ROCKY MOUNTAIN LOWER MONTANE-FOOTHILL SHRUBLAND ECOLOGICAL SYSTEM

ECOLOGICAL INTEGRITY ASSESSMENT

photo by S. Neid

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ECOLOGICAL INTEGRITY ASSESSMENT

A. INTRODUCTION

A.1 Classification Summary

CES306.822 Rocky Mountain Lower Montane-Foothill Shrubland

Landcover class:	Shrubland
Spatial Scale & Pattern:	Large patch
Classification Confidence:	Moderate
Required Classifiers:	Natural/Seminatural, Vegetated (> 10% vascular cover), Upland
Diagnostic Classifiers:	Montane Lower Montane Lowland Foothill Shrubland (Shrub-dominated) Very Shallow Soil Aridic Intermediate Disturbance Interval Periodicity/Polycyclic Disturbance
Non-Diagnostic Classifiers:	Canyon Colluvial slope Foothill(s) Gulch Midslope Ridge Temperate Temperate Continental Mineral: W/ A-Horizon <10 cm Short (50-100 yrs) Persistence

U.S. Distribution: CO, MT, NM, SD, WY, potentially occurs in NE
Global Range: Found in the foothills, canyon slopes and lower mountains of the Rocky Mountains and on outcrops and canyon slopes in the western Great Plains. It ranges from southern New Mexico extending north into Wyoming, and west into the Intermountain region.
Primary Biogeographic Division: 306 – Rocky Mountain
TNC Ecoregions:

10	Wyoming Basins	Confident or certain
20	Southern Rocky Mountains	Confident or certain
21	Arizona-New Mexico Mountains	Confident or certain
25	Black Hills	Confident or certain
26	Northern Great Plains Steppe	Confident or certain
27	Central Shortgrass Prairie	Confident or certain

Concept Summary: This ecological system is found in the foothills, canyon slopes and lower mountains of the Rocky Mountains and on outcrops and canyon slopes in the western Great Plains. It ranges from southern New Mexico extending north into Wyoming, and west into the Intermountain region. These shrublands occur between 1500-2900 m elevations and are usually associated with exposed sites, rocky substrates, and dry conditions, which limit tree growth. It is common where *Quercus gambelii* is absent, such as the northern Colorado Front Range and in drier foothills and prairie hills. This system is generally drier than Rocky Mountain Gambel Oak-Mixed Montane Shrubland (CES306.818), but may include mesic montane shrublands where *Quercus gambelii* does not occur. Scattered trees or inclusions of grassland patches or steppe may be present, but the vegetation is typically dominated by a variety of shrubs including *Amelanchier utahensis, Cercocarpus montanus, Purshia tridentata, Rhus trilobata, Ribes cereum, Symphoricarpos oreophilus,* or *Yucca glauca*. In northeastern Wyoming and north into adjacent Montana, *Cercocarpus ledifolius,* usually with *Artemisia tridentata*, is the common dominant shrub. Grasses are represented as species of *Muhlenbergia, Bouteloua, Hesperostipa,* and *Pseudoroegneria spicata*. Fires play an important role in this system as the dominant shrubs usually have a severe die-back, although some plants will stump sprout. *Cercocarpus montanus* requires a disturbance such as fire to reproduce, either by seed sprout or root crown sprouting. Fire suppression may have allowed an invasion of trees into some of these shrublands, but in many cases sites are too xeric for tree growth.

Similar Ecological Systems

CES306.818 Rocky Mountain Gambel Oak-Mixed Montane Shrubland

Component Associations

ALLIANCE/Association name	Element code	G rank
ARTEMISIA FRIGIDA SHRUBLAND ALLIANCE (A.2565)		
Artemisia frigida / Bouteloua gracilis Dwarf-shrubland [Provisional]	CEGL002782	GNR
ARTEMISIA NOVA SHRUB HERBACEOUS ALLIANCE (A.1105)		
Artemisia nova / Leymus salinus Shrub Herbaceous Vegetation	CEGL001421	G1G2Q
CERCOCARPUS MONTANUS SHRUB HERBACEOUS ALLIANCE (A.1538)		
Cercocarpus montanus / Muhlenbergia emersleyi Shrub Herbaceous Vegetation	CEGL001500	G4
CERCOCARPUS MONTANUS SHRUBLAND ALLIANCE (A.896)		
Cercocarpus montanus - Rhus trilobata / Andropogon gerardii Shrubland	CEGL002912	G2G3
Cercocarpus montanus / Achnatherum scribneri Shrubland	CEGL002913	G3
Cercocarpus montanus / Bouteloua curtipendula Shrubland	CEGL001086	G5
Cercocarpus montanus / Elymus lanceolatus ssp. lanceolatus Shrubland	CEGL001087	GU
Cercocarpus montanus / Garrya flavescens Shrubland	CEGL001088	GNR
Cercocarpus montanus / Hesperostipa comata Shrubland	CEGL001092	G2
Cercocarpus montanus / Hesperostipa neomexicana Shrubland	CEGL002911	G2G3
Cercocarpus montanus / Muhlenbergia montana Shrubland	CEGL002914	GU
Cercocarpus montanus / Muhlenbergia pauciflora Shrubland	CEGL001089	GNR
Cercocarpus montanus / Pseudoroegneria spicata Shrubland	CEGL001090	G4
Cercocarpus montanus / Rhus trilobata var. trilobata Shrubland	CEGL001091	GNRQ
Cercocarpus montanus var. paucidentatus / Petrophyton caespitosum Shrubland	CEGL004589	G3?
PRUNUS VIRGINIANA SHRUBLAND ALLIANCE (A.919)		
Prunus virginiana - (Prunus americana) Shrubland	CEGL001108	G4Q
PURSHIA TRIDENTATA SHRUBLAND ALLIANCE (A.825)		
Purshia tridentata / Artemisia frigida / Hesperostipa comata Shrubland	CEGL001055	G1G2
Purshia tridentata / Muhlenbergia montana Shrubland	CEGL001057	G2

PURSHIA TRIDENTATA SHRUB HERBACEOUS ALLIANCE (A.1523)		
Purshia tridentata / Hesperostipa comata Shrub Herbaceous Vegetation	CEGL001498	G2
RHUS TRILOBATA SHRUB HERBACEOUS ALLIANCE (A.1537)		
Rhus trilobata / Festuca idahoensis Shrub Herbaceous Vegetation	CEGL001505	G2?
Rhus trilobata / Pseudoroegneria spicata Shrub Herbaceous Vegetation	CEGL001120	G4
Rhus trilobata Rocky Mountain Shrub Herbaceous Vegetation	CEGL002910	G2
RIBES CEREUM SHRUBLAND ALLIANCE (A.923)		
Ribes cereum / Leymus ambiguus Shrubland	CEGL001124	G2
SYMPHORICARPOS OCCIDENTALIS TEMPORARILY FLOODED SHRUBLAND ALLIANCE (A.961)		
Symphoricarpos occidentalis Shrubland	CEGL001131	G4G5
Symphoricarpos oreophilus Shrubland	CEGL002951	GNR

A.2 Ecological System Description

A.2.1 Environment

These shrublands are large patch communities that occur in the foothills, ridges, canyon slopes and lower mountains of the Rocky Mountains and on outcrops, mesas, and canyon slopes in the western Great Plains, at elevations between 1500-2900m (4900-9500 ft). The system ranges from southern New Mexico north into Wyoming, and west into the Intermountain region. Variation in the composition of foothills-lower montane shrublands across the range of the system is poorly described. In general, these are mixed shrublands of areas where oak is absent, although they may intergrade in places with oak/mixed mountain shrublands, such as at the northern extent of *Quercus gambelii* along the mountain front in Colorado (Vestal 1917, Whitfield 1933), or with other *Quercus* species on the Mesa de Maya (Rogers 1950). The component associations typically form a patchy mosiac of shrub communities that can change noticably across short geographic distances and are, as well, often transitional between plains systems and montane systems. These shrublands appear to be environmentally intermediate between grasslands and savanna/forest associations, being drier than the latter, and moister than the former (Vestal 1919).

