) land-cover classification available on a statewide basis for Arizona, Colorado, Nevada, New Mexico, and Utah land-cover. The MRCL database is used to obtain data for the remaining states. The spatial arrangement of land cover and land uses, specifically the spatial arrangement of natural land cover, is quantified from these datasets. We recognize the vegetative cover of portions of the landscape may have changed since these vegetative layers were generated. These results should be considered, at best, the lowest estimate for the degree of habitat fragmentation in the region. A new National Land Cover Dataset based on 2001 satellite imagery is expected by the second quarter of 2006 (see http://www.mrlc.gov for current status) and will be used at that time for an assessment of trends in fragmentation.

Model Development and Analysis

To identify regional land-cover patterns, we use the information listed above to create a comprehensive database of county-level road and land-cover data. The information is catalogued in a geographic information system (GIS) and used to develop and map landscape composition in terms of natural and human-modified land cover.[26] In this analysis, roads, development, agriculture, and recently mined, quarried, or drilled areas are considered "human-modified" (i.e., unnatural); all other land-cover types are deemed "natural." Water is not considered in our analysis.

The classification is evaluated in terms of several identifiable and measurable elements of habitat fragmentation using FRAGSTATS,[27] a publicly available computer program created to describe patterns of fragmentation across a landscape.

Indicators of Habitat Fragmentation

In this analysis, habitat fragmentation is evaluated using several indicators, each of which provides different and important information about the landscape composition of Rocky Mountain counties. Each indicator, and our hypothesis about its effects on biological diversity, is interpreted in the table. Counties are ranked based on the sum of the normalized percentage of their landscape occupied by natural land cover and the normalized density of natural land-cover occurrences (these values are shaded in grey). Other indicators provided ancillary information on the degree of habitat fragmentation per county.

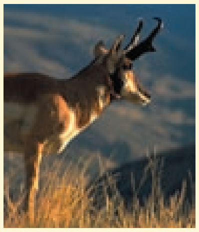
Figure 2

INDICATOR	DESCRIPTION	INTERPRETATION
Total Natural Patch Area (ha)	How many hectares of natural land cover are located in the county?	Value indicates the total amount (ha) of natural habitat in the county. Generally, larger natural habitat patches are considered to have greater ecological intactness and to retain more species.
Normalized Total Natural Patch Area (%)	What percentage of the county retains a natural land cover (normalized per-county size)?	Value indicates the percentage of natural habitat in the county (ha). A lower value indicates that a smaller percent of the county retains a form of natural land cover. Counties with a smaller percentage of natural land cover usually experience a greater degree of habitat fragmentation. Thus, they may retain fewer intact ecological processes and fewer species over time.
Total Landscape Area (ha)	How large is the county (ha)?	Value used to normalize other indicators. Normalization of values facilitates comparison of counties across the region.
Normalized Natural Area Patch Density (%)	How many patches of natural area are contained in the county (normalized by county size)?	Value indicates a degree of habitat fragmentation. An unfragmented county will have most of its natural areas contained in a few patches - patch density will be low. If the landscape is highly fragmented- i.e., there are large numbers of disconnected patches, patch density is high. Higher degrees of habitat fragmentation are expected to decrease the diversity of the biota over time.
Largest Natural Patch (ha)	What size (ha) is the largest natural patch in the county?	Value indicates the types and number of species and communities that can persist in the patch and in the county. Larger patches are typical of a less fragmented landscape. These places typically support a more diverse range of species, especially those with larger home ranges.
Largest Natural Patch Index (%)	What proportion of the county is represented by the largest natural patch?	Value indicates the degree of landscape intactness. Higher values signify a county with large, intact natural areas, i.e., less fragmentation. A greater diversity of species will thrive in places containing large concentrations of intact habitat.
Mean Area of Natural Patches (ha)	If you randomly picked a patch in the county, what is the expected natural patch size?	Value indicates the expected size (ha) of a randomly picked natural patch. Larger average patch size suggests that species and communities that require larger areas are more likely to find them in this area. Higher values indicate larger sized natural areas.
Coefficient of Natural Patch Variation (%)	How diverse is the range of natural patch sizes in the county?	Value indicates the level of variation in the size of natural areas. A lower percentage signifies that county is less natural in the sense that natural patches are regular standard size and generally indicates a greater level of human influence on the landscape. A high percentage signifies a greater variation in the size and shape of natural areas, and thus types of species that can be supported by the landscape.

