Current Landscape Condition for The Bighorn National Forest Ecosystem

Rocky Mountain Region of the USDA Forest Service

Technical Coordinator:
Claudia Regan
Regional Landscape Ecologist

Terrestrial Ecosystem Assessment Design Team:
Bernie Bornong, Dean Erhard, Julie Grode, Kent Houston, Mark Hatcher, Jennifer Ross, and Jim Thinnes

Terrestrial Ecosystem Assessment Production Team:
Dean Erhard, Greg Hayward, Dan Kashian, Nancy McDonald, Sigrid Resh, Jennifer Ross, David Shadis, and Molly Welker

Team Members

Bernie Bornong
Forest Silviculturist
Bighorn National Forest
2013 Eastside 2nd Street
Sheridan, WY 82801

Dean Erhard
Ecologist
Rio Grande National Forest
1803 West Highway 160
Monte Vista, CO 81144

Julie Grode
Wildlife Biologist
White River National Forest
P.O. Box 948
Glenwood Springs, CO 81602

Mark Hatcher
Range Conservationist
Grand Mesa, Uncompahgre and
Gunnison National Forests
2250 Highway 50
Delta, CO 81416-8723

Dr. Greg Hayward
Regional Wildlife Ecologist
Rocky Mountain Region
USDA Forest Service
740 Simms Street
Golden, CO 80401

Kent Houston
Soils Scientist/Ecologist
Shoshone National Forest
808 Meadow Lane
Cody, WY 82414-4516

Dr. Dan Kashian
Post-doctoral Fellow
Dept. of Forest, Rangeland,
and Watershed Stewardship
Colorado State University
Fort Collins, CO 80523

Nancy McDonald
Writer/Editor
Rocky Mountain Region
USDA Forest Service
740 Simms Street
Golden, CO 80401

Dr. Claudia Regan
Regional Landscape Ecologist
Rocky Mountain Region
USDA Forest Service
740 Simms Street
Golden, CO 80401

Dr. Sigrid Resh
Forest Ecologist
Affiliate Faculty
Dept. of Forest, Rangeland,
and Watershed Stewardship
Colorado State University
Fort Collins, CO 80523

Jennifer Ross
GIS Analyst
Rocky Mountain Region
USDA Forest Service
740 Simms Street
Golden, CO 80401

David Shadis
National Fire Plan Ecologist
Rocky Mountain Region
USDA Forest Service
740 Simms Street
Golden, CO 80401

Jim Thinnes
Timber Program Manager and
Forest Silviculturist
White River National Forest
P.O. Box 948
Glenwood Springs, CO 81602

Molly Welker
Technical Writer/Editor
2150B Centre Ave.
Stop 2E6
Fort Collins, CO 80526

Preface

The Species Conservation Project is a strategic effort by the Rocky Mountain Region of the USDA Forest Service to provide rigorous scientific tools that support ecological conservation on the National Forests and Grasslands. Such tools will allow us to create management programs that are explicitly designed to enhance the viability of at-risk plant and animal species and the integrity of ecosystems.

The Species Conservation Project is conducting *species assessments* of about 300 at-risk plants and animals and *ecosystem assessments* of multi-scaled ecological units. Ecosystem assessments are being done for both terrestrial and aquatic-riparian-wetland systems. Synthesis models will blend the results of both types of assessments to support the analysis of ecological tradeoffs and the development of conservation options.

Terrestrial ecosystem assessments define historic and current patterns of vegetation communities and landscapes, effects of natural and human disturbances, and ecological risks and restoration options. Terrestrial ecosystem assessments have two parts; historic range of variation assessments and current landscape condition assessments. Leading ecologists are writing *Historic Range of Variation Assessments* for 10 large ecological subregions and 4 key ecosystem types in the Region. Forest Service specialists are conducting the *Current Landscape Condition Assessments* on a few large ecological subregions per year.

This document, the Current Landscape Condition Assessment of the Bighorn National Forest Ecosystem, consists of seven principal parts:

- Chapter 1 - Introduction
- Chapter 2 - Ecological and Socio-economic Context of the Assessment Area
- Chapter 3 - Existing Vegetation Condition
- Chapter 4 - Influences on Landscape Condition
- Chapter 5 - Landscape Patterns
- Chapter 6 - Areas of Special Biodiversity Significance
- Chapter 7 - Synthesis

TABLE OF CONTENTS

List of Figures and Tables

Chapter 1 - Introduction

Context for Terrestrial Ecosystem Assessments in Region 2

Terrestrial ecosystem assessments are one of several elements of the Rocky Mountain Region's Species Conservation Project (SCP). The project was initiated by the Regional Leadership Team, and chartered in January 2001, as a Region-wide coordinated approach to significantly improve the effectiveness of agency management of species, particularly species facing risks to viability, and to enhance management for ecological integrity and sustainability. The SCP focus is on developing and implementing approaches to improve the integration of species and ecosystem management in forest and project planning at multiple temporal and spatial scales as demanded by the National Forest Management Act (NFMA) and associated regulations. Approaches bring together several concepts developed over the past two decades within the context of ecosystem management science (Christensen *et al.* 1996, Grumbine 1997), conservation biology (Hunter 1991, Murphy and Noon 1991, Meffe and Carroll 1997, Scott and Csuti 1997), and recent efforts at improved implementation of the NFMA (Tongass National Forest Land Resource Management Plan 1997, Northwest Forest Plan 1997, Sierra Nevada Forest Plan 2001). With this foundation in the current science of ecosystem management and conservation biology, the SCP reflects the ideas described in recent agency guidance (Holthausen *et al.* date, Undersecretary of Agriculture 2001, Deputy Chief USFS 2002, Liggett *et al.* 2003).

Terrestrial Ecosystem Assessment Components

Several broad questions relevant to the condition of terrestrial ecosystems are addressed in the two major parts of the terrestrial ecosystem assessments: the *Historic Range of Variation Assessments* (HRV) and the *Current Landscape Condition Assessments* (CLC). The HRV Assessment of the Bighorn National Forest (Meyer and Knight 2003) provides background on system function with a focus on the insights historical ecology can provide on dominant disturbance agents and the influence these agents have on vegetation patterns, particularly for forested ecosystems. Meyer and Knight's work helps us understand the dominant processes influencing ecosystem dynamics and the resulting expected ranges in terrestrial ecosystem condition (Swanson *et al.* 1993; Morgan *et al.* 1994; Holling and Meffe 1996; Landres *et al.* 1999; Swetnam *et al.* 1999). In contrast, the Current Landscape Condition Assessment of the Bighorn Ecosystem describes the current status, probable trajectories, and integrity or sustainability concerns of the assessment area. The HRV Assessment contributes to the CLC Assessments by providing a basis for understanding the degree of departure in ecosystem composition, structure, and function from the ranges expected under historic disturbances regimes to the current condition which is influenced by alteration of disturbance regimes and land use practices during and since Euro-American settlement. This two-part approach of developing an understanding of ecological context is well grounded in the current ecosystem management and conservation biology literature (Christensen *et al.* 1996, Grumbine 1997, Aber *et al.* 2000, Dale *et al.* 2000, Groves *et al.* 2002).

Application of the Terrestrial Ecosystem Assessments

Application of information from the Bighorn Ecosystem Assessments provides a scientific foundation for forest planning and project planning. However, productive use of the products goes far beyond these basic planning processes. Examples of how the terrestrial ecological assessments can be used include the following:

(1) Training and orientation of new (or transfer) employees regarding the ecology of the Bighorn terrestrial systems.
(2) Providing a common understanding of terrestrial vegetation dynamics and conditions for the education of the public and Bighorn National Forest partners regarding ecological disturbances, ecological change, and current ecologic conditions.
(3) Providing the scientific basis for discussions with political officials regarding fire, insect, and disease processes in the Region.
(4) Providing the scientific basis to increase effectiveness and efficiency in development and application of the Accelerated Watershed Restoration Program (AWRP) by:
   a. Improving classification of fire risk.
   b. Improving prioritization of projects.
   c. Clarifying an understanding of native disturbance processes and therefore increases understanding of the ecological constraints to meeting desired conditions.
   d. Increasing public understanding of the historical patterns of forest vegetation and historic disturbance patterns in the Region.
(5) Providing a strong scientific foundation for Forest Planning by improving understanding of terrestrial systems at several stages in Forest planning, including:

Analysis of Management Situation: Terrestrial assessments provide a strong foundation for identifying restoration issues, determining the direction of forest change, and understanding the capability of the forest to produce desired resources.

G*oals and Objectives*: Terrestrial assessments aid in evaluating the efficacy of goals and objectives and also aid in identifying unrealistic goals that are beyond the capability of the ecological system.

Forest-wide Standards: Terrestrial assessments provide an understanding of ecological norms and variation in ecological conditions to improve framing of standards for ecological condition.

Alternatives: Terrestrial assessments aid in development of alternatives by establishing a sound basis for predicting the capability of the land.

Management Area Direction: Terrestrial assessments provide an understanding of current conditions and potential future change, which is critical to establishing direction for particular land areas.

EIS Affected Environment and Environmental Consequences: Terrestrial assessments are critical for evaluating the scientific foundation for the assumptions made in designing the selected alternative and for predicting effects of management actions on the terrestrial vegetation.

Monitoring: Terrestrial assessments aid in identifying those ecological characteristics that should be expected to change as a consequence of management and in identifying those that will be important to monitor.

(1) Providing a scientific foundation for project planning similar to that outlined above for Forest Planning but also:
   a. Provide understanding to facilitate identification of priority restoration opportunities.
   b. Aid in identifying projects that attempt to change ecological systems in directions that are counter to ecological development and therefore will require extra-continued management.

Objectives of the Bighorn Ecosystem Current Landscape Condition Assessment

The following issues were identified by the Bighorn National Forest staff as relevant to the assessment area and important in driving the content of the assessment:

(1) Biological diversity and species viability
(2) Forest and rangeland health
(3) Natural disturbances and disturbance hazard and risk
(4) Roadless areas, wilderness, special areas
(5) Risk associated with land use practices and vegetation management

To address these issues, this report focuses on a spatial characterization of current ecological condition and identifies geographic areas or ecosystem characteristics with possible sustainability concerns. The details of CLC assessment objectives, content, and approaches including scale issues and reporting units are explained in the companion protocol document (Regan *et al.* 2003). The assessment will:

(1) Describe the key features of current vegetation condition and landscape pattern of the Bighorn ecosystem.
(2) Describe the magnitude of land use influences and vegetation management on key features of vegetation condition and landscape pattern.
(3) Represent spatially areas of disturbance regime departure, disturbance risk, vulnerability to invasive species, risks of invasive species, and modeled rangeland condition.
(4) Ensure that most of the readily available broad ecosystem information is in place when biologists consider particular species issues in the context of ecosystem condition.
(5) Illustrate the unique ecological characteristics of the Forest.
(6) Reveal the separate contributions that each District or mid-scale planning unit can or cannot make to particular conservation efforts.
(7) Identify representative reference landscapes.
(8) Identify areas of possible ecological integrity concern or high priority areas for ecological restoration.
(9) Provide a template and an information foundation for analyses and assessments at finer scales.
(10) Complement the reserve-based conservation approach (The Nature Conservancy 2000) by providing information on condition of all lands in the assessment area.

Limitations of the Bighorn CLC Assessment

The scope of the Bighorn CLC Assessment is limited to a description of the current terrestrial ecosystem condition using readily available information. Several important tasks are not accomplished by this report. The Bighorn CLC assessment will not:

(1) Address the relevance of the current ecological condition to particular species.
(2) Integrate information from the aquatic, riparian, and wetland assessments and species assessments.
(3) Evaluate ecosystem effects of management scenarios.
(4) Design a network of preserves (The Nature Conservancy 2000).

The CLC Assessment, along with the HRV Assessment, should be used in conjunction with other products produced from the SCP to fully accomplish the job of understanding and developing plans or management approaches to accomplish species conservation and ecological sustainability. In the original design of the SCP, much of this integrative work would be accomplished in the “synthesis tools” phase of the project. However, with the SCP under constraining budgets, opportunities for formalized synthesis tools are limited.

The ability to draw conclusions about ecological implications is limited by the availability of information relating condition to ecological function. Inventory data exist to allow for doing an adequate job of describing condition for many ecosystem attributes. However, available inventory and monitoring data rarely ever address ecological response to condition. So, the ability to draw conclusions about implications is almost entirely limited to relying on information published in the literature. Further, implications of the findings to species are addressed when individual species are considered in the context of assessment findings. So, implications would be more substantively addressed at a later integration step.

The assessment content is also limited by the availability of data. Only readily available data were considered in developing the assessment (i.e., no new data were collected and there were no extensive data development efforts). For a number of assessment components, no data existed or data were not available electronically. In these cases, data gaps were identified and information needs were prioritized.

Organization of the Bighorn CLC Assessment

Following the introduction, the Bighorn CLC Assessment is organized into six additional chapters:

- Chapter 2 - Ecological and Socio-economic Context of the Assessment Area
- Chapter 3 - Existing Vegetation Condition
- Chapter 4 - Influences on Landscape Condition
- Chapter 5 - Landscape Patterns
- Chapter 6 - Areas of Special Biodiversity Significance
- Chapter 7 - Synthesis

In order to fully appreciate the current landscape condition of the BNF, ecological and socio-economic contexts (Chapter 2) are provided. The ecological context of the assessment area addresses a combination of the environmental, physiographic, and biological drivers. An understanding of the current ecological condition is not complete without the knowledge of previous and current human interaction with the ecosystem as well as future demands. Therefore, the socio-economic context of the assessment area is provided to address the historic and current human influences in the area including land ownership allocations and resource uses. The socio-economic portion of Chapter 2 is not designed to be a complete, independent socio-economic assessment. Its purpose is to simply summarize and present socio-economic information relevant to the current ecological condition. Without this portion, a complete and holistic understanding of current landscape would not be possible. These ecological and socio-economic components provide the foundation for comprehension and assessment of the current landscape condition.

The Existing Vegetation Condition (Chapter 3) component of the assessment is an ecosystem-level analysis intended to provide detailed descriptions of individual major cover types identified within the Bighorn ecosystem. This component is divided into two modules (3A Forest and Woodland and 3B Grassland and Shrubland). Chapter 3 is unlike other chapters in that it is organized by major cover type. This is to focus on the features of vegetation that can be considered one type at a time (or stand level features). The features of the landscape that transcend individual vegetation types, such as wildfire, invasive species, or landscape structure, are discussed in Chapter 4 and 5 – Influences on the Landscape and Landscape Pattern.

The Landscape Influences (Chapter 4) component of the assessment evaluates current and potential influences on landscape condition. It is divided into seven modules (A. Wildfire, Insects, and Disease; B. Forest and Woodland Vegetation Management; C. Grassland and Shrubland Vegetation Management; D. Invasive Species; E. Roads and Trails; F. Recreation and Exurban Development; G. Minerals, Oil, and Gas). Although some of the influences may be associated within individual cover types, the focus of the analysis is from a landscape ecology perspective. This means that the influences are discussed in the context of multiple temporal and spatial scales. The landscape may encompass many individual vegetation types and, in fact, a feature of landscape pattern is the relative distribution of types within the landscape. The various analysis scales need to include at least one analysis following ecological boundaries as well as management defined boundaries to fully analyze the affects of these influences on the landscape and discover impacts that may focus on particular ecological land type associations or on management defined geographic areas.

The Landscape Patterns (Chapter 5) component combines the ecological and socio-economic context information with existing vegetation condition and landscape influences to give a broad scale pattern of ecosystems on the Bighorn landscape. The landscape patterns component has two modules – forested and woodland vegetation and grassland and shrubland vegetation. This is done to look at specific issues relating to how management practices and natural disturbance are affecting key features of the landscape pattern that are relevant to the particular life form.

Areas of Special Biodiversity Significance (Chapter 6) focuses on vegetation or areas located within the Bighorn assessment area that have been identified as unique, at risk, or habitats of special biodiversity significance. This is a landscape level analysis that is intended to draw attention to specific details, thus adding to the landscape pattern component. The value of each area is discussed as it relates to the current vegetation condition, landscape influences, and landscape pattern.

The Synthesis (Chapter 7) component evaluates the current landscape condition from an ecological integrity and sustainability perspective by synthesizing key points from each of the modules.

Bighorn Ecosystem Assessment Area

The Bighorn National Forest (BNF) is located in north-central Wyoming (Fig. 1.1) in the Bighorn Mountains Section (McNab and Avers 1994) of the Southern Rocky Mountain Province (Bailey 1995). The Great Plains to the east and the Intermountain Semi-Desert to the west surround the Big Horn Mountains. Although the Southern Rocky Mountain province reaches from the Front Range of Colorado nearly to the Great Salt Lake, and from Yellowstone National Park to north-central New Mexico, it is not contiguous. The assessment area is defined by the Bighorn Mountains Section, which is physically isolated from the Absaroka Range to the west, by the Big Horn Basin and the Laramie Mountains to the southeast, and by the Powder River Basin.

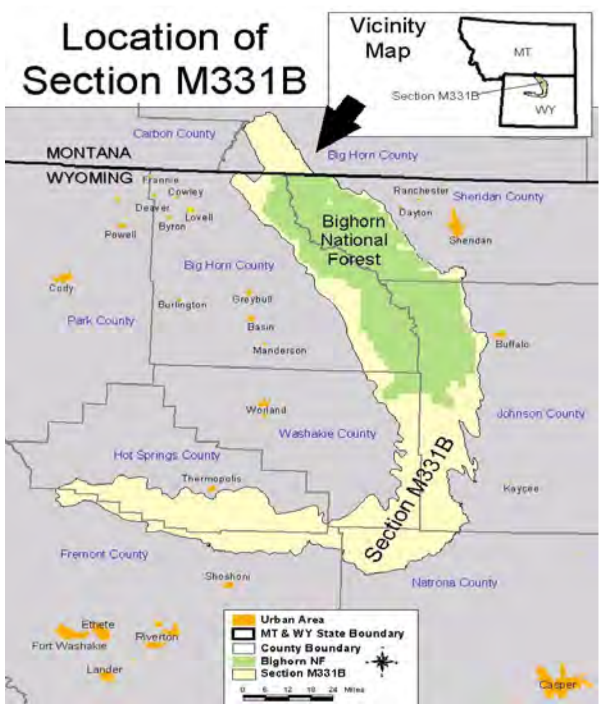


Figure 1-1. Location map of the Bighorn National Forest within Section M331B.

Literature Cited

Aber, J., N. Christensen, I. Fernandez, J. Franklin, L. Hidinger, M. Hunter, J. MacMahon, D. Mladenoff, J. Pastor, D. Perry, R. Slangen, and H.van Miegroet. 2000. Applying ecological principles to management of U. S. National Forests. Issues in Ecology No. 6. Ecological Society of America. Washington, D.C., USA.

Bailey, R.G. 1995. Description of the ecoregions of the United States. 2nd ed. Misc. Publ. No. 1391 (rev.). with separate map, scale = 1:7,500,000. USDA Forest Service, Washington, D.C., USA.

Christensen, N.L., A.M. Bartuska, J.H. Brown, S. Carpenter, C. D'Antonio, R. Francis, J.F. Franklin, J.A. MacMahon, R.F. Noss, D.J. Parsons, C.H. Peterson, M.G. Turner, and R.G. Woodmansee. 1996. The report of the Ecological Society of America committee on the scientific basis of ecosystem management. Ecological Applications **6**(3):665-691.

Dale, V. H., S. Brown, R. A. Haeuber, N. T. Hobbs, N. Huntly, R. J.Naiman, W. E. Riebsame, M. G. Turner, and T. J. Valone. 2000. Ecological principles and guidelines for managing the use of land. Ecological Applications **10**:639-670.

Groves, C. R., D. B. Jensen, L. L.Valutis, K. H. Redford, M. L. Shaffer, J. M. Scott, J. V. Baumgartner, J. V. Higgins, M. W. Beck, and M. G. Anderson. 2002. Planning for biodiversity conservation: Putting conservation science into practice. BioScience **52**:499-512.

Grumbine, R.E. 1997. Reflections on "What is ecosystem management?" Conservation Biology **11**:41-47.

Holling, C.S. and G.K. Meffe. 1996. Command and control and the pathology of natural resource management. Conservation Biology 10(2):328-337.

Hunter, M. L. Jr. 1991. Coping with ignorance: the coarse filter strategy for maintaining biodiversity. Pages 266-281 *in* K. A. Kohm editor. Balancing on the brink of extinction: the endangered species act and lessons for the future. Island Press.

Landres, P.B., P. Morgan, and F.J. Swanson. 1999. Overview of the use of natural variability concepts in managing ecological systems. Ecological Applications 9:1179-1188.

Ligget *et al.* 2003.

McNab, W.H. and P.E. Avers. 1994. Ecological subregions of the United States: section descriptions. Administrative Publ. WO-WSA-5. USDA Forest Service. Washington, D.C., USA.

Meffe, G. K, and C. R. Carroll. 1997. Principles of conservation biology. 2nd edition. Sinauer. Sunderland, MA, USA.

Meyer, C.B., and D.H. Knight. 2003. Historic variability for upland vegetation in the Bighorn National Forest, Wyoming. Unpublished report on file at Bighorn National Forest Supervisor's Office, Sheridan, WY, USA.

Morgan, P., G.H. Aplet, H.B. Hauflet *et al.* 1994. Historical range of variability: A useful tool for evaluating ecosystem change. Journal of Sustainable Forestry 2:87-111.

Murphy, D. D., and B. R. Noon. 1991. Coping with uncertainty in wildlife biology. Journal of Wildlife Management **55**:773-782.

Northwest Forest Plan: An Ecosystem Approach, Watersheds, Communities, and People. 1997 Region 6, Pacific Northwest Region.

Regan, C., D. Erhard, G. Hayward, D. Kashian, *et al.* 2003. Protocol for developing terrestrial ecosystem current landscape condition assessments for the Rocky Mountain Region of the USDA Forest Service.

Scott, J. M., B. Csuti. 1997. Noah worked two jobs. Conservation Biology **11**:1255-1257.

Sierra Nevada Forest Plan. Jan 2001. (Amendment Jan 2004). USDA ForestService, Pacific Southwest Region, R5-MB-046.

Swanson, F.J., J.A. Jones, D.O. Wallin and J.H. Cissel. 1993. Natural variability – implications for ecosystem management. In M.E. Jensen and P.S. Bourgeron (eds.), Ecosystem Management: Principles and Applications. Vol. II. Eastside Forest Health Assessment. USDA Forest Service General Technical Report PNW-GTR-318:89-103.

Swetnam, T. W., C. D. Allen,and J. L. Betancourt. 1999. Applied historical ecology: using the past to manage for the future. Ecological Applications **9**:1189-1206.

Tongass National Forest Land Resource Management Plan. 1997. USDA Forest Service, Alaska Region, Ri0-MB-338d.

Chapter 2 - Ecological and Social-Economic Context

Objectives

Description of the ecological context of the assessment area, identifying the physical and/or biological factors that create ecological patterns and provide a foundation for interpreting the current ecological condition will be included in this chapter. Description of the social and economic context of the assessment area, identifying known primary socioeconomic factors that serve as a basis for interpreting ecological condition will also be discussed. A summarization of the important broad scale patterns of resource management and land uses that influence vegetation condition, landscape pattern, and ecosystem function is also included.

Introduction

A synopsis of the constraining environmental factors, or the ecological template, is required as a means of understanding ecosystem structure and function at multiple scales in the Big Horn Mountains and the Bighorn National Forest (BNF). Current landscapes in the Rocky Mountains have resulted from many causes, including biotic interactions, past and present human activities, and natural disturbances. However, the effects of broad-scale environmental factors such as climate, geology, and physiography set the stage for essentially all biotic activity that occurs in a given ecological setting (Bailey 1996, Turner *et al.* 2001). Understanding these constraints is therefore critical for comprehending the ecology of the BNF and for designing and implementing ecologically sustainable management practices.

This module (or chapter) describes the ecological context of ecosystems of the BNF using the ecological hierarchy provided by National Hierarchical Framework of Ecological Units (USFS ECOMAP 1993). It then includes a detailed description of climate patterns, geology, the effects of fauna and humans on vegetation and ecosystem processes. The companion historic range of variation assessment (Meyer and Knight 2003) addresses the influences of natural disturbance processes and historic land uses on vegetation structure, pattern, and function. Vegetation types are described in detail in Modules 3A and 3B.

Hierarchy of Ecological Units

Ecosystems, and the complex patterns they form across landscapes, can be described within a hierarchical framework. This framework consists of multi-scaled systems where each system constrains the environment from which the lower scales of organization evolve. Each level of organization is a discrete functional entity, but is also part of the larger whole. Such a hierarchical concept allows us to visualize the linkages between different scales of ecological organization.

Ecosystem composition, structure, and function determine diversity patterns across a range of spatio-temporal scales, such that the ecological hierarchy level of interest is determined by the assessment question. The ecological context may well be described for the BNF using the National Hierarchical Framework of Ecological Units (Table 2-1; USFS ECOMAP 1993) as a uniform method of describing and delineating areas with similar ecological potentials. Within this system, the scales of ecosystems are described in terms of vegetation patterns, biotic processes, environmental constraints, and disturbances.

Table 2-2 summarizes the criteria used to differentiate each ecological unit in the national hierarchy (USFS ECOMAP 1993). At the largest scales, Ecological Domains, Divisions, and Provinces are defined on the basis of broad regional climate similarity,

Table 2-1. National hierarchy of ecological units.

Planning and Analysis Scale	Ecological Units	Purpose, Objectives, and General Use	General Size Range
Ecoregions Global Continental Regional	Domain Division Province	Broad applicability for modeling and sampling RPA assessment. International planning	1,000,000s to 10,000s of square miles
Subregions	Sections Subsections	RPA planning multi-forest, statewide, and multi-agency analysis and assessment	1,000s to 10s of square miles
Landscape	Landtype Association	Forest or area-wide planning, and watershed analysis	1,000s to 100s of acres
Land Unit	Landtype Landtype Phase	Project and management area planning and analysis	100s to less than 10 acres

areas of differing vegetation, and broad soil categories. The BNF falls within the Dry Domain, characterized by a relatively dry climate; the Temperate Steppe Division, characterized by a semi-arid continental climatic regime with mountainous altitudinal zonation; and the Southern Rocky Mountain Steppe - Open Woodland - Coniferous Forest - Alpine Meadow Province (M331; Bailey 1996).

Provinces are further subdivided into Sections, which include broad areas of similar geologic origin, geomorphic process, stratigraphy, drainage networks, topography, and regional climate. Sections are then further divided into Subsections, Landtype Associations (LTAs), and Landtypes (Tables 2-1 and 2-2). The BNF lies within the Big Horn Mountains Section (M331B) (McNab and Avers 1994) and is comprised of two Subsections (Fig. 2-1) and 10 LTAs. LTAs are based on similarities in geology, soils, and plant associations (Fig. 2-2). The subsections and LTAs in the BNF include the following:

<u>Big Horn Mountains, Sedimentary Subsection (M331Ba)</u>

- M331Ba-01 Sedimentary Breaklands
- M331Ba-02 Landslide/Colluvial Deposits
- M331Ba-03 Sedimentary Mountain Slopes, Limestone/Dolomite
- M331Ba-04 Sedimentary Mountain Slopes, Shale/Sandstone (calcareous)
- M331Ba-05 Sedimentary Mountain Slopes, Shale/Sandstone (non-calcareous)

<u>Big Horn Mountains, Granitic/Gneiss Subsection (M331Bb)</u>

- M331Bb-01 Granitic Breaklands
- M331Bb-02 Glacial Cirquelands
- M331Bb-03 Glacial/Tertiary Terrace Deposits
- M331Bb-04 Granitic Mountain Slopes, Steep
- M331Bb-05 Granitic Mountain Slopes, Gentle
- M331Bb-06 Alpine Mountain Slopes and Ridges

Detailed descriptions for Sections, Subsections, and LTAs are provided in Appendix A. For purposes of this assessment, most data are summarized for the Big Horn Mountains Section and for LTAs only.

Table 2-2. Principal map unit design criteria of Ecological Units[1].

Ecological Unit	Design Criteria
Domain	• Broad climatic zones or groups (e.g., dry, humid, tropical).
Division	• Regional climatic types (Koppen 1931, Trewartha 1968) • Vegetational affinities (e.g., prairie or forest). • Soil order.
Province	• Dominant potential natural vegetation (Kuchler 1964) • Highland or mountains with complex vertical climate-vegetation-soil zonation.
Section	• Geomorphic province, geologic age, stratigraphy, lithology. • Regional climatic data. • Phases of soil orders, suborders, or great groups. • Potential natural vegetation. • Potential natural communities (PNC)[2].
Subsection	• Geomorphic process, surficial geology, lithology. • Phases of soil orders, suborders, or great groups. • Subregional climatic data. • PNC-formation or series.
Landtype Association	• Geomorphic process, geologic formation, surficial geology, and elevation. • Phases of soil subgroups, families, or series. • Local climate. • PNC-series, subseries, plant associations.
Landtype	• Landform and topography (elevation, aspect, slope gradient, and position). • Rock type, geomorphic process. • Phases of soil subgroups, families, or series. • PNC-plant associations.
Landtype Phase	• Phases of soil families or series. • Landform and slope position. • PNC-plant associations or phases.

[1]The criteria listed are broad categories of environmental and landscape components. The actual classes of components chosen for designing map units depend on the objectives for the map.
[2]Potential Natural Community Vegetation that would develop if all successional sequences were completed under present site conditions.

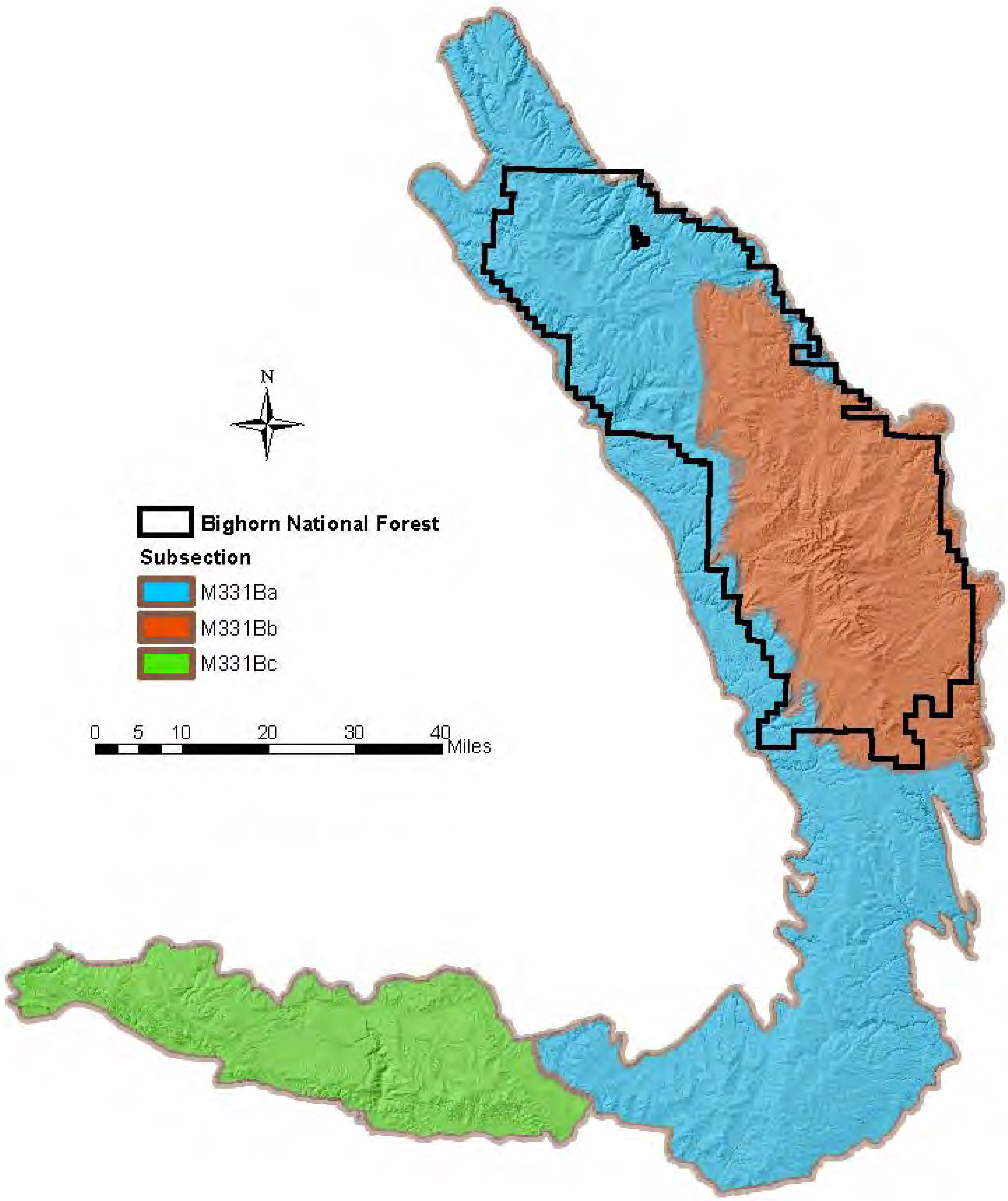


Figure 2-1. The Bighorn National Forest relative to the Big Horn Mountains Section (M331B) and its three associated Subsections.

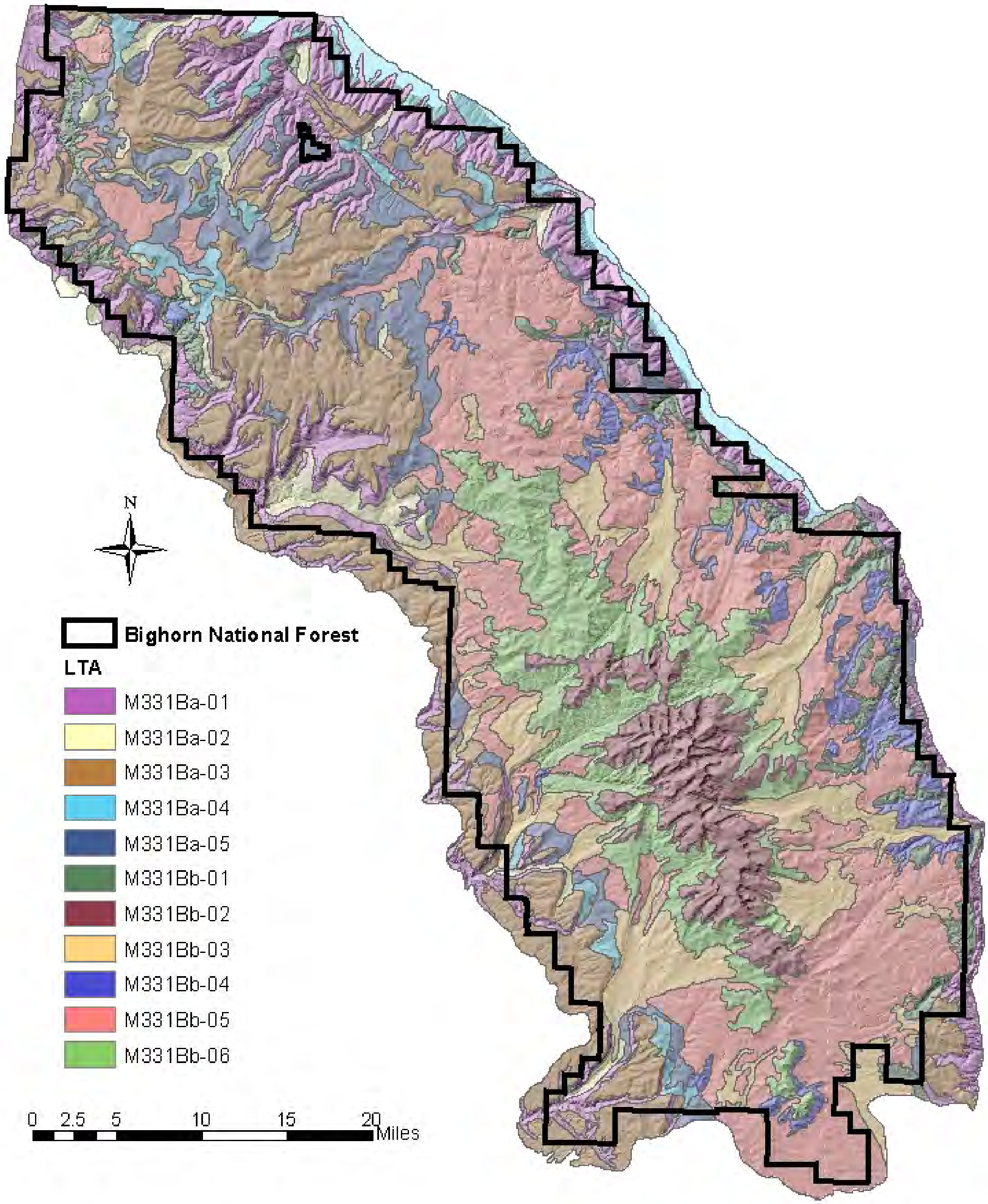


Figure 2-2. Landtype Associations (LTAs) for the Bighorn National Forest.

Biogeographic Significance

The Big Horn Mountains are located in the province described as the Southern Rocky Mountain Steppe—Open Woodland—Coniferous Forest—Alpine Meadow (M331) (Fig. 2-3). Although the province itself reaches from the Front Range of Colorado nearly to the Great Salt Lake and from Yellowstone National Park to north-central New Mexico, it is not contiguous. The cut-out view of the M331 Province (on the right in Fig. 2-3) is essentially the central and southern spine of the Rocky Mountains.

The Big Horn Mountains Section is physically isolated from the Absaroka Range to the west by the Big Horn Basin and the Laramie Mountains to the southeast by the Powder River Basin; and grasslands dominate both basins. The Section is 2.8 million acres (1.1 million ha) in area and contains most of the habitat in the immediate area above 8,000 feet (2,440 m). Furthermore, the Section is 49% forested (the Bighorn National Forest is 57% forested), representing the only major forested region in the immediate area. Clearly, the BNF is a veritable “island” of mountainous, forested terrain.

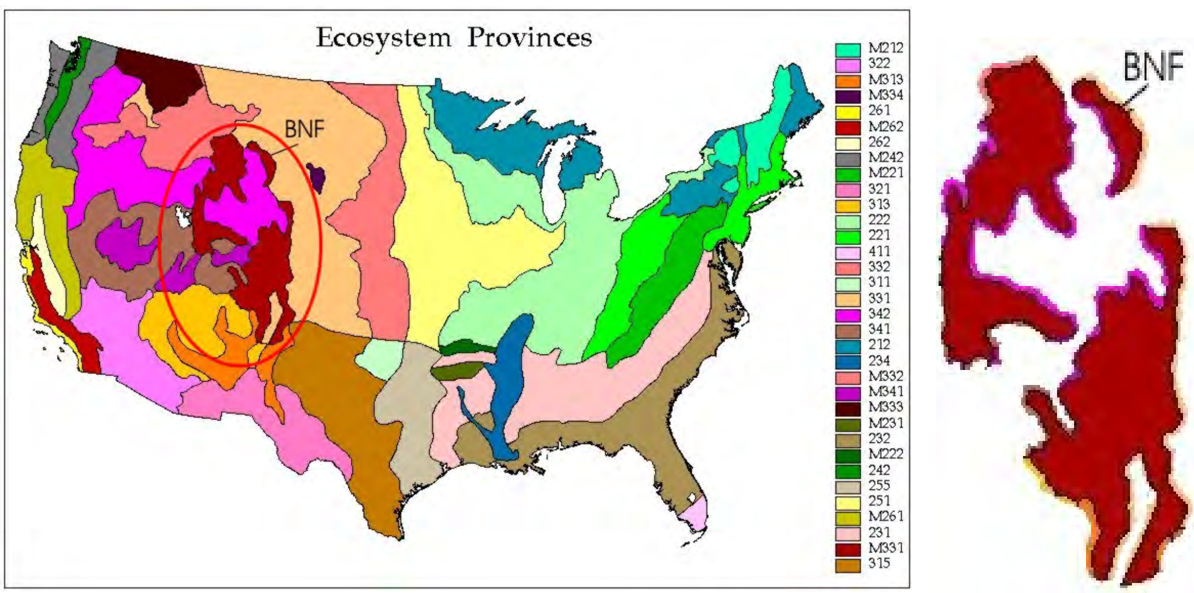


Figure 2-3. Ecological Provinces (left) and cut-out of M331 Southern Rocky Mountain Steppe--Open Woodland-Coniferous Forest--Alpine Meadow Province (*source: http://www.fs.fed.us /colorimagemap/ecoreg1_provinces.html*).

Climate

Historical Climate Patterns

Meyer and Knight (2003) briefly summarized important historic climatic variations in Wyoming and Colorado (Table 2-3). At about the end of the Pleistocene (approximately 10,000 years before present), a significant warming trend influenced the spatial and elevational distribution of vegetation. Since that time, the Rocky Mountains have experienced several cooling and warming trends. Presently, this area is experiencing a period of overall warmer climate relative to the last 1,000 years (Meyer and Knight 2003).

Table 2-3. Chronology of major climatic, geologic, and vegetation history in Wyoming and Colorado (adapted from Meyer and Knight 2003). Note mybp = million years before present and ybp = years before present.

Time	Climate/Geology	Vegetation
2 mybp – 10,000 ybp (Pleistocene epoch)	Six glacial advances and retreats; flooding, creation of outwash plains, loess and soil development	Coniferous forests, shrublands and grasslands (many broad-leaved trees now regionally extinct)
127,000 ybp	Interglacial period	Douglas-fir and limber pine common in Yellowstone
15,000 ybp	Glacial advance; temperatures 18-23º F (10-13º C) colder than today; permafrost	Trees in Yellowstone confined to a narrow elevational band; lowlands tundra-like
11,500 ybp	Temperatures 9-11º F (5-6º C) cooler than today; retreat of glacial ice	Upper treeline about 1,970 ft (600 m) lower than today in Yellowstone; gradually colonized by Engelmann spruce and later by subalpine fir and whitebark pine in some areas (11,000 – 9,500 ybp)
9,500 ybp	Continued warming	Establishment of lodgepole pine at higher elevations and Douglas-fir in foothills in Yellowstone
9,000 – 7,000 ybp		Upper treeline at its lowest in Colorado Front Range
7,000 – 4,000 ybp	Antithermal period, comparatively warm and dry conditions	Expansion of sagebrush, greasewood, juniper and grasses; spruce and fir retreated to higher elevations; elevational range of spruce and fir reduced
4,000 ybp – present	Neoglacial period of gradual cooling	Expansion of forests to previous elevational ranges
ca. 1350 – 1500 AD and 1700 – 1900 AD	Characterized by cooler temperatures (during "Little Ice Age")	Potential glacial advances in the mountains
1850 AD – present	Generally warmer and wetter than "Little Ice Age;" 20th century warmer than previous 1,000 years	Increased tree recruitment near upper treeline (Hessl and Baker 1997), in subalpine meadows (Jakubos and Romme 1993) and in montane forests (Savage *et al.* 1996)

Current Macro-Topographic Influences

The following climate synopsis was derived from previous climate summaries published in Hoffman and Alexander (1976), Despain (1973), Girard *et al.* (1997), and Nesser (1986). Current online data sources were also extracted from selected nearby weather stations and summarized here, with emphasis on climatic influences on the Big Horn Mountains.

The Big Horn Mountains are strongly influenced by the Absaroka Range of the Rocky Mountains, which lie 75 miles (121 km) to the west. Between the Absaroka Range and the west flank of the Big Horn Mountains is the Big Horn Basin, a temperate desert receiving about 7 inches (18 cm) of annual precipitation. Any westerly winds are down-slope and therefore very dry. The Pryor Mountains to the northwest and the Owl Creek Mountains to the southwest prevent moisture-laden winds from reaching the west flank of the Big Horn Mountains (Fig. 2-4). Consequently, the western side of the Section generally receives less precipitation than the eastern side.

Figure 2-4. Terrain view of the Big Horn Mountains vicinity.

Rainfall on the western slope of the Big Horns comes primarily from regional weather patterns that produce airflow from the north or northwest. This allows moisture-laden air to enter the Big Horn Basin through the gap between the Pryor Mountains and the Beartooth portion of the Absaroka Range. The air then releases its moisture as it rises over the Big Horn Mountains. Annual precipitation generally increases in the Section with increasing elevation. Figures 2-5 and 2-6 show generalized maps of mean annual precipitation and air temperature for Section M331B and the surrounding vicinity.

The eastern slope of the Big Horn Mountains receives moisture from easterly winds coming from the prairies. The Powder River to the east receives approximately 11 to 15 inches (28 to 38 cm) of annual precipitation. The major storm tracks are to the north and produce winds mostly from the northeast, yielding higher precipitation on the northeast section of the Big Horn Mountains and intensifying the rain shadow effect southeast of Cloud Peak. The source of precipitation is from the prairies to the north and east, although the source of storm cells is originally from the Pacific Ocean.

In the winter, cold air masses from Canada bring strong northerly and northwesterly winds, low temperatures, and snow. Warm winds from the west and southwest often follow the passage of these fronts and moderate the weather. Upslope conditions that cause precipitation occur frequently in winter and spring on the eastern side of the Big Horn Mountains. In summer, local thunderstorms move in a northeasterly direction in the mountains, and tornados have also occurred in scattered locations (Nesser 1986).

Precipitation and Temperature Ranges, Means, and Seasons

In the Big Horn Mountains, mean annual precipitation varies from about 15 inches (38 cm) below 6,000 feet (1,830 m) in elevation to about 25 inches (64 cm) above 7,500 feet (2,300 m). The higher peaks (>10,000 feet or 3,050 m) receive as much as 40 inches (102 cm) (Hoffman and Alexander 1976). At the higher elevations, precipitation is more equally distributed throughout the year, but a higher proportion falls as snow. At lower elevations, most precipitation falls as rain during the months of April through September.

Weather stations at Shell, Burgess Junction, and Dayton bisect the northern end of the Big Horn Mountains (Fig 2.7). Burgess Junction is the only station actually located on the BNF. Stations at Thermopolis, Ten Sleep, Billy Creek, and Buffalo form a southern line across the Section. Data from these weather stations provided the monthly average precipitation and temperature summaries shown in Figure 2-8.

The mean maximum temperature at Burgess Junction is 69.5º F (21º C) in July and 5º F (-15º C) in January. Nesser (1986) noted extremes of -42º F (-41º C) and 99º F (37º C) recorded at the Hunter Ranger Station, 12 miles (19 km) west of Buffalo, Wyoming at 7,300 feet (2,225 m).

The weather station data reveal two peaks of precipitation: one in the spring and a smaller peak in the fall. Mean total monthly snowfall patterns differ on the west and east sides of the Big Horn Mountains: the Dayton and Buffalo stations have the highest average total monthly snowfall in December; the Burgess Junction and Billy Creek stations peak in April; and the Shell and Ten Sleep stations peak in January. The distribution of precipitation appears to become more uniform at higher elevations (see Burgess Junction station in Fig. 2-8).

An annual climate summary was constructed from the monthly weather data. The Thermopolis and Burgess Junction stations, on average, are the warmest and coldest locations, respectively (Fig. 2-9). The Shell and Burgess Junction stations, on average, are the driest and wettest locations, respectively. Mean annual precipitation ranges from 10.2 inches (26 cm) at the Shell Station to 21.3 inches (54 cm) at the Burgess Junction station. Mean annual snowfall is the highest at the Burgess Junction station (Fig. 2-10). And Nesser (1986) reported perennial snowfields on the flanks of Cloud, Blacktooth, and other peaks in the central Big Horn Mountains.

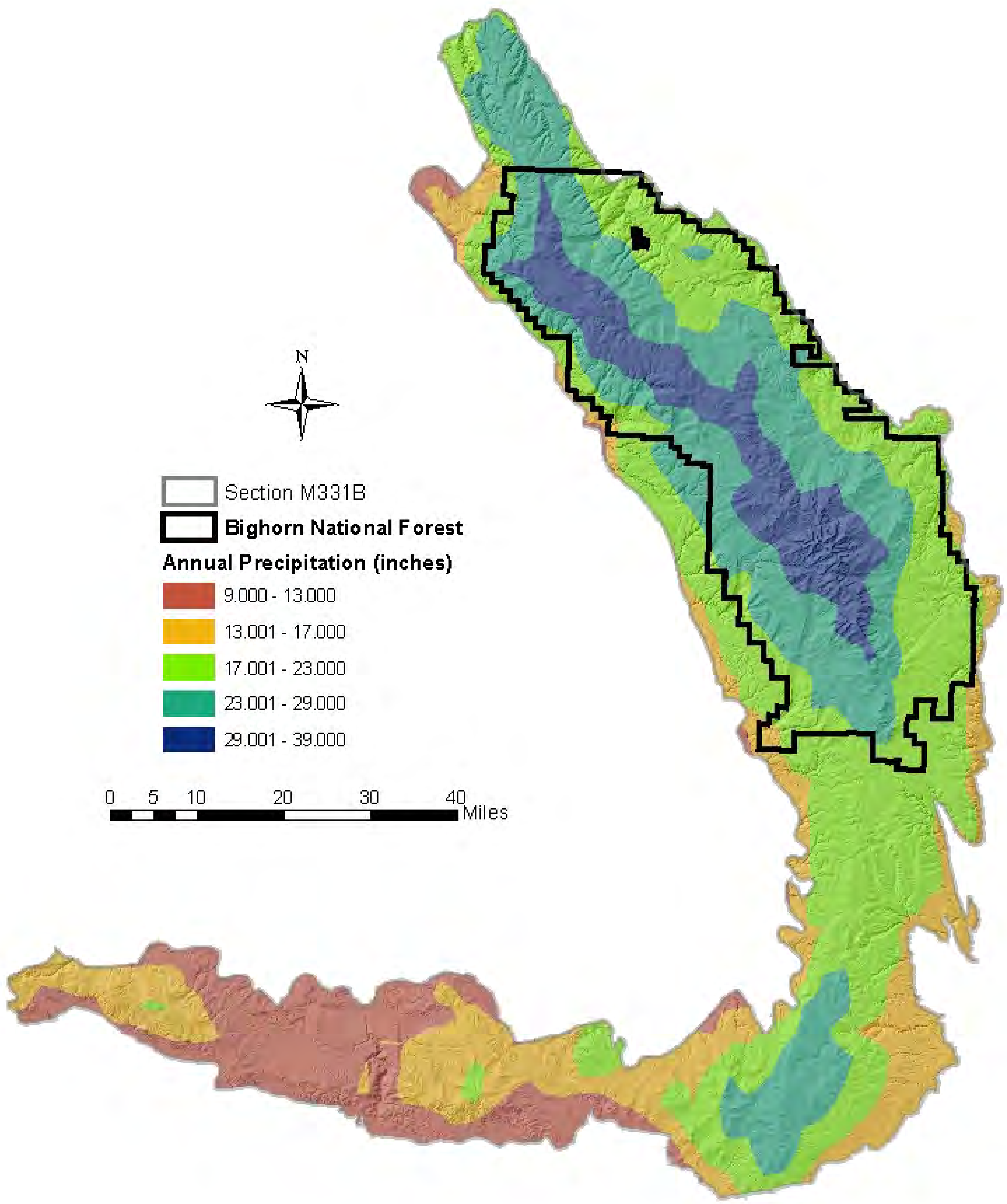


Figure 2-5. Mean annual precipitation for the Big Horn Mountains (*source:* *http://www.ocs.orst.edu/prism/prism_new.html*).

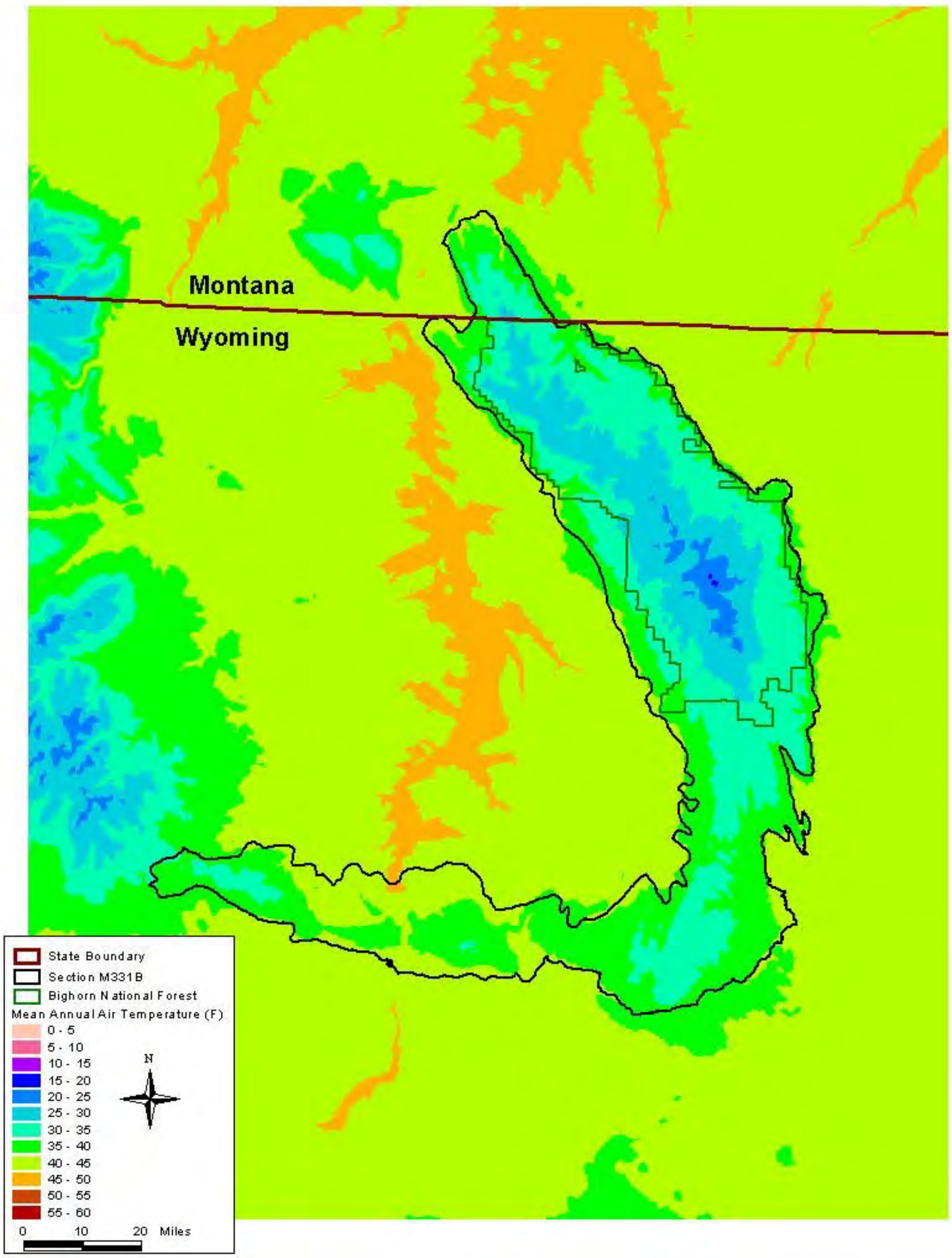


Figure 2-6. Mean annual air temperature for the Big Horn Mountains and the surrounding vicinity (*source: http://www.ocs.orst.edu/prism/prism_new.html*).

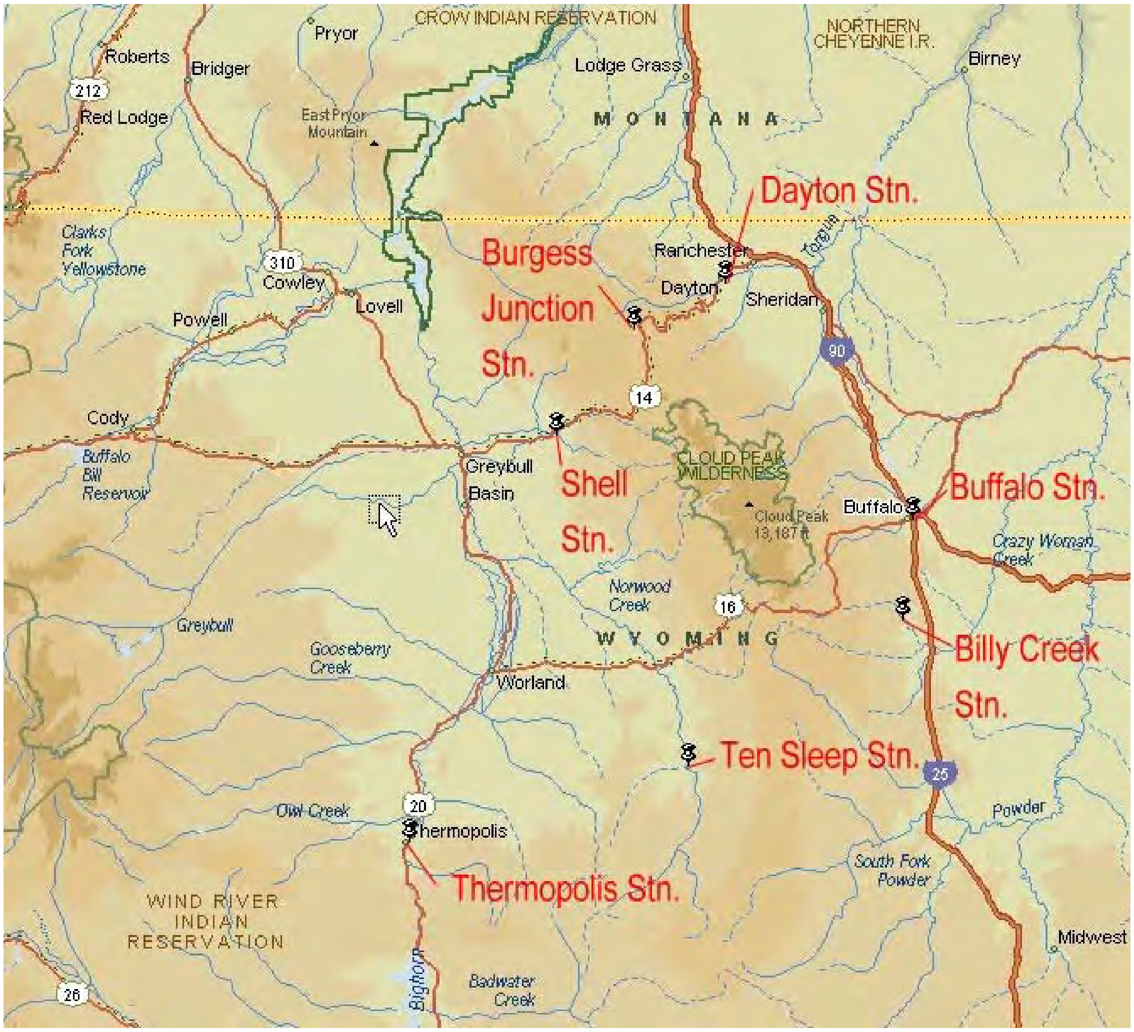


Figure 2-7. Selected Wyoming weather stations within or near the Big Horn Mountains.

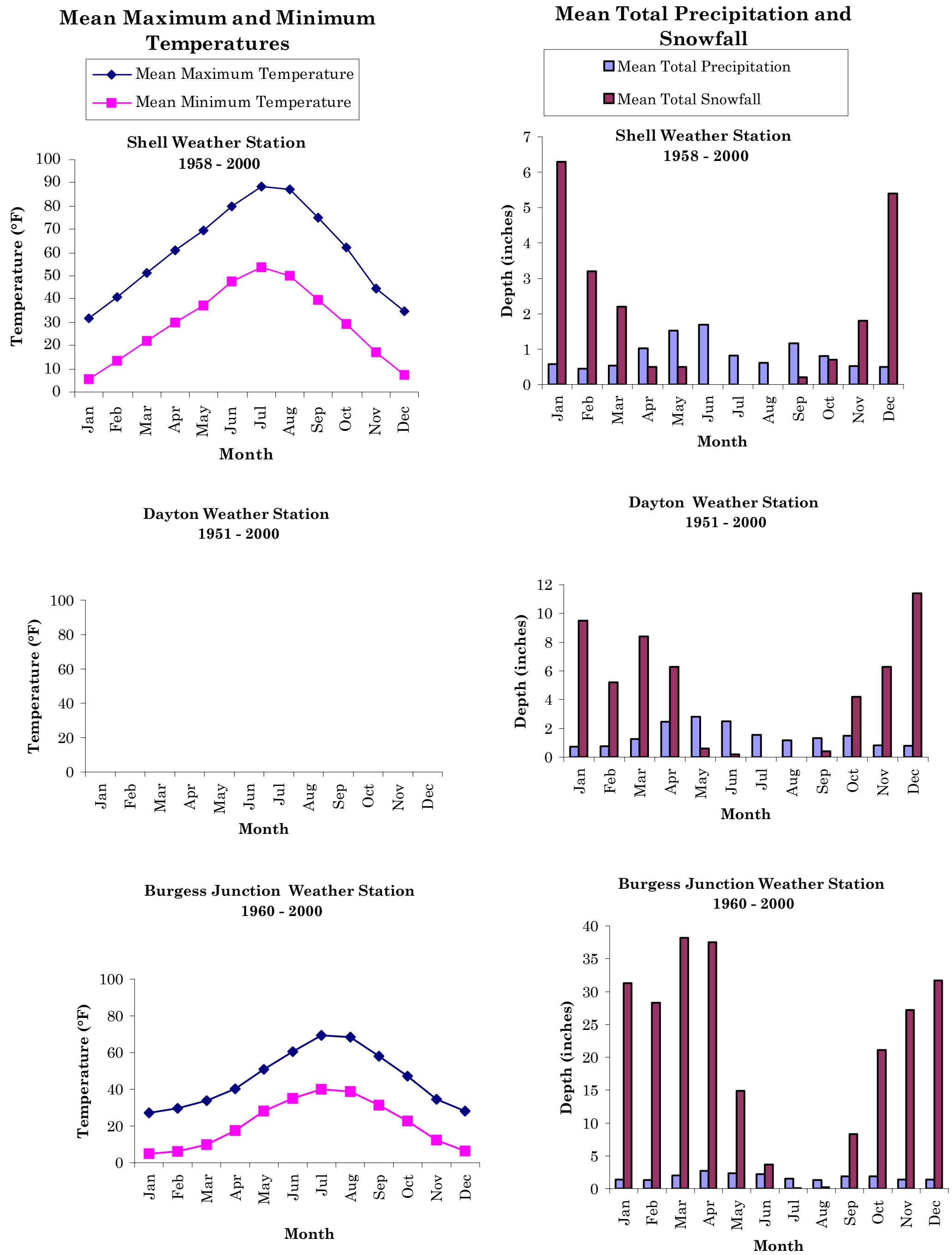


Figure 2-8. Mean monthly temperature and precipitation summaries from selected Wyoming weather stations within or near the Big Horn Mountains. (source: http://www.wrcc.dri.edu/summary/climsmwy.html). Note Dayton data is missing.

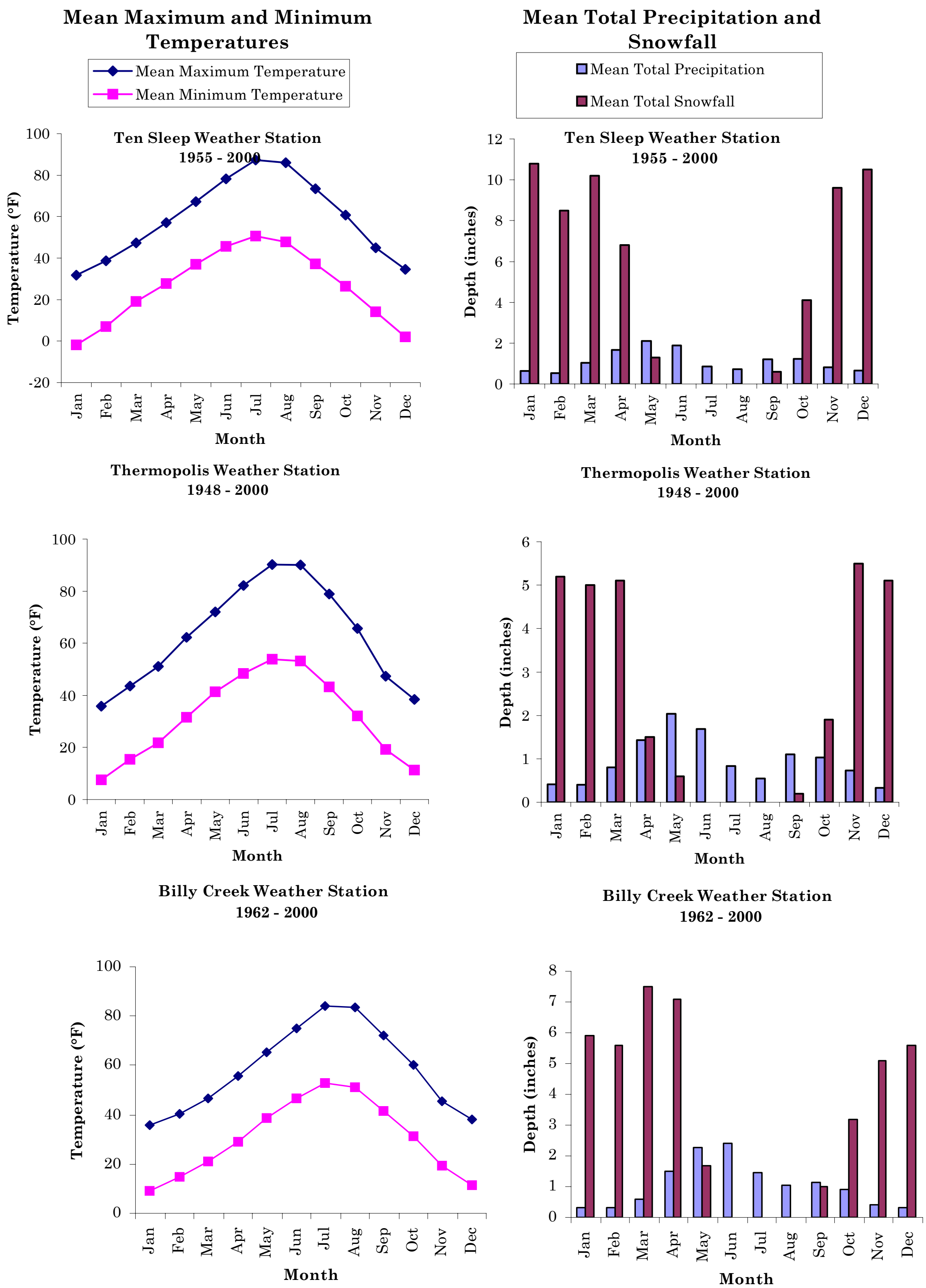
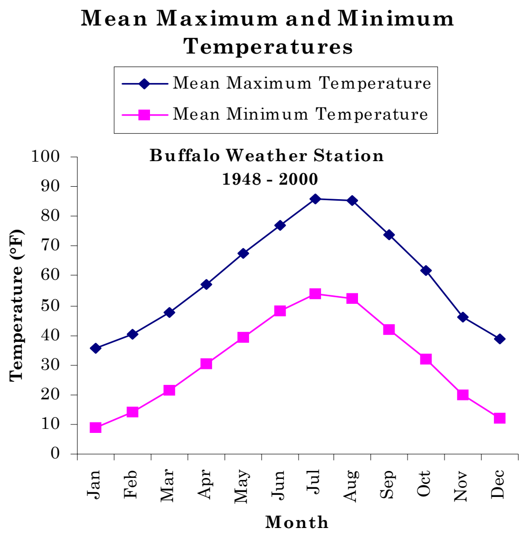


Figure 2-8 (continued).



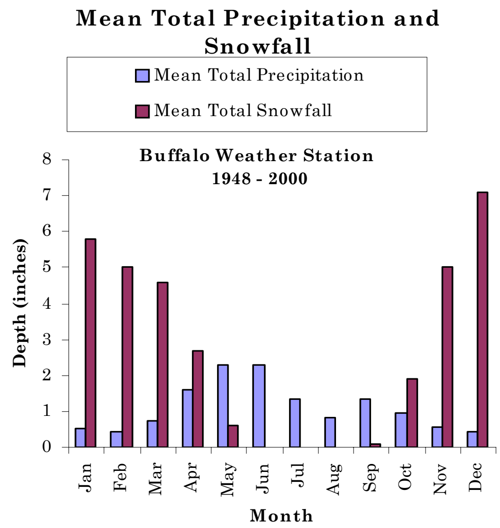
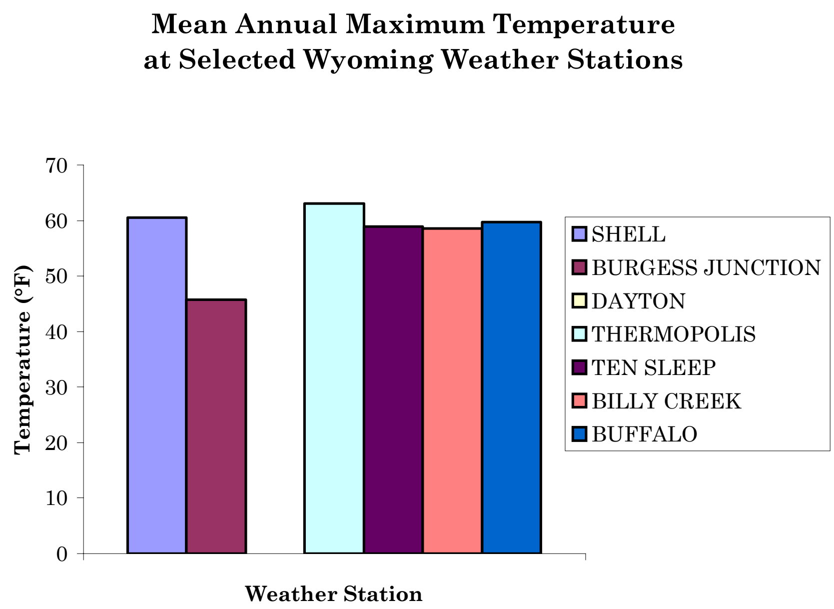


Figure 2-8 (continued).



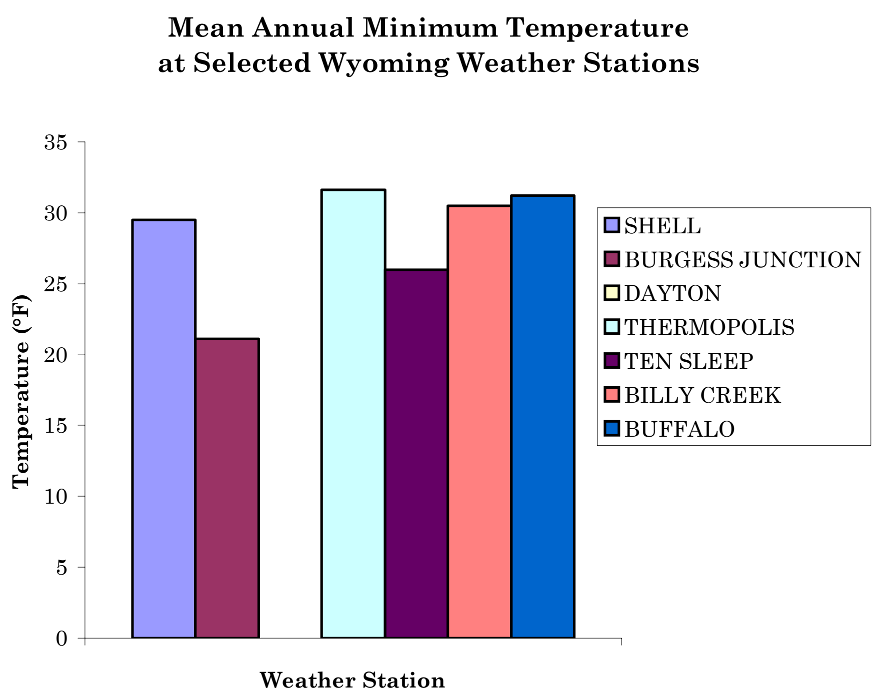
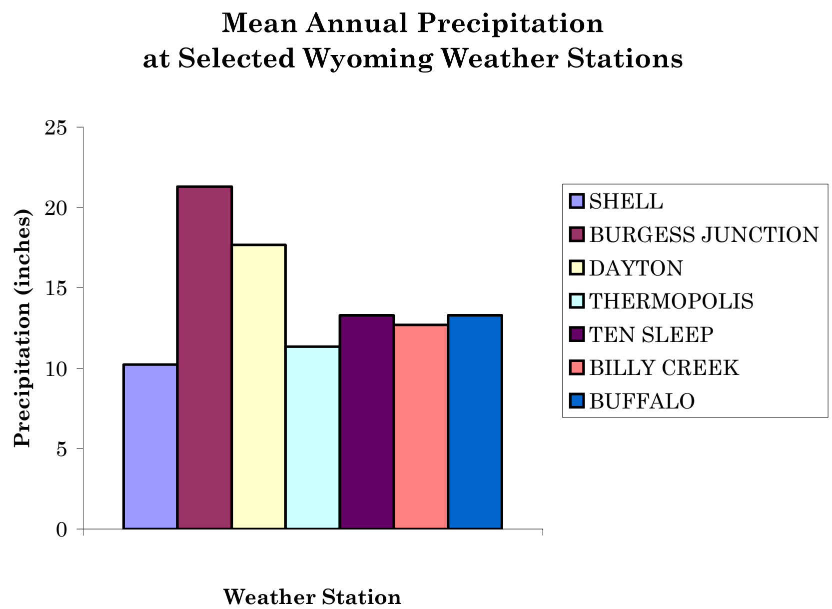


Figure 2-9. Average annual maximum (upper) and minimum (lower) temperatures at selected Wyoming weather stations (*source: http://www.wrcc.dri.edu/summary/climsmwy.html*). Note Dayton data is missing.



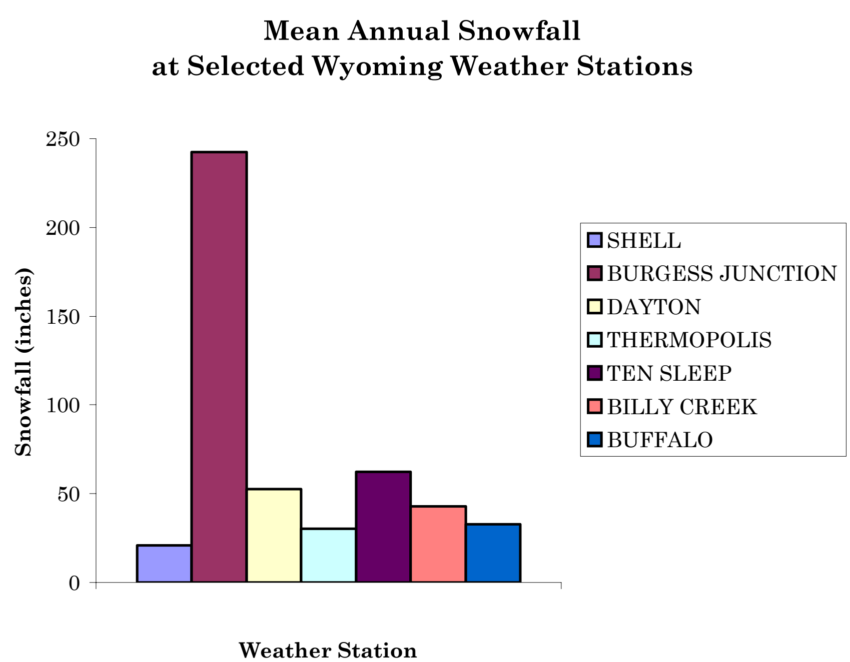


Figure 2-10. Average annual precipitation and snowfall at selected Wyoming weather stations (*source:* *http://www.wrcc.dri.edu/summary/climsmwy.html*).

Wind Patterns

The Western Regional Climate Center provides summarized wind data for major weather. Table 2-4 shows the yearly mean wind speed and prevailing direction for the four closest weather stations to the Section. Each of these stations has a recorded historical peak wind gust approaching or exceeding 70 mph.

Table 2-4. Wind speed and direction for four selected weather stations near the Bighorn National Forest (*Source: h ttp://www.wrcc.dri.edu/summary/lcd.html*).

Weather Station Location	Mean Annual Wind Speed		Prevailing Direction
	mph	km/h	
Billings, MT	11.2	18.0	SW
Sheridan, WY	8.0	12.9	NW
Casper, WY	12.8	20.6	SW
Lander, WY	6.8	10.9	SW

Summary

The significance of broad-scale climate patterns is their major constraint of the distribution and abundance of vegetation of the Big Horn Mountains. As will be discussed in Chapters 3 and 4, the differences in temperature and precipitation along the western vs. eastern slope of the Big Horns and across elevational gradients are important factors to determine the distribution of forest types, but also the presence of forest vs. non-forest vegetation, the differentiation of disturbance regimes, and the presence of human activities. The precipitation patterns occur at regional rather than local scales, and thus a broad-scale context is necessary to fully assess finer-scale patterns of ecosystem structure and processes, and the anthropogenic effects on the existing vegetation of the BNF.

Physiographic Description

Geology

Because geologic diversity defines the subsequent distribution of soils and vegetation, (Despain 1973) geology directly affects land productivity and subsequent management implications and land use on the BNF. Similar to climate, a basic understanding of geology within the Big Horns is therefore necessary to understand landscape patterns.

The present Big Horn Mountain range was uplifted during the Laramide orogeny or mountain building period, probably during Eocene times. It rose before the uplift of the Black Hills to the east, but after the rise of the Beartooth, Absaroka, and Wind River Mountains to the west (Sharp 1948). The Big Horn Mountains were formed from the uplift of three large basement blocks resulting in a large, somewhat crescent-shaped anticline near the edge of the Cordilleran geosyncline (Bucher *et al.* 1933, Wilson 1938, Hoppin and Jennings 1971). The northern and southern blocks are presently at heights of 8,850 feet (2,700 m) in the southern Big Horn Mountains. The central block was lifted higher and it is here that large granite peaks, including Cloud Peak, are found. Figure 2-11 shows the spatial distribution of geologic time periods as they relate to the BNF.

The sedimentary layers remaining on the range and comprising the flanks consist of Paleozoic shale, limestone, dolomites, and sandstone. Resting on the granite is a thin discontinuous layer, the coarse Flathead sandstone 270-370 feet (82-112 m) thick. Overlying this is the Gros Ventre Formation, a green shale 400-450 feet (122-137 m) thick, and the upper portion is largely interbedded with limestone. These beds were deposited during the mid to late Cambrian. Upon these rests the Big Horn dolomite and limestone

(302 feet/92 m) deposited during Ordovician time, followed by 250-1,100 feet (76-336 m) of Madison limestone deposited during the Mississippian. The Amsden Formation followed with 200-365 feet (61-112 m) of red shale and white sandstone deposited during the Mississippian and Pennsylvanian. Tensleep sandstone, deposited by wind and water during the Pennsylvanian, is found around the flank of the range and forms many of the flatirons. Such formations can also be found in some areas on top of the southern block (Darton 1906a, Wilson 1938, Demorest 1941). Figures 2-12 and 2-13 show the stratigraphy and surficial geology (parent material) of the BNF, respectively.

Glacial history is integral to the development of soils, particularly because glacial activity redistributes parent material across a landscape. During the Pleistocene, glaciers formed only in the higher valleys of the central portion of the Big Horns, and none of the glaciers reached the base of the range. Unlike the Greater Yellowstone Area, there was no ice cap glacier. However, most of the higher elevation surfaces between glaciers were covered with nèvè, or granular ice formed by recrystallization of snow, during Pleistocene glacial advances (Mathes 1900). Similar to glaciers, mass movements (such as landslides) affect land use and productivity; historical landslide activity is not uncommon on the BNF (Fig. 2-13), and is also an important factor influencing soil distribution.

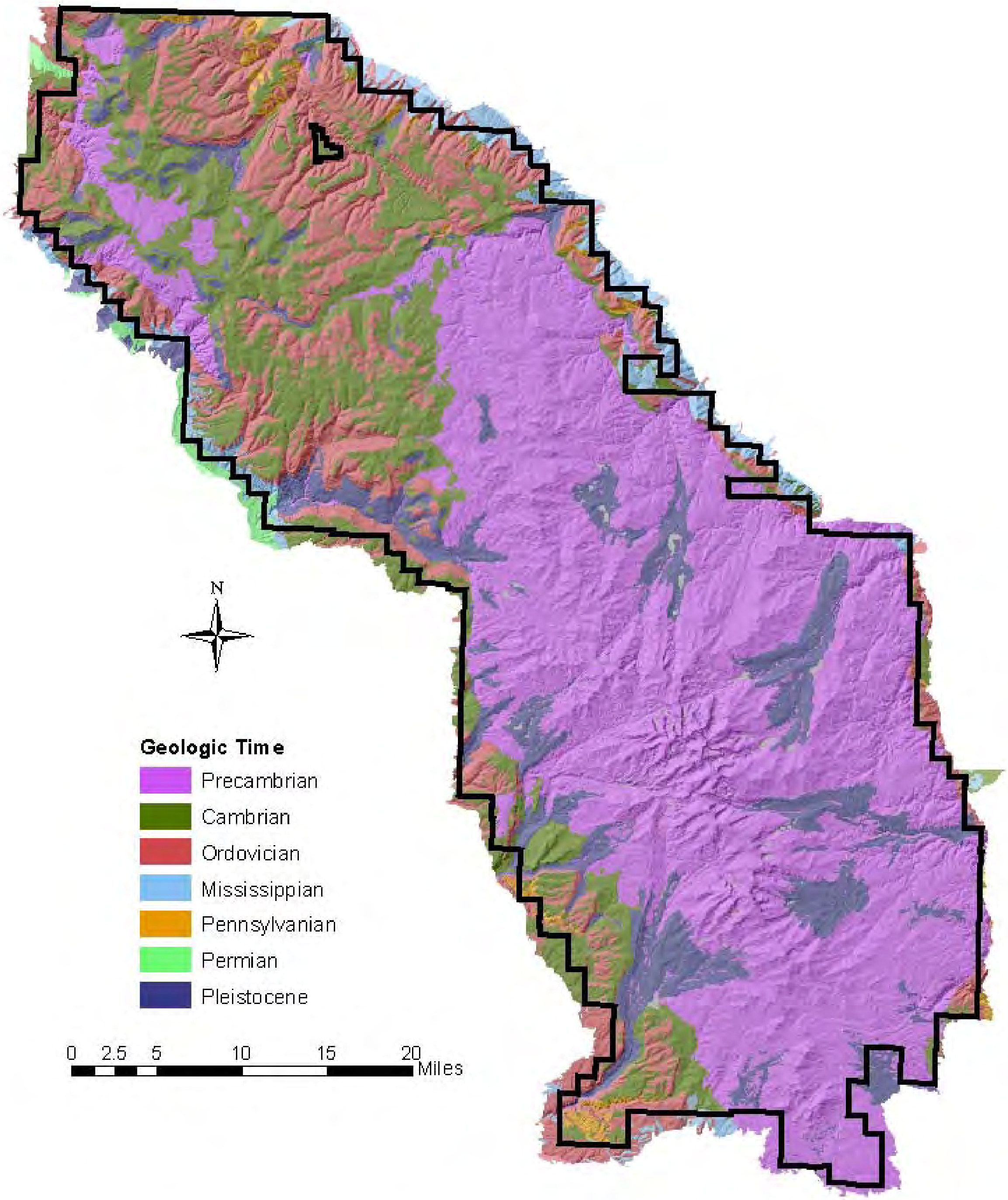


Figure 2-11. Spatial distribution of geologic time periods on the Bighorn National Forest.

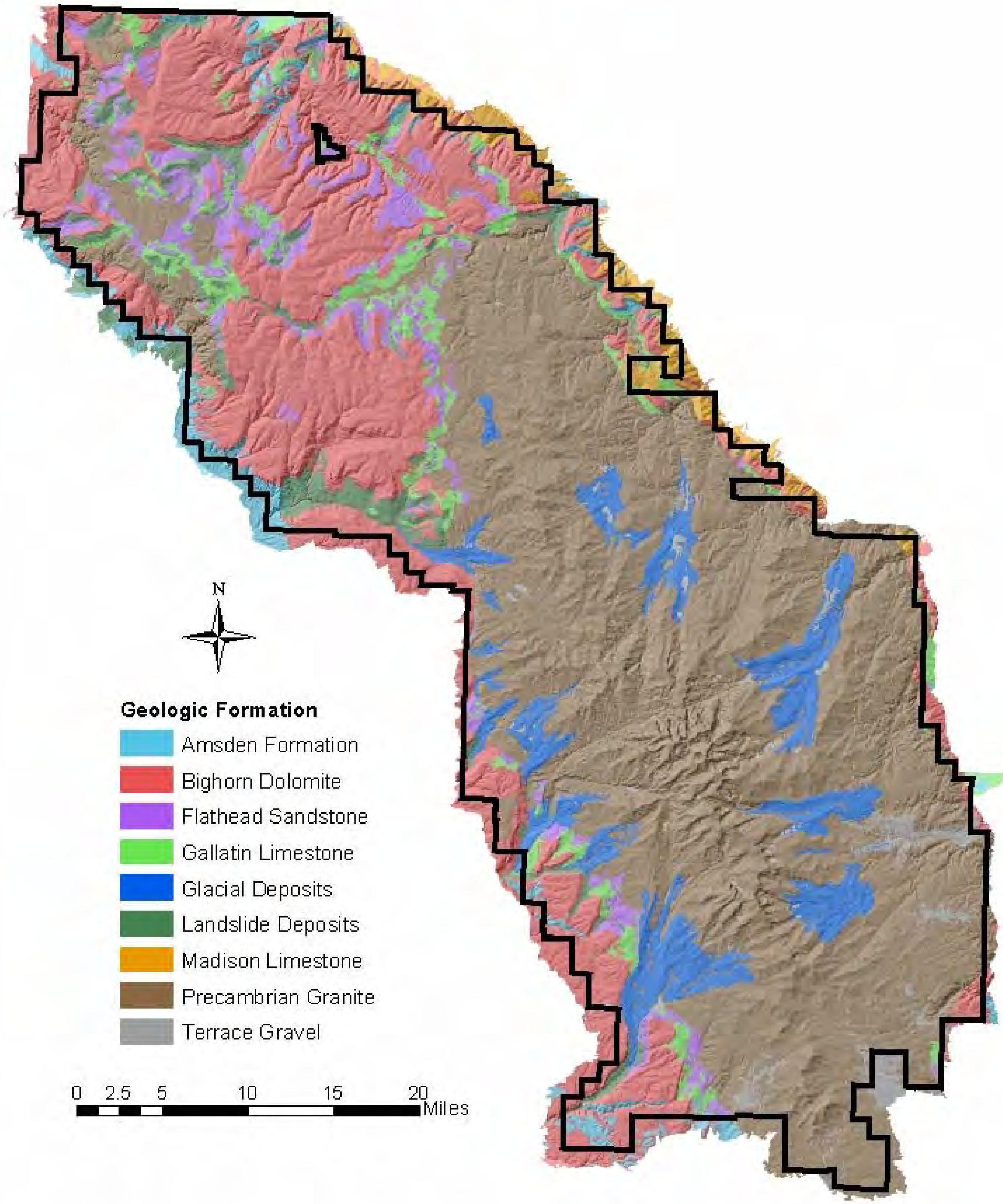


Figure 2-12. Geological stratigraphy of the Bighorn National Forest.

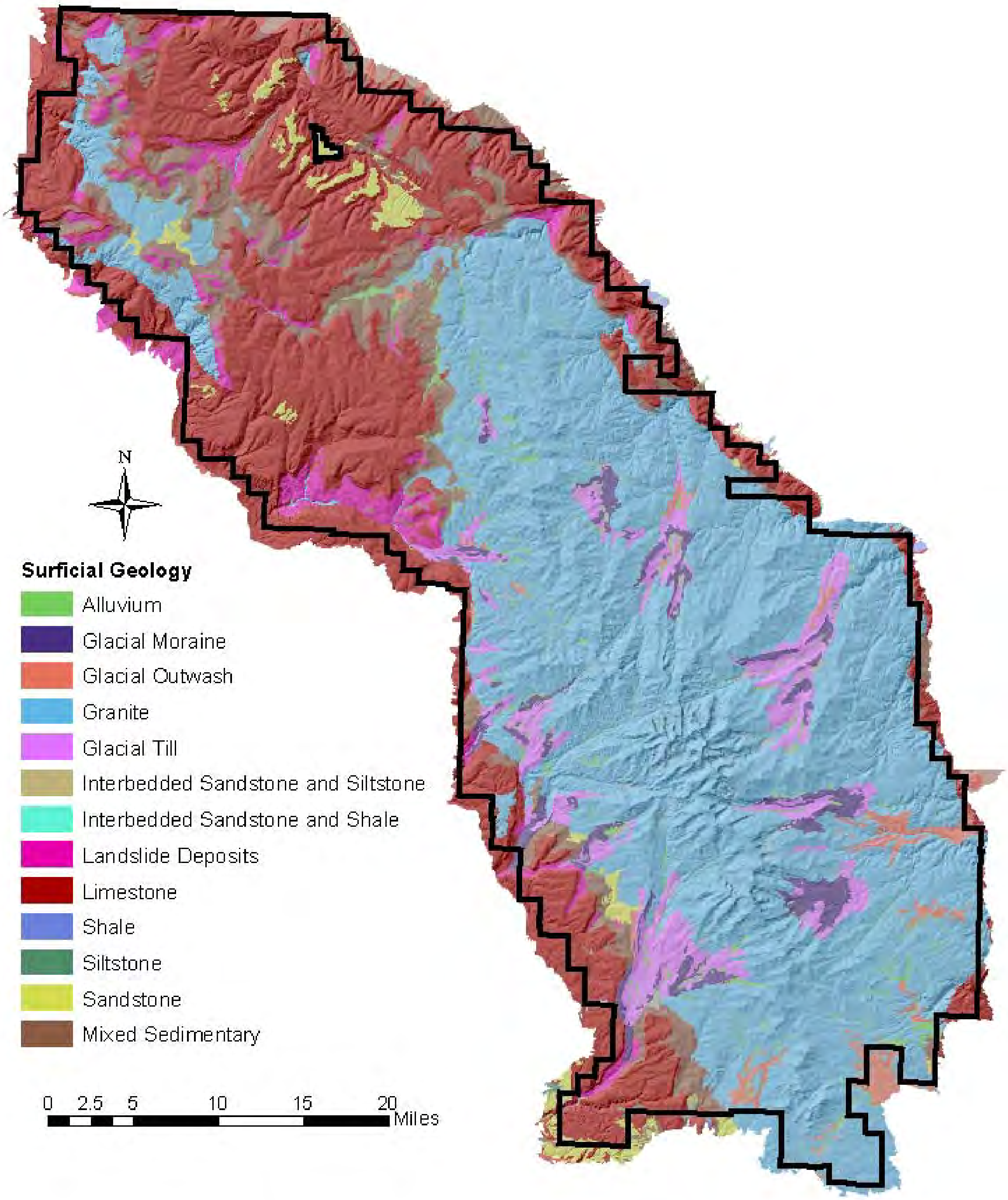


Figure 2-13. Surficial geology of the Bighorn National Forest.

Soils

Soils in the Big Horn Mountains are typically shallow, although some deep soils occur in alluvial or colluvial basins. Textures are generally sandy to loamy, with many rock fragments, and include Cryic Borolls, Ochrepts, and Boralfs (McNab and Avers 1994). Typic Cryoboralfs are the most common soil family on the BNF (Table 2-5). Soils derived from granite and shale are acid (pH 4.8 – 6.8), shallower, coarser, and less well developed, while those derived from limestone are basic (pH 7.1-8.0), finer in texture, and deeper. Soils of both origins are generally more acid in the upper horizons. Well-developed horizons are found in soils at elevations higher than 7,700 feet (2,340 m) were little or no glaciation occurred; those on glacial features and at lower elevations are less developed (Despain 1973).

Table 2-5. Coverage of soil families in the Bighorn National Forest.

Soil Family	Coverage in BNF		LTA(s) with Highest Coverage
	acres	hectares	
Typic Cryoboralfs	566,000	229,000	M331 Bb-05
Argic Cryoborolls	242,000	98,000	M331 Bb-05, M331 Ba-03
Pergelic Cryumbrepts	60,000	24,300	M331 Bb-06
Ustic Torriothents	34,000	13,800	M331 Ba-01
Typic Cryothents	21,000	8,500	M331 Ba-02
Calcic Cryoborolls	17,000	6,800	M331 Ba-03
Lithic Argiborolls	8, 000	3,200	M331 Ba-04

Because LTAs typically have a strong association to a given soil suborder or family, soils of the BNF are described in more specific detail based on their occurrence in LTAs. The spatial distribution of soil characteristics may thus be inferred from that of LTAs and from the descriptions that follow:

Sedimentary Breaklands (M331Ba-01): Soils occur on steep mountainsides (40-70% slopes) and colluvial slopes. Parent material consists of sedimentary residuum and colluvium, and includes Typic Cryoboralfs and Ustic Torriorthents. Soils are often loose, shallow, and rocky, and may have high droughtiness.

Landslide/Colluvial Deposits (M331Ba-02): Soils occur on moderately stable to stable landslide deposits on gentle slopes (10-40%). Parent material consists of colluvium from limestone, shale, and sandstone and includes Typic Cryorthents and Argic Cryoborolls. Soils may be loose or have high shrink/swell characteristics.

Limestone/Dolomite Sedimentary Mountain Slopes (M331Ba-03): Soils occur on gentle to moderate (5-30% slopes) mountainsides, ridges, toeslopes, and fans. Parent material consists of calcareous residuum, colluvium, and alluvium, and includes mainly Typic Cryoboralfs and Argic Cryoborolls, but also Calcic Cryoborolls. Soils are often loose, shallow, and rocky, and may have high droughtiness and high shrink/swell activity.

Calcareous Shale/Sandstone Sedimentary Mountain Slopes (M331Ba-04): Soils occur on flat areas to moderate mountainsides, toeslopes, and fans (2-35% slopes). Parent material consists of residuum, colluvium, and alluvium, and includes Argic Cryoborolls and Lithic Argiborolls. Soils are often shallow, rocky, and may have high shrink/swell characteristics.

Non-calcareous Shale/Sandstone Sedimentary Mountain Slopes (M331Ba-05): Soils occur on flat areas to moderate mountainsides, toeslopes, and fans (2-35% slopes). Parent material consists of residuum, colluvium, and

alluvium, and includes Typic Cryoboralfs and Argic Cryoborolls. Soils are often shallow, rocky, acid, and may have high droughtiness.
Granitic Breaklands (M331Bb-01): Soils occur mainly on steep mountainsides (40-70% slopes). Parent material consists of residuum and colluvium, and includes mainly Typic Cryoboralfs. Soils are shallow and rocky, and have the potential for mass movement due to their presence on very steep slopes.

Glacial Cirquelands (M331Bb-02): Soils occur in glacial cirque basins and among periglacial rubble (10-30% slopes). Parent material consists of residuum and talus, and includes mainly debris among rock outcrops. Soils are shallow and very rocky.

Glacial/Tertiary Terrace Deposits (M331Bb-03): Soils occur on flat areas to moderate slopes of glacial moraines and terraces (2-40% slopes). Parent material consists of glacial till and outwash, and includes Typic Cryoboralfs and Argic Cryoborolls. Soils may be deep but are often rocky, acid, and may have high shrink/swell characteristics.

Steep Granitic Mountain Slopes (M331Bb-04): Soils occur on moderate to steep mountainsides (25-50% slopes). Parent material consists of residuum and includes mainly Typic Cryoboralfs. Soils are often shallow, rocky, acid, and may have high droughtiness.

Gentle Granitic Mountain Slopes (M331Bb-05): Soils occur on flat areas to moderate mountainsides, fans, and outwash plains (5-25% slopes). Parent material consists of residuum and colluvium, and includes Typic Cryoboralfs and Argic Cryoborolls. Soils are often shallow, rocky, and may have high shrink/swell characteristics.

Alpine Mountain Slopes and Ridges (M331Bb-06): Soils occur on flat areas to moderate mountainsides, alpine ridges, and glacial trough valleys (5-35% slopes). Parent material consists of residuum and till, and includes mainly Pergelic Cryumbrepts but also some Typic Cryoboralfs. Soils are often shallow and rocky.

Vegetation

The potential natural vegetation (PNV) of the Bighorn National Forest is displayed in Figure 2-14. The approach to developing this map is outlined in detail in the companion protocol document (Regan *et al.* 2003). The Bighorn PNV model was largely based on information from the published literature or available classifications and databases (Despain 1972, Hoffman and Alexander 1976, Nesser 1986, Girard 1997, and Welp *et al.* 2000). In this analysis, PNV represents the best understanding of potential vegetation based on climatic and soil influences. The map does not incorporate vegetation response under expected disturbance regimes. However, it does serve as a useful foundation for a basic understanding of Bighorn vegetation and as a starting point for several analyses employed in the assessment. Natural disturbance regimes and expected vegetation response to these regimes is addressed in the companion Bighorn Historic Range of Variation Assessment (Meyer and Knight 2003).

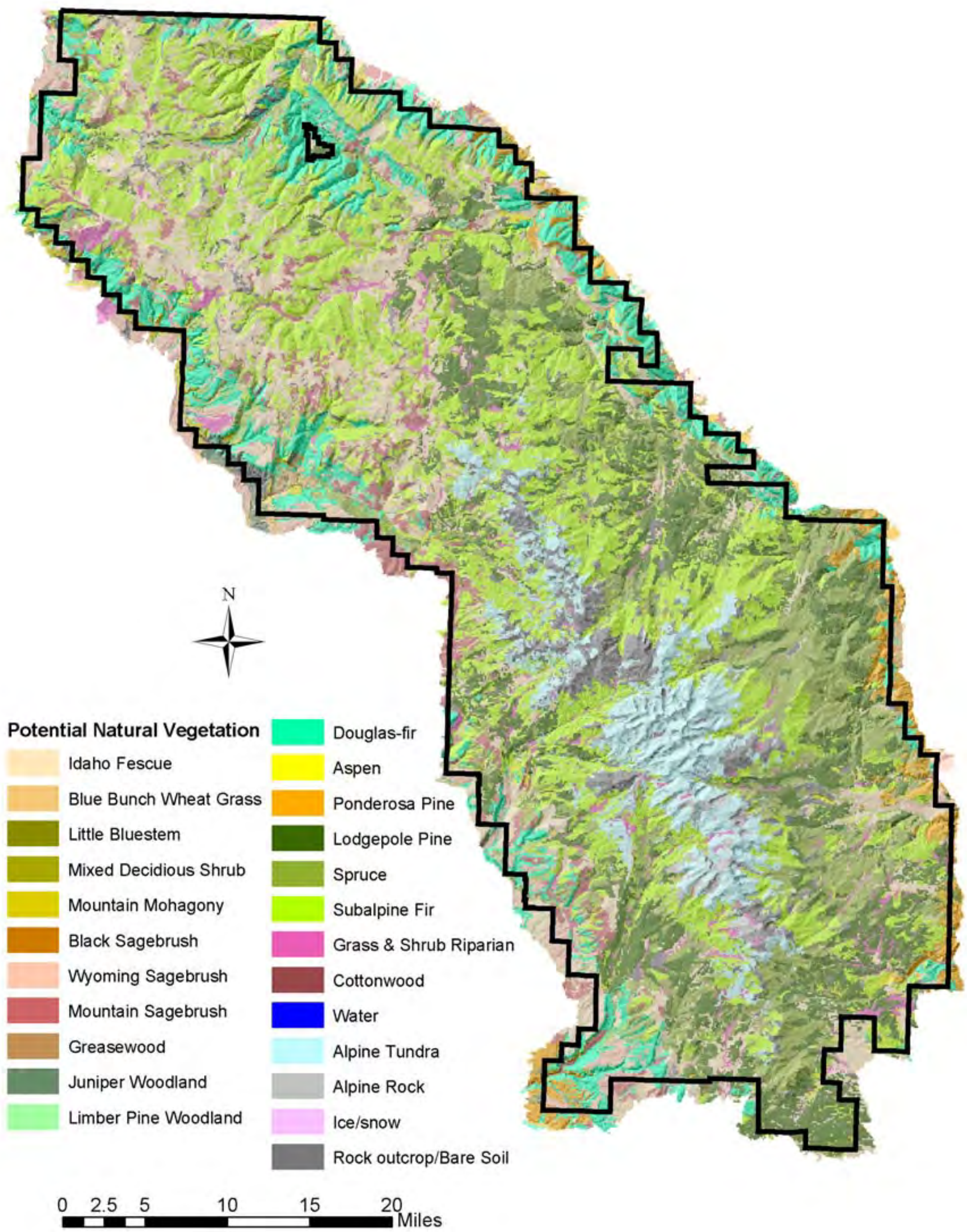


Figure 2-14. Potential Natural Vegetation (PNV) map.

Fauna of the Big Horn Mountains and Bighorn National Forest

This section provides a broad and very general overview of the terrestrial species occurrences in the Bighorn ecosystem. It also discusses changes in distributions of species that may have important influences on ecosystem condition, and generally addresses the ecological implications of these changes in species distributions. Pertinent historical and current conditions will be presented as background information on those species that are potential "ecosystem drivers" or at a minimum have the potential to influence ecosystem processes.

Overview

The Big Horn Mountains rise from about 4,000 feet to over 13,000 feet in elevation, forming a large boreal and alpine island populated with most of the vertebrates usually associated with forest and tundra. The Big Horn Basin to the west is a cold desert, supporting several basin-adapted taxa, such as white-tailed prairie dog (*Cynomys leucurus*) and sage sparrow (*Amphispiza belli*). The Powder River Basin to the east is on the periphery of the Great Plains grasslands, and forms the western edge of the range of grassland obligates such as least weasel (*Mustela nivalis*) and Baird's sparrow (*Ammodramus bairdii*).