Although this system is often associated with exposed sites, rocky substrates, and dry conditions which limit tree growth, the principle species characterizing these shrublands form associations that range from xeric to mesic. Many of the associations achieve their best growth under more mesic conditions, such as north facing slopes, narrow canyons, and relatively moist ravines and depressions (Ramaley 1931). Extensive stands of some types, however, may also be found on very dry, exceedingly shallow, rocky soils (Doyle et al. 2005). Sites are generally moderate to steeply sloping (20-60%), but some stands may occur on in patches on rock ledges, scree and other steep slopes (50-100%). Aspects are variable. The distribution of these shrublands is determined by soil moisture availability and by a fire frequency and intensity that is balanced between elimination of shrubs and limitation of tree invasion.

Climate

These lower montane and foothills shrublands occur in a generally mountainous region subject to a continental climate. Winters are cold and summers moderately warm. Montane locations are generally cool, with low humidity. Local climates are strongly affected by differences in elevation, but the effect of topographical features in creating local air movements is also noticable (WRCC 2004). Wide variations occur within short distances. In general, temperature decreases and precipitation increases with altitude, resulting in a foothill and lower montane habitat that is appreciably more mesic than that of the adjacent plains. Precipitation patterns differ between the east and west sides of the Continental Divide. Prevailing air currents arefrom westerly directions. Moisture from storms originating in the Pacific Ocean falls as rain or snow on the mountaintops and westward-facing slopes. Eastern slope areas receive precipitation primarily from spring or summer storms originating in the Gulf of Mexico, and have warmer, drier winters.

Geology and soils
Soils of the lower montane and foothills shrublands are generally poorly developed from rocky, coarse textured colluvial or residual material (Vestal 1917, Whitfield 1933, Rogers 1950). Parent material is variable, including metamorphics such as gneiss and schist, igneous granite, or sedimentary limestone and sandstone. Substrate may control the composition of the shrub community to some extent. Most soils of this system are classified as Entisols. They are poorly developed, well-drained, and coarse-textured, with much exposed bare ground and rock. There is typically a shallow A horizon over a cambic B horizon over rocky C horizons.

A.2.2 Vegetation & Ecosystem

Communities of the Rocky Mountain Lower Montane-Foothill Shrubland system are diverse, and species composition varies with elevation, aspect, soils, and disturbance history. Only a few of the component associations have a widespread distribution; many are restricted to a relatively small portion of the region. Communities range from xeric to mesic, and may be transitional to riparian woodland and shrublands. The dominant shrub species are generally well adapted to poor soils, dry sites, and disturbance by fire (Table 1). Association of this system are dominated by low to moderate hight shrubs averaging 1-2 m in height. The herbaceous stratum rarely exceeds 1m in height. Communities are classified as shrubland or shrub herbaceaous vegetation. Many of the dominant shrub species are also members of the shrub layer in ponderosa or mixed conifer woodlands.

Vegetation cover may be sparse to dense, and dominant shrub species may include *Amelanchier alnifolia, Amelanchier utahensis, Cercocarpus montanus, Prunus virginiana, Purshia tridentata, Rhus trilobata, Ribes cereum, Symphoricarpos* spp., or *Yucca glauca*. In northeastern Wyoming and north into adjacent Montana, *Cercocarpus ledifolius,* usually with *Artemisia tridentata*, is the common dominant shrub. Additional shrub species that may be present or may form lower montane foothill shrubland communities in the absence of *Quercus gambelii* include *Arctostaphylos uva-ursi, Artemisia frigida, Artemisia nova, Atriplex confertifolia, Chrysothamnus* spp., *Jamesia americana, Krascheninnikovia lanata, Physocarpus monogynus, Prunus americana, Rubus deliciosus,* and *Yucca glauca.*

Understory grass species vary with site conditions; common species include *Muhlenbergia montana, Bouteloua gracilis, Bouteloua curtipendula, Festuca arizonica, Hesperostipa comata,* and *Pseudoroegneria spicata*. Other graminoids that may be present are *Achnatherum hymenoides, Andropogon gerardii, Aristida purpurea, Bromus* spp., *Carex* spp., *Elymus albicans, Elymus elymoides, Elymus trachycaulus, Festuca arizonica, Koeleria macrantha, Leucopoa kingi, Muhlenbergia filiculmis*, and *Schizachyrium scoparium*. The introduced grasses *Bromus tectorum, B. inermis,* and *Poa pratensis* are often present. Forbs and dwarf-shrubs typically have low cover, and may include *Achillea millefolium, Antennaria* spp., *Allium textile, Artemisia ludoviciana, Astragalus* spp., *Chenopodium berlandieri, Eriogonum umbellatum, Erigeron pumilus, Hedeoma hispida, Helianthus pumilus, Heterotheca villosa, Lesquerella montana, Mertensia lanceolata, Opuntia polyacantha,* and *Potentilla* spp., among others. Scattered individuals of *Juniperus scopulorum, Pinus ponderosa*, or other conifers may be present.

Table 1. Characteristics of dominant shrub species.

	Cercocarpus montanus	***Purshia tridentata***	***Prunus virginiana***	***Ribes cereum***	***Rhus trilobata***	***Symphoricarpos occidentalis***	***Symphoricarpos oreophilus***
C:N ratio	Medium/low	Medium/low	High	Medium	High	Medium	Medium
Palatablity to browsers	High	High	High	High	Medium	High	Low
Palatablity to grazers	Low	Medium	Low	High	Low	Low	Medium
Protein potential	Medium	Medium	Medium	High	Low	Low	Medium
Fire tolerance	High	Low	High	High	Medium	High	High
Precip. range (cm)	25–64	20–50	33–165	33-89	20-50	30–114	30–100
Min. frost free days	90	100	120	??	140	110	100
Min. temp. (°C)	-39	-38	-42	-30	-47	-38	-36
Shade tolerance	Intermediate	Intermediate	Intolerant	Intolerant	Intermediate	Intermediate	Intermediate
Pollination	Wind	Animal	Animal	Animal	Animal	Animal	Animal
Seed dispersal	Wind	Mammal	Bird	Bird	Bird	Bird	Bird
Soil texture adaptation:							
Fine	No	No	Yes	No	No	No	Yes
Medium	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Coarse	Yes	Yes	Yes	Yes	Yes	No	No
Fertility requirement	Low	Medium	Medium	Low	Low	Medium	Low
pH range	6–8	5.6–8.4	5.2–8.4	6.5-7.5	6.5-8.2	6.6–8	5.–7.5
Min. root depth (cm)	50	50	50	50	30	46	30
Moisture use	Low	Low	Medium	Low	Low	Low	Low
Anaerobic tolerance	None	Low	Medium	None	None	None	None
CaCO3 tolerance	High	High	High	High	Low	High	Low
Drought tolerance	High	High	Medium	High	Medium	High	High
Salinity tolerance	None	None	None	None	Low	Low	Low

Adapted from Paschke et al. (2003), with additional information from USDA, NRCS (2007) and Pendleton et al. (1989).

Biogeochemistry and productivity

Dominant shrubs of this system produce litter that is generally intermediate in carbon content; fire and natural decomposition probably contribute more-or-less equally to above-ground nutrient release. Soil nutrients not generally believed to be limiting (Medin 1960), although soils are poorly developed. Locally adapted races of shrubs may be common; Medin (1960), and Brotherson et al. (1984) found variable responses to soil substrate type in different populations of *Cercocarpus montanus* in Colorado and Utah. The dominant shrub species depend on soil organisms for proper mineral nutrition, especially in poor soils (Paschke et al. 2003). Production is more likely to be limited by water availability, and consquently is fairly low. Productivity is temporarily increased by fire that releases nutrients.