Each of these indicators provides important information about the landscape composition of Rocky Mountain counties.[28] The results from each indicator are combined to create a comparative index of habitat fragmentation for each of the region's counties. This index is used to generate maps and tables that represent the degree of habitat fragmentation on a per-county basis. The specific indicators chosen for this analysis are represented in Figure 2.

Recognizing the difficulty of developing a simple and meaningful ecological index of landscape fragmentation,[29] we assume that greater biological diversity and complexity are present in counties with larger patches of natural vegetation.[30] Given this assumption, we determine the two most important indicators of fragmentation are natural patch size and natural patch density.[31] Counties are ranked based on the sum of the normalized percentage of their landscape occupied by natural land cover ("natural patch size") and the normalized density of natural land-cover occurrences ("natural patch density"). Other indicators provide ancillary information about the landscape composition of each county. We believe this approach yields robust, easily interpreted values relating to ecosystem integrity, and that these measures can be rolled up into a common indicator of fragmentation comparable across counties.[32]

Photo courtesy of The Nature Conservancy, copyright Milton Rand.



Habitat Fragmentation and Biodiversity
Pronghorn

The Pronghorn is one of North America's best known symbols of the western prairies and shrublands. In the early 1800s, the number of Pronghorn probably equaled or exceeded that of the bison. However, the Pronghorn population declined to nearly 15,000 individuals during the first half of the 21st century. Subsequently this species made a remarkable recovery, now numbering approximately one million individuals by 1997. However, Pronghorn are beginning to decline again due to habitat loss in areas with growing human populations.[43] The construction of fencing hinders movement in this wide-ranging species. When combined with the encroachment of incompatible land uses such as agriculture, recreation, or exurban development, the remaining natural patches of habitat are often too small to sustain a population or even a herd of Pronghorn. Patches of habitat smaller than about 15,000 acres are not generally used by Pronghorn.[44] The species is highly imperiled in parts of Arizona and New Mexico, those in Colorado's Front Range are restricted to increasingly smaller and more isolated pockets of habitat (e.g., in the area near Pueblo West), and populations in the sagebrush shrublands are being impacted by wheat farming, recreation, and oil and gas development. This species is not likely to disappear from the American West, but as the area of suitable habitat continues to decline, the number of areas in which Pronghorn can successfully occupy will also decline.

Results

The FRAGSTATS analysis demonstrates that there are patterns in both the amount and distribution of natural land cover and in patterns of habitat fragmentation in the eight-state Rocky Mountain region. The results are displayed in the maps and tables below.

The Amount and Distribution of Natural Land Cover in the Rockies

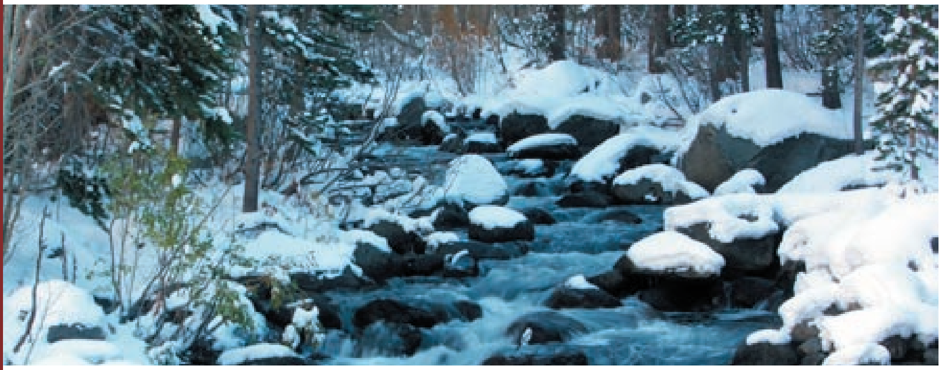
Figure 3 displays a map of region-level patterns of natural habitat in the Rocky Mountain region. Remarkably, with respect to land cover, the vast majority of the West remains relatively natural. Of the 547 million acres of western lands, only 13.4 percent, or 73 million acres (30 million ha), are heavily human modified. The remaining 86.6 percent, or 474 million acres (192 million ha), of the region retain some form of natural land cover.