Most of the wildlife species found in the BNF are typical of the Rocky Mountains and nearby plains. Bird species include Swainson's hawk (*Buteo swainsoni*), golden eagle (*Aquila chrysaetos*), blue grouse (*Dendragapus obscurus*), sage-grouse (*Centrocercus urophasianus*), Steller's jay (*Cyanocitta stelleri*), gray jay (*Perisoreus canadensis*), Clark's nutcracker, Townsend's solitaire (*Myadestes townsendi*), green-tailed towhee (*Pipilo chlorurus*), and western tanager (*Piranga ludoviciana*). Including the neotropical migrant species, more than 200 avian species range from the plains into the montane habitats. Species of birds on the edge of their range include calliope hummingbird (*Stellula calliope*), indigo bunting (*Passerina cyanea*), and clay-colored sparrow (*Spizella pallida*).

Typical herbivores include white-tailed deer (*Odocoileus virginianus*), mule deer (*Odocoileus hemionus*), elk (*Cervus elaphus*), pronghorn (*Antilocapra americana*), snowshoe hare (*Lepus americanus*), and yellow-bellied marmot (*Marmota flaviventris*). Carnivores include black bear (*Ursus americanus*), coyote (*Canis latrans*), bobcat (*Lynx rufus*), mountain lion (*Puma concolor*), and other small predators such as weasels, raptors, and owls.

Herptofauna found in this Section are the spotted frog (*Rana pretiosa*), wood frog (*Rana sylvatica*), leopard frog (*Rana pipiens*), boreal chorus frog (*Pseudacris maculata*), Woodhouse's toad (*Bufo woodhousii*), rubber boa (*Charina bottae*), blotched tiger salamander (*Ambystoma tigrinum melanostictum*) and the prairie rattlesnake (*Crotalus viridis viridis*).

Wildlife History of the Big Horn Mountains

Predators

Prior to 1850, wolves (*Canis lupus*) and grizzly bear (*Ursus arctos*) were common on the plains surrounding the Forest, as well as on the mountains that became the BNF. Wolves and grizzlies inhabited the prairies to prey on bison, but they also used the higher elevations on the Forest in summer and fall to prey upon elk and deer. Lynx (*Lynx canadensis*) and marten (*Martes americana*) were dependent on the boreal forest habitats at the higher elevations. Warder (2001) estimated 90 lynx occurring on the Forest in the early 1900s. The habitat generalist bobcat, coyote, and mountain lion also occurred both on and around the Forest. Although no evidence of wolverine (*Gulo gulo*) documents their former existence in the Big Horn Mountains (Ruggiero *et al*. 1994), several reliable observations have been made over the past few decades, likely indicating a dispersal movement through the Section (Warder 2001).

During the market-hunting period in the late 1800s, record numbers of predators were found on the plains surrounding the Big Horns, feeding on the surplus carcasses left behind once hides were removed. As predator populations increased, aggressive predator control was undertaken in the early 1900s to protect livestock interests and the increasingly rare wild ungulates. As a result, wolves and grizzly bears were extirpated from the Big Horn Mountains by 1940. Lynx likely exist in the Big Horns today in very low numbers, if they indeed exist. Marten, bobcat, coyote, and mountain lion still exist, although mountain lion and coyote may be at lower population levels than during pre-settlement due to hunting (Warder 2001). Black bear were treated more as a game animal than a predator, with approximately 200 estimated to occur in the early 1900s. Hunting has also likely reduced the number of black bears today.

Raptors declined during the early 1900s due to shooting, and later were further reduced by DDT and other pesticides; most raptor populations are recovering since many pesticides have been banned. Peregrine falcons (*Falco peregrinus*) historically nested in the Section, but were extirpated. Recent hatching efforts and species protection have promoted their re-establishment. Many canyons and cliffs in the Section are potential nesting habitat, including Shell and Devil's Canyons.

Herbivores

Bison occurred on the prairie and basin grasslands surrounding the Big Horn Mountains, as well as in the mountains. Bison on the plains have been well documented; two sources have also noted the occurrence of mountain bison in the Big Horn Mountains. Mountain bison are classified as a separate species (*Bison athabascae*), and are smaller than the plains bison (*Bos bis*on) with longer and darker hair. The mountain bison lived in small groups numbering between 5 and 30, and they probably moved altitudinally with the seasons. This species still exists in Canada, where some pure populations of "wood buffalo" still exist. Dary (1989) has two documentations of mountain bison in the Big Horn Mountains in 1882 and 1889. Both bison species were hunted to extirpation from the Big Horn Mountains and Basin by 1900.

Elk and deer were common on the Forest as well as the plains prior to 1850, but elk were described as less than 100 animals and had basically been extirpated from the plains by 1900, due to market hunting and severe winters in 1886 and 1887. Populations rebounded after transplants were conducted between 1910 and 1920, as well as hunting regulations enacted in the early 1900s. The current management objective is to have 7,100 elk on the Forest, which is most likely similar to historical levels. Deer populations followed similar trends and now have rebounded. Current population levels for the entire Section are approximately as follows: 10,000 elk, 84,000 mule deer, and at least 500 moose.

Big Horn sheep (*Orvis canadensis*) were common prior to 1850 as evidenced by the name of the mountains. They occurred both on the plains and on the Forest, but were relegated to the Forest and its surrounding steep faces and cliffs to escape market-hunting pressure during the late 1800s. Bighorn sheep did not recover after the turn of the century as elk and deer did. Their numbers remained at fewer than 200 through the 1920s, but were thought to be substantially higher prior to the market-hunting era. Populations declined further after the 1920s and still are at less than 50 animals after numerous transplant attempts. Their lack of recovery may be the result of the transfer of disease from domestic sheep (Goodson 1982), which were at high numbers (up to 118,000 on the Forest) annually from 1906 through 1916. High numbers of domestic sheep remained on the Forest through the 1950s.

There is no historical evidence of a resident moose population, though they were present in the Rockies to the west of the Forest in the Greater Yellowstone Ecosystem, and there are historical records of individual moose wandering through the Big Horn Mountains. Moose were transplanted to the Forest in 1948, and have now established a resident population of over 500 animals.

Beavers attracted early explorers and trappers in the Big Horn Mountains, and fewer than 200 remained on the Forest by 1919 (Warder 2001). Beavers rebounded for a time after transplants were conducted in the 1940s. However, beaver populations have again declined since the 1940s; populations have not rebounded even after trapping was eliminated in the North Tongue River area. Beaver are likely approaching early 1900s population levels due to habitat loss; willow and aspen habitats are each less than 1% of the BNF, and many herbivores are competing for these preferred habitats.

Red squirrels (*Tamiasciurus hudsonicus*) were likely at very low populations in the early 1900s, as there were concerns then over the lack of "pine squirrels" due to indiscriminate killing and hunting (Blair 1987). After the large wildfires of the late 1800s, this species was already at low population levels, being limited to the remaining mature spruce-fir habitats. The species currently is believed to be at medium to high populations, due to the maturing of conifer stands and low hunting pressure.

Influences of Species on Ecosystems

Herbivores

Large herbivores such as bison, moose, elk, and deer, influence vegetation structure and composition. For example, plains bison were certainly a driver of ecosystem structure and function in many ways. Intensive grazing and trampling of grassland habitats influenced evolution of the grasses and species composition of the landscape. Rivers on the plains had few cottonwood trees compared to current landscapes, possibly due to intensive grazing. Bison in the higher elevations likely prevented pine and aspen encroachment into the grassland parks and meadows by intensive grazing. Bison also influenced the ecosystems by providing predator (including humans) and scavenger species with an excellent food source.

The other large herbivores in the Big Horn landscape also influence species composition and structure. The winter range habitats are most likely to be influenced, because large numbers of these species tend to concentrate there for long periods. These are generally the mid- to lower-elevation shrub, aspen, and ponderosa pine habitats. Elk and moose are especially attracted to aspen and willow for foraging, habitat that is <1% in the Big Horn Mountains. Concentrated use may affect stand structure by restricting regeneration as well as affecting condition of mature stands. Elk and moose would most likely concentrate during winter at mid-elevations and possibly in the valley bottoms at lower elevations. Mule deer winter in shrub-steppe habitats, primarily in sagebrush and mountain mahogany. Loss of shrub-steppe habitats to agricultural development and urbanization may further concentrate deer on smaller areas of winter habitats.

Implications of Additional Ungulate Grazing

In some areas, the combined grazing effect of all the large ungulates (elk, moose, deer, and domestic livestock) may negatively affect the condition and long-term sustainability or function of aspen, shrub-steppe, and willow habitats. In aspen and willow, lack of regeneration could result in a long-term loss of the habitat type. In shrub-steppe habitats, overgrazing of grasses and forbs under and surrounding the shrubs can result in loss of nesting habitat for ground-nesting bird and small mammal species. Overgrazing may decrease fire frequency in the ecosystem due to removal of fine fuels (grasses and forbs) that carry low-severity fires. Decreasing fire frequency may promote sagebrush encroachment into grasslands, which may alter the fire regime towards more severe fire events, which in turn may change the long-term age structure and community composition of stands across the landscape.

Implications of Beaver Population Reduction

Beaver readily influence the ecosystem by creating ponds, which influence the structure and composition of the adjacent vegetation and hydrology of the watershed. Although beaver populations are currently at much lower populations than during pre-settlement, they still actively help to regenerate portions of aspen and willow stands adjacent to the beaver complex by cutting down many of the stems along the edge of the stand, which stimulates sprouting and the regeneration.

Some changes in vegetation structure and lower abundance of younger age aspen and willow may have occurred with lower populations of beaver. Loss of beavers results in loss of ponds that slow stream flow during spring run-off, which could result in more bank erosion. The loss of these pond ecosystems also influences the abundance and distribution of many associated wildlife species. It also influences long-term vegetation composition, as the sediment from old beaver ponds provides good substrate for willows; removal of beaver from such a system will thus reduce these important wildlife habitat types.

Implications of Predator Population Reduction

Because wolf, grizzly bear, and lynx have been largely reduced and/or extirpated from the Big Horn Mountains, the predator niche or function in the ecosystem may be currently outside of the natural range of variability. Historically, grizzly bears and wolves not only helped regulate ungulate population levels but also prevented herds from concentrating in one area for long periods of time. Wolves have begun to re-colonize the Section. Grizzly bears inhabited the Section historically, but were extirpated by 1940. The Section was not included within the recovery areas identified in the Grizzly Bear Recovery Plan. Should the grizzly bear be de-listed, the state of Wyoming's Bear Management Plan proposes to discourage future re-colonization of the Section by grizzly bears. The coyote, black bear, and mountain lion may have replaced some but not all of the predator functions of these species.

Biogeographical Implications for Wildlife

The Big Horn Mountains are on the eastern edge of the montane and boreal forests at the northern extreme and eastern edge of the Southern Rocky Mountain Province and the western edge of the Great Plains. The Section is thus on the eastern fringe of the range of many boreal species, and the western edge of many of the grassland obligates of the Great Plains.

Because boreal and alpine habitats in the Big Horn landscape are essentially isolated from other boreal and alpine systems, there may not be much emigration or immigration to maintain genetic flow for some species. The Big Horn populations of some small mammals and amphibians have been isolated from other populations for several thousand years, and therefore have the potential to be genetically unique. Generally, populations that are at the fringe of their range or are isolated, have a higher potential for evolutionary changes, as they adapt to their specific environments. These populations may become sub-species and eventually separate species in evolutionary timeframe (e.g., BHM pika).

Summary of Faunal Influences

Changes in Species Composition and Population Levels

Four species have been extirpated from the Big Horn Section since pre-settlement times: wolf, grizzly bear, bison, and otter. Three other species (Big Horn sheep, beaver and peregrine falcon) are at much lower population levels than historical levels. Most of the changes or extirpations in these species populations were caused by unregulated harvest; the peregrine population was reduced due to pesticide use. Some species are experiencing moderate population declines in more recent timeframes. In general, these are species associated with sagebrush-steppe ecosystems, which are declining due to agriculture and urbanization. Only one species that drastically affects vegetation, the moose, has been introduced into the Big Horn Mountains. Historically, individual moose wandered across the Forest only occasionally.

Implications for Vegetation Structure and Composition

Loss of Top Predator Species

Elk and deer, without the natural predators wolf and grizzly bear, can concentrate in areas on winter range, which could lead to vegetation overuse in some cover types. On the BNF, current populations are estimated to be at levels similar to what they were before European settlement, which may have important implications for vegetation without predators. In some cases, aspen stands are browsed heavily (barked) and no young aspen sprouts are regenerating. Cattle grazing during the summer months complicate this effect. Cumulatively, elk and cattle grazing may negatively affect the ability of lower-elevation aspen stands to regenerate.

Loss of Bison

The loss of the native mountain bison from the ecosystem is of significance to the high grassland ecosystems. Cattle have replaced the grazing function of bison, but likely at higher grazing levels. Domestic cattle also are not constantly mobile like wild animals, which were moved by predators. Cattle grazing tends to be concentrated in the riparian areas, as cattle need and prefer to be near water. Therefore, cattle grazing may influence the condition of riparian communities over time more dramatically than the mountain bison did.

Beaver Population Reduction

Although beaver populations have rebounded somewhat on the BNF since they were nearly exterminated in the early 1900s, there still are drainages that never re-populated. Beaver can actively regenerate portions of aspen stands adjacent to the beaver complex, by cutting down many of the mature trees along the edge of the stand. Some changes in vegetation structure have likely occurred even with the lower populations of beaver, but they are probably not significant.

Moose Herd Establishment

The addition of a resident herd of over 500 moose has likely affected both willow and aspen vegetation types. Browsing of aspen sprouts by elk, cattle, and moose may have cumulative effects on the ability of aspen stands to regenerate.

Anthropogenic Factors

People have been, and will continue to be, an integral part of the environment of the Big Horn Mountains. The objective of this section is to explore the anthropogenic influences on the natural resources of this landscape to set a context for interpreting ecological condition.

Historical Context

Several Native American tribes, including the Crow, Shoshone, and Snakes, lived in the Powder River and Big Horn Basins in the 1700s. By 1812, the Crow were the dominant culture using the area (Murray 1980). Within a few decades, the Powder River Basin had become part of the country dominated by the Sioux and Northern Cheyenne.

In 1802 the first European men of record came within close-up view of the Big Horn Mountains. The first recorded crossing of the Big Horns came a decade later, when a party with the American Fur Company crossed over near Powder River Pass. While fur trappers traveled through Big Horn Mountain country, there is not much indication of the kind of intensive trapping activity found in some other mountain regions (Murray 1980).

Likewise, mining in the Big Horn Mountains was never an important activity. In his 1906 review of the Big Horn Mountains, Darton concluded that there was little chance that the area would become important for its mineral resources (Darton 1906). The most significant area of mining was in the Bald Mountain vicinity, where gold was mined for two years in the early 1890s.

Several major historical influences continue to affect the resources of the Big Horn Mountains to this day. While Europeans settled many areas of the West as early as the 1840s and 1850s, the Big Horn Mountains remained largely the domain of Native Americans until after the Battle of Little Big Horn in 1876. Earlier attempts to settle the eastern side of the Big Horn Mountains was successfully resisted by the Sioux and Northern Cheyenne people. In 1867, they forced the U.S. Army to abandon Fort Phil Kearney. The city of Sheridan, for example, was not organized until 1882, and most of the Big Horn Basin communities were not organized until about 1900. Therefore, the impact of European man on the resources of the Big Horn Mountains was rather minimal until about 1880.

Numerous reservoirs were constructed in the Big Horns in the 1890s, and many of the communities, including Buffalo, Sheridan, and Tensleep get drinking water from streams originating in the Big Horn Mountains.

Logging operations for fuelwood and building materials had minor impacts along the fringes of the Big Horn Mountains. Logging for railroad ties, or tie-hacking, was important in the Tongue and Clear Creek watersheds, however. The South Tongue River area was heavily tie-hacked between 1893 and 1908. While there was some stream alteration for tie drives in portions of the Tongue River, a large tie-flume network was developed. Tie-hacking in the Clear Creek watershed above Buffalo did not begin until 1924, and lasted about a decade. Annual reports in the local papers listed tens of thousands of dollars of "stream improvements" or channel straightening and debris removal activities documented to have long-lasting effects (Young *et al*. 1994). One other lasting effect of the early tie-hacking was that the high-grade operation left the "lame, sick, and lazy", which may have lasting effects on the forest's gene pool (Howe 1996).

Livestock grazing most influenced the settlement patterns and resource use in the Big Horn Mountains. The first permanent settlers were ranchers. While the record is not clear on when livestock were first grazed in the mountains (Murray 1980), by the time the Big Horn Reserve was established in 1897, livestock were utilizing the summer range of the area heavily (Jack 1900). This level of grazing significantly impacted natural resources. Improved grazing practices have allowed some of those resources to recover (Figs. 2-15 and 2-16).

Figure 2-15. Ground worn down and trampled hard and willows killed by sheep. Near crossing of the North Fork of Crazy Woman Creek (photo from Jack, John G. 1900. Forest and Grazing Conditions in the Big Horn Forest Reserve, Wyoming. Unpublished manuscript on file at Bighorn National Forest Supervisor's Office, Sheridan, WY).

Figure 2-16. Photo shows the same location as in Figure 2-15. For reference, note the rocks in the upper right corner of the picture above the willows and below the upland grassland. Photo was taken around 1975.

The grazing legacy of the settlement period has had several lasting effects:

- Despite huge decreases in the numbers of permitted livestock, the Bighorn National Forest remains a relatively heavily stocked National Forest.
- The communities around the Big Horn Mountains have a "cowboy western" identity that promotes tourism and helps define the "sense of place" felt by people living in the area.

Current Demographic Condition and Future Trends

Projected Changes in Demographic Trends

Five of the eight counties in the assement area show a very low, or non-existent, population growth rate (Fig. 2-17). In fact, three of the counties have experienced population decreases over different time periods (Table 2-6).

The three largest counties, Natrona, Fremont, and Sheridan, have seen consistent population growth increases, with the exception of the energy "bust" in 1990. It can be expected that the projected increase in population will lead to more recreation demand on the BNF.

These trends are likely to continue. Figures 2-18 and 2-19 show how residential density is projected to change between 1960 and 2050. The areas around Sheridan, Buffalo, and Greybull are expected to have noticeable residential density increases (Fig. 2-20).

Perhaps the most significant impact of sprawl from an ecosystem perspective is the amount of habitat and open space being turned into an urban setting. Because elk summer on the Bighorn National Forest but spend their winters in the adjacent basins, for example, increasing urban sprawl will decrease critical winter habitat and forage. Western Wyoming elk herds are already fed in approximately ten locations as a result of a "hunting season demand" for this species that exceeds the winter range capacity. This conflict between human and wildlife habitat is felt by other species, such as black bear and mountain lion. Another impact of urban sprawl is the decrease in open space and low populations that current residents prize as a quality of life indicators.

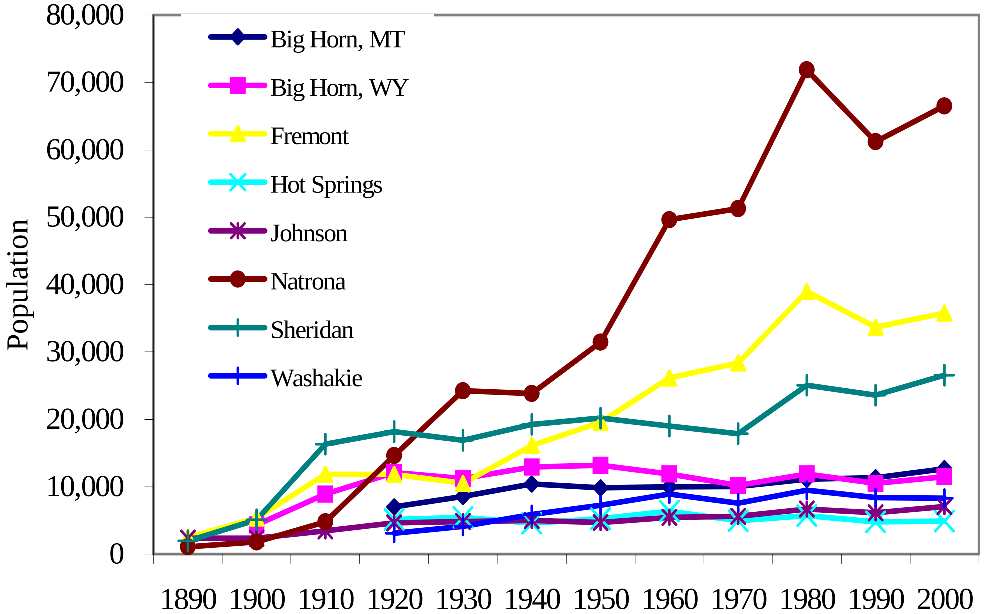


Figure 2-17. Change in county population for the eight counties containing the Big Horn Mountain Section from 1890 to 2000 (*source: U.S. Census Bureau*).

Table 2-6. Wyoming counties experiencing a long-term decline in population.

County	Year	Population	Percent Decline
Big Horn	1920	12,105	5%
	2000	11,461	
Hot Springs	1920	5,164	5%
	2000	4,882	
Washakie	1960	8,883	7%
	2000	8,289	

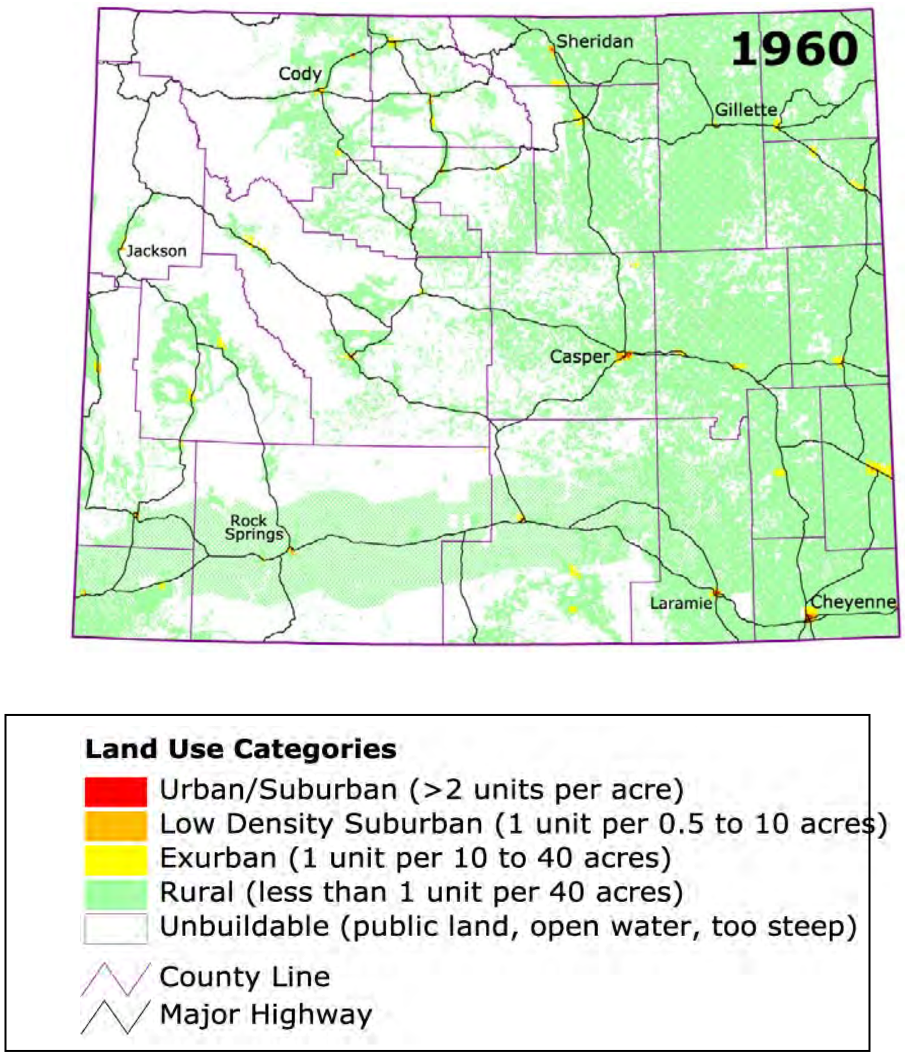


Figure 2-18. Map of residential density in 1960 (*source: Center for the American West, University of Colorado – Boulder,* http://www.centerwest.org/futures).

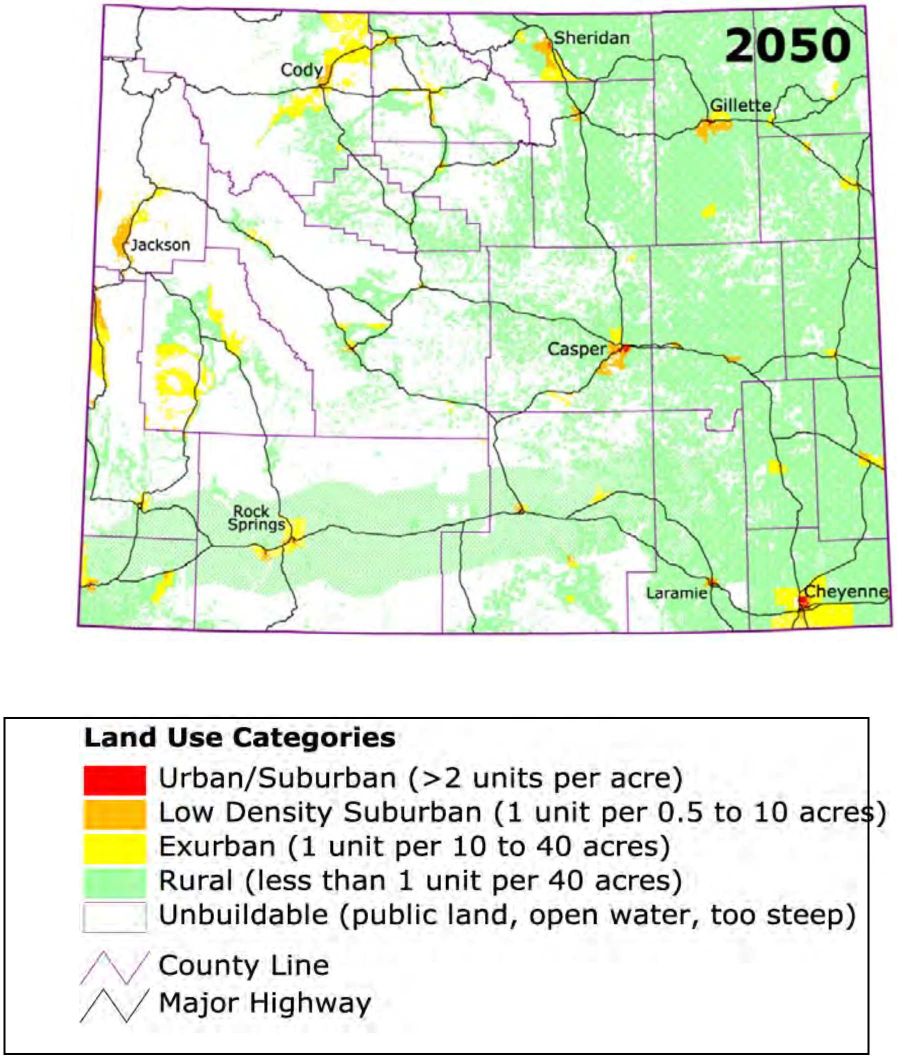


Figure 2-19. Map of projected residential density in 2050 (*source: Center for the American West, University of Colorado – Boulder, <u>http://www.centerwest.org/futures/</u>*).

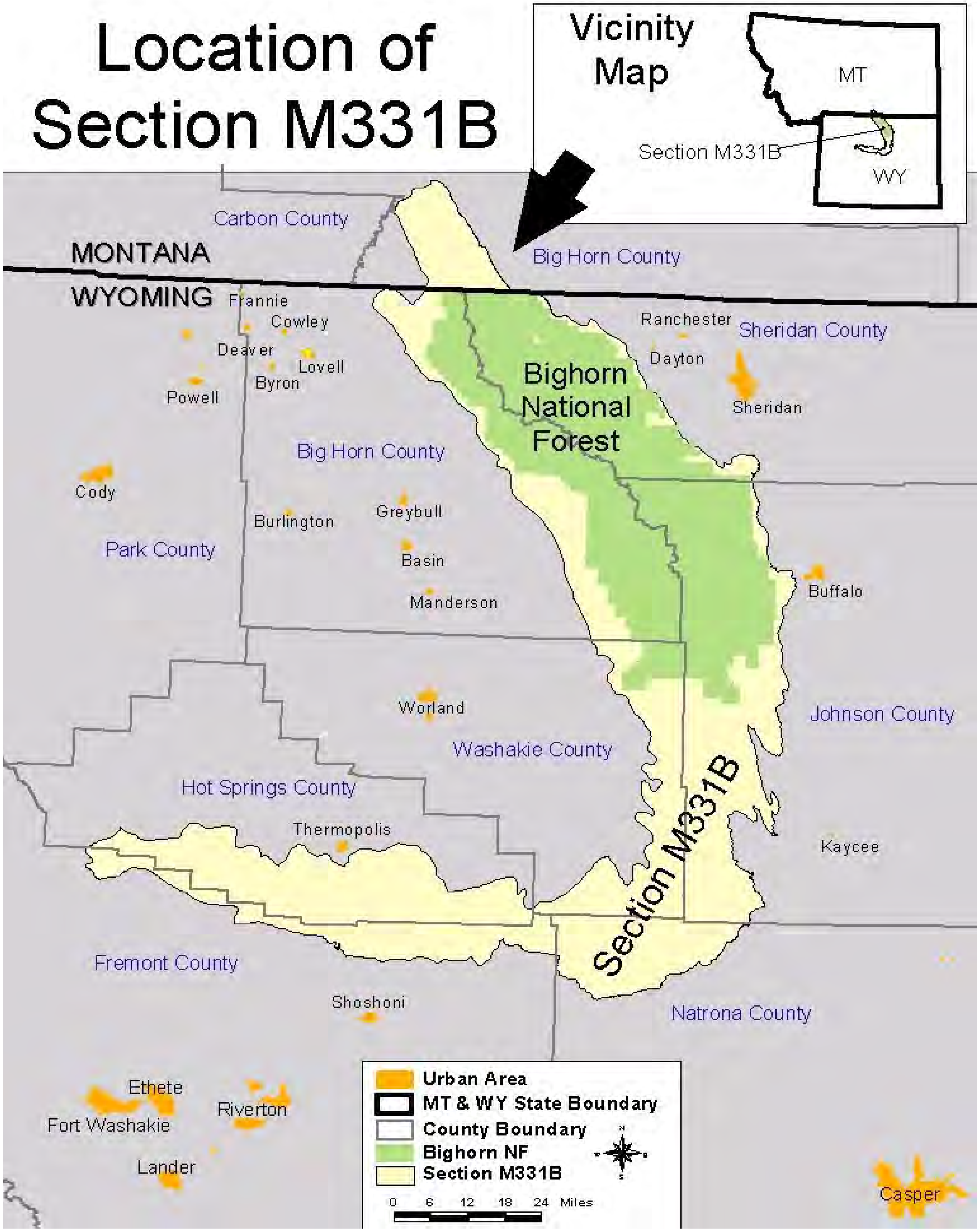


Figure 2-20. Map of counties and major cities near the BNF.

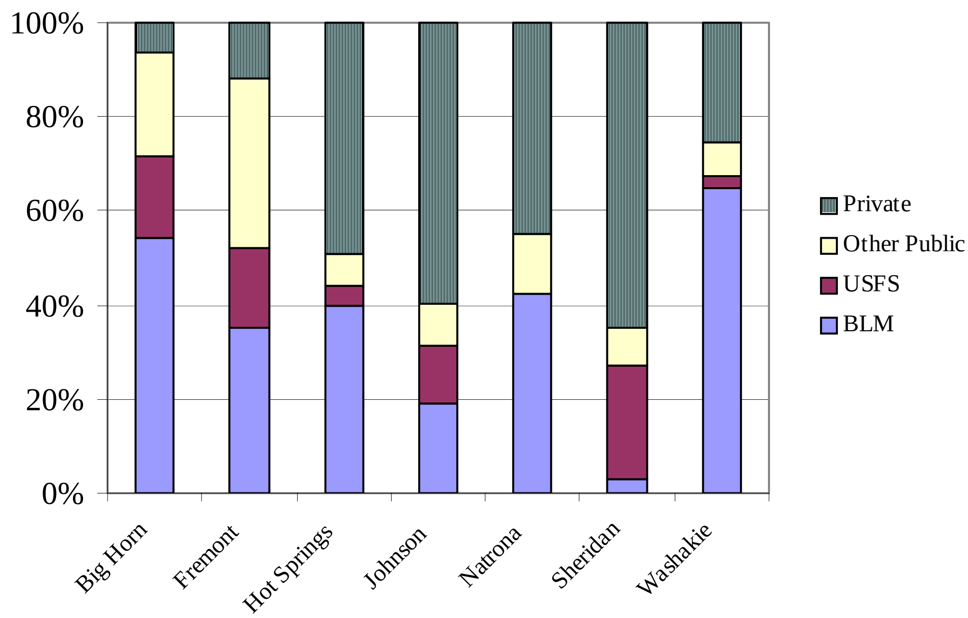


Figure 2-21. Major landowners for the seven Wyoming counties containing the Big Horn Mountain Section (*source: Equality State Almanac, 1998*).

Land Ownership and Land Use Patterns

Figure 2-21 shows a breakdown of landownership for the seven Wyoming counties in the study area. Nearly 94% of Big Horn County is in public ownership. Private land influences, such as agriculture or subdivision development, have had, and will continue to have, a very small impact upon the landscape in that county. Other counties with proportionally large amounts of public land are Fremont and Washakie. On the other end of the public ownership scale are Sheridan and Johnson Counties. The landscapes in these counties have the potential to be dramatically changed through private land management decisions. The Crow and Northern Cheyenne Indian Reservations predominantly own the portion of the Big Horn Mountain Section in Big Horn County, Montana.

The largest landowner in Section M331B is the USDA Forest Service (39%), followed by private lands (24%), and Bureau of Land Management lands (17%; Table 2-7). These data are from Wyoming (Merrill *et al.* 1996) and Montana (Fisher *et al.* 1998) GAP data. The pattern of land ownership on the landscape differs strongly by landowner (Fig. 2-22a-b). The Bighorn National Forest is largely continuous, containing only a few small islands within the National Forest boundary belonging to private landowners. Outside the National Forest, private landownership forms a fairly contiguous pattern across the Section, particularly south of the Forest. Land managed by the Bureau of Land Management (BLM) is generally located around the fringes of the Section, particularly at lower elevations dominated by grasslands; BLM land also tends to perforate private land ownership in several areas. Besides Indian Reservations, which own 17% of land contiguously located in the far western end of the Section (as well as in the northern extent of the Section, north of the Wyoming-Montana border), the next largest landowner is the State of Wyoming, whose land is by design very scattered and discontinuous across the Section (Fig. 2-22a-b).

Land ownership in the Big Horn Mountains may determine patterns of land use and management across the landscape, which in turn has important consequences for ecological sustainability, biodiversity, and species viability. As the primary landowner in the Big Horn Mountains Section, the Forest Service has an opportunity to provide a significant contribution to – and to determine the sustainability of – the ecological condition of the area. This is particularly true if the forests of the Section are to be managed as part of a larger, regional landscape ecosystem. Notably, private landowners will also play a major role in determining the ecological condition of the area, and may require significant collaboration and/or compensation to obtain common goals of land management for the Section. Similarly, because it manages 17% of the Section, the Bureau of Land Management also has the opportunity for significant collaboration with the Forest Service

Logging

The Wyoming timber economy is discussed in Rideout and Hesslyn (2000). The only large sawmill remaining within the Big Horn Mountain Section is Wyoming Sawmills in Sheridan, which employs about 100 people in the mill and 100 contractors to supply wood to the mill.

Sawtimber outputs from the BNF have decreased from about 15 million board feet (mbf) annually during the 1980s to about 2 mbf annually since 1992. To remain viable, Wyoming Sawmills changed its primary raw product source from the Bighorn National Forest to the ponderosa pine forests of eastern Montana. Most of that timber is on private land, although some is on the Northern Cheyenne and Crow Indian Reservations. According to the University of Montana's Charles Keegan, declines in timber from federal lands in western Montana are at least partially responsible for the increased timber output in eastern Montana from 70 mbf in 1989 to 220 mbf in 1995 (Billings Gazette, September 14, 1997).

Coalbed methane

The coal-bed methane boom has impacted Sheridan and Johnson Counties recently. The technology and market to extract methane from the world-class coal seams underlying the Powder River Basin recently exploded in a drilling and transportation boom not seen since the oil and coal boom of the early 1970s.

The largest environmental impact associated with coal-bed methane development is the millions of gallons of Madison Formation water pumped out of the coal seams to "free" the methane gas for extraction. While other states, including Colorado, require this water to be re-injected into the ground, Wyoming has few to no regulations governing this water, so most is either stored in surface ponds or simply discharged onto the surface.

.

Table 2-7. Land ownership in Section M331B – Forest Service lands in bold (*source: MT and WY GAP data).*

Ownership	Acres	Hectares	Percent
National Wildlife Refuge	279	113	<1
State Park Lands	1,786	723	<1
Open Water	5,405	2,187	<1
Nature Conservancy Preserve	9,819	3,974	<1
State Wildlife Habitat Management Area	19,886	8,047	1
Wyoming State Land	142,351	57,608	5
Indian Reservation	368,653	149,189	13
Bureau of Land Management	487,837	197,421	17
Private Lands	688,846	278,767	24
Bighorn National Forest	**1,098,579**	**444,581**	**39**
TOTAL	2,823,441	1,142,611	100

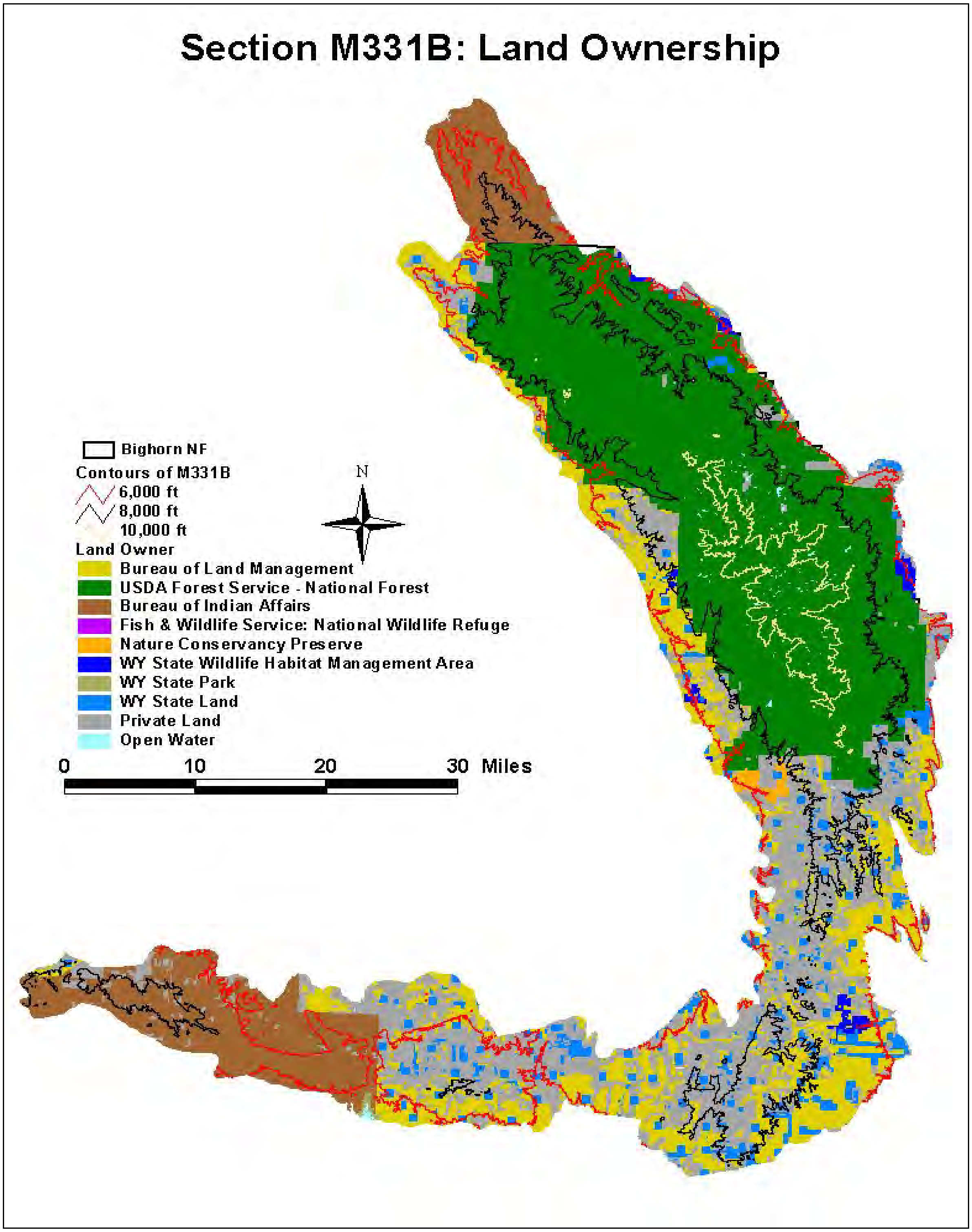


Figure 2.22a. Land ownership patterns in the Big Horn Mountains Section (M331).

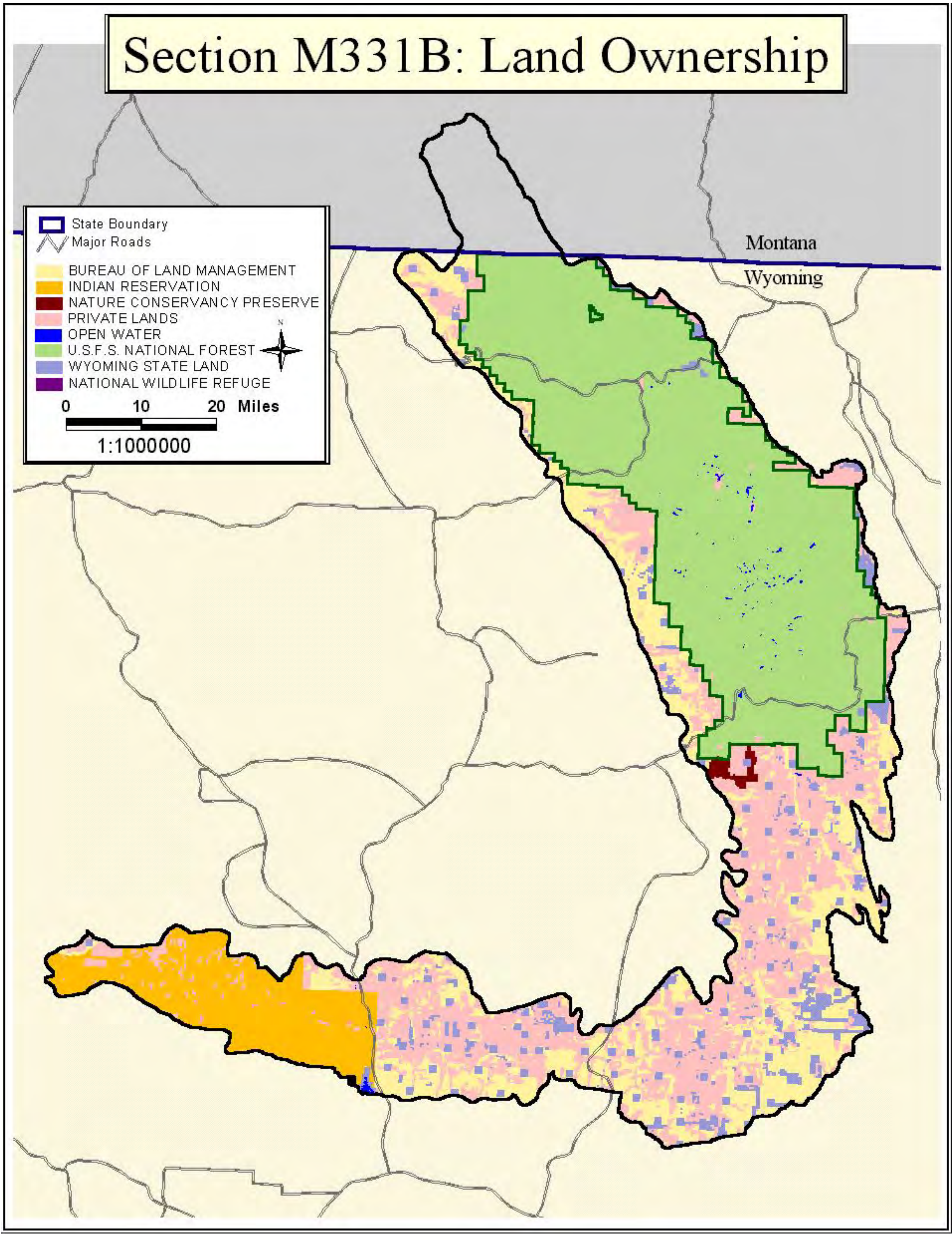


Figure 2-22b. Land ownership patterns in the Big Horn Mountains Section (M331).

The population growth associated with this boom was not taken into account in the Center for the American West's population growth projections discussed previously in this module. The primary expected effects from this boom on the resources of the Big Horn Mountain Section are:

- An increase in general recreation levels.
- A disproportionate increase in motorized recreation levels.
- A potential for increased air pollution, because it is expected that some power plants will be constructed in the Powder River Basin.

Agriculture

The largest agricultural activity in terms of total value of sales in the Big Horn Mountain Section is shown in Table 2-8.

Some interpretations from this table:

- Cattle and calves are the largest agricultural product in the Big Horn Mountain area.
- Farm crops, including barley and sugar beets, are important products in the Big Horn Basin. Sugar beets do not show in Table1-8, presumably because they are grown under contract with sugar factories in Worland and Lovell
- The agriculture industry, as a whole, in the Big Horn Basin area is less dependent upon the Bighorn National Forest than the east side counties since they have a broader agricultural base.
- Johnson county ranks 16th in the United States out of 2,787 counties in terms of total sales of sheep, lamb, and wool. The United States' sheep industry has declined precipitously over the past decade, ostensibly due to foreign competition from Australia and New Zealand.
- The total number of sheep and lambs in Johnson County dropped by 31% between 1992 and 1997, while the number of sheep operations declined by 18%.
- While there are currently only 16,500 sheep left on the Bighorn National Forest (down from 374,734 sheep in 1904), those producers depend on the National Forest for a significant portion of their operation.

Bighorn National Forest grazing permits result in 122 full-time equivalent jobs, $6.74 million in economic activity, and $1.77 million of personal income in the four-county area around the Forest (Fletcher *et al.* 1998).

The number of jobs, economic activity, and income do not indicate the total value of the ranching industry to the communities near the Big Horn Mountains. The U.S. Department of Commerce Regional Economic Information System (1969-1999) shows that in 1999, the agriculture and agricultural service sectors provided 9.4% of the jobs in the four counties. However, only 4.5% of the four county's 1999 labor earnings were from these two sectors (Taylor and Coupal 2003). These numbers do not reflect the overall level of importance local residents place upon the agriculture sector. The original settlement of this area by Europeans was led by the livestock industry, and the communities retain a "western cowboy" lifestyle and image that encourages tourism. In addition, private land ranches in Johnson and Sheridan counties provide most of the open space found in those counties.

Van Tassell and Richardson (1998) studied what impact federal grazing reductions would have upon a hypothetical, representative federal land ranching operation in Washakie and Big Horn Counties, Wyoming. Their 2,200-acre ranch at the base of the BNF was a cow-calf operation of 300 head of mother cows and associated replacements and bulls. The operation utilized state, Forest Service, and Bureau of Land Management grazing permits.

Table 2-8. Top five agricultural products by total value of sales (thousands of 1997 dollars) in four Wyoming counties (*source: U.S. Department of Agriculture, 1997 Census of Agriculture*).

Big Horn		Johnson		Sheridan		Washakie	
Commodity	Value	Commodity	Value	Commodity	Value	Commodity	Value
Cattle	$14,214	Cattle	$21,333	Cattle	$30,992	Cattle	$12,938
Other crops	$12,233	Sheep	$4,813	Hay	$2,644	Other crops	$7,471
Barley	$5,624	Hay	$1,176	Sheep	$1,186	Barley	$2,969
Hay	$3,817	Bees/honey	$153	Horses	$969	Sheep	$2,645
Sheep	$2,806	Horses	$150	Other Livestock	$840	Hay	$1,279

Among the results:

- Economies of size, obtained through the additional cows the ranch was able to maintain because of federal grazing permits, were important to the success of this ranch. Costs of buildings, fences, corrals, and equipment were all reduced on a per-cow basis because of the federal grazing permits.
- While some labor fixity was apparent, the ranch was not able to maintain enough work to employ a full-time person when federal permits were lost.

Many BNF permittees have said that, if they lost forest-grazing privileges, they would make adjustments on their base properties until they could no longer stay in business. The simulation analysis in this study shows that equity erodes rapidly as federal permits are removed. The potential exists, therefore, that without federal grazing permits, much of the land around National Forests could change ownership. Because of the price most land around National Forests can demand, the danger is that those lands would be subdivided into ranchettes or other residences rather than stay in agricultural use.

Several non-governmental organizations are working to maintain open spaces. The Ucross Foundation supports the Wyoming Open Lands project. The executive director provided a forum for landowners to work together to provide economic incentives for preserving open space. The Nature Conservancy Big Horn Lands Program has an office in Sheridan to purchase conservation easements. Protecting the remnants of the public domain by placing them under federal management made the largest conservation gains 100 years ago. It is likely that the largest conservation gains in the future will be made on private lands by private landowners working with organizations such as Wyoming Open Lands and The Nature Conservancy.

Recreation

Tourism is a large industry in the Big Horn Mountain area. The area has been primarily advertised as a stopover between the Black Hills and Yellowstone National Park ever since the “Black to Yellow Trail” promotion began in about 1905. Table 2-9 shows the relative importance of tourism to the overall economies of the Wyoming counties within the Big Horn Mountain Subsection.

Winter tourism is increasing, especially the number of snowmobilers. The Big Horns have a well-developed State trail system, and the numerous large parks provide excellent snowmobiling. Nearly all of the lodges on the mountain are increasing their capacity to capitalize on this growth, and speculation is that it will increase even more rapidly if Yellowstone is closed to snowmobiling. With the exception of the Wilderness and the wildlife winter range areas, the Bighorn National Forest is open to off-trail over-the-snow vehicles between November 15 and March 15. The small amount of winter range on the National Forest is closed to snowmobiles.

The 1985 Bighorn National Forest Plan was written before 4-wheel all terrain vehicles (ATVs) were as developed and widely used as they are now. Management of this type of recreation has lagged behind the huge increase in use seen since the late 1980s. Approximately 125,000 acres on the BNF are open to off-road vehicles in the summer.

Table 2-9. Tourism jobs and earnings compared to total jobs and earnings by Wyoming county.

County	Employment (jobs)		Percentage of Total Jobs in Tourism[3]	Industry Earnings ($ million)		Percentage of Total Earnings in Tourism[3]
	Tourism[1]	County Total[2]		Tourism[1]	County Total[2]	
Big Horn	460	5,680	8.1%	3.9	127.1	3.1%
Johnson	650	4,162	15.6%	6.7	62.8	10.7%
Sheridan	1,440	16,028	9.0%	14.6	333.4	4.4%
Washakie	410	5,389	7.6%	3.1	188.2	1.6%

1 Data from Runyan Associates (2001). Data are for 2000.
2 Data from U.S. Department of Commerce, Bureau of Economic Analysis. Data are for 1998.
3 Although comparing the previous two columns is not strictly accurate because the data were taken two years apart, the percentages approximate the importance of tourism in the local economies.

Key Findings and Significant Gaps

- Livestock grazing has had effects upon the resource conditions, and the current stocking rates are a result of historic grazing levels and settlement patterns.
- Local communities' identities are closely tied to the western cowboy culture and tourism.
- The Bighorn National Forest is far from any large urban centers, yet urban sprawl is expected to continue which will impact the elk habitat and open space around the BNF.
- Both private and public landownership in the Big Horn Mountains will impact the ecological sustainability, biodiversity, and species viability in the area.
- Decline of forest grazing levels could lead to additional subdivision of property in Sheridan and Johnson counties, although how much of this phenomenon is attributable to Forest decisions versus non National Forest issues such as livestock markets, community demographic changes, and other items is conjectural.
- Most summer visitors are pass-through visitors, traveling between the Black Hills and Yellowstone National Park.
- There is relatively little conflict between winter recreation use and resource issues, at least compared to other Rocky Mountain forests.

Literature Cited

Bailey, R.G. 1996. Ecosystem Geography. Springer-Verlag, New York. 204 pp.

Blair, N. 1987. The History of Wildlife Management in Wyoming. Wyoming Game and Fish Department, Cheyenne, WY. 295 pp.

Bornong, B.R. and K. Atchley. 1996. Social Profile for the Upper Wind River Valley. Report for the Continuing Education in Ecosystem Management program. Report on file at: U.S. Department of Agriculture, Forest Service, Bighorn National Forest Supervisor's Office, Sheridan, WY. 5p.

Bucher *et al.* 1933

Darton, N.H. 1906. Geology of the Big Horn Mountains. Professional Paper No. 51. Washington, DC: U.S. Department of the Interior, Geological Survey. Government Printing Office. 129p.

Demorest, M. 1941. Critical structural features of the Big Horn Mountains, Wyomng: Geological Society of America Bulletin, Vol. 52 pp. 161-176.

Despain, D.G. 1973. Vegetation of the Big Horn Mountains, Wyoming, in relation to substrate and climate. Ecological Monographs 43:329-355.

Fisher F.B., J.C. Winne, M.M. Thornton, and others. 1998. Montanan land cover atlas. Unpublished report. Montana Cooperative Wildlife Research Unit, University of Montana, Missoula. 50pp.

Fletcher, R.R., G.W. Borden, T.R. Harris, D.T. Taylor, and B.R. Moline. 1998. Comparison of Economic Impacts from Public-land-based Tourism and Grazing: A Case Study. In: Stubble Height and Utilization Measurements: Uses and Misuses. Oregon State University Agricultural Experiment Station, p. 57-70.

Girard, M.; Wheeler, D.L.; Mills, S.B. 1997. Classification of riparian communities on the Bighorn National Forest. U.S. Department of Agriculture, Forest Service, Rocky Mountain Region, R2-RR-97-02.

Goodson 1982

Hoffman G. and R. Alexander. 1976. Forest vegetation of the Bighorn Mountains, Wyoming: A habitat classification. U.S. Forest Service Research Paper RM-276.

Hoppin and Jennings 1971

Howe, G.E. 1996. Genetics Service Trip to Bighorn National Forest. Unpublished report on file at: Department of Agriculture, Forest Service, Bighorn National Forest Supervisor's Office, Sheridan, WY. 18 pp.

Jack, J.G. 1900. Forest and Grazing Conditions in the Bighorn Forest Reserve, Wyoming, 1900. Unpublished report on file at: Department of Agriculture, Forest Service, Bighorn National Forest Supervisor's Office, Sheridan, WY. 178 pp.

Koppen 1931

Kuchler 1964

McNab, W. H. and P.E. Avers, 1994. Ecological subregions of the United States: Section descriptions. USDA Forest Service, Ecosystem Management, Washington DC. 267 pp.

Merrill. E.H., T.W. Kohley, M.E. Herdendorf, and others. 1996. Wyoming GAP analysis: A geographic analysis of biodiversity. Final report, Wyoming Cooperative Fishery and Wildlife Research Unit, University of Wyoming, Laramie, WY.

Meyer, C.B., Knight, D.H. 2003. Historic variability for upland vegetation in the Bighorn National Forest, Sheridan, Wyoming and the Division of Renewable Resources, Rocky Mountain Region, U.S. Forest Service, Lakewood, Colorado. USFS Agreement No. 1102-0003-98-043.

Murray, R.A. 1980. Multiple Use in the Bighorns: The Story of the Bighorn National Forest, Volume 3. Unpublished report on file at: Department of Agriculture, Forest Service, Bighorn National Forest Supervisor's Office, Sheridan, WY. 428 pp.

Nesser, J.A. 1986. Soil survey of Bighorn National Forest, Wyoming. Sheridan, WY. USDA Forest Service and Soil Conservation Service; in cooperation with Wyoming Agricultural Experiment Station. 99 pp. with maps.

Rideout, D.B. and H. Hesseln. 2000. Wyoming Timber Market Analysis: The New Western

Timber Economy. Report prepared for the Wyoming National Forests. Report on file at: Department of Agriculture, Forest Service, Bighorn National Forest Supervisor's Office, Sheridan, WY. 58pp.

Ruggiero, L.F., Aubry, K.B., Buskirk, S.W. *et al.* (tech. eds.) 1994. The scientific basis for conserving forest carnivores: American marten, fisher, lynx and wolverine in the western United States. Gen. Tech. Rep. RM-254. Ft. Collins, CO; USDA, Forest Service, Rocky Mountain Forest and Range Experiment Station. 184 pp.

Runyan, Dean, and Associates. 2001. The Economic Impact of Travel on Wyoming. Unpublished report prepared for the State Office of Travel and Tourism, Wyoming Business Council. On file at Bighorn National Forest Supervisor's Office, Sheridan, WY. 49 pp.

Sharp 1948

Taylor, T. and R. Coupal 2003. Unpublished reports for Bighorn National Forest Plan Revision. On file at the Bighorn National Forest Supervisor's Office, Sheridan WY.

Trewartha 1968

Turner, M.G., R.H. Gardner, and R.V. O'Neill. 2001. Pattern and Process: Landscape Ecology in Theory and Practice. Springer-Verlag, New York, New York. 401 pp.

USDA Forest Service. 1993. National hierarchical framework of ecological units. Washington, DC: U.S. Department of Agriculture, Forest Service, ECOMAP. 28 pp.

Van Tassell, L.W. and J.W. Richardson. 1998. Impact of Federal Grazing Reductions on Wyoming Ranches. In: Stubble Height and Utilization Measurements: Uses and Misuses. Oregon State University Agricultural Experiment Station, 50-56 p.

Warder, J. 2001. Terrestrial wildlife, aquatic wildlife, and rare plant species emphasis categories. Draft report for the Bighorn National Forest Plan Revision. 25 pp.

Warder, J. 2001. Wildlife history of the Bighorn National Forest. Draft Report for the Bighorn National Forest Plan Revision. 6 pp.

Wilson 1938

Young, M.K., D. Haire, and M.A. Bozek. 1994. The Effect and Extent of Railroad Tie Drives in Streams of Southeastern Wyoming. Western Journal of Applied Forestry 9(4): 125-130.

Appendix A - Description of Section M331B – Big Horn Mountains

(McNab and Avers 1994)

Geomorphology. There are high mountains with sharp crests, rolling uplands, and dissected hills, with alpine glaciation dominating the upper third of the area. The rugged hills and mountains are cut by many narrow valleys with steep gradients. Elevation ranges from 4,000 to 13,000 ft (1.220 to 3,962 m). This Section is within the Middle Rocky Mountains physiographic province.

Lithology and Stratigraphy. The central part of the Section is Precambrian quartz monzonite to quartz diorite in the north and Precambrian gneiss in the south. The periphery of the Section is Paleozoic carbonates and shales. A small area in the extreme northeast of the Section is Cretaceous sandstones, siltstones, and shales.

Soil Taxa. Soils include Cryic Borolls, Ochrepts, and Boralfs. These soils are generally shallow to moderately deep, but some deep soils occur in alluvial and colluvial basins. Textures are generally loamy or sandy, with large amounts of rock fragments.

Potential Natural Vegetation. Kuchler mapped potential vegetation as Douglas-fir forest and western spruce-fir forest (50%) and wheatgrass-needlegrass-shrubsteppe (50%). Common tree species include lodgepole pine, Douglas-fir, subalpine fir, and Engelmann spruce. Idaho fescue, bluebunch wheatgrass, and mountain big sagebrush are common grass and shrub species.

Fauna. Birds are those typical of the Rocky Mountains. Species include ferruginous and Swainson's hawks, golden eagle, blue grouse, sage grouse, mountain plover, Steller's and gray jay, Clark's nutcracker, Townsend's solitaire, green-tailed towhee, and western tanager. Species nearing the edge of their ranges are calliope hummingbird, indigo bunting, and clay-colored sparrow. Typical herbivores and carnivores include white-tailed deer, mule deer, elk, moose, pronghorn, black bear, bobcat, and cougar. Smaller common herbivores include the snowshoe hare, yellow-bellied marmot, and the northern flying squirrel. Bison are historically associated with this Section. Herpetofauna typical of this Section are the spotted frog, rubber boa, boreal toad, blotched tiger salamander, and at lower elevations, the prairie rattlesnake.

Climate. Precipitation ranges from 15 to 40 in (380 to 1,020 mm), with much occurring as spring and fall rains. Climate is cold continental with dry, cold winters. Temperature averages 36 to 43 F (2 to 6 C). The growing season lasts 45 to 90 days.

Surface Water Characteristics. This area has medium to fine density dendritic patterns with moderate gradients. Streams are deeply entrenched as they leave the mountains. Lakes occur in glaciated terrain, as well as in high elevation cirques and basins. Major streams include the Tongue, Shell, and Tensleep.

Disturbance Regimes. Fire, insects, and disease are the dominant natural sources of disturbance. Fire has historically been fairly frequent, low intensity, and patchy; however, fire suppression has caused this pattern to change to less frequent, more intense, larger fires.

Land Use. The land is used for timber harvest, livestock grazing, wildlife habitat, watershed, and recreation.

Cultural Ecology. Reserved.

Compiled by Northern Region and Rocky Mountain Region.

Big Horn Mountains, Sedimentary Subsection (M331Ba) (Reiners *et al.* 1999)

This Subsection consists mainly of Mesozoic and Paleozoic limestone, dolomite and sandstone, although it includes some plutonic rocks in the North, and gneissic rocks in the south. Deep, steeply walled canyons cut through the dipping sedimentary rocks, particularly along the eastern flank. Mixed grass prairie is mapped for much of this area although it has a distinct mountain meadow character associated with the higher elevations. Juniper woodland is found at lower elevations on rocky outcrops, and Douglas-fir in the canyons.

The majority of this Subsection is included in the Bighorn National Forest LTA coverage. Nine polygons in the northwest of this Subsection have been mapped, seven of which are designated as "low mountains," one is "high hills," and one is "irregular plains."

Big Horn Mountains, Granitic/Gneiss Subsection (M331Bb) (Reiners *et al.* 1999)

This Subsection is embedded within the Big Horn Mountains Sedimentary Subsection. Although it roughly follows the delineation of Freeouf (1996), our Subsection boundary was digitized using both relief and geologic coverages and follows more closely the contact between gneissic and plutonic rocks with the surrounding sedimentary rocks. This area is generally higher and more rugged than the sedimentary Subsection, and soils consist primarily of Rock Outcrop and Lithic Cyorthents. Vegetation includes bare rock, alpine tundra, lodgepole pine forest, spruce-fir forest, mountain big sagebrush, mountain meadow grassland, and ponderosa pine woodland along the lower margins.

The majority of this Subsection is included in the Bighorn National Forest LTA coverage. We have mapped only four polygons in the Buffalo Resource Area within this Subsection. Landtype Associations include "Footslope", "Low Hills", "High Hills", and "Low Mountains".

Owl Creek Mountains Subsection (M331Bc) (Reiners *et al.* 1999)

Our delineation of the boundary between the Owl Creek Mountains and Big Horn Mountains Subsections roughly follows that of Freeouf (1996), but it is slightly to the east. Our line follows along Bridger Creek to the south, and Kirby Creek to the north. This line is roughly the topographic low dividing these two mountain ranges. This Subsection bounds on the west with the Absaroka Range and Southern Absaroka Range Subsections, on the north with the Big Horn Basin, and on the south with the Eastern and the Western Wind River Basin Subsections. The low range comprising this Subsection is cored with Precambrian rocks in places, but for the most part consists of Paleozoic sedimentary rocks dipping gently to the north. This is not a very high range and therefore is relatively dry. Common soils are Typic Hapludolls and Typic Hapludalfs on the sedimentary rocks with Rock Outcrop and Lithic Cryorothents on the Precambrian plutonic and metamorphic rocks. Vegetation is similar to that of the Big Horn Sedimentary Subsection.

This Subsection is contained entirely within our northwest Wyoming map area. The majority of the Subsection is mapped as "High Hills," although other Landtype Associations include "Low Hills", "Open Low Hills", "Hills", "Single Cuesta", "Alluvial Valley", and "River Valley".

Bighorn National Forest LandType Associations

M331Ba-01 **Sedimentary Breaklands**

Location: Big Horn Mountain range in northern Wyoming, in Big Horn Mountain Section, Sedimentary Subsection.

Concept: This LTA is typically composed of steep mountainsides, escarpments and canyon walls, and steep colluvial slopes. The vegetation is a mosaic of Douglas-fir forest, shrubland, and mountain grasslands.

General Characteristics:

Topography: Steep mountainsides, escarpments, talus; relief 1500 - 2500'.
Elevation: 5000 - 9000'
Slope: 40 to 70%
Extent: 188,525 acres for IRI; 134,068 acres within Forest; 12.0% of Forest.
22,301 acres of grass, 2.0%; 111,767 acres of trees, 10.0%
Climatic Zone: Lower Montane, Lower Montane and Montane, and Montane
Average Annual Precipitation: 15 to 35 inches
Average Annual Temperature: 31 to 38 degrees F.
Formations: Big Horn Dolomite, Madison Limestone, Amsden Formation, Tensleep Sandstone
Lithology: Sandstone, Limestone, Dolomite, Interbedded sandstone and shale
Parent Material: Sedimentary residuum and colluvium
Potential Natural Vegetation: Douglas-fir, mountain ninebark, Utah juniper, mountain mahogany, big sagebrush, Idaho fescue, bluebunch wheatgrass
Soil Classification: Typic Cryoboralfs - 60%
Ustic Torriorthents - 25%
Rock Outcrop - 15%

Use and Management:

Windthrow Hazard: Severe - rock fragments, depth to bedrock
Moderate - loose material
Prescribed Burning Limitations: Severe - slope, depth to bedrock, on grassland thin organic layer, rock outcrop
Reforestation Potential: Low - droughtiness
Moderate - depth to bedrock, rock fragments
Revegetation Potential: Poor - slope, droughtiness, depth to bedrock
Fair - too alkaline, shrink-swell, rock fragments
Surfaced Roads Limitations: Severe - slope, depth to bedrock, large stones
Moderate - shrink-swell, low strength, frost action
Unsurfaced Roads Limitations: Severe - slope, too stony
Moderate - dusty
Slope Stability Hazard: Low
Debris Flow Hazard: Moderate - slopes <55%
High - slopes >55%

M331Ba-02 Landslide/Colluvial Deposits

Location: Big Horn Mountain range in northern Wyoming in Big Horn Mountain Section, Sedimentary Subsection.

Concept: This LTA is typically composed of moderately stable to stable landslide deposits. The vegetation is mostly mountain shrubland and grassland.

General Characteristics:

Topography: Complex slopes, relief from 200 to 600'
Elevation: 5000 - 9000'
Slope: 10 to 40%
Extent: 38,838 acres for IRI; 35,295 arcres within Forest; 3.2% of Forest; all grass/shrub.
Climatic Zone: Lower Montane and Montane, Montane, Montane and Subalpine
Average Annual Precipitation: 15 to 35 inches
Average Annual Temperature: 33 to 38 degrees F.
Formations: Flathead Sandstone, Gros Ventre Formation, Gallatin Limestone, Big Horn Dolomite, Madison Limestone, Amsden Formation, Tensleep Sandstone, Chugwater Formation
Lithology: Colluvial/landslide deposits.
Parent Material: Colluvium from limestone, shale, and sandstone
Potential Natural Vegetation: Big sagebrush, Idaho fescue, black sagebrush, bluebunch wheatgrass
Soil Classification: Typic Cryorthents - 60%
Argic Cryoborolls - 40%

Use and Management:

Windthrow Hazard: Moderate - loose material
Prescribed Burning Limitations: Severe - slope, on grassland - thin organic layer
Revegetation Potential: Poor - slope, shrink-swell
Fair - too alkaline, depth to bedrock
Surfaced Roads Limitations: Severe - slope, shrink-swell
Moderate - low strength, frost action
Unsurfaced Roads Limitations: Moderate - slope
Slope Stability Hazard: High
Debris Flow Hazard: Low

M331Ba-03 Sedimentary Mountain Slopes, Limestone/Dolomite

Location: Big Horn Mountain range in northern Wyoming in Big Horn Mountain Section, Sedimentary Subsection.

Concept: This LTA is typically composed of mountainsides, ridges, toeslopes, and fans. The vegetation is a mosaic of mountain grassland and Douglas-fir/Engelmann spruce forest.

General Characteristics:

Topography: Moderately-complex slopes, strongly dissected.
Elevation: 5500 to 10,500'
Slope: 5 to 30%
Extent: 215,481 acres for IRI; 166,282 within Forest; 14.9% of Forest.
103,357 acres of grass, 9.0%; 62,925 acres of trees, 5.9%
Climatic Zone: Montane, Montane and Subalpine

Average Annual Precipitation: 15 to 35 inches
Average Annual Temperature: 31 to 38 degrees F.
Formations: Gallatin Limestone, Big Horn Dolomite, Madison Limestone
Lithology: Limestone and dolomite
Parent Material: Residuum, colluvium, and alluvium (calcareous)
Potential Natural Vegetation: Douglas-fir, Engelmann spruce, mountain ninebark, grouse whortleberry, Idaho fescue, silky lupine.
Soil Classification: Typic Cryoboralfs - 50%
Argic Cryoborolls - 40%
Calcic Cryoborolls - 10%

__Use and Management:__
Windthrow Hazard: Moderate - loose material
Severe - rock fragments and depth to bedrock
Prescribed Burning Limitations: Severe - on grassland - thin organic layer
Moderate - slope, depth to bedrock, some stoniness and slope
Reforestation Potential: Low - droughtiness
Moderate - depth to bedrock, rock fragments
Revegetation Potential: Poor - slope, depth to bedrock
Fair - shrink-swell, droughtiness, too alkaline
Surfaced Road Limitations: Severe - slope
Moderate - shrink-swell, frost action, low strength, depth to bedrock, large stones
Unsurfaced Road Limitations: Moderate - slope, dust
Severe - too stony
Slope Stability Hazard: Low
Debris Flow Hazard: Low

M331Ba-04 Sedimentary Mountain Slopes, Shale/Sandstone (Calcareous)

__Location:__ Big Horn Mountain range in northern Wyoming in Big Horn Mountain Section, Sedimentary Subsection.

__Concept:__ This LTA is typically composed of mountainsides, toeslopes, and fans. The vegetation is a mosaic of mountain shrubland and grassland.

__General Characteristics:__
Topography: Moderately dissected mountain slopes
Elevation: 6000 to 9500'
Slope: 2 to 35%
Extent: 57,136 acres for IRI; 27,058 within Forest; 2.5% of Forest; all grass/shrub
Climatic Zone: Lower Montane, Lower Montane and Montane, Montane, Montane and Subalpine
Average Annual Precipitation: 15 to 35 inches
Average Annual Temperature: 31 to 38 degrees F.
Formations: Gallatin Limestone, Amsden Formation, Tensleep Sandstone, Chugwater Formation
Lithology: Interbedded sandstone, limestone, and shale.
Parent Material: Residuum, colluvium, and alluvium
Potential Natural Vegetation: Idaho fescue, big sagebrush, bluebunch wheatgrass, silky lupine
Soil Classification: Argic Cryoborolls - 70%
Lithic Argiborolls - 30%

Use and Management:

Windthrow Hazard: Moderate - loose material
Severe - rock fragments and depth to bedrock
Prescribed Burning Limitations: Severe - on grassland - thin organic layer
Moderate - slope, depth to bedrock
Revegetation Potential: Poor - slope, rock fragments, depth to bedrock
Fair - shrink-swell, too alkaline, too clayey
Surfaced Roads Limitations: Severe - slope, depth to bedrock
Moderate - shrink-swell, frost action, low strength
Unsurfaced Roads Limitations: Severe - slope, too stony
Moderate - dusty
Slope Stability Hazard: High - on shale and slopes > 27%
Debris Flow Hazard: Low

M331Ba-05 Sedimentary Mountain Slopes, Shale/Sandstone (Non-calcareous)

Location: Big Horn Mountain range in northern Wyoming in Big Horn Mountain Section, Sedimentary Subsection.

Concept: This LTA is typically composed of mountainsides, toeslopes, and fans. The vegetation is a mosaic of lodgepole pine/Engelmann spruce forest and grasslands.

General Characteristics:

Topography: Moderately dissected mountainsides.
Elevation: 6000 to 10,000'
Slope: 2 to 35%
Extent: 85,855 acres for IRI; 81,617 acres within Forest; 7.3% of Forest
26,762 acres of grass, 2.4%; 54,855 acres of trees, 4.9%
Climatic Zone: Montane, Montane and Subalpine
Average Annual Precipitation: 15 to 35 inches
Average Annual Temperature: 31 to 35 degrees F.
Formations: Flathead Sandstone, Gros Ventre Formation
Lithology: Interbedded sandstone and shale, sandstone, shale
Parent Material: Residuum, colluvium, and alluvium
Potential Natural Vegetation: Lodgepole pine, Engelmann spruce, grouse whortleberry, Idaho fescue
Soil Classification: Typic Cryoboralfs - 55%
Argic Cryoborolls - 45%

Use and Management:

Windthrow Hazard: Moderate - loose material
Severe - depth to bedrock
Prescribed Burning Limitations: Severe - on grassland - thin organic layer
Moderate - depth to bedrock
Reforestation Potential: Moderate - depth to bedrock, too acid
Low - droughtiness
Revegetation Potential: Poor - slope, shrink-swell
Fair - depth to bedrock, too acid
Surfaced Roads Limitations: Severe - slope
Unsurfaced Roads Limitations: Moderate - slope
Slope Stability Hazard: High
Debris Flow Hazard: Low

M331Bb-01 **Granitic Breaklands**

Location: Big Horn Mountain range in northern Wyoming in Big Horn Mountain Section, Granitic/Gneiss Subsection.

Concept: This LTA is typically composed of steep mountainsides, escarpments, and canyon walls. Rock outcrop and rubble land are common. The sparse vegetation is mainly grassland, lodgepole pine, grouse whortleberry.

General Characteristics:
Topography: Complex slopes, strong dissection, relief 1500 - 2500'.
Elevation: 6500 - 10,500'
Slope: Dominately 40 to 70%
Extent: 44,406 acres for IRI; 39,278 acres within Forest; 3.5% of Forest
14,495 acres of Rock outcrop/grass, 1.3%; 24,783 acres of trees/Rock outcrop; 2.2%
Climatic Zone: Montane and Subalpine, Subalpine, and Alpine
Average Annual Precipitation: 25 to 35 inches
Average Annual Temperature: 28 to 35 degrees F.
Formations: Precambrian granite and gneiss
Lithology: Granite and/or gneiss
Parent Material: Residuum and colluvium
Potential Natural Vegetation: Alpine vegetation, lodgepole pine, grouse whortleberry
Soil Classification: Rock outcrop - 60%
Typic Cryoboralfs - 40%

Use and Management:
Windthrow Hazard: Severe - depth to bedrock, rock fragments
Prescribed Burning Limitations: Severe - depth to bedrock, too stony
Reforestation Potential: Low - droughtiness, too acid
Moderate - depth to bedrock, rock fragments
Revegetation Potential: Poor - slope, rock fragments, depth to bedrock
Surfaced Roads Limitations: Severe - slope, large stones, depth to bedrock
Moderate - shrink-swell
Unsurfaced Roads Limitations: Severe - slope, too stony
Slope Stability Hazard: Low
Debris Flow Hazard: High

M331Bb-02 **Glacial Cirquelands**

Location: Big Horn Mountain range in northern Wyoming in Big Horn Mountain Section, Granitic/Gneiss Subsection.

Concept: This LTA is typically composed of glacial cirque headwalls, cirque basins, and periglacial rubble and talus. The vegetation is a sparse alpine community.

General Characteristics:
Topography: Very steep mountainsides, cirques.
Elevation: 9500 - 13,000'
Slope: 10 to 130%

Extent: 64,418 acres all within Forest; 5.8% of Forest; all Rock outcrop with inclusions of alpine vegetation
Climatic Zone: Alpine
Average Annual Precipitation: 30 to 40 inches
Average Annual Temperature: 28 to 32 degrees F.
Formations: Precambrian granite and gneiss
Lithology: Granite and/or gneiss
Parent Material: Residuum and talus
Potential Natural Vegetation: Sparse alpine plant community
Soil Classification: Rock outcrop, hard

Use and Management:
Windthrow Hazard: Severe - depth to bedrock, rock fragments
Prescribed Burning Limitations: Severe - depth to bedrock, too stony
Revegetation Potential: Poor - slope, rock fragments, depth to bedrock
Surfaced Roads Limitations: Severe - slope, depth to bedrock, large stones
Unsurfaced Roads Limitations: Severe - slope, too stony
Slope Stability Hazard: Low
Debris Flow Hazard: High

M331Bb-03 Glacial/Tertiary Terrace Deposits

Location: Big Horn Mountain range in northern Wyoming in Big Horn Mountain Section, Granitic/Gneiss Subsection.

Concept: This LTA is typically composed of glacial moraines and Tertiary terraces. The vegetation is a mosaic of lodgepole pine forest, shrubland, and mountain grasslands.

General Characteristics:
Topography: Bull Lake Stade: highly weathered moraine, Pinedale Stade: potholes and lakes moraine, old terraces.
Elevation: 6500 - 9000'
Slope: 2 to 40%
Extent: 105,715 acres for IRI; 99,140 acres within Forest; 9.0% of Forest
24,532 acres of grass, 2.2%; 74,608 acres of trees, 6.8%
Climatic Zone: Montane, Montane and Subalpine
Average Annual Precipitation: 25 to 35 inches
Average Annual Temperature: 31 to 35 degrees F.
Formations: Precambrian granite and gneiss
Lithology: Granite and/or gneiss
Parent Material: Till and outwash
Potential Natural Vegetation: Lodgepole pine, grouse whortleberry, Idaho fescue, big sagebrush
Soil Classification: Typic Cryoboralfs - 70%
Argic Cryoborolls - 30%

Use and Management:
Windthrow Hazard: Severe - rock fragments, wetness in glacial moraines
Moderate - loose material
Prescribed Burning Limitations: Severe - on grassland - thin organic layer, too sandy
Moderate - slope
Reforestation Potential: Low - rock fragments, too acid

Moderate - droughtiness
Revegetation Potential: Poor - slope, rock fragments
Fair - shrink-swell, too acid
Surfaced Roads Limitations: Severe - slope, large stones
Moderate - shrink-swell, frost action, low strength
Unsurfaced Roads Limitations: Severe - too stony, ponding
Moderate - slope
Slope Stability Hazard: Moderate - on slopes <27%; High - on slopes >27%
Debris Flow Hazard: Low

M331Ba-04 Granitic Mountain Slopes, Steep

Location: Big Horn Mountain range in northern Wyoming in Big Horn Mountain Section, Granitic/Gneiss Subsection.

Concept: This LTA is typically composed of steep mountainsides. The vegetation is dominately lodgepole pine forest.

General Characteristics:
Topography: Moderately dissected mountainsides.
Elevation: 7000 - 9500'
Slope: 25 to 50%
Extent: 42,826 acres for IRI; 41,767 acres within Forest ; 3.8% of Forest; all trees/Rock outcrop
Climatic Zone: Montane and Subalpine
Average Annual Precipitation: 25 to 35 inches
Average Annual Temperature: 31 to 35 degrees F.
Formations: Precambrian granite and gneiss
Lithology: Granite and/or gneiss
Parent Material: Residuum
Potential Natural Vegetation: Lodgepole pine, grouse whortleberry
Soil Classification: Typic Cryoboralfs - 80%
Rock outcrop - 20%

Use and Management:
Windthrow Hazard: Severe - loose material, rock fragments
Moderate - depth to bedrock
Prescribed Burning Limitations: Moderate - slope, thin organic layer
Severe - rock outcrop
Reforestation Potential: Low - droughtiness, too acid
Moderate - depth to bedrock, rock fragments
Revegetation Potential: Poor - slope, depth to bedrock, too acid
Fair - shrink-swell, droughtiness
Surfaced Roads Limitations: Severe - slope, depth to bedrock
Moderate - shrink-swell, frost action
Unsurfaced Roads Limitations: Severe - slope, too stony
Slope Stability Hazard: Low
Debris Flow Hazard: Moderate

M331Ba-05 Granitic Mountain Slopes, Gentle

Location: Big Horn Mountain range in northern Wyoming in Big Horn Mountain Section, Granitic/Gneiss Subsection.

Concept: This LTA is typically composed of mountainsides, fans, and outwash plains. Floodplains and wetlands are common. The vegetation is a mosaic of lodgepole pine/Engelmann spruce forest and mountain grasslands.

General Characteristics:

Topography: Moderately dissected mountain slopes, floodplains, wetlands.
Elevation: 7000 - 9500'
Slope: 5 to 25%
Extent: 318,046 acres for IRI; 303,242 acres within Forest; 27.2% of Forest
45,718 acres of grass, 4.1%; 257,524 acres of trees, 23.1%
Climatic Zone: Montane and Subalpine
Average Annual Precipitation: 25 to 35 inches
Average Annual Temperature: 31 to 35 degrees F.
Formations: Precambrian granite and gneiss
Lithology: Granite and/or gneiss
Parent Material: Residuum and colluvium
Potential Natural Vegetation: Lodgepole pine, Engelmann spruce, grouse whortleberry, Idaho fescue
Soil Classification: Typic Cryoboralfs - 75%
Argic Cryoborolls - 25%

Use and Management:

Windthrow Hazard: Severe - loose material
Moderate - rock fragments, depth to bedrock
Prescribed Burning Limitations: Severe - depth to bedrock
Moderate - slope, thin organic layer
Reforestation Potential: Low - droughtiness, too acid
Moderate - depth to bedrock, rock fragments
Revegetation Potential: Poor - slope
Fair - too acid, too sandy, shrink-swell
Surfaced Roads Limitations: Severe - slope
Moderate - depth to bedrock, shrink-swell, frost action, large stones
Unsurface Roads Limitations: Moderate - slope
Slope Stability Hazard: Low
Debris Flow Hazard: Moderate

M331Ba-06 Alpine Mountains and Ridges

Location: Big Horn Mountain range in northern Wyoming in Big Horn Mountain Section, Granitic/Gneiss Subsection.

Concept: This LTA is typically composed of mountainsides, alpine ridges, and glacial trough valleys. The vegetation is dominately an alpine community and some Engelmann spruce forest.

General Characteristics:

Topography: Strongly dissected mountainsides, ridges, valleys.
Elevation: 9000 - 11,000'
Slope: 5 to 35%
Extent: 120,314 acres for IRI; 119,976 acres within Forest; 10.8% of Forest
108,162 acres of grass/Rock outcrop, 9.7%; 11,814 acres of trees, 1.1%
Climatic Zone: Subalpine, Alpine
Average Annual Precipitation: 30 to 40 inches
Average Annual Temperature: 29 to 33 degrees F.
Formations: Precambrian Granite and Gneiss
Lithology: Granite and/or gneiss
Parent Material: Residuum and till
Potential Natural Vegetation: Sparse alpine community, Engelmann spruce
Soil Classification: Pergelic Cryumbrepts - 50%
Rock outcrop - 40%
Typic Cryoboralfs - 10%

Use and Management:

Windthrow Hazard: Severe - depth to bedrock, rock fragments
Moderate - loose material
Prescribed Burning Limitations: Severe - depth to bedrock, thin organic layer
Reforestation Potential: Low - droughtiness, too acid
Moderate - depth to bedrock, rock fragments
Revegetation Potential: Poor - slope, depth to bedrock, rock fragments, too acid
Fair - shrink-swell, too sandy
Surfaced Roads Limitations: Severe - slope, depth to bedrock, large stones
Moderate - shrink-swell, frost action, low strength
Unsurfaced Roads Limitations: Severe - too stony
Moderate - slope
Slope Stability Hazard: Low
Debris Flow Hazard: Low

Chapter 3 - Existing Vegetation Condition
Module 3A - Forests and Woodlands

Objectives

A description of the current composition, structure, function, and spatial distribution of the vegetation, by major cover type, of the assessment area is presented in this chapter. Emphasis will be on ecosystem structure and composition due to limited information on ecological function. We had to rely on current inventory data to the extent they were available. An evaluation of the current condition in the context of what is known about the historic range of variation is included and the description is organized by major vegetation types.

Introduction

The forest and woodland vegetation types described in this Module include spruce/fir (*Picea engelmanii-Abies lasiocarpa*), lodgepole pine (*Pinus contorta*), aspen (*Populus tremuloides*), Douglas-fir (*Pseudotsuga menzeisii*), ponderosa pine (*Pinus ponderosa*) forests, limber pine (*Pinus flexilis*) forests and woodlands, and juniper (primarily *Juniperus osteosperma*) woodlands. Forests and woodlands associated with riparian or wetland ecosystems are not addressed here but are discussed in the Aquatic, Riparian, and Wetland Ecosystem Assessment for the Bighorn National Forest (Winters *et al.* 2004). See Module 5A for a description of the landscape patterns of forest and woodland cover types as a whole.

Module 3A consists of a detailed description of each of the above forest and woodland cover types. The following information is presented, where available, for each forest type (data are those collected for the BNF; not all information is available for every forest type):

- *Composition:* Distribution and description, characteristic dominate species and associations, successional characteristics, changes in species composition or departures from HRV.
- *Structure:* Stand age and diameter-class distributions, Habitat Structural Stage descriptions and distribution, stand density, old-growth/older forest characteristics, stand structural components, (i.e., snags, coarse woody debris characteristics, canopy cover, vertical complexity), and changes in structure or departures from HRV.
- *Function*: Biomass, productivity, and habitat characteristics, cycling and storage of carbon and nutrients.
- *Natural disturbances:* Important natural disturbances specific to that forest type on the BNF.

Existing vegetation is described using primarily common vegetation unit (CVU) maps, GAP land cover types for Wyoming (Merrill *et al.* 1996) and Montana (Fisher *et al.* 1998), and a series of studies found in the ecological literature (Despain 1973). Where data for a given vegetation type are lacking for the Forest, a general description of the expected patterns for the type is given based on the literature. Structure and age data are from the Bighorn National Forest inventory. No inventory exists for old-growth forests so information presented on old-growth or older forests, based here on use of HSS data, is limited by the lack of inventory. This information should be considered tentative and would be strengthened by inventories of old-growth forest condition and distribution.

Discrepancies between data sets, particularly as reflected in the extent of each forest type, are due in part to the means of data collection and summary in differing databases. For example, the Wyoming GAP project (Merrill *et al.* 1996) provides a statewide vegetation map derived from 30-m satellite imagery, while the Forest-wide CVU maps were interpreted from aerial photographs. Thus differences between the "GAP" mapping versus the CVU mapping presented in this assessment may be attributed to interpretation at different scales and at different resolutions, and do not imply errors in the report.

Spruce/Fir Forest

<u>Composition</u>

Spatial Distribution

Engelmann spruce-subalpine fir forests are the second most dominant cover type (236,330 acres/95,640 ha) in the Big Horn Mountains (Table M3A-1). It consists of forests where Engelmann spruce and/or subalpine fir dominates the canopy, and total canopy cover exceeds 25% (see Region 2 IRI-CVU protocols). Spruce/fir forests occur across most of the BNF, most often on cool, mesic, north-facing slopes between 7,500 and 10,000 feet (2,300 and 3,000 m; Fig. M3A-1), often on alfisols (Nesser 1986); the lower spruce/fir forests typically occur in cold-air drainages. Spruce/fir forests also occur in riparian areas as well as upland conifer forests, and may be mixed with other coniferous forests at the upper montane zone.

Despain (1973) lists several factors that influence the distribution of spruce/fir forests in the Big Horn Mountains. They are found at the highest elevations, and along the fringes of timberline around the highest granite peaks where increased precipitation ameliorates poor, granitic substrate conditions. The cover type is best developed in the northern portion of the Big Horn Mountains, where the mean precipitation (mainly water content of snow in early May) is highest. Spruce/fir is typically found in the Big Horn Mountains on sedimentary substrates on the west flank of the range, and on granitic substrates only at high elevations.

Table M3A-1. CVU forest types in the Bighorn National Forest.

CVU Forest Type	Acres	Hectares	
Lodgepole Pine	359,354	145,426	46%
Spruce/Fir	236,330	95,640	30%
Douglas-Fir	113,198	45,810	14%
Ponderosa Pine	37,324	15,105	5%
Aspen/Cottonwood	12,746	5,158	2%
Juniper	6,308	2,553	<1%
Limber Pine	16,235	6,570	2%
TOTALS	781,496	316,262	100%

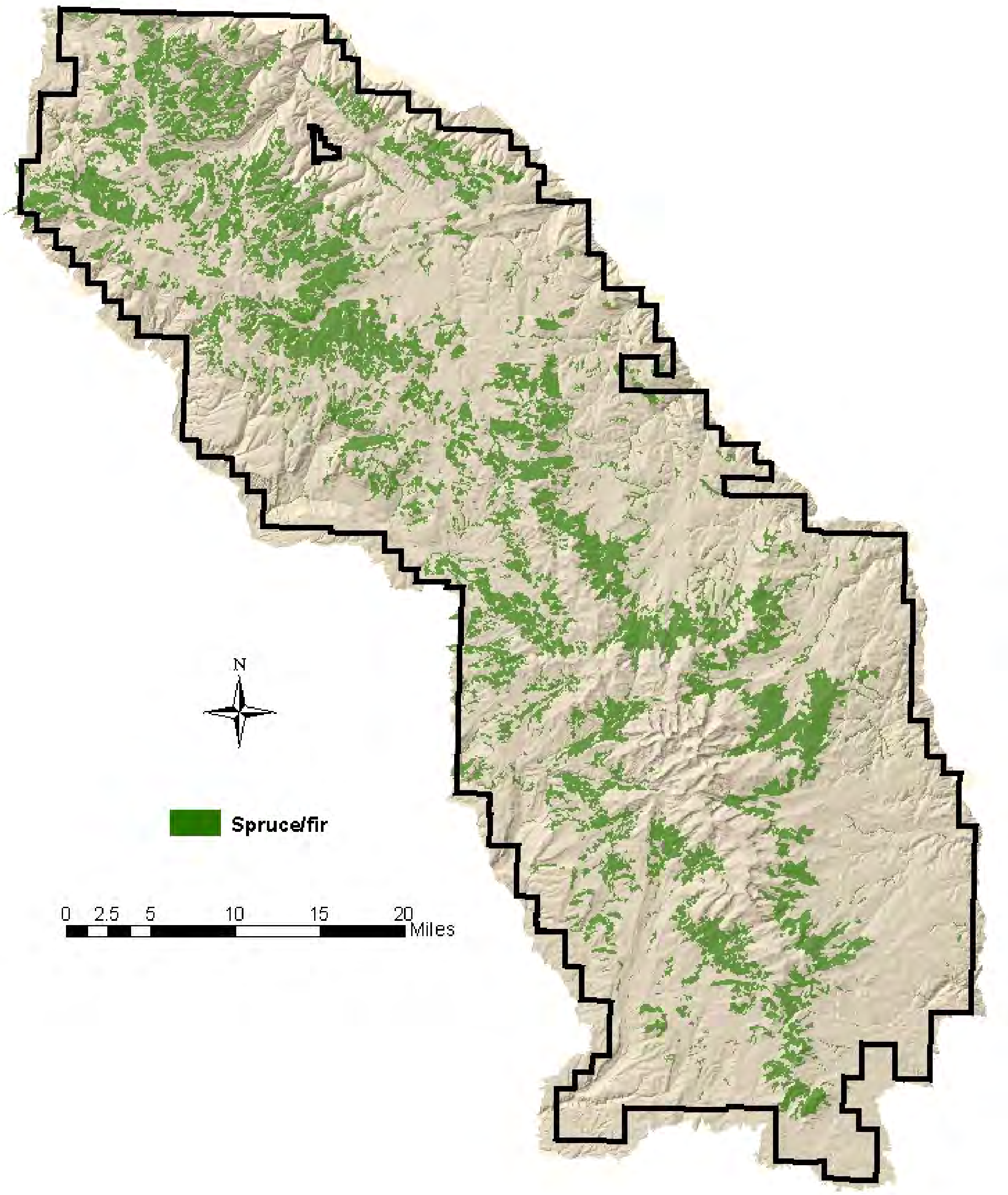


Figure M3A-1. Geographic distribution of spruce/fir forests in the Bighorn National Forest (CVU database).

Hoffman and Alexander (1976) differentiate between Engelman spruce and subalpine fir forest cover types, although they note that Engelmann spruce is a "co-climax dominant" with subalpine fir in the Big Horn Mountains, with little evidence of replacement by subalpine fir. The ecology and distribution of these two dominant forest species are so intertwined that the existing vegetation condition discussion in this Module will focus on the spruce/fir forest.

White spruce (*Picea glauca* (Moench) Voss) also occurs occasionally in the Big Horn Mountains (Nelson and Hartman 1984), but will be used interchangeably with Engelmann spruce in this Module for several reasons. First, relatively few studies have documented its distribution in the Big Horn Mountains. More importantly, white spruce hybridizes with Engelmann spruce, often making their differentiation difficult (Hoffman and Alexander 1976). Additional investigation of the abundance and distribution of white spruce in the Big Horn Mountains is needed.

The Characteristic Dominant Species and Associations

Hoffman and Alexander (1976) identified four habitat types dominated by either Engelmann spruce or subalpine fir (Table M3A-2). They include *Picea engelmannii/ Vaccinium scoparium,* which includes spruce as the major dominant and *Abies lasiocarpa/Shepherdia canadensis*, *A. lasiocarpa/Vaccinium scoparium*, and *A. lasiocarpa/Arnica cordifolia*, each of which feature spruce and fir as co-dominants. All four-habitat types consider lodgepole pine to be a seral species, and Douglas-fir to be a seral species in some stands.

Table M3A-2. Habitat types identified by Hoffman and Alexander (1976) for spruce/fir forests in the Big Horn Mountains. C = major climax species, S = seral, and s = seral in some stands.

Habitat type	Douglas-fir	Lodgepole pine	Engelmann spruce	Subalpine fir	Important species
P. engelmanni/ Vaccinium scoparium	s	S	C		*Juniperus communis, Antennaria racemosa, Arnica cordifolia, Epilobium angustifolium, Fragaria virginiana, Lupinus argenteus, Rosa acicularis, Senecio strepthanthifolius, Poa nervosa*
A. lasiocarpa/ Shepherdia Canadensis	s	S	C	C	*Juniperus communis, Berberis repens, Linnaea borealis, Spiraea betulifolia, Rosa acicularis, Pyrola secunda, Arnica cordifolia*
A. lasiocarpa/ Vaccinium scoparium	s	S	C	C	*Poa nervosa, Antennaria racemosa, Arnica cordifolia, Epilobium angustifolium, Lupinus argenteus, Fragaria virginiana, Potentilla diversifolia, Pyrola secunda*
A. lasiocarpa/ Arnica cordifolia	s	S	C	C	*Ribes lacustre, Poa nervosa, Antennaria racemosa, Allium brevistylum, Arnica latifolia, Epilobium angustifolium, Fragaria virginiana, Galium boreale, Lupinus argenteus, Moneses uniflora, Pyrola secunda, Thalictrum occidentale*

Despain (1973) also listed understory species he observed in spruce/fir forests in the Big Horn Mountains. These included: *Cladonia* spp., *Peltigera* spp., *Pyrola secunda, Arnica cordifolia, Arnica latifolia, Vaccinium scoparium, Epilobium angustifolium, Luzula parviflora, Carex* spp., *Frageria virginiana, Antennaria racemosa*, and *Gallium boreale*. Despain also noted that lichens and mosses consistently accounted for 20-30% of all ground cover. *Juniperus communis*, various gooseberry species (*Ribes* spp.), *Potentilla diversifolia*, and *Orthilia secunda* are also important (Hoffman and Alexander 1976).

Successional Characteristics

The site factors necessary for Engelmann spruce regeneration have been studied extensively in the Rocky Mountains. Alexander and Shepperd (1984) and Alexander *et al*. (1984) noted that subalpine fir is slightly more shade-tolerant than Engelmann spruce; 40-60% shade favors spruce establishment and >50% shade typically favors fir. Considerable attention has been given to the dynamic complexity of spruce/fir forests, and particularly to how Engelmann spruce maintains its co-dominance despite the prolific reproduction and slight advantage in shade tolerance of subalpine fir (Knight 1994). This co-dominance has been largely attributed to the fact that subalpine fir has a shorter lifespan, especially because it is susceptible to a host of insects and diseases (Veblen 1986).

Aplet *et al*. (1988) have proposed the following model of spruce/fir co-dominance:

> "*Following a stand-replacing disturbance, the site is colonized by both spruce and fir. After 100-200 years, spruce no longer establish in the understory. In an additional 100 years, the dominant overstory cohort begins to senesce, creating canopy gaps and favorable conditions for spruce re-initiation. A second-generation spruce/fir forest then develops and persists until the next stand-replacing disturbance*."

The overstory may be dominated by lodgepole pine in younger spruce/fir potential stands, but late-successional stands are characterized by Engelmann spruce being dominant or co-dominant with decadent lodgepole pine. Lodgepole pine often is present as a seral species on granitic parent materials, while on limestone Douglas-fir is often seral (Welp et al. 2000). Aspen is also a common seral species. Seral trees persist for long times in many spruce/fir stands, and the overstory may be a mix of early- and late-successional species. As Knight (1994) notes, these spruce/fir forests probably are changing slowly after past disturbance rather than acting as stable communities.

Changes in Species Composition/Departures from HRV

Although compositional changes are difficult to determine in the context of HRV, most compositional changes in spruce/fir forests are likely the result of natural successional processes. The extent of predictable compositional changes may be estimated by comparing current vegetation (CVU) to potential natural vegetation (PNV). For example, of the 466,464 acres (188,772 ha) considered to have the potential to be spruce/fir forest, 47% is indeed currently spruce/fir forest, 42% is lodgepole pine, 8% is currently Douglas-fir, and 1% is aspen. Except for Douglas-fir forests, Stahelin (1943) identifies each of these forest types as potential seral stages of spruce/fir. Hoffman and Alexander (1976) include Douglas-fir forests as a seral stage.

<u>Structure</u>

Stand Age and Diameter Class Distributions

Engelmann spruce is the largest high-elevation species in the Big Horn Mountains. Trees may reach 45 in (114 cm) in diameter, although average diameters are typically 20-25 in (51-64 cm). Engelmann spruce is long-lived, averaging approximately 300 years maximum age. Dominant spruce may be 250 to 450 years old while 500- to 600-year-old Engelmann spruce are not uncommon (Alexander 1987). Spruce up to 550 year old are found on the BNF near Powder River Pass. Subalpine fir in the Big Horn Mountains range from scrubby, krummholz forms at treeline (Knight 1994) to closed forest conditions with diameters up to 20-24 in (51-

61 cm) (Alexander 1987). Subalpine fir may live for 300 years (Aplet *et al*. 1988), but mortality typically occurs in the 125- to 175-year-old age classes, often due to susceptibility to insects and diseases (Schmid and Hinds 1974, Veblen 1986).

Despain (1973) characterized the spruce/fir forests of the Big Horn Mountains as well-spaced, ranging from 240-273 trees/acre (592-675 trees/ha). Individuals in these forests are fairly large, ranging from 15-26 in (38-66 cm) in diameter. Engelmann spruce are much larger in diameter than subalpine fir, exhibiting an average basal area six times that of subalpine fir (37.6 m^2/ha or 163.8 ft^2/acre vs. 6.6 m^2/ha or 28.7 ft^2/acre) although the two species are similar in density in these forests. Engelmann spruce exhibits a normal or bell-shaped size class distribution, with a modal size between 12 and 16 in (31 and 41 cm). In contrast, subalpine fir contains many smaller individuals, with few individuals greater than 15 in (38 cm) in diameter. Fir saplings are on average ten times greater in number than spruce saplings (Despain 1973). Although there are some discrepancies between methodologies, data collected on the BNF since Despain's research reveals similar stand structural characteristics (Table M3A-3).

Table M3A-3. Stand structural characteristics for spruce/fir stands within three LTAs in the Bighorn National Forest.

	M331-Ba03	M331-Ba05	M331-Bb05
	6 plots/SF/large	3 plots/SF/large	7 plots/SF/large
Age (years)	163	160	149
Height (feet)	49	57	45
Quadratic mean diameter	71	78	63
Basal area (ft^2/acre)	164	160	120
Total density (trees/acre)	2915	3034	1208
Tree density, >5" DBH (trees/acre)	240	184	212
Hard snags per acre	53	58	47
Soft snags per acre	0	2	3

Habitat Structural Stages

Habitat Structural Stages (HSS) provide a coarse-filter look at habitat provided by forests, and provides an indication of forest size and density that can be interpreted for wildlife habitat suitability (Hoover and Wills 1987). Structural stages describe the developmental stages of tree stands in terms of tree size and canopy closure, and may approximate the succession of a forest stand from regeneration to maturity. Habitat Structural Stages include four categories: grass/forb (Stage 1), shrub/seedling (Stage 2), sapling/pole (Stage 3), and mature (Stage 4). The letter corresponding to each stage (a, b, or c) represents the degree of canopy closure, with "c" being most closed. Habitat Structural Stages 1T and 2T represent forest stands that were recently disturbed and are in a "temporary" grass/forb structural stage.

In general, spruce/fir forests of the BNF are typically pole-sized or mature with closed-canopies (Fig. M3A-2). Approximately 84% of the spruce/fir forests on the BNF are classified as Stages 3B, 3C, 4B, or 4C, suggesting that relatively few stand-replacing disturbances have occurred in the past 1-2 centuries in this forest type, or at least that such disturbances have not been extensive. Much of the Stage 4 spruce/fir forest is found at the lower elevations within the spruce/fir zone (Fig. M3A-3). This suggests that the smaller size of individuals in Stage 3 spruce/fir forests may reflect the harsher climate, shorter growing season, and less productive sites at higher elevations rather than stand age.