Animals
Shrub communities of this system can provide important seasonal food and cover for wildlife at critical times of the year. Many of the dominant species are highly palatable to browsing animals (Table 1), as well as producing edible seeds and fruits that are important to birds, bears, and other wildlife. These shrublands also supply nesting opportunities both in cavities and on branches, important cover, and seasonal forage. Mammals that use these shrublands include pronghorn, mule deer, elk, bighorn sheep, mountain goats, black bear, and numerous smaller species (Turley et al. 1999, Zlatnik 1999, Anderson 2004, Gucker 2006). Shrubland bird species include Columbian sharp-tailed grouse, Brewer's sparrow, sage sparrow, gray flycatcher, dusky flycatcher, Green-tailed Towhee, common poorwill, Virginia's warbler, black-throated gray warbler, and lazuli bunting (Nicholoff 2003).

A.2.3 Dynamics

Fire
Fire is a naturally occurring process in lower montane and foothill shrublands, but the system is not always fire-driven. Fire suppression may have allowed an invasion of trees into some of these shrublands, but in many cases sites are too xeric for much tree growth, even in the absence of fire. With the exception of *Purshia tridentata*, the dominant shrubs are generally able to survive fire and resprout vigorously after being top-killed. Variation in response to fire within and between species may gradually change the composition of a shrubland. Repeated fires may greatly decrease shrub abundance.

Historic fires were probably low intensity due to open canopies and lower fuel abundance. Less frequent fires have allowed the development of denser stands, and reduced the available open sites for seedling establishment. These denser stands support much greater fuel loads, so when fires do occur they are likely to be more severe than in the past. Fire regimes in this type are probably naturally variable, depending on local site factors. Fire can greatly increase available soil nutrients in this system, although erosion potential also increases (Gucker 2006).

Herbivory
Dominant shrubs in this ecological system are generally palatable to browsing animals, and are tolerant of herbiverory at moderate levels. Herbivory affects energy and material flow in the system, but may also have differential impacts on life history stages of species. Turley et al. (2003) found that *Cercocarpus montanus* is able to compensate for annual growth lost to herbivory, at least under conditions of high resource availibility. However, unbrowsed shrubs produced many more flowers and seeds than browsed shrubs.

A.2.4 Landscape

These foothill and lower montane shrublands are often transitional between grassland or shrubland types and savanna or forest ecosystems. These adjacent systems may be characterized by different or conflicting natural processes. An occurrence that is embedded in an intact landscape retains connectivity to adjacent and nearby systems that permits species dispersal and recolonization. A surrounding landscape that is composed of natural vegetation in good condition can buffer a small occurrence, provide migration corridors for important species, and serve as refugia for those species in case of widespread disturbance. Similarly, highly modified surrounding landscapes may facilitate the loss of native species from a patch as well as serve as sources of invasive species. Small, fragmented shrublands are likely to be less resistant to colonization by non-native species. It is important, however, to distinguish between patchiness that is caused by intervening non-natural vegetation, and the natural patchiness that arises because these communities are closely tied to soil moisture and substrate.

A.2.5 Size

Throughout its range, this system is found as a large patch type. Large patch communities, although sometimes covering extensive areas, usually have fairly distinct boundaries, require specific environmental conditions, and are strongly linked to and dependent upon the landscape around them. Like matrix communities, large-patch communities are influenced by large-scale processes, but these tend to be modified by specific site features that influence the community (Anderson et al. 1999).

Evaluation of the size of an occurrence should consider its current extent in relation to what would be ecologically possible given the precipitation and soils of the area. The natural size of an occurrence of lower montane or foothills shrubland will be determined largely by a site's topography, soils, and ecosystem processes. If an occurrence has not been reduced in size by human impacts or is surrounded by natural landscape that has not been affected by human disturbances, then size is less important to the assessment of ecological integrity. If, however, human disturbances have decreased the size of the occurrence, or if the surrounding landscape is impacted and has the potential to affect the site, bigger occurrences are able to buffer against these impacts better than smaller sized occurrences due to the fact they generally possess a higher diversity of abiotic and biotic processes allowing them to recover and remain more resilient. Under such circumstances, size may be more important in assessing ecological integrity. Larger occurrences (e.g. >5000 acres) can provide refuge for edge sensitive species, and would likely contain sufficient internal variability to capture characteristic biophysical gradients and retain natural geomorphic disturbance. Under such circumstances, size may be an important factor in assessing ecological integrity.

A.3 Ecological Integrity

A.3.1 Threats

Alteration of historic disturbance regime

Lower montane and foothill shrublands evolved with a variety of native browsers and grazers, and many of the important shrub species are tolerant of browsing by these herbivores. Changes in patterns of grazing disturbance from over-use by native herbivores or domestic livestock have the potential to alter environmental factors such as species composition, soil compaction, nutrient levels, and vegetation structure. Heavy concentrations of domestic livestock can have significant impacts on shrub growth and reprodution. These effects may be compounded by winter use by large populations of native ungulates.

Fire is a naturally occurring but highly variable natural disturbance in this system, and response to fire is variable between shrub species. Although fire has historically played a part in the composition and distribution of these shrublands, alteration of fire intensity and frequency, can result in tree invasion in some areas, or the development of dense stands outside the range of natural historic variation. In general, fire suppression has led to the development of dense communities dominated by old, decadent shrubs with substantial amounts of standing dead organic matter. In consequence, fires that do occur are likely to be intense and recovery slow. Ecotonal areas between grassland and ponderosa or juniper savanna may be especially vulnerable to successional changes.

Habitat conversion
Land use within the lower montane and foothills shrublands as well as in adjacent areas can fragment the landscape and reduce connectivity between patches and between occurrences and the surrounding landscape. This fragmentation can adversely affect the movement of surface/groundwater, nutrients, and dispersal of plants and animals. In the Colorado Front Range, many of these habitats are in areas that are highly desirable for suburban or exurban development, roads, or recreational infrastructure.

Non consumptive biological resource use
Many of the occurrences of this system along the mountain front are found on public (open space) lands where recreational use can be a major source of disturbance.

Invasive species
Increasing small-acreage exurban development with livestock ("ranchettes") appears to be increasing the incidence of weedy exotic species such as *Bromus tectorum* these habitats.

A.3.2 Justification of Metrics

<u>Landscape Context</u>: Land use in the adjacent land as well as in the larger surrounding landscape has important effects on the connectivity and sustainability of many ecological processes critical to this system. The amount and configuration of natural landscape will determine the degree to which natural processes such as fire and species dispersal can function or be simulated by management.

<u>Biotic condition</u>: Species composition and diversity, presence and regeneration of characteristic native plants, invasion of exotics, and structural diversity are important measures of biological integrity.

<u>Abiotic Condition</u>: Ecological processes including the water cycle, energy flow, and nutrient cycling support characteristic plant and animal comunities. Measures of physical components are used as indicators of the integrity of these functions.

Size: Because it is difficult to characterize the potential size of an occurrence of this system due to its ecotonal nature, size is addressed by evaluating the total area of the occurrence and the area that is in A-ranked biotic and abiotic condition classes.

A.3.3 Ecological Integrity Metrics

A synopsis of the ecological metrics and ratings is presented in Table 1. The three tiers refer to levels of intensity of sampling required to document a metric. Tier 1 metrics are able to be assessed using remote sensing imagery, such as satellite or aerial photos. Tier 2 typically require some kind of ground sampling, but may require only qualitative or semi-quantitative data. Tier 3 metrics typically require a more intensive plot sampling or other intensive sampling approach. A given measure could be assessed at multiple tiers, though some tiers are not doable at Tier 1 (i.e., they require a ground visit). The focus for

Core and Supplementary Metrics
The Scorecard (see Tables 1 & 2) contains two types of metrics: Core and Supplementary. Separating the metrics into these two categories allows the user to adjust the Scorecard to available resources, such as time and funding, as well as providing a mechanism to tailor the Scorecard to specific information needs of the user.

Core metrics are shaded gray in Tables 1 & 2 and represent the minimal metrics that should be applied to assess ecological integrity. Sometimes, a Tier 3 Core metric might be used to replace Tier 2 Core Metrics. For example, if a Vegetation Index of Biotic Integrity is used, then it would not be necessary to use similar Tier 2 Core metrics such as Percentage of Native Graminoids, Percentage of Native Plants, etc.