The portions of the region most heavily impacted by human land uses occur along the Interstate-25 corridor of Colorado's Front Range and the Interstate-70 corridor of Utah. Each of the region's major urban centers, including Salt Lake City, Utah; Flagstaff, Arizona; Las Vegas, Nevada; and Denver and Colorado Springs, Colorado, also exert a strong negative influence on the naturalness of their surrounding landscapes. The availability of native habitat is also reduced in intensely cultivated and irrigated lands, including Colorado's eastern plains and Idaho's southeastern and northwestern plains. In these agricultural areas, nonnative monocultures have replaced native prairie grasslands and shrublands.

Current Patterns of Landscape Fragmentation in the Rockies

Figure 4 displays a map of county-level habitat fragmentation patterns. Using the Jenks method, counties are shaded based on natural groupings in the data (i.e., minimum within class differences, maximum between class differences). Counties identified in green to light green are more likely to contain large and presumably ecologically intact patches of natural habitat. In these places, a greater portion of the native diversity of species should thrive in these large concentrations of intact natural lands. Of the 281 counties in the region, 247 (87 percent) still retain greater than 75 percent of their land area in some form of natural land cover.

The most highly fragmented counties are represented in increasing shades of yellow. In these areas, human modified land-cover types dominate up to 94 percent of the total county area. Resulting from this greater level of human influence on the landscape, natural areas are found in smaller and more disconnected patches, a typical pattern in more fragmented landscapes. Of the five counties with less than 25 percent natural land cover, four are found along the Colorado Front Range. In the counties where habitat fragmentation is greatest, the remaining species and communities may face significant challenges in meeting their life-history requirements.



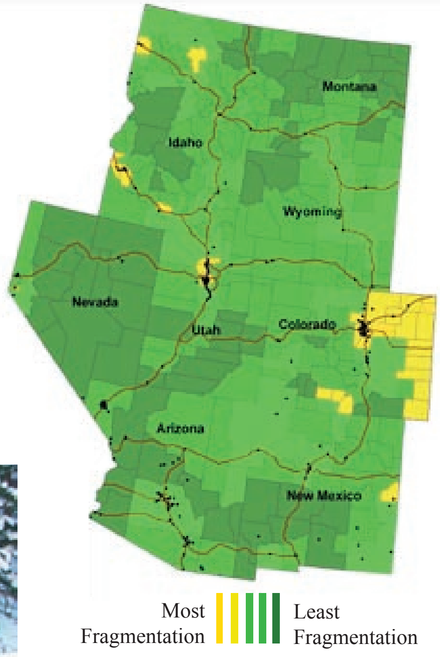
Current Amount and Distribution of

Natural Land Uses

Green areas represent the remaining areas of natural cover contained within the Rocky Mountain landscape. Areas highly impacted by human influence, including urban settlement and agricultural development, are represented in yellow.
Figure 3

County-Level Fragmentation Patterns

The dark green areas represent the counties with the least fragmented landscapes, relative to one another. Yellow represents the most highly fragmented counties.
Figure 4



Top 10
Most and Least Fragmented Counties

This table lists the 10 least and the 10 most highly fragmented counties in the Rocky Mountain region, as well as the indicators and values used to determine their rank. Each of the 10 least fragmented counties retains greater than 93 percent of its landscape in some form of natural land cover and has a natural patch density of less than 0.1 percent (most of its natural areas contained in a few patches). However, greater than 46 percent of the region's counties retain greater than 90 percent of their landscape in some form of natural land cover. On the other hand, the 10 most highly fragmented counties listed in the table provide an accurate representation of the counties where fragmentation levels are greatest. In these counties, the combined effects of landscape conversion and a large number of disconnected patches result in a much more highly fragmented landscape.