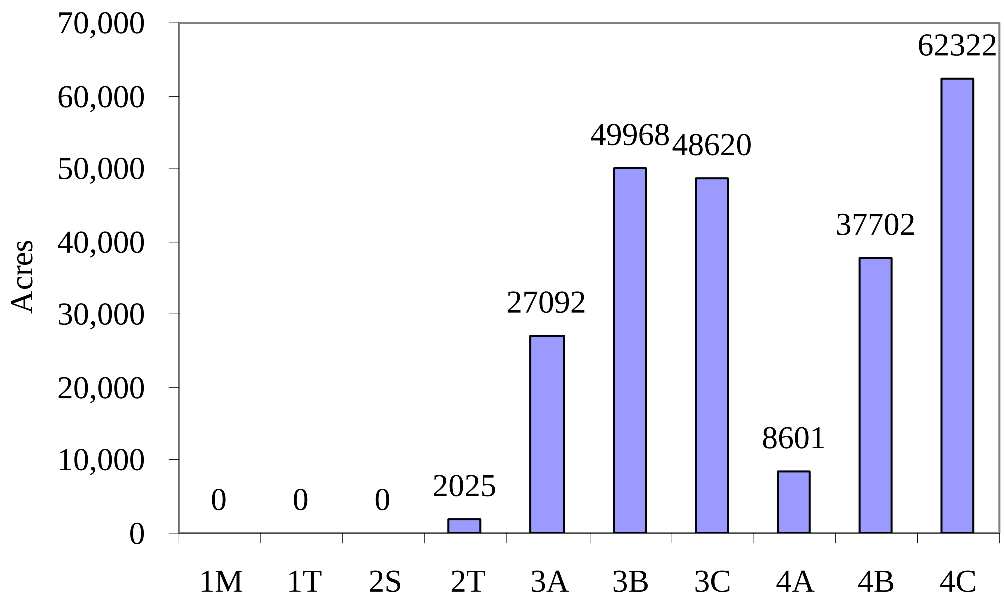


Figure M3A-2. Acres of spruce/fir forests in each Habitat Structural Stage on the Bighorn National Forest.

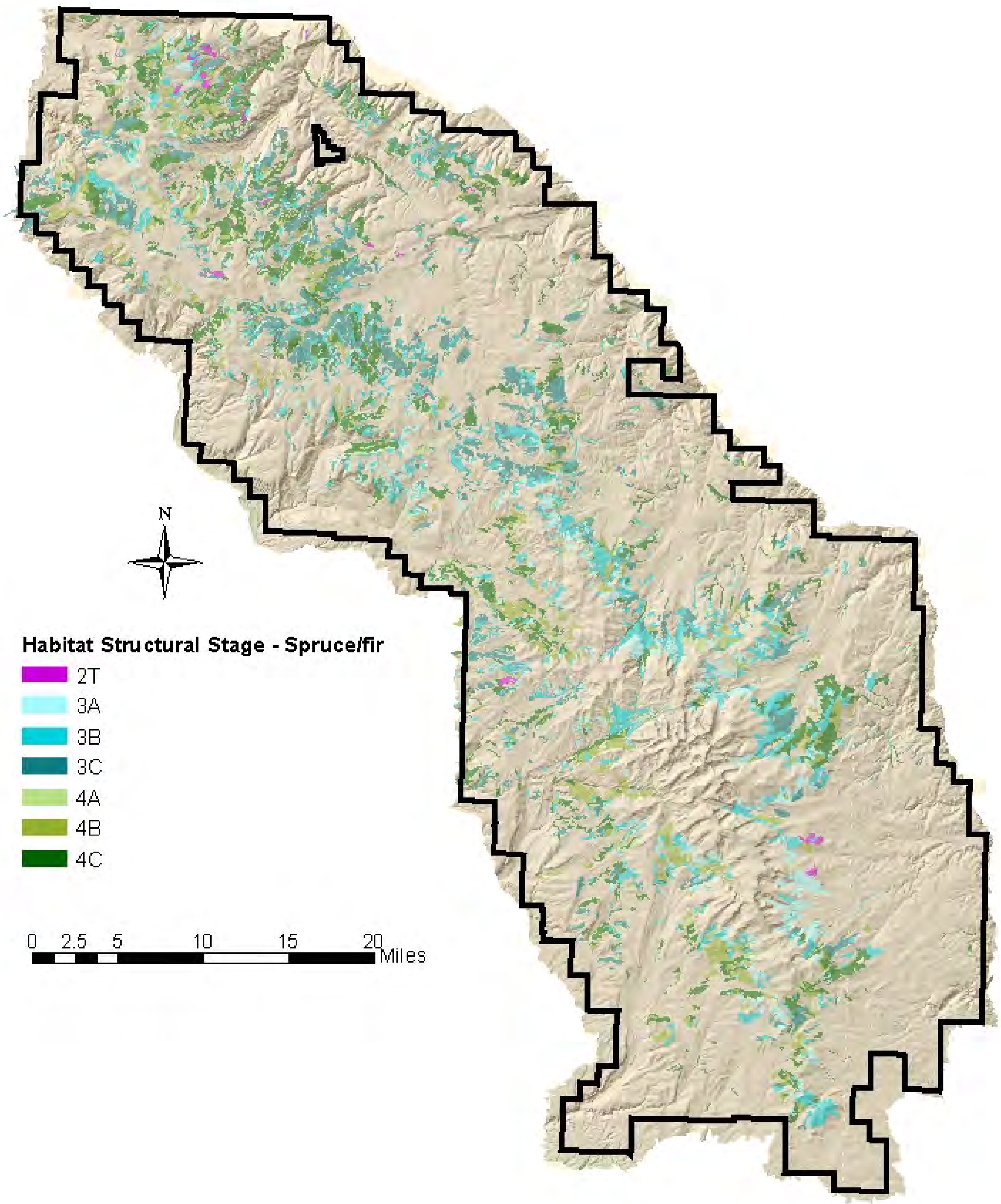


Figure M3A-3. Location of Habitat Structural Stages of spruce/fir forests in the Bighorn National Forest (CVU database).

Stand Density

Despain noted stand densities in the Big Horn Mountains range from 592 to 675 trees/ha (240 to 273 trees/acre) for trees > 4" DBH. Similarly, densities of spruce/fir forests aged 149-163 years in three LTAs in the Section (M331-Ba-03, M331-Ba-05, M331-Bb-05) averaged 524 trees/ha (212 trees/acre) for trees >5" DBH, and ranged from 2,985 to 7,497 trees/ha (1,208 to 3,034 trees/acre) when all trees are included. When considered by habitat structure stage for trees >5" DBH, densities of spruce/fir forests on the BNF average 378 trees/ha (153 trees/acre) in Stage 4A, 509 trees/ha (206 trees/acre) in Stage 4B, and 1,060 trees/ha (429 trees/acre) for Stage 4C. Currently, data describing the spatial variability of tree densities across the Forest are not available.

Old-Growth/Older Forest Characteristics

Old-growth characteristics are difficult to determine, since the definition of old-growth varies throughout the literature. For example, Franklin and Spies (1991) describe old-growth forests as having large live trees, large snags, and large amounts of coarse woody debris. Oliver and Larsen (1996) define old-growth as the point in the development of the stand when the original cohort has been replaced in the absence of stand-replacing disturbance. In any case, Mehl (1992) suggests that spruce/fir forests approach an old-growth stage at approximately 300 years, but many individuals may be only 200 years old. In this instance, canopy mortality is high, multiple canopy layers exist, understory trees begin to penetrate gaps, and large amounts of coarse woody debris have accumulated.

Accurate stand origin data exist for approximately half of the spruce/fir forests on the BNF. Given this lack of stand origin data, approximately 15% of the spruce/fir forests on the Forest is known to be 200 years or older, with only 1% known to be 300 years or older (Fig. M3A-4). At least 37% are 100 to 240 years old.

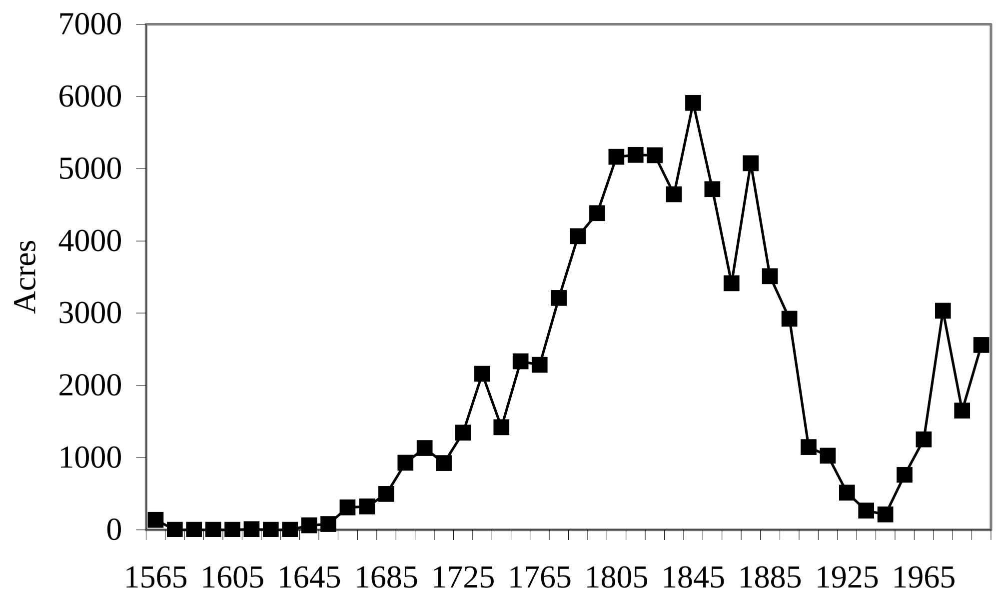


Figure M3A-4. Stand origin dates for spruce/fir forests on the Bighorn National Forest. Only 50% of the area of spruce/fir forest on the BNF is represented.

Stand Structural Components

Snags—As with coarse woody debris, snag structural characteristics in spruce/fir forests should be expected to vary with stand age and time since disturbance. Every type of natural disturbance with the exception of wind naturally creates snags. For example, several hundred snags per acre are likely present in the first few decades following a stand-replacing fire. Far fewer are likely to be present in a young, aggrading forest as the original snags fall, and few snags will be present until mortality occurs in the aging stand. Currently, snag densities are only notable in Habitat Structural Stages 3 and 4 (Figure M3A-5). Snag density is highest where trees are largest and canopy closure is highest (Stages 4B and 4C), possibly because increased competition from neighboring tree canopies increases the susceptibility of an individual tree to mortality (Barnes *et al.* 1998).

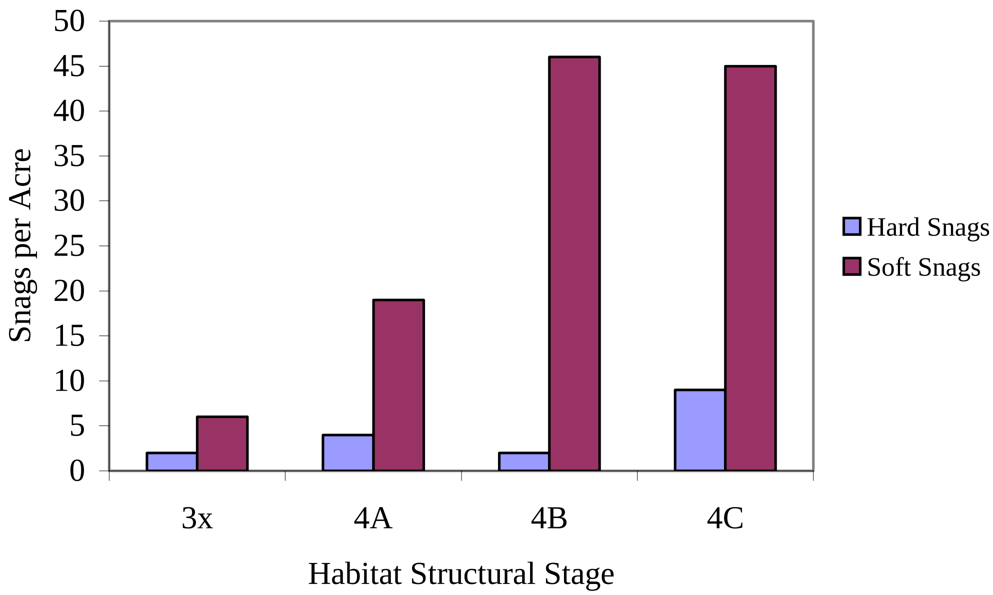


Figure M3A-5. Snag density in spruce/fir forests in the Bighorn National Forest.

Coarse Woody Debris—The expected range of coarse woody debris for spruce/fir forests on the BNF is difficult to estimate without accurate inventory data. Coarse woody debris mass should be expected to be high 50-100 years following a stand-replacing disturbance, to decrease as decomposition reduces fallen snags to soil wood, and then to increase again with stand age (Meyer and Knight 2003). Despain (1973) noted that in mature spruce/fir stands in the Big Horn Mountains, " . . .much deadfall makes moving through them quite laborious." Graham *et al.* (1994) suggested that 16.5 to 32.9 Mg/ha of coarse woody debris represented a natural range in the *A. lasiocarpa/Vaccinium scoparium* habitat type. More research and data collection are needed to describe the existing condition of coarse woody debris in spruce/fir forests of the BNF.

Canopy Cover—At the scale of the BNF, 47% of the spruce/fir forests (111,201 acres/45,001 ha) exhibit canopy cover of >70%, approximately 38% exhibit canopy cover between 40 and 70%, and 15% have sparse canopy coverage of <40%. Canopy coverage is lowest at the highest elevations in the southern half of the BNF, where stand density is lowest and trees rarely form closed-canopy stands (Fig. M3A-6). In contrast, spruce/fir forests with the heaviest canopy cover tend to be in the northern half of the BNF. These forests correspond with those Despain (1973) described as being "best developed".

At the stand level, spruce/fir forests, like most coniferous stands that develop after fire, are naturally patchy in terms of tree density. Patchiness is typically high immediately following stand initiation, as seedlings colonize a recently disturbed site. Patchiness decreases and tree distribution becomes more random as seedlings begin to mature and density-dependent competition ensues. Because within-stand disturbance events typically occur at the scale of individual trees in mature spruce/fir forests, patchiness again increases as regeneration occurs in canopy gaps following individual tree mortality.

Vertical Complexity—Canopy structure is the organization of aboveground components of vegetation in space and time (Parker 1995, Norman and Campbell 1989). By modifying the availability of energy (Yoda 1974, Parker *et al.* 2002), water (McCune and Boyce 1992), and nutrients (Parker 1983, Heath and Huebert 1999), as well as environmental conditions such as temperature (Shaw and Pereira 1982), and wind speed (Fitzjarrald *et al.* 1990, Daudet *et al.* 1999), canopy structure creates a variety of microhabitats, a range of microclimates, places to hide from predators, and so on (Begon *et al.* 1996). The greater the number of canopy strata (e.g., emergents, overstory, midcanopy, understory, ground layer, etc.), the greater the modification of resources and environmental conditions, resulting in vertical complexity. Forest inventory data do not provide information on the vertical complexity of forests. Spruce/Fir forests are typically uneven-aged and contain a large amount of regeneration. Despain (1973) noted that most seedlings (usually subalpine fir) were at least 25 cm (10 in) high and very numerous in the Big Horn Mountains. In general, however, the understory of spruce/fir forests in the Big Horn Mountains is sparse. Shrub layers may include *Juniperus communis, Ribes lacustre,* or *R. montigenum*, but they typically provide less than 1% coverage. Data on vertical complexity are needed for spruce/fir forests of varying density, age, and productivity.

Changes in Structure/Anthropogenic Influences/Departures from HRV

The primary human influence on spruce/fir stand structure is timber harvesting. Fire suppression and exclusion are likely not important stand scale factors in high-elevation forests such as spruce/fir that are characterized by stand-replacing crown fires (Romme and Despain 1989). Furthermore, grazing typically is not important or common in high-elevation forests.

Portions of the BNF harvested under Forest Service management comprise less than 9% of the forest areas as a whole; less than 7,100 ha (17,500 acres) of spruce/fir forest have been affected by timber harvesting. Though relatively low in area, harvesting has affected a larger area of spruce/fir forest than either fire (5,300 acres/ 2,150 ha) or wind (1,100 acres/ 430 ha) over the last 40 years. Since the 1960s, shelterwood preparation cuts, seedcuts, and clearcuts have been the most common timber harvesting activities, all of which peaked in the 1980s and have since declined (Figure M3A-7).

Effects of timber harvesting on stand structure in high-elevation forests depends on the silvicultural activity. To some extent, clearcutting mimics the effects of a stand-replacing fire in spruce/fir forests. Although post-disturbance regeneration and seedling density may differ from those resulting from natural disturbances, they do appear to be within the HRV (Meyer and Knight 2003). Thinning treatments reduce the density of forest stands, though the thinning goal of 750 trees/ha (300 trees/acre) in the BNF is considered to be within the HRV (Meyer and Knight 2003). Thinning and selective harvesting tend to reduce percent canopy cover below the HRV. Shelterwood cutting also creates canopy gaps not typical of natural disturbances.

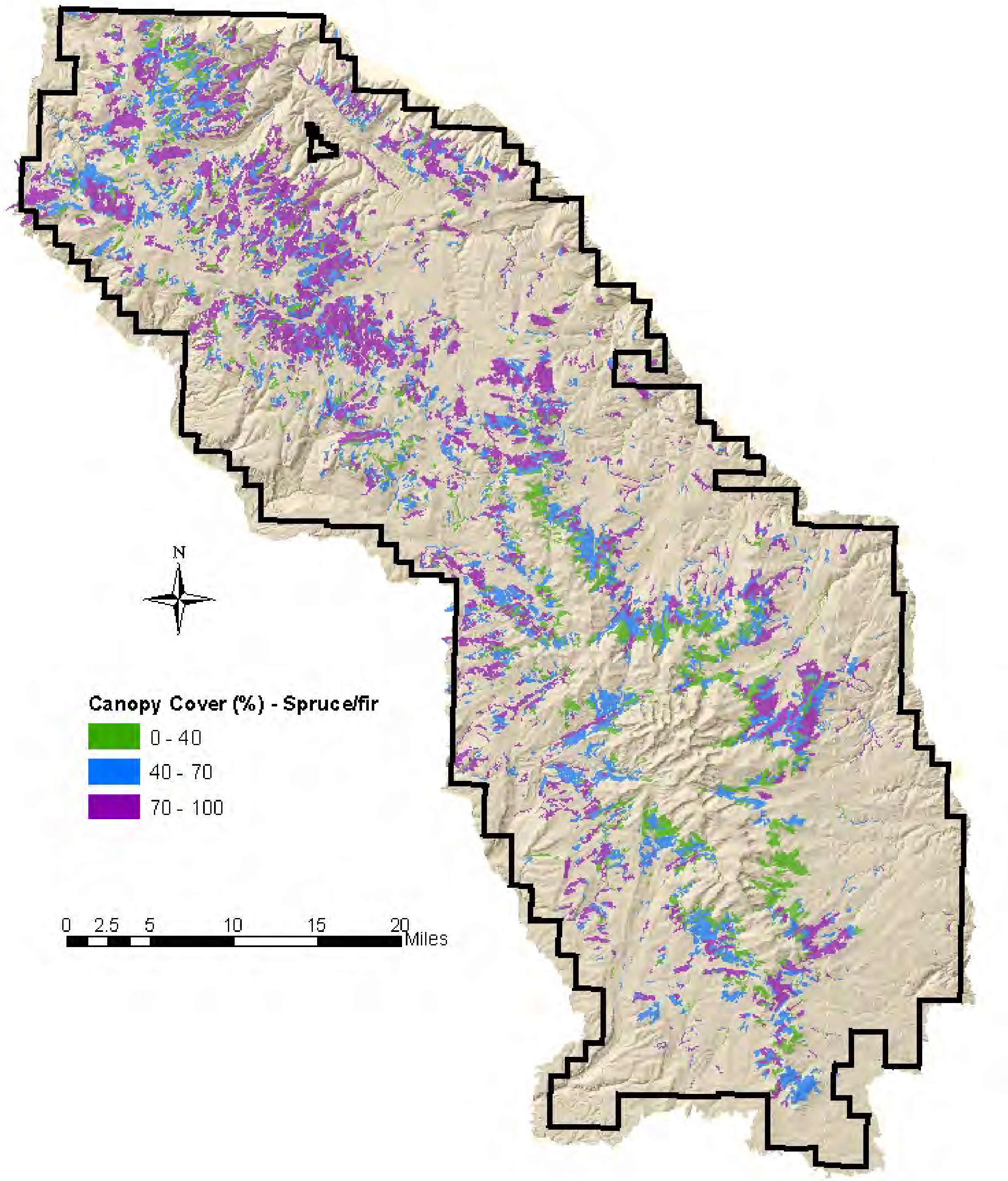


Figure M3A-6. Percent canopy coverage for spruce/fir forests on the Bighorn National Forest (CVU database).

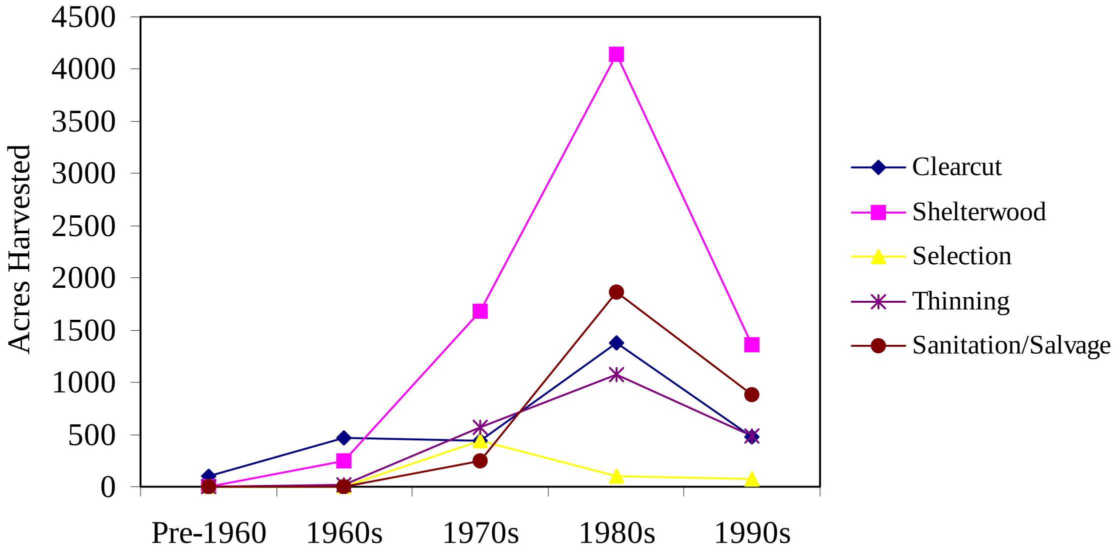


Figure M3A-7. Summary of timber harvesting activities in spruce/fir forests on the Bighorn National Forest since the 1960s.

It is important to note that timber harvesting may create legacies at the stand and landscape scales that persist for centuries. For example, timber harvesting since the 1800s has converted forested areas of large, old trees to stands of younger, smaller trees. Thus, the age and size-class structures of many areas on the BNF may lie outside the HRV. Landscape patterns due to harvesting are described in detail in Modules 4B and 5A.

<u>Function</u>

Virtually no functional information has been collected specifically for the spruce/fir forests of the BNF. Although a brief description of functional characteristics of spruce/fir forests follows for northern Colorado, they could differ significantly for forests even in close proximity.

Biomass and Productivity Characteristics

In spruce/fir forests of north-central Colorado, Arthur and Fahey (1992) measured total ecosystem biomass as 42 kg/m^2 (8.4 lbs/ft^2), divided approximately evenly among soil organic matter, detrital biomass (including deadwood and forest floor), and living biomass. Total forest biomass (not including soil organic matter) was 28.9 km/m^2 (5.8 lbs/ft^2), of which root biomass was only 11%. Net primary production (NPP) was 520 g/m^2/yr (0.1 lbs/ft^2/yr), of which fine root production was about 27% and foliar production was 30% (Arthur and Fahey 1992). For older (>200 years) spruce/fir forests in Rocky Mountain National Park, Binkley *et al.* (2003) found aboveground tree biomass to average 253 Mg/ha (688 tons/acre), and aboveground NPP as 3,700 kg/ha/yr (20,206 lbs/acre/yr). Larger trees (>35 cm or 14 in. in diameter) accounted for 70% of aboveground biomass, but smaller trees contributed 70% of the production of woody biomass. Across these older stands, stands with greater biomass showed higher rates of both ANPP and resource use (Binkley *et al.* 2003).

Cycling and Storage of Carbon and Nutrients

In spruce/fir forests of north central Colorado, Arthur and Fahey (1992) noted that much more nitrogen was recycled via fine root turnover (1.6 g/m^2/yr, or 0.02 lbs/ft^2/yr) than aboveground litter fall (0.9 g/m^2/yr or 0.01 lbs/ft^2/yr), whereas four times more calcium was returned via litter fall than from fine roots. Nutrient resorption proved a higher percentage of the annual nitrogen requirement; this forest used nitrogen less efficiently (and was less productive) than a similar forest in southwestern Alberta (Arthur and Fahey 1992).

Natural Disturbances

Fire is the most important natural disturbance shaping the stand and landscape structure of spruce/fir and other high-elevation forests in the Big Horn Mountains. In similar forests in the boreal zone, Johnson (1992) noted that primarily extensive but infrequent stand-replacing fires characterize spruce/fir forests. In the BNF, Meyer and Knight (2003) estimated the fire-free interval to range from 150 to 700 years. The BNF has not had fires totaling more than 8,100 ha (20,000 acres) since the early 1900s (see Module 4A for greater detail on fire history). Though it is characterized by large, stand-replacing fires, only 2,150 ha (5,300 acres) of spruce/fir forests have burned on the BNF since the 1950s.

Wind is also an important natural disturbance in spruce/fir and other high-elevation forests. The effects of wind on forests are highly variable, in that they may blow down only a few trees, or they may destroy stands over thousands of acres (Alexander 1987). Nine blowdowns in the BNF between 1955 and 1998 affected approximately 1,900 ha (770 acres) and averaged 211 hectares (85 acres) in size. The return interval for wind in the BNF is not clear (Meyer and Knight 2003).

The most prominent insect threat to spruce/fir forests in the Big Horn Mountains is the spruce beetle (*Dendroctonus rufipennis*). Spruce beetle outbreaks associated with blowdowns were discovered in the Big Horn Mountains in the 1970s and 1980s. Spruce beetles are currently at endemic levels, but several moderately large pockets of spruce mortality occurred near a blowdown area at Little Big Horn (Harris *et al*. 1998). The Little Big Horns is currently the highest risk area for spruce beetle outbreak in the Big Horn Mountains.

"Fir decline" is widespread thoughout the spruce/fir forests of the Rocky Mountains, but subalpine fir in the Big Horn Mountains currently experiences the highest level of mortality in the Rockies. Fir decline is caused by a combined effect of the western balsam bark beetle (*Dryocetes confuses*) and root pathogens, likely either *Armillaria* spp. or *Annosus* spp. (Harris *et al*. 1998). Fir decline has been known to be active in Rocky Mountain forests since at least 1965 (Schmid and Hinds 1974), and is now considered to be at outbreak level throughout the Big Horn Mountains.

Summary of Key Findings for Spruce/Fir Forest Type

- Spruce/fir forest is the second-most common forest type on the Bighorn National Forest, and occupies 236,330 acres (95,639 ha) at the highest elevations on the landscape.

- The co-dominance of Engelmann spruce and subalpine fir is the result of the shorter lifespan of fir, which allows spruce to occupy gaps and persist for many years in the canopy.

- Most spruce/fir forests on the Bighorn National Forest are pole-sized or mature, closed canopy forests between 100 and 240 years old.

- Timber harvesting may have a variety of effects on spruce/fir stand structure that are outside the historical range of variability, but fewer than 7,100 ha (17,500 acres) of spruce/fir forest have been affected by timber harvesting over the past 40 years.

- Fire is likely the dominant force shaping the structure of spruce/fir forest in the Big Horn Mountains, but relatively few acres have burned over the past century. Insect outbreaks appear to be the current mode of natural disturbance affecting this forest type today.

Lodgepole Pine Forest

Composition

Spatial Distribution

Lodgepole pine is the most common tree species (359,354 acres/145,426 ha) in the Big Horn Mountains. It is found throughout the upper montane and subalpine forest zones on a variety of topographic positions (Despain 1973, Hoffman and Alexander 1976, Reid *et al.* 1999), typically on soils classified as inceptisols or alfisols (Nesser 1986). It consists of nearly pure stands where canopy coverage exceeds 25% (see R2 IRI-CVU protocols) at elevations between 2,100 m (6,600 ft) and timberline at 2,900 m (10,000 ft) (Hoffman and Alexander 1976).

Lodgepole pine forests are common in the central third of the Big Horn Mountains and on the southern half of the BNF, where stands are nearly continuous and occur on most granitic soil (Fig. M3A-8). Further north, small stands of lodgepole pine occur in isolated areas within expanses of spruce/fir forests on sedimentary-derived soils (Despain 1973). Small stands also occur in the northern third (on granite outcrops or Flathead sandstone) and the southern third (on granite or Tensleep sandstone). Lodgepole pine is usually absent on limestone and dolomite substrates (Despain 1973, Steele *et al*. 1983, Pfister *et al*. 1977).

The Characteristic Dominant Species and Associations

Hoffman and Alexander (1976) identified two habitat types dominated by lodgepole pine (Table M3A-4): *Pinus contorta/Arctostaphylos uva-ursi* and *Pinus contorta/Vaccinium scoparium*, both of which feature lodgepole pine as the sole dominant species.

Despain (1973) noted that lodgepole pine stands in the Big Horn Mountains typically have very sparse understories, but may include Engelmann spruce, subalpine fir, and/or Douglas-fir saplings.

The undergrowth may include an open shrub layer, or it may consist of herbs. *Ribes lacustre* may form a shrub layer of less than 1% cover where conditions are more mesic, and *Juniperus communis* (1-2% cover) where conditions are drier. Other shrub species include *Vaccinium scoparium* and *Arctostaphylos uva-ursi*; *Vaccinium scoparium* is very common in open stands and is abundant in high cover. Hoffman and Alexander (1976) and Steele *et al.* (1983) also report stands in which *Shepherdia canadensis* forms a dense shrub layer. Herbaceous species include *Arnica cordifolia, Carex* spp., *Senecio streptanthifolius*, *Antennaria rosea,* and *Lupinus argenteus*. *Antennaria rosea* is also common but occurs only in scattered patches.

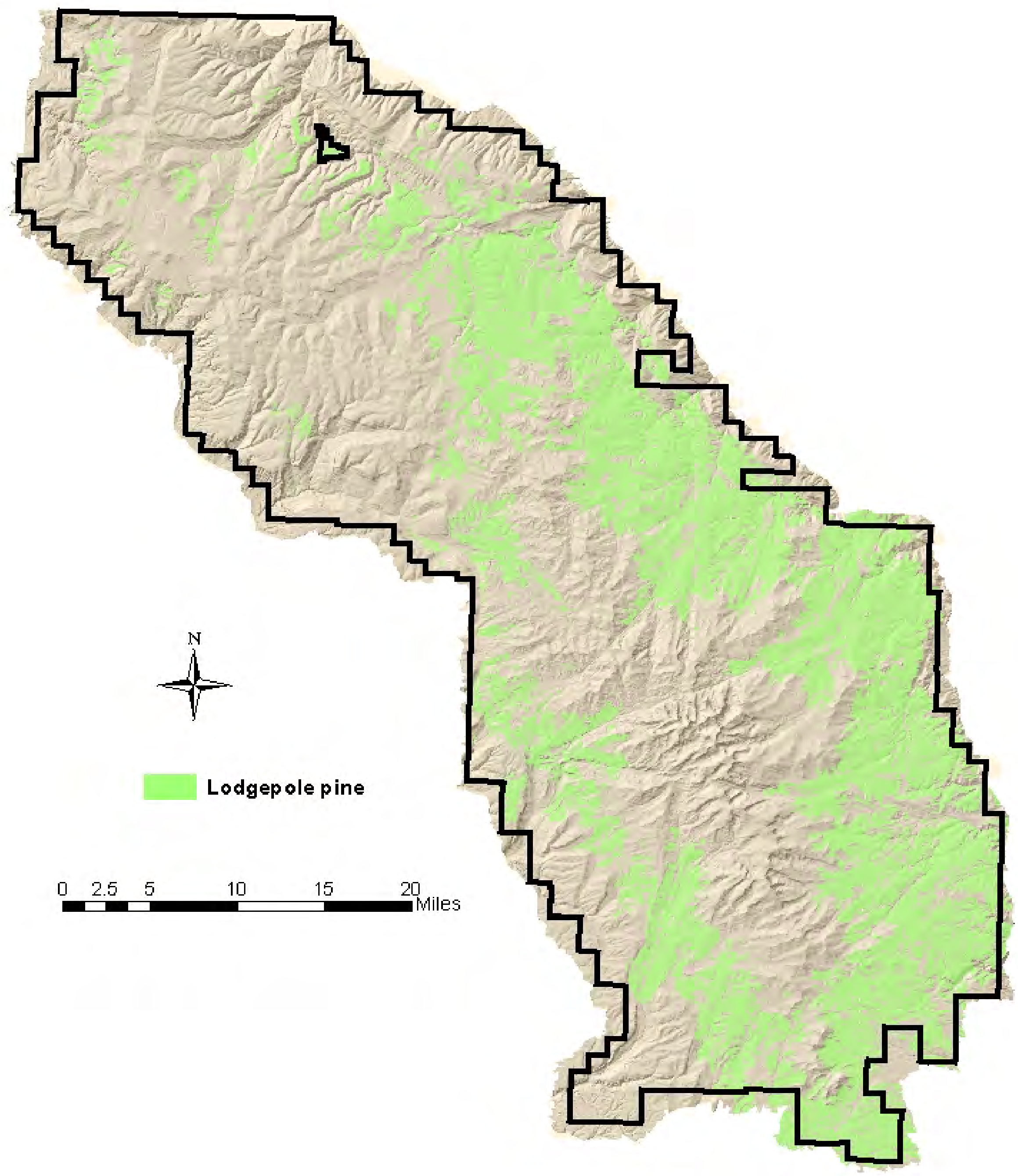


Figure M3A-8. Distribution of lodgepole pine on the Bighorn National Forest (CVU database).

Table M3A-4. Lodgepole pine habitat types identified by Hoffman and Alexander (1976) for the Big Horn Mountains.

Habitat type	Description	Important species
P. contorta/ Arctostaphylos uva-ursi	Warmest, driest, and most frequently burned lodgepole pine habitat type. Confined to soils of granitic origin with low fertility.	*Juniperus communis, Spiraea betulifolia, Lupinus argenteus, Senecio strepthanthifolius, Solidago spathulata*
P. contorta/ Vaccinium scoparium	Central third of the Big Horn Mountains on granitic soils, but more on mesic habitats than the *P. contorta/Arctostaphylos uva-ursi* habitat type.	*Poa nervosa, Antennaria rosea, Arnica cordifolia, Epilobium angustifolium,Poa interior, Trisetum spicatum,Rosa acicularis*

Successional Characteristics

The regeneration strategy of lodgepole pine may be the most interesting of any forest type in the Big Horn Mountains, mainly due to cone serotiny. Lodgepole pine produces viable seed at an early age, often 5 to 10 years, and is a prolific seed producer (Lotan and Critchfield 1990). Cones are persistent and often serotinous to such a degree that viable seeds may remain on mature trees for many decades or until the heat of a fire breaks the resinous bonds between the cone scales. As a result, lodgepole pine has long been regarded as a fire-dependent species because it commonly regenerates in very dense stands where the cones are highly serotinous. Tinker *et al.* (1994) found that serotiny varied from 0 to 60% across the landscape of Yellowstone National Park. The percentage of trees in a stand having serotinous cones thus has important consequences for immediate post-fire seedling densities, as well as long-term development of stand structure (Kashian 2002).

Lodgeole pine very often is found in pure or nearly pure stands, but Hoffman and Alexander (1976) and Jones and Ogle (2000) describe lodgepole pine as both seral and stable (i.e., climax) in the Big Horn Mountains. Where lodgepole pine forests are primarily seral, canopy dominance may be shared with the late-successional species. Houston (2001), as part of this assessment, estimated 214,000 acres (86,600 ha) of lodgepole pine to be seral within the Bighorn National Forest (Fig. M3A-9). Higher elevation, mesic sites have approximately 100,000 acres (40,500 ha) of lodgepole pine that is seral to subalpine fir, and 98,000 acres (39,700 ha) seral to Engelmann spruce. Lower elevation, xeric sites have 8,500 acres (3,450 ha) and 7,500 acres (3,050 ha) that are seral to Douglas-fir and ponderosa pine, respectively. Seral lodgepole pine is typically found as even-aged stands with a high proportion of serotinous cones, though serotiny may be highly variable in lodgepole pine (Tinker *et al.* 1994).

Stable stands of lodgepole pine can be found at intermediate elevations in the Big Horn Mountains as the dominant species. For example, Steele *et al.* (1983) note that on the eastern flank of the Wind River Range, persistent lodgepole pine stands are found on gentle terrain unlikely to support extensive, catastrophic fires. Where lodgepole pine is the potential natural vegetation, it may have several age classes and no competition from its common associates (Hoffman and Alexander 1976). Bornong (1996) has identified stable lodgepole pine stands as old as 500 years. Houston (2001) estimated lodgepole pine is a late-successional species on 171,000 acres (69,200 ha) in the BNF.

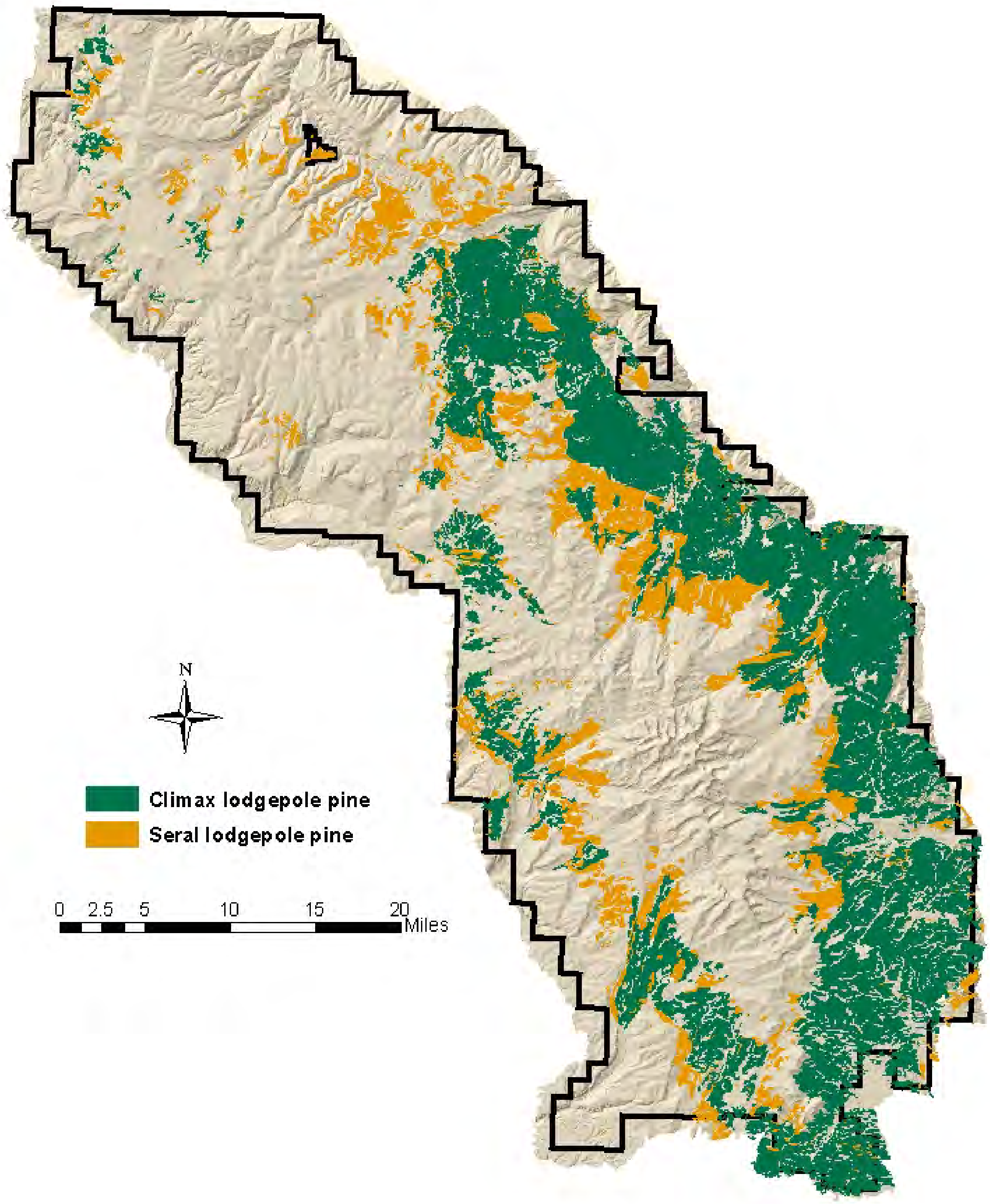


Figure M3A-9. Location of stable (climax) vs. seral lodgepole pine forests on the Bighorn National Forest.

Changes in Species Composition/Departures from HRV

As in spruce/fir forests, most compositional changes in lodgepole pine forests are likely the result of natural successional processes. Changes in species composition in this forest type almost always occur in seral stands, where the direction of change is toward dominance of the late-successional forest type for the site. When comparing potential (PNV) to current vegetation (CVU), of the 173,528 acres (70,224 ha) considered to have the potential to be lodgepole pine forest, 98% is currently lodgepole pine forest, and the remainder is grass or forb vegetation types.

Structure

Stand Age and Diameter Class Distributions

Lodgepole pine typically reaches 20 to 25 cm (8 to 10 in) diameter at breast height between 150 and 200 years (Despain 1973). Although often a seral species, lodgepole pine is long-lived. Lodgepole pine trees 400 to 500 years old are not uncommon in undisturbed landscapes with very long fire intervals.

Despain (1973) described lodgepole pine stands in the Big Horn Mountains as having highly variable stand characteristics. The stands were stratified into sparse stands with densities of 773 to 1,045 trees/ha (313 to 423 trees/acre) with basal areas of 24.2 to 30.6 m^2/ha (105.4 to 133.3 ft^2/acre) and mean diameters close to 20 cm (8 in), and dense stands with densities of 7,765 to 11,385 trees/ha (3,142 to 4,607 trees/acre) with basal areas of 37.2 to 49.4 m^2/ha (162 to 215.2 ft^2/acre) and means diameters of about 5 cm (2 in). The stands are generally even-aged, with most of the trees in only two or three size classes. The sparse stands are generally 125 to 225 years old, while the denser stands are typically younger. Data collected on the BNF since Despain's research reveal similar stand structural characteristics (Table M3A-5).

Table M3A-5. Stand structural characteristics for lodgepole pine forests classified as Habitat Structural Stages 3 and 4 in the Bighorn National Forest.

	Structural Stage 3	Structural Stage 4
Number of stands	85	74
Age (years)	111	143
Height (feet)	40	45
Quadratic mean diameter (inches)	5.3	7.4
Basal area (ft^2/acre)	133	125
Total density (trees/acre)	1243	1380
Tree density, >5" DBH (trees/acre)	365	232
Hard snags per acre	4	6
Soft snags per acre	11	26
Gross growth (ft^3/ac/yr)	28	26
Timber productivity (ft^3/ac/yr)	22	24

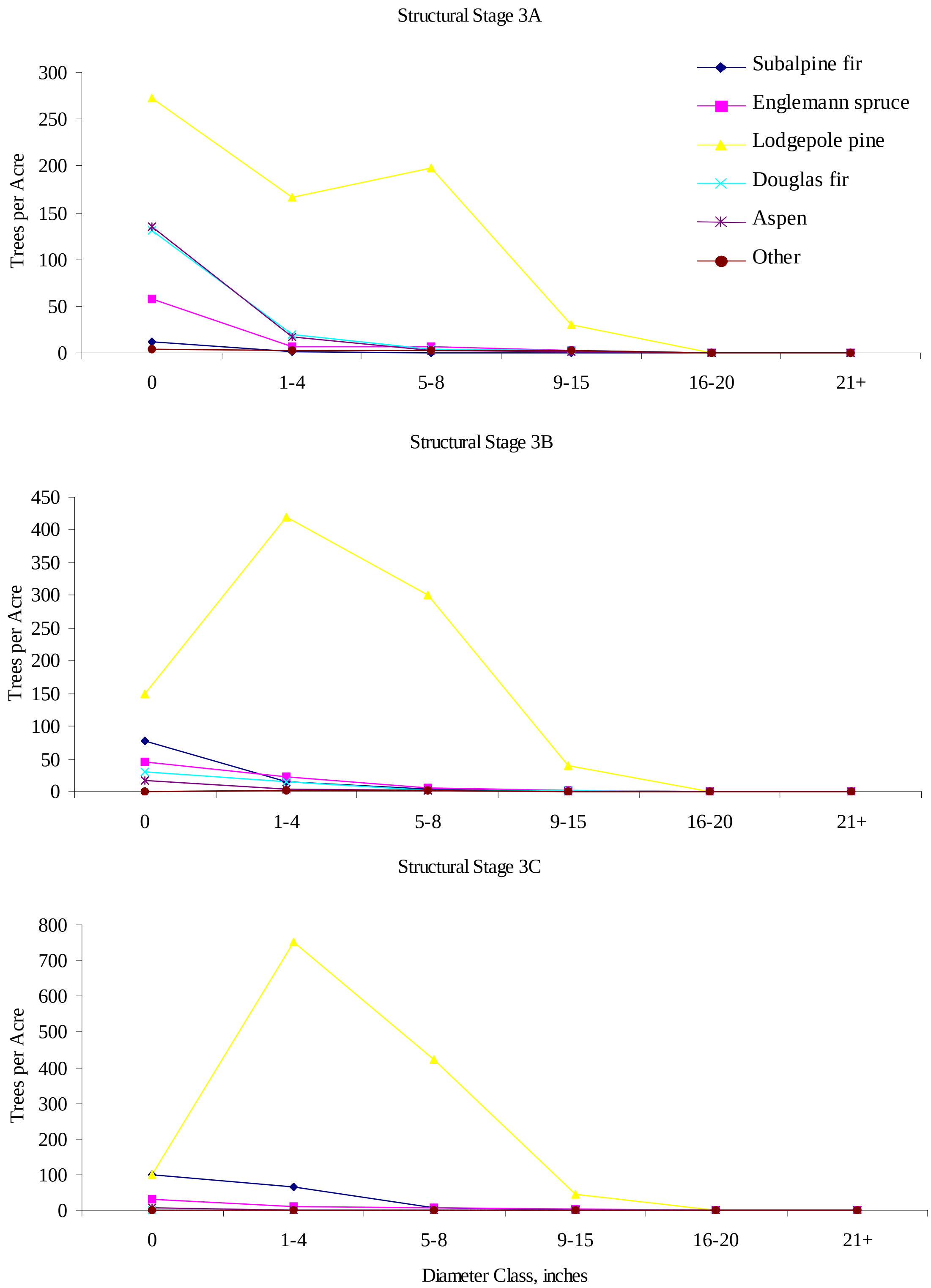


Figure M3A-10. Tree density by diameter class for lodgepole pine Habitat Structural Stages (3A-C and 4A-C) on the Bighorn National Forest.

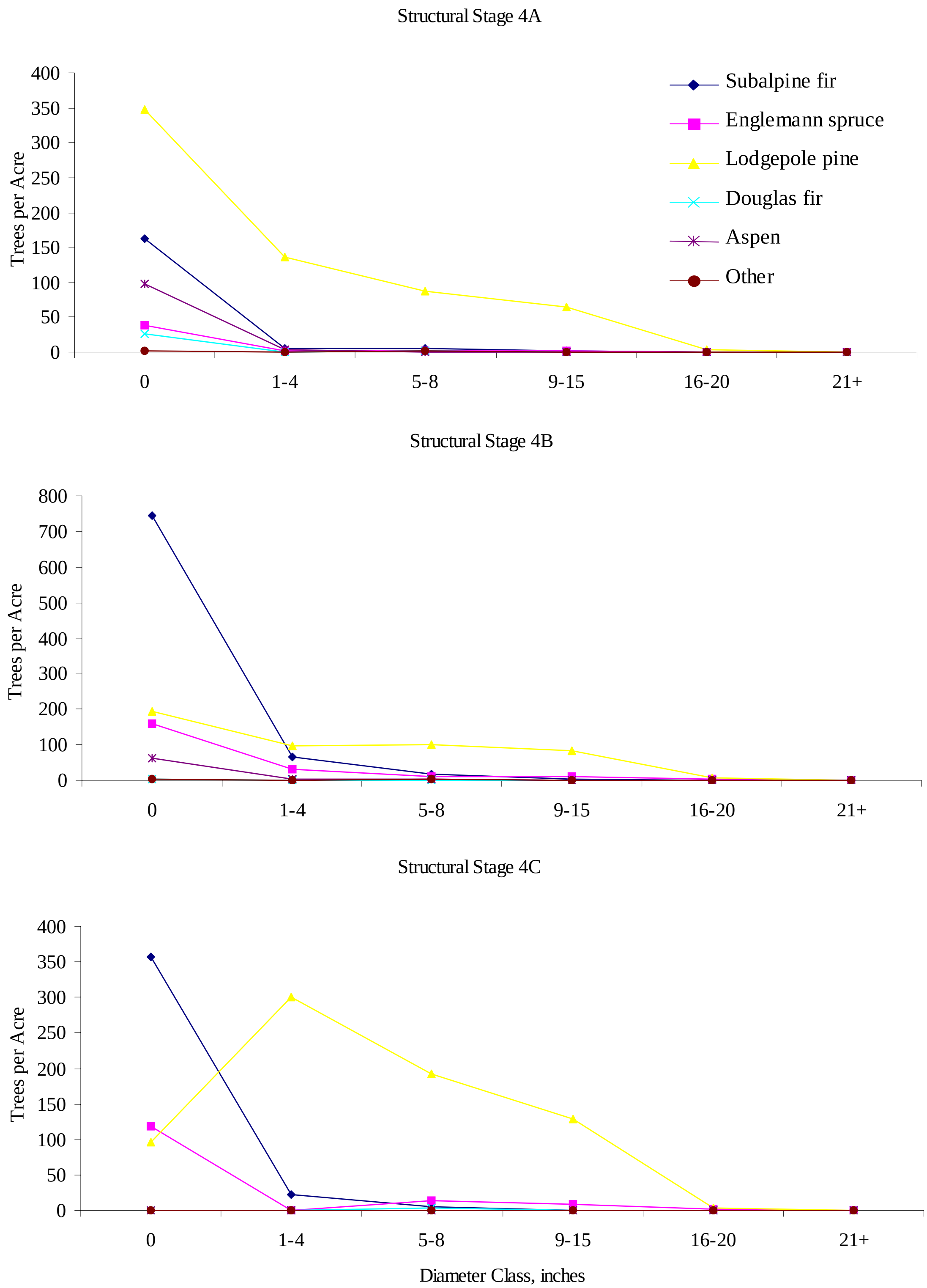


Figure M3A-10 continued. Tree density by diameter class for lodgepole pine Habitat Structural Stages (3A-C and 4A-C) on the Bighorn National Forest.

Size structures are also quite variable in lodgepole pine forests. When examined by Habitat Structural Stage (Fig. M3A-10), lodgepole pine smaller than 8 inches (3 in) diameter appears to dominate stands classified as Stage 3. Other species are prevalent only in the smallest size classes (saplings) in Stage 3A. Size structure is more variable across Stage 4, with lodgepole pine the dominant species in every size class but the smallest. Other species, primarily the shade-tolerant subalpine fir, dominant the seedling size class in both Stages 4B and 4C. In at least some of these stands, lodgepole pine may be seral to spruce/fir forests.

Habitat Structural Stages

Lodgepole pine forests of the BNF are typically pole-sized, closed-canopy forests (Fig. M3A-11). Approximately 68% of the lodgepole pine forests on the BNF are classified as Stages 3B or 3C. Only 25% is classified as Stage 4, suggesting that either relatively few stands persist to large tree sizes (i.e., seral stands) or that the higher densities in this cover type preclude the development of large-diameter trees.

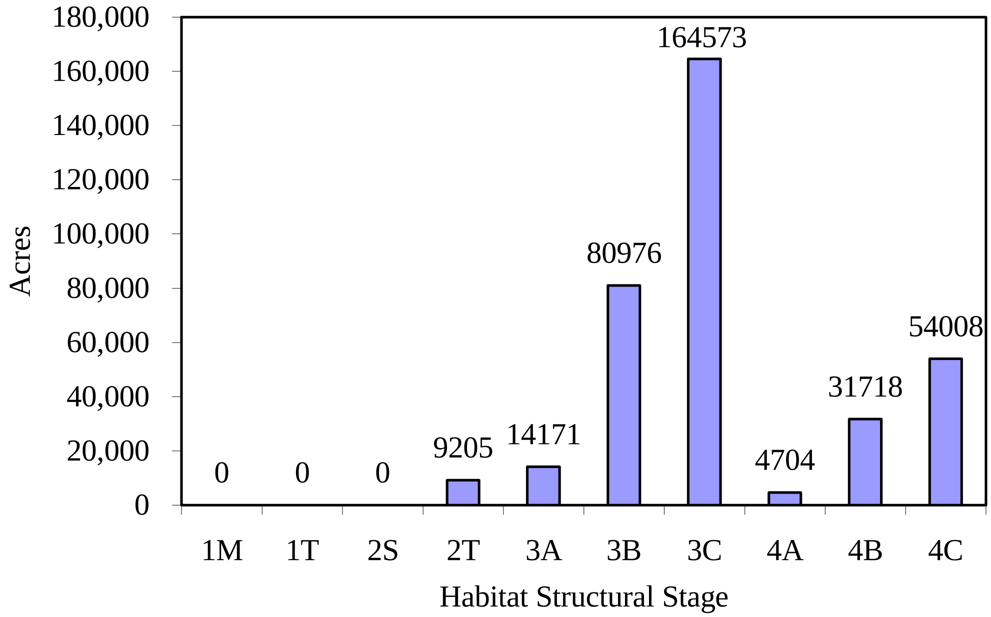


Figure M3A-11. Acres of lodgepole pine forests in each Habitat Structural Stage on the Bighorn National Forest.

Much of the lodgepole pine forest classified as Stage 3C is at the lower elevations within the lodgepole pine zone in the southeast portion of the BNF in rather large, contiguous patches (Fig. M3A-12). Most isolated islands, particularly those in the northern portion of the Forest, are classified as Stage 4. Stages 3 and 4 have very similar structural attributes, particularly in productivity, density, height, and basal area. Stage 4 forests are slightly older than those in Stage 3, but most lodgepole pine forests in the Big Horn Mountains appear to be fairly young, given that much of Yellowstone National Park consists of lodgepole stands older than 200 years (Despain 1990). Stands classified as Stage 2 are generally on clearcut or burned areas (Fig. M3A-12).

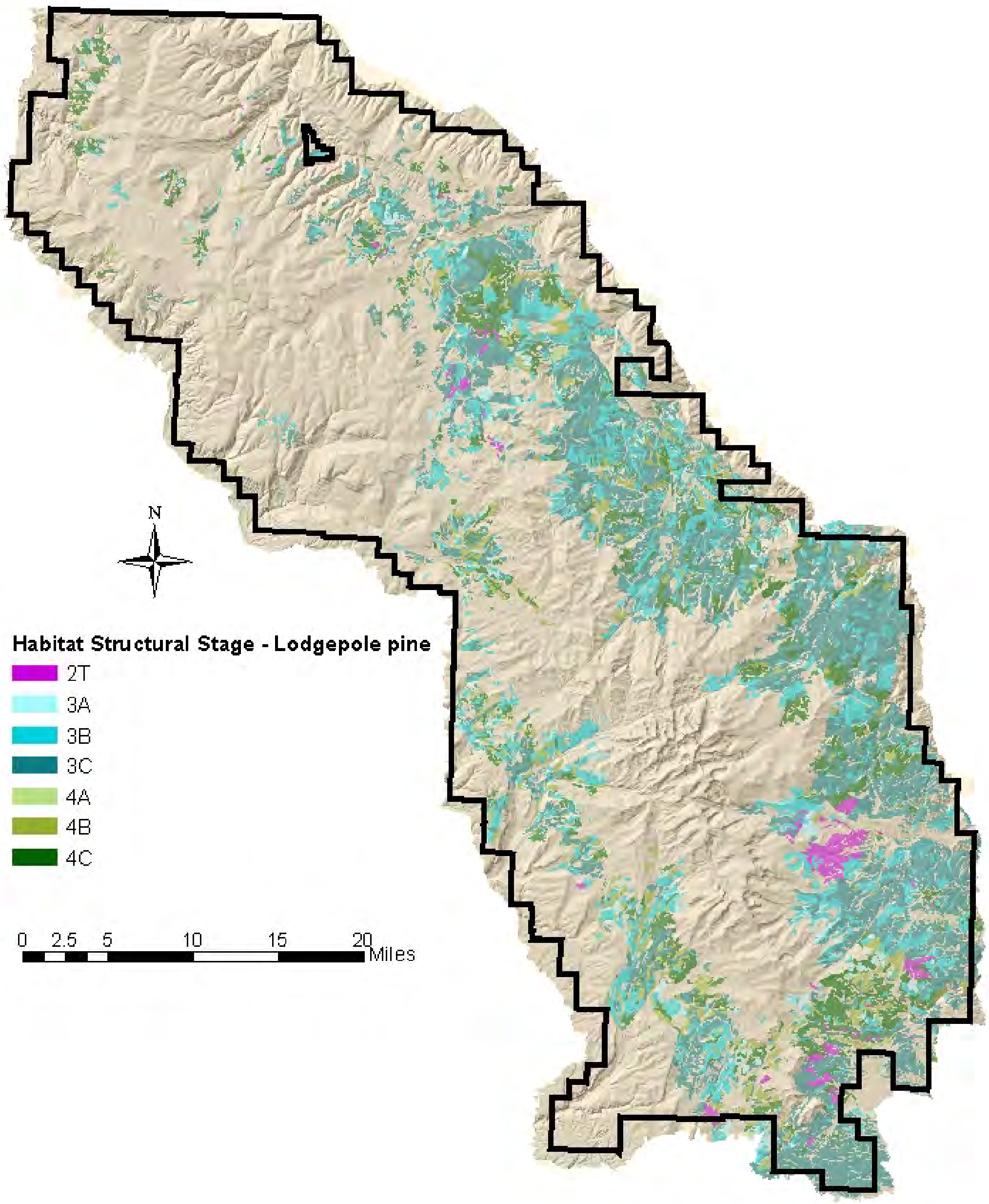


Figure M3A-12. Location of Habitat Structural Stages of lodgepole pine forests in the Bighorn National Forest (CVU database).

Stand Density

Despain (1973) noted highly variable stand densities in the Big Horn Mountains, averaging 4,060 trees/ha (1,640 trees/acre) but ranging from 770 to 11,400 trees/ha (315 to 4,600 trees/acre). This enormous variability is not uncommon for this cover type in the Rocky Mountains. In Yellowstone National Park, Kashian (2002) documented stand densities ranging from fewer than 500 to greater than 12,000 trees/ha (200 to 4,800 trees/acre). Stand density is closely related to stand age, and is heavily influenced by initial post-fire seedling densities. On average, younger stands were found to be the densest, and density generally declined with increasing age. The variability in stand density across the landscape decreased with increasing stand age, suggesting a convergence of stand densities due to stand-level processes such as self-thinning in initially dense stands and infilling in initially sparse stands. Lodgepole pine stands that developed by infilling were common in all age classes, suggesting that initial stand conditions, primarily seedling density, are strong determinants of the variability present in stand structure.

Old-Growth/Older Forest Characteristics

Late-successional stands of lodgepole pine are typically described as "old-growth". These lodgepole stands have an overstory of large old trees with sparse crowns and dead and dying tops. Old-growth stands are at least 150 years old and have at least 10 trees/ha (4 trees/acre) over 10 inches (25 cm) DBH (Mehl 1992). Old-growth lodgepole pine stands may also be characterized as having a fairly well-developed understory of saplings of Engleman spruce, subalpine fir, or Douglas-fir, and a generally all-aged distribution of lodgepole pine within the stand resulting from mortality of dominant canopy trees (Kashian 2002, Romme 1982). In some cases, however, saplings of subalpine fir and Engelmann spruce are conspicuously absent in the understory of stable lodgepole pine stands. Large-diameter coarse woody debris is also common in old-growth lodgepole pine stands and is generally in a wide range of decay classes. Because high-elevation lodgepole pine stands in the Big Horn Mountains are generally characterized by long fire intervals, human activities in the Big Horn Mountains have likely not altered the within-stand characteristics of old-growth lodgepole pine stands.

Accurate stand origin data exist for approximately 68% of the lodgepole pine forests on the BNF. For this portion of the cover type, approximately 52% is known to be at least 150 years old, so that much of this cover type on the BNF may be defined as "old-growth" in terms of age alone. Only 5% is known to be 200 years or older (Fig. M3A-13). At least 55% of the lodgepole pine forest on the BNF ranges from 60 to 210 years old.

Stand Structural Components

Snags—Few data exist describe snag structure of lodgepole pine forests in the Big Horn Mountains. Snag density appears to be highest in older, more closed-canopy forests such as those classified as Stage 4 (Table M3A-5). Snags density averages 15 per acre (37 snags per ha) in forests classified as Stage 3 and 32 snags per acre (79 snags per ha) in those classified as Stage 4. As with coarse woody debris, snag structural characteristics in lodgepole pine forests should be expected to vary with stand age and time since disturbance. Snag density immediately following stand-replacing disturbances will vary greatly based on pre-disturbance tree density and disturbance intensity. Tinker and Knight (2000) noted highly variable snag densities in lodgepole pine forests following the 1988 Yellowstone fires that represented, on average, about 115 Mg/ha (313 tons/acre). In contrast, snags in mature (100- to 200-year-old) forests in Yellowstone represented less than 10 Mg/ha (27 tons/ha).

Coarse Woody Debris—Lodgepole pine forests in Wyoming are among the most studied for attributes of coarse woody debris in the Rocky Mountains. Tinker and Knight (2000) observed approximately 70 Mg/ha of total downed wood in recently-burned forest in Yellowstone National Park. Coarse woody debris was characterized mainly by wood 8 to 30 cm (3 to 12 in) in diameter; fine woody debris (< 7.5 cm/3 in diameter) represented 4.5 Mg/ha (12.2 tons/acre).

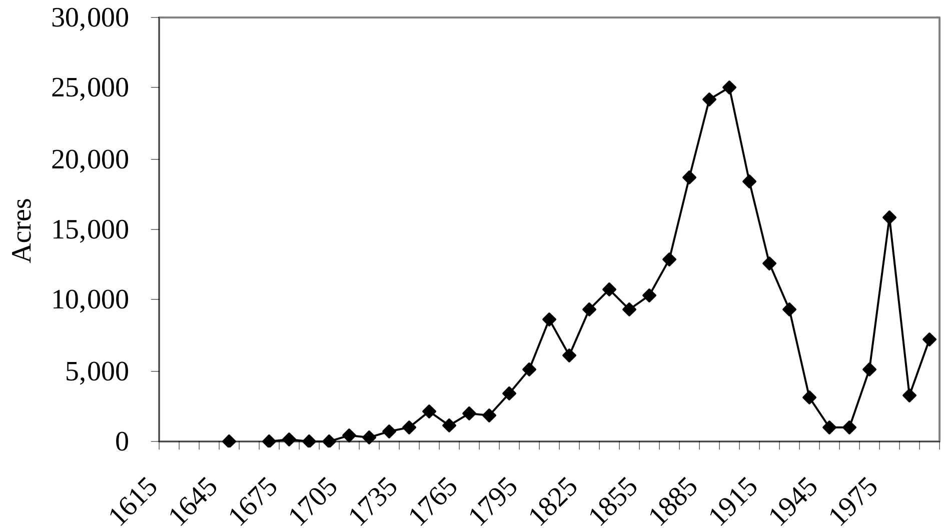


Figure M3A-13. Stand origin dates for lodgepole pine forests on the Bighorn National Forest. Only 68% of the area of lodgepole pine forest on the BNF is represented.

When standing dead snags were included in the coarse woody debris estimates, total woody debris averaged 175 Mg/ha (4,757 tons/ha) for recently burned stands. Approximately 40 Mg/ha (109 tons/acre) of downed wood were observed in stands ranging from 100 to 200 years. Less than 25 % of this estimate was represented by small wood, <7.5 diameters. When standing snags and stumps were included in the estimate, coarse woody debris estimates approached 60 Mg/ha (163 tons/acre) for stands in Yellowstone. Although lodgepole pine forests in Yellowstone are similar to those in the Big Horn Mountains, additional data collection are needed to accurately describe the existing condition of coarse woody debris in lodgepole pine forests of the BNF.

Canopy Cover—Canopy coverage is relatively high across the majority of the BNF: 61% of the lodgepole pine forests (219,670 acres/88,898 ha) exhibit canopy cover of >70%, approximately 32% exhibit canopy cover between 40 and 70%, and 7% has very sparse canopy coverage (< 40%). Areas of sparse canopy coverage are scattered, and many correspond with areas of timber harvesting (Fig. M3A-14). Canopy coverage is heaviest in the large, contiguous stands along the eastern side of the BNF.

The within-stand patterns of patchiness of lodgepole pine forests are similar to those of spruce/fir forests described in the previous section. Patchiness is typically high immediately following disturbance, and decreases as seedlings begin to mature and density-dependent competition develops. In Yellowstone, Kashian (2002) noted that initially dense lodgepole pine stands typically move from a clustered, patchy distribution to a more even, random distribution as they self-thin. In initially sparse stands, tree distribution tends be far less patchy throughout the life of the stand.

Vertical Complexity—Vertical complexity data are lacking for lodgepole pine forests, but it is likely fairly low, given the closed nature of most stands on the BNF. Despain (1973) noted relatively little understory growth in lodgepole pine stands, neither shrubs nor herbaceous, except for the most open stands. *Ribes lacustre* and *Juniperus communis* are both present in open stands, but rarely account for more than 1% cover.

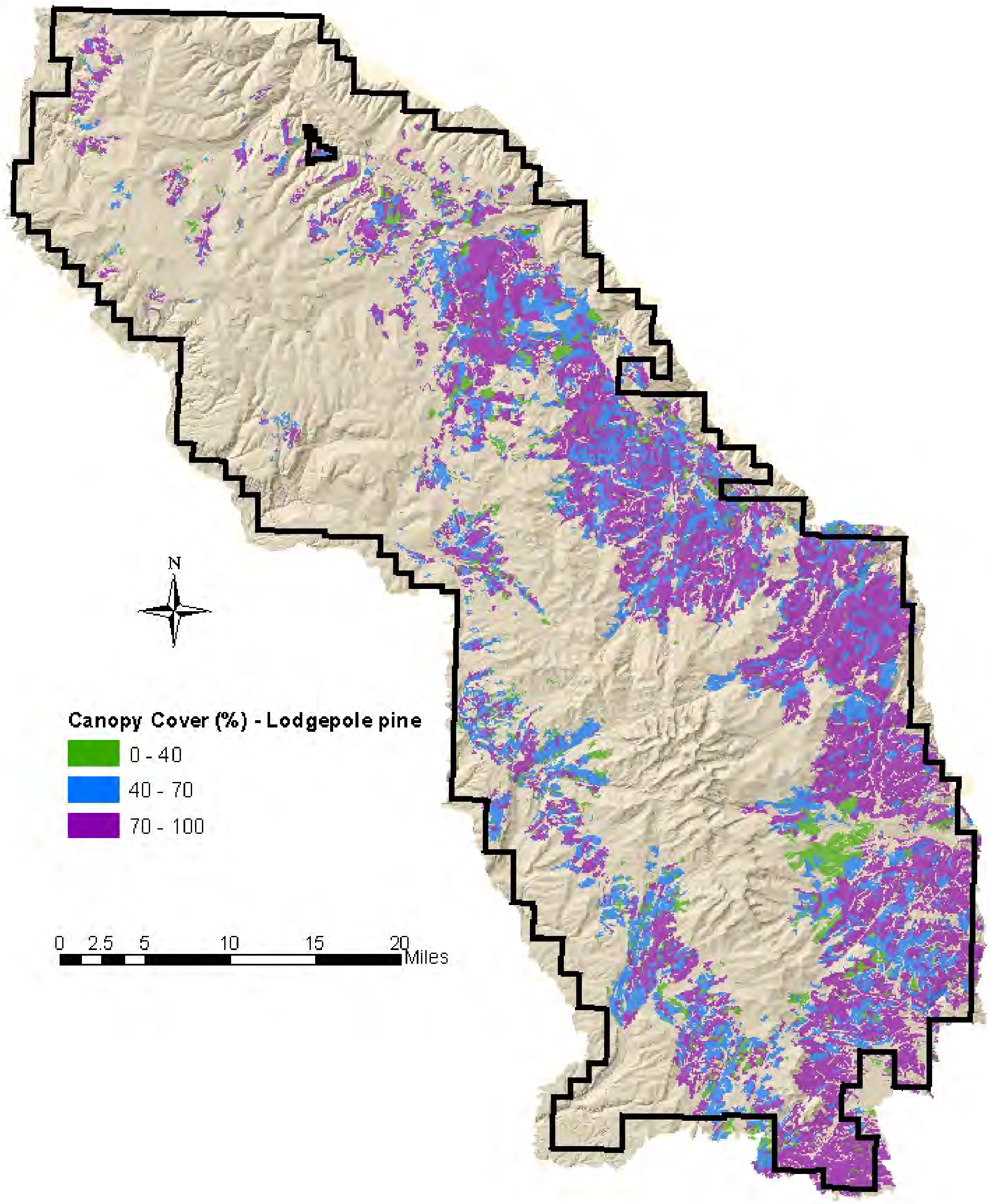


Figure M3A-14. Percent canopy coverage for lodgepole pine forests on the Bighorn National Forest (CVU database).

Changes in Structure/Anthropogenic Influences/Departures from HRV

Similar to spruce/fir forests, the primary human influence on lodgepole pine stand structure in the Big Horns is timber harvesting. Fire suppression is likely not an important factor in forests characterized by stand-replacing crown fires (Romme and Despain 1989), and grazing is not common in lodgepole pine forests.

Lodgepole pine (both seral and stable stands) has been the most harvested forest type in the Big Horn Mountains. Harvest techniques have varied over time (Fig. M3A-15). Approximately 3,300 acres (1,300 ha) of lodgepole pine was harvested prior to 1960. Lodgepole pine was harvested on 12,500 acres (5,100 ha) in the 1960s. These harvests tended to be 200- to 400-acre (80- to 160-ha) clearcuts, with 8,800 acres (3,600 ha) clearcut and 3,300 acres (1,300 ha) thinned. Shelterwood harvest became more common in the 1970s with 8,000 acres (3,200 ha) in shelterwood harvests, 5,900 acres (2,400 ha) in clearcuts, 3,600 acres (1,500 ha) in thinning, and 1,400 acres (570 ha) using other silvicultural systems. These harvest areas typically covered 30 to 200 acres (12 to 80 ha) and totaled 18,900 acres (7,650 ha). The 1980s had nearly 29,000 acres (12,000 ha) of timber harvest with individual harvest units of 5 to 30 acres (2 to 12 ha). The silvicultural treatments were 2,700 acres (1,100 ha) in clearcuts, 11,400 acres (4,600 ha) in shelterwood harvests, 2,400 acres (970 ha) of commercial thinning, 10,000 acres (4,000 ha) of pre-commercial thinning, 800 acres (300 ha) of selection harvest, and 1,400 acres (570 ha) of salvage/sanitation work. Timber management has included approximately 14,000 acres (5,700 ha) since 1990 with 1,500 acres (600 ha) clearcut, 3,300 acres (1,300 ha) of shelterwood harvest, 1,300 acres (530 ha) of salvage/sanitation work, 7,300 acres (3,000 ha) of pre-commercial thinning, and 200 acres (80 ha) using other silvicultural systems. While fewer than 128,500 acres (52,000 ha) of lodgepole pine forest have been affected by timber harvesting since the 1960s, it has affected a larger area of lodgepole pine forest than either fire (11,500 acres/4,700 ha) or wind (870 acres/350 ha) over the last 40 years.

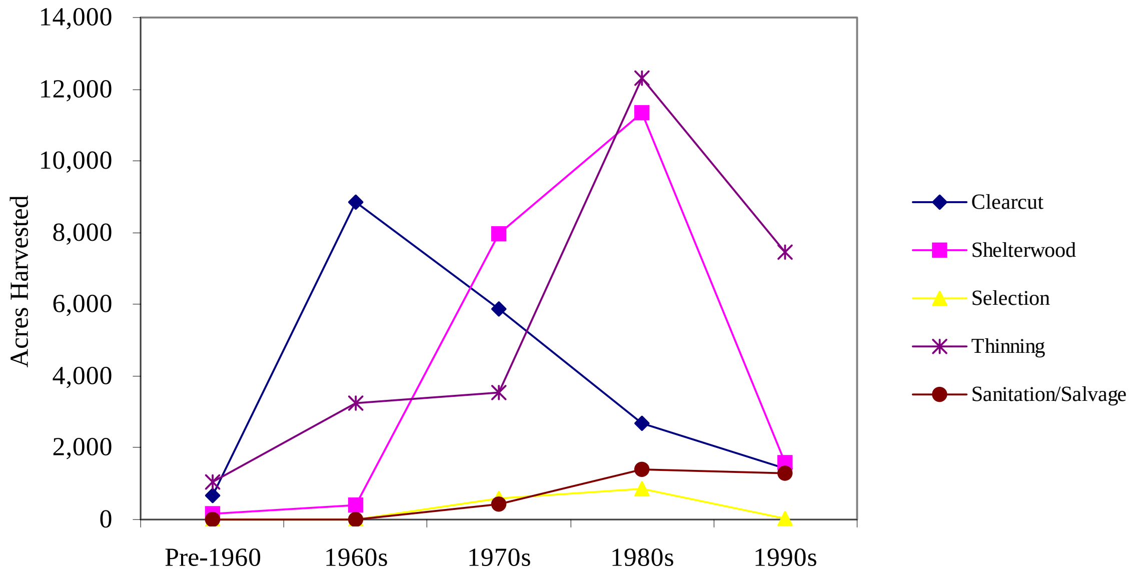


Figure M3A-15. Summary of timber harvesting activities in lodgepole pine forests on the Bighorn National Forest since the 1960s.

The influence of fire on forest structure may have been reduced during the past century as timber management began to influence forest structure. Timber harvest may create some effects similar to fire; however, other structural variables are in contrast to natural processes. Tree and snag density, species diversity, genetic diversity, coarse woody debris, soil characteristics, regeneration time, and canopy gaps in managed stands may be different than in natural stands (Meyer and Knight 2003). The effects of fire and harvesting on landscape patterns in lodgepole pine forests are described in detail in Modules 4A and 4B.

Function

While lodgepole pine forests have been intensively studied in the northern Rocky Mountains, no studies have been conducted in the Big Horn Mountains. Similar to the previous section describing spruce/fir forests, a brief description of functional characteristics for lodgepole pine forests follows, but specific values are very likely different for forests in the BNF.

Biomass and Productivity Characteristics

The descriptions of aboveground biomass and productivity for lodgepole pine forests most applicable to the BNF have been conducted in the Medicine Bow National Forest in southeastern Wyoming. Smith and Resh (1999) measured aboveground living biomass as 4,400 to 6,200 g C/m^2 (0.87 to 1.23 lbs C/ft^2) for stands 50-100 years old, but 7,500 g C/m^2 (1.5 lbs C/ft^2) in 260-year-old stands. In their study, forest floor biomass increased from 776 to 1,321 g C/m2 (0.15 to 0.26 lbs C/ft^2) in a chronosequence of stands aged 30 through 260 years (Smith and Resh 1999). Pearson *et al.* (1987) noted maximum biomass accumulation rates that peaked in even-aged stands aged 40 to 60 years at 2.5 to 3.2 Mg/ha/yr (6.8 to 8.7 tons/acre/yr); uneven-aged stands that developed via meadow invasion peaked at 1.5 Mg/ha/yr (4.1 tons/acre/yr) after 80 years. The majority of biomass increment was found in living vegetation, with maximum forest floor biomass increment representing only 25% of that of living vegetation (Pearson *et al.* 1987). In Yellowstone National Park, Litton *et al.* (2003) noted a wide range of total NPP for 13-year-old lodgepole pine stands of varying density, ranging from 222 to 13,685 kg/ha/yr (1,212 to 74,734 lbs/acre/yr).

As with many forest types, lodgepole pine forests exhibit an age-related change in ANPP. Olsson *et al.* (1998) noted measured ANPP as 2,220 kg/ha/yr (12,123 lbs/acre/yr) for 30-year old stands and 4,590 kg/ha/yr (25,066 lbs/acre/yr) for 50-year-old stands, but then noted a decrease to 4,190 kg/ha/yr (22,882 lbs/acre/yr) at 100 years and 1,920 kg/ha/yr (10,485 lbs/acres/yr) at 200 years. Smith and Resh (1999) noted a maximum ANPP in their chronosequence in a 30-year-old stand at 192 g C/m^2/yr, (0.04 lbs C/ft^2/yr) decreasing to only 92 g C/m^2/yr (0.02 lbs C/ft^2/yr) by age 260 years.

Cycling and Storage of Carbon and Nutrients

Pearson *et al.* (1987) noted that the forest floor is the major biomass compartment accounting for immobilization of nitrogen, phosphorus, and calcium in lodgepole pine forests of southeastern Wyoming; most potassium is immobilized in the living biomass compartment. Maximum nutrient rates occurred at approximately 50 years. Olsson *et al.* (1998) noted the highest nitrogen content in needle litterfall (5.8 kg/ha/yr or 31.7 lbs/acre/year), wood increment (1.2 kg/ha/yr or 6.6 lbs/acre/year), and nitrogen uptake (7.1 kg/ha/yr or 38.8 lbs/acre/year) in stands <50 years old; Binkley *et al.* (1995) found stands <45 years had higher net nitrification (0.9 kg/ha/yr or 4.9 lbs/acre/year) and mineralization rates (4.6 kg/ha/yr or 25.1 lbs/acre/year) than stands >110 years (0 kg/ha/yr net nitrification, 1.5 kg/ha/year or 8.2 lbs/acre/year mineralization).

Carbon allocation in lodgepole pine also appears to change with stand age. Smith and Resh (1999) noted an increase in carbon allocation to woody tissue with stand age, but a corresponding increase in allocation to foliage. Total root carbon allocation (TRCA), or the difference between annual soil respiration, annual litter inputs, and changes in root biomass, was similar for stands aged 30-100 years, ranging from 481 to 539 g C/m^2/yr (0.1 to 0.11 lbs/ft^2/year), but decreased significantly in a stand aged 260 years (391 g

C/m^2/yr or 0.08 lbs/ft^2/year). Litton *et al.* (2003) noted that below ground biomass allocation increased with tree density due to differences in tree size in young stands in Yellowstone. They found that the ratio of belowground to total biomass decreased with tree size from 0.44 for basal diameters of 0.5 cm (0.2 in) found in dense stands to 0.11 for basal diameters of 8 cm (3 in) in sparser stands.

Natural Disturbances

Fire is the predominant natural disturbance in the Big Horn Mountains. Meyer and Knight (2003) determined the fire-free interval for an individual high elevation stand is 150 to 700 years in the BNF. Lodgepole pine in Yellowstone National Park has had stand replacing fires covering 5 to 25% of the landscape approximately every 100 years. The Big Horn Mountains may have a slightly different fire regime, but Yellowstone provides a perspective for unmanaged high-elevation forests in the BNF (Meyer and Knight 2003).

Though troublesome in other lodgepole pine forests, mountain pine beetles have not caused extensive loss of lodgepole pine in the Big Horn Mountains. Cold, high elevations found in the Big Horn Mountains may inhibit mountain pine beetle epidemics (Amman 1989), but lower-elevation lodgepole pine, particularly older stands, are at risk (Meyer and Knight 2003). Epidemics typically start in stressed trees greater than 20 cm (8 in) dbh and over 80 years old. Groups of 100 or more trees may be killed, which reduces the average stand diameter and creates openings (Schmid and Mata 1996). An epidemic can be expected to occur on the BNF every 20 to 40 years, and last 1 to 10 years (Schmid and Mata 1996). Amman *et al.* (1977) estimated lodgepole pine forests above 2,500 m (8,200 feet) are susceptible to stand mortality rates less than 25%, while lower elevation mortality rates are up to 50%.

Comandra blister rust is the most common disease in lodgepole pine in the Big Horn Mountains. Lundquist (1993) used roadside surveys to determine 77% of the townships had infected lodgepole pine, and 20% of the townships were severely infected. The infected areas are scattered throughout the Forest, with the severe infections on the east side. Trees 80 to 90 years old are most susceptible to *Comandra* blister rust (Geils and Jacobi 1990, Johnson 1986). The rust increased dramatically between 1910 and 1945 as a result of unusually warm, moist summers and a preponderance of susceptible lodgepole pine (Krebill 1965).

Dwarf mistletoe is the second-most widespread disease on the BNF (Meyer and Knight 2003). Johnson (1986) found 36% of the stands he surveyed along existing roads were infected, with the most severe infections in the southern portion of the Forest.

Summary of Key Findings for Lodgepole Pine Forest Type

- Lodgepole pine is the most common forest type on the BNF, comprising 359,354 acres (145,426 ha) and found most often on granitic substrates.

- Lodgepole pine exists on the BNF both seral to more shade-tolerant species (primarily subalpine fir and Engelmann spruce) or persistent as a late-successional stand.

- Lodgepole pine cone serotiny may be highly variable across the Big Horn Mountains, which may have significant effects on post-disturbance stand development.

- Nearly half of the cover type on the BNF is older than 150 years, which satisfies at least some criteria of old-growth characteristics for lodgepole pine.

- Various timber harvest methods have not mimicked natural disturbance regimes, resulting in some departure from the historic stand structure and patch size. Over 80% of the lodgepole pine on the Forest has not been harvested.

Aspen Forest

Composition

Spatial Distribution

Trembling aspen is the most widely distributed tree in North America (Perala 1990), but occupies only about 1% of the land area in the Big Horn Mountains. Aspen forests currently cover approximately 11,353 acres (4,594 ha) on the BNF (Fig. M3A-16). Although aspen forests have been described by Despain (1973) as being "unimportant as a community type" in the Big Horn Mountains, the importance of aspen for biodiversity and aesthetics is disproportionately large compared to the amount of land it covers. The vegetation is not valuable for timber production but does have high habitat values for big game and non-game species (Hoffman and Alexander 1976, Alexander *et al.* 1986).

Aspen forests occur mainly as pure stands in small scattered patches throughout the BNF (Fig. M3A-16), in both uplands and riparian zones, ranging in size from a few trees to a few acres, often along the fringes of lodgepole pine forests or as small patches of trees in the forest matrix (Knight 1994). Aspen occurs on both sedimentary (37%) and granitic (63%) soils, usually classified as alfisols (Nesser 1986). Unlike coniferous species, aspen distribution across the Big Horn Mountains depends more upon moisture availability than on elevation or substrate, typically occuring in seeps or low, wet areas. The general restriction of aspen to moist areas is probably due to the intolerance of aspen seedlings, rather than mature trees, to drought (Knight 1994).

Characteristic Dominant Species and Associations

Aspen forests, as compared to coniferous forests, typically develop abundant herbaceous and woody understories, both because of the higher moisture availability and the higher light availability at the forest floor (Meyer and Knight 2003). As a result, such stands support a higher diversity of animals, particularly birds, than other forest types in the Big Horn Mountains (Merrill *et al.* 1993). Some stands may have a well-developed grass understory that thrives in the characteristically moist conditions. In addition, the deciduous nature of aspen is thought to promote the growth of grasses due to enhanced nutrient availability as the deciduous leaves decompose (Peet 1988). The thick growth of grasses may help resist establishment of other tree species.

Hoffman and Alexander (1976) identified only one habitat type dominated by aspen in the Big Horn Mountains (Table M3A-6). This type includes *Populus tremuloides* as the dominant overstory species and *Lupinus argenteus* as the dominant understory species, with several other important associated species. The fact that *Lupinus* fixes atmospheric nitrogen into a form available for plants may lead to higher fixation rates in aspen forests than other forest cover types (Knight 1994).

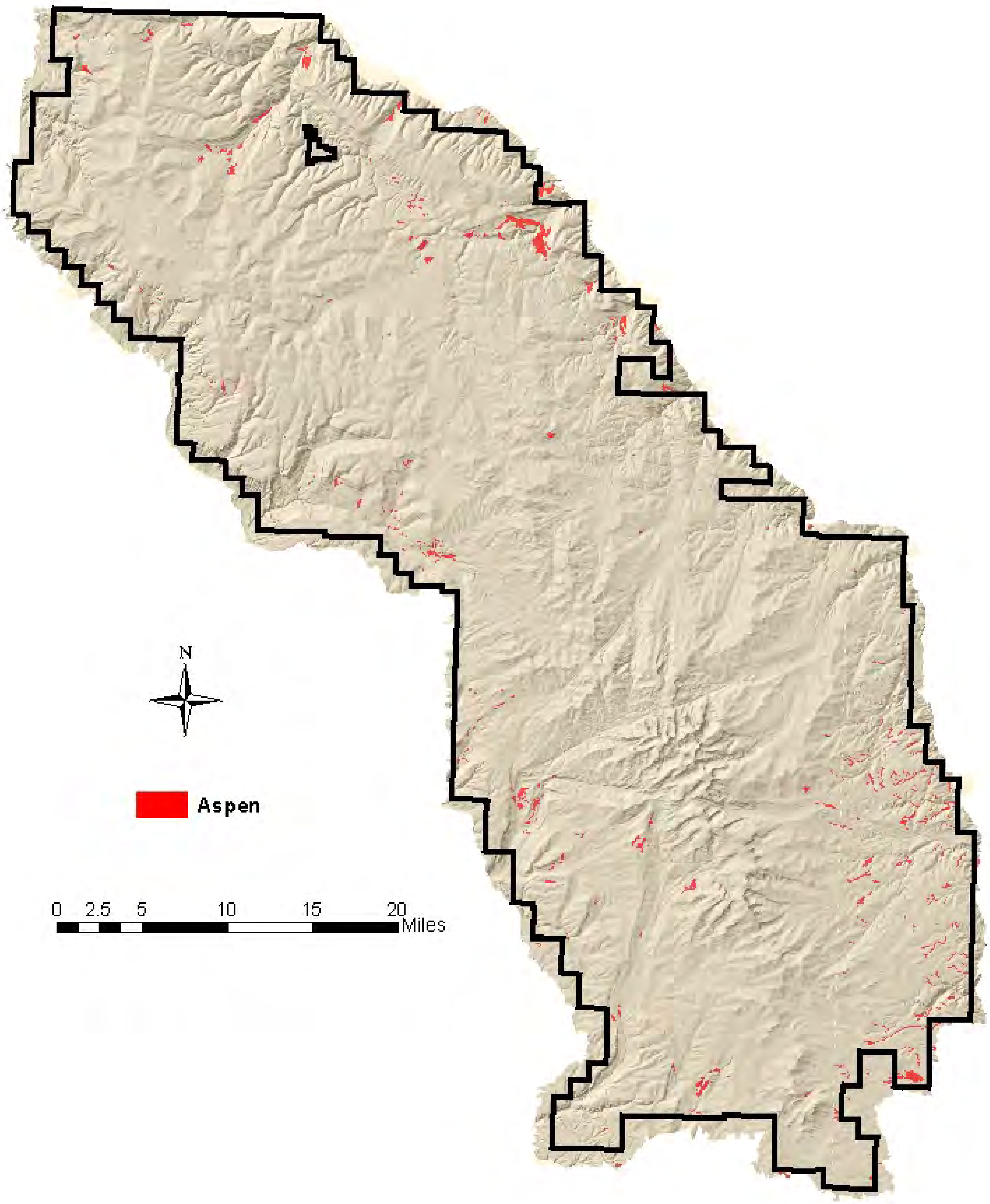


Figure M3A-16. Distribution of aspen on the Bighorn National Forest (CVU database).

Table M3A-6. Aspen habitat type identified by Hoffman and Alexander (1976) for the Big Horn Mountains.

Habitat type	Important species
P. tremuloides/Lupinus argenteus	*Fragaria viginiana, Poa nervosa, Agropyron spicatum, Carex platylepis, Carex scopulorum, Festuca idahoensis, Heserochloa kingii, Achillea millefolium, Astragalus alpinus, Anemone multifida, Lupinus wyethii, Taraxicum officianale, Trifolium spp., Juniperus communis, Ribes lacustre, Potentilla fruticosa, Phleum pratense, Dactylis glomerata.*

Despain (1973) described only one aspen stand in the Big Horn Mountains, which he characterized as having a well-developed herb layer and an understory of *Prunus*, *Crataegus*, and *Amelanchier* spp. He noted that aspen forests fringing lodgepole pine forests in the east-central portion of the Big Horn Mountains typically have an "extension of the neighboring grasslands" as the dominant understory layer. A variety of other species can dominate the understory of aspen stands, but the more common species are *Calamagrostis canadensis*, *Poa pratensis, Symphoricarpos* spp., and *Thalictrum fendleri* (Hoffman and Alexander 1976, Girard *et al.* 1997).

Successional Characteristics

Aspen spreads vegetatively by sprouting from roots, forming clonal populations typically in pure or nearly pure stands. It becomes most abundant immediately following a stand-replacing disturbance after which it sprouts vigorously from the roots (Barnes 1966). Often this occurs when a few aspen sprouts persist in the understory of coniferous forests, which often are subjected to high-severity disturbances. Small stands in the BNF and elsewhere probably arose from just a few individuals that spread vegetatively. Regeneration of aspen following disturbance is a key to its persistence in the forest matrix (Steele *et al.* 1983, Alexander *et al.* 1986, Peet 1988, Knight 1994). Establishment from seed is uncommon (Knight 1994, Romme *et al.* 1997).

Aspen forests may be seral or late successional in the Big Horn Mountains and elsewhere in the Rocky Mountains, depending on site conditions and historical factors (Mueggler 1985). For example, aspen stands may be seral to lodgepole pine, or more often Engelmann spruce or subalpine fir at higher elevations, where long fire intervals, stand replacing fires, and abundant seed sources facilitate the invasion of aspen understories by spruce and fir. In contrast, aspen may be stable or climax at lower elevations, where shorter fire intervals and lower-intensity fires may be sufficient to eliminate shade-tolerant conifers in the understory (Romme *et al.* 2001). However, some aspen on the BNF is known to be seral to Douglas-fir, ponderosa pine, and limber pine (Peet 1988, Knight 1994). Where other species do not become established, aspen persists as a stable community, with sprouts replacing the older stems as they senesce (Knight 1994). Relatively few data are available that quantify the proportion of seral relative to late-successional aspen forests on the BNF.

Changes in Species Composition/Departures from HRV

Since aspen forests are typically dominated by a single species, most compositional changes are likely the result of a given stand being seral vs. late successional. Changes in species composition in this forest type almost always occur in seral aspen stands, where the direction of change is toward dominance of the stable forest type for the site, typically spruce/fir or lodgepole pine. Human effects may enhance compositional changes if they disrupt natural disturbance regimes. For example, suppression or exclusion of fires in lower-elevation aspen forests, where coniferous understories are held in check by frequent, low-intensity fires, may facilitate succession to other dominant overstory species. Grazing may also affect the composition of aspen forests by reducing aspen regeneration and/or understory coverage, or increasing the presence of invasive species such as Kentucky bluegrass (*Poa pratensis*) (Meyer and Knight 2003).

The potential decline of aspen stands in the Rocky Mountains is quite controversial. When comparing potential (PNV) to current vegetation (CVU), of the 4,704 acres (1,904 ha) considered to have the potential to be aspen forest, 58% is currently aspen forest, 38% is currently grassland, and the remainder is forb or shrub vegetation types. The fact that the area of potential aspen coverage not currently occupied by aspen is mostly grassland suggests that aspen decline, if it is occurring in the Big Horn Mountains, is likely due to a lack of aspen regeneration rather than loss of seral aspen stands via succession (Romme *et al.* 1995). A lack of aspen regeneration may result from a variety of factors that may interact, including heavy ungulate browsing, climate change, and fire suppression (Hessel 2002, Romme *et al.* 1995, Romme *et al.* 2001). More research is needed to properly quantify the current condition of aspen forests on the BNF, and particularly whether aspen regeneration has declined in this region as it has in many other parts of western North America.

Structure

Stand Age and Diameter Class Distributions

In the typical aspen stand he sampled, Despain (1973) noted that stem diameter was typically very small, generally 6 to 15 cm (2 to 6 in), and height was approximately 4 to 8 m (13 to 26 ft). Reid *et al.* (1999) noted that the typical aspen stand includes a closed canopy 5 to 18 m (15 to 60 ft) in height. Given the dominance of Stage 3 and 4 Habitat Structural Stages in aspen forests across the BNF, however, it is likely that the latter description is accurate for most aspen stands existing today. Aspen is a relatively short-lived, seral species with an approximate average maximum age of 125 years, though some stands may live up to 160 years or more. The BNF contains at least 12 acres (5 ha) of aspen forests that may be almost 200 years old.

Very little data describing aspen stand structural characteristics are available for the BNF, likely because of its minor coverage. Stands are generally even-aged, although older, more open stands may develop an uneven-aged structure when there is little competition with shade-tolerant conifers in the understory. Stem diameters are likely variable only when an uneven-aged stand structure is present. The variability of tree size across the Forest, which includes stands dominated by small (2-13 cm /1-5 in diameter), medium (13-23 cm/5-9 in) and large (23-41 cm/ 9-16 in) trees, may reflect differences in stand density, although stand age is also an important factor affecting aspen diameter (Fig. M3A-17).

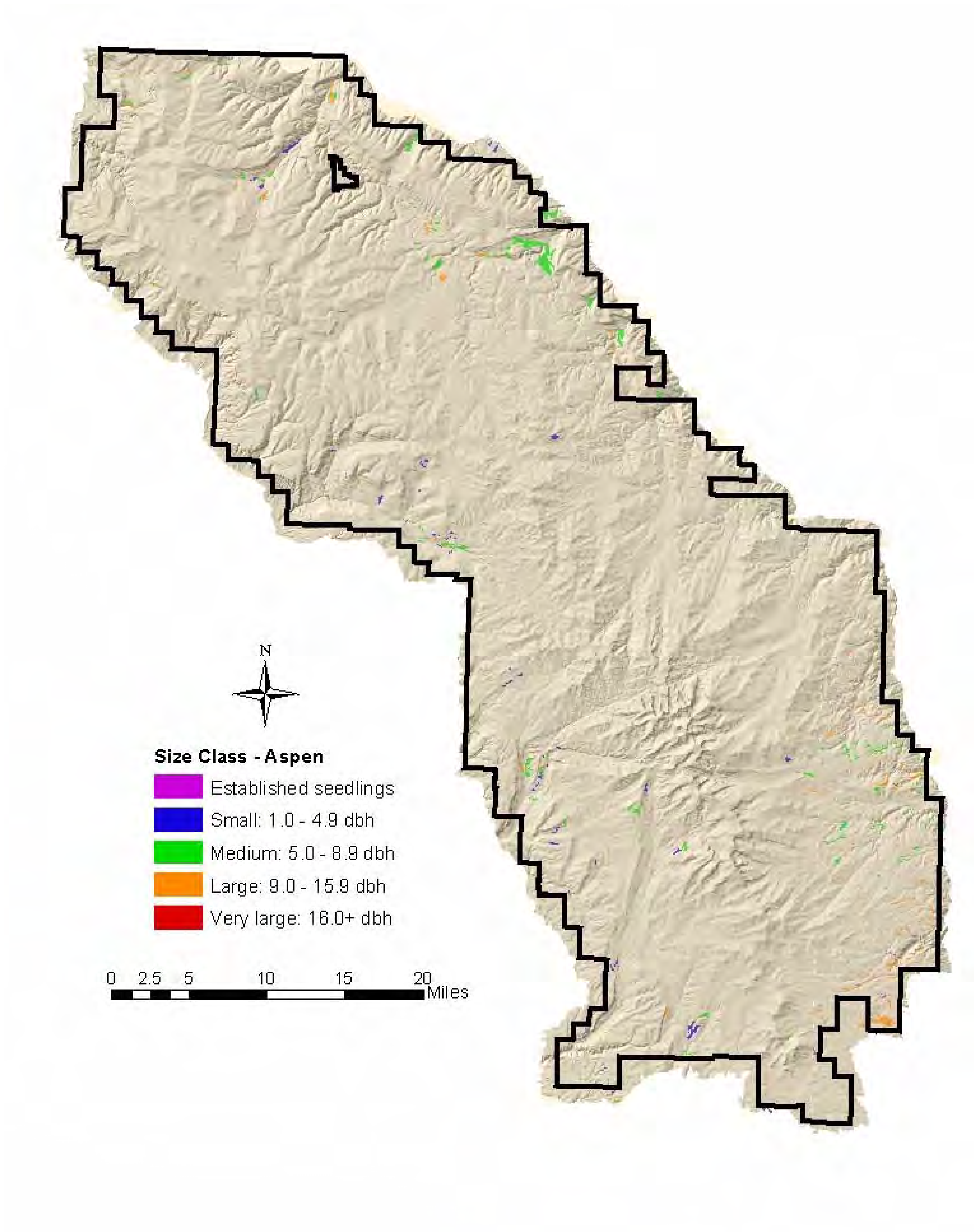


Figure M3A-17. Location of size classes of aspen forests in the Bighorn National Forest (CVU database).

Habitat Structural Stages

Aspen forests of the BNF are typically pole-sized, closed-canopy forests (Fig. M3A-18). Approximately 60% of the aspen forests on the BNF are classified as Stages 3A or 3B. One-third of the aspen forest type is classified as Stage 4, showing that many stands persist to large trees sizes. Less than 2% of the aspen forests on the BNF are classified as Stage 2, and no Stage 1 forests exist; such a trend again suggests a relative lack of aspen regeneration on the Forest.

Much of the aspen forest classified as Stage 4 appears at the lower elevations in the southeast portion of the BNF in small patches (Fig. M3A-19). Aspen forests classified as Stage 3 are well distributed across the Forest, particularly at the higher elevations. The largest contiguous patch of aspen forest in the northeast portion of the BNF is also classified as Stage 3.

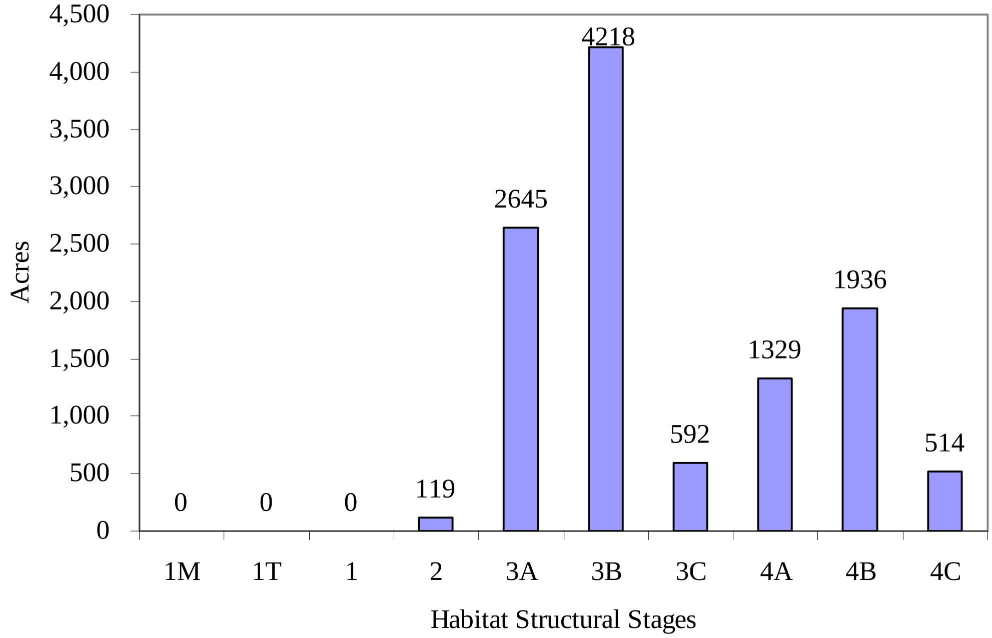


Figure M3A-18. Acres of aspen forests in each Habitat Structural Stage on the Bighorn National Forest.