Supplementary metrics are those which should be applied if available resources allow a more in depth assessment or if these metrics add desired information to the assessment. Supplementary metrics are those which are not shaded in Tables 1 & 2.

A.4 Scorecard Protocols

For each metric, a rating is developed and scored as A – (Excellent) to D – (Poor). The background, methods, and rationale for each metric are provided in section B. Each metric is rated, then various metrics are rolled together into one of four categories: Landscape Context, Biotic Condition, Abiotic Condition, and Size. A point-based approach is used to roll-up the various metrics into Category Scores.

Points are assigned for each rating level (A, B, C, D) within a metric. The default set of points are A = 5.0, B = 4.0, C = 3.0, D = 1.0. Sometimes, within a category, one measure is judged to be more important than the other(s). For such cases, each metric will be weighted according to its perceived importance. Points for the various measures are then added up and divided by the total number of metrics. The resulting score is used to assign an A-D rating for the category. After adjusting for importance, the Category scores could then be averaged to arrive at an Overall Ecological Integrity Score.

Supplementary metrics are not included in the Rating Protocol. However, they could be incorporated if the user desired.

Table 2. Overall Set of Metrics for the Rocky Mountain Lower Montane – Foothills Shrubland System.

Tier: 1 = Remote Sensing, 2 = Rapid, 3 =Intensive. Shading indicates core metrics.

Category	**Essential Ecological Attribute**	**Indicators / Metrics**	**Tier**
LANDSCAPE CONTEXT	Landscape Composition	Adjacent land use	1
		Buffer width	1
		Percentage of unfragmented landscape within 1 km	1
BIOTIC CONDITION	Community Composition	Percent cover of native plant species	2
		Floristic quality index	3
		Presence and abundance of invasive spp.	2, 3
	Patch Diversity	Patch structure - variety	2
		Patch structure - interspersion	2
ABIOTIC CONDITION	Energy/Material Flow	Soil erosion & compaction	2
		Disturbance & Fragmentation – land use within occurrence	1
SIZE	Size	Total area of system occurrence	1
		Area of system occurrence in best Biotic and Abiotic Condition class	1

Table 3. Metrics and Rating Criteria for the Rocky Mountain Lower Montane – Foothills Shrubland System.

Tier: 1 = Remote Sensing, 2 = Rapid, 3 =Intensive. (Alpha-numeric codes in parentheses is reference to the metric ID and corresponds to the section in which the metric is described). Confidence column indicates that reasonable logic and/or data support the index. Shading indicates core metrics.

Category	**Essential Ecological Attributes**	**Indicators/ Metics**	**Tier**	**Metric Ranking Criteria**			
				Excellent (A)	Good (B)	Fair (C)	Poor (D)
LANDSCAPE CONTEXT	Landscape Compostion	Adjacent land use (B.1.1)	1	Average land use score = 1.0 – 0.95	Average land use score = 0.80 – 0.95	Average land use score = 0.40 – 0.80	Average land use score = <0.40
		Buffer width (B.1.2)	1	Wide >500m	Medium 250 – 500m	Narrow 100 – 250m	Very narrow < 100 m
	Landscape Pattern and Process	Percentage of unfragmented landscape within 1 km. (B.1.3)	1	Embedded in 90-100% unfragmented, roadless natural landscape; internal fragmentation absent	Embedded in 60-90% unfragmented natural landscape; internal fragmentation minimal	Embedded in 20-60%% unfragmented natural landscape; Internal fragmentation moderate	Embedded in < 20% unfragmented natural landscape. Internal fragmentation high
BIOTIC CONDITION	Community composition	Percent cover of native plant species (B.2.1)	2	100% cover of native plant specis	85-100% cover of native plant specis	50-85% cover of native plant specis	<50% cover of native plant specis
		Floristic quality index (Mean C) (B.2.2)	3	>4.5	3.5 – 4.5	3.0 – 3.5	<3.0
		Presence and abundance of noxious species (B.2.3)		Invasive exotics with major potential to alter structure and composition are absent	Invasive exotics with major potential to alter structure and composition occupy less than 1% of occurrence.	Invasive exotics with major potential to alter structure and composition occupy less than 3% of occurrence.	Invasive exotics with major potential to alter structure and composition occupy more than 5% of occurrence.
	Community Extent	Patch structure – variety (B.2.5)	2	> 75-100% of possible patch types are present in the occurrence	> 50-75% of possible patch types are present in the occurrence	25-50% of possible patch types are present in the occurrence	< 25% of possible patch types are present in the occurrence

Category	Essential Ecological Attributes	Indicators/ Metics	Tier	Metric Ranking Criteria			
				Excellent (A)	Good (B)	Fair (C)	Poor (D)
		Patch structure – interspersion (B.2.6)	2	Horizontal structure consists of a very complex array of nested and/or interspersed, irregular biotic/abiotic patches, with no single dominant patch type	Horizontal structure consists of a moderately complex array of nested or interspersed biotic/abiotic patches, with no single dominant patch type	Horizontal structure consists of a simple array of nested or interspersed biotic/abiotic patches.	Horizontal structure consists of one dominant patch type and thus has relatively no interspersion
ABIOTIC CONDITION	Energy/ Material Flow	Soil erosion & compaction (B.3.1)	2,3	Score = 4.5-5.0	Score = 3.5-4.4	Score = 2.5-3.4	Score = 1.0-2.4
		Land use within the occurrence (B.3.2)	1, 2	Average land use score = 1.0 – 0.95	Average land use score = 0.80 – 0.95	Average land use score = 0.40 – 0.80	Average land use score = <0.40
SIZE	Size	Total area of system occurrence (B.4.1)	1	> 5000 acres	2000-5000 acres	100 -2000 acres	< 1000 acres
		Area of system occurrence in best Biotic and Abiotic Condition class (B.4.2)	1	> 5000 acres	2000-5000 acres	100 -2000 acres	< 1000 acres

A.4.1 Landscape Context Rating Protocol

Rate the Landscape Context metrics according to their associated protocols (see Table 3 and details in Section B). Use the scoring table below (Table 4) to roll up the metrics into an overall Landscape Context rating.

Rationale for Scoring: Adjacent land use, buffer width, and connectivity of the occurrence are judged to be more important than the amount of fragmentation within 1 km of the occurrence since an occurrence with no other natural communities bordering it is very unlikely to have a strong biological connection to other natural lands at a further distance.

Thus, the following weights apply to the Landscape Context metrics:

Table 4. Landscape Context Rating Calculation.

Measure	Definition	Tier	A	B	C	D	Weight	Score (weight x rating)
Adjacent Land Use (B.1.1)	Addresses the intensity of human dominated land uses within 100 m of the occurrence.	1	5	4	3	1	0.40	
Buffer Width (B.1.2)	Buffers are vegetated, natural (non-anthropogenic) areas that surround an occurrence.	1	5	4	3	1	0.30	
Percentage of unfragmented landscape within 1 km. (B.1.3)	An unfragmented landscape has no barriers to the movement and connectivity of species, water, nutrients, etc. between natural ecological systems.	1	5	4	3	1	0.30	
Landscape Context Rating	A = 4.5 - 5.0 B = 3.5 – 4.4 C = 2.5 – 3.4 D = 1.0 – 2.4							**Total = sum of N scores**

A.4.2 Biotic Condition Rating Protocol

Rate the Biotic Condition metrics according to their associated protocols (see Table 3 and details in Section B). Use the scoring table below (Table 5) to roll up the metrics into an overall Biotic Condition rating.

Rationale for Scoring: The Floristic Quality Index (FQI) metric is judged to be more important than the other metrics as the FQI provides a more reliable indicator of biotic condition.

Scoring for Biotic Condition is a bit more complex. For example, the Floristic Quality Index (FQI) may or may not be assessed, depending on resources (since it is a Tier 3 metric). If it is included then the weights without parentheses apply to the Biotic

Condition metrics. If FQI is not included then the weight in parentheses is used for the Tier 2 metrics.