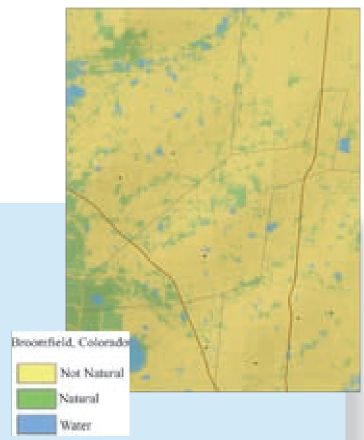
Figure 5

	County Name	Indicators of Fragmentation							
		Total Natural Patch Area (ha)	Normalized Total Natural Patch Area (%)	Total Landscape Area (ha)	Normalized Natural Area Patch Density (%)	Largest Natural Patch Index (%)	Largest Natural Patch (ha)	Mean Area of Natural Patches (ha)	Coefficient of Natural Patch Variation (%)
Least Fragmented	1 - Fergus, Montana	1,086,264	96	1,126,928	0.03	14.38	162,040	59,145	417
	2 - McCone, Montana	662,917	95	696,265	0.02	7.35	51,185	17,596	186
	3 - Hinsdale, Colorado	266,624	96	279,055	0.06	55.24	154,148	99,446	759
	4 - Chouteau, Montana	974,736	95	1,029,173	0.05	12.07	124,251	30,435	372
	5 - Dawson, Montana	585,120	94	620,523	0.05	7.33	45,505	13,937	265
	6 - San Juan, Colorado	98,490	95	103,791	0.07	49.49	51,368	32,382	469
	7 - Grand, Utah	892,673	94	948,250	0.06	32.75	310,558	118,575	886
	8 - Lincoln, Nevada	2,592,403	94	2,745,001	0.07	5.98	164,239	30,266	467
	9 - Mineral, Colorado	226,705	95	239,418	0.08	56.10	134,304	96,571	887
	10 - Greenlee, Arizona	442,788	94	472,133	0.06	33.65	158,856	71,816	684
Most Fragmented	273 - Alamosa, Colorado	106,504	58	182,250	1.02	6.91	12,585	3,408	763
	274 - Logan, Colorado	242,849	51	479,840	0.88	2.16	10,372	3,409	762
	275 - Sedgwick, Colorado	45,399	31	145,787	0.61	3.24	4,717	2,127	637
	276 - Canyon, Idaho	93,819	60	156,100	1.36	1.14	1,783	327	253
	277 - Arapahoe, Colorado	87,742	42	207,453	1.04	7.18	14,886	3,795	963
	278 - Phillips, Colorado	26,486	15	178,750	0.78	2.68	4,786	1,364	840
	279 - Adams, Colorado	64,846	21	306,264	1.37	2.01	6,161	1,269	900
	280 - Denver, Colorado	2,449	6	40,479	1.08	0.26	104	33	222
	281 - Broomfield, Colorado	1,988	18	11,015	2.02	4.69	517	186	446

Profiling Habitat Fragmentation
Fergus, Montana – Least Fragmented County

Fergus is a large (1,126,928 ha, 2,783,512 ac), micropolitan county (def. a non-metropolitan county with an urban population of 20,000 or more and adjacent to a metropolitan area) with little habitat fragmentation due to roads and other forms of development. Greater than 96 percent of the county retains some form of natural land cover. An extremely low patch density (0.3) indicates that existing habitat loss has not separated the county's natural areas into a large number of smaller patches (see Figure 5).

At just over 162,000 ha (400,000 ac), the largest natural patch in the county may support most native species and natural processes. When considered in the context of other very large patches, this largest patch may include species whose life cycles require large expanses of relatively undisturbed territory. While the largest patch dominates much of the county (14 percent), the remaining natural landscape also contains a high diversity of natural area patch sizes (patch size coefficient of variation = 22.7). The existence of several smaller natural patches within the county's developed areas has the effect of decreasing the average patch area to 3223 ha (7961 ac). However, the average (or expected) patch area of this size is still large enough to support many species and ecological processes.