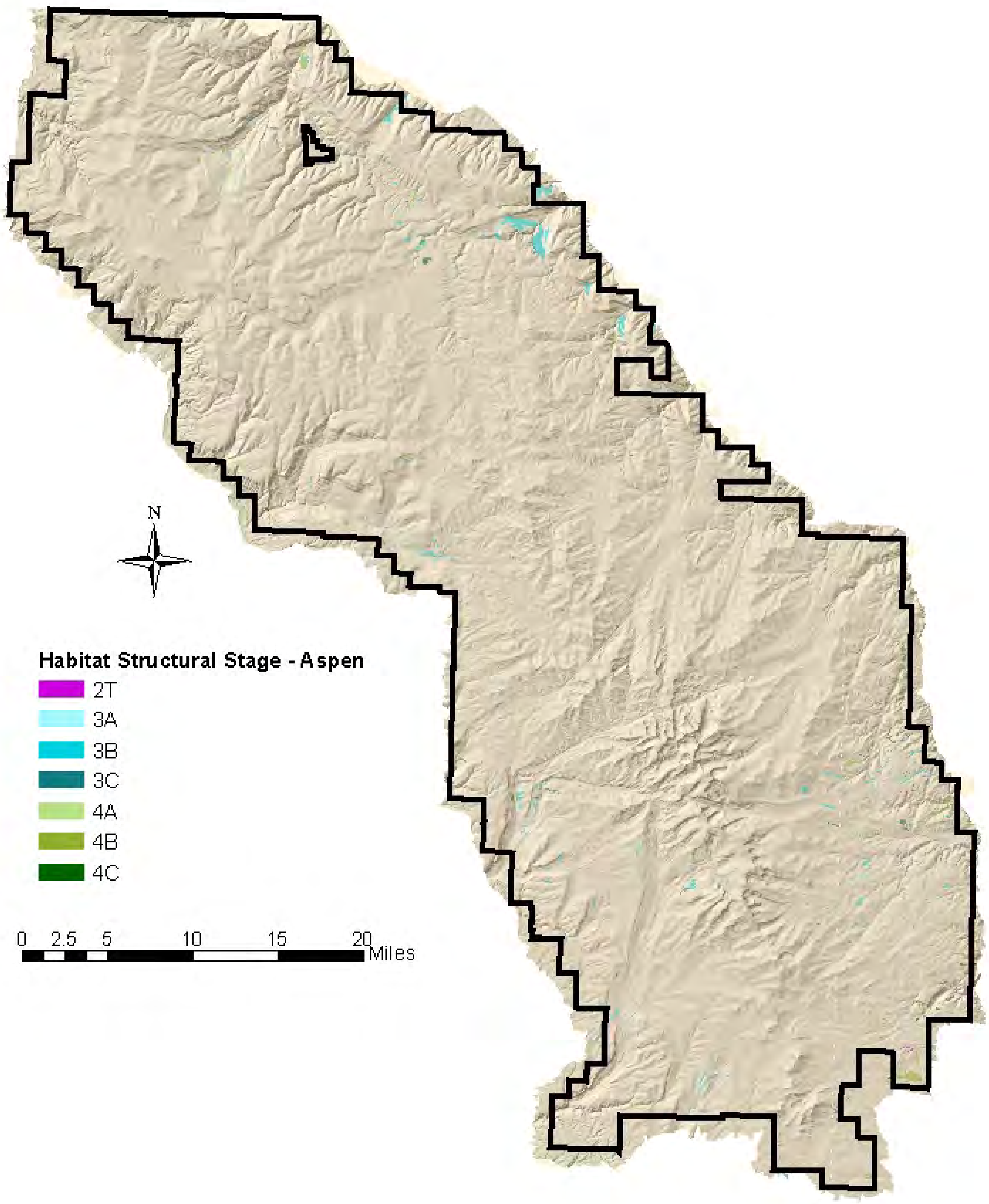


Figure M3A-19. Location of Habitat Structural Stages of aspen forests in the Bighorn National Forest (CVU database).

Stand Density

Few data describing stand densities exist for the BNF, but stand density likely varies considerably with age, as older stands have far fewer stems than younger, regenerating stands. Stand density also likely varies within older stands, based upon site conditions and historical contingencies (Romme *et al.* 2001).

Old-Growth/Older Forest Characteristics

According to Mehl (1992), even seral aspen stands can exhibit characteristics of old-growth. Old-growth seral aspen stands are described as having a single, generally closed, canopy level of trees at least 100 years old, a spruce/fir understory, and tree diameters that vary considerably. If the stand is considered stable, the canopy will be closed, consist of large, old (at least 100 years) trees, and have few understory conifers and little dead wood. The overstory trees in a stable aspen stand may become increasingly variable in size once the stand begins to deteriorate.

Accurate stand origin data exist for approximately 31% of the aspen forests on the BNF. For this portion of the cover type, only about 16% may be defined as "old-growth" in terms of age alone. Only 2% is known to be older than 100 years (Fig. M3A-20). At least 69% of the aspen forests on the BNF are 50 years old or younger.

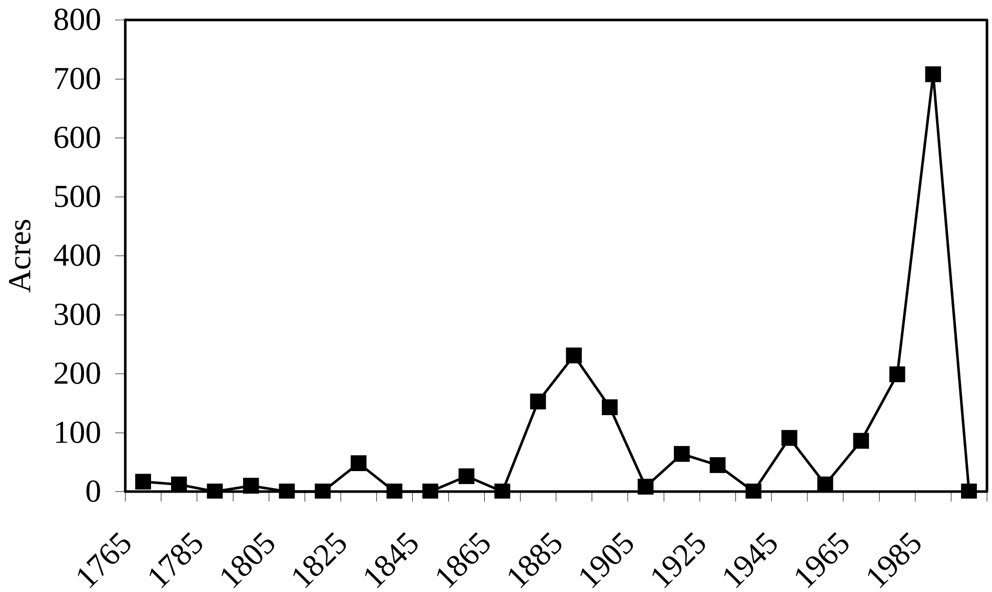


Figure M3A-20. Stand origin dates for aspen forests on the Bighorn National Forest. Only 31% of the area of aspen forest on the Forest is represented.

Stand Structural Components

Snags—Few data are available on snag structure of aspen forests in the Big Horns. Typically, aspen snags are small, since aspen rarely exceeds 38 cm (15 in) diameter in the Big Horn Mountains. Dead wood does not remain standing for very long, given the prevalence of decomposing organisms. The susceptibility of live aspen to fungal diseases also results in most aspen stands older than about 50 years having at least some standing dead wood. For aspen forests in Alberta, mean snag density in stands 20-40 years old is about 18 snags/ha (7 snags/acre) increasing to 62 to 100 snags/ha (25 to 40 snags/ha) in stands up to 100 years old. Snag falldown rates varied from 9 to 21% of snags/year depending upon stand age (Lee 1998).

Coarse Woody Debris—Few data are available to describe the current condition of coarse woody debris characteristics in aspen forests. Furthermore, most studies of coarse woody debris in aspen forests have been conducted in the boreal forest, where aspen coverage is much more widespread than in the Rocky Mountains. In stands in Alberta, Canada, the number of pieces of coarse woody debris was higher in young stands, but the volume was higher in older stands. The degree of spatial heterogeneity within and among stands decreased as stands matured (Lee *et al.* 1997). Stands older than 120 years averaged about 26 m^3/ha (2,269 ft^3/acre) of coarse woody debris that had originated with the current stand; including coarse woody debris developed from the stand-forming disturbance raised the total to nearly 77 m^3/ha (1,100 ft^3/acre). Aspen forests on the BNF probably have less coarse woody debris, due to their longer growing seasons and subsequent higher rates of decay. In any case, coarse woody debris is certainly present in aspen forests on the BNF, given the prevalence of diseases such as root disease, canker-causing fungi, and heart-rotting fungus in older aspen (Allen and Harris 1999). Aspen forests are also very susceptible to wind damage, given their weak stems and brittle branches (Veblen and Lorenz 1991). Much of the coarse woody debris may be in advanced stages of decay in aspen forests, due to their occurrence in areas characterized by relatively high moisture availability, which promotes decomposing organisms.

Ripple and Larsen (2001) found that aspen seedlings and suckers found among coniferous downfall, where they were protected from ungulate browsing and provided with a relatively cool, moist habitat, were often twice as tall as adjacent unprotected aspen seedlings and suckers. Thus coarse woody debris of species other than aspen may also be important for the persistence of aspen forest. Coarse woody debris in aspen forests has also been shown to be beneficial to small mammals (Moses and Boutin 2001) and may affect vascular plant community composition (Lee and Sturgess 2001) in the boreal forest.

Canopy Cover—On the BNF, 55% of the aspen forests (6,212 acres/2,514 ha) have canopy cover between 40 and 70%, approximately 35% have very sparse canopy coverage (< 40%), and 10% have canopy cover >70%. Canopy coverage is relatively low across the majority of the BNF. Areas of sparse canopy coverage typically occur in the larger aspen stands, while heavier canopy coverage is typically found in smaller, scattered stands (Fig. M3A-21). Canopy coverage <70% is probably not uncommon for aspen stands, which generally have rather open canopies.

The within-stand patterns of patchiness of aspen are not well understood. Stem patchiness is likely high immediately following a disturbance, when clonal regeneration is heavy, and decreases as seedlings begin to mature and density-dependent competition develops. Patchiness is much more difficult to assume without direct measurement in aspen forests due to the clonal nature of aspen, which reduces competition for water and nutrients.

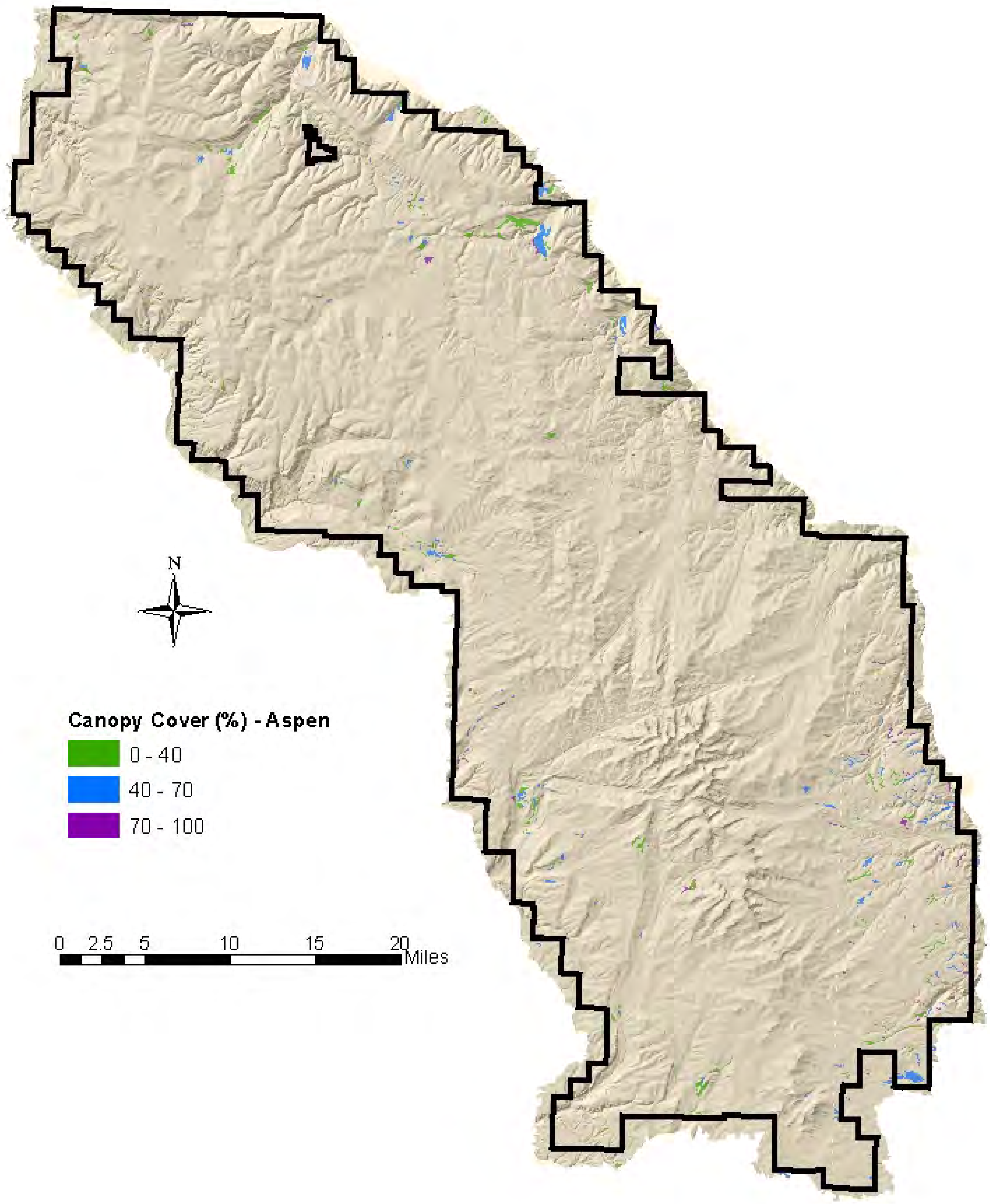


Figure M3A-21. Percent canopy coverage for aspen forests on the Bighorn National Forest.

Vertical Complexity—Vertical complexity data are lacking for aspen forests, but it is likely fairly high, given the open nature of many aspen stands on the Forest and their occurrence in areas of higher moisture availability. Despain (1973) noted that aspen stands typically have either a grassland-like understory, or a well-developed herbaceous layer that includes woody species such as *Prunus, Crataegus,* and *Amelanchier* spp. In addition, multi-storied stands can be caused by encroaching conifers mixed throughout the aspen clone.

Changes in Structure/Anthropogenic Influences/Departures from HRV

Many aspen stands support grazing by livestock and wildlife (Hoffman and Alexander 1976, Steele *et al*. 1983, Alexander *et al.* 1986). Domestic livestock have browsed aspen since their introduction into the Big Horn Mountains in the late 1800s, particularly before the establishment of the Forest Reserves near the turn of the century. Jack (1900) noted, "Wherever the Quaking Aspen occurs on the ground that has been overstocked or where other food is not abundant all foliage within reach is generally stripped from the plants and young shoots are browsed." At least some investigators (Kay 1990) suggest that browsing by wildlife and domestic livestock is responsible for the apparent loss of vigor and amount of aspen in the Rocky Mountains.

Since aspen regenerates asexually from root sprouts when the overstory trees are removed, fires favor the regeneration of aspen stands and likely were responsible for the regeneration of many large stands in Colorado and Wyoming (Meyer and Knight 2003). Fire frequencies for aspen stands are likely similar to the intervals found in the adjacent forests, since the aspen stands often burn when the adjacent coniferous stands burn. Thus, human effects on the fire regimes in adjacent forests likely affect aspen forests in a similar manner. Aspen forests at lower elevations, where fire frequencies may have decreased as a result of fire suppression, may have experienced longer fire intervals and subsequent lower regeneration. Aspen forests at higher elevations have likely been unaffected by human influences on the fire regime.

Very few of the aspen forests have been affected by timber harvesting on the BNF since the 1950s, although the cause of the recent regeneration of aspen in some parts of the Forest is likely due to mechanical treatment as well as an increase in fires in the late 1980s (Meyer and Knight 2003).

<u>Function</u>

No functional information has been collected specifically for the aspen forests of the BNF. Furthermore, few or no studies have examined in detail the functional characteristics of aspen forests in the Rocky Mountains of the U.S.; most studies have been conducted in Canadian or Alaskan forests where aspen cover is much more extensive.

Biomass and Productivity Characteristics

Using minimal field data and regression models to predict ANPP from satellite imagery, Hansen *et al.* (2000) provided rough estimates of ANPP of aspen forests below 7,200 feet (2,200 m) in elevation in the Greater Yellowstone Ecosystem. They estimated total ANPP in aspen cover types to be 4,413 kg/ha/yr (24,099 lbs/acre/yr); 41% of this estimate was represented by trees, while 31 and 28% were represented by shrubs and herbaceous vegetation in the aspen cover types, respectively. Aspen forests exhibited lower ANPP than cottonwood or Douglas-fir forests, but higher than burned or unburned lodgepole pine forests, sagebrush shrublands, and grasslands.

Cycling and Storage of Carbon and Nutrients

No data on cycling and storage of carbon or nutrients are available for aspen forests.

<u>Natural Disturbances</u>

Fire is the predominant natural disturbance in aspen forests in the Big Horn Mountains, although the fire regime is extremely difficult to reconstruct. Heavy browsing by deer and elk is also a management concern because continual removal of sprouts may reduce the vegetative spread and viability of aspen (Steele *et al.*

1983, Knight 1994). Girard (1997) found the regeneration of aspen is a serious problem on the BNF due to heavy browsing, and states that many of the aspen stands currently being treated subsequently need to be fenced from livestock and wildlife to protect new shoots.

In addition to fire and browsing, aspen forests are affected by various defoliating insects, particularly the forest tent caterpillar (*Malacosoma disstria*) and the large aspen tortrix (*Choristoneura conflicta*). The forest tent caterpillar may defoliate entire trees and stands early in the spring when the leaves are expanding. Although the trees may produce a second set of new leaves within a season, consecutive years of defoliation may be fatal. The aspen tortrix defoliates trees, but also mines aspen buds and may persist for several years (Allen and Harris 1999). Epidemics of the forest tent caterpillar may occur every 10 to 20 years in the southwestern U.S. No epidemics of the aspen tortrix have been reported for the BNF, and little evidence suggests that infestations by either insect is outside the historical range of variability (Meyer and Knight 2003).

Aspen stands are also susceptible to pathogens such as root diseases, canker-causing fungi, and heart rot fungus (*Phellinus tremulae*). Hinds (1985) suggests that increasing acreage of older aspen forests on the BNF due to fire suppression may increase the occurrence of these pathogens. Aspen are also susceptible to windthrow, although no records of major windthrow events in aspen exist for the Forest (Meyer and Knight 2003).

Summary of Key Findings for Aspen Forest Type

- Aspen forests comprise a minor portion of the forested area of the Bighorn National Forest, occupying 11,353 acres (4,594 ha) in seeps and low areas with high moisture availability.

- Aspen forests on the BNF are small and sparse, with average diameters between 5 and 9 inches (13 and 23 cm) and canopy coverage between 40 and 70%.

- Similar to lodgepole pine, aspen forests on the BNF that may be either seral to more shade-tolerant species (primarily subalpine fir and Engelmann spruce) or persistent as a late-successional stand.
- Most aspen stands on the BNF are young, typically less than 100 years old.
- Climate change, fire suppression, and ungulate browsing may have increased the fire interval in adjacent forest ecosystems, such that aspen forests may have experienced fewer natural disturbances and subsequently lower levels of regeneration.

Douglas-Fir Forest

Composition

Spatial Distribution

Douglas-fir is the third-most dominant forest cover type on the BNF, comprising about 14% of the forested acres (113,197 acres/ 45,809 ha). While Douglas-fir on the Forest occurs between 1,829 and 2,743 m (6,000 and 9,000 feet), it is most common between 2,000 and 2,300 m (6,500 and 7,500 feet) (Despain 1973). On the east flank of the Big Horn Mountains, Douglas-fir occurs between ponderosa pine and lodgepole pine forests. On the west flank, it is often the forest type at the lowest elevation, due to the absence of ponderosa pine forests there (Despain 1973, Hoffman and Alexander 1976). Douglas-fir forests nearly form a ring around the boundary of the BNF (Fig. M3A-22).

Stable Douglas-fir stands are found between 6,100 and 8,600 feet (1,900 and 2,600 m) on soils derived from limestone or dolomite (Despain 1973, Reid *et al.* 1999) on soils typically classified as well-drained alfisols (Nesser 1986). Ninety-three percent of the acreage of Douglas-fir in the Big Horn Mountains occurs on sedimentary soils, with limestone- or dolomite-derived soils providing the best-developed forests (Despain 1973, Hoffman and Alexander 1976). Thus Douglas-fir rarely competes with lodgepole pine in these ecosystems, since the latter is restricted to granitic substrates. On the eastern slopes, Douglas-fir forests occur on more moist sites than those dominated by ponderosa pine; on the western slopes, it occurs on the drier sites while stands of Engelmann spruce grow on the more moist sites (Hoffman and Alexander 1976). Hoffman and Anderson (1983) consider site indexes to be relatively low.

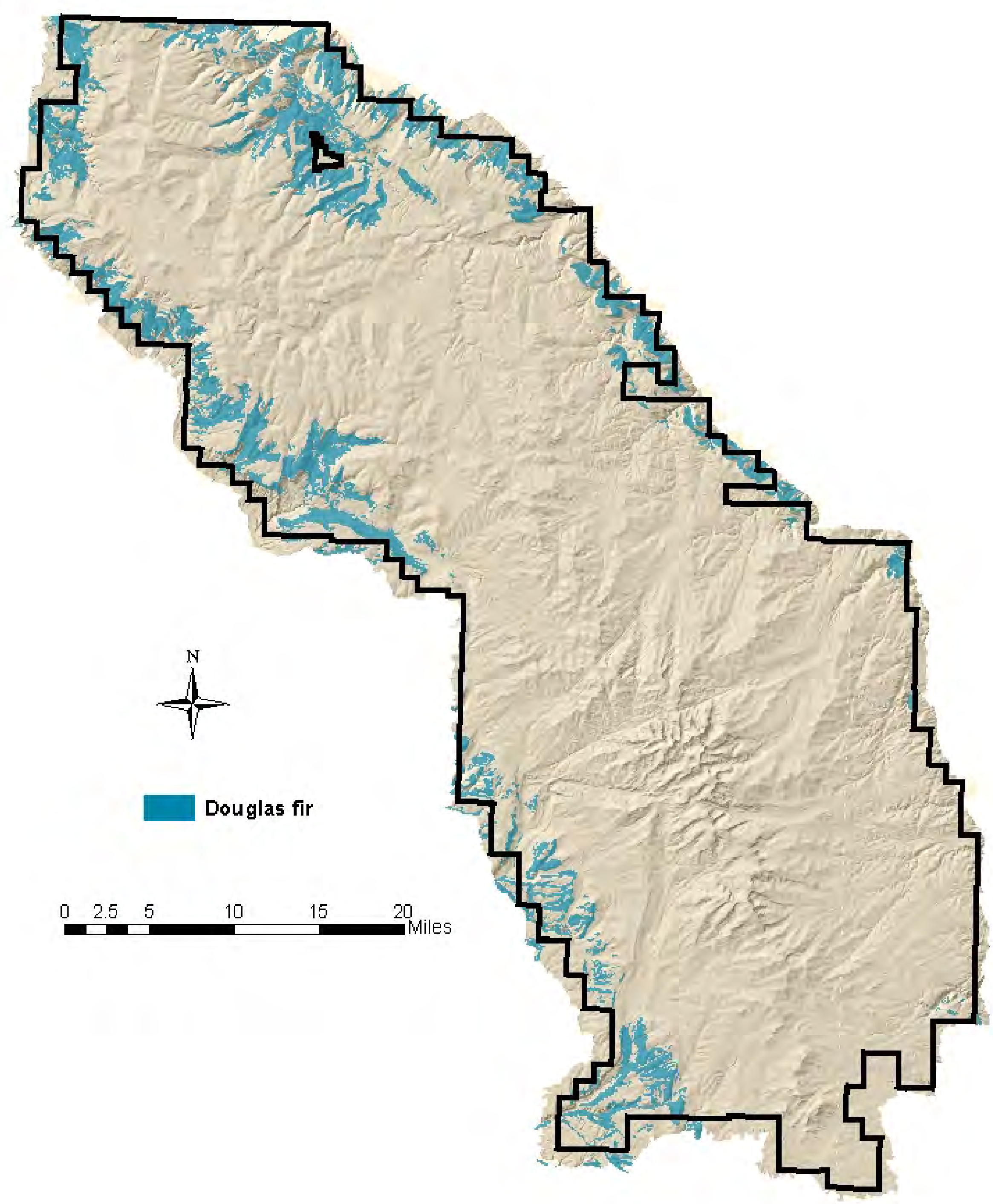


Figure M3A-22. Distribution of Douglas-fir forests on the Bighorn National Forest (CVU database).

The Characteristic Dominant Species and Associations

Hoffman and Alexander (1976) identified three habitat types dominated by Douglas-fir in the Big Horn Mountains (Table M3A-7). They include *Pseudotsuga menziesii/Berberis repens, Juniperus communis* phase, in which ponderosa pine is seral and limber pine is seral in some stands; *Pseudotsuga menziesii/Berberis repens,* where ponderosa, lodgepole, and limber pine are seral in some stands; and *P. menziesii/Physocarpus monogynus*, where ponderosa pine is seral and limber and lodgepole pines are seral in some stands. All habitat types feature Douglas-fir as the sole dominant species.

Table M3A-7. Habitat types for Douglas-fir identified by Hoffman and Alexander (1976) for the Big Horn Mountains. C = major climax species, S = seral, and s = seral in some stands.

Habitat type	Ponderosa pine	Douglas-fir	Limber pine	Lodgepole pine	Important species
P. menziesii/ Berberis repens, Juniperus communis phase	S	C	s		*Arnica cordifolia, Lupinus argenteus, Symphoricarpos oreophilus, Galium boreale, Rosa acicularis, Hesperochloa kingii, Festuca ovina, Astragalus miser*
P. menziesii/ Berberis repens	s	C	s	s	*Juniperus communis,Arnica cordifolia, Ribes lacustre, Symphoricarpos oreophilus, Hesperochloa kingii, Poa Spp.,Galium boreale, Senecio streptanthifolius, Smilacina racemosa*
P. menziesii/ Physocarpus monogynus	S	C	s	s	*Rosa acicularis, Symphoricarpos oreophilus, Berberis repens, Spiraea betulifolia*

Douglas-fir forests occur as open woodlands or closed forests depending on site productivity and fire, which affects the understory species present. Despain (1973) noted that Douglas-fir stands in the Big Horn Mountains typically have understories consisting mostly of the dominant tree species. Spruce saplings are the most common understory species at higher elevations, but Douglas-fir seedlings dominate at lower elevations. *Ribes lacustre* may form a shrub layer of less than 1% cover in high-elevation stands, and *Juniperus communis* (1% cover) dominates at lower elevations. Herbacous plants form a well-covered forest floor, though species composition is quite variable among stands. Grasses such as *Hesperochloa kingii* and *Poa* spp. were common among stands, and lichens such as *Cladonia* spp. and *Peltigera* spp. *are* also common. Other common understory species are *Mahonia repens*, *Physocarpus opulifolus,* and *Spirea* spp. (Hoffman and Alexander 1976, Welp *et al.* 1988). Open stands also include *Festuca idahoensis* and *Pseudoroegneria spicatum* (Hoffman and Alexander 1976, Steele *et al.* 1983, Reid *et al.* 1999).

Successional Characteristics

Douglas-fir is a late-successional species across much of its range on the BNF (Despain 1973, Hoffman and Alexander 1976). It is seral to spruce/fir forests at higher elevations and can replace ponderosa pine at some lower elevation sites (Despain 1973). In addition, Douglas-fir types may never reach dominance on sites where short fire intervals maintain ponderosa pine at lower elevations that would otherwise be replaced by Douglas-fir (Fischer and Clayton 1983). At higher elevations, lodgepole pine can persist on a site if Douglas-fir seedlings are continually destroyed by fire (Fischer and Clayton 1983).

The compositional nature of Douglas-fir forests depends strongly on whether the stand is seral or persistent, which is heavily influenced by aspect and soil type. In warm, dry, low-elevation environments, Douglas-fir is restricted to north slopes where it forms pure seral and stable forests and where conditions are too extreme for spruce/fir forests (Despain 1973). These areas often have grass/forb or sagebrush habitats on the south slopes, thus forming Douglas-fir "forested islands". At higher elevations, where growing conditions are cooler and wetter, Douglas-fir may grow on any aspect, but spruce and fir are also able to survive and Douglas-fir acts as a seral forest only. Douglas-fir is shade tolerant and can generally reproduce under its own canopy, so stands tend to be uneven-aged rather than even-aged. Pure stands usually originate from fires, and persist due to their ability to withstand frequent, low-intensity fires.

Changes in Species Composition/Departures from HRV

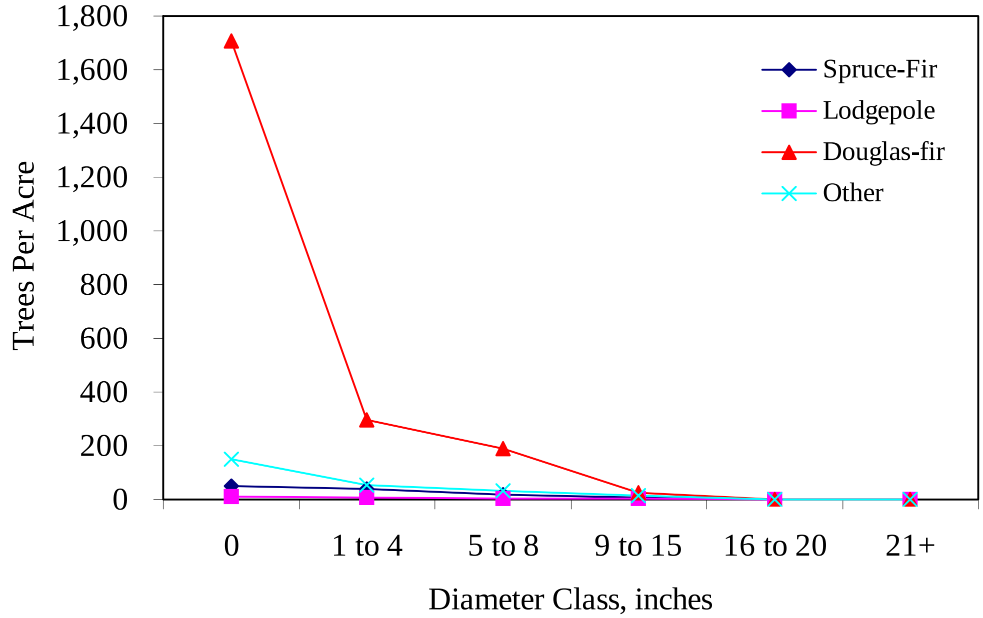
Compositional changes in Douglas-fir forests primarily occur where the species is seral and Douglas-fir is most often succeeded by spruce/fir forests. Compositional changes rarely move towards lodgepole pine forests, since the two species occur only rarely on the similar substrates. On the east flank of the Forest, Douglas-fir may occur in mixed stands with ponderosa pine where the elevational zones of those forest types merge. When comparing potential to current vegetation, 70% of the 109,673 acres (44,383 ha) considered to have the potential to be Douglas-fir forest (PNV) is indeed currently Douglas-fir forest (CVU), 12% is currently ponderosa pine, and 8% is each in lodgepole pine and limber pine. Hoffmann and Alexander (1976) identify each of these forest types as potential seral stages of Douglas-fir forests (Table M3-7).

<u>Structure</u>

Stand Age and Diameter Class Distributions

Despain (1973) characterized the Douglas-fir forests of the Big Horn Mountains as well-spaced, ranging from 1,366 to 1,792 trees/ha (553 to 725 trees/acre). Individuals in these forests are medium-sized, ranging from 10 to 20 inches (25 to 50 cm) in diameter. Basal area ranges from 56 to 73 m^2/ha (244 to 318 ft^2/acre). The stands are generally even-aged with moderate to heavy regeneration in the understory. Douglas-fir typically reaches 20 cm (8 in) diameter by 200 years (Mehl 1992). Douglas-fir is very long-lived, typically living until 400 years, but potentially up to 700 years.

Size structures of Douglas-fir forests show relatively little variability across Habitat Structural Stage (Figs. M3A-23a and M3A-23b). Across all stages, Douglas-fir dominates all size classes, particularly the seedling class. Spruce and fir gain sapling and seedling density in Stages 4B and 4C. Although some Douglas-fir may be seral to spruce/fir in these stages, the dominance of Douglas-fir in the understory of all stages suggests that spruce/fir is present mainly because of its shade tolerance. Douglas-fir dominates all size classes (Figs. M3A-24a and M3A-24b), and is particularly dominant in pole-sized diameter classes (5 to 8 in/13 to 20 cm in Stage 3, 9 to 15 in/23 to 38 cm in Stage 4). As with tree density, spruce and fir gain increasing dominance in stands classified as Stage 4, but Douglas-fir remains the dominant species across all stages.



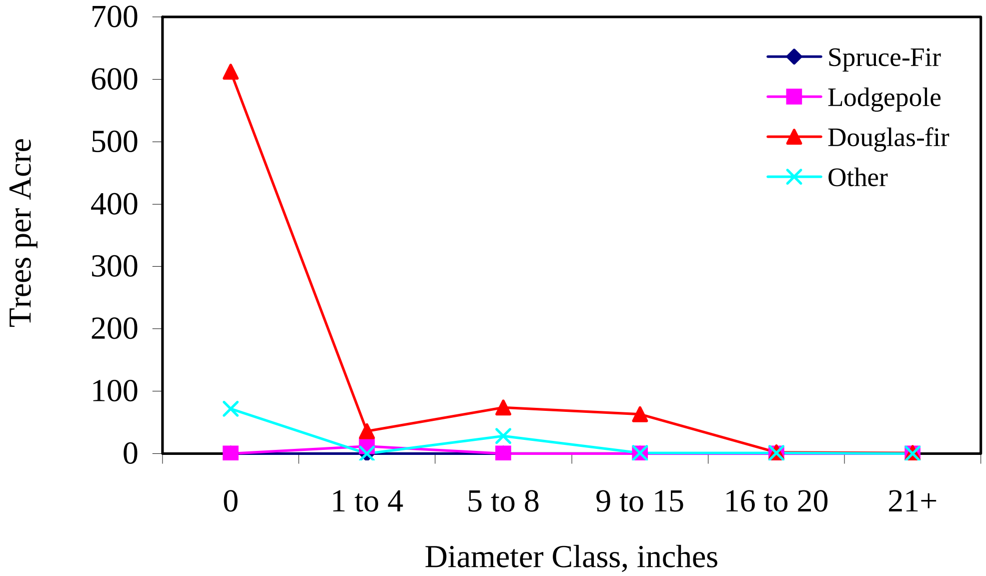
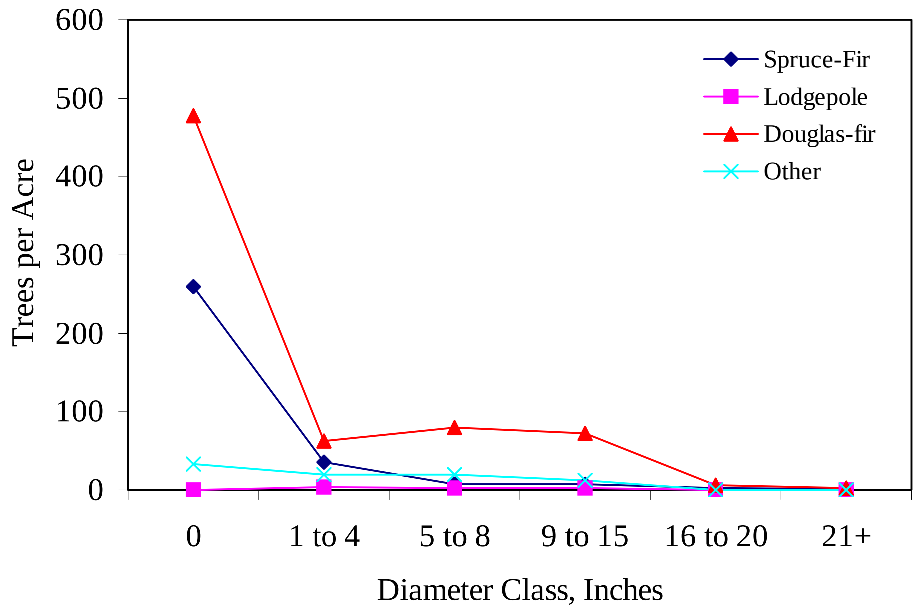


Figure M3A-23a. Density of trees by diameter class for Douglas-fir stands of the Bighorn National Forest, Habitat Structural Stages 3 (top pane) and 4A (bottom pane).



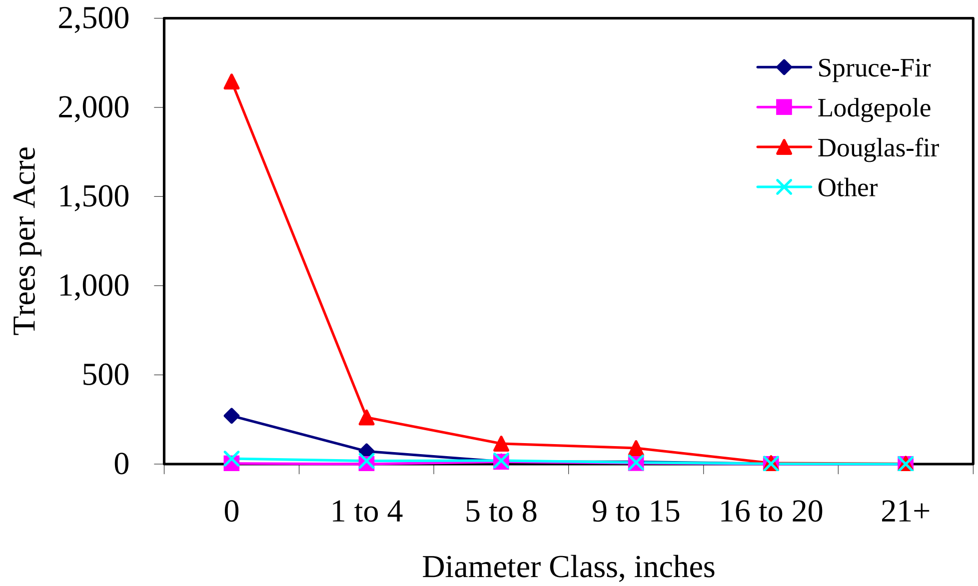
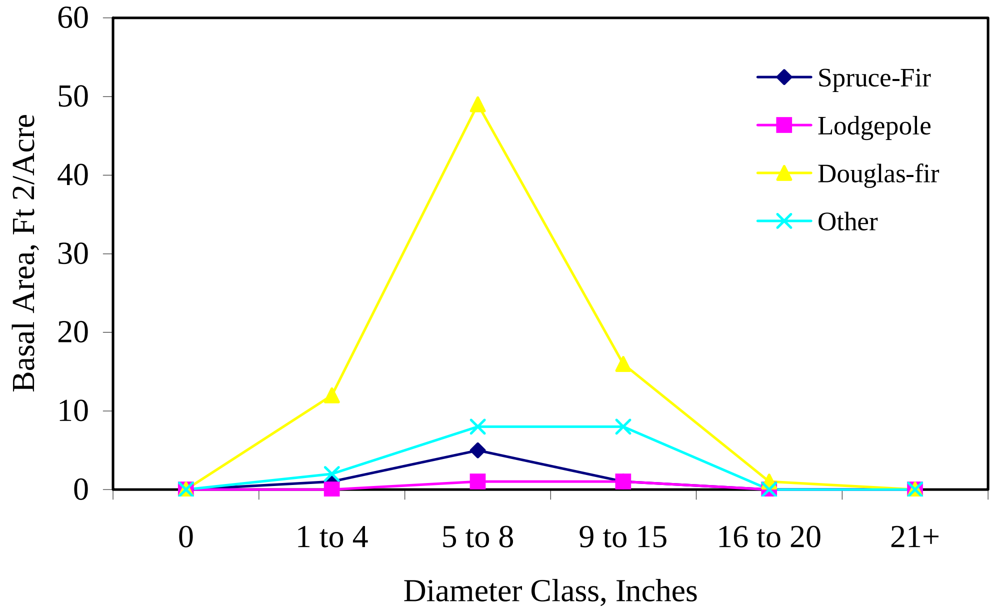


Figure M3A-23b. Density of trees by diameter class for Douglas-fir stands of the Bighorn National Forest, Habitat Structural Stages 4B (top pane) and 4C (bottom pane).



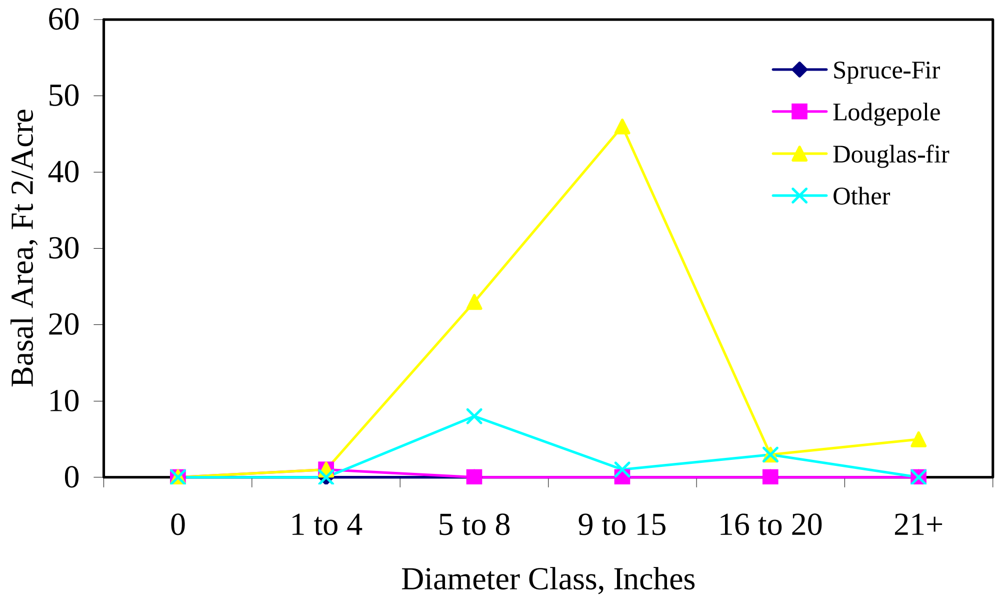
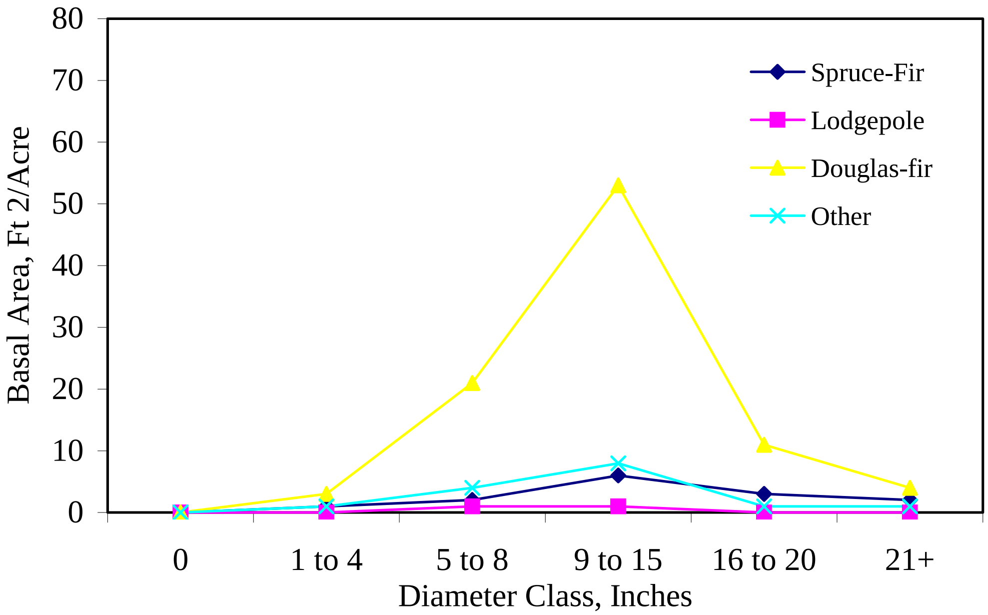


Figure M3A-24a. Basal area by diameter class for Douglas-fir stands of the Bighorn National Forest, Habitat Structural Stages 3 (top pane) and 4A (bottom pane).



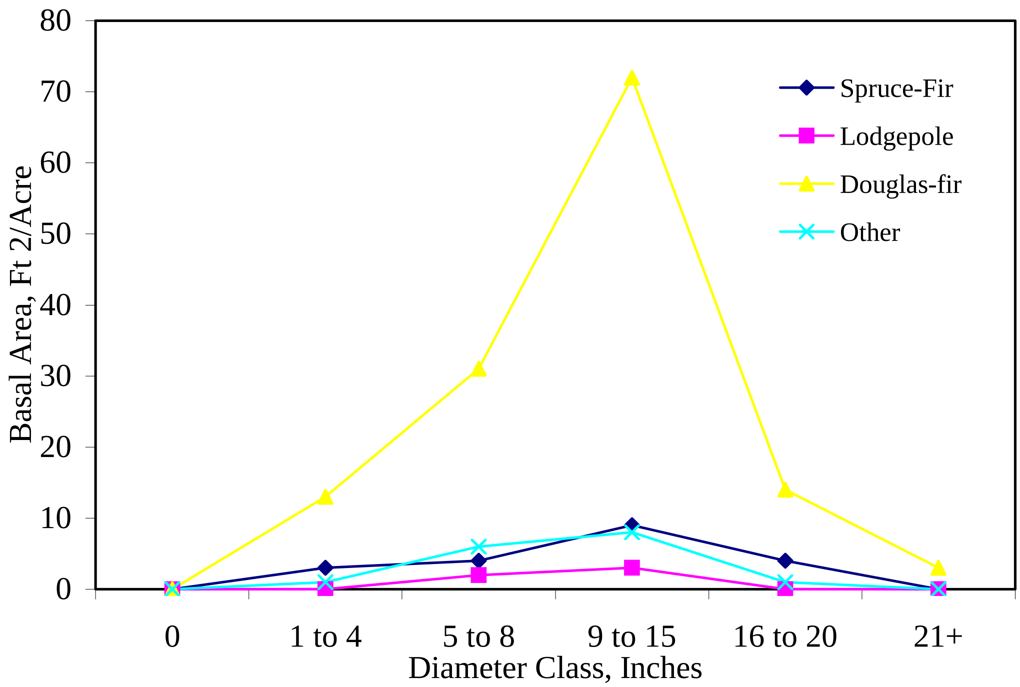


Figure M3A-24b. Basal area by diameter class for Douglas-fir stands of the Bighorn National Forest, Habitat Structural Stages 4B (top panel) and 4C (bottom panel).

Habitat Structural Stages

Douglas-fir forests of the BNF are typically pole-sized, closed-canopy forests (Fig. M3A-25). Approximately 78% (88,393 acres/35,772 ha) of the Douglas-fir forests on the BNF are classified as Stages 3B, 3C, or 4C, suggesting that most forests of this type occur with densities sufficient to provide relatively high canopy cover. Given the relatively thick, complex canopy structure of Douglas-fir forests, such a trend is not surprising. Spatially, the Habitat Structural Stages of Douglas-fir forests appear to show little pattern within its elevation zone on the BNF (Fig. M3A-26). Forests classified as Stage 3 are often juxtaposed with those classified as Stage 4, but often show very clear boundaries between the two stages. Such a pattern suggests that Habitat Structural Stages may be heavily influenced by slope and aspect (Fig. M3A-26).

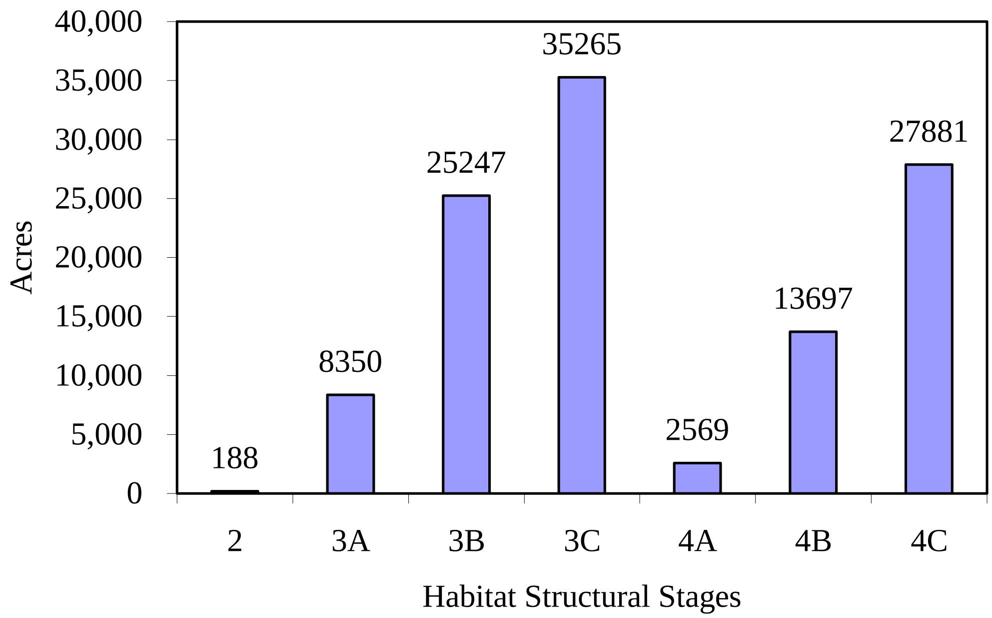


Figure M3A-25. Acres of Douglas-fir forests in each Habitat Structural Stage on the Bighorn National Forest.

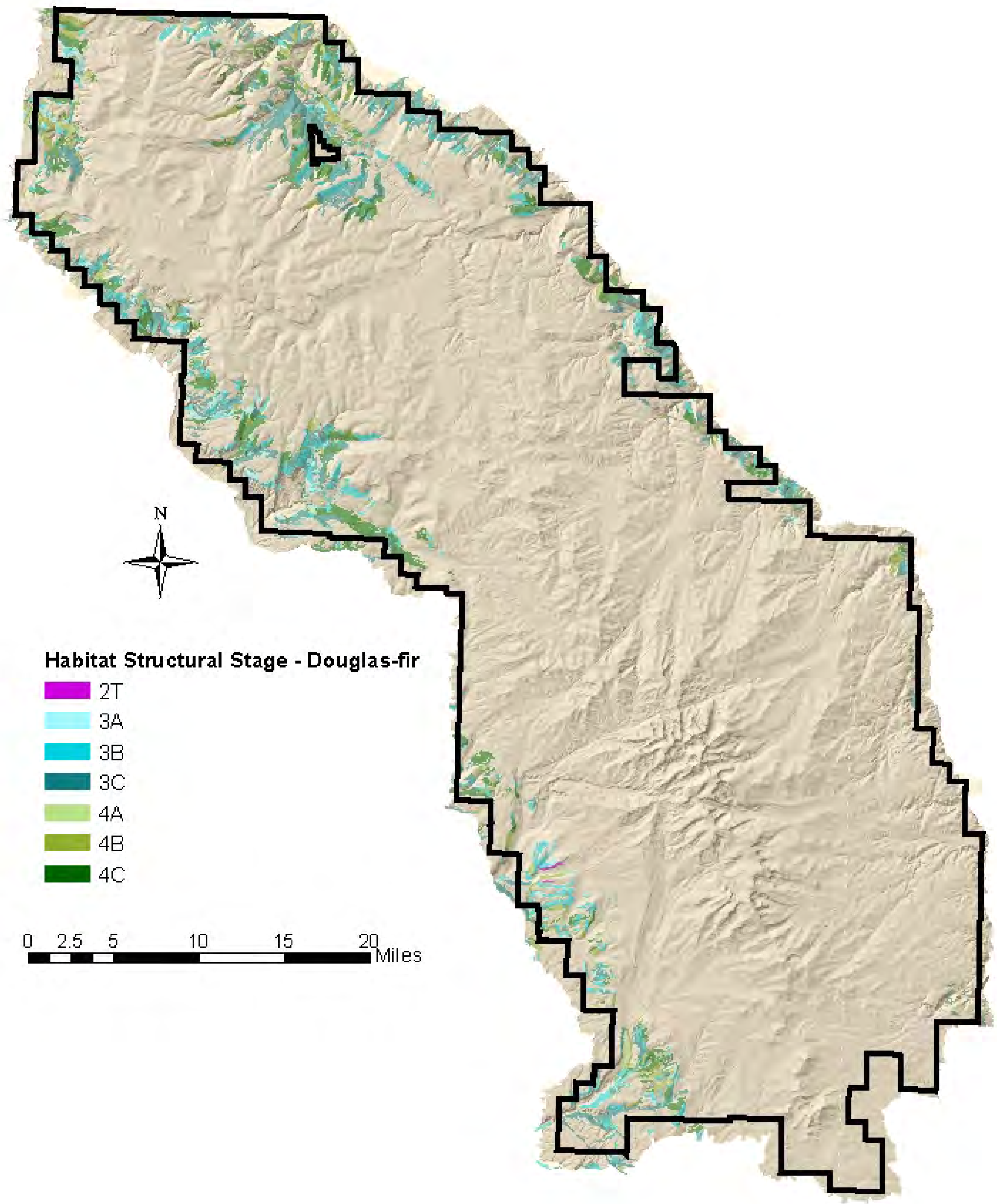


Figure M3A-26. Location of Habitat Structural Stages of Douglas-fir forests in the Bighorn National Forest (CVU database).

Stand Density

Densities of Douglas-fir forests of the Big Horn Mountains range from 1,366 to 1,792 trees/ha (553 to 725 trees/acre; Despain 1973). Data collected on the BNF suggest that densities range from 176 to 471 trees/ha (71 to 191 trees/acre) for trees >1 inch (2.5 cm) in diameter; for trees >9 inches (23 cm) in diameter, densities range from 25 to 95 trees/ha (10 to 38 trees/acre). Stand densities are quite variable based on Habitat Structural Stage; for all trees > 1 inch, densities are highest in Stage 3 and in Stage 4C; for only trees > 9 inches, densities increase with Habitat Structural Stage and are highest in Stage 4C (Figs. M3A-23 and M3A-24).

Old-Growth/Older Forest Characteristics

Old-growth Douglas-fir stands have an overstory of almost entirely Douglas-fir, consisting of relatively few, large trees at least 200 years old, and with at least 10 trees/acre over 18 inches (46 cm) DBH (Mehl 1992). High variation in tree diameters, broken and/or patchy canopy, standing dead trees or snags, and a wide range of tree vigor also characterize old-growth Douglas-fir stands. Because frequent fire intervals and low-intensity fires historically characterized low-elevation Douglas-fir stands in the Big Horn Mountains, human activities in the Big Horns, particularly fire suppression, may have altered the within-stand characteristics of old-growth Douglas-fir stands (Meyer and Knight 2003). Fire suppression has likely increased the density of many Douglas-fir forests in the Big Horn Mountains, such that smaller trees, higher densities, and more snags and woody debris may characterize some older stands.

Douglas-fir is known to reach diameters of up to 50 inches (127 cm) in the Tepee Creek area and heights of approximately 100 feet (31 m) just west of Meadowlark Lake. Trees up to 400 years old are known in the Tepee Creek area. One stand in the Tepee Creek area had a Stage 2 stand average diameter of 23 inches (58 cm). Based on these statistics, it is clear that Douglas-fir on the BNF have reached old ages and large sizes.

Accurate stand origin data exist for approximately 29% of the Douglas-fir forests on the BNF. For this portion of the cover type, only 8% is known to be at least 200 years old (Fig. M3A-27), such that relatively little of this cover type may be defined as "old-growth" in terms of age alone, although the sample area is very limited. Photo-interpretation of the BNF has suggested that only 1% of the entire Douglas-fir forest type is old-growth (Meyer and Knight 2003). At least 21% of the Douglas-fir forests on the BNF range from 90 to 210 years old.

Stand Structural Components

Snags—In Douglas-fir forests of the Big Horn Mountains, snag density appears to be highest in older, more closed-canopy forests such as those classified as Stage 4 (Fig. M3A-28). Moreover, snags appear to be most common in Stage 4C (43 snags per acre/106 snags per ha), where trees are largest (and potentially oldest) and canopy closure is highest. Snags average 18 per acre (47 per ha) in forests classified as Stage 3, and 66 snags per acre (163 snags per ha) in those classified as Stage 4. As with coarse woody debris, snag structural characteristics in Douglas-fir forests should be expected to vary with stand age and time since disturbance. Given the less-severe fire regime in Douglas-fir forests, the number of snags should increase with stand age.

Coarse Woody Debris—Although Douglas-fir forests are among the first and most extensively studied for coarse woody debris characteristics, most studies have been conducted in the Pacific Northwest. Because Douglas-fir forest ecosystems in that region are vastly different in stand structure, growing season, decomposition rates, and stand dynamics from those of the Big Horn Mountains and the interior Rocky Mountains in general, coarse woody debris from Pacific Northwestern Douglas-fir forests will not be discussed here for comparison.

Few data about coarse woody debris exist for the Big Horn Mountains, but general trends can probably be assumed. In contrast to spruce/fir and lodgepole pine forests, lower amounts of downed wood are likely created following fires in Douglas-fir forests of the Big Horns, assuming that fires are primarily less severe surface fires and are only occasionally stand-replacing.

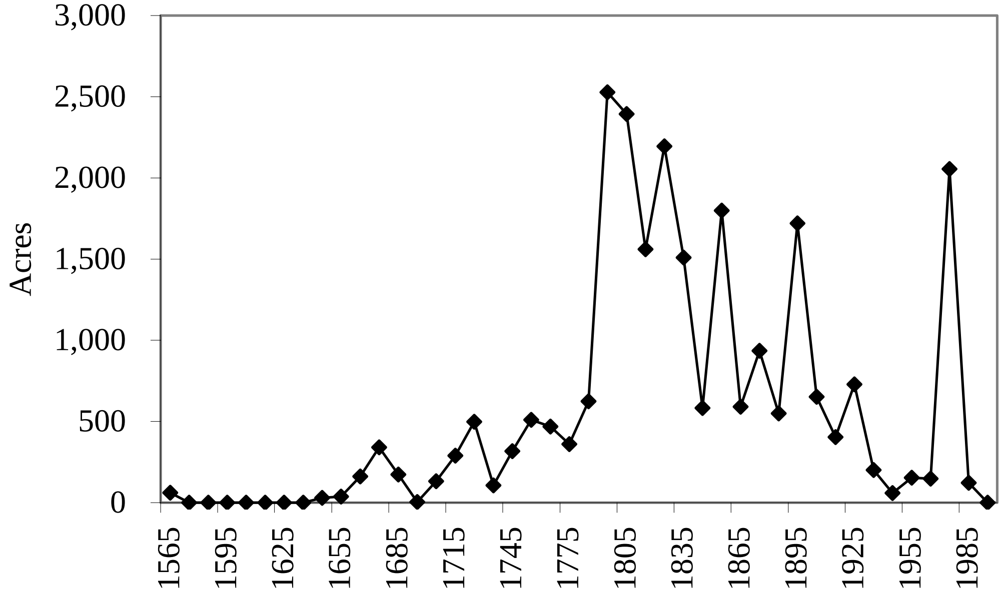


Figure M3A-27. Stand origin dates for Douglas-fir forests on the Bighorn National Forest. Only 29 percent of the area of Douglas-fir forest on the BNF is represented.

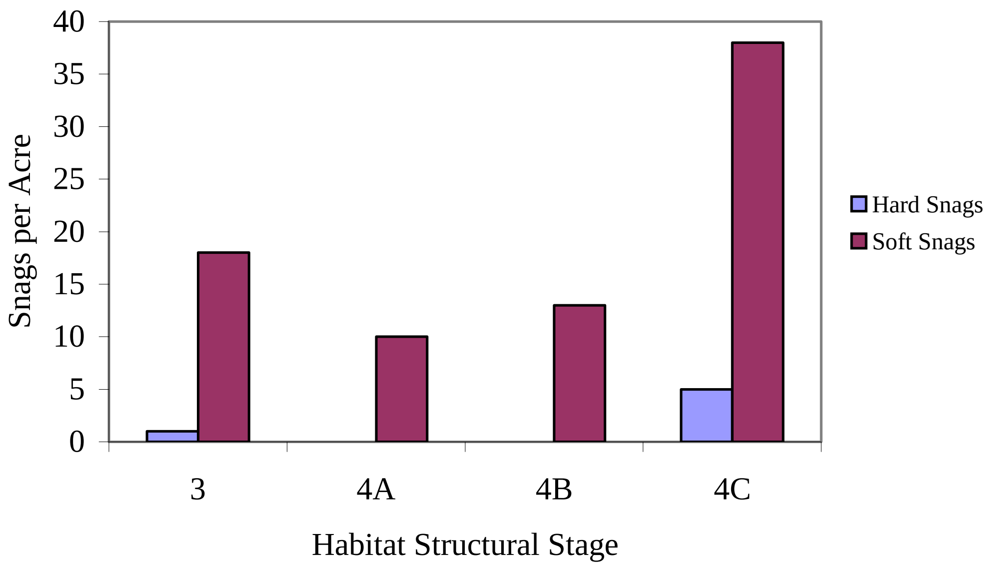


Figure M3A-28. Snag density by Habitat Structural Stage in Douglas-fir forests in the Bighorn National Forest**.**

In addition, frequent surface fires may be more likely to consume coarse woody debris already on the ground than less frequent stand-replacing fires (Meyer and Knight 2003). If fire suppression in Douglas-fir forests in the Big Horns has decreased the frequency of surface fires, coarse woody debris may accumulate. Less coarse woody debris is likely present in Douglas-fir forests than in high-elevation forests, however. Graham *et al.* (1994) suggest that 10 to 20 Mg/ha (27 to 54 lbs/acre) of coarse woody debris is the natural range for the *P. menzesii/ Physocarpus malvaceus* habitat type in western Montana, and that 27.3 to 54.7 Mg/ha (74 to 149 lbs/acre) is standard for the *P. menzesii/Calmagrostis rubescens* habitat type.

Canopy Cover—On the BNF, 56% of the Douglas-fir forests (63,146 acres/25,554 ha) exhibit canopy cover of >70%, approximately 34% exhibit canopy cover between 40 and 70%, and 10% has very sparse canopy coverage (< 40%). Canopy coverage appears to be heaviest in Douglas-fir forests at the northern and eastern sides of the Forest as compared to the western side. This pattern may be related to differences in precipitation on the drier western flank vs. the wetter eastern flank of the Big Horn Mountains (Despain 1973). In addition, slope and aspect appear to play an important role in determining Douglas-fir canopy cover, particularly in the southern portion of the BNF (Fig. M3A-29). Canopy coverage is heaviest in the large, contiguous stands along the eastern side of the Forest.

There is even more within-stand patterns of patchiness than that seen in spruce/fir and lodgepole pine forests. Because of its shade tolerance, Douglas-fir is inherently patchy, with patchiness increasing with stand age and further stand development.

Vertical Complexity—Vertical complexity data is lacking for Douglas-fir forests. Despain (1973) noted relatively little understory growth in Douglas-fir stands, but *Ribes lacustre* and *Juniperus communis* both account for more than 1% cover within the understory.

Changes in Structure/Anthropogenic Influences/Departures from HRV

The primary human influence on Douglas-fir stand structure in the Big Horns is fire suppression (Meyer and Knight 2003). Fire suppression and the elimination of Native American fires has resulted in increased stand density in many areas of the Big Horn Mountains, so that many Douglas-fir forests have been altered from open stands to closed, more dense stands. Grazing has likely also influenced the structure of Douglas-fir forests via its effect on herbaceous vegetation that formerly supported frequent, low-severity fires. The direct effect of fire suppression on Douglas-fir forests in the Big Horns is unclear, however, because little is known about the fire history of these forests. Meyer and Knight (2003) have suggested that fire suppression has lengthened the mean fire interval beyond its historic range of variability for these forests, but additional, site-specific studies or fire histories are required for the Big Horn Mountains.

Relatively little timber has been harvested in the Douglas-fir forests on the Bighorn in the past 40 years, despite the fact that it is a desirable wood for commercial purposes. Fewer than 2,000 acres (800 ha) have been affected by timber harvesting since the 1960s, primarily because the Forest Service classified Douglas-fir as a non-commercial species for this portion of Region 2, at least through the early 1980s, because so little silvicultural information was available on inland Douglas-fir. Very little Douglas-fir has been clearcut in the Big Horn Mountains, as most silvicultural activities have involved shelterwood cutting, especially in the 1980s (Fig. M3A-30). Despain suggested that Douglas-fir forests in the Big Horn Mountains were extensively harvested during the settlement period (approximately the 1870s – 1930s) due to their accessibility near the base of the Big Horn Mountains. For the most part, this vegetation no longer supports livestock grazing but can provide browsing for wildlife. Stands accumulate some snow in the winter that provides runoff for the regional watersheds.

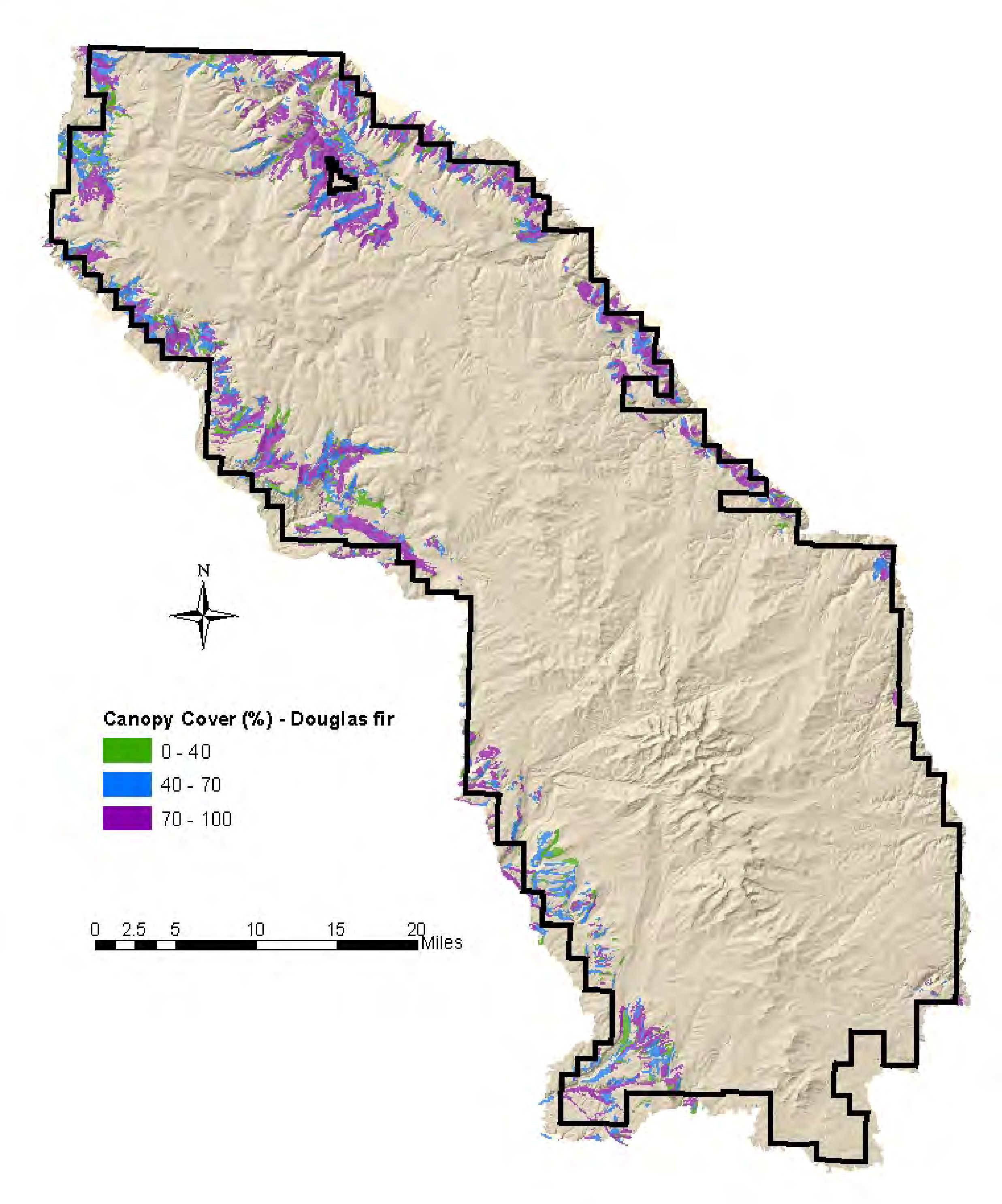


Figure M3A-29. Percent canopy coverage for Douglas-fir forests on the Bighorn National Forest (CVU database).

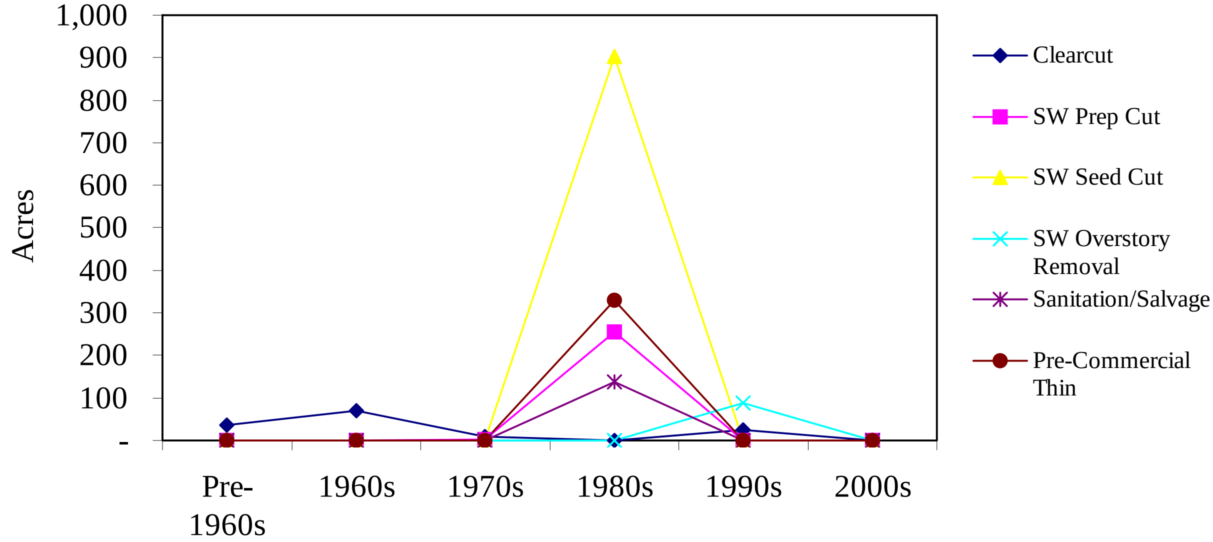


Figure M3A-30. Summary of timber harvesting activities in Douglas-fir forests on the Bighorn National Forest since the 1960s.

.

Function

No functional data for Douglas-fir forests describing the above- or below-ground biomass, productivity, carbon storage, or nutrient cycling are available for the Big Horn Mountains. Few data exist for Douglas-fir in the U.S. Rocky Mountains in general, because of the minor importance of the cover type in the Intermountain West, at least in pure stands, as compared to spruce/fir and lodgepole pine forests. The majority of functional studies of Douglas-fir forests have been completed in the Pacific Northwest, which has a climate and growing season too drastically different from that of northern Wyoming to warrant comparison in this Assessment.

Natural Disturbances

Primary natural disturbance factors for Douglas-fir forests include fire, insects, and, to a limited extent, grazing. Fire has an important influence in shaping this forest type (Fischer and Clayton 1983, Peet 1988, Knight 1994, Jones and Fertig 1998, Jones and Fertig 1999a-e), and maintaining stands in a pre-settlement condition is thought to require occasional fire (Knight 1994). Douglas-fir is adapted to surface fires at maturity since it has thick bark that protects the trunk, although it also has lower limbs that may carry flames into the crown (Fischer and Clayton 1983). This architecture is not as adaptive for surface fires as trees with few lower limbs such as ponderosa pine. Based on this information, Douglas-fir forests are no doubt adapted to high-frequency, low-intensity burns but probably not to the degree of ponderosa pine forests.

Douglas-fir is susceptible to damage caused by dwarf mistletoe (*Arceuthobium* spp.), western spruce budworm (*Choristoneura fumiferana*), and Douglas-fir beetle (*Dendroctonus pseudotsugae*) (Eyre 1980, Knight 1994). Dwarf mistletoe reduces growth while Douglas-fir beetle kills mature trees. The western spruce budworm reduces growth and with repeated defoliation eventually kills the tree (Eyre 1980). Grazing in more open stands can lead to a decrease in the amount of Idaho fescue and bluebunch wheatgrass.

Summary of Key Findings for Douglas-Fir Forest Type

- Douglas-fir represents the third-most common forest type on the BNF, comprising 113,197 acres (45,809 ha) and found at mid- to lower-elevations between 1,800 and 2,900 m (6,000 and 9,000 feet), most often on sedimentary substrates.

- Douglas-fir is distributed as a "ring" around the boundaries of the Forest, primarily as typically pole-sized, closed-canopy forests (Stages 3B, 3C, and 4C).

- Relatively few data exist to describe important forest ecosystem attributes for interior Douglas-fir, particularly that in the Big Horn Mountains. Additional research is required to identify key characteristics of coarse woody debris, ecosystem function, and fire history in these forests.

- Although the sample area is very small for determining stand origin dates, relatively few acres of Douglas-fir forests in the Big Horn Mountains are older than 200 years.
-
- Douglas-fir forests have likely been strongly influenced by fire suppression, grazing, and timber harvesting activities during the settlement period. Additional fire history studies are needed to determine the degree of alteration from the historic range of variability.

Ponderosa Pine Forest

Composition

Spatial Distribution

Ponderosa pine has a limited range in the Big Horn Mountains, where it occurs in the lowest elevations of the conifer forest and covers approximately 37,324 acres (15,105 ha) on the BNF, only 3% of the forested area on the Forest. Ponderosa pine forests on the BNF typically occur below 2,600 m (8,500 feet) and are most common between 1,500 and 2,100 m (5,000 and 7,000 feet) (Despain 1973). This forest type typically occurs on the east slope at the base of the mountains (Fig. M3A-31). Ponderosa pine forest ends abruptly in grasslands on the lower eastern slopes (Despain 1973). A small pocket of open, persistent ponderosa pine forests also occur in Tensleep Canyon in the extreme southwestern portion of the BNF, but otherwise the forest type is absent from the western flank of the Forest. Nearly 80% of all ponderosa pine forests on the BNF are found on coarse-textured, rocky, sedimentary substrates (Despain 1973, Hoffman and Alexander 1976).

Ponderosa pine is a fairly drought-tolerant species growing on drier forest sites (Hoffman and Alexander 1976, Eyre 1980) with coarse-textured, well-drained soils. It is not as shade tolerant as Douglas-fir, which allows the latter species to establish and eventually replace it on more mesic sites (Knight 1994). Ponderosa pine stands grow on all slope aspects and grades, but are more common on moderate to steep slopes and ridge tops (Reid *et al.* 1999). Stands tend to have a more closed canopy with increasing elevation due to wetter conditions (Peet 1988).

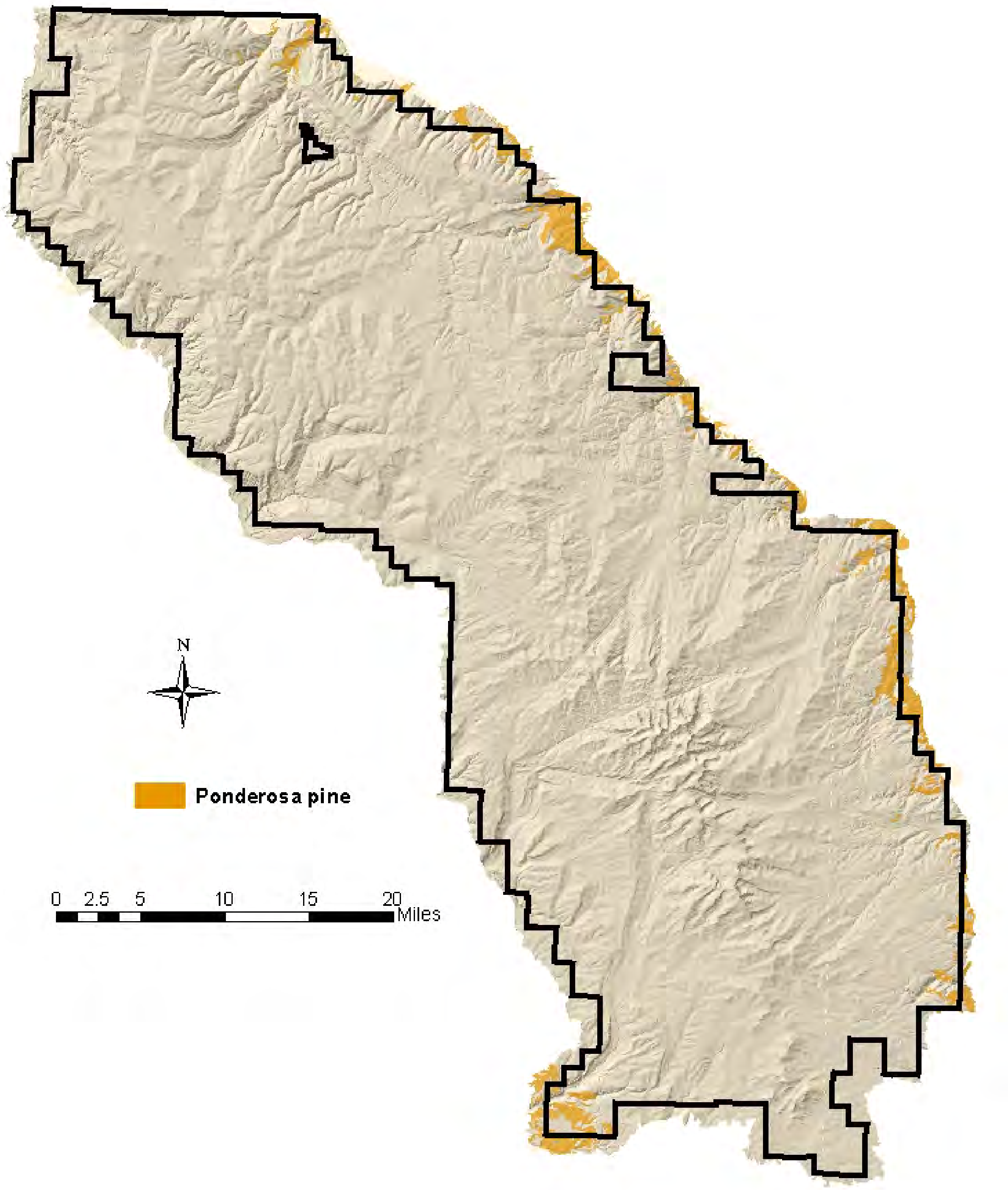


Figure M3A-31. Distribution of ponderosa pine forests on the Bighorn National Forest (CVU database).

The Characteristic Dominant Species and Associations

Hoffman and Alexander (1976) identified five habitat types dominated by ponderosa pine in the Big Horn Mountains (Table M3A-8): *Pinus ponderosa/Pseudoroegneria spicatum, P. ponderosa/Festuca idahoensis, P. ponderosa/Spiraea betulifolia, P. ponderosa/ Physocarpus monogynus,* and *P. ponderosa/Juniperus communis*, all of which feature ponderosa pine as the dominant species.

Table M3A-8. Ponderosa pine habitat types identified by Hoffman and Alexander (1976) for the Big Horn Mountains.

Habitat type	Description	Important species
P. ponderosa/ Pseudoroegneria spicatum	Driest and warmest of the ponderosa series, below the eastern national forest boundary on southern aspects. Tree reproduction is sporadic, resulting in open patches of even-aged trees.	*Pseudoroegneria spicatum, Aristida longiseta, Carex filifolia, Koeleria cristata, Stipa comata, Artemisia frigida, Prunus virginiana, Viola nuttalli, Antennaria parviflora, Balsamorhiza sagittata* and *Astragalus succulentus.*
P. ponderosa/ Festuca idahoensis	Tree reproduction is more consistent over time than in the drier bluebunch wheatgrass habitat type, but it also follows episodic cycles. Increased fire protection has encouraged both graminoids and forbs that compete more effectively than tree seedlings for limited soil moisture.	*Festuca idahoensis*, *Carex filifolia, Pseudoroegneria spicatum, Bromus tectorum, Hesperochloa kingii, Koeleria cristata, Rhus trilobata, Prunus virginiana, Artemisia frigida, Rosa acicularis, Symphoricarpos albus, Balsamorhiza sagittata, Cerastium arvense, Cystopteris fragilis, Achillea millefolium, Anemone patens, Antennaria rosea,* and *Astragalus succulentus.*
P. ponderosa/ Spiraea betulifolia	The understory vegetation is a mixture of grasses, perennial forbs, and low shrubs. The mesophytic habitat results in a more closed overstory structure and tree reproduction is more abundant than in the previous habitat types.	*Spiraea betulifolia, Symphoricarpos albus, Festuca idahoensis, Hesperochloa kingii, Poa palustris, Clematis tenuiloba, Galiurn boreale, Balsamorhiza sagittata, Lomatium dissecturn, Lupinus argenteus,* and *Smilacina racemosa.*
P. ponderosa/ Physocarpus monogynus	Confined to the east slope of the Big Horn Mountains on northern aspects that receive little or no direct solar radiation. It is the most productive of the climax ponderosa pine sites. Understory vegetation is dominated by mountain ninebark and is relatively rich in species.	*Physocarpus monogynus, Acer glabrum, Amelanchier anifolia, Clematis tenuiloba, Berberis repens, Rosa acieularis, Spiraea betulifolia, Symphoricarpos albus, Festuca idahoensis, Hesperochloa kingii, Poa interior, Poa palustris, Antennaria rosed, Balsamorhiza sagittata, Cerastium arvense, Cystopteris fragilis, Galium boreale, Lupinus argenteus, Carex xerantica, Stipa columbiana, Aster conspicuus, Epilobium angustifolium,* and *Fragaria* spp.
P. ponderosa/ Juniperus communis	Limited to the southeastern portion of the Big Horn Mountains. Sparse understory.	*Juniperous communis, Hesperochloa kingii, Poa interior, Agoseris glauca, Astragalus miser, Lonatium ambibuum,* and *Clematis tenuiloba.*

Similar to Douglas-fir, ponderosa pine stands in the Big Horns typically have understories consisting mostly of the dominant tree species (Despain 1973). Douglas-fir seedlings and limber pine seedlings are also found beneath ponderosa pine, but are far more sparse. Ponderosa pine forests typically have a well-established shrub layer that is highly variable from stand to stand. Where stand density is higher, a *Physocarpus monogynus-Symphoricarpus alba* or *Physocarpus monogynus-Juniperus communis-Shepherdia canadensis* shrub community may be present at 5-10% cover.

Where stand density is low, the ground cover is often dominated by *Pseudoroegneria spicatum,* with *Clematis pseudoalpina*, *Symphoricarpus alba*, *Galium alba*, and *Spiraea betulifolia* also present. Other species include *Arctostaphylos uva-ursi, Carex rossii*, *Pseudoroegneria spicatum*, and *Festuca idahoensis* (Hoffman and Alexander 1976, Alexander *et al.* 1986).

Successional Characteristics

Ponderosa pine is considered a late-successional species for much of its range on the BNF (Despain 1973, Hoffman and Alexander 1976), particularly at lower elevations and on dry ridges, where Douglas-fir cannot thrive. Where the ponderosa pine and Douglas-fir elevational zones merge at higher elevations, ponderosa pine is seral to Douglas-fir (Despain 1973). Ponderosa pine is shade intolerant and often (though not always) persists in open-grown, poorly-stocked stands maintained by frequent, low-intensity fires. The overstory is dominated by ponderosa pine, but aspen may be present (Hoffman and Alexander 1976). Ponderosa pine is typically a late-successional species where fire has not been completely excluded and relatively pure stands exists. Where fire exclusion has allowed shade-tolerant Douglas-fir to become established, ponderosa pine is often considered seral (Mehl 1992). Such conditions are rare in the Big Horns, however, because the species are typically separated by substrate (Despain 1973, Meyer and Knight 2003). Where ponderosa pine and Douglas-fir are found on the same site, stands with closed canopies may be co-dominated by Douglas-fir (Reid *et al.* 1999).

Changes in Species Composition/Departures from HRV

Compositional changes in ponderosa pine forests are not particularly evident in the Big Horn Mountains except where Douglas-fir replaces ponderosa pine in the absence of fire (Meyer and Knight 2003). Approximately 67% (23,337 acres/9,444 ha) of the 34,760 acres (14,066 ha) considered having the potential to be ponderosa pine forest (PNV) is currently ponderosa pine forest (CVU), 21% is currently lodgepole pine, 5% is juniper, and 4% is aspen.

Structure

Stand Age and Diameter Class Distributions

Relatively few stand structural data are available for this minor forest type, but ponderosa pine in the Big Horns typically forms clumpy stands with 865 to 1,730 trees/ha (350 to 700 trees/acre). Young stands on better sites may have up to 3,460 trees/ha (1,400 trees/acre). Basal areas range from 8.2 to 27.9 m^2/ha (35.7 to 121.5 ft^2/acre; Despain 1973).

Habitat Structural Stages

Ponderosa pine forests of the BNF are typically pole-sized, closed-canopy forests (Fig. M3A-32). Approximately 63% (23,453 acres/9,491 ha) of the ponderosa pine forests on the BNF are classified as Stages 3B, 3C, or 4C, suggesting that most forests of this type on the Forest occur as medium-sized trees across their range (Fig. M3A-33). Habitat Structural Stages of ponderosa forests appear to be stratified by elevation in the BNF, where stands classified as Stage 3 are typically found at lower elevations (Fig. M3A-34).

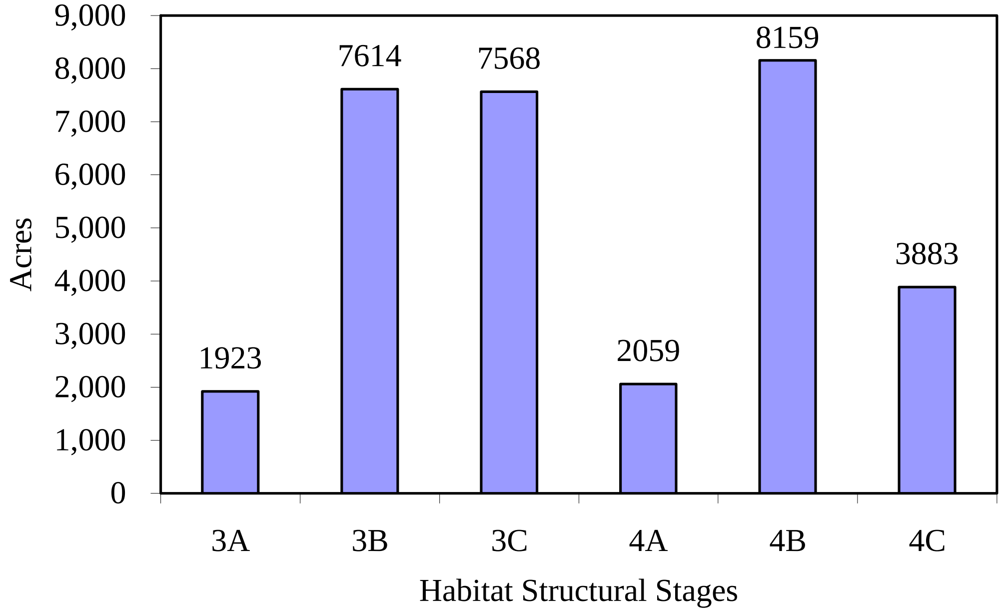


Figure M3A-32. Acres of ponderosa pine forests in each Habitat Structural Stage on the Bighorn National Forest.

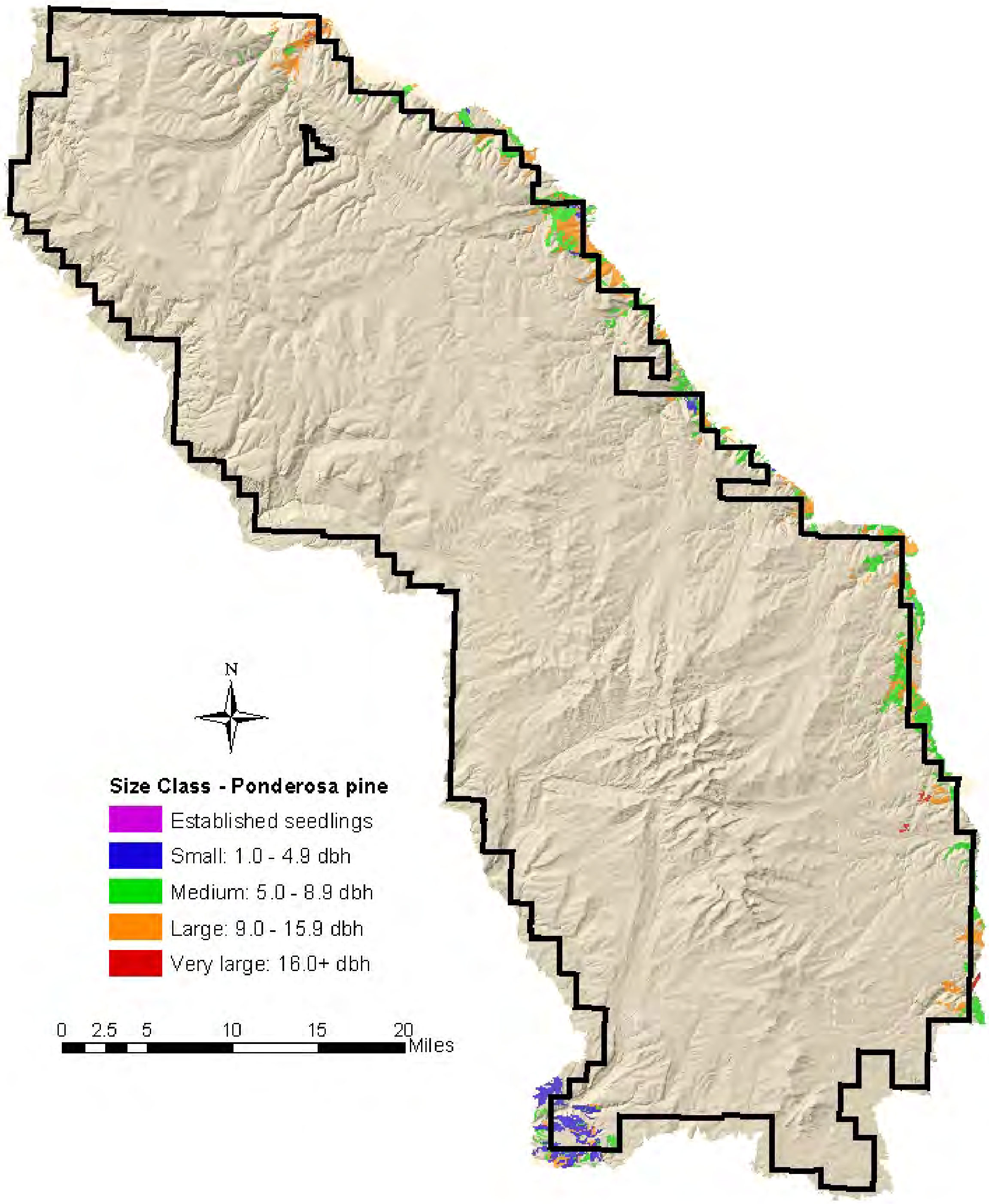


Figure M3A-33. Location of size classes of ponderosa pine forests in the Bighorn National Forest (CVU database).

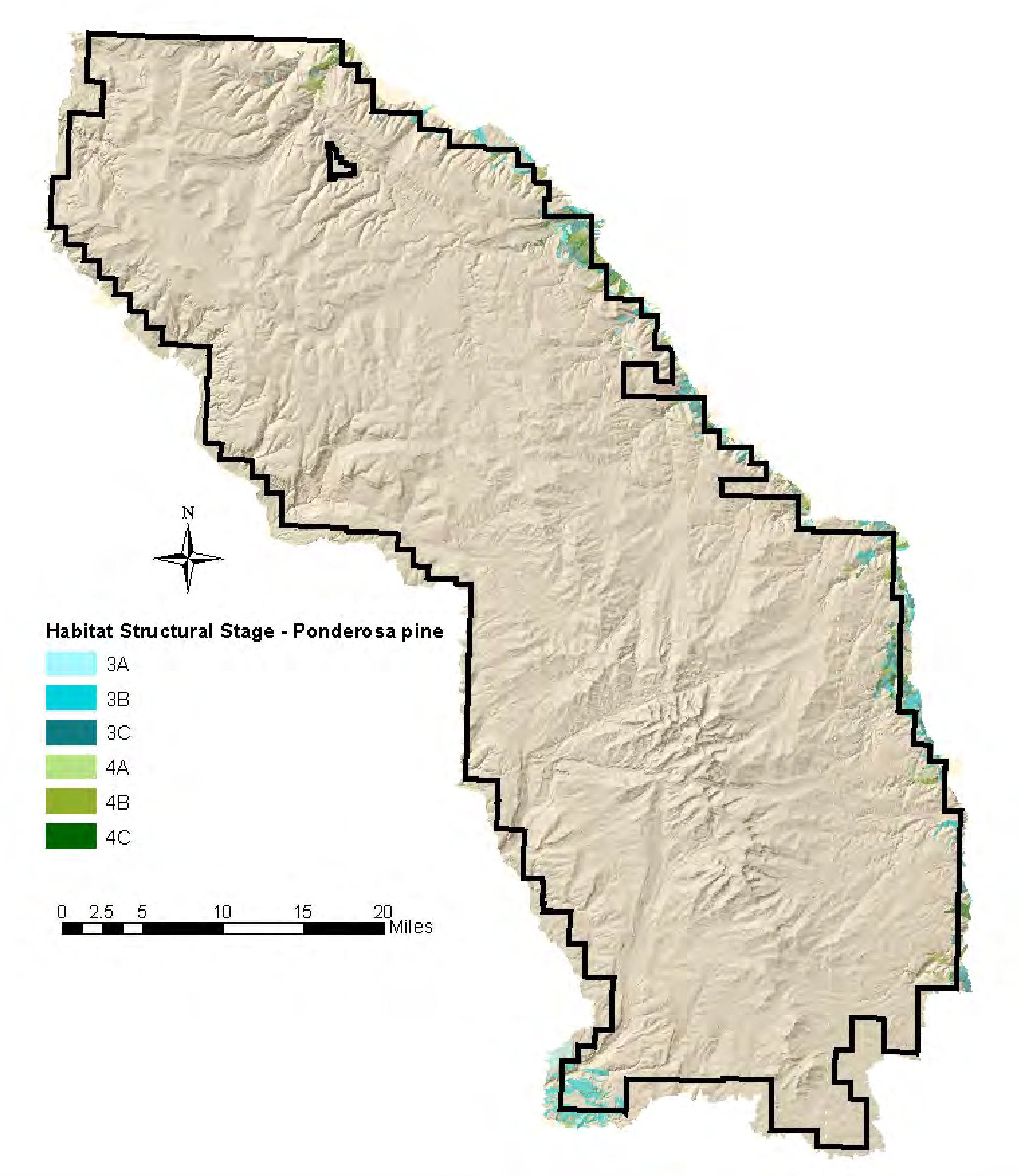


Figure M3A-34. Location of Habitat Structural Stages of ponderosa pine forests in the Bighorn National Forest (CVU database).

Stand Density

Denser stands of ponderosa pine likely existed historically on sites where fire did not occur for 40 to 50 years. These stands were interspersed on the landscape with savannas and grassy areas (Meyer and Knight 2001, Romme *et al.* 2000). In many cases, the individual stand structural characteristics today may not exceed the HRV, although landscape structure probably does lie outside the HRV, as natural disturbances rarely create the dense, even-aged stands that are common today (Meyer and Knight 2003). Where fire has been suppressed, the number of large trees in the stand is reduced and age and size distribution is skewed towards younger, smaller trees in even-aged stands.

Old-Growth/Older Forest Characteristics

Because of its rather limited distribution, old-growth ponderosa pine stands are not well described for the Bighorn region. They may be most similar to those found in the Black Hills, which feature ponderosa pine ecosystems both affected and unaffected by frequent, low-intensity fires. Stands including fire are characterized by older trees with open branches, irregular and flattened crowns, little downed material, and few small trees. These forests include some trees that are a minimum of 160 years old, and have at least 10 trees/acre (4 trees/ha) with a diameter larger than 16 inches (41 cm) (Mehl 1992). Old-growth ponderosa pine stands are also characterized by high variation in tree diameters, broken and/or patchy canopy, limited downed dead trees or snags, and few canopy layers. Similar to low-elevation Douglas-fir stands in the Big Horns, old-growth ponderosa pine forests are characterized by frequent fire intervals and low-intensity fires, a pattern that may have been altered by human activities in the Big Horns, particularly fire suppression (Meyer and Knight 2003). Like Douglas-fir forests, fire suppression has likely increased the density of many ponderosa pine forests in the Big Horns, such that some older stands may be characterized by smaller trees, higher densities, and more snags and woody debris.

Accurate stand origin data exist for approximately 28% of the ponderosa pine forests on the BNF. For this portion of the cover type, only 1% is known to be at least 160 years old (Fig. M3A-34), which is consistent with Despain's (1973) observation of "characteristically young" forests in the Big Horn Mountains. Thus, little of the ponderosa pine forests in the BNF may be defined as "old-growth", at least in terms of age alone. The majority of the ponderosa pine forests range from 60 to 100 years old (Despain 1973).

Stand Structural Components

Snags—In southwestern Colorado and the Front Range, Robertson and Bowser (1999) found mature ponderosa pine stands averaged approximately 12 snags per ha (5 snags per acre), ranging between zero and 150 snags per ha (0 to 61 snags per acre). Snags in this area averaged 1.3 m^2/ha (5.4 ft^2/acre) basal area, and 0.4 m^3/ha (34.9 ft^3/acre) volume. No estimates of snag density, basal area, or volume exist for ponderosa pine forests of the Big Horn Mountains.

Coarse Woody Debris—Few data are available to describe the current condition of coarse woody debris in this minor component of the forested area on the BNF. In southwestern Colorado and the Front Range, coarse woody debris (downed) was approximately 15.9 m^3/ha (1,387.7 ft^3/acre) in mature (>100 years) ponderosa pine stands, with a range from zero to 238.7 m^3/ha (20,833.1 ft^3/acre) (Robertson and Bowser 1999). In the BNF, it is likely that coarse woody debris and snags are present but limited, due to the longevity of ponderosa pine, their fairly open stand conditions, and the generally localized problems of pathogens and insects across the Forest (Meyer and Knight 2003). Downed wood and snags are more likely to be found in ponderosa pine stands that have increased in tree density due to fire exclusion (Mehl 1992).

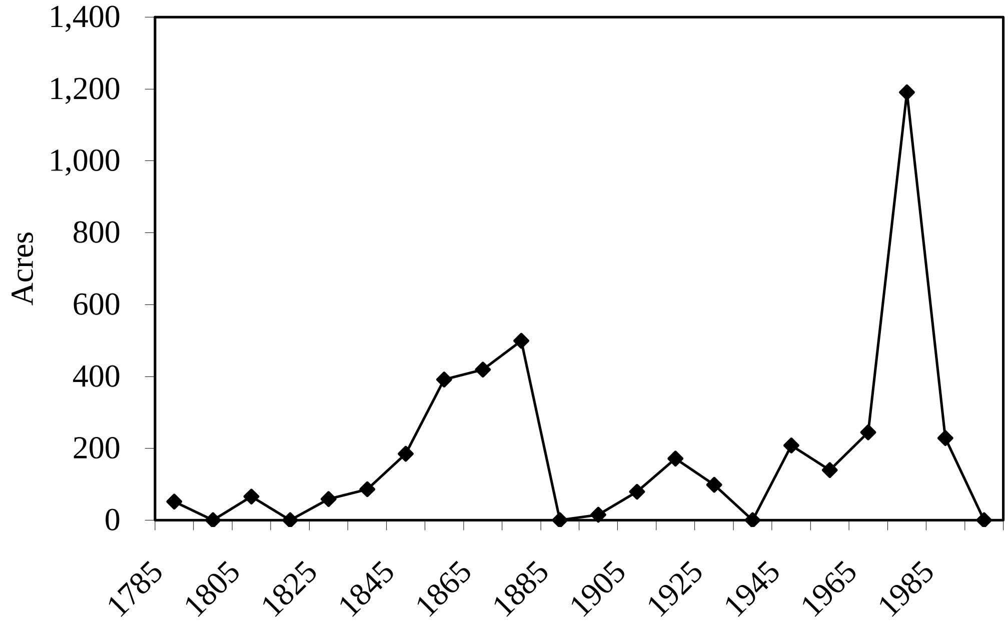


Figure M3A-35. Stand origin dates for ponderosa pine forests on the Bighorn National Forest. Only 28% of the area of ponderosa pine forest on the BNF is represented.

Canopy Cover—On the BNF, 40% of the ponderosa pine forests (15,033 acres/6,084 ha) exhibit canopy cover of >70%, approximately 41% exhibit canopy cover between 40 and 70%, and 19% has sparse canopy coverage (< 40%). Canopy coverage of 40 to 70% is likely the norm for ponderosa pine forests (Meyer and Knight 2003). Canopy coverage shows no discernable spatial pattern across its range, and heavy canopy coverage (>70%) is evident along the entire eastern flank of the Forest (Fig. M3A-36). Canopy coverage is much lighter in the isolated patch in the extreme southwest corner of the Forest, probably because ponderosa pine occurs there within a steep canyon. With the lack of detailed stand structural data, the prevalence of heavy canopy cover may be an indicator of increased stand densities due to fire suppression. However, it remains difficult to determine the existing condition of ponderosa pine stand structure based wholly or in part on canopy cover, because the HRV of canopy cover has not been determined. Open-grown stands of ponderosa pine classically exhibit an extremely patchy distribution of trees (Despain 1973, Mehl 1992). Patchiness often dwindles with fire suppression, however, as young ponderosa pine fill in the gaps (Mast and Veblen 1999). Thus, stands subjected to fire suppression typically exhibit far less patchy tree distributions than those where frequent, low-intensity fires are still a part of the ecosystem.

Vertical Complexity—As with most other forest types in the Big Horns, data describing vertical complexity of ponderosa pine forests are lacking for the BNF. Despain (1973) noted the presence of ponderosa pine and Douglas-fir seedlings in the understory. In addition, species such as *Physocarpus monogynus*, *Symphoricarpus alba*, *Juniperus communis*, *Spiraea betulifolia*, and *Shepherdia canadensis* may form significant shrub layers, particularly in open stands. Ground-coverage is very thick with *Agropyron spicatum, Clematis pseudoalpina*, and *Galium alba* when stand density is low.