Table 5. Biotic Condition Rating Calculation.

Measure	Definition	Tier	A	B	C	D	Weight*	Score (weight x rating)
Percent of Cover of Native Plant Species (B.2.1)	Percent of the plant species which are native to the Southern Rocky Mountains.	2	5	4	3	1	0.20 (0.70)	
Floristic Quality Index (Mean C) (B.2.2)	The mean conservatism of all the native species growing in the occurrence.	3	5	4	3	1	0.60 (N/A)	
Presence and abundance of noxious species. (B.2.3)	Presence/abundance of invasive exotics with major potential to alter structure and composition of system.	2	5	4	3	1	0.20 (0.30)	
Biotic Condition Rating	A = 4.5 - 5.0 B = 3.5 – 4.4 C = 2.5 – 3.4 D = 1.0 – 2.4							**Total = sum of N scores**

* The weight in parentheses is used when metric B.2.2 is not used.

A.4.3 Abiotic Condition Rating Protocol

Rate the Abiotic Condition metrics according to their associated protocols (see Table 3 and details in Section B). Use the scoring table below (Table 6) roll up the metrics into an overall Abiotic Condition rating.

Rationale for Scoring: Quantitative water table data are judged to more reliable than the other metrics for indicating Abiotic Condition (shaded metric in Table 5). However, if such data are lacking then stressor related metrics (Land Use & Hydrological Alterations) are perceived to provide more dependable information concerning Abiotic Condition.

Table 6. Abiotic Condition Rating Calculation.

Measure	Definition	Tier	A	B	C	D	Weight*	Score (weight x rating)
Soil erosion & compaction (B.3.1)		2,3	5	5	0	0	0.50	
Disturbance & Fragmentation – land use within occurrence	Addresses the intensity of human dominated land uses within the occurrence.	1, 2	5	4	3	1	0.50	
Abiotic Condition Rating	A = 4.5 - 5.0 B = 3.5 – 4.4 C = 2.5 – 3.4 D = 1.0 – 2.4							**Total = sum of N scores**

A.4.4 Size Rating Protocol

Rate the two measures according to the metrics protocols (see Table 2 and details in Section B). Use the scoring table below (Table 6) to roll up the metrics into an overall Size rating.

<u>Rationale for Scoring</u>: Since the importance of size is contingent on human disturbance both within and adjacent to the occurrence, two scenarios are used to calculate size:

(1) When Landscape Context Rating = "A":
Size Rating = Relative Size metric rating (weights w/o parentheses)

(2) When Landscape Context Rating = "B, C, or D".
Size Rating = (weights in parentheses)

Table 7. Size Rating Calculation.

Measure	Definition	Tier	A	B	C	D	Weight*	Score (weight x rating)
Total size (B.4.1)	The current size of the occurrence	1	5	4	3	1	0.0 (0.40)	
Size of area in best condition (B.4.2)	Area of system occurrence in best Biotic and Abiotic Condition class	1	5	4	3	1	1.0 (0.60)	
Size Rating	A = 4.5 - 5.0 B = 3.5 – 4.4 C = 2.5 – 3.4 D = 1.0 – 2.4							**Total = sum of N scores**

* The weight in parentheses is used when Landscape Context Rating = B, C, or D.

A.4.5 Overall Ecological Integrity Rating Protocol

If an Overall Ecological Integrity Score is desired for a site, then a weighted-point system should be used with the following rules:

1. If Landscape Context = *A* then the Overall Ecological Integrity Rank = **[Abiotic Condition Score *(0.35)] + [Biotic Condition Score *(0.25)] + [Landscape Context Score * (0.25)] + [Size Score * (0.15)]**

2. If Landscape Context is *B*, *C*, or *D* AND Size = *A* then the Overall Ecological Integrity Rank = **[Abiotic Condition Score *(0.35)] + [Biotic Condition Score *(0.25)] + [Size Score * (0.25)] + [Landscape Context Score * (0.15)]**

3. If Landscape Context is *B*, *C*, or *D* AND Size = *B* then the Overall Ecological Integrity Rank = **[Abiotic Condition Score *(0.35)] + [Biotic Condition Score *(0.25)] + [Landscape Context Score * (0.20)] + [Size Score * (0.20)]**

4. If Landscape Context is *B*, *C*, or *D* AND Size = *C* or *D* then the Overall Ecological Integrity Rank = **[Abiotic Condition Score *(0.35)] + [Biotic Condition Score *(0.25)] + [Landscape Context Score * (0.25)] + [Size Score * (0.15)]**

The Overall Ecological Rating is then assigned using the following criteria:

A = 4.5 - 5.0
B = 3.5 – 4.4
C = 2.5 – 3.4
D = 1.0 – 2.4

B. PROTOCOL DOCUMENTATION FOR METRICS

Note: Much of the following discussion is adapted from Rocchio (2006).

B.1 Landscape Context Metrics

B.1.1. Adjacent Land Use

Definition: This metric addresses the intensity of human dominated land uses within 500 m of the occurrence.

Background: This metric is one aspect of the landscape context of an individual occurrences of the ecological system.

Rationale for Selection of the Variable: These communities are closely tied to edaphic conditions, so minor breaks or small barriers due to changes in substrate are part of the natural distribution and variability. If the breaks are larger, barriers may exist for some species. Primary criteria to be considered are the reaction of native species to fragmentation, seed dispersal by dominant shrubs, and the dispersal behavior and requirements of invertebrates, small mammals and birds. The intensity of human activity in the landscape has a proportionate impact on the ecological processes of natural systems. Each land use type occurring in the 500 m buffer is assigned a coefficient ranging from 0.0 to 1.0 indicating its relative impact to the occurrence (Hauer et al. 2002).

Measurement Protocol: This metric is measured by documenting surrounding land use(s) within 500 m of the occurrence. This should be completed in the field then verified in the office using aerial photographs or GIS. However, with access to current aerial photography and/or GIS data a rough calculation of Land Use can be made in the office. Ideally, both field data as well as remote sensing tools are used to identify an accurate % of each land use within 100 m of the edge.

To calculate a Total Land Use Score estimate the % of the adjacent area within 500 m under each Land Use type and then plug the corresponding coefficient (Table 8) with some manipulation to account for regional application) into the following equation:

$$\textit{Sub-land use score} = \sum \text{LU x PC}/100$$

where**:** LU = Land Use Score for Land Use Type; PC = % of adjacent area in Land Use Type.

Do this for each land use within 500 m of the occurrence edge, then sum the Sub-Land Use Score(s) to arrive at a Total Land Score. For example, if 30% of the adjacent area was under moderate grazing (0.3 * 0.6 = 0.18), 10% composed of unpaved roads (0.1 * 0.1 = 0.01), and 40% was a natural area (e.g. no human land use) (1.0 * 0.4 = 0.4), the Total Land Use Score would = 0.59 (0.18 + 0.01 + 0.40).

Metric Rating: Assign the metric an Excellent, Good, Fair, or Poor rating on the scorecard.