Profiling Habitat Fragmentation
Broomfield, Colorado – Most Fragmented County

Broomfield is a small metropolitan county (def. a county in a metropolitan area with a population of greater than 250,000) located along the Front Range of Colorado. Only 18 percent of Broomfield County's 11,015 ac are recognized by our analysis as natural (See Figure 5). This dominance of developed areas results in a pattern of highly fragmented natural places. The remaining patches of native ecosystems are small and numerous (patch density = 2.02). While the range and diversity of patch sizes within Broomfield County are high (patch size coefficient of variation = 445.56), the size of the largest natural area, 517 ha, can support a less complex diversity of species. Ecological processes may be highly altered. The average (or expected) patch size of 185.89 ha can support only those species which tolerate or use small patches of natural areas or those which can make use of the county's disconnected patches and the surrounding non-natural matrix.

In the 1990s, Colorado was ranked the third fastest growing state (http://www.censusscope.org/us/s8/chart_popl.html, accessed on 27 Jan. 2006). The state's population is expected to reach seven million by 2030. As a result of this expanding population, thousands of acres of open space are converted to development each year. Surface water extraction threatens native fish and riparian plant communities around the state. Development patterns have been a primary cause of altered fire regimes, leaving many overgrown forests to threaten human life and property.

Conservation Costs and Opportunities – The Impacts of Habitat Fragmentation in the Rockies

This research provides an improved understanding of land-cover patterns, i.e., the distribution of natural and human-modified lands, and the varying levels of habitat fragmentation across the Rocky Mountain region. The western United States still retains the ability to preserve and restore representations of nearly all of its native species and habitats. This analysis demonstrates that 87 percent of the region still retains some form of natural land cover, and that 246 of the region's 281 counties have greater than 75 percent natural land cover. These large, more intact places are critical to the long-term well-being of many of the plants, animals, and ecosystems that represent the vast diversity of life in the Rocky Mountain region.

The Rocky Mountain region is at a crossroads—and the challenges are large. Approximately 67 percent of the region's counties, both urban and rural, grew faster than the national average in the 1990s,[33] and by 2003, four of the nation's top ten fastest-growing states were in the Rocky Mountains (Nevada, Arizona, Idaho, and Utah).[34] When human expansion fragments the landscape to the extent that it limits the reproductive success, mortality, and movement patterns of plants and animals, biodiversity will be negatively impacted.[35] Because of this, the lands and waters of the Rocky Mountain region are being altered in ways that have significant impacts on the plants, animals, natural communities, and our human way of life. Ultimately, the loss of these special places will forever alter the wild character of the West.

Whether small or large, all Rocky Mountain counties can play a role in retaining a network of important areas of potential habitat. Protecting these places will enable the West to maintain its diverse ecosystems and the remarkable array of plants and wildlife that depend on these habitats.[36] It is imperative to recognize the region's collective responsibility in maintaining this network of natural places. However, because development decisions are inherently local,[37] this information can be used by counties to explore their potential role in conserving the region's biological diversity and to design important contributions to the preservation of the region's natural heritage. Using the results of this research, the municipalities of the West can consider current patterns of land-cover and fragmentation, and potential effects of land cover change to biological diversity, when making municipal land use planning decisions.[38] Working together, the region can seek new ways to mitigate growth demands without compromising the quality of life for future generations.

To be successful, the conservation of natural areas must be representative of the Rocky Mountain region's varied mountains, plains, and desert habitats, and of its resident and migratory species. Designing conservation strategies based on ecological principles,[39] adaptive management, and around the region's existing large habitat patches can effectively provide for conservation of ecosystems,