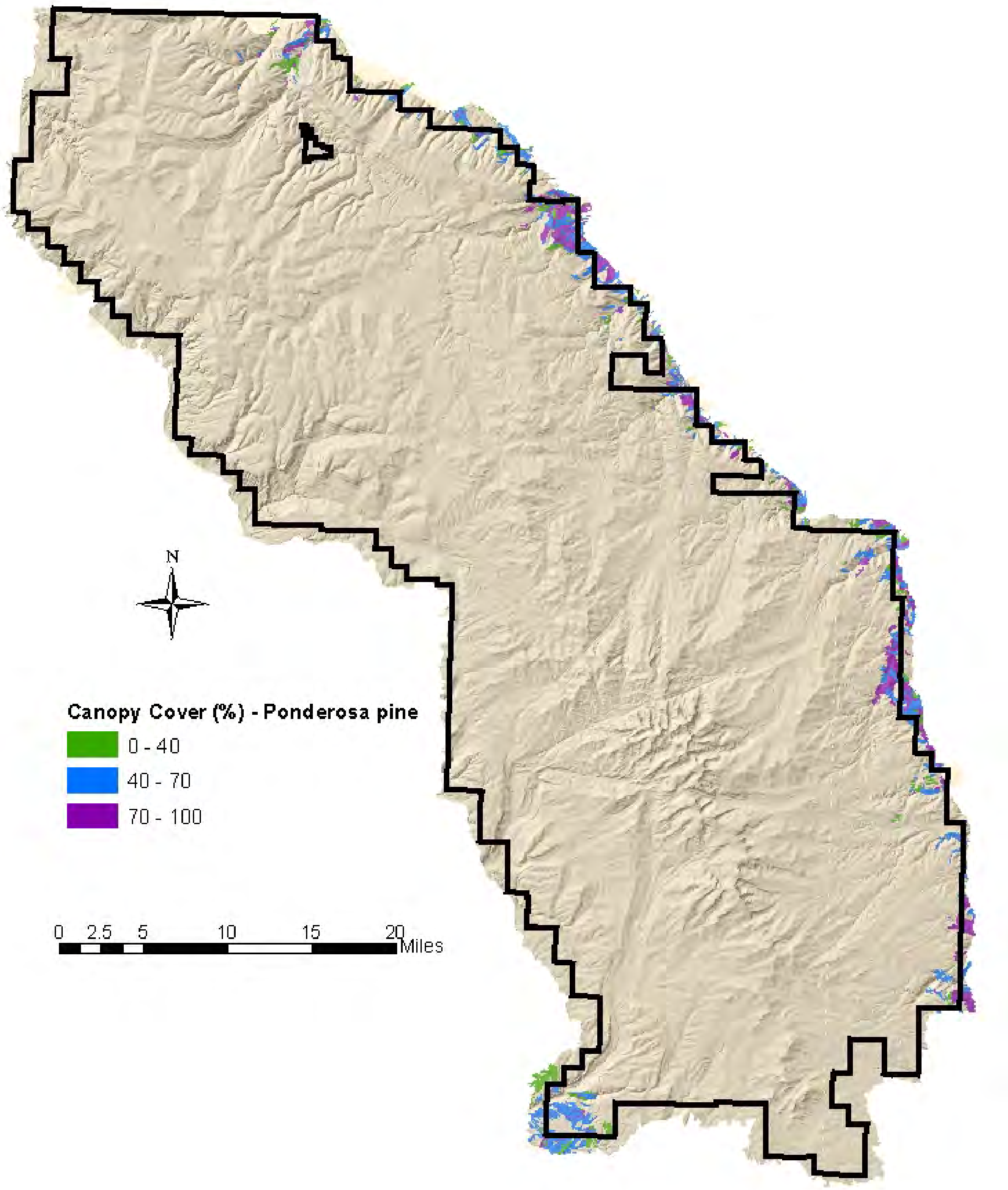


Figure M3A-36. Percent canopy coverage for ponderosa pine forests on the Bighorn National Forest (CVU database).

Changes in Structure/Anthropogenic Influences/Departures from HRV

As with Douglas-fir forests, the primary human influence on ponderosa pine stand structure in the Big Horn Mountains is fire suppression (Meyer and Knight 2003), which has increased stand density and moved many stands from open to closed. Grazing, still an active land use, has likely altered the fire regime in ponderosa pine forests, as they can be an important source of forage for livestock and wildlife. Stands provide cover for wildlife, particularly in mosaics with grassland vegetation. As with Douglas-fir forests, detailed fire history studies for the Big Horn Mountains are currently lacking.

There is no documented timber harvest in ponderosa pine stands on Bighorn National Forest in the past several decades. Wood production is considered moderate to poor with limited harvesting on the more productive sites (Hoffman and Alexander 1976, Alexander *et al*. 1986). Jack (1900) identified timber harvest in the ponderosa pine forests in the late 1800s, though it is not known how much or in what areas the harvests occurred. These activities may have contributed to the open conditions found on the landscape today (Meyer and Knight 2003). Despain (1973) deduced that the ponderosa pine forests of the Big Horn Mountains were the nearest sources of logs for early forts and houses built in the region, and noted several stumps of trees that were likely 25 to 50 cm (10 to 20 in) when cut.

Some of the more productive stands also have deep snow packs that supply water to larger watersheds during snowmelt (Alexander *et al*. 1986). Stands can be important for recreation, including picnic and campground areas (Hoffman and Alexander 1976).

Function

Similar to Douglas-fir forests, no functional data describing ANPP, NPP, the above- or below-ground biomass, carbon storage, or nutrient cycling are available for the Big Horn Mountains, and few data exist for the northern Rocky Mountains. These data are even lacking for the Black Hills and for Colorado, where ponderosa pine forests are much more extensive and well studied. The majority of functional studies of ponderosa pine forests have been completed in northern Arizona, which is not an adequate comparison for the BNF.

Natural Disturbances

Primary natural disturbance factors for ponderosa pine forest in the BNF include fire and insects. Fire was historically the most obvious natural disturbance. The historic fire regime in ponderosa pine forests is considered to be low-intensity surface fires that mostly killed small trees, with the thick-barked trees typically surviving. Pre-settlement-era fire scars indicate a mean fire interval of 26 to 33 years in the Laramie Range (Brown *et al*. 2000) and 14 to 27 years in the Devil's Tower National Monument (Fisher *et al*. 1987). Fire suppression and overgrazing, which can lead to denser tree growth because of more successful seedling establishment due to reduced competition from grasses (Knight 1994), have likely reduced the size of fire events in the low-elevation portions of the BNF below the historic range of variability (Meyer and Knight 2003). Stand-replacing fires currently are a threat in stands with a dense layer of trees (Fischer and Clayton 1983). Today, mountain pine beetle is the primary disturbance affecting ponderosa pine trees in the Big Horn Mountains. Older trees tend to be more susceptible to the beetles because they are less able to protect themselves by producing resins (Knight 1994). The mountain pine beetle population fluctuates over time with serious epidemics occurring in the 1950s and 1970s that killed over 6,000 trees (Meyer and Knight 2003). Mountain pine beetle outbreaks can cover large areas, reduce the average tree diameter in stands, create small or large openings, and allow species such as Douglas-fir to become more dominant in ponderosa pine stands (Schmid and Mata 1996). Epidemic return intervals at the stand level occur every 50 to 100 years (Johnson 1995, Schmid and Mata 1996). Diseases and windthrow do not seem to have much influence on ponderosa pine in the Big Horns (Meyer and Knight 2003).

Summary of Key Findings for Ponderosa Pine Forest Type

- Ponderosa pine forests are a minor forest component on the BNF, occupying 37,324 acres (15,105 ha) between 1,520 and 1,830 m (5,000 and 6,000 feet) in elevation, primarily along the eastern boundary of the Forest.

- Although no timber harvesting has occurred in ponderosa pine forests in the last century, the Big Horn Mountains are quite young and represent a legacy of timber harvest that occurred during the settlement period. As a result, very few acres of ponderosa forests in the Big Horn Mountains may be considered old-growth.

- Fire suppression and harvesting have reduced the expected variability in stand structure, resulting in higher forest density and fewer large trees. Many ponderosa pine stands are therefore younger and denser with smaller trees in more even-aged stands than those that comprised the historic landscape.

- Relatively few data exist to describe important forest ecosystem attributes for ponderosa pine in the Big Horn Mountains, likely because its distribution is so limited in the region.

Limber Pine Woodlands

Composition

Spatial Distribution

Limber pine woodlands cover only 2% (16,234 acres/6,570 ha) of the forested acres on the BNF (Fig. M3A-37). Limber pine woodlands are primarily restricted to the lower elevation areas in the Big Horn Mountains, at or near the same elevations as Douglas-fir and ponderosa pine (approximately between 1,520 and 1,980 m/5,000 and 6,500 feet). However, individual limber pines are known at or slightly below treeline in the Big Horn Mountains (Knight 1994) and small stands may occur on windswept ridges and slopes that are some of the harshest sites with tree cover (DeVelice and Lesica 1993, Knight 1994, Reid *et al.* 1999). On the BNF, limber pine woodlands are small and scattered, generally near the borders of the Forest on all sides except the southeast (Fig. M3A-37).

Approximately 99% of all limber pine woodlands occur on sedimentary substrates in the BNF, usually on calcareous soils (Despain 1973). Soil surfaces often have exposed bedrock and a considerable amount of bare ground (Reid *et al.* 1999). This vegetation occurs on such harsh sites presumably due to the poor competitive ability of limber pine seedlings (Knight 1994). Clark's nutcracker (*Nucifraga columbiana*) and some small mammals disperse the seed of limber pine (see below) and are thought to influence the local distribution of stands.

The Characteristic Dominate Species and Associations

Hoffman and Alexander (1976) did not consider limber pine woodlands when identifying habitat types of the Big Horn Mountains, but suggested they were seral to Douglas-fir. Merrill *et al.* (1996) suggest that limber pine often occurs with juniper woodlands and/or with shrubs or grasses in the understory. Fisher *et al.* (1998) list important associated plants as *Artemisia tridentata, Juniperus* spp., *Pseudoroegneria spicatum*, *Chrysothamnus* spp., *Bouteloua gracilis,* and *Festuca idahoensis*, all of which are also important associated plants in juniper woodlands. Limber pine woodlands include both closed-canopy forests and open woodlands where trees constitute more than 25% of the total vegetative cover (Merrill *et al.* 1996). Other important understory species include *Cercocarpus montanus* and *Arctostaphylos uva-ursi* (Steele *et al.* 1983, Jankovsky-Jones *et al.* 1995, Welp *et al.* 1998).

Successional Characteristics

In the BNF, limber pine woodlands occur primarily at middle to lower elevations, although individual limber pines may be found miles from the next nearest limber pine, because of seed distribution by Clark's nutcracker (Knight 1994). Clark's nutcracker can carry up to 125 limber pine seeds in a single trip, and may cache them as far as 23 km (14 miles) from their source (Steele 1990). Typical cache sites are windswept ridges and southerly slopes, where snow does not accumulate and the ground is exposed the earliest in the spring. Since limber pine seeds otherwise disseminates only by gravity, the locations of many limber pine stands are likely the result of site preferences of dispersal agents (Steele 1990).

Limber pine occurs in the BNF in stands mixed with either spruce and fir, Douglas-fir, aspen, or ponderosa pine. Despain (1973) and Hoffman and Alexander (1976) considered limber pine successional to Douglas-fir types. However, more recent work by Steele *et al.* (1983) and Pfister *et al.* (1977) suggests that Douglas-fir is a co-dominate species in the limber pine type. Despain (1973) hypothesized that limber pine may perform a similar ecological function as pinyon pine at low elevations. The largest limber pine woodlands appear to occur outside of the BNF boundaries to the south, and are intermixed with juniper woodlands (see Introduction). Most limber pine woodlands within the Forest are very small and occur among other forest types. As a result, extremely limited data are available for limber pine woodlands on the BNF itself.

Changes in Species Composition/Departures from HRV

Few data exist to describe compositional changes in limber pine woodlands. However, likely changes include an increase in Douglas-fir where limber pine is seral or in closed canopy forests. Composition in open woodlands may not change in the Big Horn Mountains except where woodlands encroach sagebrush or grassland areas in the absence of fire (Meyer and Knight 2003). More than 75% (2,405 acres/973 ha) of the 3,204 acres (1,297 ha) considered to have the potential to be limber pine woodlands (PNV) is currently limber pine woodlands (CVU); 15% is currently juniper woodlands, 8% is aspen, and 2% is grassland.

<u>Structure</u>

Stand Age and Diameter Class Distributions

Virtually no stand structural data are available for this minor forest type, but limber pine woodlands in the Big Horn Mountains may occur as very open, patchy stands with approximately 30% canopy cover or as forests with full canopy closure (Merrill *et al.* 1996). On the BNF, size classes range from small (1 to 5 inches/2.5 to 13 cm) to large (9 to 16 inches/23 to 41 in) diameter trees between high-elevation spruce/fir forests and low-elevation ponderosa pine forests, with no apparent correlation between size and elevation (Fig. M3A-38). The relatively limited portion of limber pine coverage on the BNF in the early (<1 inch) size class, perhaps representing a newly-regenerated stand, occurs in the northern portion of the Forest at high elevation. Since limber pine stands establish as a result of seed caching, stands are initially even-aged, becoming increasing uneven-aged with time as more seeds are cached into the understory.

Habitat Structural Stages

Limber pine woodlands of the BNF are typically pole-sized, closed-canopy forests (Fig. M3A-39). Approximately 69% (11,217 acres/4,539ha) of the limber pine woodlands on the Forest are classified as Stages 3A or 3B, suggesting that most forests of this type occur as medium-sized trees across their range in the Big Horn Mountains (Fig. M3A-38).

Habitat Structural Stages of limber pine woodlands do not appear to be well-separated across the BNF, although stands classified as Stage 4 tend to be clustered into four distinct regions with the Forest: the extreme north, extreme southwest, and the west- and east-central portions of the Big Horn Mountains (Fig. M3A-40). Stage 4 stands may correspond to older adjacent stands of other forest types that have not been affected by recent human or natural disturbance.

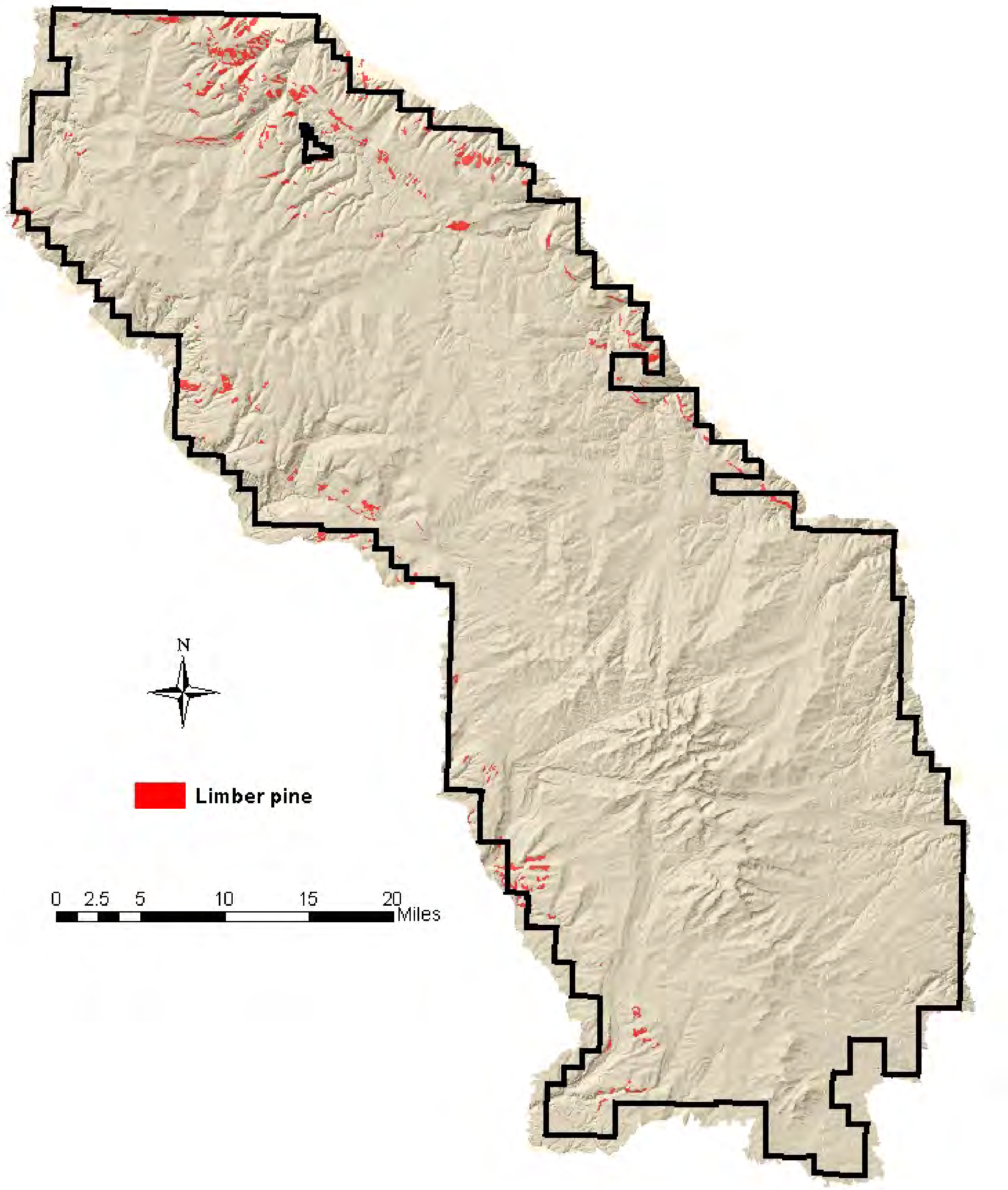


Figure M3A-37. Distribution of limber pine woodlands on the Bighorn National Forest (CVU database).

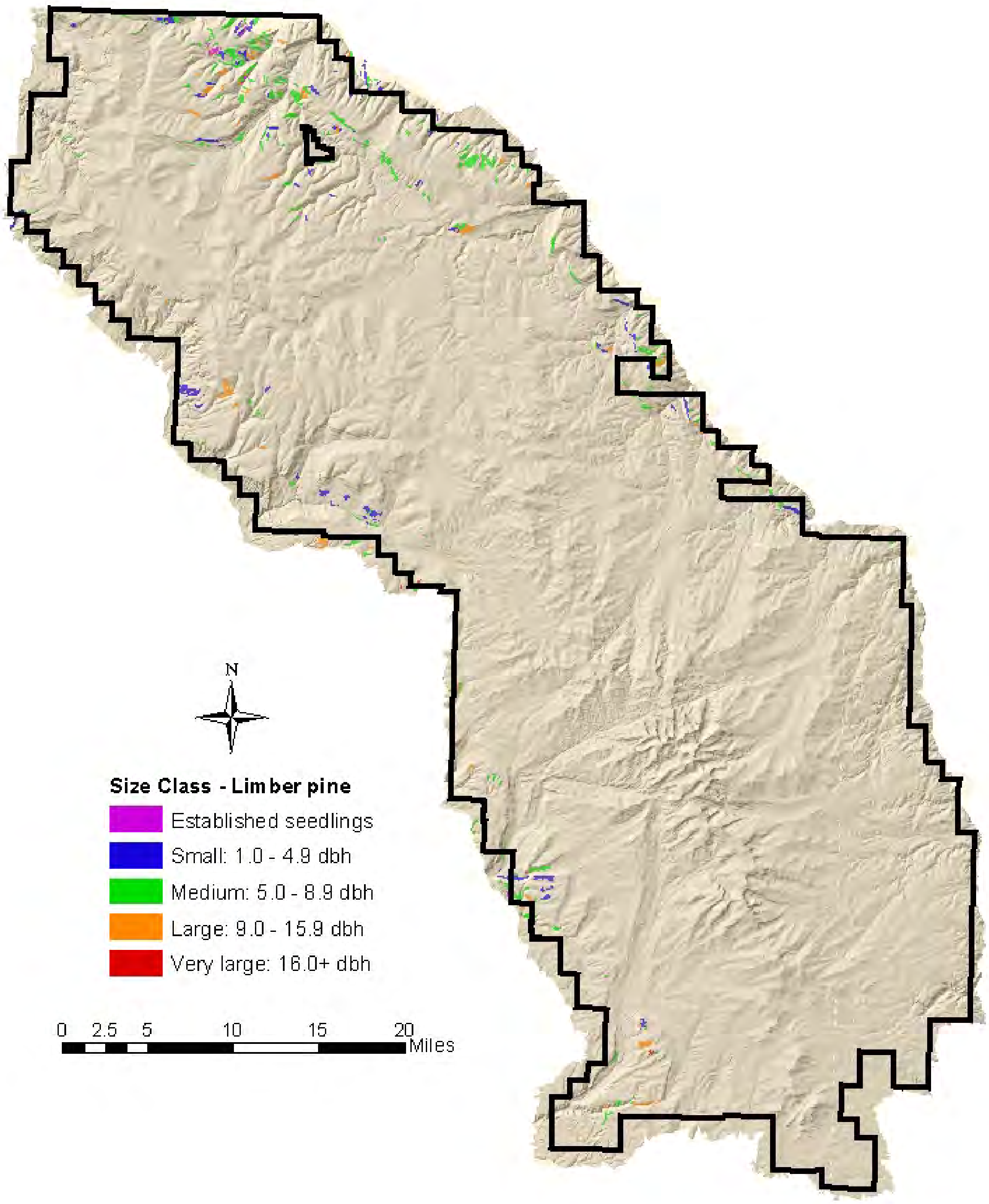


Figure M3A-38. Location of size classes of limber pine woodlands in the Bighorn National Forest (CVU database).

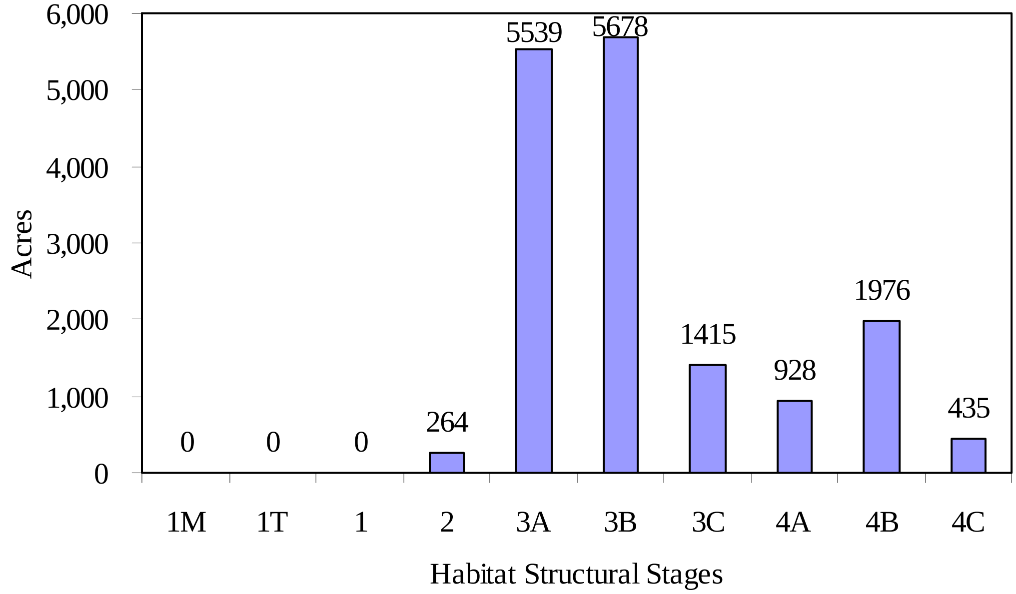


Figure M3A-39. Acres of limber pine woodlands in each Habitat Structural Stage on the Bighorn National Forest.

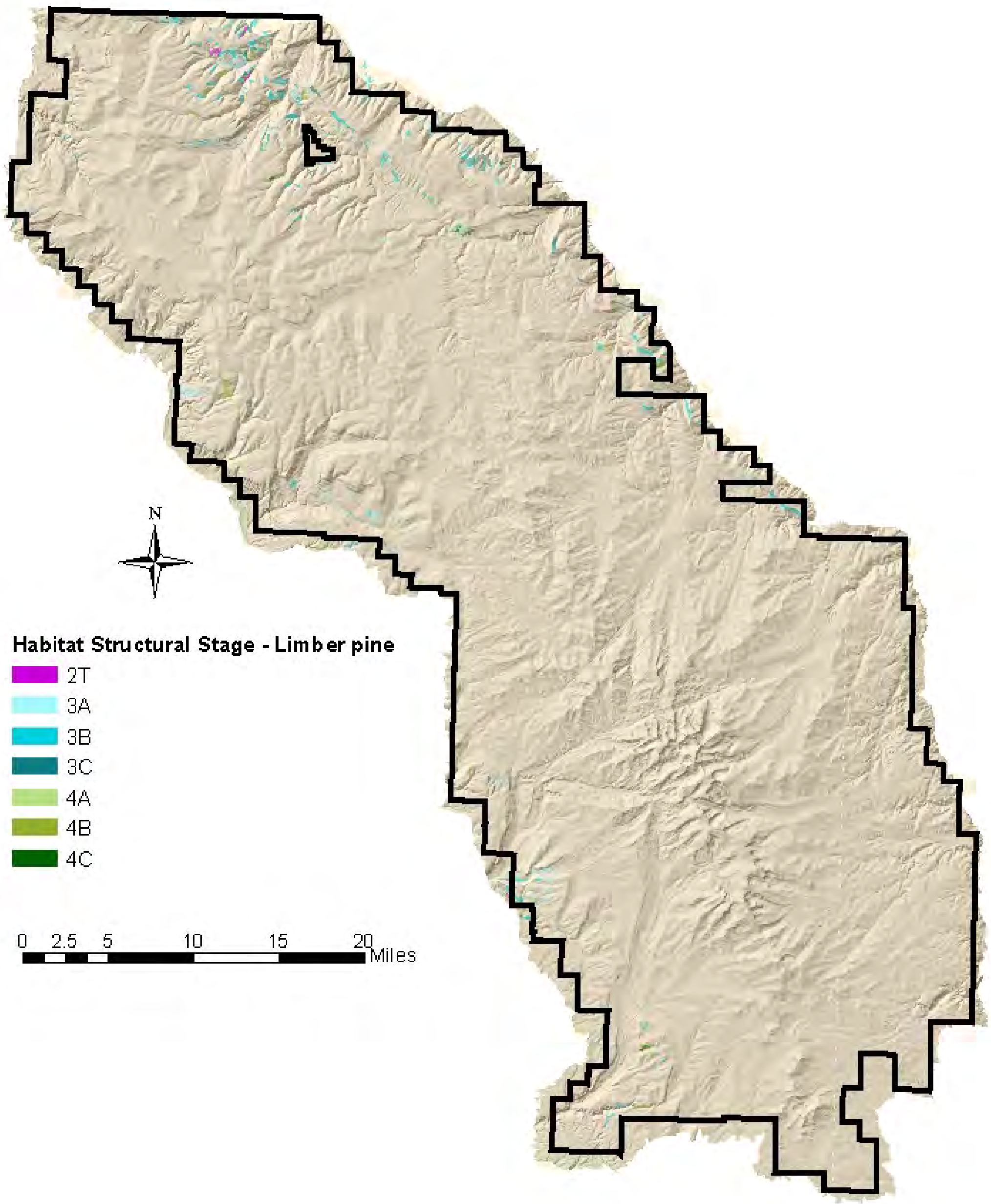


Figure M3A-40. Location of Habitat Structural Stages of limber pine woodlands in the Bighorn National Forest (CVU database).

Stand Density

Stand density data are not available for limber pine on the BNF. However, stand densities of open limber pine woodlands may have increased with fire suppression, thereby decreasing patchiness.

Old-Growth/Older Forest Characteristics

Because of its limited distribution, old-growth limber pine woodland stands are not described for the Big Horn Mountains. It is notable, however, that isolated, individual limber pine over 2,000 years old have been found on ridges and near treeline throughout Wyoming. Data describing old-growth forests of limber pine on the BNF and elsewhere in the Rocky Mountains are desperately needed.

Accurate stand origin data exist for approximately 33% of the limber pine woodlands on the BNF. For this portion of the cover type, approximately 14% is known to be older than 160 years (Fig. M3A-41). Only about 4% of the limber pine woodlands are older than 250 years, and the majority (61%) on the BNF range from 90 to 160 years old.

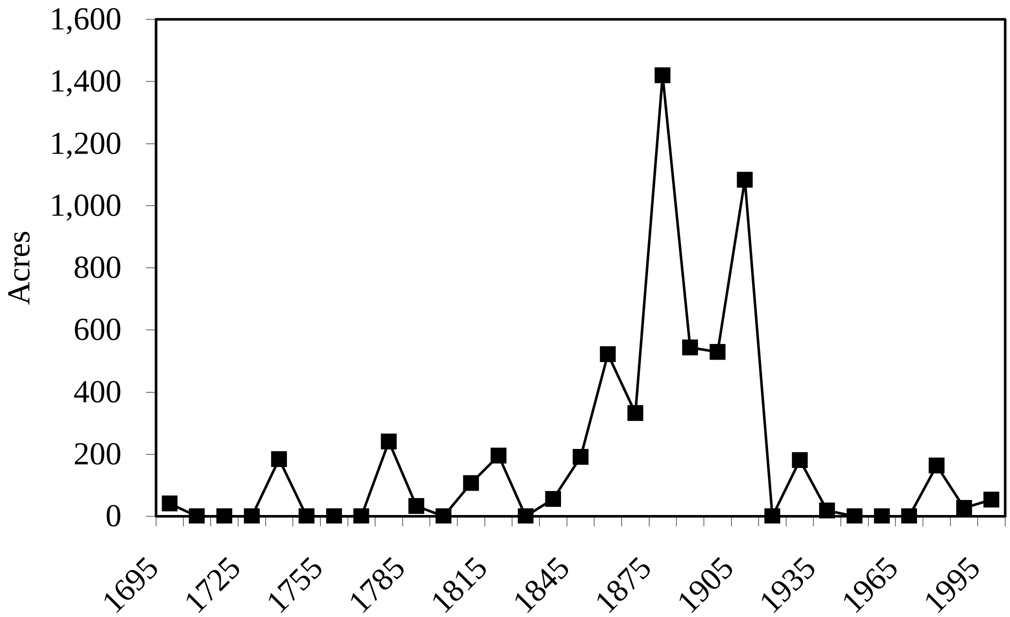


Figure M3A-41. Stand origin dates for ponderosa pine forests on the Bighorn National Forest. Only 33% of the area of limber pine woodland on the BNF is represented.

Stand Structural Components

Snags—see *Coarse Woody Debris* section below.

Coarse Woody Debris—No data are available to describe the current condition of coarse woody debris and snags of this minor component of the forested area on the BNF. Coarse woody debris and snags are probably present but limited in limber pine woodlands due to their fairly open conditions. Closed canopy forests of limber pine, which create conditions of higher competition for light, may have more coarse woody debris and snags.

White pine blister rust (*Cronartium ribicola*) is widespread in the Big Horn Mountains, and has been located in Tensleep Canyon as well as the Tongue Canyon and Goose Creek drainages. In Montana and southern Alberta, over a third of the limber pine trees have been killed by white pine blister rust, and 90% of the remaining trees are infected (Kendall 1998). With such levels of mortality, snags and coarse woody debris are likely to increase in limber pine woodlands in the Big Horn Mountains.

Canopy Cover—Across the BNF, limber pine woodlands have a tree-dominated layer that forms an open canopy, which is generally light to moderate. Nearly 48% (7,762 acres/3,142 ha) of all limber pine woodlands exhibit 40 to 70% canopy coverage, and 41% (6,622 acres/2,680 ha) exhibit light canopy coverage (<40%). Far fewer acres (1,850 acres/750 ha, 11% of total) exhibit >70% canopy coverage, suggesting that open limber pine woodlands are far more common on the BNF than closed-canopy forests. Closed-canopy limber pine woodlands appear to be most common at lower elevations, although little pattern is clear for canopy coverage in general (Fig. M3A-42).

Sparse, patchy stands with highly discontinuous canopies are probably typical for limber pine woodlands in the Big Horn Mountains (Despain 1973). In both open- and closed-canopy limber pine woodlands, however, stem distribution is likely very patchy throughout the life of the stand, as seeds are nearly always cached in small, tight clusters, resulting in a clumped pattern of subsequent seedlings.

Vertical Complexity—Virtually no data describing vertical complexity of limber pine woodlands are available for the BNF, as few investigators have fully described the composition of these forested areas. Given their similarity to and interspersion with juniper woodlands, however, the presence of shrubs such as *Artemisia tridentata* and *Juniperus* spp., as well as low-habit species such as *Pseudoroegneria spicatum* and *Chrysothamnus* spp., may provide important vertical complexity (Despain 1973, Fisher *et al.* 1998).

Changes in Structure/Anthropogenic Influences/Departures from HRV

There is no documented timber harvest in limber pine woodlands on the BNF in the 20th century, although a small area may have been disturbed where harvesting was incidental to other more economical species such as ponderosa pine.

Other important human influences are difficult to ascertain with so little data. If limber pine woodlands are affected similarly to juniper woodlands, then humans have likely had important influences on limber pine woodlands in the Big Horns via disturbances such as grazing and fire suppression (Meyer and Knight 2003). More research is needed to document the disturbance history and associated human influences on this rare forest type on the BNF.

Function

Similar to other forest types, no functional data describing productivity, biomass, or carbon or other nutrient pools are available for the Big Horn Mountains. Such data are difficult to ascertain for most of the Rocky Mountains, likely because the forests and woodlands of limber pine are rarely extensive.

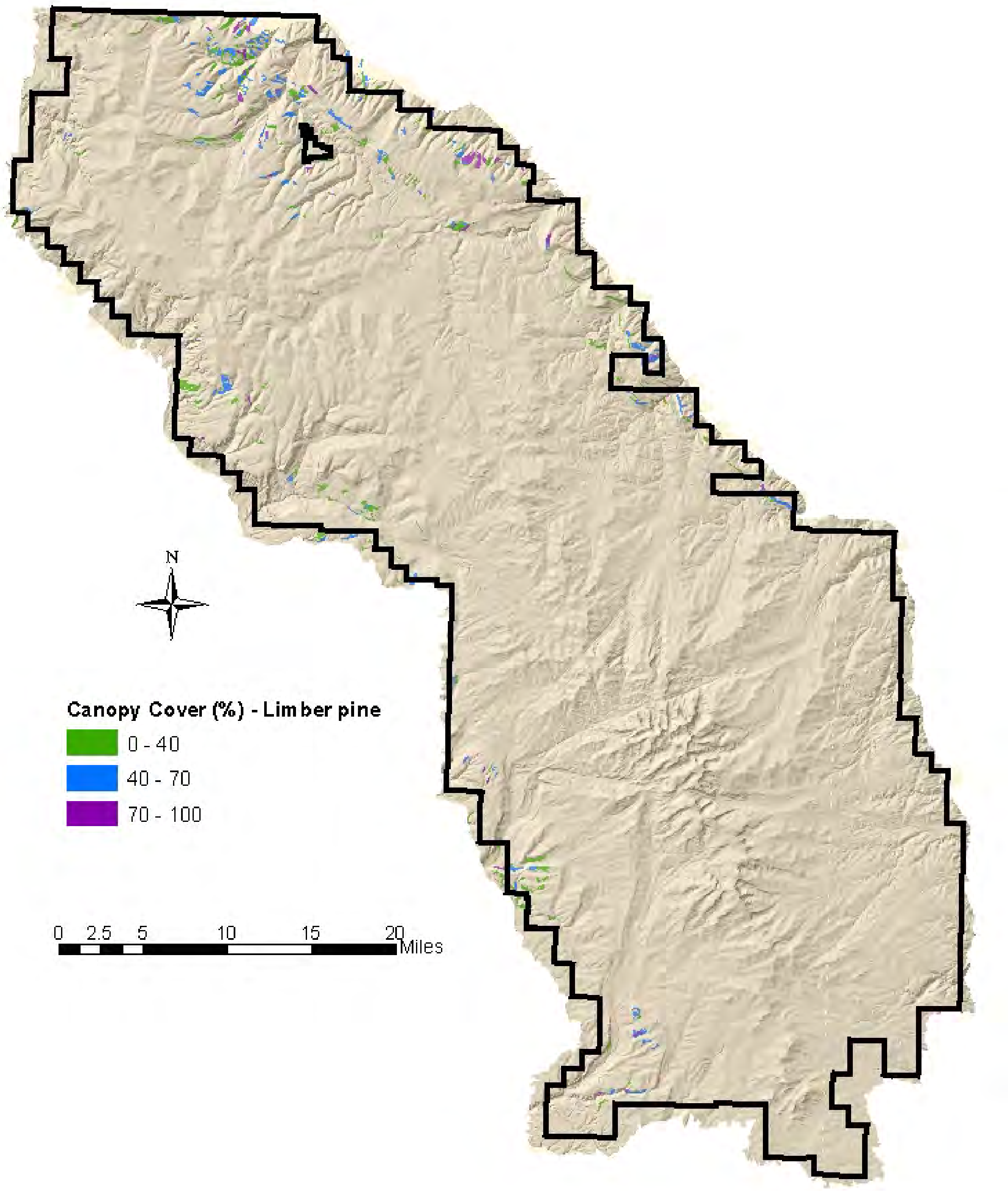


Figure M3A-42. Percent canopy coverage for limber pine forests on the Bighorn National Forest.

Natural Disturbances

Primary natural disturbance factors for limber pine woodlands in the BNF include fire and disease. Limber pine trees are adapted to surface fires because they have thick bark at the base of the trunk protecting the cambium. This species also produces a tight cluster of needles around terminal buds for protection against high temperatures (Fischer and Clayton 1983). Fischer and Clayton (1983) estimate the fire return interval of limber pine woodlands to be 50 to 100 years. Stands are not subjected to more frequent fires because of low productivity and subsequent low fuel accumulation (Steele *et al.* 1983), although Fischer and Clayton (1983) suggest that fires may be more frequent (still low intensity) if grasses dominate the understory. Prescribed fire programs in the Big Horn Basin, carried out by the Bureau of Land Management and Forest Service, have targeted the limber pine type. In some cases this has resulted in stand replacement canopy burns, possibly a result of natural fire regimes being interrupted by suppression activities.

Limber pine is susceptible to white pine blister rust. This introduced plant disease has destroyed many stands in the northern Rocky Mountains (Kendall 1998). Heavy mortality is expected in Wyoming and Colorado in the next 50 to 100 years. Considerable research on blister rust has been directed towards whitebark pine (*Pinus albicaulis*), another member of the white pine group that has important links to grizzly bear (*Ursus arctos*) management.

This type is considered important habitat for elk and mule deer (Steele *et al.* 1983), although browse on limber pines is relatively unimportant.

Summary of Key Findings for Limber Pine Woodland Type

- Limber pine woodlands comprise a very minor portion of the forested area of the BNF, occupying fewer than 16,234 acres (6,570 ha) on sedimentary soils between 1,520 and 1,980 m (5,000 and 6,500 feet). Limber pine woodlands are large and contiguous to the south of the BNF, but are restricted to very small, scattered stands within the Forest itself.

- Limber pine may form closed canopy forests or sparse, open woodlands. On the BNF, limber pine stands occur in association with spruce/fir, Douglas-fir, or ponderosa pine forests. Closed canopy forests generally occur at lower elevations.

- Because the disturbance history of limber pine woodlands is not well understood, such that the effects of humans on the existing condition of this forest type on the BNF is difficult to ascertain.

- Few data exist to adequately describe the existing condition of limber pine woodlands on the BNF.

Juniper Woodlands

Composition

Spatial Distribution

Juniper woodlands in the BNF are dominated by several species of juniper, mainly Utah juniper (hereafter referred to as "juniper"). Rocky Mountain juniper (*Juniperus scopulorum* Sarg.) also occurs in these woodlands as a minor component in more moist drainages. Although juniper woodlands occupy approximately 326,000 acres in the Big Horn Mountains Section, their distribution is extremely limited on the BNF. Juniper woodlands occur exclusively at low elevations between 1,500 and 2,100 m (5,000 and 7,000 feet) along the drier western edge of the Forest, though not continuously. The cover type is not found on the eastern edge of the BNF (Fig. M3A-43). About 6,300 acres (2,550 ha) of juniper woodlands (8% of total forested area) are found on the Forest.

Distribution of this type is strongly related to rocky sedimentary parent materials that are usually calcareous (Despain 1973). Soils are classified as shallow torriorthents (Nesser 1986). Juniper woodlands on the BNF are best developed on coarse, sedimentary soils not covered or mixed with alluvial sediments (Despain 1973). Although pinyon-juniper woodlands are quite common in the Great Basin, juniper woodlands are a rarer type, especially as far north as the Big Horn Mountains. Very limited data are available about the juniper woodlands on the BNF; existing data from other areas describe pinyon-juniper woodlands, whose composition, structure, and function are likely very different.

The Characteristic Dominant Species and Associations

Hoffman and Alexander (1976) did not consider juniper woodlands when identifying habitat types of the Big Horn Mountains, but associated plants include *Artemisia tridentata, Pseudoroegneria spicatum*, *Chrysothamnus* spp., *Opuntia polyacantha, Symphoricarpos* spp., *Bouteloua gracilis,* and *Festuca idahoensis* (Despain 1973, Fisher *et al.* 1998). Juniper woodlands rarely have a closed canopy, and ground cover is very patchy and discontinuous (Despain 1973). Other common associated plants include *Artemisia nova, Gutierrezia sarothrae*, *Koeleria macrantha,* and *Poa sandbergii*. Other trees that may be minor associates of this forest type in the BNF include Douglas-fir and limber pine.

Successional Characteristics

Juniper woodlands in the Big Horn Mountains occur exclusively at the lowest elevations, typically between grasslands and the lowest forest cover type where site conditions are too hot and dry for forest development. The juniper woodlands found in the Big Horns may represent a variation of pinyon-juniper woodlands of the Southwest, with pinyon pine (*Pinus edulis*) absent. The composition of juniper woodlands is often quite stable, as competition is mainly from subordinate woody shrubs and herbaceous plants that do not out-compete juniper for light.

Changes in Species Composition/Departures from HRV

Composition in juniper woodlands generally does not change in the Big Horn Mountains, except where juniper encroaches sagebrush or grassland areas in the absence of fire (Meyer and Knight 2003). Unlike Utah juniper stands in Colorado, Utah and Nevada, however, invasion into adjacent grass and shrublands from existing stands is not common. Only 53% (2,707 acres/1,095 ha) of the 5,067 acres (2,051 ha) considered to have the potential to be juniper woodlands (PNV) is currently juniper woodlands (CVU), the remainder being primarily shrub and grassland types.

Structure

Stand Age and Diameter Class Distributions

Virtually no stand structural data are available for this minor forest type, but juniper woodlands in the Big Horns typically occur as very open, patchy stands with approximately 30% canopy cover (Despain 1973). Size classes are dominated by juniper in the small size classes, which represent stems with diameters 1 to 5 inches (2.5 to 13 cm) (Fig. M3A-44). Few juniper woodlands on the BNF are dominated by trees in the medium size class (5 to 9 inches/13 to 23 cm diameter) and only a small patch of large trees (9 to 16 inches/23 to 41 cm diameter) is found on the west-central boundary of the Forest. As fires in junipers woodlands are typically stand replacing (Romme *et al.* 2002), stands are likely to be initially even-aged, although this structure likely becomes increasingly uneven-aged with time following the disturbance.

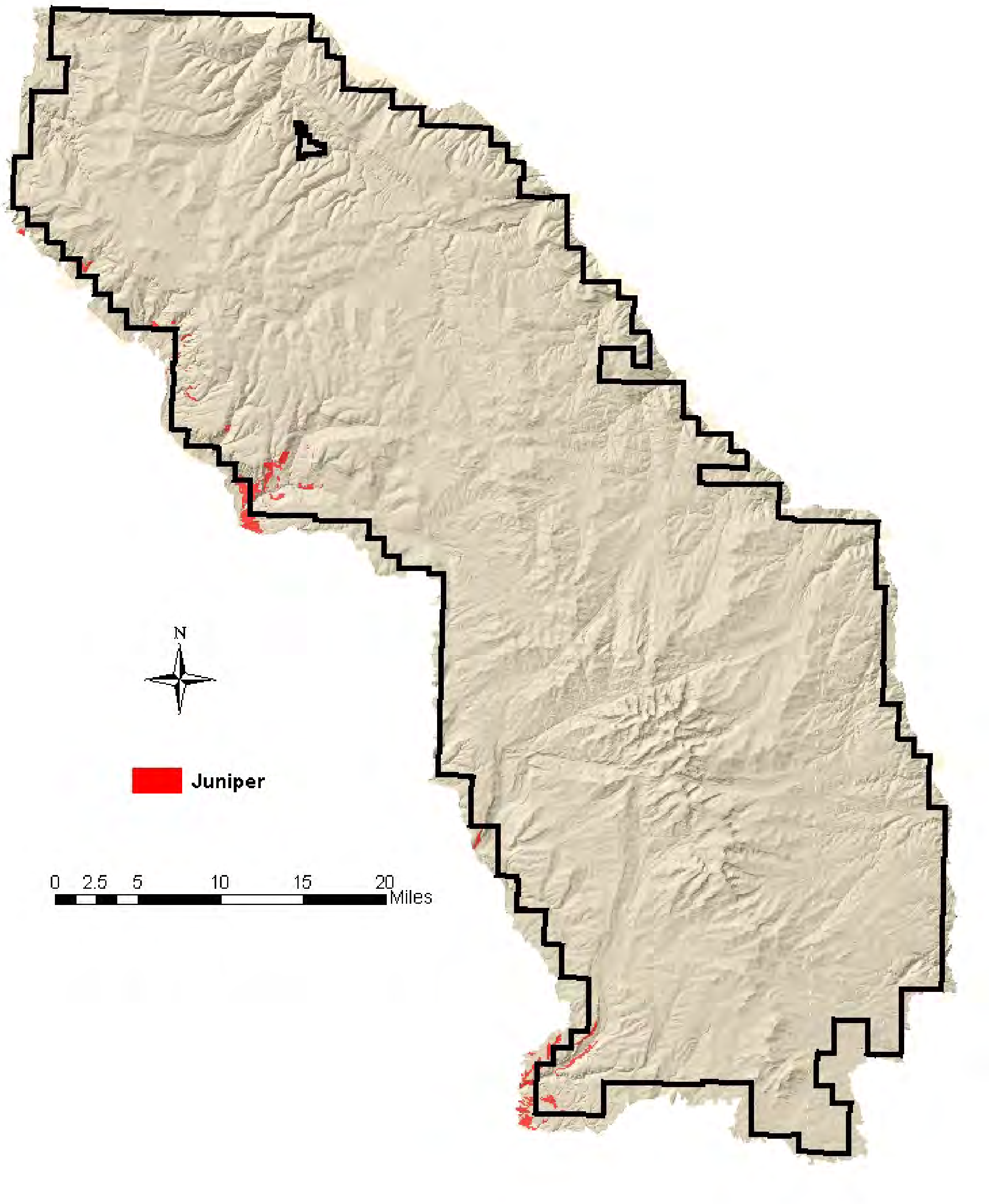


Figure M3A-43. Distribution of juniper woodlands on the Bighorn National Forest (CVU database).

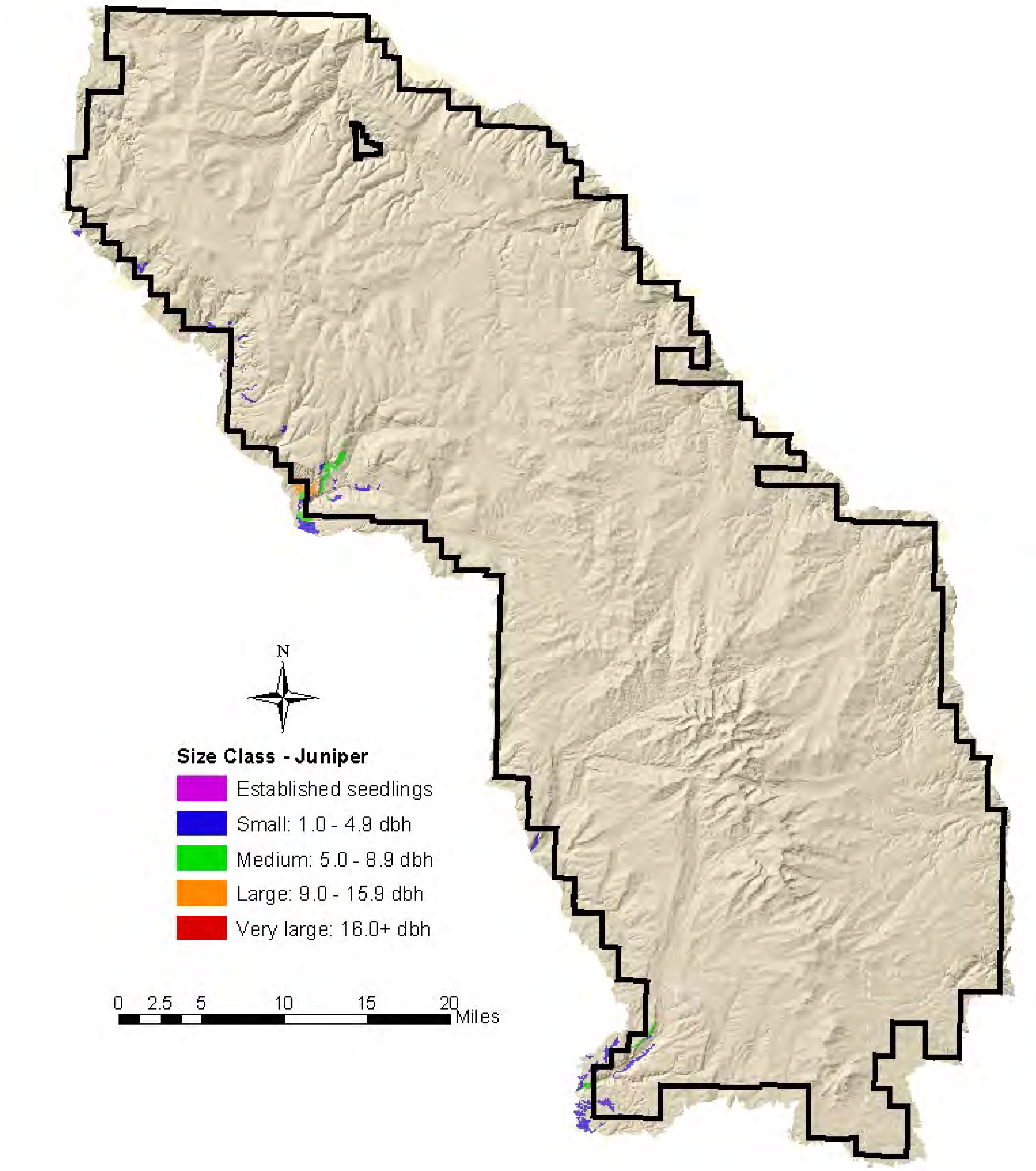


Figure M3A-44. Location of size classes of juniper woodlands in the Bighorn National Forest (CVU database).

Habitat Structural Stages

Most juniper woodlands (87%) on the BNF are classified as either Habitat Structural Stage 3A or 3B, suggesting that most juniper woodlands include pole-sized trees in relatively open conditions (Fig. M3A-45). Less than 10% of the juniper woodlands on the BNF are classified as Stage 2S, which represents well-established shrubs or seedlings less than one inch in diameter and >10% canopy coverage.

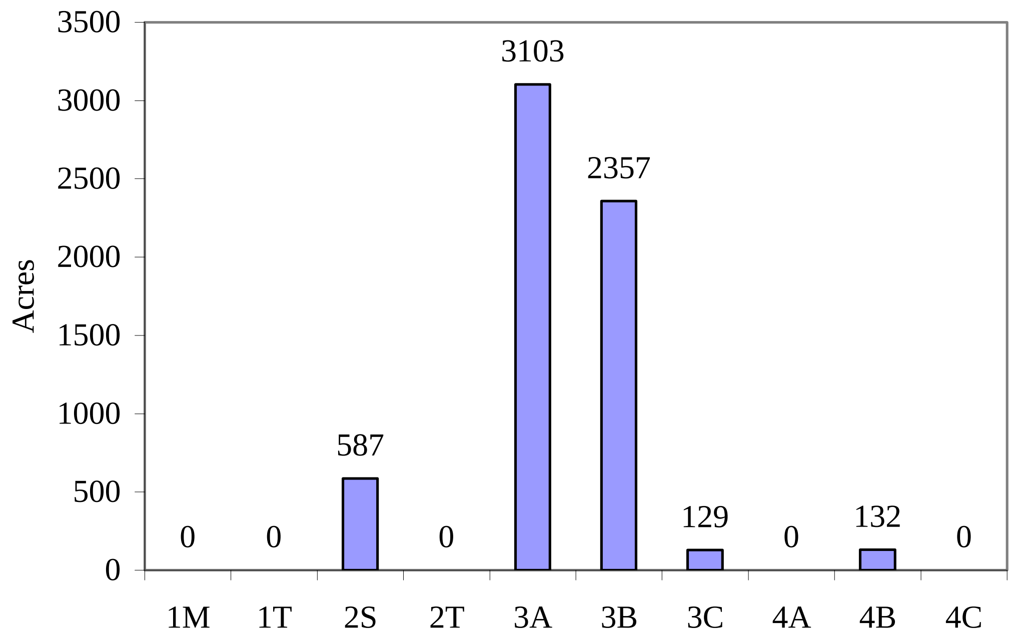


Figure M3A-45. Acres of juniper woodlands in each Habitat Structural Stage on the Bighorn National Forest.

Stand Density

No data describing stand densities in juniper woodlands in the BNF are currently available.

Old-Growth/Older Forest Characteristics

Because of its limited distribution, no old-growth juniper woodlands stands are described for the Big Horn Mountains. In fact, the difficulty of aging juniper precludes the determination of age structures of juniper woodlands across the West, especially in the absence of the more easily-aged pinyon pine. Age data for juniper woodlands and associated communities are generally poorly understood (Floyd *et al.* 2000), and virtually no stand origin data exist for juniper woodlands on the BNF.

For pinyon-juniper woodlands of the southern Rocky Mountains, Mehl (1992) and Popp *et al.* 1992) described old-growth stands as having 30 trees/acre (12 trees/ha), live trees at least 12 inches (30 cm) at the root collar, trees at least 200 years old, basal area 23 ft^2/acre (5 m^2/ha), variation in tree diameters, at least one snag per acre, and at least 2 downed logs per acre, with canopy cover about 30%. Miller *et al.* (1999) have published a classification of juniper and pinyon-juniper woodlands for the Intermountain West, but juniper woodlands of the Big Horn Mountains are not included.

Stand Structural Components

Snags— see *Coarse Woody Debris* section below.

Coarse Woody Debris—No data are available to describe the current condition of coarse woody debris and snags of this minor component of the forested area on the BNF. They likely are present but limited in juniper woodlands due to their fairly open conditions. Juniper snags tend to decay very slowly, however, and are likely persistent on a site for many decades after a disturbance (Floyd *et al.* 2000).

Canopy Cover—Across the BNF, canopy coverage of juniper woodlands is generally light (< 40%), although slope and aspect appear to have some influence on the percent canopy cover (Fig. M3A-46). Only one area of high (>70%) canopy coverage is found on the Forest, which is the same small stand with larger-diameter trees.

Sparse, patchy stands with highly discontinuous canopies are typical for juniper woodlands in the Big Horn Mountains (Despain 1973). Stand densities of juniper woodlands may have increased with fire suppression, and patchiness of trees may have therefore decreased, but it remains difficult to ascertain whether such alterations are outside of the historical range of variability (Romme *et al*. 2002).

Vertical Complexity—Virtually no data describing vertical complexity of juniper woodlands are available for the BNF. Despain (1973) noted that the typically low, bushy junipers in the Big Horn Mountains leave little room for growth of any vegetation beneath each individual, and that the grass and herbaceous layer among the junipers in juniper woodlands is also exceedingly sparse. Nevertheless, Despain (1973) noted the presence of low-habit species such as *Pseudoroegneria spicatum, Opuntia polyacantha,* and *Chrysothamnus* spp.

Changes in Structure/Anthropogenic Influences/Departures from HRV

As in other western juniper woodlands, humans have likely had important influences on juniper woodlands in the Big Horns via disturbances such as grazing and fire suppression (Meyer and Knight 2003). Research in the Great Basin, for example, has clearly demonstrated that juniper woodlands have increased in density throughout the 20th century, and many areas of juniper have expanded their range. Potential causes of juniper expansion are many. Overgrazing of grasslands by livestock has removed fine fuels and decreased fire frequencies, leading to increases in woody fuels and non-native plants (Tausch 1999, Tausch and Nowak 1999, Young *et al.* 1987). Fire exclusion has further exacerbated juniper invasion of grasslands (Miller and Wigand 1994, Miller and Tausch 2001). Given the adjacency of juniper woodlands to grassland ecosystems on the western flank of the Big Horn Mountains, juniper expansion is a possibility, especially since the Big Horn Mountains are among the most heavily grazed areas in the region (Meyer and Knight 2003). However, few data exist to support or refute this hypothesis. Meyer and Knight (2003) suggested that increases in forest and shrub encroachment due to fire suppression and grazing, may not be beyond the historical range of variability at the stand and/or the landscape level.

There is no documented timber harvest in juniper woodlands on the Bighorn National Forest in the 20th century. Despain (1973) reasoned that juniper was too "low and scrubby" to be of any economic value "aside from fence posts for local ranchers."

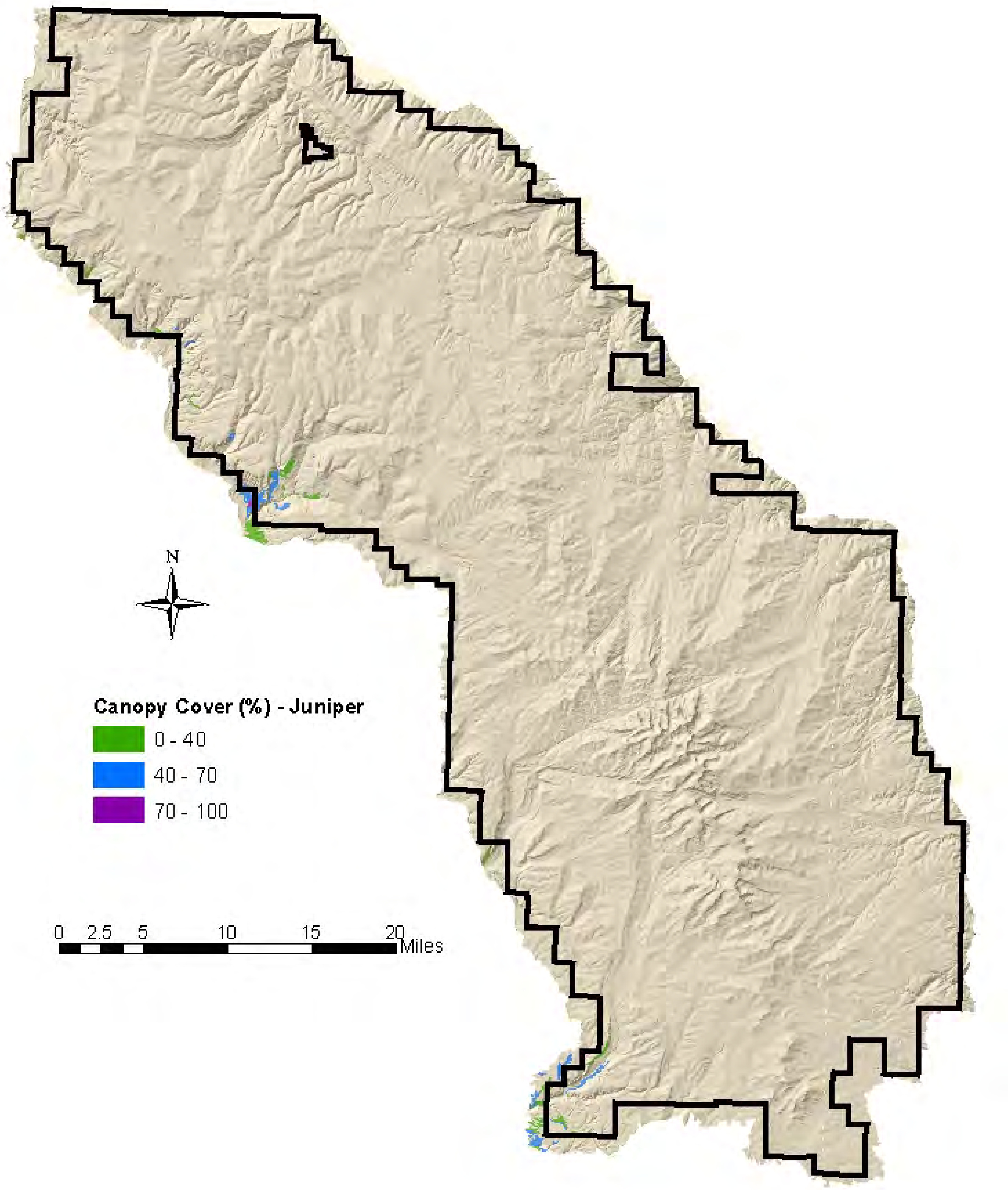


Figure M3A-46. Location of canopy coverage of juniper woodlands in the Bighorn National Forest (CVU database).

Function

No functional data describing productivity, biomass, or carbon or other nutrient pools are available for juniper woodlands in the Big Horn Mountains. Such data have not been determined for most of the Rocky Mountains, in part because even the structure of juniper-dominated woodlands is just beginning to be investigated.

Natural Disturbances

The primary natural disturbance factor in juniper woodlands of the BNF is fire, although virtually no fire history data exist for this forest type. In southwestern Colorado, Romme *et al.* (2002) hypothesize the possibility of multiple fire regimes for pinyon-juniper forests, depending largely on the density of forest cover. Where trees essentially form a savanna (such as those that have been described in Arizona and New Mexico), the grassy ground-cover component may carry frequent, low-intensity fires similar to those in many ponderosa pine forests. Where the vegetation forms shrubby woodlands (such as that in the Great Basin and Colorado Plateau), fire may generally be stand-replacing at intervals of several decades. In pinyon-juniper forests like those in the Great Basin, the Colorado Plateau, Oregon, California, and Arizona, fire is very rare (perhaps at intervals of > 500 years) but extremely severe when it does occur.

Summary of Key Findings for Juniper Woodland Type

- Juniper woodlands comprise a very minor portion of the forested area of the BNF, occupying fewer 6,308 acres (2,552 ha) on coarse, sedimentary soils between 1,520 and 2,140 m (5,000 and 7,000 feet). Juniper woodlands are restricted to small pockets along the drier western flank of the Forest.

- Juniper woodlands on the BNF are generally small and sparse, with average diameters less than 5 inches (13 cm) and canopy coverage less than 40%.

- Fire suppression and grazing may have increased the fire interval in adjacent grassland ecosystems, such that juniper woodlands may have expanded their range over the past century. However, it is not clear whether this expansion is within the historical range of variability.

- Virtually no data exist to adequately describe the existing condition of juniper woodlands on the BNF.

Forest Composition and Structure by LTA

This section briefly describes the variability in the proportion of each cover type and Habitat Structural Stage as it occurs with Landtype Associations on the BNF. Cover type areas are calculated from the CVU database. The climate, geology, physiography, and soils associated with each LTA are described in detail in Appendix A of Chapter 2.

Within the BNF, forest cover types vary considerably by Landtype Association (LTAs) (Table MA3-9). Spruce/Fir, lodgepole pine, and aspen forests occur on every LTA, but spruce/fir is most commonly found on limestone/dolomite sedimentary mountain slopes, granitic mountain slopes, and in the alpine zone. Lodgepole pine and aspen forests show the greatest affinity for granitic mountain slopes. Aspen is also most common in landslide/colluvial deposits and granitic breaklands. Douglas-fir and limber pine appear to be most common in sedimentary breaklands and sedimentary mountain slopes, ponderosa pine is most common in sedimentary and granitic breaklands, and juniper is most common on sedimentary breaklands and calcareous, sandstone sedimentary mountain slopes (Table M3A-9).

Table M3A-9. Acreage (hectares in parentheses) of forest cover types in the Bighorn National Forest by Landtype Association.

LTA	Spruce/Fir	Lodgepole pine	Douglas-fir	Ponderosa pine	Juniper	Limber pine	Aspen
Sedimentary breaklands (Ba-01)	21,563 (8,726)	4,500 (1,821)	72,954 (29,524)	19,351 (7,831)	2,136 (864)	10,593 (4,287)	653 (264)
Landslide/colluvial deposits (Ba-02)	4,399 (1,780)	525 (212)	5,381 (2,178)	555 (225)	976 (395)	1,359 (550)	1,573 (637)
Sedimentary mountain slopes – limestone /dolomite (Ba-03)	50,510 (20,441)	9,856 (3,989)	20,401 (8,256)	4,559 (1845)	2,876 (1,164)	2,950 (1,194)	465 (188)
Sedimentary mountain slopes – sandstone/shale calcareous (Ba-04)	3,384 (1,369)	873 (353)	2,076 (840)	3,661 (1482)	6 (2)	768 (311)	635 (257)
Sedimentary mountain slopes – sandstone/shale non-calcareous (Ba-05)	23,742 (9,608)	19,513 (7,897)	4,464 (1,807)	1,046 (423)	0	328 (133)	918 (372)
Granitic breaklands (Bb-01)	4,777 (1,933)	20,487 (8291)	5,795 (2,345)	4,961 (2,008)	90 (36)	208 (84)	1,404 (568)
Glacial cirquelands (Bb-02)	3,921 (1,587)	60 (24)	0	0	0	0	62 (25)
Glacial terrace deposits (Bb-03)	14,787 (5,984)	58,320 (23,601)	685 (277)	64 (26)	0	2 (1)	976 (395)
Steep granitic mountain slopes (Bb-04)	3,642 (1,474)	32,600 (13,193)	705 (285)	1,743 (705)	0	0	855 (346)
Gentle granitic mountain slopes (Bb-05)	56,946 (23,045)	200,239 (81,034)	268 (108)	345 (140)	0	2 (1)	3,411 (1,380)
Alpine (Bb-06)	48,441 (19,603)	11,929 (4,828)	0	0	0	0	401 (162)

Sedimentary breaklands (M331 Ba-01)

Sedimentary breaklands occupy 188,524 acres (76,293 ha) of the BNF, and are dominated by Douglas-fir (39%), ponderosa pine (10%), and spruce/fir (11%) forests. Limber pine forests (6%), grasslands (5%), and big sagebrush (4%) are minor cover types in the LTA. Nearly 38% of the LTA is classified as Habitat Structural Stages 3B and 3C (69,958 acres/28,311 ha); Stage 4C also occupies a significant portion of the LTA (16%; 30,841 acres/12,480 ha).

Landslide/colluvial deposits (M331 Ba-02)

Landslide and colluvial deposits occupy 38,837 acres (15,716 ha) of the BNF, and are dominated by grasslands (33%) and big sagebrush (18%). Douglas-fir (14%), spruce/fir (11%), and aspen forests (4%) are minor cover types in the LTA. Subsequently, 33% of the LTA is classified as Habitat Structural Stage 1M (12,858 acres/5,203 ha), which corresponds to grassland types; Stage 2S, which represents shrubs and seedlings, also occupies a significant portion of the LTA (25%; 9,558 acres/3,868 ha), as does Stage 3B (12%; 4,586 acres/1,855 ha).

Limestone/dolomite sedimentary mountain slopes (M331 Ba-03)

Limestone and dolomite sedimentary mountain slopes occupy 223,099 acres (90,285 ha) of the BNF, and are dominated by grasslands (26%) and by spruce/fir (23%) and big sagebrush (16%). Douglas-fir forests (9%) and lodgepole pine forest (4%) are minor cover types in the LTA. Coverage of the LTA is distributed among Habitat Structural Stages 1M (25%; 56,652 acres/22,926 ha), Stage 2S, (21%; 46,501 acres/18,818 ha), Stage 3C (9%; 21,099 acres/8,538 ha), and Stage 4C (10%; 22,532 acres/9,118 ha).

Calcareous shale/sandstone sedimentary mountain slopes (M331 Ba-04)

Calcareous shale and sandstone sedimentary mountain slopes occupy 49,516 acres (20,038 ha) of the BNF, and are dominated by grasslands (33%) and big sagebrush (11%). Ponderosa pine (7%), and spruce/fir (7%) are minor cover types in the LTA. Most of the LTA is dominated by grasslands and shrubs or seedlings; nearly 19% of the LTA is classified as Habitat Structural Stage 2S (9,307 acres/3,766 ha). Stage 1M also occupies a significant portion of the LTA (33%; 16,514 acres/6,683 ha).

Non-calcareous shale/sandstone sedimentary mountain slopes (M331 Ba-05)

Non-calcareous shale and sandstone sedimentary mountain slopes occupy 85,854 acres (34,744 ha) of the BNF, and are dominated by spruce/fir forests (28%) and grasslands (30%), as well as lodgepole pine forests (23%). Big sagebrush (5%) and Douglas-fir forests (5%) are minor cover types in the LTA. Nearly 31% of the LTA is classified as Habitat Structural Stage 1M (10,767 acres/4,357 ha), 20% is represented by Stage 3C (17,502 acres/7,082ha) and 17% is represented by Stage 4C (14,168 acres/5,733 ha).

Granitic breaklands (M331 Bb-01)

Granitic breaklands occupy 44,405 acres (17,970 ha) of the BNF, and are dominated by lodgepole pine forest (46%). Douglas-fir (13%), spruce/fir (11%), and ponderosa pine forests (11%) are important minor cover types in the LTA. Almost 49% of the LTA is classified as Habitat Structural Stages 3B and 3C (21,864 acres/8,848 ha); Stages 4B and 4C also occupy a significant portion of the LTA (28%; 12,595 acres/5,097 ha).

Glacial cirquelands (M331 Bb-02)

Glacial cirquelands occupy 64,417 acres (26,068 ha) of the BNF, and are covered mostly by bare rock or soil (86%). Where vegetation is present, it is dominated by spruce/fir forest (6%) and grasslands (6%). The most common Habitat Structural Stages in the LTA are Stages 1M (4,175 acres/1,690 ha) and 3A (3%; 1,990 acres/805 ha).

Glacial/tertiary terrace deposits (M331 Bb-03)

Glacial and tertiary terrace deposits occupy 105,714 acres (42,781 ha) of the BNF, and are dominated by lodgepole pine forests (55%). Spruce/Fir forest (14%), and grasslands (21%) are important minor cover types in the LTA. Most of the LTA (26%) is classified as Habitat Structural Stage 3C (28,366 acres/11,479 ha), but Stage 1M (21%; 22,296 acres/9,022 ha), Stage 3B (16%; 16,926 acres/6,850ha), and Stage 4C (11%; 11,819 acres/4,783 ha) also occupy a significant portion of the LTA.

Steep granitic mountain slopes (M331 Bb-04)

Steep granitic mountain slopes occupy 42,826 acres (17,331 ha) of the BNF, dominated by lodgepole pine forests (76%; 32,599acres/13192ha). Spruce/fir forest (9%), grasslands (4%), and ponderosa pine (4%) are important minor cover types in the LTA. Habitat Structural Stage 3C occupies 51% of the LTA (21,871 acres/8850 ha). Stage 3B (21%; 8,875 acres/ 3,592 ha) and 4C (11%; 4,919 acres/1,991 ha) also occupy significant portions of the LTA.

Gentle granitic mountain slopes (M331 Bb-05)

Gentle granitic mountain slopes occupy 318,044 acres (128,708 ha) of the BNF, dominated lodgepole pine forests (63%). Spruce/Fir forest (18%), and grasslands (12%) are important minor cover types in the LTA.

Habitat Structural Stage 3C occupies 34% of the LTA (108,442 acres/43,885 ha), but Stages 3B (17%; 53,298 acres/21,569 ha) and 4C (16%; 50,355 acres/20,378 ha) also occupy a significant portion of the LTA.

Alpine mountain slopes and ridges (M331 Bb-06)

Alpine mountain slopes and ridges occupy 120,313 acres (48,689 ha) of the BNF, and are dominated by spruce/fir forests (40%) and grasslands (24%). Lodgepole pine forests (10%) are also important in the LTA. Reflecting the alpine nature of the LTA, 24% of the LTA is classified as Habitat Structural Stage 1M (29,395 acres/11,896 ha), which corresponds to grassland types; 32% of the LTA is classified as Stages 3A and 3B (38,221 acres/15,467 ha) and 9% (10,862 acres/4,395 ha) is classified as Stage 4B.

Information Gaps for Describing Existing Conditions of Forests

The following information gaps are categorized into two groups. The first group of questions ("Additional data required") deals with data and information that were not available for inclusion based on the time resources available for completion of the Assessment. Such data and information are likely available in U.S. Forest Service databases or in the literature and should be included in a subsequent draft of the Assessment.

The second group of questions ("Information gaps") deals with data and/or information that is currently unavailable, suggesting the need for further research and data collection. Both sets of questions represent a "running list" of gaps that are not inclusive of all possible improvements to the next draft Assessment.

Additional Data Required

(1) What successional pathways have been documented and modeled for each forest cover type? Are descriptions and/or successional diagrams available for inclusion in the Assessment?

(2) What is the range of conditions of coarse woody debris for each forest cover type? Are descriptions and data available in the literature?

(3) Although Mehl (1992) provides old-growth characteristics for most of the forest types described in this Module, are there other descriptions of old growth for forest types in this region that may also apply? Are there available stand and landscape data for forests in the Big Horn Mountains that may be used to estimate the current condition of old-growth forests on the Bighorn National Forest?

(4) How does stand density vary across the landscape for each forest type? What are the possible landscape determinants responsible for this variability?

(5) Can we obtain basic data (stand structure, composition, age data, etc.) for the minor forest types (ponderosa pine, limber pine, and juniper) on the Bighorn National Forest?

(6) Are data on stand structure and composition available at multiple units of stratification (i.e., LTAs rather than simply Forest-wide)?

(7) What is the evidence in the literature for the trends and patterns discussed in the Assessment? Are there exceptions or variations? (Note: This Module contains relatively little literature review or citation to the scientific literature, which is essential to a complete, articulate assessment of current conditions of forested areas in the Big Horn Mountains).

Information Gaps

(1) What is the range of characteristics of coarse woody debris across forest types in this region, and across stands of varying management history and structure within a given forest type?

(2) What is the fire history of each forest type in the Big Horn Mountains? How do these fire regimes resemble or differ from the standard "model" of fire regimes for that forest type in other regions of western North America?

(3) What are the key characteristics of carbon/nutrient cycling and storage in the Bighorn National Forest? How applicable are studies of similar forest types outside the Big Horn region on the Bighorn National Forest?

(4) What conditions of vertical complexity currently exist for different forest types on the Bighorn National Forest, and for different stand structures within each forest type?

(5) What are the direct effects of past management practices (fire suppression, grazing, timber harvest, etc.) on the different forest types on the Bighorn National Forest? How do ecosystems affected by humans in the Forest compare to those outside the Forest? What are the needs for restoration across the Forest?

Literature Cited

Allen, K.K., and J.L Harris. 1999. Insects and diseases of the Bighorn National Forest. Internal report, Bighorn National Forest, Sheridan, Wyoming.

Alexander, R.R. 1987. Ecology, silviculture, and management of the Engelmann spruce-subalpine fir type in the central and southern Rocky Mountains. USDA Forest Service Agricultural Handbook No. 659, Washington, D.C. 144 pp.

Alexander, R.R., and W. D. Shepperd. 1984. Silvical characteristics of Engelmann spruce. USDA Forest Service, Rocky Mountain Forest and Experiment Station General Technical Report RM-114. Fort Collins, CO: 38 pp.

Alexander, R.R., R. C. Shearer, and W.D. Shepperd. 1984. Silvical characteristics of subalpine fir. USDA Forest Service, Rocky Mountain Forest and Experiment Station General Technical Report RM-115. Fort Collins, CO: 29 pp.

Amman, G.D. (comp.). 1989. Symposium on the management of lodgepole pine to minimize losses to the mountain pine beetle. USDA Forest Service Intermountain Forest and Range Experiment Station, General Technical Report INT-262.

Amman, G.D., M.D. McGregor, D.B. Cahill, and W.H. Klein. 1977. Guidelines for reducing lossess of lodgepole pine to the moutain pine beetele in unmanaged stands in the Rocky Mountains. General Technical Report INT-36, USDA Forest Service, Intermountain Forest and Range Experiment Station, Ogden, UT.

Aplet, G.H., R.D. Laven, and F.W. Smith. 1988. Patterns of community dynamics in Colorado Engelmann spruce-subalpine fir forests. Ecology **69**: 312-319.

Arthur, M.A., and T.J. Fahey. 1992. Biomass and nutrients in an Engelmann spruce-subalpine fir forest in north central Colorado – pools, annual production, and internal cycling. Canadian Journal of Forest Research **22**: 315-325.

Barnes, B.V. 1966. The clonal growth habit of American aspens. Ecology **47**: 439-447.

Barnes, B.V., D.R. Zak, S.R. Denton, S.H. Spurr. 1998. Forest Ecology. 4th Edition. John Wiley & Sons, Inc. New York, New York.

Begon, M., J.L. Harper, and C.R. Townsend. 1996. Ecology: individuals, populations and communities 3rd edition. Blackwell Science Ltd., London, UK.

Binkley, D., F.W. Smith, Y. Son. 1995. Nutrient supply and declines in leaf-area and production in lodgepole pine. Canadian Journal of Forest Research **25**: 621-628.

Binkley, D., U. Olsson, R. Rochelle, T. Stohlgren, and N. Nikolov. 2003. Structure, production and resource use in some old-growth spruce/fir forests in the front range of the Rocky Mountains, USA. Forest Ecology and Management **172**: 271-279.

Bornong, B.R. 1996. Silvicultural certification prescription. Report on file at Bighorn National Forest Supervisor's Office, Sheridan, Wyoming.

Daudet, F.-A., X. Le Roux, H. Sinoquet, and B. Adam. 1999. Wind speed and leaf boundary layer conductance variation within tree crown: consequences on leaf-to-atmosphere coupling and tree functions. Agricultural and Forest Meteorology 97:171-185.

Eyre, F.H. 1980. Forest Cover Types of the United States and Canada. Society of American Foresters, Washington D.C., USA.

Fischer, W.C. and B.D. Clayton. 1983. Fire Ecology of Montana Forest Habitat Types East of the Continental Divide. USDA Forest Service General Technical Report INT-141. Intermountain Forest and Range Experimental Station, Ogden, UT, USA.

Fitzjarrald, D.R., K.E. Moore, O.M.R. Cabral, J. Scolar, A.O. Manzi, and L.D. de Abreu Sa. 1990. Daytime turbulent exchange between the Amazon forest and the atmosphere. Journal of Geophysical Research 95(10):16825-15838.

Girard, Michele, David L. Wheeler, and Stephanie B. Mills. 1997. Classification of riparian communities on the Bighorn National Forest. USDA Forest Service, Rocky Mountain Region, R2-RR097-02.

Heath, J. A., and B. J. Huebert. 1999. Cloudwater deposition as a source of fixed nitrogen in a Hawaiian montane forest. Biogeochemistry 44:119-134.

Hessel 2002

Hinds 1985

Hoffman, G., and R. Alexander. 1976. Forest vegetation of the Big Horn Mountains, Wyoming: a habitat classification. US Forest Service Research Paper RM-276.

Hoover, R.L., and D.L. Wills. 1987. Managing forested lands for wildlife. Colorado Division of Wildlife in cooperation with USDA Forest Service, Rocky Mountain Region, Denver, Colorado. 459 pages.

Houston 2001

Jankovsky-Jones, Mabel, George P. Jones, and Walter Fertig. 1995. Ecological evaluation for the potential Platte Ridge and North Platte River Canyon research natural area within the Medicine Bow National Forest, Albany County, Wyoming. Wyoming Natural Diversity Database, The Nature Conservancy, Laramie WY. Unpublished

Johnson, D.W. 1986. A summary of dwarf mistletoe program activities in the Rocky Mountain region, 1970-1986. USDA Forest Service, Timber, Forest Pest, and Cooperative Forestry Pest Management, Rocky Mountain region, Technical Report R2-36.

Johnson, D.W. 1995. Ecology and management of forest insects and diseases on the Medicine Bow National Forest. Draft white paper – USDA Forest Service, Region 2, Forest Insect and Disease Methods Group, Lakewood, CO.

Johnson, E.A. 1992. Fire and vegetation dynamics. Cambridge University Press, New York. 129 pp.

Jones and Fertig 1998

Jones, G.P., and W. Fertig. 1999a. Ecological evaluation of the potential Grizzly Creek research natural area within the Shoshone National Forest, Park County, Wyoming. Wyoming Natural Diversity database, University of Wyoming, Laramie, WY. Unpublished.

Jones, G.P., and W. Fertig. 1999b. Ecological evaluation of the potential Sheep Mesa research natural area within the Shoshone National Forest, Park County, Wyoming. Wyoming Natural Diversity database, University of Wyoming, Laramie, WY. Unpublished.

Jones, G.P., and W. Fertig. 1999c. Ecological evaluation of the potential Arrow Mountain research natural area within the Shoshone National Forest, Park County, Wyoming. Wyoming Natural Diversity database, University of Wyoming, Laramie, WY. Unpublished.

Jones, G.P., and W. Fertig. 1999d. Ecological evaluation of the potential Beartooth Butte research natural area within the Shoshone National Forest, Park County, Wyoming. Wyoming Natural Diversity database, University of Wyoming, Laramie, WY. Unpublished.

Jones, G.P., and W. Fertig. 1999e. Ecological evaluation of the potential Roaring Fork Mountain research natural area within the Shoshone National Forest, Park County, Wyoming. Wyoming Natural Diversity database, University of Wyoming, Laramie, WY. Unpublished.

Jones and Ogle 2000

Kashian, D.M. 2002. Landscape variability and convergence in forest structure and function following large fires in Yellowstone National Park. PhD Dissertation, University of Wisconsin-Madison, Madison, WI.

Kay, C.E. 1990. Yellowstone northern elk herd: a critical evaluation of the natural regulation paradigm. PhD dissertation, Utah State University, Logan, UT.

Kendall, K.C. 1998. Limber pine. Page 486 in: Mac, Michael J. (project director). Status and trends of the nation's biological resources. Volume 2. USDI Geological Survey.

Knight, D.H. 1994. Mountains and plains: The ecology of Wyoming landscapes. Yale University Press, 338 pp.

Krebill 1965

Lee, P. 1998. Dynamics of snags in aspen-dominated midboreal forests. Forest Ecology and Management **105**: 263-272.

Lee, P.C., S. Crites, M. Nietfeld, H. VanNguyen, and J.B. Stelfox. 1997. Characteristics and origins of deadwood material in aspen-dominated boreal forests. Ecological Applications **7**: 691-701.

Lee, P., and K. Sturgess. 2001. The effects of logs, stumps, and root throws on understory communities within 28-year-old aspen-dominated boreal forests. Canadian Journal of Forest Research **79**: 905-916.

Litton, C.M., M.G. Ryan, D.B. Tinker, and D.H. Knight. 2003. Belowground and aboveground biomass in young postfire lodgepole pine forests of contrasting tree density. Canadian Journal of Forest Research **33**: 351-363.

Lotan, J.E., and W.B. Critchfield. 1990. Lodgepole pine. *In*: Burns, R.M., and B.H. Honkala (eds.). Silvics of North America: 1. Conifers. Agricultural Handbook 654. USDA Forest Service, Washington, D.C. 675 pp.

Lundquist, J.E. 1993. Large sacale spatial patterns of conifer diseases in the Big Horn Mountains, Wyoming. USDA Forest Service, Research Note RM-523. Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO.

Mast, J.N., and T.T. Veblen. 1999. Tree spatial patterns and stand development along the pine-grassland ecotone in the Colorado Front Range. Canadian Journal of Forest Research **29**: 575-584.

McCune, B.C. and R.L. Boyce. 1992. Precipitation and the transfer of water, nutrient and pollutants in tree canopies. Trends Ecology and Evolution 7:4-7.

Mehl, M.S. 1992. Old-growth descriptions for the major forest cover types in the Rocky Mountain region. Pp. 106-120 in M.R. Kaufmann, W.H. Moir, and R.L. Bassett (tech. coords.). Old-growth forests in the Southwest and Rocky Mountain regions: proceedings of a workshop. USDA Forest Service General Technical Report RM-213, Rocky Mountain Forest and Range Experiment Station, Ft. Collins, CO.

Merrill, E.H., T.W. Kohley, M.E. Herdendorf, W.A. Reiners, K.L. Driese, R.W. Marrs, and S.H. Anderson. 1996. Wyoming gap analysis: a geographic analysis of biodiversity. Final report, Wyoming Cooperative Fishery and Wildlife Research Unit, University of Wyoming, Laramie, WY.

Meyer, C.B., and D.H. Knight. 2003. Historic variability for upland vegetation in the Bighorn National Forest, Wyoming. Unpublished report on file at Bighorn National Forest Supervisor's Office, Sheridan, Wyoming.

Miller, R.F., and P.E. Wigand. 1994. Holocene changes in semiarid pinyon-juniper woodlands. BioScience **44**: 465-474.

Miller, R., R. Tausch, and W. Waichler. 1999. Old-growth juniper and pinyon woodlands. Pp. 375-384 in S.B. Monsen and R. Stevens (comp.). Proceedings: Ecology and management of pinyon-juniper communities within the Interior West. 1997 September 15-18; Provo, UT. Proc. RMRS-P-9, Ogden, UT: U.S.D.A. Forest Service, Rocky Mountain Research Station. 411pp.

Miller, R.F., and R.J. Tausch. 2001. The role of fire in juniper and pinyon woodlands: a descriptive analysis. Pp. 15-30 *in*: Galley, K.E.M., and T.P. Wilson (eds.). Proceedings of the invasive species workshop: the role of fire in the control and spread of invasive species. Fire conference 2000: The First National Congress on fire ecology, prevention, and management. Miscellaneous Publication Number 11, Tall Timbers Research Station, Tallahasee, FL.

Moses, R.A., and S. Boutin. 2001. The influence of clear-cut logging and residual leave material on small mammal populations in aspen-dominated boreal mixedwoods. Canadian Journal of Forest Research **31**: 483-495.

Mueggler, W.F. 1985. Vegetation associations. Pages 45-56 In: N.V. DeByle and R.P. Winokur (eds.). Aspen: Ecology and management in the western United States. USDA Forest Service General Technical Report RM-119, Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO.

Nelson and Hartman 1984

Nesser 1986

Norman, J.M. and G.S. Campbell. 1989. Canopy structure. Pages 301-325 *in* R.W. Pearcy, J.R. Ehleringer, H.A. Mooney, and P.W. Rundel, editors. Plant physiological ecology: field methods and instrumentation. Chapman & Hall, London, UK.

Oliver, C.D., and B.C. Larsen. 1996. Forest stand dynamics. John Wiley and Sons, New York. 520 pp.

Olsson, U., D. Binkley, and F.W. 1998. Nitrogen supply, nitrogen use, and production in an age sequence of lodgepole pine. Forest Science **44**: 454-457.

Parker, G.G. 1983. Throughfall and stemflow in the forest nutrient cycle. Advances in Ecological Research 13:57-133.

Parker, G.G. 1995. Structure and microclimate of forest canopies. Pages 73-106 *in* M. Lowman, N. Nadkarni, editors. Forest canopies - a review of research on a biological frontier. Academic Press, San Diego, USA.

Parker, G.G., M.M. Davis, and S.M. Chapotin. 2002. Canopy light transmittance in Doulgas-fir-western hemlock stands. Tree Physiology 22:147-157.

Pearson, J.A., D.H. Knight, and T.J. Fahey. 1987. Biomass and nutrient accumulation during stand development in Wyoming lodgepole pine forests. Ecology **68**: 1966-1973.

Peet, P.K. 1988. Forests of the Rocky Mountains. Chapter 3 *in*: Barbour, M., and W.D. Billings (eds.). Terrestrial vegetation of North America. Cambridge University Press. 434 pp.

Perala, D.A. 1990. Quaking aspen. *In*: Burns, R.M., and B.H. Honkala (eds.). Silvics of North America: 2. Hardwoods. Agricultural Handbook 654. USDA Forest Service, Washington, D.C. 877 pp.

Pfister, R.D., B.L. Kovalchik, S.F. Arno, and R.C. Presby. 1977. Forest habitat types of Montana. USDA Forest Service General Technical Report INT-34. Intermountain Forest and Range Experiment Station, Ogden UT

Popp, J.B., P.D. Jackson, and R.L. Bassett. 1992. Old-growth concepts from habitat data in the Southwest. Pp. 100-105 in M.R. Kaufmann, W.H. Moir, and R.L. Bassett (tech. coords.). Old-growth forests in the Southwest and Rocky Mountain regions: proceedings of a workshop. USDA Forest Service General Technical Report RM-213, Rocky Mountain Forest and Range Experiment Station, Ft. Collins, CO.

Reid, M.S., K.A. Shultz, P.J. Comer, M.H. Schindel, D.R. Culver, D.A. Sarr, and M.C. Damm. 1999. An alliance level classification of the vegetation of the conterminous western United States. A Report to the Idaho Cooperative Fish and Wildlife Research Unit and the National Gap Analysis Program. The Nature Conservancy, Western Conservation Science Department, Boulder, Colorado.

Ripple, W.J., and E.J. Larsen. 2001. The role of postfire coarse woody debris in aspen regeneration. Western Journal of Applied Forestry **16**: 61-64.

Robertson, P.A., and Y.H. Bowser. 1999. Coarse woody debris in mature *Pinus ponderosa* stands in Colorado. Journal of the Torrey Botanical Society **126**: 255-267.

Romme, W.H. 1982. Fire and landscape diversity in subalpine forests of Yellowstone National Park. Ecological Monographs **52**: 199-221.

Romme, W.H., and D.G. Despain. 1989. Historical perspective on the Yellowstone fires of 1988. Bioscience **39**: 695-699.

Romme, W.H., M.G. Turner, L.L. Wallace, and J.S. Walker. 1995. Aspen, elk, and fire in northern Yellowstone National Park.. Ecology 76: 2097-2106.

Romme, W.H., M.G. Turner, R.H. Gardner, W.W. Hargrove, G.A. Tuskan, D.G. Despain, and R.R. Renkin. 1997. A rare episode of sexual reproduction in aspen (*Populus tremuloides* Michx.) following the 1988 Yellowstone fires. Natural Areas Journal **17**: 17-25.

Romme, W.H., M.L. Floyd, D. Hanna, and J.S. Redders. 2000. Using natural disturbance regimes as a basis for mitigating impacts of anthropogeic fragmentation. Pages 377-400 in R.L. Knight, F.W. Smith, S.W. Buskirk, W.H. Romme and W.L. Baker (eds.). Forest fragmentation in the Southern Rocky Mountains. University Press of Colorado, Boulder.

Romme, W.H., L. Floyd-Hanna, D.D. Hanna, and E. Bartlett. 2001. Aspen's ecological role in the West. USDA Forest Service Proceedings, RMRS-P-18, Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO.

Romme, W.H., L. Floyd-Hanna, and D.D. Hanna. 2002. Ancient pinyon-juniper forests of Mesa Verde and the West: A cautionary note for forest restoration programs. Paper presented at the Conference of Fire, Fuel Treatments, and Ecological Restoration: Proper Place, Appropriate Time. Fort Collins, Colorado, 16-18 April, 2002.

Schmid, J.M., and T.E. Hinds. 1974. Development of spruce/fir stands following spruce beetle outbreaks. USDA Forest Service Research Paper RM-131, Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO.

Schmid, J.M., and S.A. Mata. 1996. Natural variability of specific forest insect populations and their associated effects in Colorado. General Technical Report RM-GTR-275, USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO.

Shaw, R.H. and A.R. Pereira. 1982. Aerodynamic roughness of a plant canopy: a numerical experiment. Agriculture Meteorology 26:51-56.

Smith, F.W., and S.C. Resh. 1999. Age-related changes in production and below-ground carbon allocation in *Pinus contorta* forests. Forest Science **45**: 333-341.

Stahelin, R. 1943. Factors influencing the natural restocking of high altitude burns by coniferous trees in the central Rocky Mountains. Ecology **24**: 19-30.

Steele, R. 1990. Limber pine. *In*: Burns, R.M., and B.H. Honkala (eds.). Silvics of North America: 1. Conifers. Agricultural Handbook 654. USDA Forest Service, Washington, D.C. 675 pp.

Steele, R., S.V. Cooper, D. M. Ondov, D. W. Roberts, and R.D. Pfister. 1983. Forest habitat types of eastern Idaho-western Wyoming. USDA Forest Service General Technical Report INT-144. Intermountain Forest and Range Experiment Station, Ogden UT. 122 pp.

Tausch, R.J. 1999. Historic pinyon and juniper woodland development: *In:* Monsen, S.P., R. Stevens (comps.). Ecology and management of pinyon-juniper communities withn the Interior West. Pp. 12-18. USDA Forest Service Proceedings, RMRS-P-9, Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO.

Tausch, R.J., and R.S. Nowak. 1999. Fifty years of ecotone change between shrub and tree dominance in the Jack Springs Pinyon Research Natural Area. USDA Forest Service Proceedings, RMRS-P-9, Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO.

Tinker, D.B., and D.H. Knight. 2000. Temporal and spatial dynamics of coarse woody debris in harvested and unharvested lodgepole pine forests. Ecological Modelling **141**: 125-149.

Tinker, D.B., W.H. Romme, W.W. Hargrove, R.H. Gardner, and M.G. Turner. 1994. Landscape-scale heterogeneity in lodgepole pine serotiny. Canadian Journal of Forest Research 24: 897-903.

Town, F.E. 1899. Bighorn Forest Reserve. Pp. 165-190 *in:* Walcott, C.D. (compiler), Nineteenth annual report of the United States Geological Survey to the Secretary of Interior 1897-98. Part V – Forest Reserves. U.S. Geological Survey, Washington, DC.

Veblen, T.T. 1986. Age and size structure of subalpine forests in the Colorado Front Range. Bulletin of the Torrey Botanical Club **113**: 225-240.

Veblen, T.T., and D.C. Lorenz. 1991. The Colorado Front range: A century of ecological change. University of Utah press, Salt Lake City.

Welp, L., W.F. Fertig, G.P. jones, G.P. Beauvais, and S.M. Ogle. 2000. Fine filter analysis of the Bighorn, Medicine Bow, and Shoshone National Forests in Wyoming. Prepared for the U.S. Forest Service Region 2 by Wyoming Natural Diversity Database, University of Wyoming.

Yoda, K. 1974. Three-dimensional distribution of light intensity in a tropical rainforest of West Malaysia. Japanese Journal of Ecology 24:247-254.

Young, J.A., R.A. Evans, R.E. Eckert, Jr., and B.L. Kay. 1987. Cheatgrass. Rangelands 9: 266-270.

Module 3B - Grasslands and Shrublands

Introduction

Discussion is this module will include grassland, cropland, forbland, shrubland, and areas dominated by rock or bare soil. Riparian and wetland vegetation are not addressed in this terrestrial ecosystem assessment.

This module begins with a general description of these vegetation types found in the Big Horn Mountains Section (M331B). It then leads into a more detailed description of grassland/shrubland upland vegetation types within the Bighorn National Forest (BNF). Wyoming and Montana *Gap Analysis Project* (GAP) data were used to describe existing land cover types for the Section-level descriptions. The BNF's Integrated Resource Inventory Common Vegetation Unit (IRI-CVU) data and Welp *et al.* (2000) were used to describe existing upland vegetation at the forest level. An index to the scientific and common plant names used in this part of the assessment is provided in the Appendix. Nomenclature for scientific and common plant names follows the NRCS PLANTS national database available online at: http://plants.usda.gov

Big Horn Mountains Section M331B

The GAP land cover types for Wyoming (Merrill *et al*. 1996) and Montana (Fisher *et al.* 1998) were used to describe the grassland/shrubland upland vegetation for the Big Horn Mountains Section. Because GAP data are based on relatively broad mapping units covering an entire state, resolution is necessarily coarse. These data are useful in providing a general cover type configuration for the Section, and should also help provide a context for describing the role of the BNF relative to the Section.

Grasslands, Croplands, and Forblands

Grasslands are relatively common and widely distributed across the Big Horn Mountains Section (Table M3B-1; Fig. M3B-1). In contrast, croplands are relatively rare (Table M3B-1; Fig. M3B-1). There are no lands specifically labeled as forblands in the Section, although there are limited IRI-CVU data for the BNF. A brief description of each grassland type follows.

Table M3B-1. Area of GAP land cover types for grassland, cropland, and forbland within Section M331B (*source: WY and MT GAP data*).

GAP Land Cover Types	Section M331B 2,824,127 acres (1,142,888 ha)			Bighorn National Forest 1,110,895 acres (449,565 ha)		
	Acres	Hectares	Percent	Acres	Hectares	Percent
Mixed grass prairie	646,350	261,570	69%	108,799	44,030	30%
Subalpine meadows*	284,705	115,216	30%	252,520	102,192	69%
Very low cover grasslands	3,243	1,312	<1%	0	0	<1%
Dry-land Crops	2,533	1,025	<1%	235	95	<1%
TOTALS	936,831	379,124	100%	361,554	146,316	100%

*Includes alpine tundra

Mixed Grass Prairie

This broad grassland type contains a mixture of short grass and tall grass prairie species. These grasslands do not contain buffalo grass, *Buchloe dactyloides*, however, which is considered to be an indicator of short grass prairie. This mixed grass type often occurs in patches intermixed with shrub species (big sagebrush). Grass patches must occupy more than 50% of the landscape for the primary vegetation type to be classified as mixed grass. The vegetation may contain or be dominated by silver sagebrush, *Artemisia cana*. With the exception of *Artemisia cana*, trees or shrubs cannot occupy more than 25% of the total vegetative cover. It is found at lower elevations in the Laramie Basin, in scattered patches in the Shirley and Powder River Basins, and east of the Laramie Range. This cover type comes from the Wyoming GAP compilation (Merrill *et al*. 1996).

Subalpine Meadows

This type is dominated by graminoids and forbs within and below treeline. It is often found in mountain park situations. Trees or shrubs cannot occupy more than 25% of the total vegetative cover. It is found in all higher mountain ranges of Wyoming. The diagnostic species for this type are the following: *Polygonum bistortoides*, *Agrostis humilis*, *Lewisia pygmaea*, *Juncus drummondii*, *Phleum alpinum*, *Poa reflexa*, *Veronica wormskjoldii*, *Arnica mollis*, *Elymus trachycaulus*, *Trisetum spicatum*, *Deschampsia caespitosa*, and *Danthonia* spp. This cover type comes from the Wyoming GAP compilation (Merrill *et al*. 1996).

Alpine tundra is included here as well. It includes graminoid- and forb-dominated vegetation that occurs above treeline in the alpine zone. Common species include *Agrostis* spp., *Festuca ovina*, *Phippsia algida*, alpine mosses, lichen, *Silene acaulis*, *Geum* spp., and *Eritrichium nanum*. Trees or shrubs cannot occupy more than 25% of the total vegetative cover. The diagnostic species include: *Achillea millefolium*, *Elymus trachycaulus*, *Aster alpinus*, *Besseya wyomingensis*, *Campanula rotundifolia*, *Castilleja rhexiifolia*, *Danthonia intermedia*, *Deschampsia caespitosa*, *Festuca* spp., *Gentianella tenella* ssp. *tenella*, *Juncus drummondii*, *Lloydia serotina*, *Pedicularis parryi*, *Phacelia sericea*, *Phleum alpinum*, *Polygonum bistortoides*, *Potentilla diversifolia*, *Primula parryi*, *Salix planifolia*, and *Trisetum spicatum*. This cover type also comes from the Wyoming GAP compilation (Merrill *et al*. 1996).