Measure (Metric) Rating			
Excellent	**Good**	**Fair**	**Poor**
Average Land Use Score = 1.0-0.95	Average Land Use Score = 0.80-0.95	Average Land Use Score = 0.4-0.80	Average Land Use Score = < 0.4

Data:

Table 8. Current Land Use and Corresponding Land Use Coefficients

Current Land Use	Coefficient
Paved roads/parking lots/residential or commercially developed buildings/gravel pit operation/ Energy development (pumping station/ wind machine farm / strip mine)	0.0
Unpaved Roads (e.g., driveway, tractor trail) / Mining / Energy development (well pad, pipeline, exploration)	0.1
Agriculture (tilled crop production)	0.2
Heavy grazing by livestock / intense recreation (ATV use/camping/popular fishing spot, etc.)	0.3
Logging, chaining, or tree removal with 50-75% of trees >50 cm dbh removed	0.4
Hayed	0.5
Moderate grazing	0.6
Moderate recreation (high-use trail)	0.7
Selective logging or tree removal with <50% of trees >50 cm dbh removed	0.8
Light grazing / light recreation (low-use trail)	0.9
Fallow with no history of grazing or other human use in past 10 yrs	0.95
Natural area / land managed for native vegetation	1.0

based on Table 21 in Hauer et al. (2002)

Scaling Rationale: Land uses have differing degrees of potential impact. Some land uses have minimal impact, such as simply altering the integrity of native vegetation (e.g., recreation and grazing), while other activities (e.g., hay production and agriculture) may replace native vegetation with nonnative or cultural vegetation yet still provide potential cover for species movement. Intensive land uses (i.e., urban development, roads, mining, etc.) may completely destroy vegetation and drastically alter hydrological processes. The coefficients were assigned according to best scientific judgment regarding each land use's potential impact (Hauer et al. 2002).

Confidence that reasonable logic and/or data support the index: Medium.

B.1.2. Buffer Width

Definition: Buffers are vegetated, natural (non-anthropogenic) areas that surround an occurrence. This includes forests, grasslands, shrublands, natural lakes and ponds, streams, or wetlands.

Background: This metric evaluates one aspect of the landscape context of an individual occurrence of the ecological system.

Rationale for Selection of the Variable: The intensity of human activity in the landscape often has a proportionate impact on the ecological processes of natural systems. The intensity of human activity in the landscape often has a proportionate impact on the ecological processes of natural systems. Buffers are known to reduce potential impacts to wetlands and riparian areas, but their effects on terrestrial ecological systems are less well studied. Although the term "buffer" is retained for this metric, there is insufficient data to confirm that an adjacent natural landscape acts to mitigate the effects of stressors on an occurrence. The relative extent of adjacent natural landscape, however, is potentially important, and is retained until further information is available. This metric may be adequately addressed by the previous metric, or may need to be replaced with some measure of fragmentation.

Measurement Protocol: This metric is measured by estimating the width of the buffer surrounding the occurrence. Buffer boundaries extend from the occurrence edge to intensive human land uses which result non-natural areas. Some land uses such as light grazing and recreation may occur in the buffer, but other more intense land uses should be considered the buffer boundary.

Measurement should be completed in the field then verified in the office using aerial photographs or GIS. Measure or estimate buffer width on four or more sides of the occurrence then take the average of those readings. This may be difficult for large occurrences or those with complex boundaries. For such cases, the overall buffer width should be estimated using best scientific judgment.

Metric Rating: Assign the metric an Excellent, Good, Fair, or Poor rating on the scorecard.

Measure (Metric) Rating			
Excellent	**Good**	**Fair**	**Poor**
Wide > 1000 m	Medium. 500 m to 1000 m	Narrow. 250 m to 500 m	Very Narrow. < 250 m

Data: N/A

Scaling Rationale: Scaling is based on minimum separation distance for an occurrence.

Confidence that reasonable logic and/or data support the index: Medium.

B.1.3 Percentage of Unfragmented Landscape Within One Kilometer

Definition: An unfragmented landscape is one in which human activity has not destroyed or severely altered the landscape, and which has no barriers to the movement and connectivity of species, water, nutrients, etc. between natural ecological systems. Fragmentation results from human activities such as timber clearcuts, roads, residential and commercial development, agriculture, mining, utility lines, railroads, etc.

Background: This metric evaluates one aspect of the landscape context of an individual occurrence of the ecological system.

Rationale for Selection of the Variable: The intensity of human activity in the landscape often has a proportionate impact on the ecological processes of natural systems. The percentage of fragmentation (e.g., anthropogenic patches) provides an estimate of connectivity among natural ecological systems. Although related to metric B.1.1 and B.1.2, this metric differs by addressing the spatial interspersion of human land use as well as considering a much larger area.

Measurement Protocol: This metric is measured by estimating the amount of unfragmented area in a one km buffer surrounding the occurrence and dividing that by the total area. This can be completed in the office using aerial photographs or GIS.

Metric Rating: Assign the metric an Excellent, Good, Fair, or Poor rating on the scorecard.

Measure (Metric) Rating			
Excellent	**Good**	**Fair**	**Poor**
Embedded in 90-100% unfragmented, roadless natural landscape; internal fragmentation absent	Embedded in 60-90% unfragmented natural landscape; internal fragmentation minimal	Embedded in 20-60%% unfragmented natural landscape; Internal fragmentation moderate	Embedded in < 20% unfragmented natural landscape. Internal fragmentation high

Data: N/A

Scaling Rationale: Less fragmentation increases connectivity between natural ecological systems and thus allow for natural exchange of species, nutrients, and water. The categorical ratings are based on Rondeau (2001).

Confidence that reasonable logic and/or data support the index: Medium.

B.2 Biotic Condition Metrics

B.2.1 Percent of Cover of Native Plant Species

Definition: Percent of the plant species which are native to the Rocky Mountainsand adjacent Western Great Plains.

Background: This metric evaluates one aspect of the condition of an individual occurrence of the ecological systems.

Rationale for Selection of the Variable: Occurrences dominated by native species typically have excellent ecological integrity. This metric is a measure of the degree to which native plant communities have been altered by human disturbance. With increasing human disturbance, non-native species invade and can dominate the occurrence.

Measurement Protocol: A qualitative, ocular estimate of cover is used to calculate and score the metric. The entire occurrence of the system should be walked and a qualitative ocular estimate of the total cover of native species growing in the area should be made. Alternatively, if time and resources allow a more quantitative determination of species presence and cover such methods (i.e. Peet et al. 1998) should be used. The metric is calculated by dividing the total cover of native species by the total cover of all species and multiplying by 100.

Metric Rating: Assign the metric an Excellent, Good, Fair, or Poor rating on the scorecard.

Measure (Metric) Rating			
Excellent	**Good**	**Fair**	**Poor**
100% cover of native plant species	85-< 100% cover of native plant species	50-85% cover of native plant species	<50% cover of native plant species

Data: N/A

Scaling Rationale: The criteria are based on suggested thresholds from Rondeau (2001), and best scientific judgment. These are tentative hypotheses as they have not been validated with quantitative data. The Colorado Natural Heritage Program is currently developing a Vegetation Index of Biotic Integrity. Data from this project will likely provide the necessary information to confirm, validate, and improve the criteria.

Confidence that reasonable logic and/or data support the index: High

B.2.2 Floristic Quality Index (Mean C)

Definition: The mean conservatism of all the native species growing in the occurrence.

Background: This metric evaluates one aspect of the condition of an individual occurrence of the ecological system.

Rationale for Selection of the Variable: Plants are generally adapted to biotic and abiotic fluctuations associated with the habitat where they grow (Wilhelm and Masters 1995). However, when disturbances to that habitat exceed the natural range of variation (e.g. many human-induced disturbances), only those plants with wide ecological tolerance will survive. In contrast, conservative species (e.g. those species with strong fidelity to habitat integrity) will decline or disappear according to the degree of human disturbance (Wilhelm and Master 1995).

The Floristic Quality Index (FQI), originally developed for the Chicago region (Swink and Wilhelm 1979, 1994) is a vegetative community index designed to assess the degree of "naturalness" of an area based on the presence of species whose ecological tolerance are limited (U.S. EPA 2002). See discussion in Rocchio (2007) for additonal information on this method.

A preliminary FQI for Colorado has been developed (Rocchio 2007). However, calibration of the FQI will likely occur over many years of use and this metric should be updated accordingly.

Measurement Protocol: Species presence/absence data need to be collected from the occurrence. Although, quantitative measurements are preferred, depending on time and financial constraints, this metric can be measured with qualitative or quantitative data. The two methods are described as follows: (1) Site Survey (semi-quantitative): walk the entire occurrence of the system and make notes of each species encountered. A thorough search of each macro- and micro-habitat is required. (2) Quantitative Plot Data: The plot method described by Peet et al. (1998) is recommended for collecting quantitative data for this metric. This method uses a 20 x 50 m plot which is typically established in a 2 x 5 arrangement of 10 x 10 m modules. However, the array of modules can be rearranged or reduced to meet site conditions (e.g. 1 x 5 for linear areas or 2 x 2 for small, circular sites). The method is suitable for most types of vegetation, provides information on species composition across spatial scales, is flexible in intensity and effort, and compatible with data from other sampling methods (Mack 2004; Peet et al. 1998).