Most and Least Fragmented Metro Counties
Figure 6

	Top Metro Counties (of 62 Total)	Indicators of Fragmentation							
		Total Natural Patch Area (ha)	Normalized Total Natural Patch Area (%)	Total Landscape Area (ha)	Normalized Natural Area Patch Density (%)	Largest Natural Patch Index (%)	Largest Natural Patch (ha)	Mean Area of Natural Patches (ha)	Coefficient of Natural Patch Variation (%)
Least Fragmented	**1 - Yavapai, Arizona**	1,890,375	90	2,096,129	0.13	3.36	70,329	17,013	478
	2 - Yuma, Arizona	1,280,953	88	1,452,080	0.10	8.49	123,209	53,294	776
	3 - Washington, Utah	558,711	90	621,439	0.14	8.04	49,947	19,352	540
	4 - Carbon, Montana	480,885	90	535,043	0.14	19.20	102,720	27,276	651
	5 - Torrance, New Mexico	778,683	90	867,217	0.18	7.58	65,718	11,825	474
	6 - Pima, Arizona	2,088,055	87	2,389,616	0.13	3.36	80,291	22,650	570
	7 - Washoe, Nevada	1,511,256	88	1,711,088	0.15	3.70	63,278	21,172	595
	8 - Juab, Utah	791,071	88	898,072	0.16	3.92	35,216	10,221	413
	9 - Boise, Idaho	438,175	88	496,006	0.17	13.16	65,276	21,093	621
	10 - Coconino, Arizona	4,329,739	90	4,816,675	0.20	12.23	588,935	97,044	1,465
Most Fragmented	**53 - Jefferson, Colorado**	133,679	67	200,009	0.73	6.26	12,511	4,231	671
	54 - Ada, Idaho	186,778	69	271,205	0.86	1.75	4,737	1,062	350
	55 - Boulder, Colorado	122,679	65	189,543	0.87	23.01	43,606	18,159	1,556
	56 - Weld, Colorado	568,623	54	1,050,775	0.81	2.94	30,925	8,260	1,106
	57 - Davis, Utah	31,182	19	164,851	0.09	4.38	7,218	4,691	468
	58 - Canyon, Idaho	93,819	60	156,100	1.36	1.14	1,783	327	253
	59 - Arapahoe, Colorado	87,742	42	207,453	1.04	7.18	14,886	3,795	963
	60 - Adams, Colorado	64,846	21	306,264	1.37	2.01	6,161	1,269	900
	61 - Denver, Colorado	2,449	6	40,479	1.08	0.26	104	33	222
	62 - Broomfield, Colorado	1,988	18	11,015	2.02	4.69	517	186	446

species and their supporting ecosystem processes.[40] Research demonstrates that top priority conservation areas include areas with substantial ecological contributions, large natural patches, and vegetated corridors that provide protection to riparian areas and that facilitate the movement of species between natural areas. Smaller patches and corridors of natural land cover interspersed throughout developed areas are also essential.[41] Conserving large natural patches such that the biodiversity is connected, perhaps through a mixture of smaller natural areas, will ensure a network of natural areas on a scale large enough to build resilience into the region's natural systems and to ensure their ability to be self-sustaining in the longterm.[42]

The natural areas in the Rocky Mountains are a vital natural and economic resource to the region. To maintain our natural heritage, we must balance the conservation of biological diversity, our ever-expanding population, and the resulting development and resource use. Successful conservation must not only protect ecosystems, but also strengthen and diversify the economies of local communities that depend on natural resources for their livelihood. The remaining natural areas provide a grand template from which a successful conservation network can be developed. In the words of John Sawhill, former president and CEO of The Nature Conservancy, "In the end, our society will be defined not only by what we create but also by what we refuse to destroy."