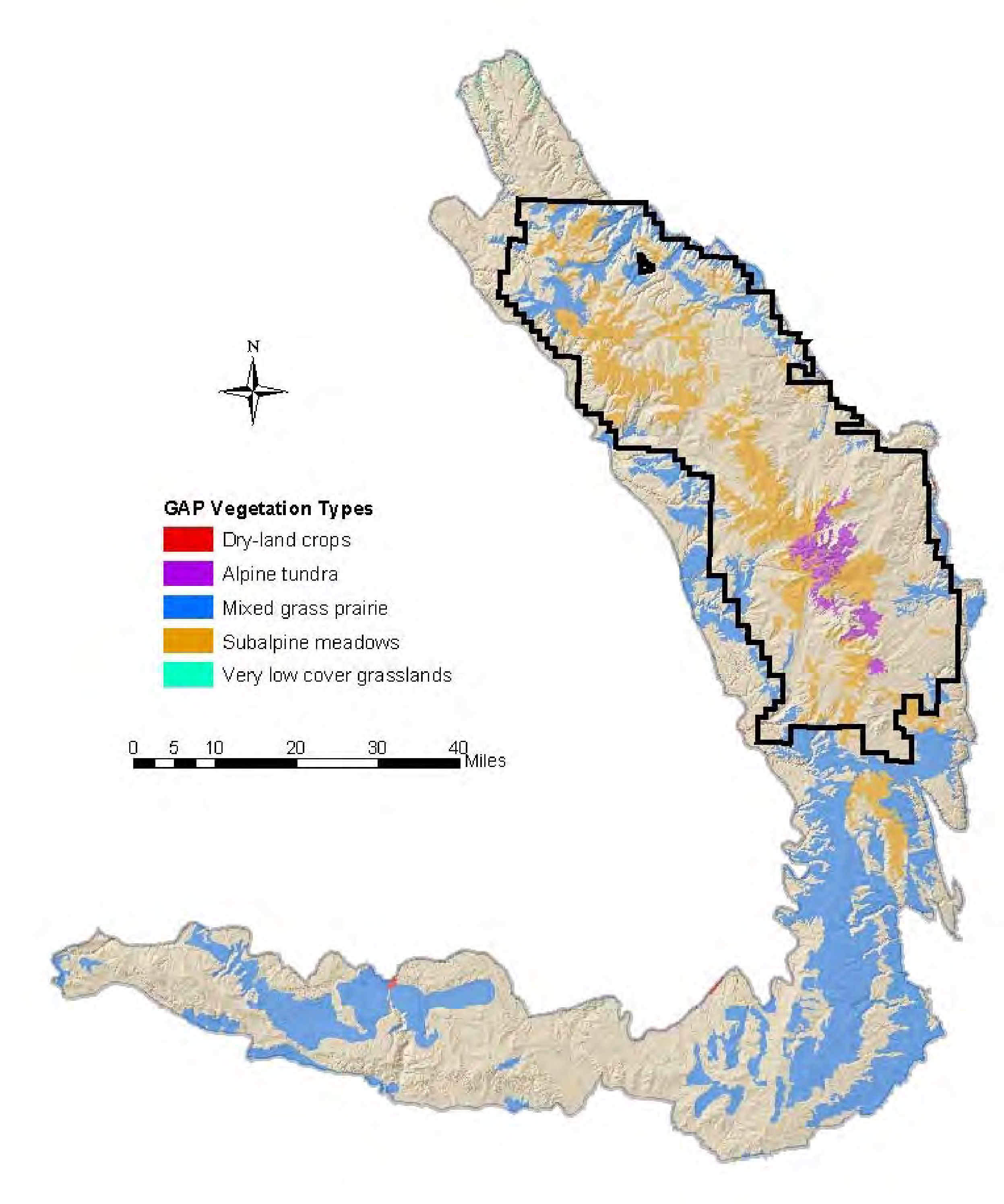


Figure M3B-1. Grasslands and croplands in the Big Horn Mountains Section (M331B; *source: Wyoming GAP* (Merrill *et al*. 1996) *and Montana GAP* (Fisher *et al*. 1998).

Very low cover grasslands

Semi-desert grasslands characterize this cover type, with total grass cover from 10 to 30%. It is dominated by short grasses and forbs, such as *Bouteloua gracilis*, *Selaginella densa*, *Bouteloua hirsuta*, *Phlox hoodii*, *Solidago missouriensis*, *Koeleria macrantha*, *Poa secunda*, *Carex inops* ssp. *heliophila*, and *Carex filifolia*. This type typically has a high amount of bare soil (20 to 60% cover). Herbage production ranges between 50 and 300 lbs/acre (56 and 741 kg/ha). Finally, this type is usually associated with alkaline soils and/or disturbed sites. This cover type comes from the Montana GAP compilation (Fisher *et al*. 1998).

Dry-land Crops

This type includes non-irrigated cropland, dryland improved pastures, fallow lands, rural development, ranch and farm facilities, and shelterbelts. The diagnostic species for this type are: small grains, wheat (*Triticum aestivum*), barley (*Hordeum vulgare*), rye (*Secale cereale*), crested wheatgrass (*Agropyron cristatum*), wheatgrass (*Elymus* spp.), and any non-irrigated crop or pasture. This cover type comes from the Wyoming GAP compilation (Merrill *et al*. 1996).

Shrublands

Shrublands are less common in the Section than are grasslands. Shrublands are generally found at lower elevations and are more prevalent along the western flank of the Big Horn Mountains and in the southern portion of the Section (Table M3B-2; Fig. M3B-2). A brief description of each shrubland type follows.

Mesic shrub-grassland associations

This type contains a co-dominance of shrub and grass species. Shrub and grass cover ranges from 10 to 50%. It is found on moist sites usually between pure grass and/or shrub dominated regions. The dominant species are *Sherpherdia argentea*, *Symphoricarpos* spp., *Rhus* spp., *Pseudoroegneria spicata*, *Andropogon* spp., *Festuca* spp., *Hesperostipa comata*, *Carex filifolia*, and *Pascopyrum smithii*. This cover type comes from the Montana GAP compilation (Fisher *et al*. 1998).

Table M3B-2. Area of GAP Land Cover Types for shrubland within Section M331B (*source: WY and MT GAP data).*

GAP Land Cover Types	**Section M331B 2,824,127 acres (1,142,888 ha)**			*Bighorn National Forest* **1,110,895 acres (449,565 ha)**		
	Acres	**Hectares**	**Percent**	**Acres**	**Hectares**	**Percent**
Mesic shrub-grassland associations	11,991	4,853	3%	1,364	552	5%
Sagebrush	337,296	136,499	86%	22,192	8,981	75%
Xeric shrub associations	42,880	17,353	11%	5,907	2,390	20%
TOTALS	392,167	158,705	100%	29,463	11,923	100%

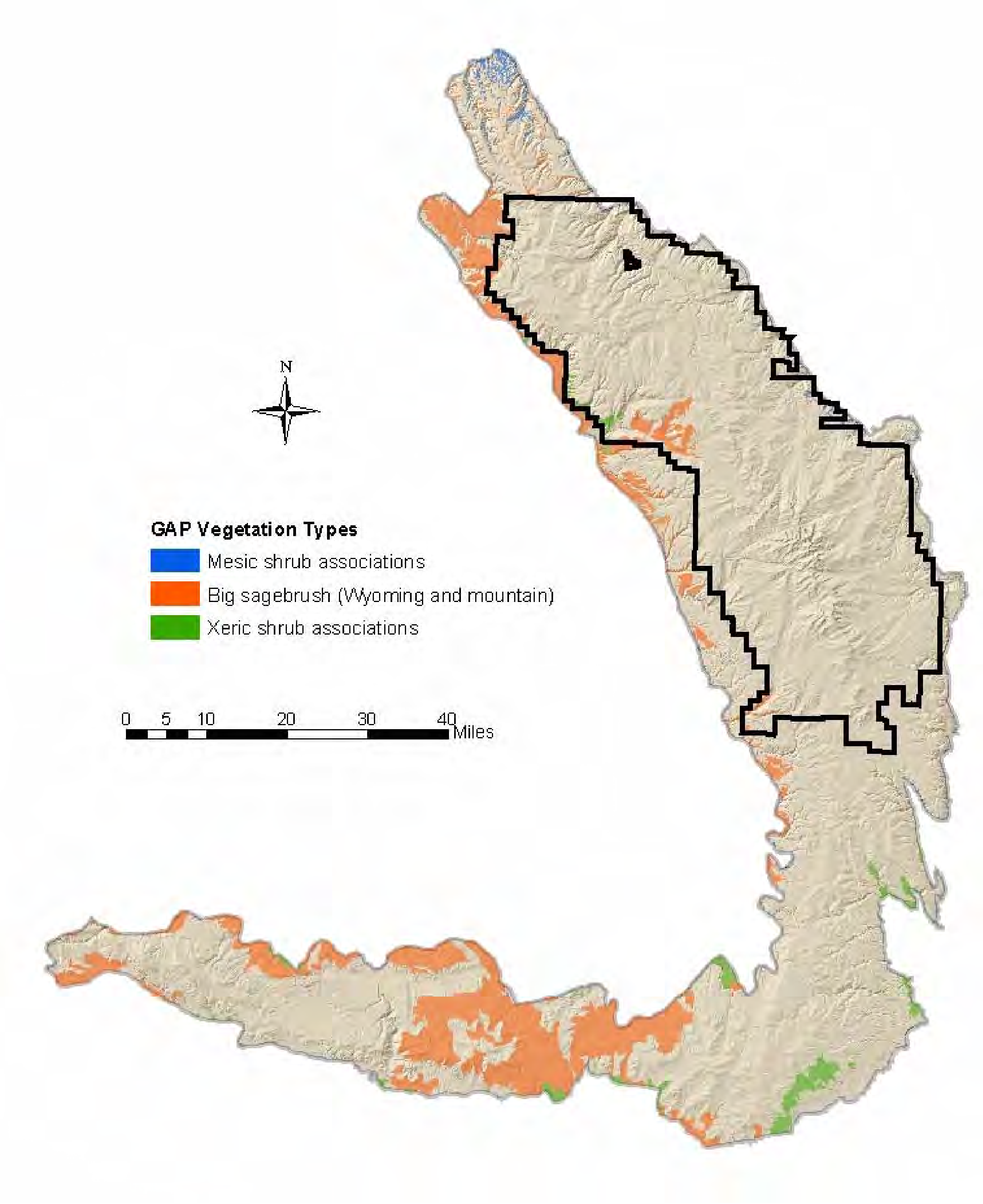


Figure M3B-2. Shrublands in the Big Horn Mountains Section (M331B; *source: Wyoming GAP* (Merrill *et al*. 1996) *and Montana GAP* (Fisher *et al*. 1998).

Sagebrush

This cover type is a mixture of two Wyoming GAP types: 1) mountain big sagebrush (*Artemisia tridentata* ssp. *vaseyana*), and 2) Wyoming big sagebrush (*Artemisia tridentata* ssp. *wyomingensis*). They are combined here because they cannot be easily separated at this scale. This combined cover type comes from the Wyoming GAP compilation (Merrill *et al.* 1996); each sagebrush species is described below:

<u>Mountain big sagebrush</u> – This shrub type is dominated by mountain big sagebrush. It is often found with mixed grasses. Mountain big sagebrush must be the dominant shrub, and total shrub cover must comprise more than 25% of the total vegetative cover. Sometimes it occurs as patches of dense sagebrush with patches of mixed grasses. In this case, the sagebrush patches must comprise more than 50% of the total landscape area. This type is widespread in the mountain ranges and higher valleys of Wyoming (Jones 1992) and is found throughout the state except east of the Laramie Range. It occupies cooler sites than basin big sagebrush (*Artemisia tridentata* ssp. *tridentata*) and more mesic sites than Wyoming big sagebrush. It often occurs in mountain parks and is intermixed with trees and at the lower margin of treeline (Merrill *et al.* 1996).

<u>Wyoming big sagebrush</u> – This is a shrub steppe type with Wyoming big sagebrush as the dominant shrub and with total shrub cover comprising more than 25% of the total vegetative cover. This type is variable in Wyoming and includes the full range from dense, homogeneous Wyoming big sagebrush to sparsely vegetated arid areas where Wyoming big sagebrush is the dominant shrub. Often, patches of Wyoming big sagebrush are found with patches of mixed grasses. In these cases the type is classified as Wyoming big sagebrush steppe if the sagebrush patches occupy more than 50% of the total landscape area or as mixed grass if the grasses occupy more than 50% of the total area. This type is found throughout most of the state with the exception of the extreme southeast corner. Often, rolling landscapes may feature Wyoming big sagebrush dominating broad slopes but with sand sagebrush (*Artemisia filifolia*) or various cushion plants on wind-swept ridges and knolls, and with mountain big sagebrush in hollows. These landscapes are complex mixtures of several sage-dominated types, but when dominated by Wyoming big sage they are classified as this type (Merrill *et al.* 1996).

<u>Xeric Shrub Associations</u>

This cover type has shrub cover dominated by species of mountain mahogany (*Cercocarpus* spp.). Shrub species must comprise more than 25% of the total vegetative cover. The dominant species are *Cercocarpus ledifolius* and *C. montanus*. Xeric upland shrub communities are found throughout Wyoming at middle elevations on shallow soils. These communities usually occur on dry slopes or flats where bedrock is very close to the surface or outcropping. They are often found along canyon walls around the margins of mountain ranges or on surfaces formed by tilted sedimentary strata. Edaphic factors are probably the most important in controlling the distribution of this type. This cover type comes from the Wyoming GAP compilation (Merrill *et al.* 1996).

<u>Rock</u>

Areas dominated by rock (rock outcrop, talus, scree, bare soil, etc.) are also relatively uncommon in the Section (Table M3B-3; Fig. M3B-3). The largest contiguous area of rock is in the Cloud Peak Wilderness area in the BNF.

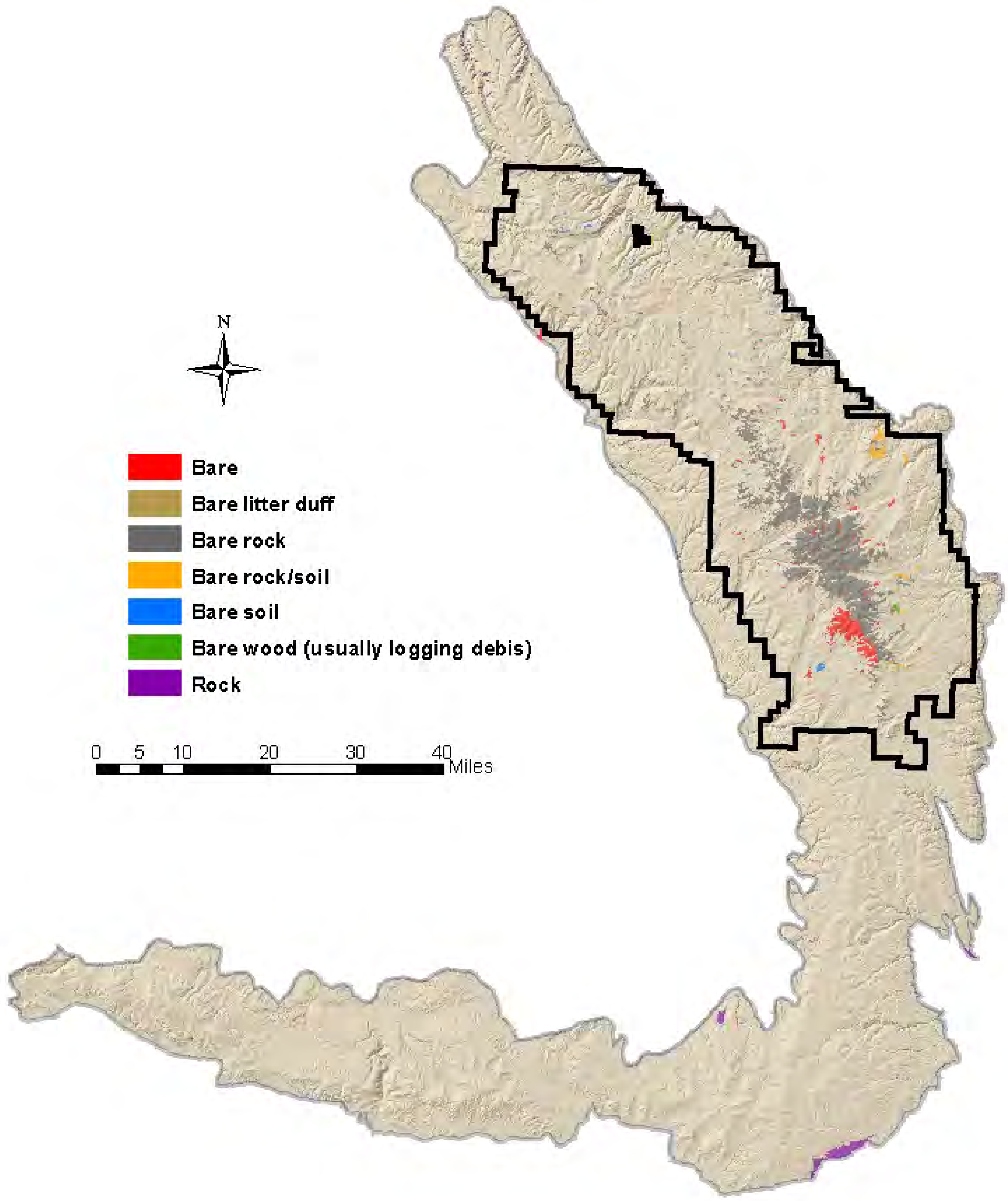


Figure M3B-3. Rock and bare-soil areas in the Big Horn Mountains Section (M331B; *source: Wyoming GAP* (Merrill *et al*. 1996) *and Montana GAP* (Fisher *et al*. 1998).

Table M3B-3. Area of GAP land cover types for rock within Section M331B (*source: WY and MT GAP data).*

GAP Land Cover Types	Section M331B 2,824,127 acres (1,142,888 ha)			Bighorn National Forest 1,110,895 acres (449,565 ha)		
	Acres	Hectares	Percent	Acres	Hectares	Percent
Rock	23,692	9,588	100%	15,642	6,330	100%

Grasslands and Shrublands of the Bighorn National Forest

Existing vegetation mapping is available from the BNF's Integrated Resource Inventory Common Vegetation Unit (IRI-CVU) data. These data are characterized and mapped at a relatively coarse scale, however. Considerable information about the forest's rangelands may be available in the Forest's individual allotment folders (Forest Service file designation 2210), but this is generally not in an electronic format. Thus, these data are not quickly or easily summarized.

For plant community descriptions, we relied extensively on the work by Welp *et al.* (2000). Their paper describes dominance types, recognized by the dominant species in the tallest vegetation layer. Each type corresponds to at least one alliance from the new National Vegetation Classification (Anderson *et al.* 1998). Welp *et al.* (2000) selected vegetation types by reviewing published and unpublished literature about Wyoming vegetation. Much of that information has been summarized for an unpublished draft classification of Wyoming plant communities (Jones 1992). Reports on potential Research Natural Areas also provided useful information.

This assessment is missing important data on successional pathways within these types. Information gaps and analysis limitations for grassland/shrubland vegetation on the BNF are identified at the conclusion of this module.

This piece of the assessment begins by providing a general description of the dominant existing vegetation cover types, followed by detailed descriptions of each type.

Vegetation Descriptions

Identifying and describing individual grassland/shrubland upland cover types for the BNF was a challenge given the coarse resolution of the Forest's IRI-CVU data. For example, there are almost 70,000 acres (28,000 ha) in the BNF's IRI-CVU database coded as forb (i.e., IRI-CVU cover type = "F"; Fig. M3B-4), yet there is very little additional information available in the database. This significantly limits meaningful interpretations of these data. Consequently, the focus of the effort that follows is generally more descriptive than analytical.

Color infrared aerial photography from 1992 (1:24,000 scale) was used as the basis for delineating and attributing grassland/ shrubland IRI-CVU polygons (USDA Forest Service 1999). The protocol for IRI-CVU only requires identification of tree species. Identification of grass, forb, and shrub species is optional, due to limitations in aerial photo interpretation (USDA Forest Service 1999).

This discussion is limited to upland grasslands and shrublands. Forblands on the BNF, as depicted by IRI-CVU, is presented here for information purposes only (Fig. M3B-4). There are insufficient data to discuss these lands meaningfully. We also will not discuss the Rock cover type beyond our treatment in the Big Horn Mountains Section M331B description.

Grasslands and shrublands make up about 21% of the BNF, according to IRI-CVU data (Table M3B-4). The published soil survey states that dominant upland (non-riparian/non-wetland) species are Idaho fescue (*Festuca idahoensis*), bluebunch wheatgrass (*Pseudoroegneria spicata*), mountain mahogany (*Cercocarpus* spp.), big sagebrush (*Artemisia tridentata*), and black sagebrush (*Artemisia nova*). Finally, alpine plant communities (primarily blackroot sedge, *Carex*

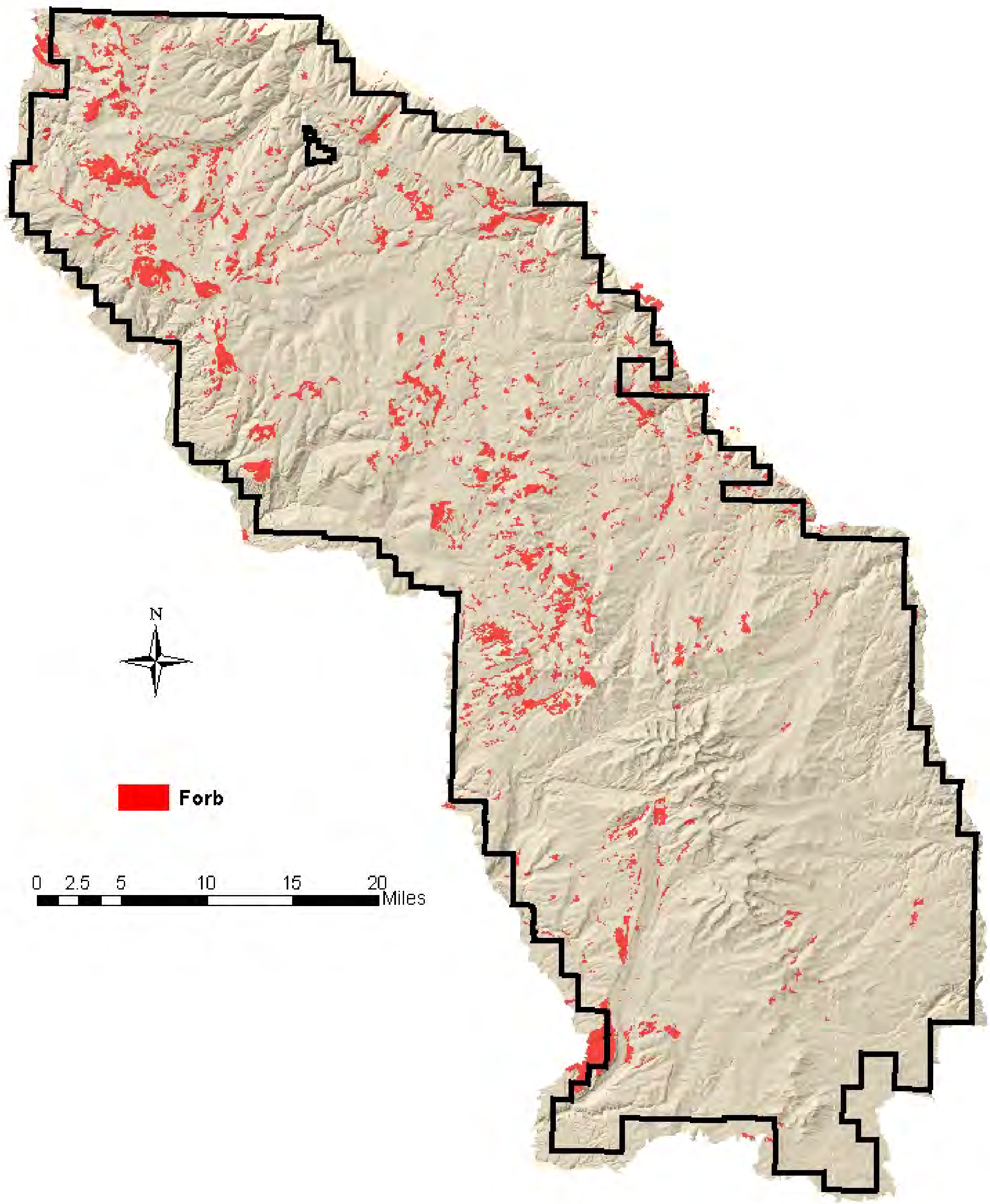


Figure M3B-4. Forblands on the BNF (*source: IRI-CVU data*).

Table M3B-4. Area by Life Form/Physical Feature on the BNF (*source: IRI-CVU data for the BNF).*			
Life Form /Physical Feature	**Acres**	**Hectares**	**Percent**
Trees	786,229	318,177	64
Shrubs	103,970	42,075	8
Grasses	158,587	64,178	13
Forbs	69,586	28,161	6
Rock/bare	110,193	44,594	9
Water	16	6	<1
TOTAL	1,228,581	497,191	100

elynoides) are present above timberline (USDA Forest Service 1986).

The selection of vegetation types to describe below was primarily based on the BNFs IRI-CVU, Welp *et al.* (2000), and the BNF's published soil survey (USDA Forest Service 1986).

Grasslands

All grassland cover types identified by IRI-CVU on the BNF are shown in Table M3B-5 and Fig. M3B-5.

Table M3B-5. Grassland cover types on the BNF (*source: IRI-CVU data*).					
IRI-CVU code	**Cover Type Name**	**Number of polygons**	**Acres**	**Hectare s**	**Percent**
GOAT	Oatgrass	2	21	9	<1
G106	Bluegrass scabland	15	593	240	<1
G304	Idaho fescue and bluebunch wheatgrass	8	1,204	487	<1
G313	Tufted hairgrass / wet sedge	59	1,857	751	1
G613	Idaho fescue	93	6,538	2,646	4
G	Grass	2,732	148,374	60,045	94
	TOTALS	2,909	158,587	64,178	100

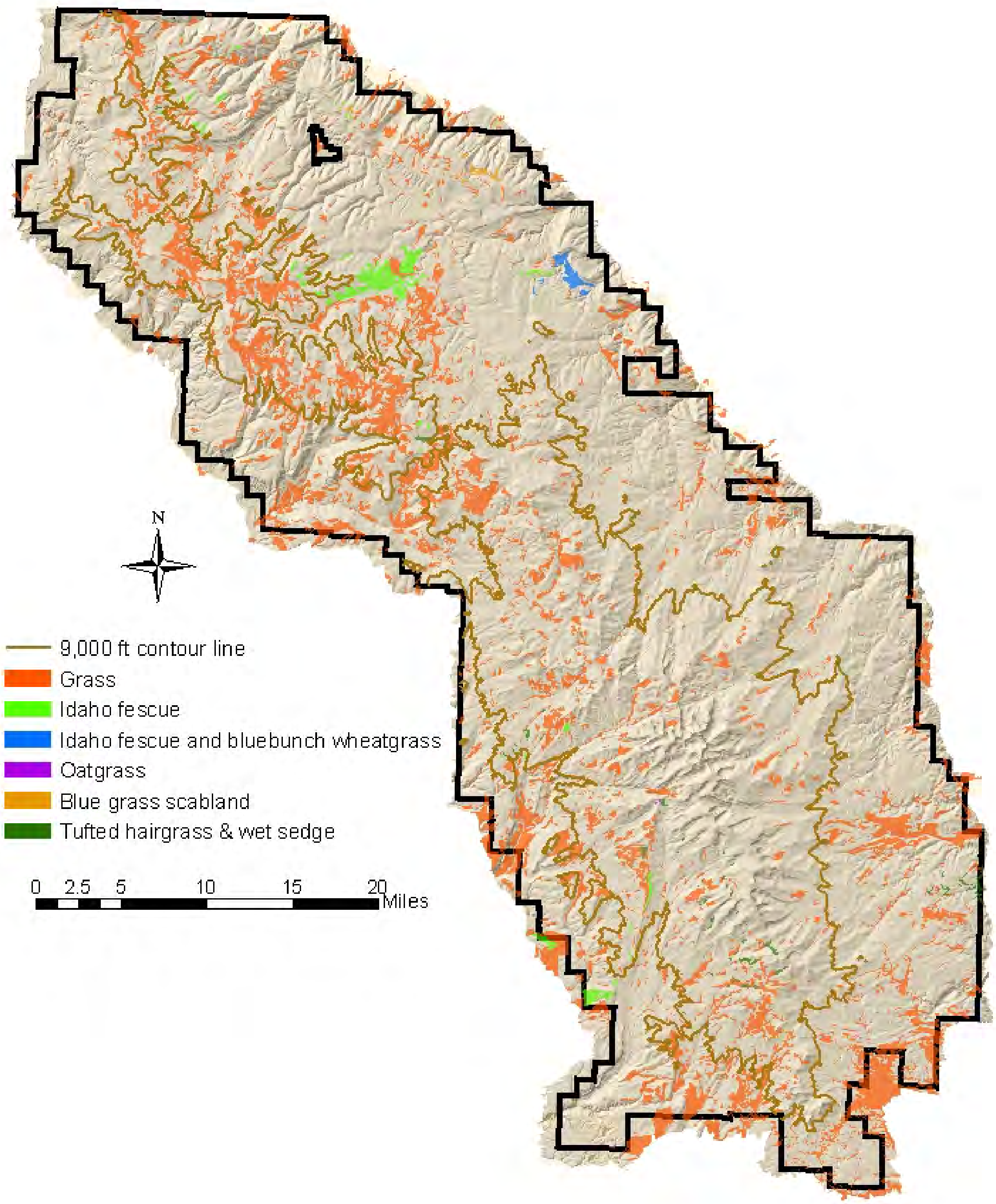


Figure M3B-5. Grasslands on the BNF with 9000 ft elevation line (*source: IRI-CVU data*).

Nearly 150,000 acres (60,000 ha) are categorized in IRI-CVU as simply grass ("G") with no further description. Other minor grassland types in IRI-CVU are bluegrass scabland (*Poa* spp.; "G106"), tufted hairgrass/wet sedge (*Deschampsia caespitosa*/*Carex* spp.; "G313"), and oatgrass (*Danthonia* spp.; "GOAT"). These types will not be discussed further since they meet at least one of the following criteria: 1) the cover type is of relatively small size on the Forest (less than 600 acres), 2) the cover type is associated with riparian or wetland ecosystems, or 3) the cover type is non-species specific (e.g., the type is listed as "grass"). Furthermore, we looked for cover types that were addressed by Welp *et al.* (2000) and were identified as occurring on the BNF. The three dominant grassland types are:

(1) Bluebunch wheatgrass (*Pseudoroegneria spicata)*

RI-CVU identifies an Idaho fescue – bluebunch wheatgrass type ("G304"). Welp et al. (2000) recognize this species as an important plant community type on the BNF.

(2) Idaho fescue (*Festuca idahoensis)*

IRI-CVU identifies an Idaho fescue type ("G613") and an Idaho fescue – bluebunch wheatgrass type ("G304"). Welp et al. (2000) recognize this species as an important plant community type on the BNF.

(3) Blackroot sedge (*Carex elynoides*)

See following section on Alpine Tundra vegetation for description. IRI-CVU does not specifically identify this type. Welp *et al.* (2000) recognize this species as an important plant community type within the alpine ecosystem of the BNF.

Detailed Grassland Descriptions

For each of the plant community types listed above, we have included a detailed description below, presented in the same order. These descriptions were primarily extracted from Welp *et al.* (2000). We also relied on vegetation descriptions by the BNF's IRI-CVU effort and the forest's published soil survey (USDA Forest Service 1986). Additional literature was used to augment the Welp *et al.* (2000) information. Finally, we relied on the online Fire Effects Information System (FEIS; http://svinet2.fs.fed.us database /feis/) for fire effects information and also for some of the management interpretations. The reader is encouraged to visit FEIS online for more detailed information.

The organization of information within each topic is as follows: first, we discuss the general characteristics of the type throughout its range; then, where information is available, we present information specific to the BNF. Very little is known about the successional relationships of these plant community types on the Forest. Mueggler and Stewart (1980) completed a habitat type classification for western Montana that may give further insight to the grasslands on the Forest. Also, the work of Tweit and Houston (1980) on the nearby Shoshone National Forest may be relevant to the BNF. However, local knowledge would be necessary before making any meaningful applications of their work. We also found that production values (peak standing crop, annual air dry mass per acre) for these vegetation types varied so much in the literature that we did not present them. Forage production values are available from Mueggler and Stewart (1980; 1981), USDA Forest Service (1986), USDA NRCS (1988) and the FEIS database (http://svinet2.fs.fed.us/database/feis/). Local BNF personnel may be better suited to refine these estimates.

Bluebunch Wheatgrass

Composition

Spatial Distribution

This vegetation type occurs throughout the western portion of the United States (Fig. M3B-6) and southwestern Canada (Reid *et al.* 1999). Merrill *et al.* (1996) have mapped this vegetation as part of the Great Basin Foothills Grassland Cover Type (31003), which occurs along the western boundary of

Figure M3B-6. Distribution of bluebunch wheatgrass in the U.S. (*source:* *http://plants.usda.gov/*).

the BNF. Despain (1973) also considers this type more common on the western slopes of the Forest, but also noted the occurrence of stands on the eastern slopes.

The IRI-CVU did not isolate this species in its vegetation mapping. Rather, it is combined with Idaho fescue and is probably included within the general "Grass" delineation; therefore we we suspect that bluebunch wheatgrass plays a more prominent role on the BNF than these data indicate (Table M3B-5 and Fig. M3B-5). Fig. M3B-7 shows the estimated Potential Natural Vegetation (PNV) projection of these cover types.

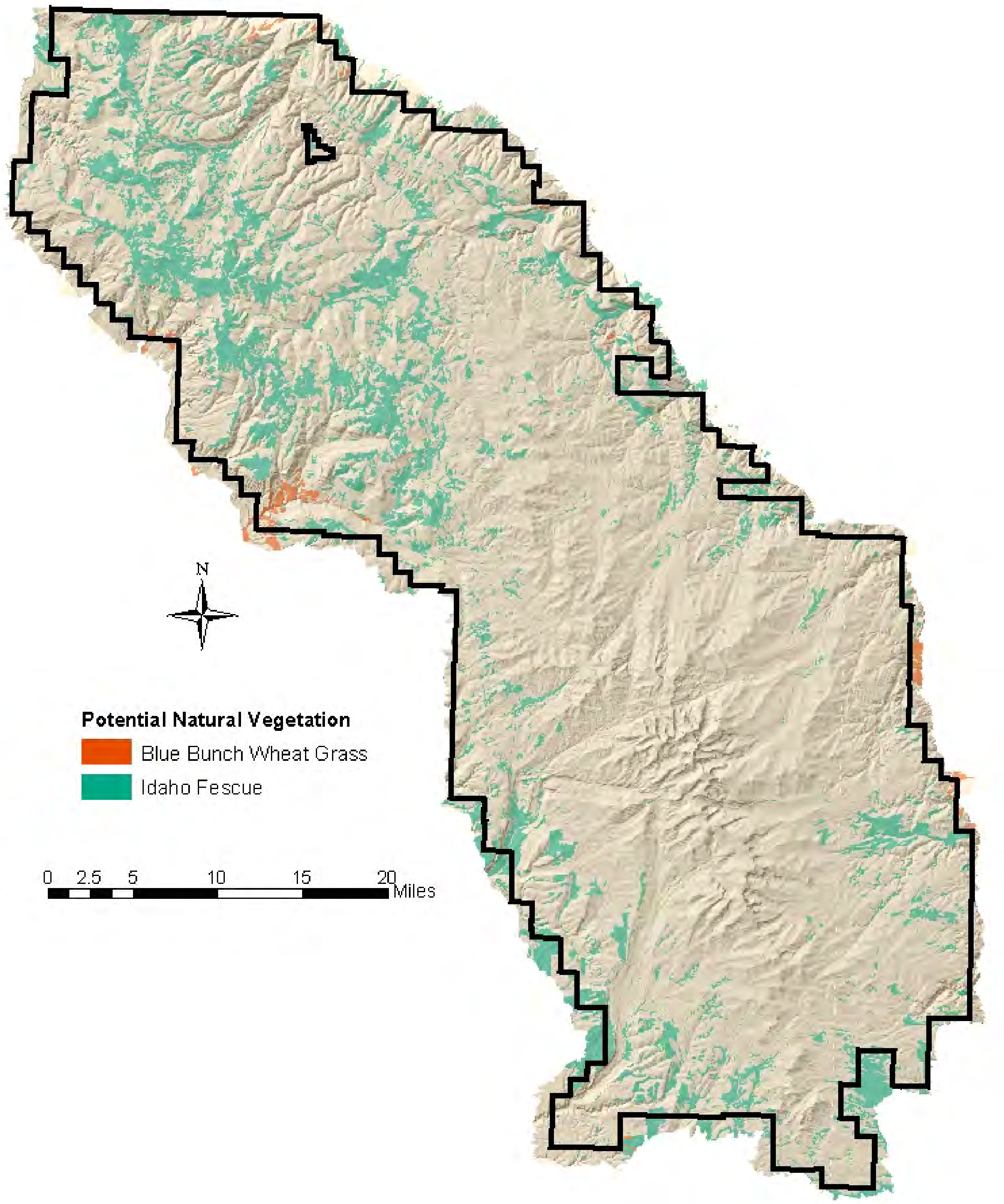


Figure M3B-7. Potential Natural Vegetation (PNV) depiction of blue bunch wheat grass and Idaho fescue; compare with Figure M3B-5 showing existing species patterns (*source: soils data for the BNF* (USDA Forest Service 1986. Interpretation by Kent Houston, Shoshone National Forest Ecologist, personal communication).

Stands occur between 3,000 and 7,500 feet (900 and 2,300 m) on gentle to steep slopes and windswept ridges. They can be found on slopes facing any direction. Soils are mostly shallow in depth and rocky with a loamy to fine texture (Comer *et al.* 1999; Peet 1988). In Wyoming, most of the precipitation falls during the growing season (Reid *et al.* 1999), and sites are considered moderately arid (Shiflet 1994).

The published soil survey for the BNF states that *Pseudoroegneria spicata* is characteristic of the lower slopes on the BNF (USDA Forest Service 1986). *Pseudoroegneria spicata* and *Festuca idahoensis* grow together, but the former loses prominence by roughly 9,000 feet (2,700 m; Scott Gall, Rangeland Management Specialist, Bighorn National Forest, personal communication). Key contour lines have been added to Figure M3B-5 to help isolate *Pseudoroegneria spicata* occurrence. We expect that most of the upland grasslands below 9,000 feet (2,700 m) contain *Pseudoroegneria spicata*, but there are insufficient data to categorize this type further. Local BNF personnel may be able to use other ancillary data (e.g., aspect, slope, topographic position, etc.) to better refine the spatial occurrence of this type.

Characteristic Dominant Species and Associations

Bluebunch wheatgrass vegetation, as described here, falls within the *Pseudoroegneria spicata* Herbaceous Alliance of the National Vegetation Classification (Anderson *et al.* 1998), as described by Reid *et al.* (1999). It also falls within the Bluebunch Wheatgrass – Sandberg Bluegrass and Bluebunch Wheatgrass – Western Wheatgrass range cover types as described by the Society for Range Management (SRM 302 and SRM 303; Shiflet 1994).

The bluebunch wheatgrass vegetation type is represented on the Bighorn National Forest by the community's habitat types, or other units shown in Table M3B-6. Correspondence of each of these units to plant associations from the National Vegetation Classification (Anderson *et al.* 1998) is shown if it is known.

Table M3B-6. Vegetation classification schemes pertinent to the *Pseudoroegneria spicata* type on the Bighorn National Forest (reported by Welp *et al.* 2000).

Reference	Name Used in Reference	NVC Equivalent	Rank
Ryan *et al.* 1994	Bluebunch Wheatgrass Dominated Vegetation	*Pseudoroegneria spicata* Herbaceous Vegetation?	G2?
Welp *et al.* 1998a	Bluebunch Wheatgrass Plant Community	*Pseudoroegneria spicata* Herbaceous Vegetation?	G2?
Merrill *et al.* 1996	Great Basin Foothills Grassland GAP Cover Type	N/A	--

In nearby Montana, Mueggler and Stewart (1980) identified an Agropyron spicatum [*Pseudoroegneria spicata*]/Poa sandbergii [*Poa secunda*] habitat type, which may occur on the BNF. It is reported from 3,000 to 6,000 feet (900 to 1,800 m) in elevation in Montana. However, more work would need to be done to verify whether this type occurs on BNF; if it does, it would be suspected along the lowest fringes of the Forest boundary.

Stands in northwestern Wyoming usually include species such as *Achillea millefolium* var. *occidentalis*, *Artemisia frigida*, *Festuca idahoensis*, *Gutierrezia sarothrae*, *Stenotus acaulis*, and *Phlox hoodii*. Stands in central and northeastern Wyoming usually include *Bouteloua gracilis*, *Carex filifolia,* and *Rhus trilobata*. *Bromus tectorum*, *Tragopogon* spp., and *Alyssum* spp. are common in degraded stands (Comer *et al.* 1999). On windswept ridges and slopes of outwash plains, the understory can include cushion plants such as

Arenaria hookeri, *Tetraneuris acaulis* var. *acaulis*, *Phlox hoodii*, *Phlox hoodii* ssp. *muscoides, Cryptantha cana*, *Eriogonum mancum*, *Machaeranthera grindelioides* var. *grindelioides*, *Townsendia spathulata*, and *Astragalus spatulatus* (DeVelice and Lesica 1993).

On the Bighorn National Forest, Despain (1973) lists several species as important associates with *Pseudoroegneria spicata* on the western slopes, including *Carex filifolia*, *Hesperostipa comata*, *Opuntia polyacantha*, and *Phlox hoodii*, along with several other graminoids and forbs. On the eastern slopes, Despain (1973) considers the most important associates to be *Schizachyrium scoparium* var. *scoparium* and *Yucca glauca*.

The published Bighorn National Forest soil survey reports that the major associated plants on the western flank are *Koeleria macrantha*, *Poa secunda*, *Carex* spp., *Hesperostipa comata*, *Opuntia polyacantha*, *Phlox* spp., and *Sphaeralcea coccinea*. On the eastern flank, *Schizachyrium scoparium* var. *scoparium* and *Yucca glauca* are in some areas; however, the eastern flank is dominantly forested to the foot of the mountains (USDA Forest Service 1986).

Successional Characteristics

This vegetation is considered climax in the Rocky Mountain region.

Structure

Stands typically have a conspicuous grass-dominated stratum that is 3 feet (1 m) high and has cover ranging from 25 to 90% (Reid *et al*. 1999). Stands also have two secondary strata, a shrub-dominated layer and a forb-dominated layer. *Pseudoroegneria spicata* can be the sole dominant of the grass layer, but more often it is found co-dominating with *Hesperostipa comata*, *Pascopyrum smithii*, or *Poa secunda* (Comer *et al*. 1999, Reid *et al*. 1999).

Function

Stands can provide forage for livestock and wildlife (Comer *et al*. 1999; Tweit and Houston 1980). In fact, *Pseudoroegneria spicata* is considered one of the most important forage grass species on western rangelands for both livestock and wildlife (Sours 1983). Forage production estimates range from 600 to 900 lbs/acre (672 to 1,008 kg/ha).

Additional Ecological Relationships

On Wyoming *Pseudoroegneria spicata* /*Festuca idahoensis* sites, the fire regime features low-severity, infrequent surface fires, with mean fire intervals (MFIs) from 17 to 62 years (Heyerdahl *et al*. 1994).

Burning *Pseudoroegneria spicata* may remove most of the aboveground biomass but does not usually result in plant mortality (Robberecht and Defosee 1995; Sapsis 1990). *Pseudoroegneria spicata* is generally favored by burning (Agee and Maruoka 1994). The buds are well protected from fire by the foliage of the plant (Agee 1996) or the buds are underground, depending on the time of year (Concannon 1978; Conrad and Poulton 1966). Burning stimulates flowering and seed setting (Agee 1996; Patton *et al*. 1988; Sapsis 1990). However, season of burning affects mortality. Britton and Clark (1978) reported 40% mortality in May-burned plants in Oregon, while June-burned plants suffered only 10% mortality. No October-burned plants died in their study.

Management Considerations

Overgrazing is problematic in this vegetation type. Initially, overgrazing decreases the cover of *Pseudoroegneria spicata* while it increases the cover of *Hesperostipa comata*, *Bromus tectorum*, and associated shrub species. In fact, Comer *et al*. (1999) suggest that co-dominance of some stands by *Hesperostipa comata* is a product of overgrazing and not representative of the climax type. Continual overgrazing eventually causes declines in *Poa secunda* and *Hesperostipa comata*, and may lead to the conversion of herbaceous vegetation into a shrub-dominated type (Comer *et al*. 1999; Tweit and Houston 1980).

Mueggler and Stewart (1980) mention that under heavy cattle or horse grazing, *Pseudoroegneria spicata* is the principal forage species to decrease within the bluebuch wheatgrass - Sandberg bluegrass habitat type. They further stated that *Artemisia frigida* and *Gutierrezia sarothrae* usually increase conspicuously with overgrazing. *Artemisia tridentata* and *Chrysothamnus* spp. may eventually become dominant on badly depleted ranges of this type. *Bromus tectorum* and *Centaurea biebersteinii* are often conspicuous invaders.

Numerous studies indicate that *Pseudoroegneria spicata* is extremely sensitive to defoliation during active growth (e.g., Arredondo and Johnson 1998; Blaisdell and Pechanec 1949; Britton *et al*. 1990; Laycock 1967; McIlvanie 1942; Mueggler 1972). Mueggler (1975) suggests using flower stalk numbers combined with maximum lengths of flower culms as a measure of plant vigor. Once vigor is lowered even moderately for this species it may require at least 6 years of protection to recover fully, and low-vigor plants may take more than 8 years of protection from grazing. Mueggler and Stewart (1980) suggest that no more than 30% utilization should occur on this species during the peak growth period. McLean and Marchand (1968) propose that *Pseudoroegneria spicata* should not be grazed in the spring until the grass is at least 4 inches (10 cm) high. Apparently, root reserves are still minimal when the leaves are 7 inches (18 cm) tall. Spring grazing must be terminated in time to permit re-growth and replenishment of root reserves. Utilization may be as high as 50 to 60% after plants have cured in late summer or fall.

Welp *et al*. (1998a) found stands of this type dominated by the exotic plant *Phleum pratense* in the Tongue River Potential Research Natural Area (Bighorn National Forest). This may be a rare case, but does raise some management concerns regarding exotic plant invasion and loss of native vegetation. *Pseudoroegneria spicata* is known to be susceptible to competition from *Centaurea diffusa* and *C. biebersteinii* elsewhere. Even under good range conditions in British Columbia, *Pseudoroegneria spicata* offered little resistance to knapweed invasion (Agriculture Canada 1979).

Quality representations of this type occur in the Bull Elk Park Research Natural Area of the Bighorn National Forest (Ryan *et al*. 1994).

One plant association is recognized on the Bighorn National Forest, and it is considered rare -- bluebunch wheatgrass herbaceous vegetation plant association (Anderson *et al*. 1998).

Idaho Fescue

Composition

Spatial distribution

This vegetation type occurs throughout the western portion of the United States (Fig. M3B-8). It occurs in the Pacific Northwest south to the Modoc Plateau in California, and east to the northwestern portion of the Great Plains and southern Rocky Mountain Region (Reid *et al*. 1999). In Wyoming, stands occur in the mountain ranges of the Rockies (Knight 1994).

On the Bighorn National Forest, stands are widespread in meadows throughout the montane (Beetle 1956; Hurd 1961), subalpine zone, and alpine zones (USDA Forest Service 1986). The Bighorn National Forest's IRI-CVU was not able to totally isolate this species in its map delineation work. Rather, it is combined with *Pseudoroegneria spicata* and is probably included within the generic "Grass" mapping (as previously shown in Table M3B-5 and Fig. M3B-5 – see *Pseudoroegneria spicata* vegetation type detailed description above).

Figure M3B-8. Distribution of *Festuca idahoensis* in the U.S. (*source: http://plants.usda.gov/).*

Little bluestem (*Andropogon scoparius*) is associated with Idaho fescue (Despain 1973), but is a minor component of the Bighorn Mountain Section, consisting of approximately 504 acres (200 ha) along the northeast edge of the Big Horn Mountains. Its distribution extends to its fullest coverage in the Great Plains – Palouse dry steppe province to the east. Detailed ecological descriptions of this type within the Bighorn section are unavailable.

F. idahoensis type grows in mountain meadows on a wide variety of topographic positions, including gentle to steep slopes, ridgetops, and flats (Beetle 1956; Hurd 1961; Knight 1994; Peet 1988; Tweit and Houston 1980). Meadows often occur on sites that are not conducive for tree establishment. Treeless areas below timberline are the result of several phenomena, including soils too saturated with water near streams, lakes, and snow packs; soils too thin with low water holding capacities on steep slopes and ridgetops; as well as cold air drainage, frost pockets, and deep snow. Any of these areas could be dominated by *F. idahoensis*. In addition, disturbances such as fire or avalanches can destroy forest cover and lead to meadow vegtation. Forest regeneration can take up to 500 years at high elevations, so grass vegetation can persist for long periods in burns (see Knight 1994 and Peet 1988 for further discussion). In the montane zone, precipitation falls mainly in the winter, forming deep snow packs. In the spring, melting snow provides an important source of moisture for plant growth (Reid *et al*. 1999). Coincidentally, stands of *F. idahoensis* have well-developed litter layers that buffer evaporative losses from the soil (Beetle 1956).

On the Bighorn National Forest, meadows occur on soils overlying granitic and sedimentary rock with a humid to sub-humid climate. Boundaries between forest and meadow vegetation have abrupt transition zones (Beetle 1956). *F. idahoensis* is present from about 6,000 feet (1,800 m) up into the grasslands above timberline (USDA Forest Service 1986). Key contour lines have been added to Figure M3B-5 to help isolate *F. idahoensis* occurrence. We expect that most of the upland grasslands above 6,000 feet (1,830 m) contain *F. idahoensis*, but there are insufficient data to categorize this type further. Local BNF personnel may be able to use other ancillary data to better refine the spatial description of this type.

Characteristic Dominant Species and Associations

Festuca idahoensis vegetation, as described here, falls within the *Festuca idahoensis* Herbaceous Alliance, *Festuca idahoensis* Alpine Herbaceous Alliance, and *Deschampsia cespitosa* Temporarily Flooded Herbaceous Alliance of the National Vegetation Classification (Anderson *et al.* 1998), as described by Reid *et al.* (1999). It also falls within the Idaho Fescue – Bluebunch Wheatgrass range cover type (SRM 304), Idaho Fescue – Slender Wheatgrass range cover type (SRM 306), Idaho Fescue – Tufted Hairgrass range cover type (SRM 308), and Idaho Fescue – Western Wheatgrass range cover type (SRM 309), as described by the Society for Range Management (Shiflet 1994).

The *F. idahoensis* vegetation type is represented on the Bighorn National Forest by the communities, habitat types, or other units shown in Table M3B-7. Correspondence of each of these units to plant associations from the National Vegetation Classification (Anderson *et al.* 1998) is shown if it is known.

Table M3B-7. Vegetation classification schemes pertinent to the *Festuca idahoensis* type on the Bighorn National Forest (reported by Welp *et al.* 2000).

Reference	Name Used in Reference	NVC Equivalent	Rank
Despain 1973	*Festuca idahoensis* communities	Unknown	--
Johnston 1987	*Festuca idahoensis / Roegneria spicata* Plant Association	*Festuca idahoensis – Pseudoroegneria spicata* Herbaceous Vegetation Plant Association	G4
Hurd 1961; Johnston 1987	*Festuca idahoensis / Lupinus sericeus* Plant Association	*Festuca idahoensis – Carex obtusata* Herbaceous Vegetation Plant Association	G3
Johnston 1987	*Festuca idahoensis* / *Leucopoa kingii* Plant Community	*Festuca idahoensis – Festuca kingii* Herbaceous Vegetation Plant Association	G2?
Welp *et al*. 1998b	Idaho Fescue / Bluebunch Wheatgrass Plant Community	*Festuca idahoensis – Pseudoroegneria spicata* Herbaceous Vegetation Plant Association	G4
Welp *et al*. 1998d	Idaho Fescue Grassland Plant Community	*Festuca idahoensis* Herbaceous Vegetation Plant Association	G2?
Welp *et al*. 1998g	Idaho Fescue / Tufted Hairgrass Plant Community	*Festuca idahoensis – Deschampsia cespitosa* Herbaceous Vegetation Plant Association	G3
Ryan *et al*. 1994	Idaho Fescue – Spike Fescue Plant Association	*Festuca idahoensis – Festuca kingii* Herbaceous Vegetation Plant Association	G2?

In addition to the types mentioned above, Mueggler and Stewart (1980) identified four additional habitat types in nearby Montana as follows (elevation range shown also):

- *Festuca idahoensis / Stipa richardsonii* [*Achnatherum richardsonii*] -- 3,600 to 6,900 feet (1,100 to 2,100 m).
- *Festuca idahoensis / Agropyron smithii* [*Pascopyrum smithii*] -- 4,000 to 6,000 feet (1,200 to 1,800 m).
- *Festuca idahoensis / Agropyron caninum* [*Elymus trachycaulus*] -- 6,500 to 8,600 feet (2,000 to 2,600 m).
- *Festuca idahoensis / Carex filifolia* -- 7,800 to 9,200 feet (2,400 to 2,800 m).

The elevation ranges should provide a sense of stratification for where these habitat types might be expected on the Bighorn National Forest. More work would need to be done to verify whether these types actually exist on the BNF.

On the Bighorn National Forest, Hurd (1961) estimated cover for stands ranging from 65 to 91%; grasses and sedges comprised 54% of the total aboveground biomass by weight. *Festuca idahoensis* is the characteristic dominant of the grass layer. Beetle (1956) found *Festuca idahoensis* constituted a larger portion of the plant cover on granitic soils than sedimentary soils. *Selaginella densa* is a characteristic associate in the stands on granitic soils (Despain 1973). Despain (1973) considered the *Festuca idahoensis* vegetation of the Big Horn Mountains unique because it lacks species commonly found in other areas. Common grasses include *Elymus trachycaulus*, *Elymus lanceolatus*, *Poa secunda*, *Koeleria macrantha*, *Danthonia intermedia*, *Carex phaeocephala*, and *Carex obtusata*. In addition, other grasses that may be found in stands include *Poa nemoralis* ssp. *interior*, *Poa fendleriana*, *Poa secunda*, *Phleum alpinum*, *Leucopoa kingii*, *Achnatherum lettermanii*, *Trisetum spicatum*, *Trisetum wolfii*, and *Agrostis scabra* (Beetle 1956, Hurd 1961). Common forbs include *Agoseris glauca*, *Lupinus sericeus*, *Geum triflorum* var. *ciliatum*, *Achillea millefolium* var. *occidentalis*, *Arenaria congesta*, *Campanula rotundifolia*, *Cerastium arvense*, *Galium boreale*, and *Polygonum bistortoides* (Hurd 1961).

The published Bighorn National Forest soil survey reports that *Festuca idahoensis* is dominant in many of the mountain meadows and grasslands both below and above timberline. In other areas it may be subdominant under *Cercocarpus* spp. or *Artemisia tridentata*. The major plant species associated with *Festuca idahoensis* are *Carex* spp., *Lupinus sericeus*, *Achillea millefolium* var. *occidentalis*, and *Agoseris* spp. Forbs are characteristic of soils derived from sedimentary material, whereas *Selaginella densa* and *Danthonia* spp. are characteristic of soils derived from granite (USDA Forest Service 1986).

Successional Characteristics

No data available.

Structure

Stands are divided into two strata, a grass-dominated layer and a forb-dominated layer. The grass layer grows to about 3 feet (1 m) in height and has cover ranging from 25 to 100%. The forb layer can also reach about 3 feet (1 m) in height with cover ranging from 0 to 60% (Reid *et al*. 1999). *Festuca idahoensis* is the characteristic species for the grass layer, but other possible co-dominants include *Carex filifolia, Carex inops* ssp. *heliophila, Carex obtusata, Danthonia intermedia, Deschampsia caespitosa, Pascopyrum smithii, Pseudoroegneria spicata*, *Elymus trachycaulus, Festuca thurberi, Geranium caespitosum, Koeleria macrantha, Leucopoa kingii, Potentilla diversifolia,* and *Achnatherum richardsonii* (DeVelice and Lesica 1993, Hurd 1961, Jones and Fertig 1999b, Reid *et al*. 1999, Shiflet 1994). Degraded stands can be invaded by *Bromus tectorum* and *Poa pratensis* (Reid *et al*. 1999). Species composition varies from stand to stand depending on factors such as elevation, soil characteristics, and topography.

Function

Stands are important sources of forage for livestock and wildlife (Beetle 1956; Hurd 1961; Reid *et al.* 1999; Shiflet 1994; Tweit and Houston 1980). Forage productivity estimates range from 800 to 1,500 lbs/acre (896 to 1,681 kg/ha).

Additional Ecological Relationships

Festuca idahoensis stands are an important source of forage for wildlife and livestock (Beetle 1956, Hurd 1961, Shiflet 1994, Tweit and Houston 1980). Comer *et al.* (1999) report that *Festuca idahoensis* is not fire-tolerant and can be severely damaged by late summer and fall burns. However, Reid *et al.* (1999) report that fire is necessary to prevent replacement by trees. This vegetation is considered both climax and seral. Thus fire is only necessary for regeneration in areas where *Festuca idahoensis* is not the climax type. Such areas can arise from any disturbance capable of removing the forest cover. It is climax vegetation in areas that favor grass cover over trees in the montane zone (Knight 1994, Peet 1988).

Festuca idahoensis grows in a dense, fine-leaved tuft. Fires tend to burn within the accumulated fine leaves at the base of the plant and may produce temperatures sufficient to kill some of the root crown (Agee 1996). Mature *Festuca idahoensis* plants are commonly reported to be severely damaged by fire in all seasons (Smith and Busby 1981; Wright *et al*. 1979). Initial mortality may be high (in excess of 75%) on severe burns, but usually varies from 20 to 50% (Barrington *et al*. 1988). *Festuca idahoensis* is commonly reported to be more sensitive to fire than *Pseudoroegneria spicata* (Blaisdell 1953, Concannon 1978, Conrad and Poulton 1966, Wright *et al*. 1979). However Robberecht and Defosse (1995), using special instrumentation to control the intensity and duration of fire treatment for individual plants, suggested the latter was more sensitive. They observed culm and biomass reduction with moderate fire severity in *Pseudoroegneria spicata*, whereas a high fire severity was required for this reduction in *Festuca idahoensis*. Also, given the same fire severity treatment, postfire culm production was initiated earlier and more rapidly in *Festuca idahoensis* (Robberecht and Defosse 1995). The estimated fire return intervals for communities containing *Festuca idahoensis* are presented in Table M3B-8.

Table M3B-8. Fire return interval for selected plant communities containing *Festuca idahoensis* (*source: FEIS database -- http://svinet2.fs.fed.us/database/feis/)*.

Community or Ecosystem	Dominant Species	Fire Return Interval Range in Years	Reference
Sagebrush steppe	*Artemisia tridentata /Pseudoroegneria spicata*	20-70	Brown and Smith (2000)
Mountain big sagebrush	*A. t.* var. *vaseyana*	5-40	Arno and Gruell (1983); Burkhardt and Tisdale (1976); Young and Evans (1981);
Wyoming big sagebrush	*A. t.* var. *wyomingensis*	10-70 (40 mean)	Vincent (1992); Young and Evans (1981)

Management Considerations

Overgrazing is the chief management concern. Grazing reduces cover of the characteristic dominant, *Festuca idahoensis*, among other species (Beetle 1956; Hurd 1961; Tweit and Houston 1980). Since livestock and wildlife graze this vegetation, Tweit and Houston (1980) suggested that managers coordinate usage to prevent conflicts and overgrazing. Degraded stands lead to management problems because they are susceptible to invasion by exotic plants, such as *Bromus tectorum* and *Poa pratensis* (Reid *et al*. 1999).

Beetle (1956) considered this vegetation type the most important source of forage for grazers in the Bighorn Mountain Range. Grazing decreases the cover of *Festuca idahoensis*, *Elymus* spp., *Bromus inermis* ssp. *pumpellianus* var. *pumpellianus*, and *Poa nemoralis* ssp. *interior*, while it increases the cover of *Carex obtusata*, *Koeleria macrantha*, *Poa cusickii*, *Poa secunda*, and *Achnatherum nelsonii* ssp. *nelsonii* (Hurd 1961). Interestingly, sheep grazing at the highest elevations increases the cover of *Festuca idahoensis*, presumably due to their preference for forbs (Beetle 1956). Beetle (1956) reported that overuse of more moist bottomlands by cattle decreased the cover of *Deschampsia cespitosa*, while it increased the cover of the exotic species, *Poa pratensis*.

Grazing can stimulate plant vitality and play a beneficial role in community stability; the key is timely grazing of plants and moderate use of the community (Johnson 1994). The amount of use *Festuca idahoensis* can sustain without adversely affecting vigor depends on numerous conditions including the combination of livestock and wildlife using the range, plant phenology, the type of grazing system used, competition from associated vegetation, plant vigor at the time of use, and site conditions (Mueggler and Stewart 1980). Mueggler (1975) found maximum leaf length was a good indicator of vigor in *Festuca idahoensis*, but noted that, because of yearly variations in weather conditions, evaluation of vigor requires comparison with protected plants of normal vigor. Many approaches to determining vigor for *Festuca idahoensis* have been used, sometimes with contradictory results. Mueggler and Stewart (1980) concluded that the only reliable approach was to observe the response of the vegetation over a period of years.

Festuca idahoensis is a “decreaser” (Dyksterhuis 1949) under heavy grazing by livestock (Eckert and Spencer 1986; Eckert and Spencer 1987; Hurd 1961) and wildlife (Gaffney 1941). Several studies have reported *Festuca idahoensis* as less abundant on areas grazed by livestock compared to ungrazed areas (Eckert and Spencer 1987; Hurd 1961; McLean *et al.* 1970; Vogel and Van Dyne 1966; Warg 1938; Wright and Wright 1948). Olson and Wallander (1997) found root and shoot biomass were 38 and 27% less on grazed than on ungrazed plants, while carbohydrate pools were similar for grazed and ungrazed plants. In contrast, *Centaurea biebersteinii* biomass was unchanged by grazing, suggesting that repeated grazing may reduce the ability of *Festuca idahoensis* to compete with invading *Centaurea biebersteinii* when both species are grazed. Merrill *et al.* (1994) found that, at the end of the growing season, standing dead material on *Festuca idahoensis* plants was less in cattle-grazed sites than on ungrazed sites; however, standing *Festuca idahoensis* biomass and crown biomass were equal on grazed and ungrazed sites. In an exclosure study including *Festuca idahoensis* sites in Wyoming and Montana, Stohlgren *et al.* (1999) report that *Festuca idahoensis* showed inconsistent responses to grazing. In northwest Wyoming, Jones (1965) found *Festuca idahoensis* decreased under cattle grazing but remained relatively unchanged by elk grazing.

Quality representations of this type occur at the Bull Elk Park Research Natural Area (Ryan *et al.* 1994) and Devil Canyon Potential Research Natural Area (Welp *et al.* 1998d) on the Bighorn National Forest.

Several plant associations have conservation ranks for this vegetation type, suggesting they are uncommon or rare. The *Festuca idahoensis* herbaceous vegetation and *Festuca idahoensis* - *Festuca kingii* [*Leucopoa kingii*] plant associations have G2(?) conservation ranks, meaning they are considered rare. *Festuca idahoensis – Carex obtusata* and *Festuca idahoensis – Deschampsia cespitosa* plant associations have G3 conservation ranks, meaning they are uncommon. The remaining plant associations have G4 conservation ranks, meaning they are abundant (Anderson *et al.* 1998; see Table M3B-7).

Alpine Tundra

Alpine tundra vegetation, alpine rock and ice and snow types consists of approximately 82,889 acres and is found only in the Big Horn Mountain subsection (M331Ba) at elevations generally greater than 10,000 feet (Fig. M3B-9). This vegetation occurs primarily on granitic substrates centered near Cloud Peak and a small area of limestone substrates at the northern end of the section. Plant diversity is high in alpine communities compared to other vegetation types in the Forest. Forage productivity is highly variable and estimates range from 300 to 1000 lbs/acre (336 to 1120 kg/ha).

Johnson and Billings (1962) describe timberline in northern Wyoming starting at approximately 9,850 feet (3,000 m). Alpine ecosystems on the Bighorn National Forest are estimated to begin around roughly 9,600 to 9,700 feet (2,900 to 2,950 m; S. Gall, Rangeland Management Specialist, Bighorn National Forest, personal communication). Both of these estimates approximate the statements in the published forest soil survey indicating the upper elevations of Engelmann spruce (*Picea engelmannii*) meeting treeline at roughly 10,000 feet (3,000 m; USDA Forest Service 1986). As a compromise, we selected an elevation of approximately 9,800 feet (2,990 m) to define the transition where alpine begins on the Forest. Local BNF personnel may want to further refine this estimate

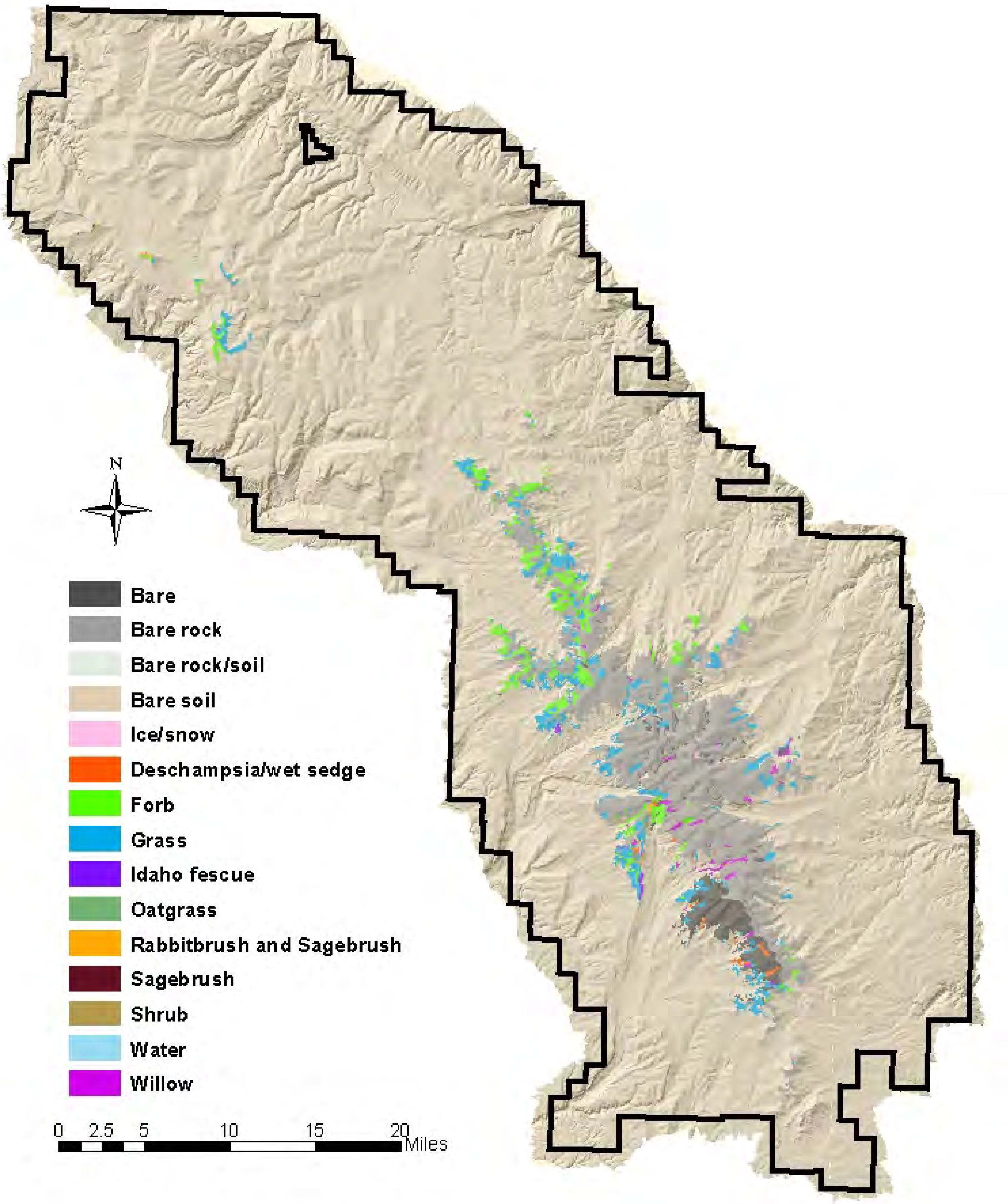


Figure M3B-9. Grassland/shrubland cover types above 9,800 feet (2,990 m) representing the alpine environment on the Bighorn National Forest *(source: IRI-CVU data*).

Table M3B-9. Cover types, listed in order of ascending prominence, on the Bighorn National Forest above 9,800 feet (2,990 m*; source: IRI-CVU*).

IRI-CVU code	Cover Type Name	Number of polygons	Acres	Hectares
W	Water	1	5	2
BBS	Bare soil	1	17	7
GOAT	Oatgrass	2	21	9
S401	Big sagebrush	4	30	12
BRS	Bare rock/soil indistinguishable	2	58	23
BIC	Ice/snow	7	155	63
S408	Rabbitbrush, sagebrush	4	156	63
G613	Idaho fescue	6	262	106
T217	Aspen	12	330	134
S	Shrub	20	511	207
G313	Tufted hairgrass/wet sedge	24	710	287
S921	Willow	59	1,760	712
T218	Lodgepole	131	1,885	763
B	Bare	163	9,191	3,720
F	Forb	231	10,836	4,385
G	Grass	405	15,349	6,212
T206	Spruce/Fir	1,234	36,079	14,601
BRO	Bare rock	592	72,321	29,267
	TOTALS	2,898	149,676	60,572

based on more detailed field knowledge. Table M3B-9 displays a list of all cover types above 9,800 feet (3,000 m) on the Forest. The prominent grassland/shrubland cover types are bare rock, grass, forb, and bare ground, in that order.

With the exception of blackroot sedge (see description below), specific alpine communities have not been well documented in the Big Horn Mountains, but it might be similar to what has been described in the Beartooth Mountains (Johnson and Billings 1962) and in the Beaverhead National Forest of Montana (Cooper *et al*. 1997). These include:

Grassland Communities	*Snowbed Communities*
Festuca idahoensis / *Potentilla diversifolia* c.t.	*Carex nigricans* c.t
Deschampsia cespitosa / *Potentilla diversifolia* c.t.	*Juncus drummondii* /*Antennaria lanata* c.t
Hesperochloa kingii [*Leucopoa kingii*] / *Oxytropis campestris* c.t.	*Phyllodoce empetriformis* /*Antennaria lanata* c.t
	Cassiope mertensiana /*Carex paysonis* c.t.
Turf Communities	*Juncus parryii* / *Erigeron ursinus* c.t.
Carex elynoides c.t.	*Salix glauca* c.t.
Carex scirpoidea / *Potentilla diversifolia* c.t.	
Carex scirpoidea / *Geum rossii* c.t.	*Wetland Communities*
Dryas octopetala / *Polygonum viviparum* c.t.	*Deschampsia cespitosa* /*Caltha leptosepala* c.t.
Salix arctica [*Salix petrophila*] / *Polygonum bistortoides* c.t.	*Carex scopulorum* /*Caltha leptosepala* c.t.
	Salix reticulata /*Caltha leptosepala* c.t.
Cushion Plant Communities	*Salix planifolia* /*Carex scopulorum* c.t.
Carex rupestris / *Potentilla ovina* c.t.	
Geum rossii /*Arenaria obtusiloba* [*Minuartia obtusiloba*] c.t.	
Dryas octopetala /*Carex rupestris* c.t.	

Many of these types may be applicable to the BNF. However, more work would need to be done to verify whether these types actually exist on the Forest.

Primary natural disturbance factors include grazing, solifuction and cryoperturbation. With domestic sheep grazing there is a general tendency to have a decrease in forbs species and an increase in graminoids species. Typical alpine increasers include woolly pussytoes (*Anntenaria lanata*), timber oatgrass (*Danthonia intermedia*) and Drummond's rush (*Juncus drummondii*). Solifluction is a slow natural slumping process that produces terraces. Cryoperturbation is a function of the freeze-thaw process. Typical features include frost boils, rock stripes, and rock polygons.

Blackroot Sedge

Composition

Spatial Distribution

Carex elynoides vegetation occurs from Idaho and Montana south to New Mexico and probably grows in the mountains of Utah and Nevada (Reid *et al*. 1999; Fig. M3B-10). This vegetation type has been described from the Shoshone National Forest (Johnson and Billings 1962; Jones and Fertig 1999c, 1999d, 1999e) and the Bighorn National Forest (Welp *et al*. 1998e). Billings (2000) gives cover data from plots along a vegetation gradient in the Medicine Bow Mountains in which *C. elynoides* is a major species in the sparse vegetation. *C. elynoides* alpine vegetation has been described from the Roosevelt National Forest to the south in Colorado (Johnston 1987).

On the Bighorn National Forest, this vegetation type has been described from the Pete's Hole area in the Crystal Creek drainage (Welp *et al*. 1998e). Given that this vegetation type is most common on carbonate sedimentary rocks, it probably occurs mainly on the northern end of the Forest, where limestone and dolomite cover much of the mountain range.

Figure M3B-10. Distribution of *Carex elynoides* in the U.S. (*source: http://plants.usda.gov/*).

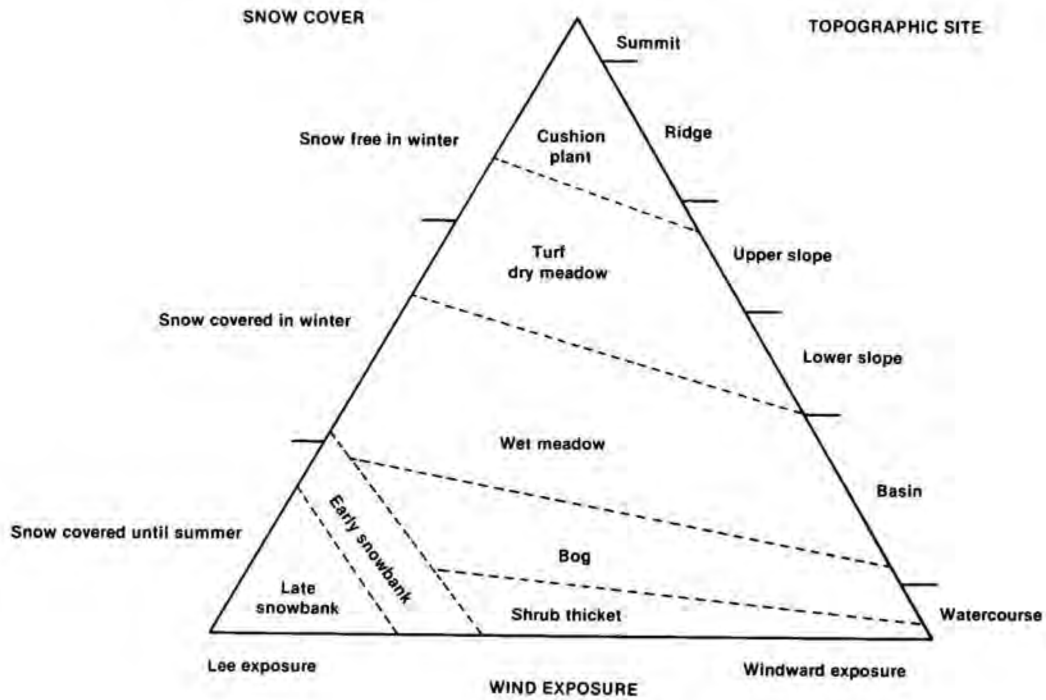


Figure M3B-11. Conceptual diagram showing alpine vegetation as influenced by topography, wind, and snow cover (adapted from Johnson and Billings 1962; Thilenius 1975).

Thilenius (1975) states that topography, wind exposure, and duration and degree of snow cover are major alpine plant community influences. These influences are illustrated in Figure M3B-11, which suggests that the alpine zone is actually a complex assemblage of different plant communities.

Carex elynoides occurs in the Shoshone National Forest primarily on slopes with aspects from southeast to northwest (Jones and Fertig 1999c, 1999d, 1999e), facing the prevailing westerly and southwesterly winds. The stands reported from the Bighorn National Forest (Welp *et al.* 1998e) grow on sites exposed to strong winds. This pattern of occurrence on windswept slopes repeats that observed for *C. elynoides* communities in Montana (Cooper *et al.* 1997) and elsewhere (Reid *et al.* 1999). It also agrees with the distribution pattern for the sedge revealed by detailed studies of vegetation gradients showing that it reaches its maximum cover on windswept slopes (Billings 2000; Johnson and Billings 1962). On the BNF, *C. elynoides* has been described as growing on carbonate sedimentary rocks (Welp *et al.* 1998e).

Characteristic Dominant Species and Associations

This *Carex elynoides* vegetation type, as it has been described on the BNF, is similar to the *C. elynoides* plant associations listed by Johnston (1987) from Colorado. It falls within the *C. elynoides* Herbaceous Alliance of the National Vegetation Classification (Anderson *et al.* (1998), as described by Reid *et al.* (1999). The *Carex elynoides* vegetation type does not correspond to any Society for Range Management rangeland cover type (Shiflet 1994).

The *Carex elynoides* vegetation type is represented on the BNF by the following community shown in Table M3B-10. Correspondence of thieunit to plant associations from the National Vegetation Classification (Anderson *et al.* 1998) is shown.

Table M3B-10. Vegetation classification schemes pertinent to the *Carex elynoides* type on the Bighorn National Forest (reported by Welp *et al*. 2000).

Reference	Name Used in Reference	NVC Equivalent	Rank
Welp *et al*. 1998e	Kobresia sedge/Ross' avens Plant Community	*Carex elynoides-Geum rossii* Plant Association	G4

Successional Characteristics

No data available.

Structure

This type consists of low-growing (< 1 foot; 0.3 m) alpine turf vegetation. Canopy cover usually exceeds 50% but may be sparse on some sites (Welp *et al*. 1998e). Graminoids usually contribute more canopy cover than do forbs, and shrubs are virtually absent. In the stands described from the Bighorn National Forests (Welp *et al.* 1998e), *C. elynoides* generally dominated the vegetation, and other species contributing substantial cover included *Geum rossii*, *Arenaria congesta*, *Erigeron* spp., *Artemisia frigida*, and *Poa secunda*. Many other species were present in small amounts. On the BNF, stands contain sparse vegetation with a high proportion of cushion plants (Welp *et al*. 1998e).

Function

Hermann (1970) reports that *C. elynoides* is important as a source of forage for domestic sheep in Utah and Wyoming.

Additional Ecological Relationships

Exposure to wind apparently is the most important factor in shaping the composition and structure of the vegetation. Stands of *C. elynoides* occur on slopes exposed to winds that remove snow and create relatively dry environments.

No information on the role of fire could be found in the literature for this plant community type.

Management Considerations

Alpine environments experience low temperatures, high winds, and high insolation (Billings 2000). The growing season is extremely short, with frost possible on any given night. Furthermore, frequent freeze-thaw cycles and needle ice damage vegetation. Wind redistributes snow, and wind-driven soil and ice particles damage vegetation. Growth and accumulation of biomass in the alpine zone is a slow process (Cooper *et al*. 1997).

No information was found in the literature on the effects of management in the *Carex elynoides* vegetation type. Cooper *et al*. (1997) mention that alpine ecosystems evolved under very little influence by humans. In the last 150 years, these ecosystems have been exposed to large-scale disturbances such as livestock grazing, mining, and road-building. Unfortunately, there have been few controlled quantitative studies to verify anecdotal evidence.

No published information on management considerations was found specific to the BNF.

Quality occurrences of this type have not been specifically identified for the BNF

The *Carex elynoides* vegetation on the Bighorn National Forest represents one plant association from the National Vegetation Classification (Anderson *et al*. 1998). It is considered common (G4 conservation rank) throughout western North America.

Shrublands

All shrubland cover types identified by IRI-CVU on the BNF are shown in Table M3B-11 and Figure M3B-12.

Table M3B-11. Shrubland cover types on the Bighorn National Forest (*source: IRI-CVU*).

IRI-CVU code	Cover Type Name	Number of polygons	Acres	Hectares	Percent of Total Area
S416	True mountain mahogany	1	14	6	<1%
S209	Skunkbrush	2	76	31	<1%
S	Shrub	140	5,426	2,196	4%
S322	Curl-leaf mountain mahogany	76	6,761	2,736	6%
S921	Willow	211	10,303	4,169	10%
S408	Rabbitbrush, sagebrush	201	14,319	5,795	14%
S401	Big sagebrush	624	67,071	27,143	65%
TOTALS		1,255	103,970	42,075	100%

Over 5,000 acres (2,200 ha) are shown in IRI-CVU as simply shrub ("S") with no further description. Other minor shrubland types in IRI-CVU are skunkbrush (*Rhus trilobata*; "S209"), true mountain mahogany (*Cercocarpus montanus*; "S416"), and willow (*Salix* spp.; "S921"). These types will not be discussed further since they meet at least one of the following criteria: 1) the cover type is of relatively small size on the Forest (less than 600 acres), 2) the cover type is associated with riparian or wetland ecosystems, or 3) the cover type is non-species specific (e.g., the type is listed as "shrub"). Furthermore, we looked for cover types that were addressed by Welp *et al*. 2000 and were identified as occurring on the BNF. The four types are:

(1) Wyoming big sagebrush *(Artemisia tridentata ssp. wyomingensis)*

IRI-CVU identifies a big sagebrush (S401) type and a rabbitbrush – sagebrush type (S408). Welp *et al*. (2000) recognize this big sagebrush subspecies as an important plant community type on the Bighorn National Forest. Rabbitbrush (*Chrysothamnus* spp.) was not identified as a dominant cover type for the Bighorn National Forest, so it is not addressed here. Furthermore, there are no data readily available to specifically identify which species of rabbitbrush occurs on the forest or its distribution.

(2) Mountain big sagebrush *(Artemisia tridentata ssp. vaseyana)*

The description above for Wyoming big sagebrush applies here as well. Welp *et al*. (2000) recognize this big sagebrush subspecies as an important plant community type on the Bighorn National Forest.

(3) Curl-leaf mountain mahogany (*Cercocarpus ledifolius*)

IRI-CVU identifies a curl-leaf mountain mahogany (S322) cover type. Welp *et al*. (2000) recognize this species as an important plant community type on the Bighorn National Forest.

(4) Black sagebrush (*Artemisia nova*)

IRI-CVU did not recognize this cover type, but it was identified by Welp *et al*. (2000) as an important plant community type on the Bighorn National Forest.

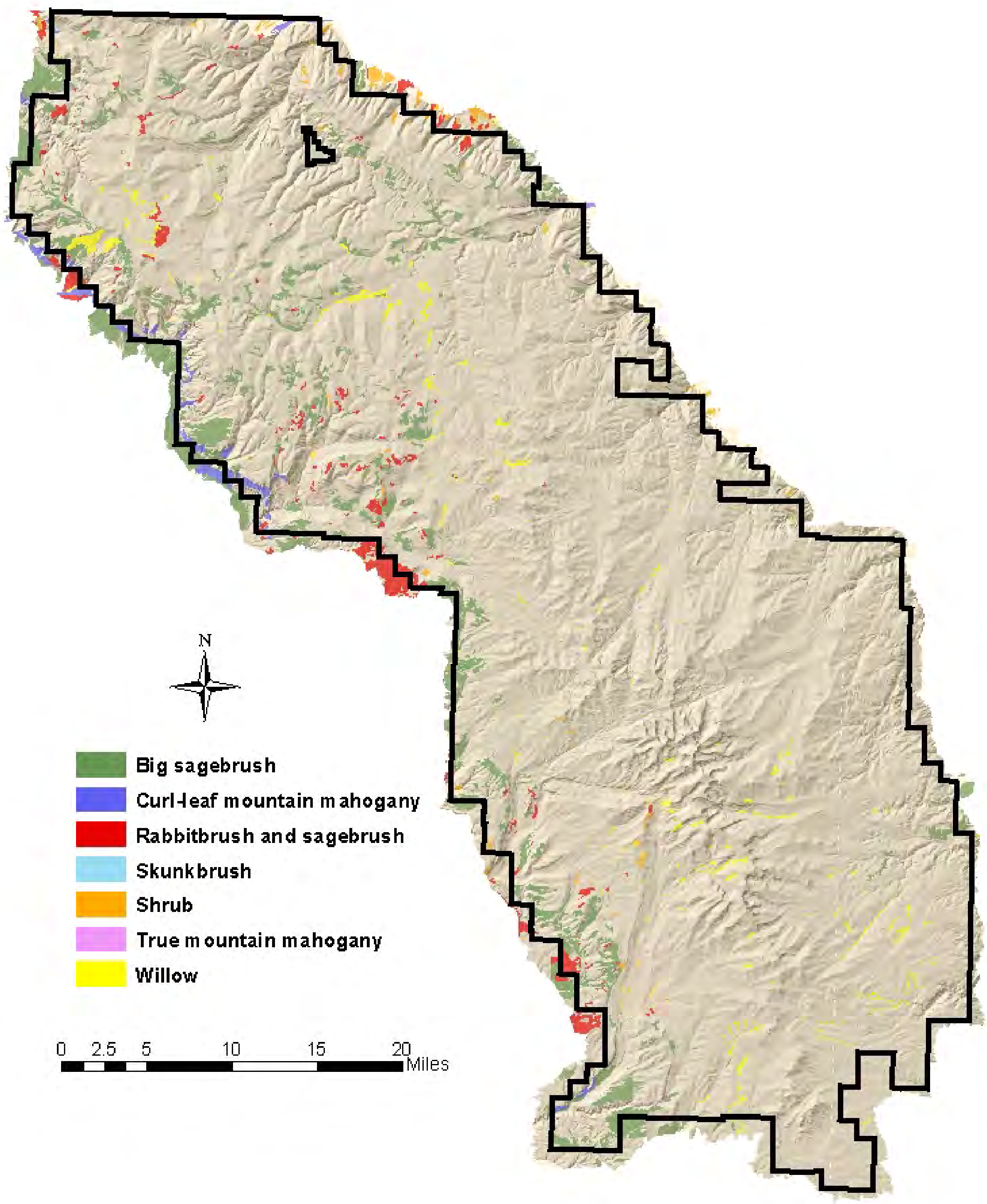


Figure M3B-12. Shrublands on the Bighorn National Forest (*source: IRI-CVU data*).

Detailed Shrubland Descriptions

Because greasewood (*Sarcobatus vermiculatus*) shrubland type is a minor component in the Bighorn Mountain Section, consisting of approximately 237 acres (100 ha) along the lower elevation fringes, we briefly describe it here. Its distribution is more important in the intermountain semi desert province to the west of the assessment area. This type is associated with high clay and salt-affected soils of the natrargid suborder. Other shrubs may include saltbush (*Atriplex confertifolia*), basin big sage (*Artemisia tridentata*, ssp. *tridentata*) and broom snakeweed (*Gutierrezia sarothrae*). Common grasses include western wheatgrass, Indian ricegrass (*Achnatherium hymenoides*) and basin wildrye (*Leymus cinereus*). Plant density is a positively correlated with soil salt content. Forage productivity is low and is estimated at 300 to 600 lbs/acre (336 to 672 kg/ha). The primary natural disturbance factor is grazing. Typically, western wheatgrass and Indian ricegrass decrease with grazing pressure in these types. Fire is infrequent due to low fuels.

We have included a detailed description for each of the cover types listed above. They are presented in the same order. These descriptions were taken from Welp *et al.* (2000) and are augmented by additional literature. We also relied on vegetation descriptions by the Bighorn National Forest's IRI-CVU effort and the Forest's published soil survey (USDA Forest Service 1986). Finally, we relied on the online Fire Effects Information System (FEIS; http://svinet2.fs.fed.us/database/feis/) for fire effects information and also for some of the management interpretations. The reader is encouraged to visit FEIS online for more information.

The organization of information within each topic is as follows: first, we discuss the general characteristics of the type throughout its range, and then, where information is available, we present information specific to the BNF. Very little is known about the successional relationships of these plant community types on the BNF. Mueggler and Stewart (1980) completed a habitat type classification for western Montana that may give further insight to the shrublands on the BNF. Also, the work of Tweit and Houston (1980) on the nearby Shoshone National Forest may be relevant to the BNF. However, local knowledge would be necessary before making any meaningful applications of their work. We also found that production values (peak standing crop, annual air dry mass per acre) for these vegetation types varied considerably in the literature, so we did not present them. Forage production values are available from Mueggler and Stewart (1980; 1981), USDA Forest Service (1986), USDA NRCS (1988) and the FEIS database (http://svinet2.fs.fed.us/ database/feis/). Local BNF personnel may be better suited to refine these estimates.

Wyoming Big Sagebrush

Composition

Spatial Distribution

Wyoming big sagebrush (*Artemisia tridentata* ssp. *wyomingensis*) vegetation is distributed throughout much of the western United States (Reid *et al.* 1999; Shiflet 1994), including the basins of Wyoming (Knight 1994; Fig. M3B-13).

This type is documented along the eastern boundary of the BNF (Merrill *et al.* 1996). The Forest's IRI-CVU was not able to isolate this subspecies in its vegetation mapping and is identified generally as big sagebrush. IRI-CVU identifies two big sagebrush mapping units: rabbitbrush – sagebrush type (S408), and big sagebrush type (S401; Table M3B-12).

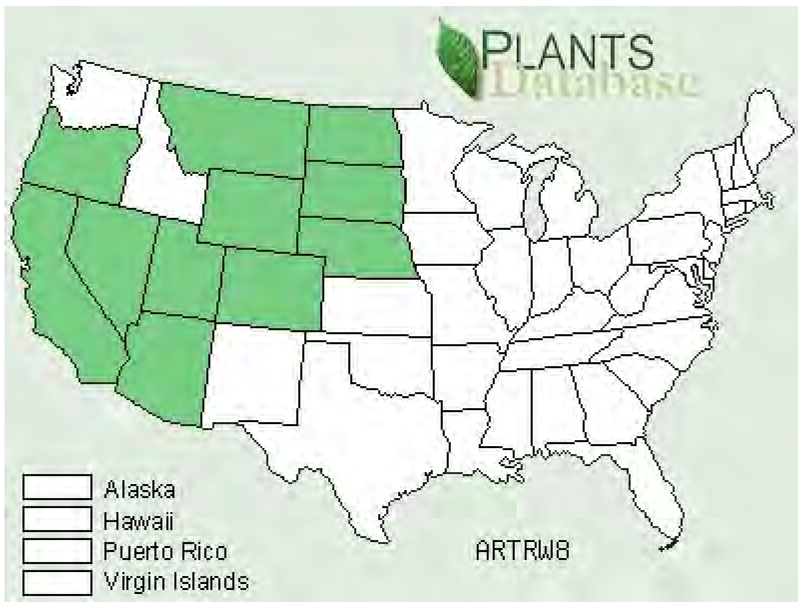


Figure M3B-13. Distribution of *Artemisia tridentata* ssp. *wyomingensis* in the U.S. *(source: http://plants.usda.gov/)*.

Table M3B-12. Big Sagebrush Cover Types on the Bighorn National Forest (*source: IRI-CVU data).*

IRI-CVU code	Cover Type Name	Number of polygons	Acres	Hectares
S408	Rabbitbrush, sagebrush	201	14,319	5,795
S401	Big sagebrush	624	67,071	27,143
	TOTALS	825	81,390	32,938

Figure M3B-12 shows the distribution of the cover types shown in Table M3B-12. The Potential Natural Vegetation (PNV) depiction for Wyoming big sagebrush (Fig. M3B-14) was an interpretation by Kent Houston (Shoshone National Forest Ecologist, personal communication) and was based on a combination of BNF soil mapping units (66, 67, 68, 69, 75, 77, 79, 90, 97, and 98; USDA Forest Service 1986) and Wyoming GAP data (code 32007; Merrill *et al.* 1996).

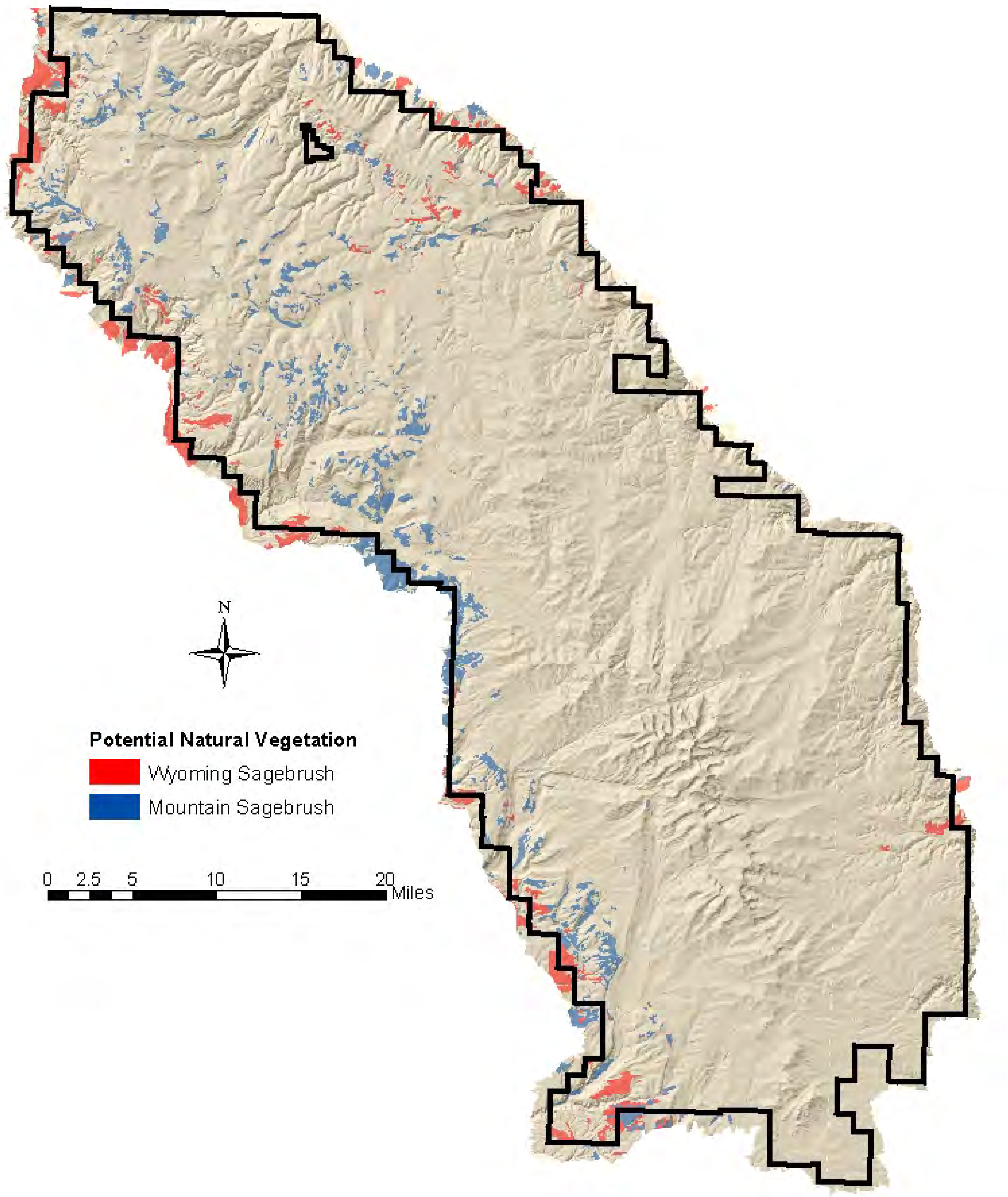


Figure M3B-14. Potential Natural Vegetation (PNV) depiction of big sagebrush estimating subspecies distribution; compare with Figure M3B-12 showing existing sagebrush areas (*source: Merrill et al. (1996), and interpretation by Kent Houston, Shoshone National Forest Ecologist, personal communication*).

This type is found from 5,500 to 9,000 feet (1,700 to 2,700 m) on sloping terrain (Knight 1994). The soils are shallow to moderately deep (Tweit and Houston 1980) with low salt accumulation (Knight 1994) and a loamy texture (Reid *et al.* 1999). Soil moisture availability is particularly important in this arid climate. The redistribution of snow into stands of this vegetation provides some of the needed moisture for spring growth (Knight 1994).

The soil survey for the BNF reports that big sagebrush is present in areas extending from the base of the mountains (probably *Artemisia tridentata* ssp. *wyomingensis*) to near timberline (probably *Artemisia tridentata* ssp. *vaseyana*), mostly on soils derived from sedimentary rock or glacial deposits (USDA Forest Service 1986).

Characteristic dominant species and associations

A. tridentata ssp. *wyomingensis* vegetation, as described here, falls within the *A. tridentata* ssp. *wyomingensis* Shrub-Herbaceous Alliance of the National Vegetation Classification (Anderson *et al.* 1998), as described by Reid *et al.* (1999). It also falls within the Wyoming Big Sagebrush rangeland cover type as described by the Society for Range Management (SRM 403; Shiflet 1994).

The *A. tridentata* ssp. *wyomingensis* vegetation type is represented on the BNF by the following communities, habitat types, or other units shown in Table M3B-13). Correspondence of each of these units to plant associations from the National Vegetation Classification (Anderson *et al.* 1998) is shown if it is known.

Table M3B-13. Vegetation Classification Schemes Pertinent to the *Artemisia tridentata* ssp. *wyomingensis* Type on the Bighorn National Forest (reported by Welp *et al.* 2000).

Reference	Name Used in Reference	NVC Equivalent	Rank
Johnston 1987	*Artemisia tridentate/Festuca idahoensis* Plant Association	Unknown	--
Merrill *et al.* 1996	Wyoming Big Sagebrush GAP Cover Type (32007)	N/A	--

In nearby Montana, Mueggler and Stewart (1980) identified three big sagebrush habitat types as follows (elevation range shown also):

- *Artemisia tridentata / Agropyron spicatum* [*Pseudoroegneria spicata*] h.t. – 4,000 to 6,000 feet (1,200 to 1,800 m).
- *Artemisia tridentata / Festuca scabrella* [*Festuca campestris*] h.t. -- 3,800 to 6,000 feet (1,200 to 1,800 m).
- *Artemisia tridentata* [suspected ssp. *vaseyana*] / *Festuca idahoensis* h.t. -- 6,000 to 8,000 feet (1,800 to 2,400 m).

Although Mueggler and Stewart (1980) did not specifically identify big sagebrush subspecies, the last habitat type above appears to be subspecies *vaseyana* based on their stand photograph. This determination was made based on shrub morphological characterisitics clearly visible in the photograph (characteristics described by Winward and Tisdale 1977). However, more work would need to be done to verify whether these types occur on the BNF.

The soil survey for the Bighorn National Forest mentions the associated species with big sagebrush. Essentially, one would find *Pseudoroegneria spicata* grassland species at the lower elevations and Idaho fescue grassland species at higher elevations (USDA Forest Service 1986).

Successional Characteristics

A. tridentata ssp. *wyomingensis* is considered a mid- to late-seral species (Eddleman and Doescher 1978; Francis 1983; Sturges 1994). The period of *A. tridentata* ssp. *wyomingensis* establishment after a stand-replacing event such as fire is typically about a decade but varies with site (Sturges 1994). Prior to re-establishment, disturbed Wyoming big sagebrush communities are mostly populated with associated grasses. Principal component analysis of *A. tridentata* ssp. *wyomingensis* steppe on the Thunder Basin National Grassland of Wyoming produced the following successional model (intervals between seres were not quantified; Benkobi and Uresk 1996):

Seral Status Plant	Community Expression
early	forbs
early intermediate	blue grama
late intermediate	western wheatgrass
late seral	Wyoming big sagebrush

There is little information documenting the status of this type on the Bighorn National Forest.

Structure

Stands are divided into two strata, a shrub-dominated layer and a grass-dominated layer. The shrub layer is typically less than 2 feet tall (0.6 m; Knight 1994) with canopy cover ranging from 25 to 40% (Comer *et al.* 1999; Reid *et al.* 1999). The grass layer can reach heights comparable to the shrub layer in wet years, with cover from 5 to 60% (Reid *et al.* 1999). *Artemisia tridentata* ssp. *wyomingensis* dominates the shrub layer while *Pseudoroegneria spicata* dominates the grass layer. Other common species include *Chrysothamnus* spp., *Gutierrezia sarothrae*, *Artemisia frigida*, *Bouteloua gracilis*, and *Koeleria macrantha*. *Bromus tectorum* is common in degraded stands (Reid *et al.* 1999; Tweit and Houston 1980).

Function

The grass and shrub layers provide forage for livestock and wildlife (Tweit and Houston 1980). Forage production estimates range from 800 to 1200 lbs/acre (896 to 1344 kg/ha).

Additional Ecological Relationships

Fires destroy the shrub layer because *Artemisia tridentata* ssp. *wyomingensis* is not fire-tolerant and must re-establish from seed following burns (Knight 1994, Reid *et al.* 1999). The time needed for re-establishment depends on factors such as precipitation, surface litter, grazing, and seed source (Knight 1994). Fires and overgrazing cause stands to be vulnerable to invasion by exotic plants, including *Bromus tectorum* (Hironaka *et al.* 1983; 1983; Knight 1994; Reid *et al.* 1999). Stands are considered climax vegetation in the absence of fire (Reid *et al.* 1999).

Fire is the principal means of renewal for decadent stands of Wyoming big sagebrush (Blank *et al.* 1994). *A. tridentata* ssp. *wyomingensis* establishes after fire from the seedbank (Beetle and Young 1965; McArthur *et al.* 1977; Schlatterer 1973), from seed produced by remnant plants that escaped fire (Bushey 1987), and from plants adjacent to the burn that disperse seed (Bushey 1987; Clifton 1981). Fires in *Artemisia tridentata* ssp. *wyomingensis* are usually not continuous, and remnant plants are the principal means of postfire reproduction (Bushey 1987). Fire does not stimulate germination of seed-banked seed, but neither does it inhibit its germination (Champlin and Winward 1982).

A. tridentata ssp. *wyomingensis* steppe communities historically had low fuel loadings and were characterized by 10- to 70-year interval, patchy fires that produced a mosaic of burned and unburned lands (Britton *et al.* 1981; Francis 1983; Klebenow 1973; Wambolt and Payne 1986; Wright *et al.* 1979; Young *et al.* 1979).

Management Considerations

A. tridentata ssp. *wyomingensis* is generally the most palatable of the big sagebrush subspecies, and big game species use it heavily, especially in winter (Schlatterer 1973). Stands are also important winter habitat for sage grouse. This vegetation also provides forage for livestock grazing, particularly in the early spring and late fall (Tweit and Houston 1980).

Overgrazing, fire, and exotic plant invasion are the main management concerns (Reid *et al.* 1999). Overgrazing leads to decreases in *Pseudoroegneria spicata* since it is preferred forage, while stimulating the growth of less palatable grasses (Tweit and Houston 1980). Mueggler and Stewart (1980) suggest shrubs also increase with overgrazing, but Tweit and Houston (1980) point out that this may not occur if shrubs are heavily browsed. Fire affects this vegetation type by destroying the shrubs and enhancing herbaceous growth (Knight 1994). While this might be desirable for raising livestock, fire reduces the amount of winter browse for big game and makes stands more vulnerable to invasion and dominance by exotic plants.

No specific information is known about management of this vegetation type on the BNF. And no specific locations have been identified as quality occurrences.