The metric is calculated by referencing only native species C value from the Colorado FQI Database (Rocchio 2007), summing the C values, and dividing by the total number of native species (Mean C).

Metric Rating: Assign the metric an Excellent, Good, Fair, or Poor rating on the scorecard.

Measure (Metric) Rating			
Excellent	**Good**	**Fair**	**Poor**
> 4.5	3.5-4.5	3.0 – 3.5	< 3.0

Data: Colorado FQI Database (Rocchio 2007).

Scaling Rationale: In the Midwest, field studies using FQI have determined that a site with a Mean C of 3.0 or less is unlikely to achieve higher C values thus this value was used as the Restoration Threshold (between Fair and Poor). In other words, those sites have been disturbed to the degree that conservative species are no longer able to survive and or compete with the less conservative species as a result of the changes to the soil and or hydrological processes on site (Wilhelm and Masters 1995). Sites with a Mean C of 3.5 or higher are considered to have at least marginal quality or integrity thus this value was used as the Minimum Integrity Threshold (between Good and Fair) (Wilhelm and Masters 1995). The threshold between Excellent and Good was assigned based on best scientific judgment upon reviewing the FQI literature. Although it is not know if these same thresholds are true for the Southern Rocky Mountains, they have been used to construct the scaling for this metric. As the FQI is applied in this region, the thresholds may change.

Confidence that reasonable logic and/or data support the index: High

B.2.3 Presence and abundance of invasive species.

Definition: This metric estimates the presence and abundance of invasive species with the potential to alter system functioning.

Background: This metric evaluates one aspect of the biotic condition of an individual occurrence of the ecological system.

Rationale for Selection of the Variable: Invasives are introduced species that can thrive in areas beyond their natural range of dispersal. These species are generally adaptable, aggressive, and have a high reproductive capacity, so that in the absence of natural enemies they can increase dramatically and displace native species. The worst invasives can change the character of an entire habitat by affecting ecosystem processes like fire, nutrient flow, flooding, etc

Measurement Protocol: This metric is measured by determining the presence and rough abundance of system altering invasive species in the occurrence. This is completed in the field and ocular estimates are used to match the categorical ratings in the scorecard.

Metric Rating: Assign the metric an Excellent, Good, Fair, or Poor rating on the scorecard.

Measure (Metric) Rating			
Excellent	**Good**	**Fair**	**Poor**
System altering invasive species, such as leafy spurge, Russian knapweed, diffuse knapweed, spotted knapweed, or yellow toadflax are either not present or occupy less than 1 percent of the occurrence, with no patches larger than 1 acre.	System altering invasive species, such as leafy spurge, knapweed species, or yellow toadflax occupy no more than 1-3% of the occurrence with no patches larger than 1 acre.	System altering invasive species, such as leafy spurge, knapweed species, or yellow toadflax occupy 3-5% of the occurrence, with some patches larger than 1 acre	System altering invasive species, such as leafy spurge, knapweed species, or yellow toadflax occupy >5% of the occurrence.

Data: N/A

Scaling Rationale: The criteria are based on thresholds from Rondeau (2001), and best scientific judgment. These are tentative hypotheses as they have not been validated with quantitative data.

Confidence that reasonable logic and/or data support the index: Medium

B.2.4 Biotic/Abiotic Patch Richness

Definition: The number of biotic/abiotic patches or habitat types present in the occurrence. The metric is not a measure of the spatial arrangement of each patch.

Background: This metric evaluates one aspect of the condition of an individual occurrence of the ecological system.

Rationale for Selection of the Variable: Ecological diversity of a site is correlated with biotic/abiotic patch richness (Collins et al. 2004). Unimpacted sites have an expected range of biotic/abiotic patches. Human-induced alterations can decrease patch richness by homogenizing microtopography, altering channel characteristics, etc.

Measurement Protocol: This metric is measured by determining the number of biotic/abiotic patches present at a site and dividing by the total number of possible patches for the specific type (Table 9). This percentage is then used to rate the metric in the scorecard.

Metric Rating: Assign the metric an Excellent, Good, Fair, or Poor rating on the scorecard.

Measure (Metric) Rating			
Excellent	**Good**	**Fair**	**Poor**
> 75-100% of possible patch types are present in the occurrence	> 50-75% of possible patch types are present in the occurrence	25-50% of possible patch types are present in the occurrence	< 25% of possible patch types are present in the occurrence

Data:

Table 9. Biotic/Abiotic Patch Types in Lower Montane – Foothills Shrubland.

Patch Type
Tree canopy
Shrub canopy
Herbaceous canopy - graminoid
Herbaceous canopy - forb
Non-vascular cover
Litter cover
Bare soil
Rock outcrop
TOTAL = 8

Scaling Rationale: Simple quartiles were used. Need additional information about appropriate breaks.

Confidence that reasonable logic and/or data support the index: Medium

B.2.5 Interspersion of Biotic/Abiotic Patches

Definition: Interspersion is the spatial arrangement of biotic/abiotic patch types within the occurrence, especially the degree to which patch types intermingle with each other (e.g. the amount of edge between patches).

Background: This metric evaluates one aspect of the condition of an individual occurrence of the ecological system.

Rationale for Selection of the Variable: Spatial heterogeneity (i.e., the types and arrangement of habitat patches within a landscape) can strongly influence the abundance and distribution of species that use a particular habitat (Pulliam et al. 1992)

Measurement Protocol: This metric is measured by determining the degree of interspersion of biotic/abiotic patches present in the occurrence. This can be completed in the field for most sites, however aerial photography may be beneficial for larger sites (Collin et al. 2004). The metric is rated by matching site interspersion with the categorical ratings in the scorecard.

Metric Rating: Assign the metric an Excellent, Good, Fair, or Poor rating on the scorecard.

Measure (Metric) Rating			
Excellent	**Good**	**Fair**	**Poor**
Horizontal structure consists of a very complex array of nested and/or interspersed, irregular biotic/abiotic patches, with no single dominant patch type	Horizontal structure consists of a moderately complex array of nested or interspersed biotic/abiotic patches, with no single dominant patch type	Horizontal structure consists of a simple array of nested or interspersed biotic/abiotic patches,	Horizontal structure consists of one dominant patch type and thus has relatively no interspersion

Data: See B.2.3 for list and definitions of Biotic Patches.

Scaling Rationale:

Confidence that reasonable logic and/or data support the index: Medium

B.3 Abiotic Condition Metrics

B.3.1 Soil erosion & compaction

Definition: An index measure of the degree to which erosion and soil compaction are out of the range of natural variation.

Background: This metric evaluates one aspect of the abiotic condition of an individual occurrence of the ecological system.

Rationale for Selection of the Variable: The functional integrity of this ecological system type is dependent in part on the the integrity of the soil surface (National Research Council 1994, Smith et al. 1995). The selected variables are part of a more comprehensive assessment of rangeland health that is focused on soil condition (Pellant et al. 1995).

Measurement Protocol: This metric is estimated in the field by observing overland water flow patterns, signs of rill formation and wind scour, the presence of pedestals and terrecettes, drainage patterns, bare ground, and soil compaction.

Metric Rating: Assign each of the six metrics in Table 10 an Excellent, Good, Fair, or Poor rating on the scorecard. Use the scores and weights shown to compile a final score.

Table 10. Soil erosion and compaction scoring.