Most and Least Fragmented Micro Counties

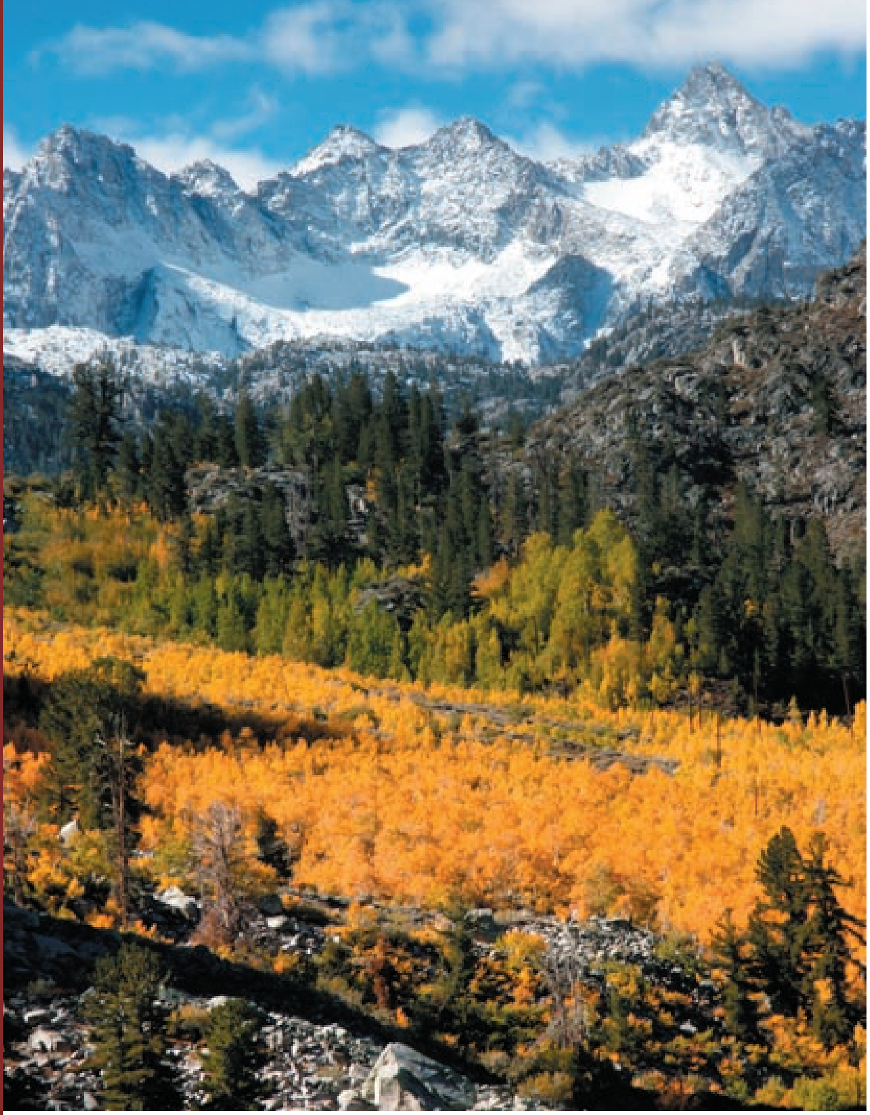
Figure 7

	Top Micro Counties (of 138 Total)	Indicators of Fragmentation							
		Total Natural Patch Area (ha)	Normalized Total Natural Patch Area (%)	Total Landscape Area (ha)	Normalized Natural Area Patch Density (%)	Largest Natural Patch Index (%)	Largest Natural Patch (ha)	Mean Area of Natural Patches (ha)	Coefficient of Natural Patch Variation (%)
Least Fragmented	**1 - Fergus, Montana**	1,086,264	96	1,126,928	0.03	14	162,040	59,145	417
	2 - Dawson, Montana	585,120	94	620,523	0.05	7	45,505	13,937	265
	3 - Grand, Utah	892,673	94	948,250	0.06	33	310,558	118,575	886
	4 - Lincoln, Nevada	2,592,403	94	2,745,001	0.07	6	164,239	30,266	467
	5 - Greenlee, Arizona	442,788	94	472,133	0.06	34	158,856	71,816	684
	6 - Toole, Montana	466,560	93	503,285	0.08	5	25,355	7,111	227
	7 - Roosevelt, Montana	579,552	93	620,376	0.10	6	34,924	10,668	322
	8 - Valley, Montana	1,205,133	92	1,309,350	0.07	8	98,226	30,952	490
	9 - Gila, Arizona	1,145,717	92	1,245,423	0.07	9	110,633	35,229	525
	10 - Las Animas, Colorado	1,130,542	92	1,225,166	0.08	13	165,005	43,424	614
Most Fragmented	**129 - Payette, Idaho**	86,237	78	109,910	0.72	9	10,252	2,665	485
	130 - Jerome, Idaho	112,716	71	157,946	0.58	6	9,559	1,456	328
	131 - Rio Grande, Colorado	166,081	71	233,953	0.66	28	65,235	32,893	1,750
	132 - Curry, New Mexico	204,566	55	368,644	0.35	3	12,036	2,258	366
	133 - Prowers, Colorado	223,587	54	411,039	0.44	3	11,638	3,301	507
	134 - Yuma, Colorado	326,014	53	611,323	0.49	3	15,715	4,191	611
	135 - Morgan, Colorado	187,233	56	332,729	0.83	8	27,082	6,826	1,001
	136 - Kit Carson, Colorado	232,408	41	561,155	0.55	1	6,685	1,335	409
	137 - Alamosa, Colorado	106,504	58	182,250	1.02	7	12,585	3,408	763
	138 - Logan, Colorado	242,849	51	479,840	0.88	2	10,372	3,409	762