Mountain Big Sagebrush

Composition

Spatial Distribution

Mountain big sagebrush (*Artemisia tridentata* ssp. *vaseyana*) type occurs throughout much of the foothill and mountainous terrain of the western United States and southwestern Canada (Shiflet 1994), including all ranges in Wyoming except the Black Hills (Knight 1994; Fig. M3B-15).

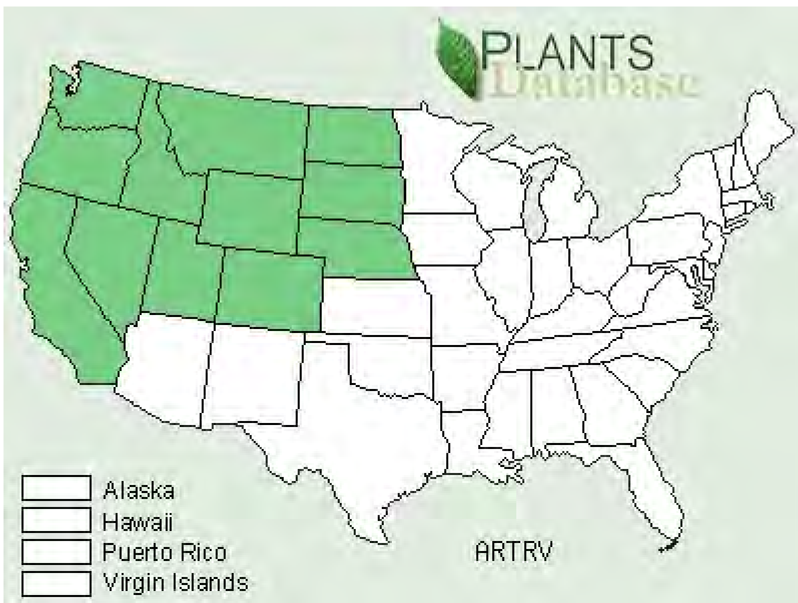


Figure M3B-15. Distribution of *Artemisia tridentata* ssp. *vaseyana* in the U.S. (*source: http://plants.usda.gov/).*

This vegetation type is known to occur along the central portion of the western slopes of the BNF. It is also found in isolated areas within the southeastern and northwestern portion of the Forest (Merrill *et al.* 1996). The Forest's IRI-CVU was not able to isolate subspecies *vaseyana* in its vegetation mapping and is identified generally as big sagebrush. IRI-CVU identifies two big sagebrush mapping units; a rabbitbrush – sagebrush type (S408), and a big sagebrush type (S401), as was shown in the *A. tridentata* ssp. *wyomingensis* detailed description.

Figure M3B-12 shows the distribution of the cover types from Table M3B-12. The Potential Natural Vegetation depiction for *A. tridentata* ssp. *vaseyana* (Fig. M3B-14) was an interpretation by Kent Houston (Shoshone National Forest Ecologist, personal communication) and was based on a combination of BNF mapping units (17, 29, 30, 41a, 41b, 70, 78, 80, 81, 82, 72, 83, and 64; USDA Forest Service 1986) and Wyoming GAP data (code 32006; Merrill *et al.* 1996).

This vegetation typically occurs at elevations between 6,500 and 9,000 feet (2,000 and 2,750 m) in the foothills (Comer *et al.* 1999). Stands occur on a variety of topographic positions from mountain slopes to stony flats. Although found on all slope aspects (Reid *et al*. 1999), stands are more common on south- or west-facing slopes (Comer *et al*. 1999). Soils are deep with a loamy texture and in some cases unstable, leading to mass movements of soil (Reid et al. 1999). The foothills are cooler and less arid than the basins where stands of *A. tridentata* ssp. *tridentata* and *A. tridentata* ssp. *wyomingensis* are more common (Knight 1994). Most of the precipitation is in the form of snow (Reid *et al*. 1999).

On the BNF, a considerable amount of bare ground and gravel can be common in stands (Welp *et al*. 1998e). Stands occur in open meadows, dry slopes, and near drainages (Welp *et al*. 1998d).

The soil survey for the BNF reports that *A. tridentata* is present in areas extending from the base of the mountains (probably *A. tridentata* ssp. *wyomingensis*) to near timberline (probably *A. tridentata* ssp. *vaseyana*), mostly on soils derived from sedimentary rock or glacial deposits (USDA Forest Service 1986).

Characteristic Dominant Species and Associations

Artemisia tridentata ssp. *vaseyana* vegetation, as described here, falls within the *A. tridentata* ssp. *vaseyana* Shrubland and Shrub-Herbaceous alliances of the National Vegetation Classification (Anderson *et al*. 1998), as described by Reid *et al*. (1999). It also falls within the Mountain Big Sagebrush range cover type as described by the Society for Range Management (SRM 402; Shiflet 1994).

The *Artemisia tridentata* ssp. *vaseyana* vegetation type is represented on the Bighorn National Forest by the communities, habitat types, or other units shown in Table M3B-14. Correspondence of each of these units to plant associations from the National Vegetation Classification (Anderson *et al*. 1998) is shown if it is known.

Table M3B-14. Vegetation Classification Schemes Pertinent to the *Artemisia tridentata* ssp. *vaseyana* Type on the Bighorn National Forest (reported by Welp *et al*. 2000).

Reference	Name Used in Reference	NVC Equivalent	Rank
Johnston 1987	*Artemisia tridentata/Festuca idahoensis* Plant Association	*Artemisia tridentata* ssp. *vaseyana/ Festuca idahoensis* Shrub Herbaceous Plant Association	G5
Welp *et al*. 1998b; 1998f	Mountain Big Sagebrush/Bluebunch Wheatgrass Plant Community	*Artemisia tridentata* ssp. *vaseyana/ Pseudoroegneria spicata* Shrubland Plant Association	G5
Welp *et al*. 1998c; 1998d; 1998e; 1998f	Mountain Big Sagebrush/Idaho Fescue Plant Community	*Artemisia tridentata* ssp. *vaseyana/ Festuca idahoensis* Shrub Herbaceous Plant Association	G5
Merrill *et al.* 1996	Mountain Big Sagebrush GAP Cover Type (32006)	N/A	--
Jones and Fertig 1999a; 1999b	Mountain Big Sagebrush/Idaho Fescue Plant Community	*Artemisia tridentata* ssp. *vaseyana/ Festuca idahoensis* Shrub Herbaceous Plant Association	G5
Jones and Fertig 1999c	*Artemisia tridentata* ssp. *tridentata/ Pseudoroegneria spicata* Plant Community	*Artemisia tridentata* ssp. *vaseyana/ Pseudoroegneria spicata* Shrubland Plant Association	G5
Merrill *et al.* 1996	Mountain Big Sagebrush GAP Cover Type (32006)	N/A	--

In nearby Montana, Mueggler and Stewart (1980) identified three big sagebrush habitat types as follows:

- *Artemisia tridentata /Agropyron spicatum* [*Pseudoroegneria spicata*] h.t. – 4,000 to 6,000 feet (1,200 to 1,800 m).
- *Artemisia tridentata / Festuca scabrella* [*Festuca campestris*] h.t. -- 3,800 to 6,000 feet (1,200 to 1,800 m).
- *Artemisia tridentata* [suspected ssp. *vaseyana*] / *Festuca idahoensis* h.t. -- 6,000 to 8,000 feet (1,800 to 2,400 m).

Although Mueggler and Stewart (1980) did not specifically identify big sagebrush subspecies, the last habitat above appears to be ssp. *vaseyana* based on their stand photograph. This determination was made based on shrub morphological characterisitics clearly visible in the photograph (characteristics described by Winward and Tisdale 1977). However, more work would need to be done to verify whether these types occur on the BNF.

On the BNF, stands may be fragmented into a mosaic of shrub-dominated and grass-dominated vegetation (Welp *et al.* 1998c). In areas with *Artemisia nova* vegetation, *A. tridentata* ssp. *vaseyana* occupies the more mesic areas (Welp *et al.* 1998b). *Juniperus* ssp. and *Pseudotsuga menziesii* may be found growing in this vegetation type (Welp *et al.* 1998b,c), as well as the exotic plant *Poa pratensis* (Welp *et al.* 1998f).

The soil survey for the Bighorn National Forest mentions the associated species with *Artemisia* spp. Essentially, one would find *Pseudoroegneria spicata* grassland species at the lower elevations and *Festuca idahoensis* grassland species at higher elevations (USDA Forest Service 1986).

Successional Characteristics

Beetle and Johnson (1982) determined that most *Artemisia* spp. stands in Wyoming, including ssp. *vaseyana*, probably represent edaphic or topographic climax. Evidence indicates that stands were historically self-replacing after fire. In that area, *Artemisia tridentata* ssp. *vaseyana* replaces pioneer grassland communities. *Pinus contorta*, and occasionally *Pseudotsuga menziesii*, were observed encroaching into established stands of *Artemisia tridentata* ssp. *vaseyana* (Beetle 1961; Beetle and Johnson 1982). Beetle and Johnson (1982) reported that *Artemisia tridentata* ssp. *vaseyana* has more potential for increasing in density than any other sagebrush species.

Tweit and Houston (1980) consider this vegetation a seral type at the higher elevations, eventually being replaced by *Pseudotsuga menziesii* or *Abies lasiocarpa* vegetation in the absence of fire. In fact, Jones and Fertig (1999a; 1999b) found stands that appeared to be in a seral stage. Authors rarely mention succession, but stands are probably climax vegetation at least in some areas.

Structure

Stands often form mosaics with other types of shrub and grass vegetation. Stands have two strata -- a shrub-dominated layer and a grass-dominated layer. The shrub layer typically grows between 1.5 and 3 feet (0.5 and 1 m) in height (Knight 1994; Reid *et al.* 1999), while cover ranges from 25 to 70%. The grass layer is also 1.5 to 3 feet (0.5 to 1 m) in height, but has less cover, ranging from 10 to 25% (Reid *et al.* 1999). *Artemisia tridentata* ssp. *vaseyana* dominates the shrub layer. Other shrubs may be present and even co-dominate the layer, including *Amelanchier alnifolia*, *Artemisia arbuscula, Artemisia tridentata* ssp. *wyomingensis, Ceanothus velutinus, Ericameria nauseosus, Chrysothamnus viscidiflorus, Purshia tridentata, Ribes cereum, Rosa woodsii,* and *Symphoricarpos oreophilus* (Wyoming Natural Diversity Database 1998; Reid *et al.* 1999). The grass layer is dominated by a variety of species, but the most common dominants are *Pseudoroegneria spicata* or *Festuca idahoensis*. Other grass species include *Leymus cinereus, Elymus lanceolatus, Koeleria macrantha, Achnatherum occidentale, Hesperostipa comata,* and *Achnatherum nelsonii* (Wyoming Natural Diversity Database 1998c; Reid *et al.* 1999).

Function

Stands support livestock grazing and are important habitat for mule deer and sage grouse (Tweit and Houston 1980). The shrubs are browsed by large ungulates (Comer *et al.* 1999).

Additional Ecological Relationships

Pre-settlement fire return intervals in *Artemisia tridentata* ssp. *vaseyana* communities varied from 15 to 25 years (Burkhardt and Tisdale 1969; Houston 1973; Miller *et al.* 2000) or as much as 40 years (Arno and Gruell 1983). For example, *Artemisia tridentata* ssp. *vaseyana* sites in southwestern Idaho show evidence of about three to five fires per century prior to 1910 (Burkhardt and Tisdale 1976). Very frequent fire suppresses *Artemisia tridentata* ssp. *vaseyana* establishment, while long fire return intervals promote tree invasion into *Artemisia tridentata* ssp. *vaseyana* communities. Arno and Gruell (1983) considered average fire intervals of about 20 years sufficient to control *Artemisia tridentata* ssp. *vaseyana* invasion in southwestern Montana grasslands.

A. tridentata ssp. *vaseyana* is readily killed by fire and requires at least 15 years to recover after fire (Bunting 1990). It does not sprout after burning, so post fire recovery is from seed (Blaisdell 1953). The literature is unclear whether fire stimulates seed germination.

Management Considerations

Overgrazing can reduce the herbaceous layer and increase shrub cover, depending on the amount of browsing (Tweit and Houston 1980). Reid *et al.* (1999) report that there is considerable debate about whether this type represents degraded steppe due to overgrazing. Fire suppression leads to a loss of this vegetation type where it is seral, particularly to *Pseudotsuga menziesii* vegetation (Fischer and Clayton 1983). Jones and Fertig (1999c) observed trees of *Pinus flexilis* in stands of *A. tridentata* ssp. *vaseyana*, suggesting that succession is proceeding to forest vegetation. In addition, Jones and Fertig (1999b) observed areas where *A. tridentata* ssp. *vaseyana* and *Pseudotsuga menziesii* vegetation formed a mosaic, indicating that these areas may be closed forest at some point without fire. At the other extreme, fire return intervals of less than five years can cause the conversion of shrub-dominated vegetation into stands of exotic annual grasses, dominated by *Bromus tectorum* (Reid *et al.* 1999). Reid *et al.* (1999) suggest fire return intervals of 30 to 70 years will maintain this vegetation type. Regardless of the return interval, fire is necessary to maintain some stands of this vegetation in locations where it is seral to forest types.

On the BNF, *Pseudotsuga menziesii* are sometimes found in stands (Welp *et al.* 1998c), suggesting that this type may be seral in some places. Fire is needed for eventual regeneration of this vegetation at those locations.

Exotic plants readily invade this vegetation, presumably due to overgrazing. This reality reduces the chance that high-quality stands exist in the region. On the BNF, quality representations occur in Devil's Canyon Potential Research Natural Area (Welp *et al.* 1998d).

For this vegetation, all plant associations that are relevant to the Bighorn National Forest and in the National Vegetation Classification have G5 conservation rank (Table M3B-14), meaning they are abundant (Anderson *et al.* 1998).

Curl-leaf Mountain Mahogany

Composition

Spatial Distribution

Curl-leaf mountain mahogany (*Cercocarpus ledifolius*) vegetation is found throughout the Great Basin from California to Wyoming (Reid *et al.* 1999; Fig. M3B-16). It is known to occur on the BNF.

Figure M3B-16. Distribution of *Cercocarpus ledifolius* in the U.S. (*source: http://plants.usda.gov/*).

Merrill *et al*. (1996) have mapped this vegetation as part of the Xeric Upland Shrub GAP Cover Type (32002). These areas are found along the eastern and western boundaries of the Bighorn National Forest. The Forest's IRI-CVU identified and mapped this plant community type (S322; Table M3B-15).

Table M3B-15. Curl-leaf Mountain Mahogany Cover Type on the Bighorn National Forest (*source: IRI-CVU data*).

IRI-CVU code	Cover Type Name	Number of polygons	Acres	Hectares
S322	Curl-leaf mountain mahogany	76	6,761	2,736
	TOTAL	76	6,761	2,736

The IRI-CVU indicates that this cover type is mostly found on the northwestern flank of the BNF at lower elevations (Fig. M3B-12).

Stands occur in the basins and foothills below 7,800 feet (2,400 m) on landforms such as escarpments and rock outcrops (Knight 1994; Reid *et al*. 1999). It can be found on very steep slopes up to a 100% grade (Shiflet 1994). Soils are rocky and shallow, being derived from sandstones, limestones, and shales (Knight 1994), but stands have mostly been found in areas with limestone bedrock across this region (Shiflet 1994; Welp *et al*. 1998a, 1998b, 1998c). The substrate is considered nutrient poor, which is thought to give the symbiotic nitrogen-fixing *C. ledifolius* an advantage over other competitors (Knight 1994). Much of the precipitation falls in the late winter or early spring (Shiflet 1994; Reid *et al*. 1999).

Within the BNF, stands occur on steep, dry slopes with shallow soils derived from limestone. In addition, they are found on limestone cliffs (Welp *et al*. 1998c). Stands are common on south facing aspects, but are not restricted to slopes facing this direction (Welp *et al*. 1998a; 1998b).

The soil survey for the BNF reports that *C. ledifolius* is present at elevations of about

6,000 to 7,000 feet (1,800 to 2,150 m) on the shallow, rocky, steeper slopes of the western flank. It is mostly associated with calcareous soils. A few scattered stands occur in areas of limestone outcrops on the eastern flank at about 5,000 feet (1,500 m; USDA Forest Service 1986).

Characteristic Dominant Species and Associations

C. ledifolius vegetation, as described here, falls within the *Cercocarpus ledifolius* Shrubland Alliance of the National Vegetation Classification (Anderson *et al.* 1998), as described by Reid *et al.* (1999). It also falls within the Curl-leaf Mountain Mahogany--Bluebunch Wheatgrass Rangeland Cover Type as described by the Society for Range Management (SRM 322; Shiflet 1994).

The *C. ledifolius* vegetation type is represented on the BNF by the communities, habitat types, or other units shown in Table M3B-16. Correspondence of each of these units to plant associations from the National Vegetation Classification (Anderson *et al.* 1998) is shown if it is known.

Table M3B-16. Vegetation classification schemes pertinent to the *Cercocarpus ledifolius* on the Bighorn National Forest (reported by Welp *et al.* 2000).

Reference	Name Used in Reference	NVC Equivalent	Rank
Johnston 1987	*Cercocarpus ledifolius*/*Roegneria spicata* Plant Association	*Cercocarpus ledifolius*/ *Pseudoroegneria spicata* Shrubland Plant Association	G4Q
Ryan *et al*. 1994	Curl-Leaf Mountain Mahogany/ Bluebunch Wheatgrass Plant Association	*Cercocarpus ledifolius*/ *Pseudoroegneria spicata* Shrubland Plant Association	G4Q
Welp *et al*. 1998a; 1998b; 1998c	Curl-Leaf Mountain Mahogany/ Bluebunch Wheatgrass Plant Community	*Cercocarpus ledifolius*/ *Pseudoroegneria spicata* Shrubland Plant Association	G4Q
Merrill *et al*. 1996	Xeric Upland Shrub GAP Cover Type (32002)	N/A	--

On the Bighorn National Forest, species composition is similar to that provided in the general description with *Cercocarpus ledifolius* dominating the stands. However, *Bromus japonicus* and *Poa pratensis* have also been found in stands, indicating exotic plants invade this vegetation on the Forest (Welp *et al*. 1998b; 1998c).

The soil survey for the BNF reports that common associated plants are *Festuca idahoensis*, *Pseudoroegneria spicata*, *Poa secunda*, *Koeleria macrantha*, *Carex* spp., *Artemisia frigida*, and *Erigeron* spp. (USDA Forest Service 1986).

Successional Characteristics

No data available.

Structure

Stands have a shrub-dominated layer ranging in height from 6 to 16 feet (1.8 to 4.9 m) with 25 to 60% cover. Grasses and shorter shrubs dominate other layers (Reid *et al.* 1999). The characteristic shrub is *Cercocarpus ledifolius*, but often other shrubs are present including *Artemisia tridentata* ssp. *wyomingensis*, *A. nova*, *Ericameria nauseosus*, *Rhus trilobata*, *Ribes cereum*, *Ribes oxyacanthoides* ssp. *setosum*, *Amelanchier alnifolia*, *Prunus virginiana*, *Symphoricarpos oreophilus*, and *Physocarpus monogynus* (Wyoming Natural Diversity Database 1998a). Isolated trees are sometimes found growing in stands, including *Juniperus scopulorum*, *Pinus ponderosa*, *Pinus flexilis*, and *Pseudotsuga menziesii* (Reid *et al.* 1999). *Pseudoroegneria spicata* is the most common grass, but *Hesperostipa comata*, *Achnatherum hymenoides*, and *Koeleria macrantha* are often present (Shiflet 1994).

Function

Stands are important winter browse for wildlife (Reid *et al*. 1999; Shiflet 1994).

Additional Ecological Relationships

Interestingly, overbrowsing causes herbivore-induced responses in the shrub that leads to new limbs having more spines. The adaptation presumably limits future browsing and lowers the risk of death for the shrub (Knight 1994). The most important characteristic of *C. ledifolius* is probably its capability of conducting symbiotic nitrogen-fixation. By increasing the supply of nitrogen, this shrub gains a competitive advantage over other species on nutrient-poor soils (Knight 1994). No information was available on the successional status of this type.

C. ledifolius is not adapted to fire (Reid *et al.* 1999), which is part of the reason stands are thought to occur on rocky soils. Such areas are not very productive so little fuel accumulates, reducing the risk of fire (Knight 1994). The pre-settlement fire regime of *C. ledifolius* communities probably varied with community type and structure. Arno and Wilson (1986) reported that the mean fire interval of *C. ledifolius* stands along the Salmon River in Idaho ranged from 13 to 22 years until the early 1900s, but lengthened considerably thereafter. However, Schultz (1987) found large *C. ledifolius* plants up to 1,350 years old in western and central Nevada, indicating that severe fire has been infrequent in some *C. ledifolius* communities. Some old-growth *C. ledifolius* plants avoid fire by growing on extremely rocky sites (Arno and Wilson 1986). The average age of *C. ledifolius* on sites in southwestern and central Montana was only 22 years, but ranged from 5 to 85 years (Duncan 1975).

C. ledifolius may depend on fire to reduce conifer competition and produce favorable soil conditions for seedling establishment. However, individual *C. ledifolius* are severely damaged by fire. It is also a weak sprouter after fire (Bradley *et al.* 1991; Bradley *et al.* 1992).

Management Considerations

Overbrowsing is a management concern for this vegetation (Reid *et al.* 1999). Although shrubs have thorns to protect against excessive use, wildlife species still heavily browse stands on winter ranges. Livestock overgrazing can also be problematic, decreasing cover of *Pseudoroegneria spicata*, while increasing cover of *Hesperostipa comata* and *Koeleria macrantha* (Shiflet 1994).

C. ledifolius reproduces by seed. It can grow vigorously after pruning, but its ability to sprout after top-kill has been described as weak or non-existent (Bradley *et al.* 1991; Bradley *et al*. 1992).

No specific information is known about the management of this vegetation on the Bighorn National Forest.

Quality representations of this type are found in the Tongue River (Welp *et al*. 1998a), Elephant Head (Welp *et al*. 1998b), and Tensleep (Welp *et al*. 1998c) Potential Research Natural Areas.

This vegetation contains one plant association in the National Vegetation Classification that is relevant to the BNF. *Cercocarpus ledifolius / Pseudoroegneria spicata* plant association has a G4Q conservation rank, meaning it is abundant (Anderson *et al*. 1998).

Black Sagebrush

Composition

Spatial Distribution

Black sagebrush (*Artemisia nova*) vegetation is widespread throughout the western United States (Reid *et al*. 1999), including the basins of Wyoming (Knight 1994; Fig. M3B-17).

Figure M3B-17. Distribution of *Artemisia nova* in the U.S. (*source: http://plants.usda.gov/*).

This vegetation is a major cover type at the Shell Canyon Research Natural Area (Ryan *et al*. 1994) and at the Elephant Head Potential Research Natural Area (Welp *et al*. 1998b). According to Welp *et al*. (1998b), stands are commonly found on the western slopes of the Bighorn Mountain Range in a mosaic with several other types of vegetation.

The soil survey for the BNF mentions that a few stands of *A. nova* are present at the lower elevations on the western slope (USDA Forest Service 1986). The Forest's IRI-CVU did not map this plant community as a dominant type, but recognized it as a secondary species within its A. *tridentata* mapping unit (S401; Table M3B-17).

Table M3B-17. Black sagebrush cover type on the Bighorn National Forest (*source: IRI-CVU data*).

IRI-CVU code	Cover Type Name	Number of polygons	Acres	Hectares
S401	Black sagebrush (mapped within big sagebrush)	3	77	31
	TOTAL	3	77	31

The IRI-CVU mapping indicates that this vegetation type is mostly found on the northwestern flank of the Bighorn National Forest at lower elevations. Figure M3B-18 shows the Potential Natural Vegetation (PNV) distribution of this cover type.

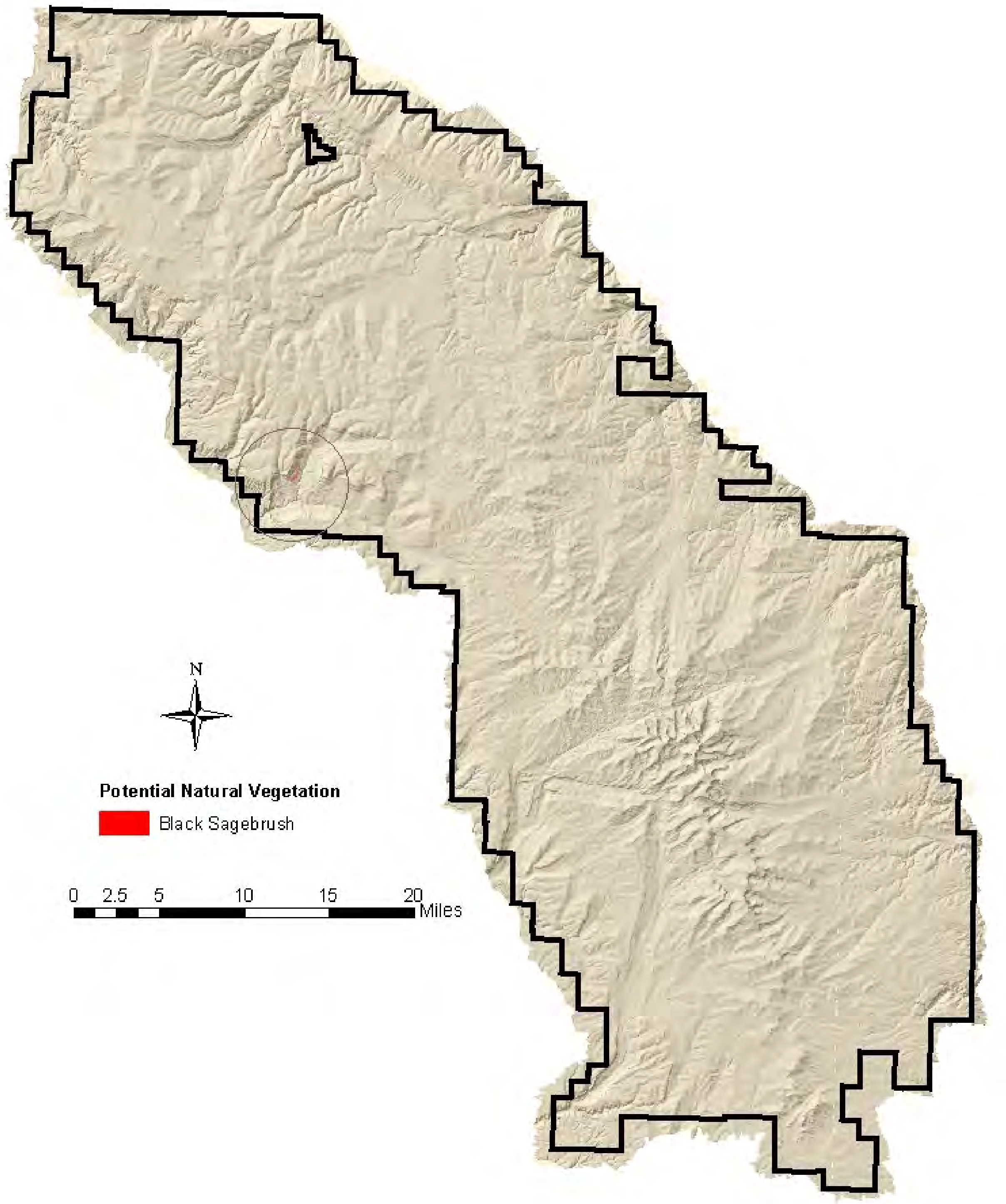


Figure M3B-18. Potential Natural Vegetation (PNV) for black sagebrush community type on the Bighorn National Forest (*source: IRI-CVU*).

This type occurs between 4,500 and 7,700 feet (1,350 and 2,350 m) in Wyoming on windswept ridges with south- and west-facing exposures (Knight 1994, Shiflet 1994). Soils may be derived from calcareous substrate and are typically coarse-textured and shallow (Knight 1994, Reid *et al*. 1999). The vegetation experiences extreme drought in the summer due to low amounts of precipitation and the low water-holding capacity of the soils. In fact, this type grows in more arid conditions than any other *Artemisia* vegetation type (Reid *et al*. 1999).

This type occurs on benches and gentle to steep slopes on the Bighorn National Forest (Ryan *et al*. 1994, Welp *et al*. 1998b). Stands have 10 to 50% exposed rock and bare soil at the surface (Welp *et al*. 1998b).

Characteristic Dominant Species and Associations

A. nova vegetation, as described here, falls within the *Artemisia nova* Dwarf-Shrubland Alliance of the National Vegetation Classification (Anderson *et al*. 1998), as described by Reid *et al*. (1999). It also falls within the Black Sagebrush-Bluebunch Wheatgrass range cover type as described by the Society for Range Management (SRM 320; Shiflet 1994).

The *A. nova* is represented on the BNF by the community in Table M3B-18. Correspondence of this unit to plant associations from the National Vegetation Classification (Anderson *et al*. 1998) is shown.

Table M3B-18. Vegetation classification schemes pertinent to the *Artemisia nova* type on the Bighorn National Forest (reported by Welp *et al*. 2000).

Reference	Name Used in Reference	NVC Equivalent	Rank
Ryan *et al*. 1994; Welp *et al*. 1994	Black Sage Brush/Bluebunch Wheatgrass Plant Community	*Artemisia nova / Pseudoroegneria spicata* Dwarf Shrubland Plant Association	G4G5

Successional characteristics

Mature, self-perpetuating stands of *A. nova* are considered to be indicators of climax conditions (Blackburn and Tueller 1970). No additional information is available on the successional status of this type on the Bighorn National Forest.

Structure

Stands are divided into two strata, a shrub-dominated layer and a grass-dominated layer (Reid *et al*. 1999). The shrub layer is less than 1.5 feet tall (0.5 m; Knight 1994, Reid *et al*. 1999) with cover ranging from 20 to 60% (Reid *et al*. 1999). The grass layer will supersede the shrub layer in height during the growing season, ranging from 1.5 to 3 feet (0.5 to 1 m) tall. Cover of the grass layer ranges from 10 to 25% (Reid *et al*. 1999). On the BNF, *A. nova* dominates the shrub layer while *Pseudoroegneria spicata* dominates the grass layer. Other species include *Koeleria macrantha*, *Arenaria hookeri*, *Stenotus acaulis*, *Gutierrezia sarothrae*, *Artemisia tridentata* ssp. *vaseyana*, and *Krascheninnikovia lanata* (Ryan *et al*. 1994, Welp *et al*. 1998b).

Function

Stands are utilized by pronghorn, mule deer, and sage grouse (Shiflet 1994), in addition to being grazed and browsed by livestock (Reid *et al*. 1999). Forage productivity is low and ranges from 500 to 800 lbs/acre (560 to 896 kg/ha).

Additional Ecological Relationships

Fires are not common in this type because the shrubs do not form a dense growth pattern (Reid *et al*. 1999). There is no information available on fire return frequencies in this vegetation type. *A. nova* is highly susceptible to fire and is readily killed by all fire intensities. Reestablishment occurs through off-site seed sources (Tisdale and Hironaka 1981; Wright *et al.* 1979).

Management Considerations

Stands can be grazed and browsed too heavily. Overgrazing decreases the cover of *Pseudoroegneria spicata* and *Achnatherum hymenoides* and increases the cover of *Hesperostipa comata* and *Koeleria macrantha*. Shrub cover can increase with overgrazing, and may require thinning to stimulate re-establishment of the herbaceous plants. However shrub cover will decline without thinning in stands that are intensively browsed. *Artemisia nova* shrub cover is desirable winter browse for wildlife occurring in snow-free areas for part of the winter (Tweit and Houston 1980). In fact, livestock browse *Artemisia nova* to a greater extent than other types of *Artemisia* shrubs (Reid *et al.* 1999).

No specific information is known about the management of this vegetation on the BNF.

This vegetation forms a single association on the Bighorn National Forest. The *Artemisia nova/Pseudoroegneria spicata* plant association has a G4G5 conservation rank, meaning it is abundant throughout its entire range (but not on the BNF) (Anderson *et al.* 1999).

Information Gaps for Describing Existing Conditions of Grassland/shrubland Upland Vegetation

The available electronic resource data describing the Forest's grassland/shrubland upland vegetation has been described and mapped at a relatively coarse scale. Considerable information about rangelands may be available in the Forest's individual range allotment folders (Forest Service file designation 2210), but this information is generally not in an electronic format. Thus, these data are not quickly or easily summarized, and a greater reliance must be shifted to local Bighorn National Forest expertise.

Greater emphasis in species identification is critically needed in vegetation mapping to accurately identify dominant plant community cover types. Resource mapping and descriptions need to avoid delineating land units generically as "forbland" or "grassland." These kinds of general descriptors greatly limit analysis and management interpretation.

Grassland/shrubland upland vegetation on the Bighorn National Forest has not received an abundance of research effort. Fundamentally, there is a need for a grassland/shrubland vegetation Historic Range of Variability assessment to summarize what is known or not known about these ecosystems. This may also help identify future research needs.

The following are some important information gaps that are limiting our ability to make interpretations about the BNF's grassland/shrubland upland vegetation. Many of these ideas somewhat overlap. Ideally, critical management information needs could be prioritized from this list, and a strategy developed for answering key questions. Ultimately, the goal is to continually improve management decisions while ensuring long-term sustainability.

(1) What are the leading management questions today regarding each plant community type? How do we anticipate those questions may change in the next 20 years, based on changing human demographics and public demands?

(2) What is the species composition of each dominant plant community type, and what leading factors are causing that composition to vary?

(3) What is the distribution of each plant community type on the Forest? Which plant community types are inadequately described and mapped? Is the descriptive information for each plant community type of sufficient detail in order to answer common management questions?

(4) Future vegetation mapping exercises need to put greater emphasis on describing finer geographic levels of grassland/shrubland vegetation units. Can we have grassland/shrubland plot data in an electronic format, including linkages between tabular and spatial data?

(5) What are the successional relationships of each plant community type relative to the potential natural vegetation? For each plant community type, what is the present dominant seral status on the landscape? What does this status mean to species associated with this type? Are there management concerns based on the dominant seral status?

(6) What is the Historic Range of Variability for each plant community type?

(7) What anthropogenic influences have affected each plant community type? What are the ecological and management implications of the composition conditions found for each plant community type?

(8) What is required to maintain each plant community type in the landscape over the long term? Are there measures of ecological integrity or sustainability that could be applied to each type?

(9) At broad landscape scales, what is the patchiness/spatial distribution of each type? At within-patch scales, what is the vertical structure arrangement of each type, and how does it vary through succession?

(10) How much production can be expected by plant community type and at PNV? Are the NRCS Range Site estimates accurate for this area? Why do production estimates vary so much in the published literature for these types?

(11) What role does disturbance play in each plant community type? What is the influence of fire, insects and pathogens, wild herbivores, and climate variation on each plant community type? What are the consequences of human intervention in any of these factors? How much intervention has occurred historically?

(12) Are there any species (wild or exotic) that have (or have had in the past) a profound influence on each type? What are those influences?

(13) What role in the ecosystem does each plant community type play in cycling carbon, nutrients (nitrogen), and water**?**

Literature Cited

Agee, J.K. 1996. Fire in the Blue Mountains: a history, ecology, and research agenda. In: Jaindl, R. G.; Quigley, T. M. (eds.). Search for a Solution: Sustaining the Land, People and Economy of the Blue Mountains. Washington, DC: American Forests: pp. 119-145.

Agee, J.K. and K.R. Maruoka. 1994. Historical fire regimes of the Blue Mountains. BMNRI-TN-1. La Grande, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Blue Mountains Natural Resources Institute. 4 p.

Agriculture Canada. 1979. Research Station: Kamloops, British Columbia. *In*: Research Branch Report 1976-1978. Kamloops, BC: Agriculture Canada, Research Branch: pp. 325-323.

Anderson, M., P. Bourgeron, M.T. Bryer, R. Crawford, L. Engelking, D. Faber-Langendoen, M. Gallyoun, K. Goodin, D.H. Grossman, S. Landaal, K. Metzler, K.D. Patterson, M. Pyne, M. Reid, L. Sneddon, and A.S. Weakly. 1998. International Classification of Ecological Communities: Terrestrial Vegetation of the United States, Volume II The National Vegetation Classification System: List of Types. The Nature Conservancy.

Arno, S.F. and G.E. Gruell. 1983. Fire history at the forest-grassland ecotone in southwestern Montana. Journal of Range Management. **36**(3):332-336.

Arno, Stephen F. and Andrew E. Wilson. 1986. Dating past fires in curlleaf mountain-mahogany communities. Journal of Range Management. **39**(3):241-243.

Arredondo, J. T. and D.A. Johnson. 1998. Clipping effects on root architecture and morphology of 3 range grasses. Journal of Range Management. **51**(2):207-214.

Barrington, M., S. Bunting, and G. Wright. 1988. A fire management plan for Craters of the Moon National Monument. Cooperative Agreement CA-9000-8-0005. Moscow, ID: University of Idaho, Range Resources Department. 52 p. Draft.

Beetle, A.A. 1956. Range survey in Wyoming's Big Horn Mountains. Wyoming Agricultural Experiment Station Bulletin 341 p.

Beetle, A.A. 1961. Range survey in Teton County, Wyoming. Part 1. Ecology of Range Resources. Bull. 376. Laramie, WY: University of Wyoming, Agricultural Experiment Station. 42 p.

Beetle, A.A. and K.L. Johnson. 1982. Sagebrush in Wyoming. Bull. 779. Laramie, WY: University of Wyoming, Agricultural Experiment Station. 68 p.

Beetle, A.A. and A.Young, 1965. A third subspecies in the Artemisia tridentata complex. Rhodora. **67**:405-406.

Benkobi, L. and D. W. Uresk. 1996. Seral stage classification and montioring model for big sagebrush/western wheatgrass/blue grama habitat. *In*: Barrow, Jerry R.; E. Durant McArthur; Ronald E. Sosebee; Robin J. Tausch (comps.). Proceedings: Shrubland Ecosystem Dynamics in a Changing Environment; 1995 May 24-25; Las Cruces, NM. Gen. Tech. Rep. INT-GTR-338. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station: 69-73 pp.

Billings, W.D.. 2000. Alpine vegetation. Chapter 14. *In*: Michael G. Barbour and William Dwight Billings (eds.). Terrestrial Vegetation of North America. 2nd edition. Cambridge University Press. 708 p.

Blackburn, W. H. and P.T. Tueller. 1970. Pinyon and juniper invasion in black sagebrush communities in east-central Nevada. Ecology. **51**(5):841-848.

Blaisdell, J.P. 1953. Ecological effects of planned burning of sagebrush-grass range on the Upper Snake River Plains. Tech. Bull. 1975. Washington, DC: U.S. Department of Agriculture. 39 p.

Blaisdell, J.P. and J.F. Pechanec. 1949. Effects of herbage removal at various dates on vigor of bluebunch wheatgrass and arrowleaf balsamroot. Ecology. **30**(3):298-305.

Blank, R.R., F.Allen, and J..A. Young. 1994. Growth and elemental content of several sagebrush-steppe species in unburned and post-wildfire soil and plant effects on soil attributes. Plant and Soil. **164**:35-41.

Bradley, A.F., W.C. Fischer, and N.V. Noste. 1992. Fire ecology of the forest habitat types of eastern Idaho and western Wyoming. Gen. Tech. Rep. INT-290. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 92 p.

Bradley, A.F., N.V. Noste, and W.C. Fischer. 1991. Fire ecology of forests and woodlands in Utah. Gen. Tech. Rep. INT-287. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 128 p.

Britton, C.M., G.R. McPherson, and F.A. Sneva. 1990. Effects of burning and clipping on five bunchgrasses in eastern Oregon. The Great Basin Naturalist. **50**(2):115-120.

Britton, C.M., R.G. Clark, and F. A. Sneva. 1981. Will your sagebrush range burn? Rangelands. **3**(5):207-208.

Britton, C.M. and R.G. Clark. 1978. Effects of season of burning on five bunchgrass species in eastern Oregon. Society for Range Management Abstracts. **31**: 21. Abstract.

Brown, J. K. and J. Kapler Smith (eds.). 2000. Wildland fire in ecosystems: effects of fire on flora. Gen. Tech. Rep. RMRS-GTR-42-vol. 2. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 257 p.

Bunting, S. C. 1990. Prescribed fire effects in sagebrush-grasslands and pinyon-juniper woodlands. *In*: Alexander, M. E.; G. F. Bisgrove (tech. coords.). The art and science of fire management: Proceedings of the 1st Interior West Fire Council annual meeting and workshop; 1988 October 24-27; Kananaskis Village, AB. Information Rep. NOR-X-309. Edmonton, AB: Forestry Canada, Northwest Region, Northern Forestry Centre: 176-181.

Burkhardt, J. W. and E. W. Tisdale. 1969. Nature and successional status of western juniper vegetation in Idaho. Journal of Range Management. **22**(4):264-270.

Burkhardt, W.J. and E. W. Tisdale. 1976. Causes of juniper invasion in southwestern Idaho. Ecology. 57: 472-484.

Bushey, C.L. 1987. Short-term vegetative response to prescribed burning in the sagebrush/grass ecosystem of the northern Great Basin; three years of postburn data from the demonstration of prescribed burning on selected Bureau of Land Management districts. Final Report. Cooperative Agreement 22-C-4-INT-33. Missoula, MT: Systems for Environmental Management. 77 p.

Champlin, M. R. and A. H. Winward (eds.). 1982. The effect of simulated fire on emergence of seeds found in the soil of big sagebrush communities. *In*: Society for Range Management Abstracts: Proceedings, 35th Annual Meeting of the Society for Range Management; February, 1982; Calgary, AB. Denver, CO: Society for Range Management: 37. Abstract.

Clifton, N.A. 1981. Response to prescribed fire in a Wyoming big sagebrush/bluebunch wheatgrass habitat type. Moscow, ID: University of Idaho. 39 p. Thesis.

Comer, P., L. Allen, S. Cooper, D. Faber-Langendoen, and G. Jones. 1999. Selected shrubland and grassland communities of the northern Great Plains. A report to the Nebraska National Forest. The Nature Conservancy. Unpublished.

Concannon, D. 1978. Plant succession on burned areas of the Artemisia tridentata/Agropyron spicatum habitat type in southeastern Oregon. Arcata, CA: Humbolt State University. 101 p. Thesis.

Conrad, C. E. and C.E. Poulton. 1966. Effect of a wildfire on Idaho fescue and bluebunch wheatgrass. Journal of Range Management. 19(3): 138-141.

Cooper, S.V., P.Lesica, and D. Page-Dumroese. 1997. Plant community classification for alpine vegetation on the Beaverhead National Forest, Montana. USDA Forest Service General Technical Report INT-GTR-362. Intermountain Research Station, Ogden UT. 61 pp.

Despain, D.G. 1973. Vegetation of the Big Horn Mountains, Wyoming, in relation to substrate and climate. Ecological Monographs 43:329-355.

DeVelice, R.L. and P. Lesica. 1993. Plant community classification for vegetation on BLM lands, Pryor Mountains, Carbon County, Montana. Montana Natural Heritage Program, Helena MT. 78 p.

Duncan, E. A. 1975. The ecology of curl-leaf mountain mahogany (Cercocarpus ledifolius Nutt.) in southwestern Montana with special reference to use by mule deer. Bozeman, MT: Montana State University. 87 p. Thesis.

Dyksterhuis, E. J. 1949. Condition and management of rangeland based on quantitative ecology. Journal of Range Management. 2:104–115.

Eckert, R.E. Jr. and J.S. Spencer. 1986. Vegetation response on allotments grazed under rest-rotation management. Journal of Range Management. 39(2): 166-174.

Eckert, R.E. Jr. and J.S. Spencer. 1987. Growth and reproduction of grasses heavily grazed under rest-rotation management. Journal of Range Management. 40(2): 156-159.

Eddleman, L.E. and P.S. Doescher. 1978. Selection of native plants for spoils revegetation based on regeneration characteristics and successional status. *In*: Land Reclamation Program, Annual Report July 1976-October 1977. ANL/LRP-2. Argonne, IL: Argonne National Laboratory, Energy & Environmental Systems Division: 132-138.

Fischer, W.C. and B.D. Clayton. 1983. Fire ecology of Montana forest habitat types east of the Continental Divide. USDA Forest Service General Technical Report INT-141. Intermountain Forest and Range Experiment Station, Ogden UT. 83 pp.

Fisher, F.B., J.C. Winne, M.M. Thornton, T.P. Tady, Z. Ma, M.M. Hart, and R. L. Redmond. 1998. Montana land cover atlas. Unpublished report. Montana Cooperative Wildlife Research Unit, The University of Montana, Missoula. viii + 50 pp.

Francis, R. E. 1983. Sagebrush-steppe habitat types in northern Colorado: a first approximation. *In*: Moir, W. H.; Leonard Hendzel (tech. cords). Proceedings of the workshop on Southwestern habitat types; 1983 April 6-8; Albuquerque, NM. Abluquerque, NM: U.S. Department of Agriculture, Forest Service, Southwestern Region: 67-71.

Gaffney, W.S. 1941. The effects of winter elk browsing, south fork of the Flathead River, Montana. Journal of Wildlife Management. 5(4): 427-453.

Hermann, F.J. 1970. Manual of the Carices of the Rocky Mountains and Colorado Basin. USDA Forest Service Agriculture Handbook No. 374. 397 pp.

Heyerdahl, E.K., D.Berry, and J.K. Agee. 1994. Fire history database of the western United States. Seattle, WA: U.S. Department of Agriculture, Pacific Northwest Research Station; Seattle, WA: University of Washington, College of Forest Resources; Final report. Interagency agreements US Environmental Protection Agency DW12934530; USDA Forest Service PNW-94-0300; University of Washington 61-2239. 57+ p.

Hironaka, M., M.A. Fosberg, and A.H. Winward. 1983. Sagebrush-grass habitat types of southern Idaho. Forest, Wildlife, and Range Experiment Station Bulletin 35. University of Idaho, Moscow, Idaho.

Houston, Douglas B. 1973. Wildfires in northern Yellowstone National Park. Ecology. 54(5): 1111-1117.

Hurd, R.M. 1961. Grassland vegetation in the Big Horn Mountains, Wyoming. Ecology 42:459-467.

Johnson, C.G., Jr. 1994. Forest health in the Blue Mountains: a plant ecologist's perspective on ecosystem processes and biological diversity. Gen. Tech. Rep. PNW-GTR-339. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 24 p.

Johnson, P.L. and W.D. Billings. 1962. The alpine vegetation of the Beartooth Plateau in relation to cryopedogenic processes and patterns. Ecological Monographs 32(2): 105-135.

Johnston, B.C. 1987. Plant Associations of Region Two. Edition 4. USDA Forest Service Rocky Mountain Region. R2-ECOL-87-2.

Jones, G.P. 1992. Wyoming plant community classification. Unpublished Rep**.** Wyoming Natural Diversity Database, The Nature Conservancy. Laramie, WY. 184pp.

Jones, G.P. and W.Fertig. 1999a. Ecological evaluation of the potential Grizzly Creek research natural area within the Shoshone National Forest, Park County, Wyoming. Wyoming Natural Diversity Database, University of Wyoming, Laramie WY. Unpublished.

Jones, G.P. and W. Fertig. 1999b. Ecological evaluation of the potential Sheep Mesa research natural area within the Shoshone

National Forest, Park County, Wyoming. Wyoming Natural Diversity Database, University of Wyoming, Laramie WY. Unpublished.

Jones, G.P. and W.Fertig. 1999c. Ecological evaluation of the potential Arrow Mountain research natural area within the Shoshone National Forest, Fremont County, Wyoming. Wyoming Natural Diversity Database, University of Wyoming, Laramie WY. Unpublished.

Jones, G.P. and W. Fertig. 1999d. Ecological evaluation of the potential Beartooth Butte research natural area within the Shoshone National Forest, Park County, Wyoming. Wyoming Natural Diversity Database, University of Wyoming, Laramie WY. Unpublished.

Jones, G.P. and W. Fertig. 1999e. Ecological evaluation of the potential Roaring Fork Mountain research natural area within the Shoshone National Forest, Fremont County, Wyoming. Wyoming Natural Diversity Database, University of Wyoming, Laramie WY. Unpublished.

Jones, W. B. 1965. Response of major plant species to elk and cattle grazing in northwestern Wyoming. Journal of Range Management. 18: 218-220.

Klebenow, D.A. 1973. The habitat requirements of sage grouse and the role of fire in management. *In*: Proceedings, annual Tall Timbers fire ecology conference; 1972 June 8-9; Lubbock, TX. No. 12. Tallahassee, FL: Tall Timbers Research Station: 305-315.

Knight, D.H. 1994. Mountains and Plains: the Ecology of Wyoming Landscapes. Yale University Press, New Haven, Connecticut.

Laycock, W.A. 1967. How heavy grazing and protection affect sagebrush-grass ranges. Journal of Range Management. 20: 206-213.

McArthur, E. D., B.C. Giunta, and A. Perry Plummer. 1977. Shrubs for restoration of depleted range and disturbed areas. Utah Science. 35: 28-33.

McIlvanie, S. K. 1942. Carbohydrate and nitrogen trends in bluebunch wheatgrass, Agropyron spicatum, with special reference to grazing influences. Plant Physiology. 17: 540-557.

McLean, A. and L. Marchard. 1968. Grassland ranges in the southern interior of British Columbia. Canadian Department of Agriculture. Publ. 1319. 28pp.

McLean, A., T.M. Lord, and A.J. Green. 1970. Utilization of the major plant communities in the Similkameen Valley, British Columbia. Journal of Range Management. 24: 346-351.

Merrill, E.H., T.W. Kohley, M.E. Herdendorf, W.A. Reiners, K.L. Driese, R.W. Marrs, and S.H. Anderson. 1996. Wyoming gap analysis: a geographic analysis of biodiversity. Final report, Wyoming Cooperative Fishery and Wildlife Research Unit, University of Wyoming, Laramie WY.

Merrill, E., J.Hak, and N.Stanton. 1994. Responses of nematodes to ungulate herbivory on bluebunch wheatgrass and Idaho fescue in Yellowstone National Park. *In*: Despain, Don G. (ed.) Plants & their environments: proceedings of the 1st biennial scientific conference on the Greater Yellowstone Ecosystem; 1991 September 16-17; Yellowstone Nat'l Park, WY. Tech. Rep. NPS/NRYELL/NRTR. Denver, CO: U.S. Department of the Interior, National Park Service, Rocky Mountain Region, Yellowstone National Park: 231-238.

Miller, R.F., T.J. Svejcar, and J.A. Rose. 2000. Impacts of western juniper on plant community composition and structure. Journal of Range Management. 53(6): 574-585.

Mueggler, W. F. 1975. Rate and pattern of vigor recovery in Idaho fescue and bluebunch wheatgrass. Journal of Range Management. 28(3):198-204.

Mueggler, W. F. 1972. Influence of competition on the response of bluebunch wheatgrass to clipping. Journal of Range Management. 25: 88-92.

Mueggler, W. F. and W.L. Stewart. 1980. Grassland and shrubland habitat types of western Montana. Gen. Tech. Rep. INT-66. Ogden, UT. U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 154 p.

Mueggler, W. F. and W.L. Stewart. 1981. Forage production on important rangeland habitat types in western Montana. Journal of Range Management. 34(5): 347-353.

Olson, B.E. and R.T. Wallander. 1997. Biomass and carbohydrates of spotted knapweed and Idaho fescue after repeated grazing. Journal of Range Management. 50(4): 409-412.

Patton, B.D., M. Hironaka, and S.C. Bunting. 1988. Effect of burning on seed production of bluebunch wheatgrass, Idaho fescue, and Columbia needlegrass. Journal of Range Management. 41(3): 232-234.

Peet, R. K. 1988. Forests of the Rocky Mountains. Chapter 3. *In*: Barbour, Michael; William Dwight Billings (eds.). Terrestrial vegetation of North America. Cambridge University Press. 434 pp.

Reid, M.S., K.A. Schulz, P.J. Comer, M.H. Schindel, D.R. Culver, D.A. Sarr, and M.C. Damm. 1999. An Alliance Level Classification of the Vegetation of the Conterminous western United States. A Report to the University of Idaho Cooperative Fish and Wildlife Research Unit and the National Gap Analysis Program. The Nature Conservancy, Western Conservation Science Department, Boulder, Colorado.

Robberecht, R. and G.E. Defosse, 1995. The relative sensitivity of two bunchgrass species to fire. International Journal of Wildland Fire. 5(3): 127-134.

Ryan, M.G., L.A. Joyce, T. Andrews, and K. Jones. 1994. Research Natural Areas in Colorado, Nebraska, North Dakota, South Dakota, and Parts of Wyoming. USDA Forest Service General Technical Report RM-251. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado. 57 pp.

Sapsis, D.B. 1990. Ecological effects of spring and fall prescribed burning on basin big sagebrush/Idaho fescue--bluebunch wheatgrass communities. Corvallis, OR: Oregon State University. 105 p. Thesis.

Schlatterer, E. F. 1973. Sagebrush species and subspecies. Range Improvement Notes. 18(2): 1-11.

Schultz, B. W. 1987. Ecology of curlleaf mountain mahogany (Cercocarpus ledifolius) in western and central Nevada: population structure and dynamics. Reno, NV: University of Nevada. 111 p.

Shiflet, T.N. (ed.). 1994. Rangeland Cover Types of the United States. Society of Range Management, Denver, Colorado.

Smith, M. A. and F.Busby. 1981. Prescribed burning: effective control of sagebrush in Wyoming. RJ-165. Laramie, WY: University of Wyoming, Agricultural Experiment Station. 12 p.

Sours, J.M. 1983. Characteristics and uses of important grasses for arid western rangelands. In: Monsen, Stephen B.; Nancy Shaw (comps.). Managing Intermountain rangelands--improvement of range and wildlife habitats: Proceedings of a symposia; 1981 September 15-17; Twin Falls, ID; 1982 June 22-24; Elko, NV. Gen. Tech. Rep. INT-157. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station: 90-94.

Stohlgren, T. J., L.D. Schell, and B. Vanden Heuvel. 1999. How grazing and soil quality affect native and exotic plant diversity in Rocky Mountain grasslands. Ecological Applications. 9(1): 45-64.

Sturges, D. L. 1994. High-elevation watershed response to sagebrush control in southcentral Wyoming. Res. Pap. RM-318. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 19 p.

Thilenius J. F. 1975. Alpine range management in the western United States--principles, practices, and problems: The status of our knowledge. USDA For. Serv. Res. Pap. RM-157, Rocky Mt. For. and Range Exp. Stn, Fort Collins, CO. 32 p.

Tisdale, E. W. and M. Hironaka. 1981. The sagebrush-grass region: a review of the ecological literature. Bull. 33. Moscow, ID: University of Idaho, Forest, Wildlife and Range Experiment Station. 31 p.

Tweit, S.J. and K.E. Houston. 1980. Grassland and Shrubland Habitat Types of the Shoshone National Forest. USDA Forest Service, Rocky Mountain Region. Unpublished.

USDA Forest Service. 1999. Bighorn National Forest IRI User's Guide. Unpublished report on file at the Supervisor's Office for the Bighorn National Forest, Sheridan, Wyoming.

USDA Forest Service. 1986. Soil Survey of Bighorn National Forest, Wyoming. USDA Forest Service and Soil Conservation Service in cooperation with Wyoming Agriculture Experiment Station. Issued April, 1986.

USDA NRCS. 1988. Range site descriptions. Technical Guide, Section IIB. Natural Resources Conservation Service. Wyoming State Office, Cheyenne, Wyoming. April, 1988.

Vincent, D.W. 1992. The sagebrush/grasslands of the upper Rio Puerco Area, New Mexico. Rangelands. 14(5): 268-271.

Vogel, W. G. and G.M. Van Dyne. 1966. Vegetation responses to grazing management on a foothill sheep range. Journal of Range Management. 19: 80-85.

Wambolt, C.L. and G.F. Payne. 1986. An 18-year comparison of control methods for Wyoming big sagebrush in southwestern Montana. Journal of Range Management. 39(4): 314-319.

Warg, S. A. 1938. Life history and economic studies of Bromus tectorum. Missoula, MT: State University of Montana. 38 p. M.S. thesis.

Welp, L., W. Fertig, and G. Jones. 1998a. Ecological evaluation of the potential Tongue River research natural area within the Bighorn National Forest, Sheridan County, Wyoming. Prepared for the USDA Forest Service, Bighorn National Forest by the Wyoming Natural Diversity Database, The Nature Conservancy. Unpublished.

Welp, L., W. Fertig, and G. Jones. 1998b. Ecological Evaluation of the Potential Elephant Head Research Natural Area within the Bighorn National Forest, Big Horn County, Wyoming. Wyoming Natural Diversity Database, University of Wyoming. Unpublished.

Welp, L., W. Fertig, and G. Jones. 1998c. Ecological evaluation of the potential Tensleep Canyon research natural area within the Bighorn National Forest, Washakie County, Wyoming. Prepared for the USDA Forest Service, Bighorn National Forest by the Wyoming Natural Diversity Database, The Nature Conservancy. Unpublished.

Welp, L., W. Fertig, and G. Jones. 1998d. Ecological evaluation of the potential Devil Canyon research natural area within the Bighorn National Forest, Big Horn County, Wyoming. Prepared for the USDA Forest Service, Bighorn National Forest by the Wyoming Natural Diversity Database, The Nature Conservancy. Unpublished.

Welp, L., W. Fertig, and G. Jones. 1998e. Ecological evaluation of the potential Pete's Hole research natural area within the Bighorn National Forest, Big Horn County, Wyoming. Prepared for the USDA Forest Service, Bighorn National Forest by the Wyoming Natural Diversity Database, The Nature Conservancy. Unpublished.

Welp, L., W. Fertig, and G. Jones. 1998f. Ecological evaluation of the potential Dry Fork research natural area within the Bighorn National Forest, Sheridan County, Wyoming. Prepared for the USDA Forest Service, Bighorn National Forest by the Wyoming Natural Diversity Database, The Nature Conservancy. Unpublished.

Welp, L., W. Fertig, and G. Jones. 1998g. Ecological evaluation of the potential McLain Lake research natural area within the Bighorn National Forest, Big Horn and Johnson Counties, Wyoming. Prepared for the USDA Forest Service, Bighorn National Forest by the Wyoming Natural Diversity Database, The Nature Conservancy. Unpublished.

Welp, L., W. F. Fertig, G. P. Jones, G.P. Beauvais, and S.M. Ogle. 2000. Fine filter analysis of the Bighorn, Medicine Bow, and Shoshone National Forests in Wyoming. Prepared for the U.S. Forest Service Region 2 by Wyoming Natural Diversity Database, University of Wyoming.

Winward, A. H. and E. W. Tisdale. 1977. Taxonomy of the Artemisia tridentata complex in Idaho. Bulletin Number 19. Moscow, ID: University of Idaho, College of Forestry, Wildlife and Range Sciences, Forest, Wildlife and Range Experiment Station. 15 p.

Wright, H.A., L.F. Neuenschwander, and C. M. Britton. 1979. The role and use of fire in sagebrush-grass and pinyon-juniper plant communities: A state-of-the-art review. Gen. Tech. Rep. INT-58. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 48 p.

Wright, J.C. and E.A. Wright. 1948. Grassland types of south central Montana. Ecology. 29(4): 449-460.

Wyoming Natural Diversity Database. 1998a. Characterization Abstract for *Cercocarpus ledifolius* var. *ledifolius* / *Elymus spicatus* (Curl-Leaf Mountain Mahogany / Bluebunch Wheatgrass Plant Association) in Wyoming. University of Wyoming, Laramie, WY. Unpublished.

Wyoming Natural Diversity Database. 1998b. Characterization Abstract for *Artemisia nova* / *Elymus spicatus* (Black Sagebrush / Bluebunch Wheatgrass) in Wyoming. University of Wyoming, Laramie, WY. Unpublished.

Wyoming Natural Diversity Database. 1998c. Characterization abstract for *Artemisia tridentata* ssp. *vaseyana – Symphoricarpos oreophilus* Shrubland and *Artemisia tridentata* ssp. *vaseyana – Symphoricarpos oreophilus* / *Pseudoroegneria spicata* Shrubland. University of Wyoming, Laramie, WY. Unpublished.

Young, J.A. and R. A. Evans. 1981. Demography and fire history of a western juniper stand. Journal of Range Management. 34(6): 501-505.

Young, J.A., R.E. Eckert, Jr., and R.A. Evans. 1979. Historical perspectives regarding the sagebrush ecosystem. *In*: The sagebrush ecosystem: a symposium: Proceedings; 1978 April; Logan, UT: Utah State University, College of Natural Resources: 1-13.

Appendix A - Grassland/Shrubland Upland Vegetation Nomenclature

(*source: PLANTS national database – http://plants.usda.gov*)

Scientific Name	Common Name
Abies lasiocarpa	subalpine fir
Achillea millefolium var. *occidentalis*	western yarrow
Achnatherum hymenoides	Indian ricegrass
Achnatherum lettermanii	Letterman's needlegrass
Achnatherum nelsonii ssp. *nelsonii*	Columbia needlegrass
Achnatherum occidentale	western needlegrass
Achnatherum richardsonii	Richardson's needlegrass
Agoseris glauca	pale agoseris
Agoseris spp.	agoseris
Agropyron cristatum	crested wheatgrass
Agrostis humilis	alpine bentgrass
Agrostis scabra	rough bentgrass
Agrostis spp.	bentgrass
Alyssum spp.	madwort
Amelanchier alnifolia	Saskatoon serviceberry
Andropogon spp.	bluestem
Antennaria lanata	woolly pussytoes
Arenaria congesta	ballhead sandwort
Arenaria hookeri	Hooker's sandwort
Arnica mollis	hairy arnica
Artemisia arbuscula	little sagebrush
Artemisia cana	silver sagebrush
Artemisia filifolia	sand sagebrush
Artemisia frigida	prairie sagewort
Artemisia nova	black sagebrush
Artemisia tridentata	big sagebrush
Artemisia tridentata ssp. *tridentata*	basin big sagebrush
Artemisia tridentata ssp. *vaseyana*	mountain big sagebrush
Artemisia tridentata ssp. *wyomingensis*	Wyoming big sagebrush
Aster alpinus	Alpine aster
Astragalus spatulatus	tufted milkvetch
Besseya wyomingensis	Wyoming besseya
Bouteloua gracilis	blue grama
Bouteloua hirsuta	hairy grama
Bromus inermis ssp. *pumpellianus* var. *pumpellianus*	Pumpelly's brome
Bromus japonicus	Japanese brome
Bromus tectorum	cheatgrass
Buchloe dactyloides	buffalo grass
Calochortus spp.	mariposa lily
Caltha leptosepala	elkslip marshmarigold
Campanula rotundifolia	bluebell bellflower
Carex elynoides	blackroot sedge
Carex filifolia	threadleaf sedge

Carex inops ssp. *heliophila*	sun sedge
Carex nigricans	black alpine sedge
Carex obtusata	obtuse sedge
Carex paysonis	Payson sedge
Carex phaeocephala	dunhead sedge
Carex rupestris	rock sedge
Carex scirpoidea	northern singlespike sedge
Carex scopulorum	mountain sedge
Cassiope mertensiana	western moss heather
Castilleja rhexiifolia	splitleaf Indian paintbrush
Ceanothus velutinus	snowbrush ceanothus
Centaurea biebersteinii	spotted knapweed
Centaurea diffusa	diffuse knapweed
Cerastium arvense	field chickweed
Cercocarpus ledifolius	curl-leaf mountain mahogany
Cercocarpus montanus	true mountain mahogany
Cercocarpus spp.	mountain mahogany
Chrysothamnus viscidiflorus	yellow rabbitbrush
Cryptantha cana	mountain cryptantha
Danthonia intermedia	timber oatgrass
Danthonia spp.	oatgrass
Deschampsia caespitosa	tufted hairgrass
Dryas octopetala	eightpetal mountain-avens
Elymus lanceolatus	streambank wheatgrass
Elymus spp.	wheatgrass
Elymus trachycaulus	slender wheatgrass
Ericameria nauseosus	rubber rabbitbrush
Erigeron spp.	fleabane
Erigeron ursinus	bear river fleabane
Eriogonum mancum	imperfect buckwheat
Eritrichium nanum	arctic alpine forget-me-not
Festuca campestris	rough fescue
Festuca idahoensis	Idaho fescue
Festuca ovina	sheep fescue
Festuca spp.	fescue
Festuca thurberi	Thurber fescue
Galium boreale	northern bedstraw
Gentianella tenella ssp. *tenella*	Dane's dwarf gentian
Geranium caespitosum	pineywoods geranium
Geum rossii	Ross' avens
Geum spp.	avens
Geum triflorum var. *ciliatum*	old man's whiskers
Gutierrezia sarothrae	broom snakeweed
Hesperostipa comata	needle and thread
Hieracium cynoglossoides	houndstongue
Hordeum vulgare	barley
Juncus drummondii	Drummond's rush
Juncus parryii	Parry rush

Juniperus scopulorum	Rocky Mountain juniper
Juniperus ssp.	Juniper
Koeleria macrantha	prairie junegrass
Krascheninnikovia lanata	winterfat
Leucopoa kingii	spike fescue
Lewisia pygmaea	pigmy bitterroot
Leymus cinereus	basin wildrye
Lloydia serotina	common alplily
Lupinus sericeus	silky lupine
Machaeranthera grindelioides var. *grindelioides*	rayless tansyaster
Minuartia obtusiloba	alpine sandwort
Opuntia polyacantha	plains pricklypear
Oxytropis campestris	white smallflower pointloco
Pascopyrum smithii	western wheatgrass
Pedicularis parryi	Parry's lousewort
Phacelia sericea	silky phacelia
Phippsia algida	icegrass
Phleum alpinum	alpine timothy
Phlox hoodii	spiny phlox
Phlox hoodii ssp. *muscoides*	musk phlox
Phyllodoce empetriformis	red mountainhealth
Physocarpus monogynus	mountain ninebark
Picea engelmannii	Engelmann spruce
Pinus contorta	lodgepole pine
Pinus flexilis	limber pine
Pinus ponderosa	ponderosa pine
Poa cusickii	Cusick’s bluegrass
Poa fendleriana	muttongrass
Poa nemoralis ssp. *interior*	inland sedge
Poa pratensis	Kentucky bluegrass
Poa reflexa	nodding bluegrass
Poa secunda	Sandberg bluegrass
Polygonum bistortoides	American bistort
Polygonum viviparum	viviparous bistort
Potentilla diversifolia	varileaf cinquefoil
Potentilla ovina	sheep cinquefoil
Primula parryi	Parry's primrose
Prunus virginiana	common chokecherry
Pseudoroegneria spicata	bluebunch wheatgrass
Pseudotsuga menziesii	Douglas-fir
Purshia tridentata	antelope bitterbrush
Rhus spp.	sumac
Rhus trilobata	skunkbush sumac
Ribes cereum	wax currant
Ribes oxyacanthoides ssp. *setosum*	redshoot gooseberry
Rosa woodsii	Woods’ rose
Salix glauca	grayleaf willow
Salix petrophila	alpine willow

Salix planifolia	diamondleaf willow
Salix reticulata	netleaf willow
Schizachyrium scoparium var. *scoparium*	little bluestem
Secale cereale	rye
Selaginella densa	dense clubmoss
Sherpherdia argentea	silver buffaloberry
Silene acaulis	moss campion
Solidago missouriensis	Missouri goldenrod
Sphaeralcea coccinea	scarlet globemallow
Stenotus acaulis	stemless mock goldenweed
Stenotus spp.	goldenweed
Symphoricarpos oreophilus	Utah snowberry
Symphoricarpos oreophilus	mountain snowberry
Symphoricarpos spp.	snowberry
Taraxacum officinale	dandelion
Tetraneuris acaulis var. *acaulis*	stemless four-nerve daisy
Townsendia spathulata	sword Townsend daisy
Tragopogon spp.	goatsbeard
Trisetum spicatum	spike trisetum
Trisetum wolfii	Wolf's trisetum
Triticum aestivum	wheat
Veronica wormskjoldii	American alpine speedwell
Yucca glauca	soapweed yucca

Chapter 4 – Influences on Landscape Condition
Module 4A - Wildfire, Insects, and Disease

Objectives

Provide a spatial representation of expected historic fire regimes. Display the current condition as a measure of the departure from historic conditions. Map areas at high risk for fire. Describe the current condition of insect and disease within the assessment area. Map areas at high risk for insect and disease activity. Identify and map ecological risks associated with the interaction of wildfire with old growth/older forests, insects and disease. To the extent possible given information limitations, discuss the ecological implications of the current condition.

Introduction

Disturbances have been identified as important drivers of heterogeneity in landscapes for several decades (Watt 1947), and have more recently been recognized as essential elements in the dominant, natural processes in ecological communities (Wu and Loucks 1995). Understanding ecological systems, particularly at broad scales, demands that we examine the patterns, consequences, and importance of disturbances (Baker 1989; Pickett and White 1985; Turner and Dale 1998). Although the concept of landscapes as mosaics of patches generated by disturbance (Pickett and White 1985) is relatively recent, ecologists have since noted the importance of natural disturbances in determining the spatial configuration for ecological processes (Paine and Levin 1981; Pickett and White 1985; Wiens 1995). In any case, understanding the nature of the disturbance mosaic and the factors controlling landscape patterns is crucial for predicting ecosystem dynamics and vegetation development in disturbance-prone landscapes (Turner *et al*. 2001).

The objective of this module is to show and describe the current landscape condition associated with natural disturbances on the Bighorn National Forest. Fire and insects are the major disturbances affecting the Bighorns and are the primary focus here. A discussion of historical fire regimes is followed by a comparison with the current condition of the landscape as a means to measure departure from historic conditions, probable hazard of severe fire, and wildfire occurrence probability. For insects, recent insect activity is summarized, as well as identification of areas of high risk of insect activity. Other natural disturbances, including windthrow and common forest pathogens, are discussed briefly.

Fire on the Bighorn Landscape

Fire has been described as the "dominant fact of forest history" (Spurr 1964), and has shaped the Rocky Mountains landscape for millennia (Clements 1910; Despain and Romme 1991; Romme and Knight 1981). Understanding how fire has changed the landscape requires an examination of historical fire regimes and the degree to which current landscapes are a reflection of these fire regimes.

<u>Historical Fires Regimes of the Bighorn National Forest</u>

To estimate the variability in fire regimes across the ecosystems of the Bighorn National Forest, fire disturbance regimes (fire return intervals and severity) were assigned to each major native plant community identified by the Potential Natural Vegetation (PNV) database (Table M4A-1). Because relatively few fire history studies have been completed for the Bighorn National Forest, the assignments are based on fire history studies in similar plant communities in the northern Rocky Mountains, as confirmed by an expert review (W.H. Romme personal communication) (see the Protocol for detailed descriptions of the historical fire regimes assigned to each vegetation type).

Grasslands and meadows, which comprise approximately 18% (199,961 acres/80,922 ha) of the Forest, typically exhibit the highest fire frequency (≤ 10 years) with high severity; this fire regime represents more than 14% of the Forest (Table M4A-1, Fig. M4A-1). Shrublands, representing 9% (99,981 acres/40,461 ha), are characterized by mixed-severity fire regimes with relatively short (10-35 years) fire intervals regardless of their species composition. Forests, particularly high-elevation spruce/fir forests, lodgepole pine forests, and low-elevation juniper woodlands, which occupy two-thirds of the total area of the Bighorn National Forest, are characterized by the most common fire regime with a frequency of > 300 years and high-severity. However, forests are most variable in terms of fire regimes when compared to grasslands or shrublands (Table M4A-1).

Table M4A-1. Historical fire regimes assigned to each vegetation type (PNV) for the Bighorn Natural Forest.

Potential Natural Vegetation (PNV) Cover	Assigned Fire Regime	Acres (Hectares)
Grassland/Meadows		
Alpine tundra	> 300 years; mixed severity	76,596 (30,997)
Bluebunch wheatgrass	≤ 10 years; high severity	6,691 (2,708)
Idaho fescue	≤ 10 years; high severity	169,231 (68,485)
Little bluestem	≤ 10 years; high severity	504 (204)
Shrubland		
Black sagebrush	10 to 35 years; mixed severity	77 (31)
Grass & Shrub riparian	10 to 35 years; mixed severity	26,847 (10,865)
Greasewood	10 to 35 years; mixed severity	238 (96)
Mixed deciduous shrub	10 to 35 years; mixed severity	1,416 (573)
Mountain mahogany	10 to 35 years; mixed severity	7,592 (3,072)
Mountain sagebrush	10 to 35 years; mixed severity	3,393 (1,373)
Sagebrush	10 to 35 years; mixed severity	71,944 (29,115)
Wyoming sagebrush	10 to 35 years; mixed severity	260 (105)
Forests		
Aspen	125 to 300 years; mixed severity	4,704 (1,904)
Cottonwood	125 to 300 years; low severity	496 (201)
Douglas-fir	35 to 100 years; mixed severity	10,967 (4,438)
Juniper woodland	> 300 years; high severity	5,067 (2,051)
Limber pine woodland	35to 100 years; mixed severity	3,204 (1,297)
Lodgepole pine (> 8,000 feet)	> 300 years; high severity	100,120 (40,517)
Lodgepole pine (< 8,000 feet)	125 to 300 years; high severity	73,408 (29,707)
Ponderosa pine	35 to 100 years; mixed severity	34,760 (14,067)
Spruce (> 8,000 feet)	> 300 years; high severity	78,853 (31,911)
Spruce (< 8,000 feet)	125 to 300 years; high severity	81,410 (32,945)
Subalpine fir (> 8,000 feet)	> 300 years; high severity	225,855 (91,400)
Subalpine fir (< 8,000 feet)	125 to 300 years; high severity	80,346 (32,515)

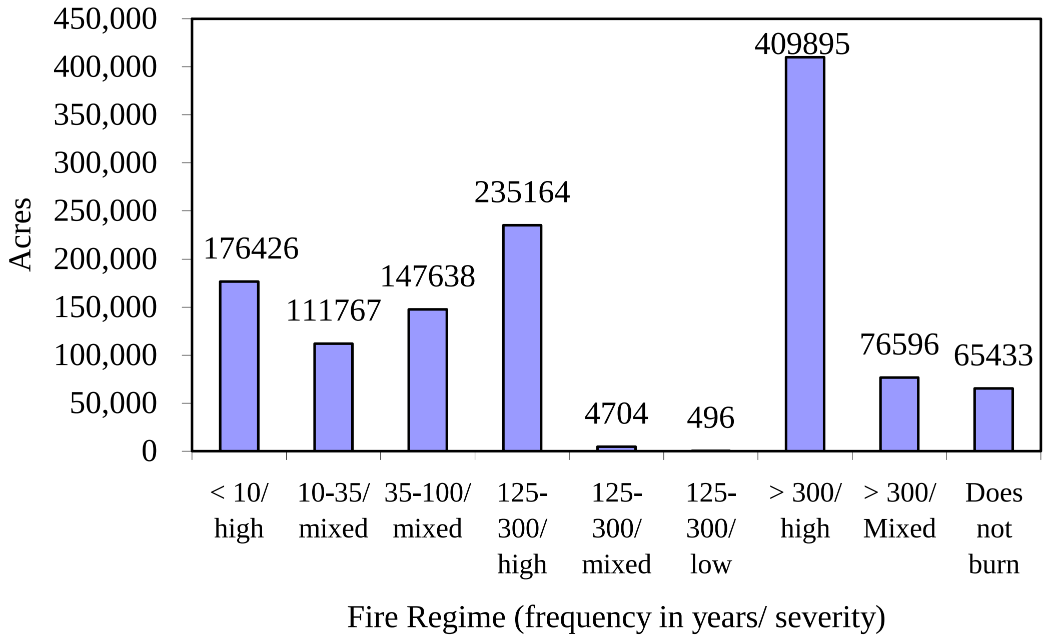


Figure M4A-1. Acreage of the Bighorn National Forest characterized by various fire regimes.

High-severity fire, the second most common fire regime, occurs every 125 to 300 years (19% of the forest area); such a fire regime is characteristic of lodgepole pine and spruce/fir forests at elevations below 8,000 feet (2,438 m). Rare fire regimes (typical of < 1% of the forest) include mixed-severity, 125- to 300-year interval regimes characteristic of aspen forests, and low-severity, 125- to 300-year fire regimes, characteristic of cottonwood forests (Table M4A-1). Both of these forest types are exceedingly rare on the Forest. Slightly more than five percent of the Bighorn National Forest is covered by water, ice, snow, rock, or bare soil.

In addition to shrublands, mixed-severity fire regimes characterize forests dominated by aspen, Douglas-fir, limber pine, and ponderosa pine, which typically are found at middle to low elevations at the margins of the Forest (Fig. M4A-2). High severity fire regimes, particularly those with long fire intervals, typically are found in the interior of the Forest at the highest elevations. Interestingly, infrequent, high-severity fire regimes are often interspersed with frequent, high-severity fire regimes characteristic of grasslands and meadows, particularly in the northern half of the Forest (Fig. M4A-2).

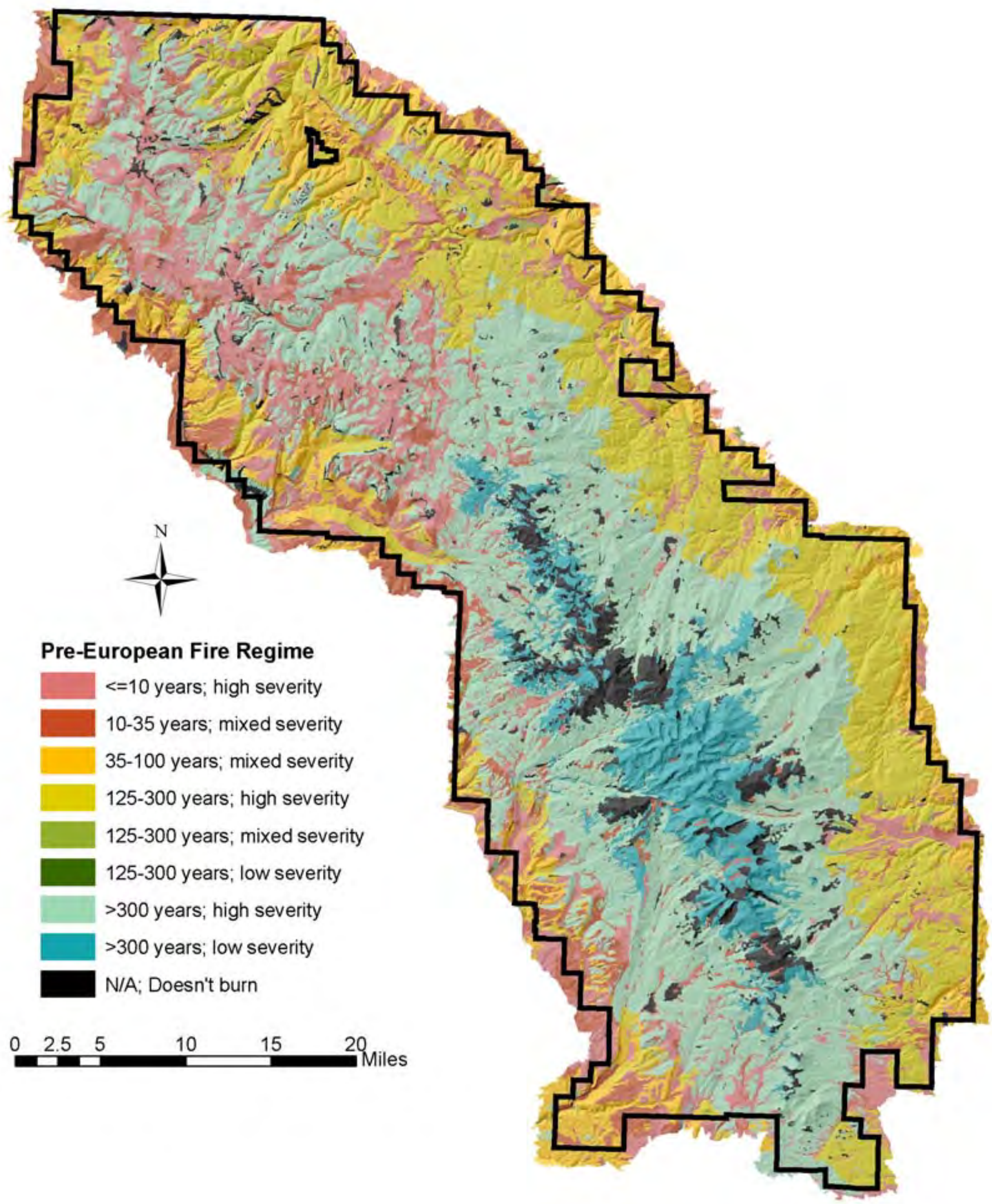


Figure M4A-2. Geographical locations of historical fire regimes within the Bighorn National Forest.

Fire Regimes by Landtype Association

The dominant fire regimes of LTAs differ based on elevation, aspect, and vegetation types within each LTA (Table M4A-2). The Big Horn Mountains, Sedimentary Subsection has 93% of the Douglas fir, 99% of the limber pine, 80% of the ponderosa pine, and 99% of the Juniper vegetation types that occur on the Forest. Starting with the Landtype Associations occupying the highest elevations in this Subsection, the Sedimentary Mountain Slopes, Limestone/Dolomite LTA has three primary fire regimes. They include very frequent (<10 years), high severity (replacement) fire regimes associated with grasslands (28%), infrequent (>300 years), high-severity fire regimes characteristic of spruce/fir forests (23%), and frequent (10 to 35 years), mixed-severity fire regimes typical of sagebrush communities (21%).

At a slightly lower elevation, the Sedimentary Mountain Slopes, Shale/Sandstone (Non-calcareous) LTA exhibits approximately equal areas of very frequent (<10 years), high-severity fire regimes (30%) associated with grasslands and infrequent (>300 years), high-severity fire regimes (26%) characteristic of spruce/fir forests.

Still lower in elevation, Landslide And Colluvial Deposits and Sedimentary Mountain Slopes, Shale/Sandstone (Calcareous) LTAs exhibit both very frequent fire intervals (< 10 years) and high-severity fire regimes associated with grasslands and frequent fire intervals (10 to 35 years) with mixed-severity fire regimes typical of shrublands (mainly sagebrush communities; Table M4A-2). Landslide And Colluvial deposits also exhibit a large component (16%) of Douglas-fir, characterized by 35- to 100-year fire intervals and mixed-severity fires.

The LTA with the lowest elevation, Sedimentary Breaklands, is dominated by frequent (35 to 100 years), mixed-severity fires regimes associated with Douglas-fir forests on south aspects (38%) and 125- to 300-year, high severity fire regimes associated with lower-elevation (<8,000 feet/2,438 m) spruce/fir forests on North aspects (25%).

Similarly, Granitic Breaklands are also dominated by moderate fire intervals (125 to 300 years) and high severity fire regimes in spruce/fir forests that represent 24% of the LTA, and by Douglas-fir forests (19%) and ponderosa pine forests (15%) that are characterized by fire intervals of 35 to 100 years and mixed-severity fires. The Steep, Granitic Mountain Slopes LTA is dominated by fire intervals of 125 to 300 years and high-severity fires characteristic of the lower-elevation spruce/fir forests (37%) and lodgepole pine forests (20%).

Table M4A-2. Dominant fire regimes and associated vegetation types of Landtype Associations (LTAs) on the Bighorn National Forest. Hectares are in parentheses.

LTA	Fire Regime	Vegetation Type	Acres	% of LTA
Sedimentary	35 to 100 years; mixed severity	Douglas-fir	65,127 (26,356)	38.4
Breaklands	125 to 300 years; high severity	Subalpine fir	23,179 (9,380)	13.7
	"	Engelmann spruce	18,395 (7,444)	10.9
Landslide/	≤ 10 years; high severity	Idaho fescue	11,027 (4,462)	28.6
Colluvial	10 to 35 years; mixed severity	Sagebrush	6,203 (2,510)	16.1
Deposits	35 to 100 years; mixed severity	Douglas-fir	5,984 (2,422)	15.5
Sedimentary Mtn	≤ 10 years; high severity	Idaho fescue	55,223 (22,348)	27.7
Slopes, Limestone	> 300 years; high severity	Subalpine fir	46,523 (18,827)	23.3
/Dolomite	10 to 35 years; mixed severity	Sagebrush	41,992 (16,994)	21.0
Sedimentary Mtn	≤ 10 years; high severity	Idaho fescue	15,051 (6,091)	39.3
Slopes, Shale/ Sandstone (Calcareous)	10 to 35 years; mixed severity	Sagebrush	5,135 (2,078)	13.4

Table M4A-2. Dominant fire regimes and associated vegetation types of Landtype Associations (LTAs) on the Bighorn National Forest. Hectares are in parentheses.

LTA	Fire Regime	Vegetation Type	Acres	% of LTA
Sedimentary Mtn Slopes, Shale/Sand-	≤ 10 years; high severity	Idaho fescue	25,522 (10,328)	29.7
Stone (Non-Calcareous)	> 300 years; high severity	Subalpine fir	22,470 (9,093)	26.2
Granitic	125 to 300 years; high severity	Engelmann spruce	9,904 (4,008)	24.0
Breaklands	35 to 100 years; mixed severity	Douglas-fir	8,075 (3,268)	18.7
	"	Ponderosa pine	6,307 (2,552)	14.7
Glacial	> 300 years; mixed severity	Alpine tundra	40,121 (16,236)	62.2
Cirquelands	> 300 years; high severity	Subalpine fir	3,749 (1,517)	5.8
Glacial/Tertiary	> 300 years; high severity	Lodgepole pine	26,139 (10,578)	25.0
Terrace Deposits	"	Subalpine fir	18,432 (7,459)	17.6
	"	Engelmann spruce	18,079 (7,316)	17.3
Granitic Mtn	125 to 300 years; high severity	Engelmann spruce	9,931 (4,019)	23.2
Slopes, Steep	"	Lodgepole pine	8,615 (3,486)	20.1
	"	Subalpine fir	5,985 (2,422)	14.0
Granitic Mtn	> 300 years; high severity	Subalpine fir	66,941 (27,090)	21.2
Slopes, Gentle	> 300 years; high severity	Lodgepole pine	60,062 (24,306)	19.1
	125 to 300 years; high severity	Lodgepole pine	49,921 (20,202)	15.2
Alpine Mountains	> 300 years; high severity	Subalpine fir	48,175 (19,496)	40.0
and Ridges	> 300 years; mixed severity	Alpine tundra	32,882 (13,307)	27.3

Several LTAs, particularly those at higher elevations (>8,000 feet/2438 m), are dominated by long fire intervals (>300 years) and high-severity fires (Table M4A-2). The Glacial and Tertiary Terrace Deposits LTA are dominated by high-elevation spruce/fir forests (35%) and lodgepole pine forests (25%). The Granitic Mountain Slopes, Gentle LTA is also dominated by high-elevation spruce/fir forests (21%) and lodgepole pine forests (19%). Granitic Mountain Slopes, Gentle LTA also include large areas of lower-elevation lodgepole pine forests (15%), characterized by shorter fire intervals (125 to 300 years). Glacial Cirquelands and Alpine Mountain Slopes and Ridges exhibit both high-elevation spruce/fir forests with long fire intervals (> 300 years) and high-severity fires, and alpine tundra with long fire intervals and mixed-severity fires (Table M4A-2). Alpine tundra dominates Glacial Cirquelands, occupying 62% of the LTA with spruce/fir forests as a secondary dominant (6%). In contrast, spruce/fir forests dominate Alpine Mountain Slopes and Ridges (40%), and alpine tundra is a secondary dominant (27%).

20th Century Fire Activity on the Bighorn National Forest

Only 61 large (≥50 acres) fires have occurred on the forest since 1910, totaling approximately 81,252 acres (32,882 ha). This amounts to only 7% of the Forest that has burned in the past 100 years. This is a reasonable amount of fire to expect in a landscape dominated by large, infrequent, high-intensity fires. Moreover, most fires appear to have occurred at lower elevations (Fig. M4A-3), which are more easily accessed by humans and also where fire return intervals are typically shorter. Notably, the largest fires have tended to occur within higher elevation forested ecosystems as compared to low-elevation woodlands and grasslands. Woodlands and grasslands tend to occur on the northwestern and southwestern flanks of the Forest and are characterized by much smaller, more numerous fires (Fig. M4A-3).

Fire activity has been extremely variable by decade (Fig. M4A-4), which suggests the importance of temporal variability in climate in this region, but also highlights the importance of human fire suppression. For example, more fires occurred between 1910 and 1919 (20 large fires) than any other decade in the 20th century, but more acres were burned in the 1920s than any other decade. Notably, a large number of fires were the cause of the large number of acres burned between 1910 and 1919, while far fewer fires (7) burned 25% more area in the 1920s. Similarly, one fire burned 5,936 acres (2,402 ha) in the 1930s, but many smaller fires characterized the 1950s, where 10 fires burned only 755 acres (306 ha; Fig. M4A-4). The effects of fire suppression are most evident between 1950 and 1979. Similar to Yellowstone National Park, fire suppression in the remote areas of the Bighorn National Forest was likely not effective until after World War II when aircraft were available for firefighting (Romme and Despain 1989).

Departures from Historical Fire Regimes on the Existing Landscape

Departures from historical fire regimes were determined by comparing current fire regime data to the last 100 years of large fire history on the Bighorn National Forest. In estimating departures from the historical natural fire regimes, we assumed that current climate and physical conditions are similar to those that existed before Euro-American activities. To estimate departure from historical fire regimes, each point on the Bighorn National Forest was assigned to one of three "Condition Classes" as suggested by Hardy *et al.* (2001):

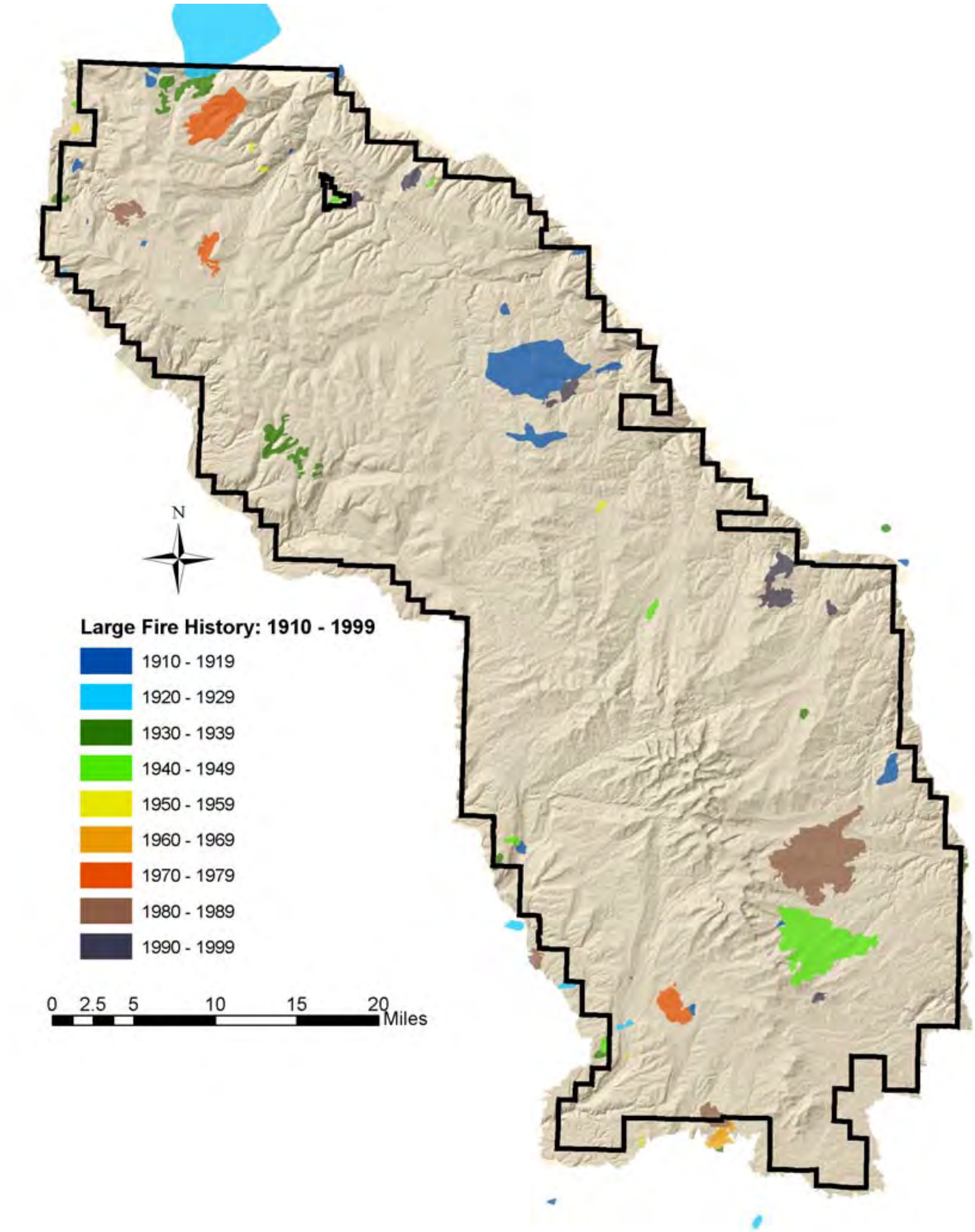


Figure M4A-3. Geographical locations of large fires on the Bighorn National Forest over the past 100 years (1910 –1999).

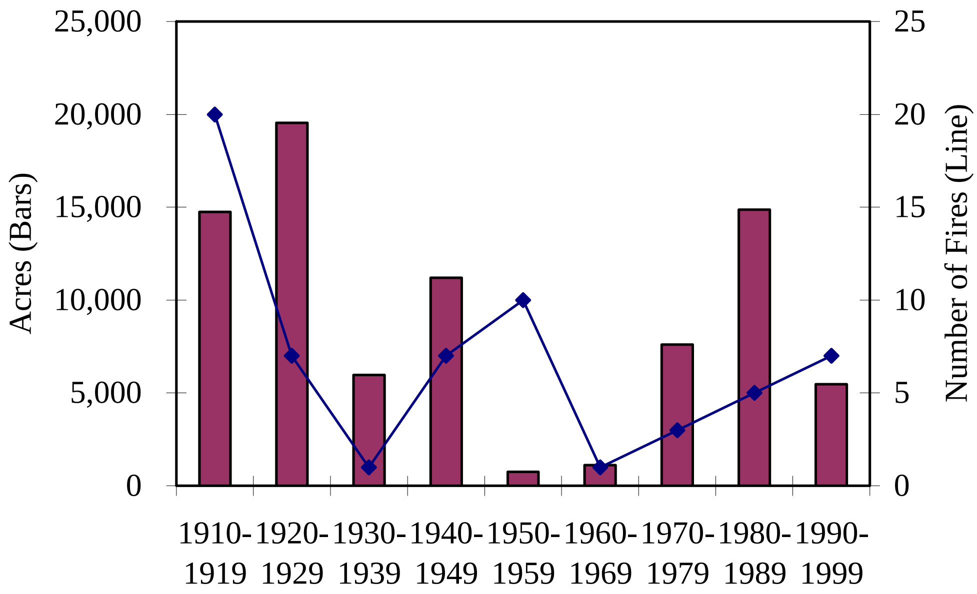


Figure M4A-4. Acres and numbers of large fires on the Bighorn National Forest, 1910-1999.

- Condition Class 1: Little departure from historical disturbance regime. Historical ecosystem attributes of disturbance regimes (patterns and frequencies of insects, disease, and fire), disturbance agents, smoke production, hydrologic function (sedimentation, stream flow, etc.), and vegetative attributes (composition, structure, and resilience to disturbance agents) are largely intact and functioning within a historical range. These areas can be maintained in a natural fire regime by prescribed fire with minimal if any mechanical treatment.

- Condition Class 2: Significant departure from historical disturbance regime. Historical ecosystem attributes have been moderately altered. One or more fire return intervals have been missed, resulting in increased fire sizes, intensities, severities, and coarser landscape patterns, or fire frequencies and intensities have increased due to the introduction and establishment of exotic plant species. These areas may need some mechanical treatments in addition to prescribed fire to be restored to natural fire regimes.

- Condition Class 3: Extreme departure from historical disturbance regime. Ecosystem attributes have been significantly altered. Multiple fire return intervals have been missed, resulting in dramatic departures from historical conditions, or fire frequency and intensities have increased due to the introduction and establishment of exotic plant species. Mechanical treatment must be implemented on these areas before prescribed fire can be introduced.

- Condition Class 0: Not applicable. Cover is rock, water, ice, snow, or bare soil.

Requirements for the assignment of each cover type on the Bighorn National Forest to a given condition class are described in detail in the Protocol.

The majority (62%) of the Bighorn National Forest is classified as Condition Class 1, and shows little or no departure from its historical fire regime (Fig. M4A-5, Table M4A-3). In contrast, 23% exhibits extremes departure from its historical fire regime (Condition Class 3). Only 10% of the Bighorn National Forest exhibits moderate departure from its historical disturbance regime; slightly more than 5% does not burn.

Overall, vegetation types dominated by grasses and forbs or characterized by shrubs or open conditions are those most significantly altered by fire suppression over the last century (Table M4A-3). Grasslands and shrublands are also characterized by the most frequent fire return intervals, such that fire suppression over the last 100 years would have had a significant impact. Of the 364,789 acres (147,625 ha) of grasslands and shrublands on the forest, only 21% are not listed as having extreme departure from their historical disturbance regime; black sagebrush is considered to be only moderately altered, and alpine tundra, which is characterized by an extremely long (>300 years) fire interval, is considered to be relatively unaltered.

Similarly, forested ecosystems on the Bighorn National Forest generally show little departure from their historical fire regimes (Table M4A-3). No forested type with a fire return interval greater than 100 years is classified as anything but Condition Class 1. Three forested types characterized by mixed-intensity fires and return intervals of 35 to 100 years (Douglas-fir, limber pine woodlands, and ponderosa pine) show at least some departure from historical disturbance regimes (Condition Class 2). Nearly 65% of Douglas-fir forests show some departure from historical ranges. Similarly, the disturbance regimes of 76% of limber pine woodlands and 98% of ponderosa pine forests are considered to be moderately altered (Table M4A-3). In general, these forest types all occur at low elevations, and are characterized by fairly short (35 to 100 years) fire return intervals, which are likely to be most affected by 100 years of fire suppression.

Departures from Historical Fire Regimes: LTAs

In general, Calcareous, Shale/Sandstone Sedimentary Mountain Slope and Landslide/Colluvial Deposits LTAs have the highest proportion of vegetated area exhibiting extreme departure from historical fire regimes (Fig. M4A-5). Typically, the vegetation types characterized as Condition Class 3 in these LTAs are grasslands and shrublands; forests typically show only low or moderate departure from historical fire regimes. Glacial/Tertiary Terrace Deposits and Gentle, Granitic Mountain Slopes LTAs also have large proportions of vegetation with extreme departure from historical fire regimes, but also have relatively high proportions of vegetated areas classified as having little departure from their historical fire regimes (Condition Class 1). Sedimentary Breaklands and Granitic Breaklands LTAs exhibit high proportions of area in Condition Class 2 and also exhibit high proportions of area in Condition Class 1, although both condition classes are dominated by forests in these LTAs. The remaining LTAs, including Limestone/Dolomite Sedimentary Mountain Slopes, Granitic Mountain Slopes Steep, Granitic Mountain Slopes Gentle, Glacial Cirquelands, and Alpine Mountain Slopes And Ridges, each are dominated by Condition Class 1, all of which feature forests as the main vegetation type.

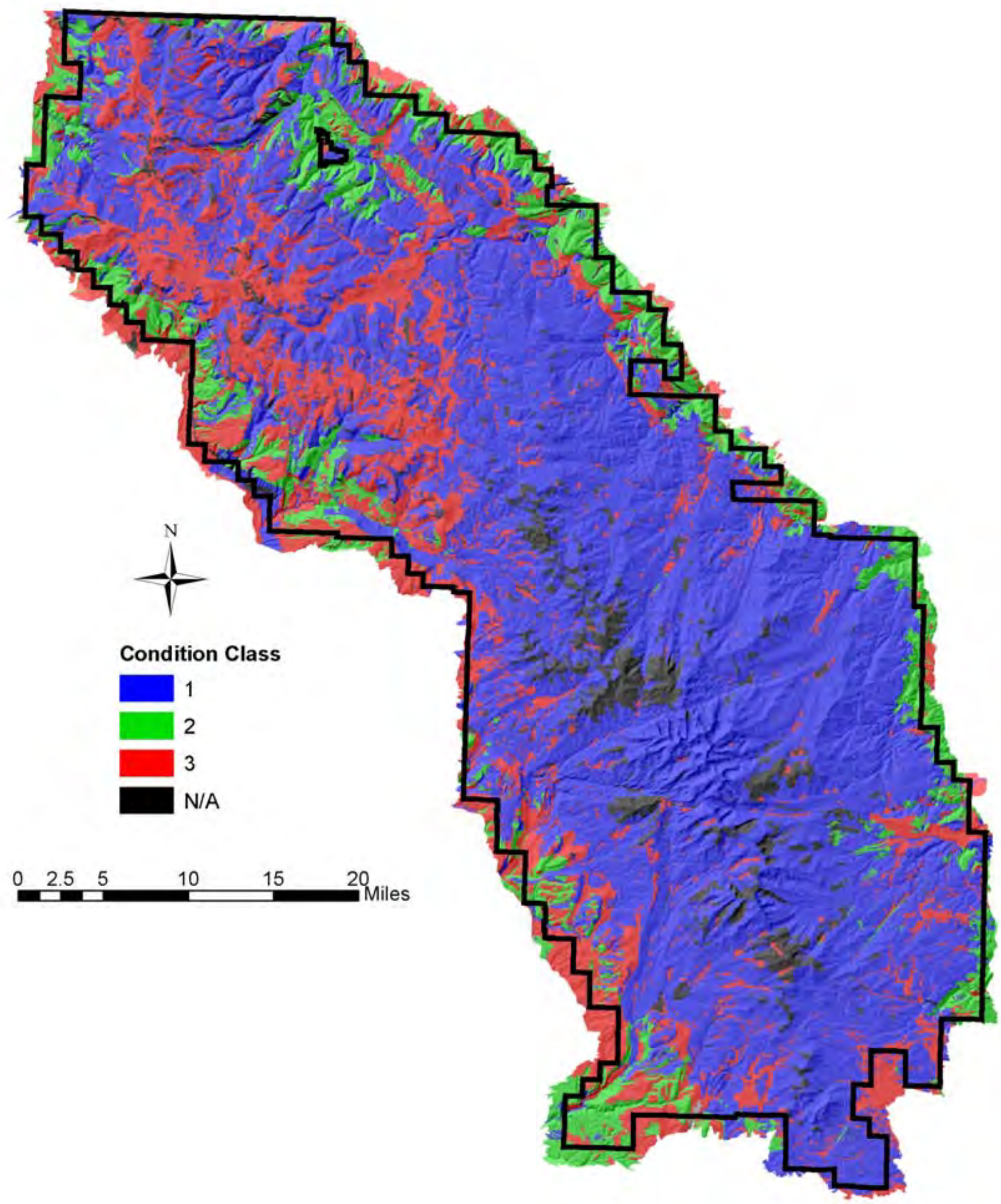


Figure M4A-5. Spatial locations of ecosystems with altered disturbance regimes on the Bighorn National Forest.