Metric (weight)	**Excellent Score = 5**	**Good Score =4**	**Fair Score = 3**	**Poor Score = 5**	**Score** (weight x rating)
Water patterns (0.10)	Minimal evidence of past or current soil deposition or erosion.	Matches what is expected for the site; erosion is minor with some instability and deposition	More numerous than expected; deposition and cut areas common; occasionally connected.	Water flow patterns may be extensive and numerous; unstable with active erosion; usually connected.	
Rills, wind scour (0.10)	Slight to no evidence	Some evidence of rill formation or accelerated wind scour	Rill formation or accelerated wind scour may be moderately active and well defined throughout most of the occurrence.	Rill formation or accelerated wind scour may be severe and well defined throughout most of the occurrence	
Pedestals and/or Terracets (0.10)	Absent or uncommon.	Occasionally present	Common	Abundant	
Drainages (0.10)	Represented as natural stable channels with no signs of unnatural erosion.	Represented as natural stable channels with only slight signs of unnatural erosion.	Gullies may be present with indications of active erosion; vegetation is intermittent on slopes. Headcuts are active;	Gullies common, with indications of active erosion and downcutting; vegetation is infrequent on	

			downcutting is apparent	slopes or bed of gully.	
Bare Ground (0.10)	Bare areas are no higher than expected for the substrate.	Bare areas are moderately larger than expected size and only sporadically connected.	Bare ground is moderate to much higher than expected for the site. Bare areas are large and may be connected.	Much higher than expected for the site. Bare areas are large and generally connected.	
Soil compaction (0.50)	Soils are not compacted and are not restrictive to water movement and root penetration.	Soil compaction moderately widespread and moderately restricts water movement and root penetration.	Soil compaction widespread and greatly restricts water movement and root penetration.	Soil compaction is extensive throughout the occurrence, severely restricting water movement and root penetration	
Final rating:	A = 4.5 - 5.0 B = 3.5 – 4.4 C = 2.5 – 3.4 D = 1.0 – 2.4				**Total = sum of N scores**

Data: Based on Pellant et al. 2005. There is some evidence that soil aggregate stability (AS) could be used as a composite index for this metric (Bestelmeyer et al. 2006), but data collection may be more labor intensive.

Scaling Rationale: In the absence of quantitative data, the scale is based on guidelines for professional judgment.

Confidence that reasonable logic and/or data support the index: High for inclusion of the index. Medium to low for the specific measures and thresholds.

B.3.2 Disturbance and Fragmentation – land use within occurrence

Definition: This metric addresses the intensity of human dominated land uses within the occurrence.

Background: This metric is one aspect of the abiotic condition of an individual occurrence of the ecological system.

Rationale for Selection of the Variable: Fragmentation and disturbance are important factors on the ecological processes of natural systems. Due to the difficulties of applying measures of fragmentation (Hargis et al. 1998, Tischendorf and Fahrig 2000) this variable is measured using the same technique as in Section B.1.1.

Measurement Protocol: This metric is measured by documenting land use(s) withinthe boundaries of the occurrence. This should be completed in the field then verified in the office using aerial photographs or GIS. However, with access to current aerial photography and/or GIS data a rough calculation of Land Use can be made in the office. Ideally, both field data as well as remote sensing tools are used to identify an accurate % of each land use.

To calculate a Total Land Use Score estimate the % of the adjacent area within the occurrence under each Land Use type and then plug the corresponding coefficient (Table 7, section B.1.1) into the following equation:

Sub-land use score = ∑ LU x PC⁄100

where**:** LU = Land Use Score for Land Use Type; PC = % of total area in Land Use Type.

Do this for each land use within the occurrence, then sum the Sub-Land Use Score(s) to arrive at a Total Land Score. For example, if 30% of the area was under moderate grazing (0.3 * 0.6 = 0.18), 10% composed of unpaved roads (0.1 * 0.1 = 0.01), and 40% was a natural area (e.g. no human land use) (1.0 * 0.4 = 0.4), the Total Land Use Score would = 0.59 (0.18 + 0.01 + 0.40).

Metric Rating: Assign the metric an Excellent, Good, Fair, or Poor rating on the scorecard.

Measure (Metric) Rating			
Excellent	**Good**	**Fair**	**Poor**
Average Land Use Score = 1.0-0.95	Average Land Use Score = 0.80-0.95	Average Land Use Score = 0.4-0.80	Average Land Use Score = < 0.4

Data:

Scaling Rationale: Land uses have differing degrees of potential impact. Some land uses have minimal impact, such as simply altering the integrity of native vegetation (e.g., recreation and grazing), while other activities (e.g., hay production and agriculture) may replace native vegetation with nonnative or cultural vegetation yet still provide potential cover for species movement. Intensive land uses (i.e., urban development, roads, mining, etc.) may completely destroy vegetation and drastically alter hydrological processes. The coefficients were assigned according to best scientific judgment regarding each land use's potential impact (Hauer et al. 2002).

Confidence that reasonable logic and/or data support the index: Medium.

B.4 Size Metrics

B.4.1 Total size of system occurrence

Definition: This metric assesses the total size of all areas included in the occurrence or stand, i.e., all stands or patches that are close enough together to fall within the same occurrence.

Background: Size (area) of the occurrence has a large effect on the internal heterogeneity and diversity of an occurrence. To define the area, rules are needed to specify when two or more patches or stands are close enough together to belong to the same occurrence.

Rationale for Selection of the Variable: Most ecological function is proportional to size of occurrences, and some is disproportionately related to large occurrences. Some ecological functions occur only, or at much greater levels, in areas in good condition, while other ecological functions may occur even in relatively poor or degraded areas. Some species are specific to habitat in the best condition while others are more tolerant of degraded examples. Other ecological functions may occur in poorer quality areas, but only at a much reduced frequency/intensity, and some species may occur there but only at low density. Poorer areas thus contribute to the ecological significance of occurrences, but to a lesser degree than areas in better condition.

Measurement Protocol: This metric is evaluated by measuring or estimating the total area of the occurrence.

Measure	Definition Tier	A Excellent	B Good	C Fair	D Poor
Total system size	Total area of system within separation distance	>5000 acres	2000-5000 acres	1000-2000 acres	< 1000 acres

Data:

Scaling Rationale: The present scale is based on the range of sizes of occurrences in Colorado and professional judgment about thresholds (Rondeau 2001). The range of sizes is expected to be similar throughout the range of the system. The scale could be improved by basing it on the correlation of species presence/richness with size values.

Confidence that reasonable logic and/or data support the index: High.

B.4.2 Size of high quality area

Definition: This metric assesses the size of the area to which the highest condition rating applies.

Background: For occurrences that are heterogeneous with regard to condition, this metric indicates the size of area which is in the best condition class. For homogeneous occurrences, this will be the same as the total system size, but for heterogeneous occurrences it may be smaller.

Rationale for Selection of the Variable: Most ecological function is proportional to size of occurrences, and some is disproportionately related to large occurrences. Some ecological functions occur only, or at much greater levels, in areas in good condition, while other ecological functions may occur even in relatively poor or degraded areas. Some species are specific to habitat in the best condition while others are more tolerant of degraded examples. Other ecological functions may occur in poorer quality areas, but only at a much reduced frequency/intensity, and some species may occur there but only at low density. Because the combined rating for the occurrence is based on a combination of size and condition, the size of the high quality area, the area corresponding to the condition rating, is the most important size measure. However, having large additional areas in poorer condition may compensate to some degree.

Measurement Protocol: This metric is evaluated by measuring or estimating the total area within the occurrence that meets the criteria for the best condition rating score given to the occurrence, the most intact area within the overall occurrence.

Measure	Definition - Tier	A Excellent	B Good	C Fair	D Poor
Size of high quality area	Area of system in best condition class (see rollup of condition metrics) 2, 3	>5000 acres	2000-5000 acres	1000-2000 acres	< 1000 acres

Data:

Scaling Rationale: The present scale is based on the range of sizes of occurrences in Colorado and professional judgment about thresholds (Rondeau 2001). The range of sizes is expected to be similar throughout the range of the system. The scale could be improved by basing it on the correlation of species presence/richness with size values.

Confidence that reasonable logic and/or data support the index: High.

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