Most and Least Fragmented Rural Counties

Figure 8

	Top Rural Counties (of 81 Total)	Indicators of Fragmentation							
		Total Natural Patch Area (ha)	Normalized Total Natural Patch Area (%)	Total Landscape Area (ha)	Normalized Natural Area Patch Density (%)	Largest Natural Patch Index (%)	Largest Natural Patch (ha)	Mean Area of Natural Patches (ha)	Coefficient of Natural Patch Variation (%)
Least Fragmented	**1 - McCone, Montana**	662,917	95	696,265	0.02	7.4	51,185	17,596	186
	2 - Hinsdale, Colorado	266,624	96	279,055	0.06	55.2	154,148	99,446	759
	3 - Chouteau, Montana	974,736	95	1,029,173	0.05	12.1	124,251	30,435	372
	4 - San Juan, Colorado	98,490	95	103,791	0.07	49.5	51,368	32,382	469
	5 - Mineral, Colorado	226,705	95	239,418	0.08	56.1	134,304	96,571	887
	6 - Daniels, Montana	347,313	94	368,226	0.07	8.2	30,123	9,219	249
	7 - Wayne, Utah	605,388	94	644,185	0.07	16.8	108,246	59,012	669
	8 - Garfield, Utah	1,256,323	93	1,352,206	0.07	12.6	170,239	56,207	659
	9 - Catron, New Mexico	1,692,875	93	1,815,215	0.08	8.8	159,140	27,237	478
	10 - Wibaux, Montana	215,336	93	232,069	0.08	13.1	30,337	11,842	296
Most Fragmented	**72 - Lincoln, Colorado**	477,727	71	677,498	0.32	3.1	21,020	6,976	557
	73 - Conejos, Colorado	251,959	77	329,351	0.50	16.8	55,267	23,742	1,236
	74 - Crook, Wyoming	557,870	76	737,143	0.56	1.5	11,182	1,981	371
	75 - Baca, Colorado	383,081	58	656,601	0.38	2.8	18,392	4,519	530
	76 - Kiowa, Colorado	250,176	54	463,537	0.29	2.6	11,990	3,400	413
	77 - Cheyenne, Colorado	253,728	56	452,218	0.38	3.8	17,368	4,483	545
	78 - Costilla, Colorado	231,519	73	315,834	1.01	18.3	57,684	15,840	1,471
	79 - Washington, Colorado	286,576	44	646,666	0.54	3.3	21,334	5,494	814
	80 - Sedgwick, Colorado	45,399	31	145,787	0.61	3.2	4,717	2,127	637
	81 - Phillips, Colorado	26,486	15	178,750	0.78	2.7	4,786	1,364	840



Endnotes

[1]The Nature Conservancy is a nonprofit organization whose mission is to preserve the plants, animals, and natural communities that represent the diversity of life on Earth by protecting the lands and waters they need to survive. We aspire to the vision articulated more than 50 years ago by Aldo Leopold in A Sand County Almanac: conservation is a state of harmony between man and nature.

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