Table M4A-3. Assignment of vegetation cover types (PNV) to condition classes to estimate departures from historical fire regimes.

Potential Natural Vegetation (PNV) Cover	Assigned Fire Regime	Assigned Condition Class
Grassland/Meadows		
Alpine tundra	> 300 years; low intensity	1
Bluebunch wheatgrass	≤ 10 years; low intensity	3
Idaho fescue	≤ 10 years; low intensity	3
Little bluestem	≤ 10 years; low intensity	3
Shrubland		
Black sagebrush	10 to 35 years; mixed intensity	2
Grass & Shrub riparian	10 to 35 years; mixed intensity	3
Greasewood	10 to 35 years; mixed intensity	3
Mixed deciduous shrub	10 to 35 years; mixed intensity	3
Mountain mahogany	10 to 35 years; mixed intensity	3
Mountain sagebrush	10 to 35 years; mixed intensity	3
Sagebrush	10 to 35 years; mixed intensity	3
Wyoming sagebrush	10 to 35 years; mixed intensity	3
Forests		
Aspen	125 to 300 years; mixed intensity	1
Cottonwood	125 to 300 years; low intensity	1
Douglas-fir	35 to 100 years; mixed intensity	1-2
Juniper woodland	> 300 years; high intensity	1
Limber pine woodland	35 to 100 years; mixed intensity	1-2
Lodgepole pine (> 8,000 feet)	> 300 years; high intensity	1
Lodgepole pine (< 8,000 feet)	125 to 300 years; high intensity	1
Ponderosa pine	35 to 100 years; mixed intensity	1-2
Spruce (> 8,000 feet)	> 300 years; high intensity	1
Spruce (< 8,000 feet)	125 to 300 years; high intensity	1
Subalpine fir (> 8,000 feet)	> 300 years; high intensity	1
Subalpine fir (< 8,000 feet)	125 to 300 years; high intensity	1
Other		
Alpine rock	N/A; Doesn't burn	0
Ice/snow/water	N/A; Doesn't burn	0
Rock outcrop/bare soil	N/A; Doesn't burn	0

Several LTAs have large proportions of broad vegetation types that exhibit extreme departure from their historical fire regimes, and in most cases the major vegetation types are grasslands and shrublands (Fig. M4A-6; Table M4A-4). In particular, within landslide/colluvial deposits, 14,834 acres (6,003 ha) of grasslands (representing 46% of the total LTA) are classified into Condition Class 3; similarly, 45% of grasslands in calcareous shale/sandstone mountain slopes, 32% of grasslands in non-calcareous shale/sandstone mountain slopes, and 20% of grasslands in glacial tertiary terrace deposits all are classified as Condition Class 3. Limestone/dolomite sedimentary mountain slopes have 20% of shrubland as well as 29% of grassland classified as having extreme departure from their historical fire regimes (Table M4A-4).

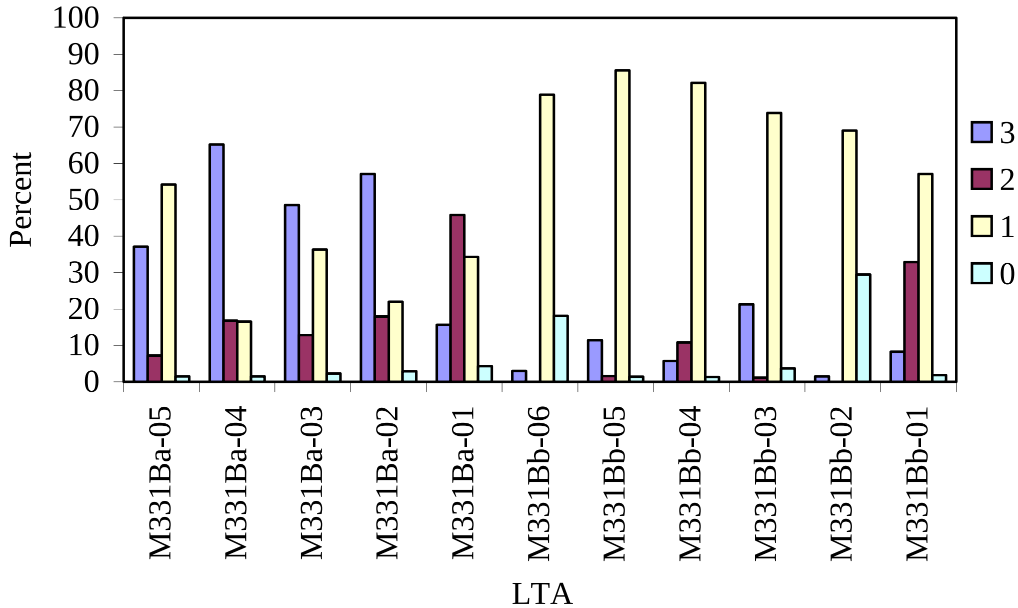


Figure M4A-6. Proportion of Landtype Associations (LTAs) in each condition class as a measure of departure from historical fire regimes on the Bighorn National Forest.

Table M4A-4. Area (acres) of dominant vegetation types in each condition class by LTA as a measure of departure from historical disturbance regimes. Percentage of total LTA is shown in parentheses.

LTA	Vegetation Type	Class 3	Class 2	Class 1
Sedimentary	Grassland	13,450 (8)	0	43 (< 1)
Breaklands	Shrubland	13,077 (8)	1,041 (1)	36 (< 1)
	Forest	0	76,673 (45)	58,055 (34)
Landslide/Colluvial	Grassland	14,834 (46)	18 (< 1)	38 (<1)
Deposits	Shrubland	970 (3)	63 (< 1)	0
	Forest	0	6,840 (26)	8,447 (26)
Sedimentary	Grassland	56,936 (29)	358 (< 1)	548 (< 1)
Mountain Slopes,	Shrubland	40,096 (20)	2,959 (1)	706 (< 1)
Limestone/Dolomite	Forest	0	22,260 (11)	71,210 (36)
Sedimentary Mtn	Grassland	17,354 (45)	0	0
Slopes, Shale/	Shrubland	7,640 (2)	74 (< 1)	216 (1)
Sandstone (Calcareous)	Forest	0	6,355 (17)	6,108 (16)
Sedimentary Mtn	Grassland	27,433 (32)	70 (< 1)	1,164 (1)
Slopes, Shale/	Shrubland	4,330 (5)	0	52 (< 1)
Sandstone (Non-Calcareous)	Forest	0	6,145 (7)	45,225 (53)
Granitic	Grassland	2,511 (6)	10 (< 1)	106 (< 1)
Breaklands	Shrubland	1,037 (2)	1 (< 1)	0
	Forest	0	14,109 (33)	24,414 (57)
Glacial	Grassland	945 (1)	0	40,122 (62)
Cirquelands	Shrubland	45 (< 1)	0	0
	Forest	0	0	4,351 (7)
Glacial/Tertiary	Grassland	21,076 (20)	734 (1)	1,413 (1)
Terrace Deposits	Shrubland	1,193 (1)	0	0
	Forest	0	482 (1)	75,824 (72)
Granitic Mtn	Grassland	1,819 (5)	4 (< 1)	9 (< 1)
Slopes, Steep	Shrubland	645 (2)	0	0
	Forest	0	4,611 (11)	34,934 (82)
Granitic Mtn	Grassland	33,324 (11)	1,366 (< 1)	5,531 (2)
Slopes, Gentle	Shrubland	2,534 (1)	91 (< 1)	29 (< 1)
	Forest	0	3,638 (1)	263,437 (84)
Alpine Mountains	Grassland	3,541 (3)	1 (< 1)	32,886 (27)
And Ridges	Shrubland	73 (< 1)	0	0
	Forest	0	0	61,992 (52)

Current Wildfire Hazard on the Bighorn National Forest

Wildfire hazard was mapped across the Bighorn National Forest using the methodology of Romme *et al*. (2001). A GIS-based model called BEHAVE was used to analyze data layers to predict total potential heat release, rate of fire spread, and flame length under 90th percentile weather conditions. Wildfire hazard for each point on the Forest was calculated. Specific parameters for 90th percentile weather conditions are described in detail in the Protocol.

Approximately half of the Forest has a moderate hazard of wildfire (Fig. M4A-7). Most of the area with high wildfire hazard is found at low elevations, only about 13% are found at middle elevations. Twenty-two Percent of the Forest is at low wildfire hazard (Fig. M4A-7).

Seventy-eight percent of grasslands exhibit high wildfire hazard, 21% of grasslands have moderate wildfire hazard, while none have low hazard. For shrublands, 96% exhibit moderate wildfire hazard, 4% exhibit have high hazard, and none exhibit low hazard. For forests, wildfire hazard generally decreases, with only 3% of the forested areas having high wildfire hazard, 61% exhibit moderate hazard, and 37% having low hazard. The area with high wildfire hazard is dominated by grassland types (Fig. M4A-7), which represent 87% of all the area having high wildfire hazard. Most of the forested area with high wildfire hazard includes lodgepole pine, (64% of the high-hazard forested area) and spruce/fir forests (30%). Vegetation types having moderate wildfire hazard are dominated by forests (74%). Once again, lodgepole pine (58%) and spruce/fir (29%) represent the majority of the forested area.

Finally, forests represent all of the low hazard area and the forests are dominated by lodgepole pine (50%) and spruce/fir (21%) forests, but Douglas-fir forests also represent an important component (18%).

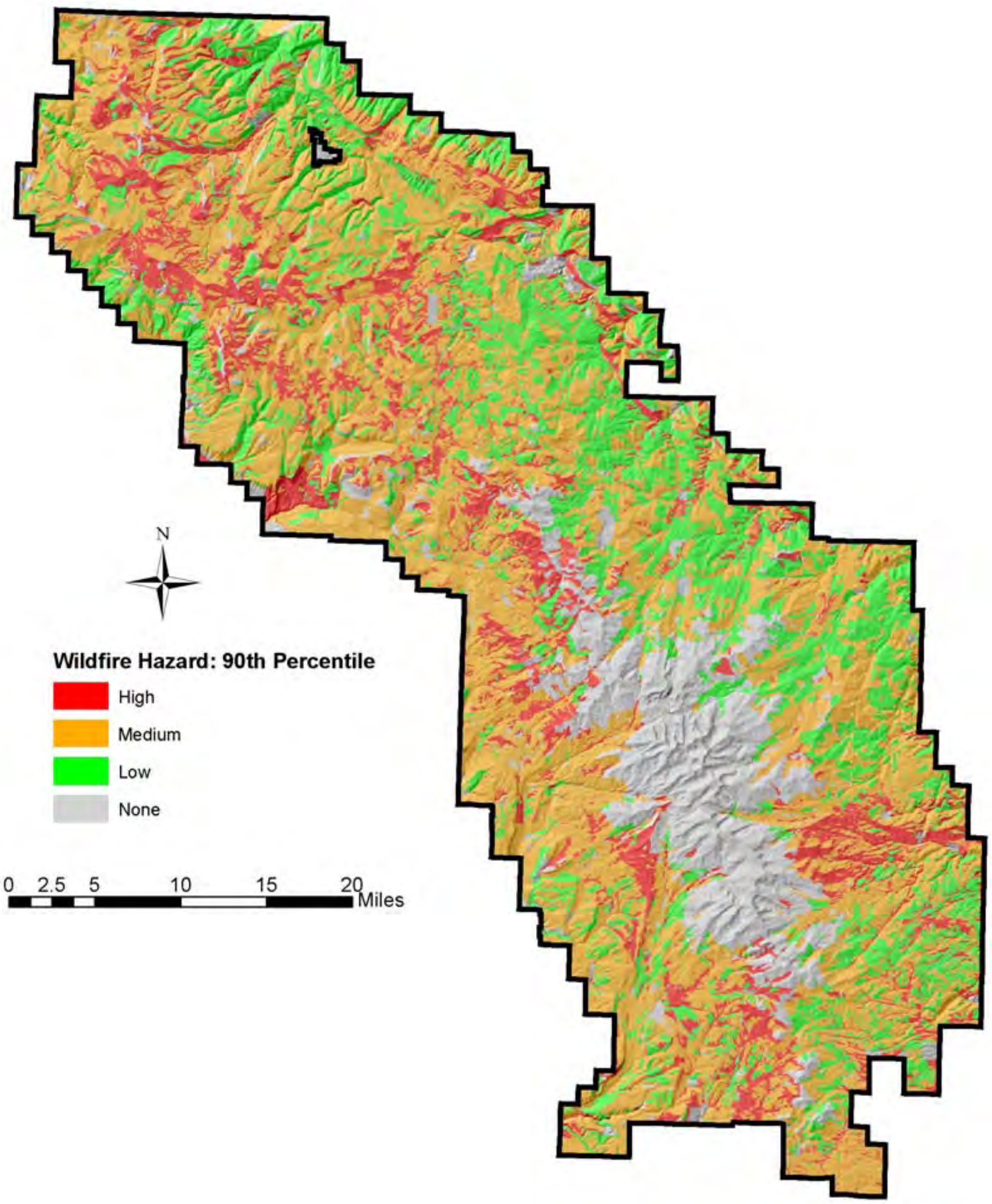


Figure M4A-7. Wildfire hazard for the Bighorn National Forest under 90th percentile weather conditions.

Current Wildfire Hazard: LTAs

Under 90th percentile weather conditions, grasslands occupy the highest proportion of vegetated area across all LTAs having high wildfire hazard (Fig. M4A-8a). Sedimentary Mountain Slopes, Limestone/dolomite (M3331 Ba-03), Gentle Granitic Mountain Slopes (M3331 Bb-05), and Alpine Mountain Slopes and Ridges (M3331 Bb-06) exhibit the most acreage of grasslands having high wildfire hazard under average conditions; Landslide/Colluvial Deposits (M3331 Ba-02, 33%), Sedimentary Mountain Slopes, Shale/Sandstone (calcareous) (M3331 Ba-04, 32%), and Sedimentary Mountain Slopes, Shale/sandstone (non-calcareous) (M3331 Ba-05, 21%) exhibited the highest proportions of vegetated area at high risk of wildfire, all in grasslands (Fig. M4A-8a). However, Glacial/Tertiary Terrace Deposits (M3331 Bb-03) and Gentle Granitic Mountain Slopes (M3331 Bb-05) also include a relatively high area of forest with high hazard under average conditions, mostly as high-elevation lodgepole pine and spruce/fir forests.

Forests and shrublands are more commonly at moderate to low risk of wildfire (Fig. M4A-8b). Gentle Granitic Mountain Slopes and Ridges (M331Bb-06) by far have the greatest area of forest at moderate and low wildfire hazard, and Sedimentary Mountain Slopes, Limestone/dolomite (M331Ba-03) have the highest area of shrubland with moderate hazard.

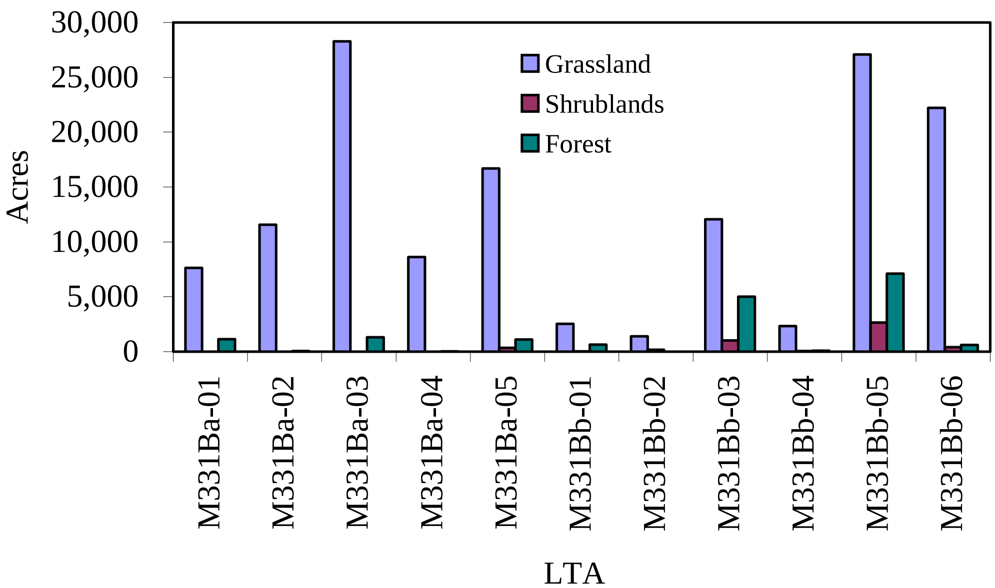


Figure M4A-8a. Acreage of high wildfire hazard within Landtype Associations (LTAs)

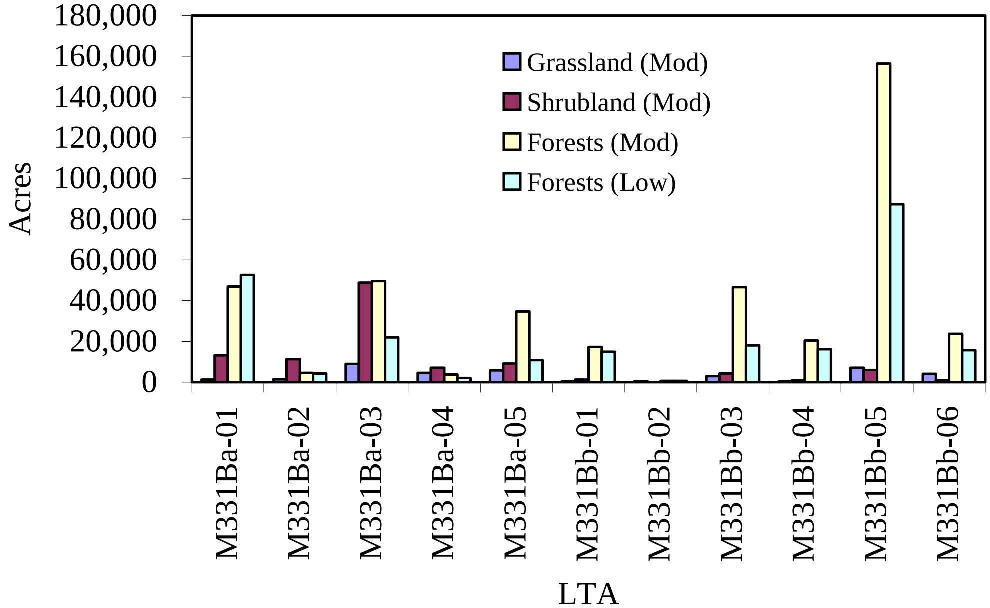


Figure M4A-8b. Acreage of moderate and low wildfire hazard within Landtype Associations (LTAs).

Current Wildfire Hazard: FPWSs

Under 90th percentile weather conditions, grasslands occupy the highest proportion of vegetated area across all FPWS having high wildfire hazard (Fig. M4A-9a). Goose Creek contains the most acreage of grasslands having high hazard, a cover type, which represents 54% of the unit. Similarly, Tongue River (17% of the unit), Shell Creek (4%), and Little Big Horn(7%) contain higher areas of high-hazard grasslands than any other units under average conditions. Notably, Clear/Crazy Woman Creek contains a significant amount of forest considered to have high wildfire hazard, though it represents only 3% of the unit. Most of this high-hazard forest is spruce/fir and lodgepole pine.

Grasslands are commonly at moderate to low risk of wildfire under average 90th percentile weather conditions (Fig. M4A-9b). Forty-five percent of Shell Creek exhibits shrubland having moderate wildfire hazard. Devil's Canyon also has a relatively high amount of shrubland with moderate hazard (60%). Clear/Crazy Woman Creek has a higher area of forest with moderate hazard than any other unit (almost 72% of the unit). Little Big Horn has a large amount of forest (70%) with low wildfire hazard.

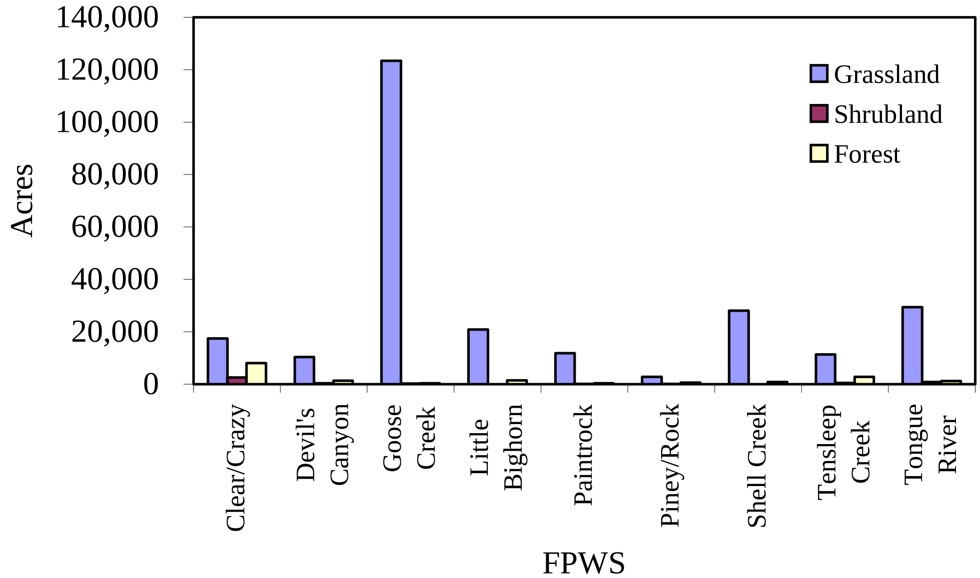


Figure M4A-9a. Acreage of high wildfire hazard with in FPWSs.

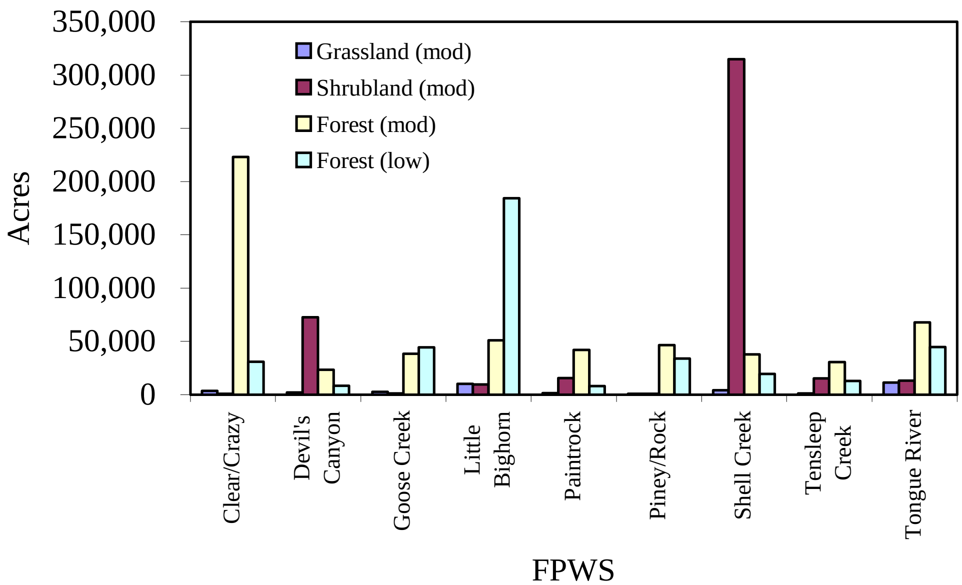


Figure M4A-9b. Acreage of moderate and low wildfire hazard with in FPWSs.

.

Wildfire Probability on the Bighorn National Forest

Probability of wildfire occurring at any location on the Bighorn National Forest within the next 10 years was calculated from modern fire records on the Forest between 1980 and 1998. The accuracy of these predictions will depend on the similarity between weather, fuel conditions, and fire starts between the two periods.

Elevation was used as a proxy to separate short- and long-interval fire regimes because data on area burned was not available. High-elevation forests are considered more mesic, retain snow cover longer into the spring, receive snow cover earlier in the fall, are characterized by cooler temperatures and higher precipitation, and generally have longer fire return intervals. An elevation of 8,000 feet (2,438 m) was used to separate long (high elevation) and short (low elevation) fire intervals. Note that the wildfire hazard results do not consider the lower probability of severe fire weather conditions at high elevations.

Wildfires smaller than 2,500 acres (1,012 ha) are a virtual certainty to occur on the forest, regardless of elevation, within the next 10 years (Table M4A-5). Fires of this size are more probable at higher elevations than at lower elevations, likely because of the differences in vegetation types. Fires larger than 5,000 acres (2,023 ha) are far less likely to occur at higher elevations than at lower elevations, however, and this again is likely a result of differences in vegetation, where forests likely to sustain large crown fires (mainly lodgepole pine and spruce/fir forests) occur at higher elevations. Very large fires (50,000 acres/20,234 ha) are not likely on the Bighorn National Forest, regardless of elevation.

Table M4A-5. Probability of wildfires of varying size above and below 8,000 feet (2,438 m) on the Bighorn National Forest.

Fire Size (acres; hectares in parenthesis)	Probability at >8,000 feet	Probability at <8,000 feet
10 (4)	1.00	1.00
100 (40)	1.00	1.00
500 (202)	1.00	0.99
1,000 (405)	0.99	0.95
2,500 (1,012)	0.90	0.88
5,000 (2,023)	0.61	0.86
10,000 (4,047)	0.45	0.86
15,000 (6,070)	0.45	0.86
25,000 (10,117)	0.12	0.59
50,000 (20,234)	0.01	0.14

Insect Disturbances in Forests on the Bighorn Landscape

Although fire is the predominant natural disturbance in the Rocky Mountains, insects cause more tree mortality each year in the United States than any other single factor (Sharpe *et al.* 1986). Indeed, mortality of trees due to insects has been an important form of natural disturbance in the Rocky Mountains, especially in spruce/fir, lodgepole pine, and ponderosa pine forests (Meyer and Knight 2003). Because relatively few studies have investigated the influence of insects on shaping the landscape of the Big Horn Mountains, this section will mainly discuss recent insect damage to the Forest, as well as risks of future insect outbreaks.

Several insects have significantly influenced the vegetation of the Bighorn National Forest, including the mountain pine beetle (*Dendroctonus ponderosae*) and the spruce beetle (*Dendroctonus rufipennis*), although their influence has not been widespread in the last 100 years (Meyer and Knight 2003). Other less important insects in high-elevation forests include the western bark beetle (*Dryocoetes confuses*), the Pandora moth (*Coloradia pandora*), and the western spruce budworm (*Choristoneura occidentalis*). In lower-elevation forests, in addition to mountain pine beetle and spruce beetle, the Douglas-fir beetle (*Dendroctonus psuedotsugae*) has a scattered but minor presence on the Bighorn National Forest. Finally, the scattered aspen stands on the Forest are also subject to the forest tent caterpillar (*Malacosoma disstria*) and the large aspen tortrix (*Choristoneura conflicta*), but the limited distribution of aspen limits the importance of these insects. Because of their dominant effects on the forests of the Bighorns, this section will primarily discuss the effects of bark beetles, particularly the mountain pine beetle and the spruce beetle.

Recent Insect Activity on the Bighorn National Forest

During the single growing season of 2001, approximately 52,255 acres (21,147 ha) were damaged by insects. Of this area, forests were most affected (86% of the area affected); grasslands (9%) and shrublands (3%) represented only minor components of the area affected. Spruce/fir forests received the majority of the insect damage (69% of the forested area), and lodgepole pine forests were the major secondary forest type affected (18%; Fig. M4A-10). The spatial distribution of insect damage on the forest reflects this near-restriction to spruce/fir and lodgepole pine forests (Fig. M4A-11). Such a result is not surprising, given that spruce, fir, and/or lodgepole pine are the primary hosts of the mountain pine beetle and/or the spruce beetle (Meyer and Knight 2003). Douglas-fir forests represented 9% of the affected area, and ponderosa pine forests, although they are relatively limited on the forest, represented 3%. Other forest types, such as juniper woodlands, limber pine woodlands, aspen forests, and cottonwood stands represent only minor portions (< 1%) of the forested area damaged by insects (Fig. M4A-10).

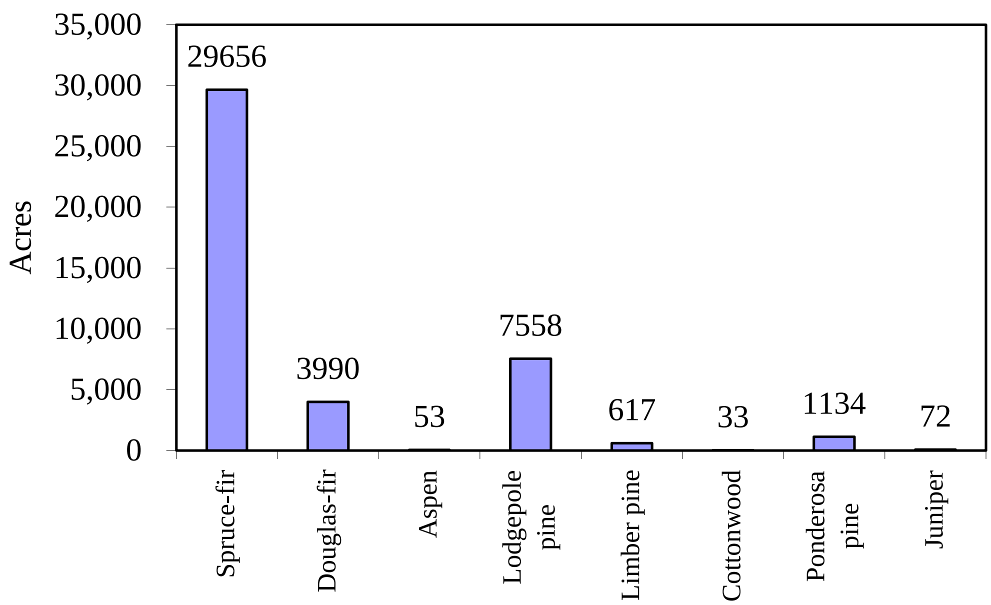


Figure M4A-10. Area of forest cover types with insect damage in 2001. Forests represented 86% of the area affected by insects in 2001 (based on CVU data).

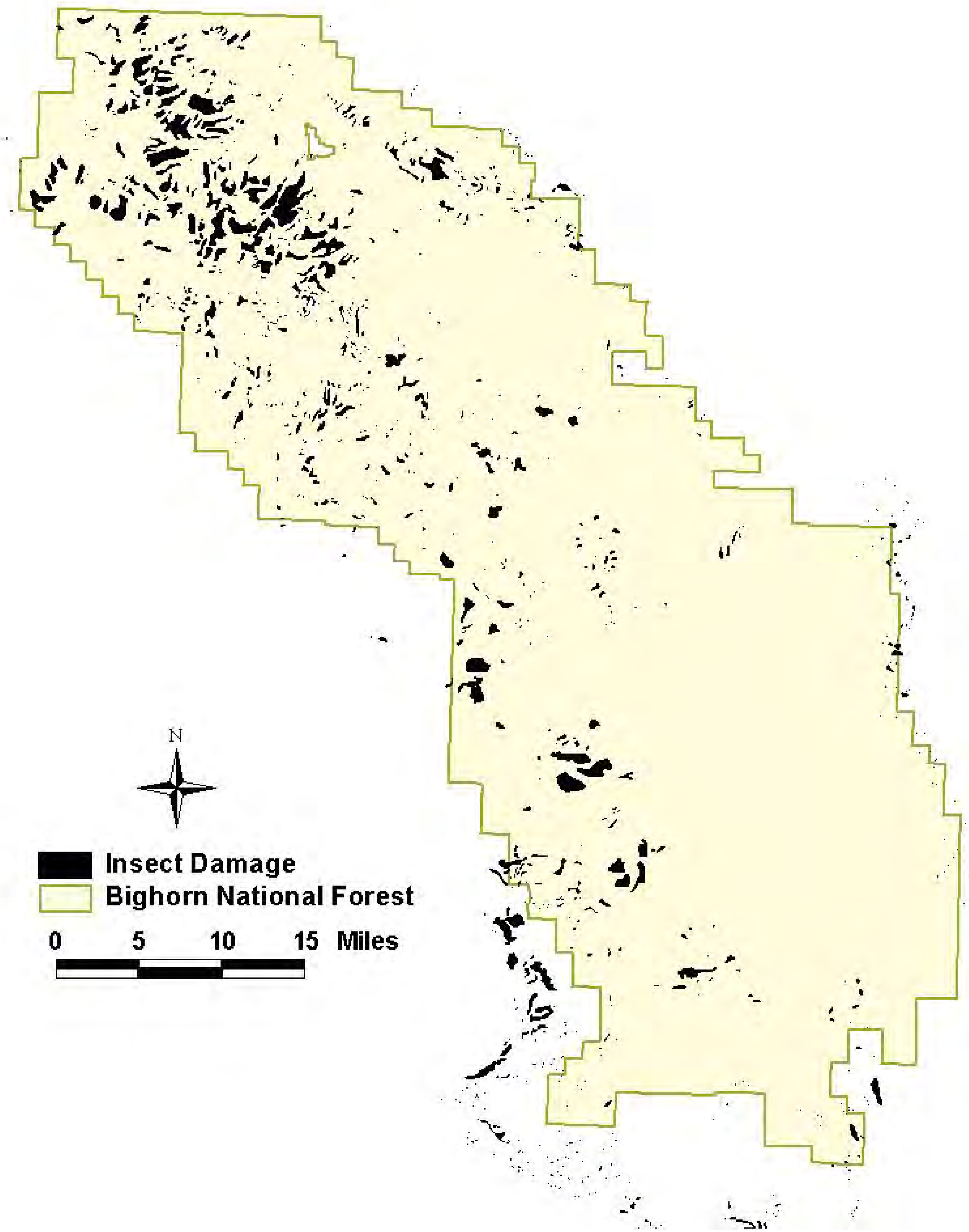


Figure M4A-11. Insect damage to forests of the Bighorn National Forest in 2001.

Recent Insect Activity with in LTAs

Every LTA except Glacial Cirquelands (M331 Bb-02) received insect damage in 2001 (Fig. M4A-12). Sedimentary Mountain Slopes, Limestone/dolomite (M331 Ba-03) exhibited the highest area of insect damage, but significant insect damage also occurred in Gentle Granitic Mountain Slopes (M331 Bb-05), Sedimentary Mountain Slopes, Shale/Sandstone (non-calcareous; M331 Ba-05), and Sedimentary Breaklands (M331 Ba-01). As before, the forest cover type received the most damage in all LTAs (Fig. M4A-12).

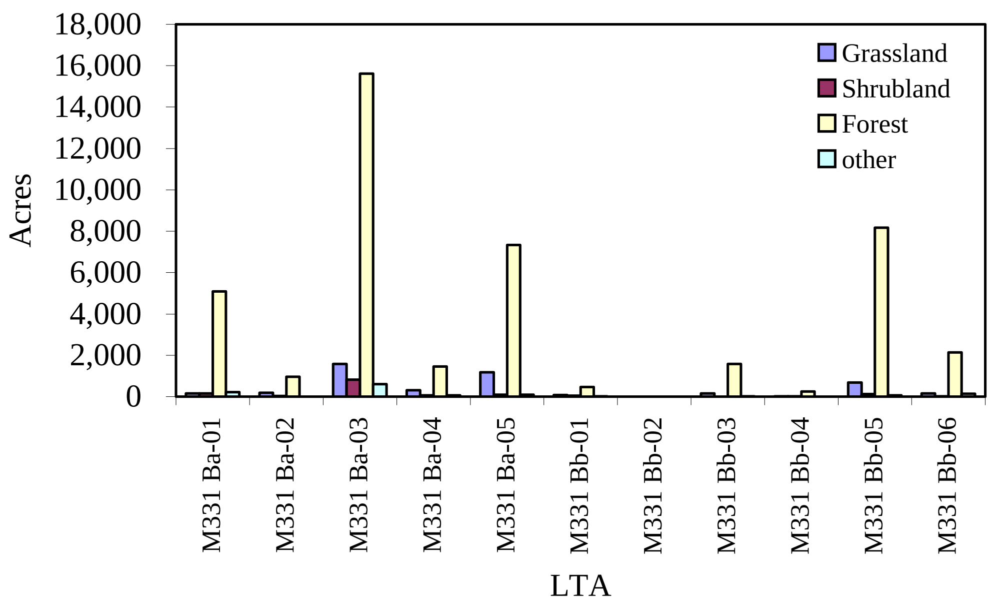


Figure M4A-12. Area of insect activity in 2001 by Landtype Associations (LTAs) on the Bighorn National Forest.

In almost all cases, spruce/fir forest was an important forest type affected by insects in each LTA. Spruce/fir forest was the primary forest affected by insects in landslide/colluvial deposits, limestone/dolomite sedimentary mountain slopes, calcareous shale/sandstone sedimentary mountain slopes, non-calcareous shale/sandstone sedimentary mountain, granitic breaklands, gentle granitic mountain slopes, and alpine mountain slopes and ridges. Lodgepole pine forest represented an important component in limestone/dolomite sedimentary mountain slopes, glacial/tertiary terrace deposits, steep granitic mountain slopes, gentle granitic mountain slopes, and alpine slopes and ridges. Notably, Douglas-fir forest was an important component of land damaged by insects in sedimentary breaklands, limestone/dolomite sedimentary mountain slopes, and was a dominant component in steep granitic mountain slopes.

Recent Insect Activity with in FPWS

All FPWS suffered insect damage during 2001 (Fig. M4A-13). Little Big Horn had the highest area of insect damage, but significant insect damage also occurred in Paintrock Creek, Shell Creek, and Devil's Canyon. As with LTAs, forests received the most damage in all FPWS; over 80% of Little Big Horn had insect-damaged forest. Tongue River had 90%, Paintrock Creek 91%, Shell Creek 87%, and Devil's Canyon 83% (Fig. M4A-13).

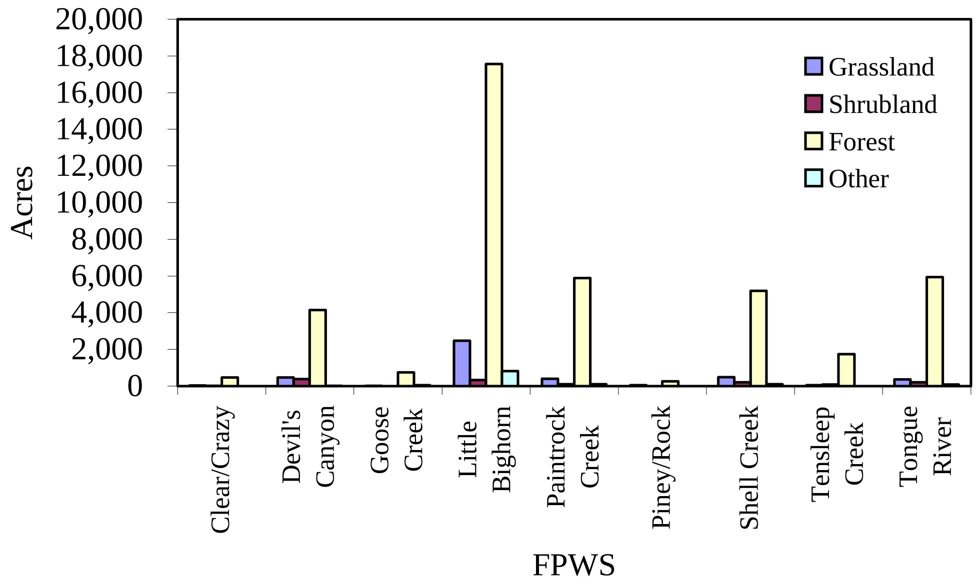


Figure M4A-13. Area of insect activity in 2001 by FPWS on the Bighorn National Forest.

Spruce/fir forest was an important forest type affected by insects in most FPWS. Spruce/fir forest was the primary forest affected by insects in Devil's Canyon, Little Bighorn, Shell Creek), and Tongue River, and was a significant component in Goose Creek, Paintrock Creek, and Tensleep Creek. Lodgepole pine forest was the dominant forest type damaged by insects at Clear/Crazy Woman Creek and Tensleep Creek, and represented an important component at Devil's Canyon, Goose Creek, Paintrock Creek, and Tongue River. Douglas-fir forest was an important component damaged by insects at Devil's Canyon and Shell Creek, and ponderosa pine forest was the dominant forest type suffering damage at Piney/Rock Creek.

Areas at Risk of Insect Damage on the Bighorn National Forest

Habitat Structural Stages were used to create a coarse rating system for estimating risk of insect damage by bark beetles. Since most bark beetle rating systems are based on stand age, average diameter, stand density index, basal area, or combinations thereof, it was assumed that habitat structural stages may approximate these characteristics.

Estimation of risk based on Habitat Structural Stages was specific to forest type. For spruce/fir, Douglas-fir, and lodgepole pine, all acres in Habitat Structural Stage 4 (4A, 4B, and 4C) are considered to be at high risk of insect damage, while all other stages are considered to be at low risk. For ponderosa pine forests and limber pine woodlands, all acres in Habitat Structural Stages 3B, 3C, 4B, and 4C are considered to be at high risk, and all others at low risk.

Using these criteria, 63% of the forest is at low risk to insect damage (Fig. M4A-14). Ponderosa pine forests appear to be at the highest risk of insect damage, with nearly 86% of its total area at high risk. Limber pine is also at a significantly risk to insect damage, with 59% at high risk. The much more extensive lodgepole pine, spruce/fir, and Douglas-fir forests show comparatively smaller proportions at high risk to insect damage (25, 46, and 39%, respectively).

Insect Damage Risk within LTAs

A relatively high proportion (71 to 91%) of ponderosa pine is at high risk to insect damage across all LTAs (Table M4A-6), particularly granitic breaklands (M331 Bb-01), sedimentary breaklands (M331 Ba-01), and non-calcareous shale/sandstone sedimentary mountain slopes (M331 Ba-05). Moderate proportions (37 to 64 %) of limber pine are at high risk across most LTAs, but the highest proportions occur in sedimentary breaklands, and granitic breaklands (Table M4A-6). Moderate proportions of spruce/fir (32 to 63%) are also at high risk across most LTAs, with the highest proportions in steep granitic mountain slopes (M331 Ba-04), landslide/colluvial deposits (M331 Ba-02), and granitic breaklands. Similarly, only moderate proportions (26 to 74 %) of Douglas-fir forests are at high risk in most LTAs, with the highest proportions in glacial/tertiary terrace deposits (M331 Bb-03) and gentle granitic mountain slopes (M331 Bb-05). Surprisingly, relatively low proportions of lodgepole pine forests (14 to 45%) are considered to be at high risk for insect damage (Table M4A-6).

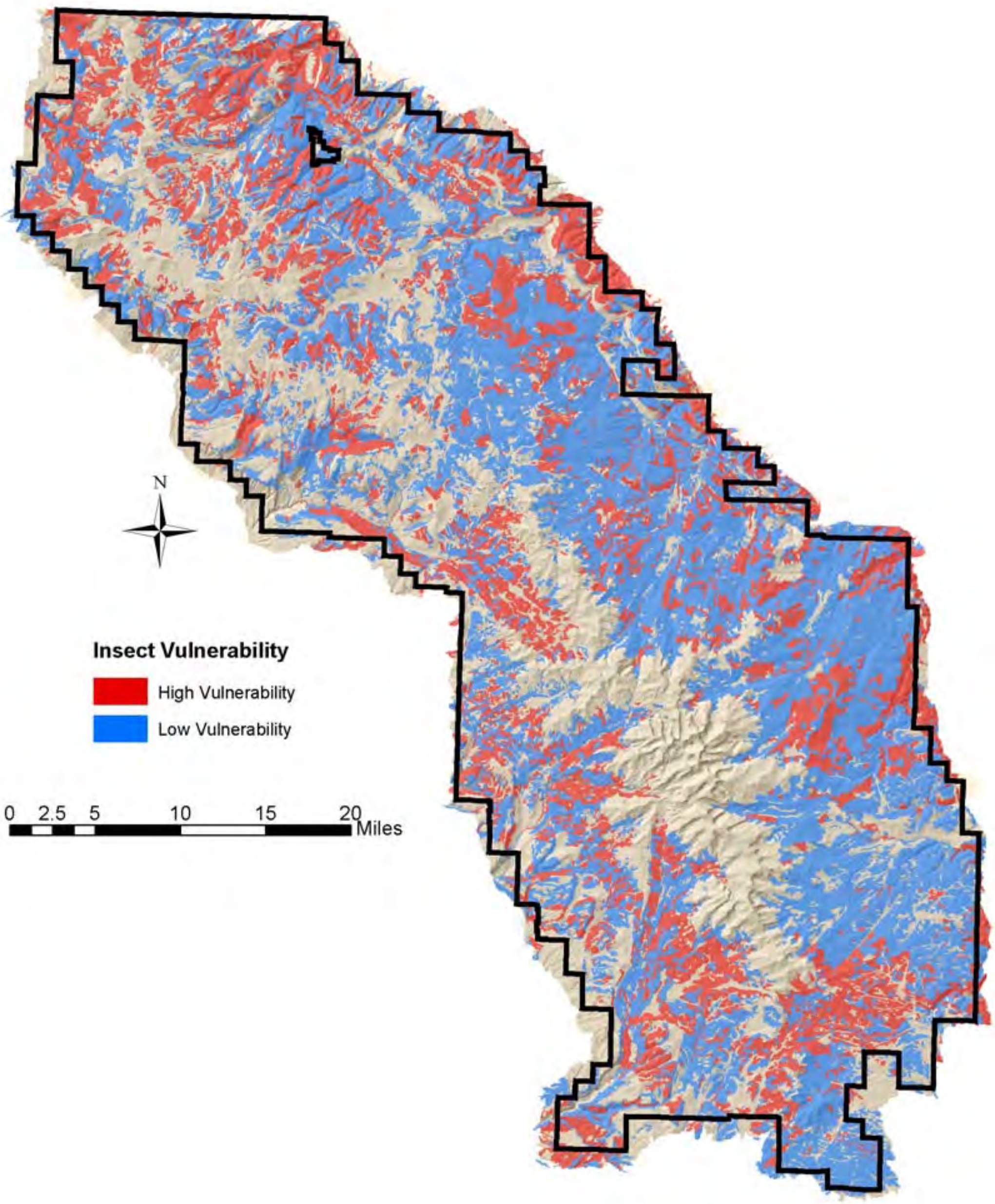


Figure M4A-14. Estimated vulnerability of insect damage to forests of the Bighorn National Forest.

Table M4A-6. Area (acres) of forest types at high risk to insect damage by LTA. Percentage of the area of each type for that LTA is in parentheses.

LTA	Douglas-fir	Lodgepole	Spruce/Fir	Ponderosa	Limber
Sedimentary Breaklands	27,518 (38)	997 (22)	11,237 (52)	17,473 (90)	6,762 (64)
Landslide/Colluvial Deposits	1,689 (31)	234 (45)	2,579 (59)	440 (79)	504 (37)
Sedimentary Mtn Slopes, Limestone/Dolomite	8,727 (43)	3,090 (31)	24,705 (49)	3,464 (76)	1,591 (54)
Sedimentary Mtn Slopes, Shale/ Sandstone (Calcareous)	544 (26)	226 (26)	2,139 (63)	2,719 (74)	373 (49)
Sedimentary Mtn Slopes, Shale/Sandstone (Non-Calcareous)	2,048 (46)	4,978 (26)	12,520 (53)	925 (88)	139 (42)
Granitic Breaklands	2,676 (46)	4,791 (23)	2,756 (58)	4,525 (91)	122 (59)
Glacial Cirquelands	0	0	542 (14)	0	0
Glacial/Tertiary Terrace Deposits	503 (74)	14,562 (25)	7,959 (54)	46 (71)	0
Granitic Mtn Slopes, Steep	268 (38)	4,698 (14)	1,785 (49)	1,415 (81)	0
Granitic Mtn Slopes, Gentle	171 (64)	54,130 (27)	26,723 (47)	266 (77)	2 (100)
Alpine Mtn And Ridges	0	2,721 (23)	15,679 (32)	0	0

Table M4A-7. Area of forest types at high risk to insect damage by FPWS. Percentage of the area of each type for that FPWS is in parentheses; total is total acres of high risk for the FPWS.

FPWS	Douglas-fir	Lodgepole Pine	Spruce/Fir	Ponderosa Pine	Limber Pine	Total
Crazy/Clear	95 (29)	19,727 (22)	7,133 (40)	1,899 (85)	0	28,854
Devil's Canyon	7,107 (53)	3,400 (75)	9,057 (54)	0	233 (72)	19,797
Goose Creek	1,195 (32)	13,229 (21)	7,422 (31)	1,213 (89)	1,027 (74)	24,086
Little Big Horn	11,563 (38)	3,187 (28)	26,044 (59)	2,028 (90)	4,225 (62)	47,046
Paintrock Creek	3,592 (42)	7,688 (32)	10,637 (51)	0	579 (46)	22,496
Piney/Rock	550 (50)	11,965 (21)	8,763 (38)	4,027 (93)	18 (61)	25,323
Shell Creek	9,032 (37)	4,485 (38)	15,661 (59)	0	573 (32)	29,750
Tensleep Creek	3,825 (38)	9,707 (36)	8,557 (57)	2,496 (91)	577 (83)	25,162
Tongue River	2,948 (36)	14,883 (25)	14,684 (32)	4,863 (84)	1,103 (57)	38,480

Across all FPWS, a high proportion (84 to 93%) of ponderosa pine is at high risk to insect damage (Table M4A-7), but especially at Piney/Rock Creek, Tensleep Creek, and Little Bighorn. Tongue River and Piney/Rock Creek exhibit the most acres of ponderosa pine forests at high risk. Fairly high proportions (32 to 83%) of limber pine are at high risk across most FPWS, but the highest proportions are at Tensleep Creek, Goose Creek, and Devil's Canyon. Moderate proportions of spruce/fir (31 to 59%) are also at high risk across most FPWS, with the highest proportions in Little Big Horn and Shell Creek. Little Big Horn has the most acres of spruce/fir forests at high risk. In addition, moderate proportions (29 to 53%) of Douglas-fir forests are at high risk, with the highest proportions at Devil's Canyon and Piney/Rock Creek and the most acres at Little Bighorn. As with LTAs, relatively low proportions of lodgepole pine forests (21 to 75%) are considered to be at high risk for insect damage (Table M4A-7).

Possible Interactions of Natural Disturbances on the Bighorn National Forest

Although discussed as separate factors in this Module, natural disturbances such as wildfire and insect damage interact. Environmental or biological factors that affect one disturbance will ultimately affect the other. Thus the spatial arrangement of the factors influencing wildfires and/or insect activity on the Bighorn landscape (including older forests, high departure from historical fire regimes, high wildfire hazard, and high insect damage risk, many of which are correlated) are described here.

Several forest cover types of the Bighorn National Forest are especially at risk to insects and/or wildfire. Spruce/fir and lodgepole pine forests, which comprise the majority of the Bighorn National Forest, are particularly at risk (Fig. M4A-15). Lodgepole pine has the highest area of high wildfire hazard under 95th percentile weather conditions and the second-most area at high risk to insect damage. Spruce/fir forests exhibit the highest area at high risk to insect damage, and the second-most area at high hazard of wildfire. Douglas-fir forests are also at fairly high risk to both wildfire and to insect damage. Ponderosa pine forests show many more acres at risk to insect damage than wildfire hazard. Limber pine woodlands exhibit 9,505 acres (3,847 ha) at risk to insects but have little hazard of wildfire (Fig. M4A-15).

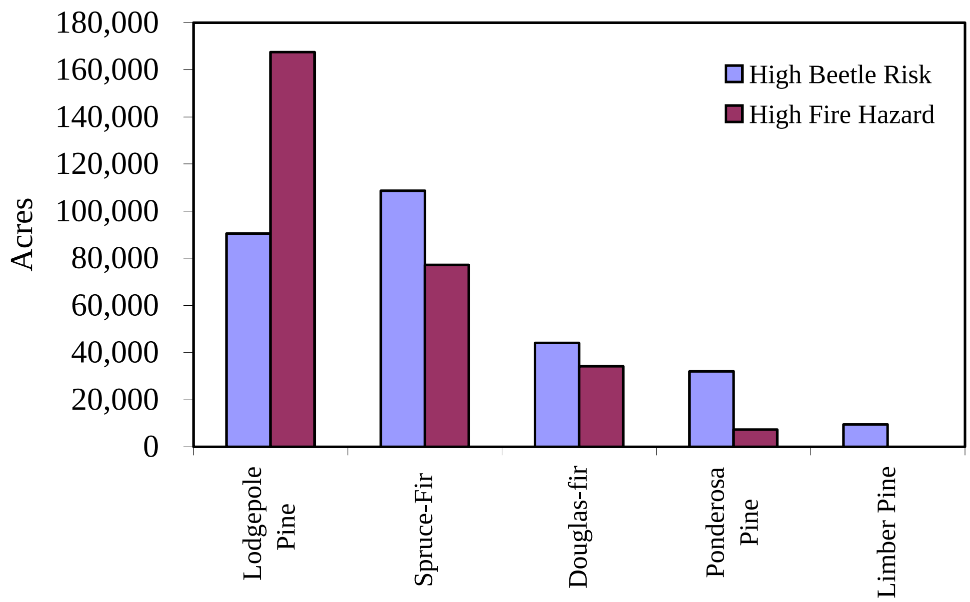


Figure M4A-15. Acres of forest types with particularly high risk to insect damage and/or wildfire hazard on the Bighorn National Forest.

In addition, areas of older forests (Habitat Structural Stage 4C) must be considered high-risk areas to both insects and wildfire, as insects (particularly bark beetles) are typically attracted to older stands where tree vigor is reduced, and wildfire hazard will likely increase in older forests as ladder fuels and fuel accumulations increase with stand age. Because older forests are often targeted for reserve, it is useful to note their risk of natural disturbances (Fig. M4A-16). Little Big Horn has the highest area of older forest at high risk to wildfire and to insect damage.

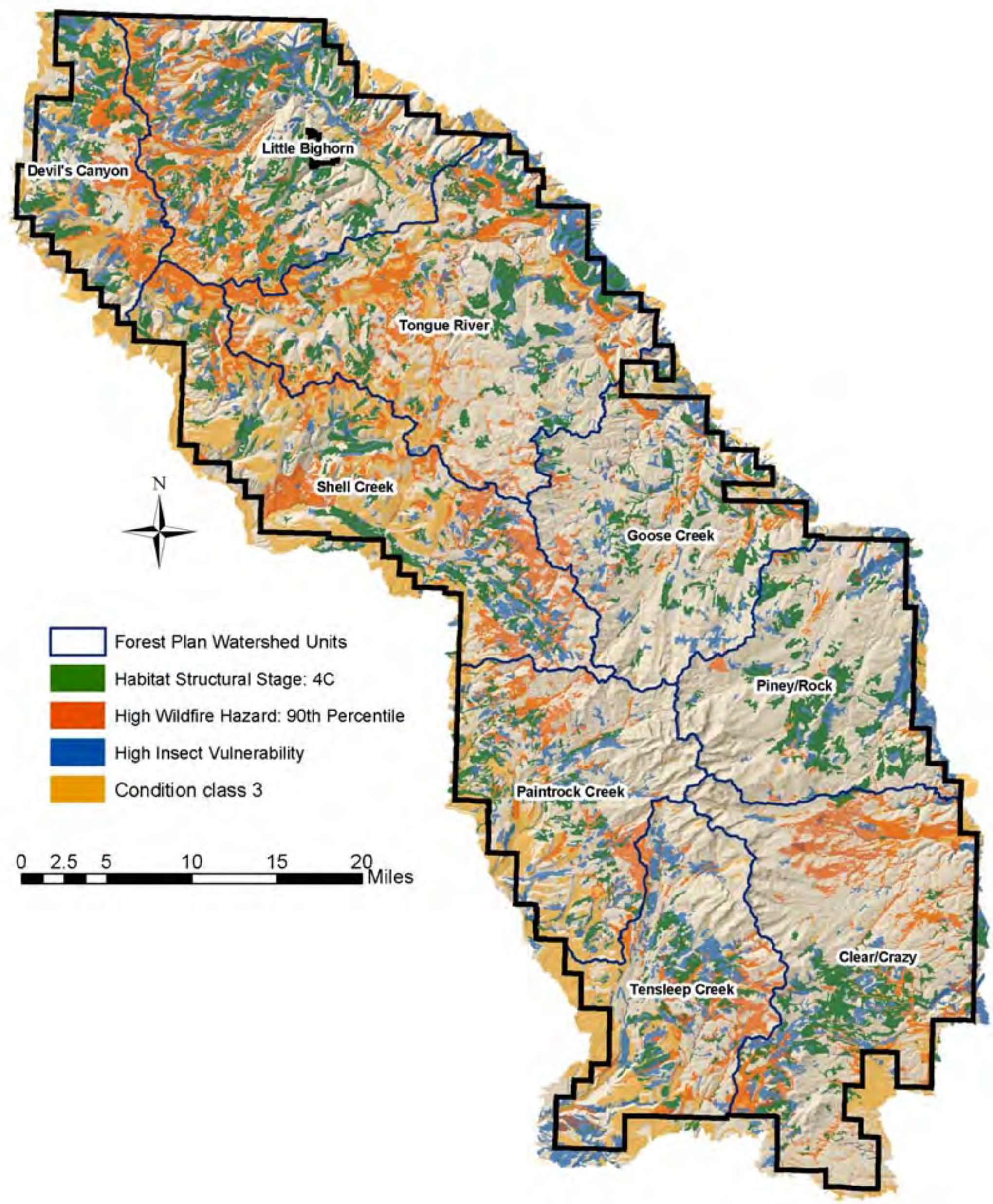


Figure M4A-16. Geographic location of older forests (Habitat Structural Stage 4C) in relation to areas of high wildfire hazard under 95th percentile weather conditions, high departure from historical fire regimes (Condition Class 3), and high insect vulnerability.

Tongue River has the second highest acreage of older forest in both of these risk categories (Table M4A-8). Goose Creek and Tensleep Creek have the fewest acres of older forest at high risk to wildfire. Tensleep Creek also has the fewest acres of older forest at high risk to insects.

Table M4A-8. Acreage of older forest by FPWS at high risk to wildfires and/or insect damage on the Bighorn National Forest. Hectares are in parentheses.

FPWS	High Wildfire Hazard	High Insect Damage Risk
Crazy/Clear	8,290 (3,355)	16,582 (6,711)
Devil's Canyon	6,895 (2,790)	11,567 (4,681)
Goose Creek	4,498 (1,820)	12,083 (4,890)
Little Bighorn	11,151 (4,513)	27,767 (11,237)
Paintrock Creek	7,340 (2,970)	10,015 (4,053)
Piney/Rock	7,534 (3,049)	15,935 (6,449)
Shell Creek	8,672 (3,509)	17,018 (6,887)
Tensleep Creek	4,950 (2,003)	8,386 (3,394)
Tongue River	9,608 (3,888)	23,375 (9,460)

Other Natural Disturbances on the Bighorn National Forest

Although this Module has focused primarily on the effects of wildfire and insect activity, other important natural disturbances also affect the existing vegetation. Several diseases and pathogens are prevalent throughout the Bighorn National Forest. Comandra blister rust (*Comandra umbellate*) and dwarf mistletoe (*Arceuthobium americanum*) are most common pathogens that affect lodgepole pine stands at high elevations in the Big Horn Mountains (Meyer and Knight 2003). Broom rusts (*Melampsorella carophyllacearum* and *Chrysomyxa arctostaphyli*) affect high-elevation spruce/fir forests, and root rot (*Armillaria* spp.) also affects fir in conjunction with the western balsam bark beetle. Other blister rusts are common at lower elevations in the Bighorns, particularly white pine blister rust (*Cronartium ribicola*), which caused fairly widespread mortality in limber pine woodlands at Tensleep Canyon in 2001. In addition, aspen stands are affected by various root diseases, canker-causing fungi, and a heart-rotting fungus (*Phellinus tremulae*). In most cases, these diseases create high mortality at local scales, but do not drastically affect the Bighorn National Forest as a whole (Meyer and Knight 2003).

Wind is also a notable disturbance on the Bighorn National Forest, particularly at high-elevations. The Forest appears to have higher windthrow than most other forests in the northern Rockies (Howe 1997), but only about nine blowdowns occurred on the Bighorn between 1955 and 1998, averaging about 211 hectares (520 acres) each (Meyer and Knight 2003). No major blowdowns have been recorded in lower elevation forests. The importance of windthrow as a natural disturbance may be less related to its direct effects on forest vegetation as is it to interactions with other disturbances, such as wildfire (due to sudden fuel accumulation) or insect outbreaks on the dead or dying windthrown trees (Meyer and Knight 2003).

Significant Information Gaps

(1) Data describing the ecological effects of natural disturbances on ecosystems of the Bighorn National Forest: What is the regeneration success of forests after stand-replacing fires or large insect outbreaks? What are the effects on plant recovery/regeneration?

(2) Data describing timing and vegetation type affected by historical large fires on the forest, as well as the ignition sources (human vs. lightning?).

(3) Insect outbreak data in addition to that of 2001; what are the historical trends of insect damage on this landscape? What is the return interval for insect outbreaks, and what are the ecological effects of outbreaks of varying size?

(4) Information to describe ecological effects of diseases and pathogens, even to show the relative insignificance of them on a landscape scale.

(5) Better information on the interaction of natural disturbances, as well as the intersections of high hazard, high departure, and high insect risk (currently hard to discern on the maps, and no data are available). Should be done by vegetation type.

(6) Stand-level data to describe effects of natural disturbances (non-stand-replacing) on stand productivity, structure, etc. How do natural disturbances affect trees/stands when they don't kill them?

Key Findings

Recent Fire History/Activity

(1) Relatively few large fires (61) have burned on the Bighorn National Forest since 1910, totaling approximately 81,000 acres (32,780 ha).

(2) Fire activity has been extremely variable by decade; more fires occurred between 1910 and 1919 than any other decade, although more area was burned in the 1920s. Fire suppression efforts are evident between 1950 and 1979 in the number of acres burned.

Current and Historical Fire Regimes

(1) Fire regimes on the Bighorn National Forest range from very frequent ($\leq$ 10 years), low-intensity fire regimes in grasslands to very infrequent (> 300 years), high-intensity fire regimes in high-elevation spruce/fir and lodgepole pine forests.

(2) The majority (62%) of the Bighorn National Forest (771,244 acres/312,111 ha) shows little or no departure from its historical fire regime; about 23 percent exhibits extreme departure.

(3) Vegetation types dominated by grasses and forbs or shrubs are generally those most affected by fire suppression during the last century. Forested areas generally show little departure from their historical fire regimes.

Wildfire Hazard

(1) Under 90th percentile weather conditions, only about 13% of the Forest is at high risk of wildfire, most of which is in grassland vegetation types.

(2) Under 95th percentile weather conditions, about 29% of the Forest exhibits high wildfire hazard, particularly in spruce/fir and lodgepole pine forests.

Recent Insect Activity and Risk

(1) In 2001, about 52,255 acres (21,147 ha) were affected by insect damage, of which 86% was forested, primarily with spruce/fir and lodgepole pine.

(2) Nearly 63% of the Forest is at relatively low risk to insect damage. Ponderosa pine and limber pine forests are currently at the highest risk of insect damage.

Older Forests, Conservation Sites, and Research Natural Areas

(1) Several areas of older forest are at high risk of wildfire and/or insects. Several areas fall within the boundaries of WYNDD Conservation Sites or current and/or potential Research Natural Areas.

Literature Cited

Baker, W.L. 1989. Landscape ecology and nature reserve design in the Boundary Waters Canoe Area, Minnesota. Ecology 70: 23-35.

Clements, F.E. 1910. The life history of lodgepole burn forests. USDA Forest Service Bulletin 79: 7-56.

Despain, D.G. 1973. Vegetation of the Big Horn Mountains, Wyoming, in relation to substrate and climate. Ecological Monographs 43: 329-355.

Despain, D.G., and W.H. Romme. 1991. Ecology and management of high-intensity fires in Yellowstone National Park. Tall Timbers Fire Ecology Conference 17.

Hardy, C.C., K.M. Schmidt, J.P. Menakis, and R.N. Sampson. 2001. Spatial data for national fire planning and fuel management. International Journal of Wildland Fire 10: 353-372.

Howe, G.E. 1997. Bighorn National Forest genetics service visit. Report on file at Bighorn National Forest Supervisor's Office, Sheridan, Wyoming.

Meyer, C.B., and D.H. Knight. 2003. Historic variability for upland vegetation in the Bighorn National Forest, Wyoming. Unpublished report on file at Bighorn National Forest Supervisor's Office, Sheridan, Wyoming.

Paine, R.T., and S.A. Levin. 1981. Intertidal landscapes: disturbance and the dynamics of pattern. Ecological Monographs 51: 145-178.

Pickett, S.T.A., and P.S. White (eds.). 1985. The ecology of natural disturbance and patch dynamics. Academic Press, New York.

Romme, W.H., and D.G. Despain. 1989. Historical perspective on the Yellowstone fires of 1988. BioScience 39: 695-699.

Romme, W.H., and D.H. Knight. 1981. Fire frequency and subalpine forest succession along a topographic gradient in Wyoming. Ecology 62: 319-326.

Romme *et al.* 2001

Sharpe, G.W., C.W. Hendee, and W.F. Sharpe. 1986. Introduction to forestry. McGraw-Hill Publishers, New York. 629 pp.

Spurr, S.H. 1964. Forest ecology. Ronald Press, New York. 352 pp.

Turner, M.G., and V.H. Dale. 1998. Comparing large, infrequent disturbances: what have we learned? Ecosystems 1: 493-496.

Turner, M.G., R.H. Gardner, and R.V. O'Neill. 2001. Pattern and process: Landscape ecology in theory and practice. Springer-Verlag, New York. 401 pp.

Watt, A.S. 1947. Pattern and process in the plant community. Journal of Ecology 35: 1-12.

Wiens, J.A. 1995. Landscape mosaics and ecological theory. In: Hansson, L., L. Fahrig, and G. Merriam (eds.). Mosaic landscapes and ecological processes. Chapman and Hall, London. Pp. 1-26.

Wu, J., and O.L. Loucks. 1995. From balance of nature to hierarchical patch dynamics: A paradigm shift in ecology. Quarterly Review of Biology **70**: 439-466.

Module 4B - Management of Forest and Woodland Ecosystems

Objective

Describe the spatial and temporal patterns of management activities on forest ecosystems within the assessment area.

Introduction

Although natural fires may create abrupt boundaries between forest and non-forest or between stand ages similar to those created by timber harvesting, strong differences exist between timber harvesting and natural disturbances. For example, in contrast to many wildfires, harvesting removes a significant number of tree boles from the site, often requires a road network, removes snags or unwanted species, and may simplify stand structure by creating more uniform tree spacing and by reducing size diversity (Smith 2000). In the Rocky Mountains of South Dakota, Wyoming, Colorado, and New Mexico, Smith (2000) noted several important influences of forestry practices on landscape pattern. First, significant portions of forests are human-created and are a legacy of the extensive disturbances associated with the settlement era. In addition, young, dense, even-aged stands dominate significant areas of forests even after a century of recovery where there has been a low level of timber harvest and an active program of fire suppression.

Ecoregional Context for Evaluation of Silvicultural Practices

Current levels of silvicultural activities are low (Table M4B-1), and only a small portion of the landscape is impacted by forestry. Nevertheless, small, dispersed cutting units planned to reduce perceived ecological impact, minimize visual impact, improve wildlife habitat for edge-preferring species (especially elk), and to increase water yield, may have caused disproportionately large perforation and fragmentation when compared to the small amount of acres harvested.

Table M4B-1. Forest Service Silvicutural Practices for Wyoming and Colorado from the 1992 – 1996 Silviculture Activities Report (*adapted from Smith 2000*).

Forest Practices	Area per year in acres (hectares)	Percentage of suitable lands	Percentage of forest land
Regeneration Cut – Forest Opening *(reproduction methods to produce even-aged stand conditions)*	4,460 (1805)	0.11%	0.03%
Regeneration Cut – Selection *(reproduction methods to produce uneven-aged stand conditions)*	3,084 (1248)	0.08%	0.02%
Thinning *(practices to alter growth by reducing tree density)*	1,164 (471)	0.03%	0.01%
Forest Health *(practices to reduce insect and disease)*	3,939 (1594)	0.10%	0.03%
Suitable NFS lands in Colorado/Wyoming are 4.0 million acres (1.62 million ha) Total forest lands are 12.8 million acres (5.18 million ha)			

If the forestry activities in Table M4B-1 were projected over a century, almost 20% of lands suitable for timber production and 6% of all forested lands would be subject to regeneration treatments. According to Smith (2000), revegetation in Wyoming and Colorado forests occurs over moderate time scales with substantial variability among forest types. For example, it takes about 50 years for lodgepole pine forests to regenerate and recover to ceiling leaf area and high net primary production after harvest (Long and Smith 1992). Aplet *et al*. (1988) mention that Engelmann spruce forests may take 250 years to develop multiple age classes after harvest. Although timber harvesting represents a substantial influence on landscape pattern, it only affects landscapes between the time of cutting and forest regeneration. Notably, anthropogenic disturbances such as some forms of recreation and most developments are permanent land use changes (see Module 4F for discussion).

Patterns of Forest Vegetation Management

Temporal Trends of Silvicultural Practices

Timber harvesting began in the Big Horn Mountains in about the mid-1860s, when the U.S. Army established Fort Phil Kearney on Piney Creek, and soldiers cut ponderosa pine for construction and fuelwood. Tie hacking peaked between 1890 and 1910 at the Tongue River and between about 1925 and 1933 at Clear Creek, with timber harvest levels of about 10 million board feet (mbf)/yr and 4 mbf/yr, respectively. The largest period of timber harvesting in the Big Horn Mountains began in the 1960s; timber harvest levels varied between 10 and 22 mbf/year between 1963 and 1992. The 1985 Forest Plan Allowable Sale Quantity is approximately 15 mbf/yr, but the BNF has been operating under an administrative “cap” of 4 to 5 mbf/yr since 1996.

The silvicultural method used in sawtimber harvest on the BNF has varied over the past 50 years (Fig. M4B-1). Clearcutting has steadily declined, while shelterwood harvesting compensated for the clearcut decline in the 1970s and 1980s. All harvesting declined significantly in the 1990s.

Silvicultural practices have implications for forest landscape pattern not only as a result of current practices, but also because they leave a legacy of past practices on the landscape for decades or even centuries after they have been implemented Only slightly more than 20% of the approximately 700,000 acres (283,280 ha) of forest (141,372 acres/57,211 ha) on the Bighorn National Forest has received some sort of silvicultural treatment over the past 50 years (Table M4B-1).

Table M4B-2. Acres harvested on the Bighorn National Forest, by silvicultural system, for dominant forest types, 1950-2000.

Silvicultural System	Aspen	Spruce/Fir	Lodgepole pine	Douglas-fir	Totals
Clearcutting	61	4,103	28,410	1,978	34,552
Shelterwood - Prep	130	3,731	20,716	472	25,049
Shelterwood - Seed	19	4,293	5,177	962	10,451
Shelterwood – Overstory Removal	0	1,382	5,173	88	6,643
Selection	0	828	1,291	0	2,119
Precommercial Thinning	32	2,600	34,695	484	37,811
Commercial Thinning	81	1,045	12,029	0	13,155
Sanitation-Salvage	4	4,036	7,349	203	11,592
Totals	327	22,018	114,840	4,187	141,372

Of the treatments, precommercial thinning (37,811 acres/15,302 ha) and clearcutting (34,552 acres/13,983 ha) were the most common. Precommercial thinning has a large effect on the pattern of stand structure across a landscape, which may be important for broad-scale primary productivity, dispersal and movement of certain flora and fauna, and the spread of disturbances, especially when relatively few forest types dominate the landscape. Clearcutting, however, which represents 24.1% of all silvicultural treatments, has an immediate, distinctly different effect on landscape patterns at multiple scales and is discussed in detail below. Shelterwood-preparation treatments also accounted for 17.7%, or 25,049 acres (10,137 ha) of the silvicultural treatments on the Bighorn National Forest.

Obviously, preferred silvicultural treatments are based on the forest type and the intended uses of the harvested wood (Table M4B-2). For example, lodgepole pine forests are typically harvested, or managed for harvest, using precommercial thinning (30.2%), clearcutting (24.7%), and shelterwood prep cuts (18%); in contrast, spruce-fir forests receive shelterwood seed tree cuts (19.5%) and sanitation/salvage cuts (18.3%, likely due to the high number of insect outbreaks that occur in this forest type) as well as clearcutting (18.6%), shelterwood prep cuts (16.9%), and precommercial thinning (11.8%). Douglas-fir forests are typically clearcut (47.2%), but also receive shelterwood seed cuts (23%); aspen forests typically receive shelterwood prep cuts (40%), but also experience limited commercial thinning (24.8%).

Lodgepole pine forests have been disproportionately affected by silvicultural treatments over the past half-century, likely because they represent the majority of the National Forest that is accessible to timber harvesting. Lodgepole pine covers 82% of all acres clearcut, 74% of all acres subjected to shelterwood cuts, 61% of all selection harvests, 92% of all thinning operations, and 63% of all sanitation-salvage operations (Table M4B-2). Because it represents such an overwhelming majority of the area harvested on the Bighorn National Forest, lodgepole pine forests are a useful indicator of temporal trends in timber harvest operations (Fig. M4B-1). In this forest type, silvicultural treatments rose from a low of 1,958 acres (792 ha) during the 1950s to a peak of 45,513 acres (18,418 ha) during the 1980s. Silvicultural treatments have fallen once again; only 5,778 acres (2,338 ha) have been affected so far this decade (Fig. M4B-1).

In addition to changing areas affected over time, the most common type of silvicultural treatment has also varied among decades within lodgepole pine forest (Fig. M4B-1). Clearcutting has been common in lodgepole pine forests in every decade, but was particularly important in the 1960s and 1970s, when over 18,600 acres (7,527 ha) were clearcut over a 20-year span. Clearcutting has markedly decreased on the National Forest since the 1970s, and only about 3,200 acres (1,295 ha) have been clearcut since 1990. Since the 1980s, clearcutting seems to have been replaced by precommercial thinning, which peaked in the 1980s (18,165 acres/ 7,351 ha) and was still common in the 1990s (9,068 acres/3,670 ha). Shelterwood prep cuts were most common during the 1970s (9,669 acres/3,913 ha) and 1980s (9,561 acres/3,869 ha), but have since been greatly reduced; shelterwood seed cuts appear to be gaining prominence since 2000. Sanitation-salvage cuts were more prominent in the 1980s and 1990s than in any other decade, likely in response to large insect outbreaks during or just prior to that time (Fig. M4B-1).

Spatial and Temporal Trends in Clearcutting

The spatial and temporal trends of clearcutting deserve special attention because it has been an important silvicultural method on the landscape since 1950, and because it can have strong effects on landscape pattern through fragmentation and perforation.

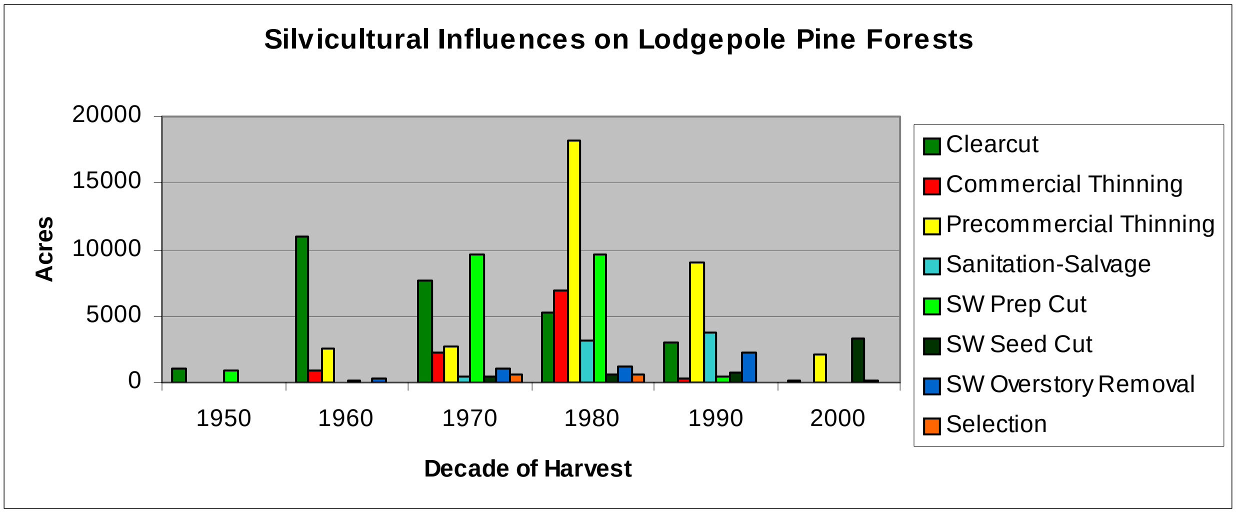


Figure M4B-1. Temporal trends in silvicultural treatments in lodgepole pine forests of the Bighorn National Forest, 1950-2000**.**

In the Bighorn National Forest, clearcut harvesting has created a mosaic of regenerating stands within a matrix of unharvested forest, primarily in spruce-fir and lodgepole pine forests, although the number of acres harvested has been relatively low (Fig. M4B-2). Clearcuts prior to 1960 were limited and not widespread, affecting only small areas in the central (Shell Creek Forest Plan Watershed Unit) and southeastern (Clear/Crazy Woman Creek FPWS) portion of the National Forest. When clearcutting became more widespread in the 1960s, it was concentrated at Clear/Crazy Woman Creek, the southern portion of Tongue River, and the southern portion of Paintrock Creek. By the 1970s, further clearcutting occurred in the above FPWS, but also spread to Little Big Horn and Goose Creek, though clearcut size was typically much smaller. In the 1980s, clearcutting continued in the above units, and large clearcuts were established in Devil's Canyon and Shell Creek. In the 1990s, clearcutting occurred in every FPWS except Devil's Canyon, Shell Creek, and Piney/Rock. In most cases, clearcuts tend to be clustered rather than widespread, occurring mainly near previously clearcut stands (Fig. M4B-2).

A greater area (12,812 acres/5,185 ha) had been clearcut at Clear/Crazy Woman Creek than at any other FPWS. After Clear/Crazy Woman Creek, Tongue River (7,707 acres/3,119 ha) had the next largest area of clearcuts, with the other FPWS units containing significantly less clearcuts (Table M4B-3). Shell Creek had few, larger clearcuts as compared to Little Big Horn, where the clearcuts are smaller and more scattered; Clear/Crazy Woman Creek and Tongue River contained both large and small clearcuts (Fig. M4B-2). Clear/Crazy Woman Creek had a higher proportion of its area clearcut (8.2%) than any other watershed. Tongue River had the next highest proportion clearcut (4.3%) (Table M4B-3). For the eight watersheds where clearcutting occurred, the proportion of the watershed clearcut averages 3.2%.

The LTA with the most area of clearcuts was the Granitic Mountain Slopes, Gentle (21,754 acres/8,804 ha), followed by Sedimentary Slopes, Shale/Sandstone (Non-calcareous) (4,742 acres/1,919 ha) (Table 4B-4). Given that lodgepole pine is the predominant cover type (64%--data not shown) of the Granitic Mountain Slopes, Gentle, it is not surprising that this LTA contains the most clearcuts. Lodgepole pine also predominates (76%--data not shown) on the Granitic Mountain Slopes, Steep LTA; however, due to the steep terrain, less than 1% of this LTA has been clearcut.

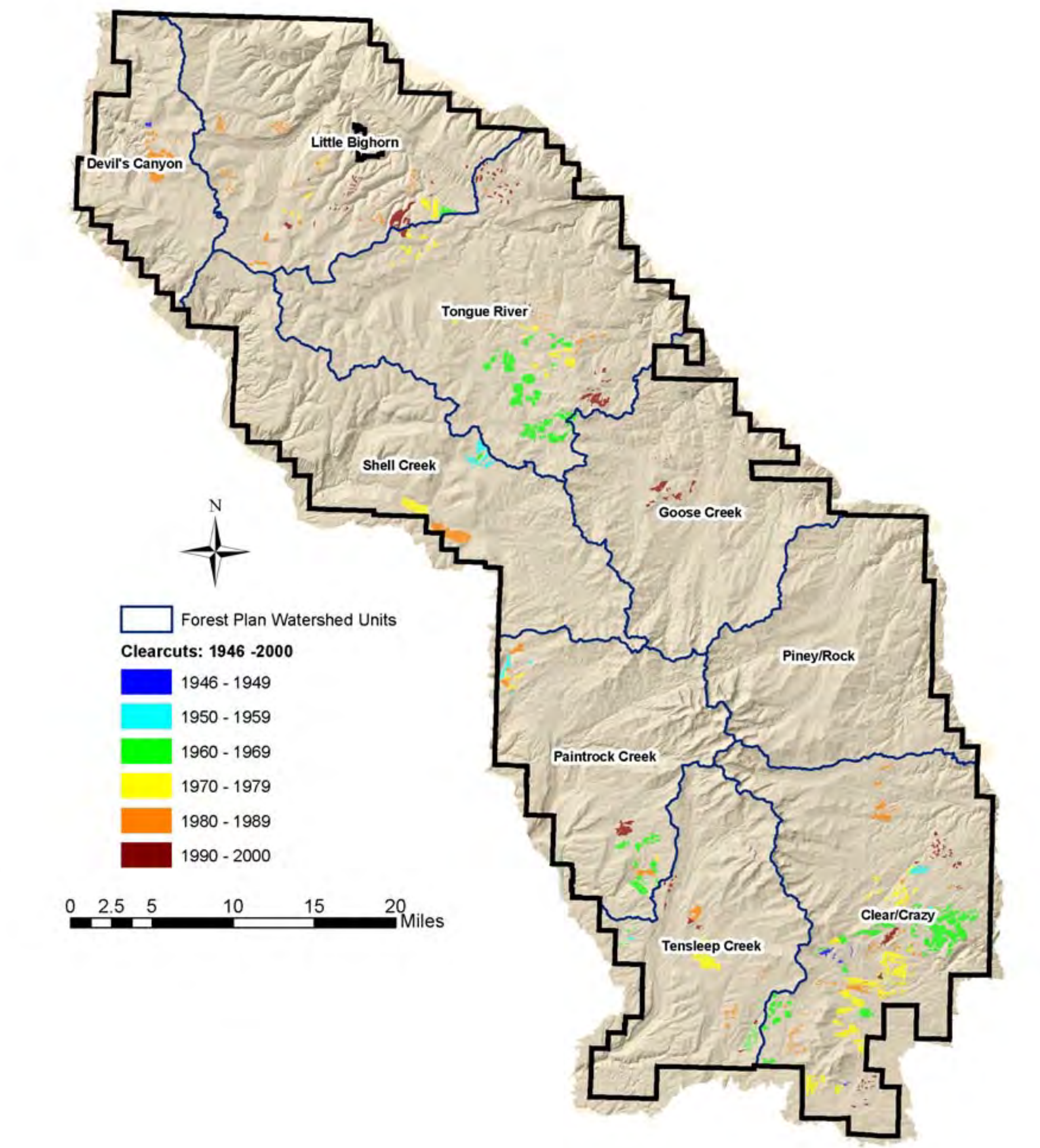


Figure M4B-2. Geographical distribution of clearcut harvests on the Bighorn National Forest since 1946.

Table M4B-3. Area clearcut in each Forest Plan Watershed Unit (FPWS) in the Bighorn National Forest, 1946-2000.

Watershed Unit	Total Acres (Hectares)	Clearcut Acres (Hectares)	Percent Clearcut
Clear/Crazy	156,117 (63,178)	12,812 (5,185)	8
Devil's Canyon	61,197 (24,766)	1,772 (717)	3
Goose Creek	116,952 (47,328)	625 (253)	<1
Little Big Horn	142,359 (57,611)	3,620 (1,465)	3
Paintrock Creek	108,215 (43,793)	2,919 (1,181)	3
Piney/Rock	110,255 (44,619)	0	0
Shell Creek	140,818 (56,987)	2,852 (1,154)	2
Tensleep Creek	101,162 (40,939)	2,420 (979)	2
Tongue River	178,519 (72,244)	7,707 (3,119)	4

Table M4B-4. Area clearcut in each LTA in the Bighorn National Forest, 1946-2000.

LTA code	LTA description	Total Acres (Hectares)	Clearcut Acres (Hectares)	Percent Clearcut
M331Ba-01	Sedimentary Breaklands	133,995 (54,226)	1,694 (686)	1
M331Ba-02	Landslide/Colluvial Deposits	35,294 (14,283)	67 (27)	< 1
M331Ba-03	Sedimentary Mountain Slopes, Limestone/Dolomite	166,069 (67,206)	3,370 (1,364)	2
M331Ba-04	Sedimentary Mountain Slopes, Shale/Sandstone (Calcareous)	27,019 (10,934)	38 (15)	< 1
M331Ba-05	Sedimentary Mountain Slopes, Shale/Sandstone (Noncalcareous)	81,616 (33,029)	4,742 (1,919)	6
M331Bb-01	Granitic Breaklands	39,278 (15,895)	385 (156)	1
M331Bb-02	Glacial Cirquelands	64,417 (26,069)	0	0
M331Bb-03	Glacial/Tertiary Terrace Deposits	99,140 (40,121)	2,588 (1,047)	3
M331Bb-04	Granitic Mountain Slopes, Steep	41,767 (16,902)	121 (49)	< 1
M331Bb-05	Granitic Mountain Slopes, Gentle	303,241 (122,718)	21,754 (8,804)	7
M331Bb-06	Alpine Mountain Slopes and Ridges	119,975 (48,552)	9 (3)	< 1

Interaction of Silviculture with Wildfire

Generally, the past 100 years have been a period of reduced fire occurrence in comparison to the 19th century (Peet 1988; Knight 1994), although this varies by elevation and geographic site (Veblen 2000). Evidence of reduced fire frequency is very clear in the montane zone (Veblen 2000), where many forest patches have probably expanded and merged during the past century. Historically, photos and tree population age structure analysis (Gruell 1985; Veblen and Lorenz 1991; Mast *et al.* 1998) show that ponderosa pine and Douglas-fir forests have spread into some former grasslands due to fire suppression. Livestock grazing and climatic variability may also have influenced this expansion (Veblen 2000). The frequency of fire occurrence in the subalpine zone has probably not been influenced greatly by fire suppression due to the typically long fire intervals (Clagg 1975; Romme and Despain 1989). See Module 4A for a detailed treatment of fire suppression and its potential effects on the Bighorn National Forest.

Clearcutting may approximate the scale of stand-replacing fires in spruce/fir and lodgepole pine forests, although stand regeneration and re-initiation often differ significantly between natural wildfires and large clearcuts. In addition, clearcuts are typically different in size, shape, and intensity across the landscape as compared to large fires. Interestingly, there have been 142,065 acres harvested from 1935-1999 (as far back as the harvesting data go), compared with 81,252 acres burned by large fires from 1910-1999 (as far back as the large fire data go). Granted this is the period of fire suppression, but these data demonstrate the influence that management activities are having on the landscape. However, under the right climatic condition, large fires could potentially burn far more acreage.

Significant Information Gaps

(1) The relationships between human disturbances, such as vegetation management, and the frequency and severity of natural disturbances?

(2) Ecological effects of silvicultural treatments with a focus on soil productivity data.

(3) The relationship between soil productiveity and Land Type Associations.

(4) Ecological effects of silvicultural treatments with a focus on species conservation questions.

Key Findings

Timber Harvesting Activities

(1) Timber has been harvested on the National Forest since the late 1940s; clearcutting activities peaked in the 1960s and declined thereafter.

(2) Lodgepole pine forests are affected by silviculture more than any other forest type, while spruce/fir forests include more area permanently reserved from timber harvest.

Fire Suppression Effects

(1) Lower elevation forests also appear to be affected by clearcutting, but fire suppression is an equally important factor in those forests. Fire suppression tends to homogenize the landscape rather than fragment it.

Literature Cited

Aplet, G., R. Laven, and F.W. Smith. 1988. Patterns of community development in Colorado Engelmann spruce-subalpine fir forests. Ecology 69:312-319.

Clagg, H.B. 1975. Fire ecology in high-elevation forests in Colorado. Colorado State University, Fort Collins, CO. Thesis.

Gruell, G.E. 1985. Indian fires in the Interior West: A widespread influence. In: Proceedings: Symposium and Workshop on Wilderness Fire. Edited by J.E. Lotan. USDA Forest Service, Gen. Tech. Report INT-182. Intermountain Forest and Range Experiment Station, Ogden, UT.

Knight, D.H. 1994. Mountains and plains: The ecology of Wyoming landscapes. Yale University Press. New Haven, CT.

Mast, J., T.T. Beblen, and Y.B. Linhart. 1998. Disturbance and climatic influences on age structure of ponderosa pine at the pine/grassland ecotone, Colorado Front Range, Journal of Biogeography 25:743-767.

Peet, R.K. 1988. Forests of the Rocky Mountains. In: North American Terrestrial Vegetation. Barbour, M.B., and W.D. Billings (eds.). Cambridge University Press, Cambridge, UK>

Romme, W.H., and D.G. Despain. 1989. Historical perspective on the Yellowstone fires of 1988. BioScience 39:695-699.

Smith F.W. 2000. Forestry practices and forest fragmentation in the Southern Rocky Mountains. In: Forest Fragmentation in the Southern Rocky Mountains. Knight, R., F. Smith, S. Buskirk, W. Romme, and W. Baker (eds.). University Press of Colorado. Boulder, CO. 474 p.

Veblen, T.T. 2000. Disturbance patterns in Southern Rocky Mountain Forests. In: Forest Fragementation in the Southern Rocky Mountains. Knight, R., F. Smith, S. Buskirk, W. Romme, and W. Baker (eds.). University Press of Colorado. Boulder, CO 474 p.

Veblen, T.T. and D.C. Lorenz. 1991. The Colorado Front Range: A century of ecological change. University of Utah Press, Salt Lake City, UT.

Module 4C - Management of Grassland and Shrubland Ecosystems

Objectives

Describe the spatial and temporal patterns of management activities on grassland and shrubland ecosystems within the assessment area. To the extent possible given information limitations, discuss the ecological implications of the current condition.

Introduction

The distribution of grasslands and shrublands is controlled by soils, moisture, and other climatic factors as well as natural disturbances that limit tree species survival. Natural fires may create abrupt boundaries between non-forest and forest, and frequent fires may have maintained open areas by eliminating woody vegetation. With the onset of fire suppression and grazing the fire regime for many of our grasslands and shrublands have been significantly lengthened allowing for woody encroachment. In addition land use practices may have influences on other aspects of the structure and composition of these ecosystems. Our ability to evaluate management influences on grassland and shrubland ecosystems in the assessment area was limited by the availability of data.

Livestock Grazing

Allotment Distribution

Today, cattle number about 27,000, and sheep number about 16,500, with a grazing season averaging a little over 90 days and 66 days, respectively (from BNF range permit data, Appendix A). Current allotment boundaries on the BNF are shown in Figure M4C-1. Near the turn of the century, Town (1899) estimated that sheep grazed over a 5- to 6-month season. Clearly, stocking has dramatically decreased from historical numbers. Historical livestock numbers tabulated by Meyer and Knight (2003) and Murray (1980) have been converted to a common unit (e.g., 1 cow= 1 Animal Unit; 5 sheep = 1 Animal Unit) for comparison purposes in Table M4C-1.

Table M4C-1. Domestic livestock numbers on the Bighorn National Forest over time (*source: Meyer and Knight 2001; Murray 1980*).

Year	Cattle		Sheep		Total Animal Units
	Number	Animal Units	Number	Animal Units	
1898	3,000	3,000	450,000	90,000	93,000
1899	3,000	3,000	150,500	30,100	33,100
1904	30,000	30,000	374,734	74,947	104,947
1910	36,000	36,000	118,000	23,600	59,600
1919	48,500	48,500	117,000	23,400	71,900
1931	32,352	32,352	126,765	25,353	57,705
1985	33,000	33,000	58,000	11,600	44,600
2002	27,000	27,000	16,500	3,300	30,300

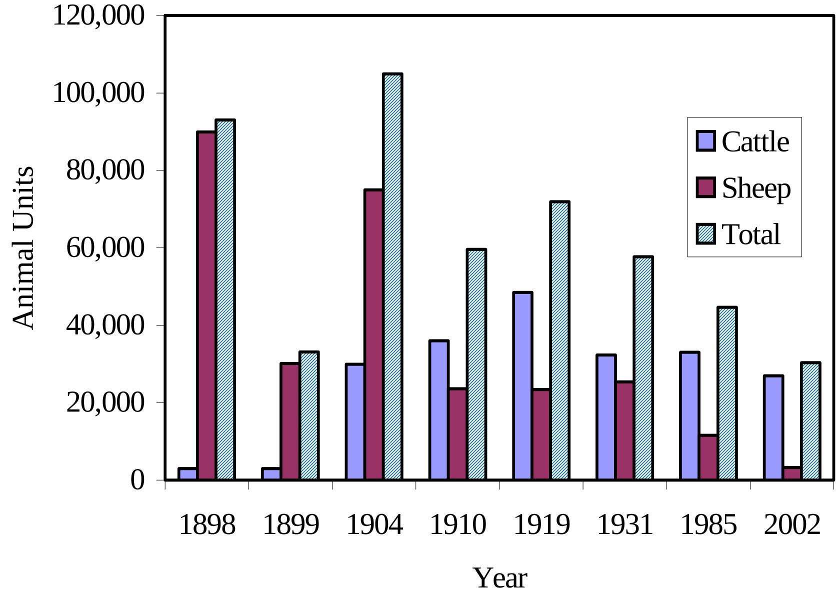


Figure M4C-1. Domestic livestock animal units for cattle, sheep, and total (cattle and sheep combined) on the Bighorn National Forest over time *(source: Meyer and Knight 2003; Murray 1980*).

Figure M4C-2 graphically illustrates total animal units for cattle and sheep over time on the Bighorn National Forest, based on the information in Table M4C-1. Currently, the BNF supports only a little over a quarter of the livestock animal units using the Forest as compared to the animal units grazing near the turn of the century. The number of sheep using the Forest has declined most dramatically, and the grazing season has decreased by more than half over this time period.

As livestock numbers have decreased, range improvements have been implemented to better control forage utilization. During the 1920s to 1940s, allotment boundaries were fenced. Between the 1960s and 1980s, interior fences were constructed to create pastures so that deferred rotation grazing systems could be initiated. Water developments were also constructed during this time (CEEM 2002).

Stocking Rate

Displaying stocking rates (expressed as acres of capable range per Animal Unit Month [AUM]) provides a basis for showing how lightly or heavily livestock are placed within each allotment on the BNF. As the stocking rate increases, then the management intensity should directly increase as well. Stocking rates, by allotment, are displayed in Figure M4C-2. Range allotment permit data (number and kind of livestock, season of use, etc.) are provided in Appendix A. In general, the stocking rates on the Forest appear to be high – especially allotments colored red or rust in Figure M4C-21.

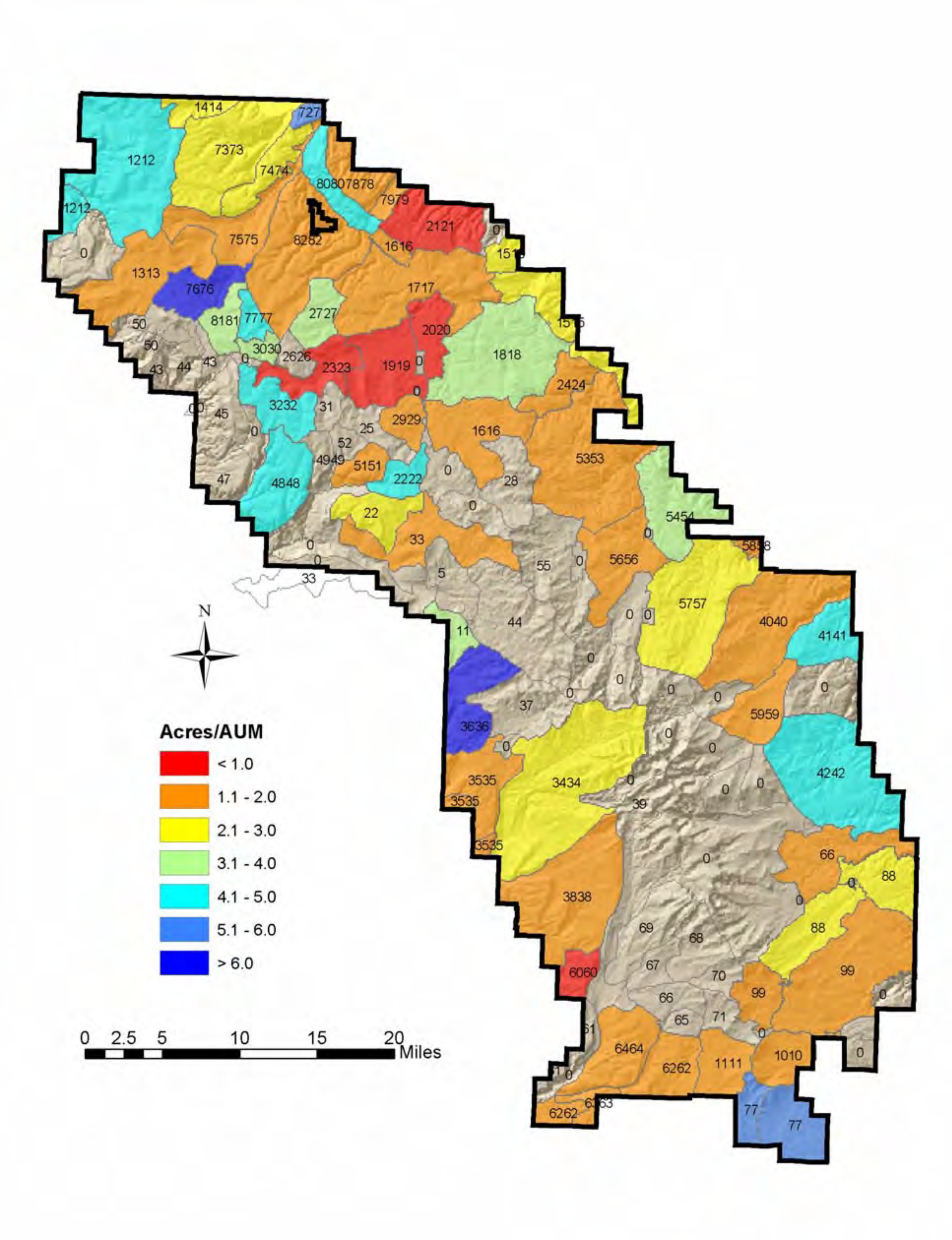


Figure M4C-2. Bighorn National Forest range allotments and stocking expressed as acres per AUM. Numbered allotments correspond to the list of allotments in Appendix A (*source: Bighorn National Forest*).

Influence on Grassland and Shrubland Vegetation Types

Season of Use & Range Condition

Current range condition may give an indication of how ecological status has changed, presumably as a result of domestic livestock grazing. Range condition data were not readily available for the entire assessment area. So, an example area for which data were available was analyzed. A summary compiled specifically for the Tensleep Assessment Area on the Bighorn National Forest (CEEM 2002) covers only a portion of the southern part of the BNF, but gives some insight to the range conditions that might be expected for other locations on the Forest.

Range condition class is fundamentally based on species composition. This includes the relative percent coverage of "decreasers", "increasers", and "invader" species – concepts described by Dyksterhuis (1949). Most of the Tensleep Assessment Area is in fair range condition (Table M4C-2). Generally, this means that the dominant, palatable range plants (decreasers) have been reduced and a corresponding increase of relatively less palatable species (increasers and invaders) is seen. Eventually, under continued overgrazing pressure, increaser species begin to decline as well.

Table M4C-2. Vegetation types and percent by range condition class for the Tensleep assessment area*.

Vegetation Type	Excellent	Good	Fair	Poor
Grassland	10%	35%	41%	14%
Sagebrush	0%	28%	61%	12%
Riparian	0%	10%	78%	12%
Timber	0%	0%	100%	0%
Aspen	0%	0%	100%	0%
Willow	0%	0%	100%	0%
All Vegetation Types by Condition Class	3%	25%	61%	11%

**Data based on range allotment records, Powder River Ranger District, Bighorn National Forest (adapted from CEEM 2002)*

Most rangeland is categorized as fair range condition. An example may help describe what this range condition might look like. For example, an Idaho fescue (*Festuca idahoensis*) grassland within a 20-inch mountain precipitation zone on deep soils in excellent range condition would be expected to be dominantly 70% graminoid species, 20% forbs, and 10% woody plants (USDA NRCS 1988). This same site in fair range condition would reveal an obvious increase in the interspace between individual Idaho fescue bunchgrass plants. The interspaces would reveal a noticeable increase in the abundance of increaser and invader species, such as cheatgrass (*Bromus tectorum*), dandelion (*Taraxacum officinale*), houndstongue (*Hieracium cynoglossoides*), and annual forbs. Big sagebrush (*Artemisia tridentata*) and other woody plants would become more dominant as condition deteriorates as well (USDA NRCS 1988).

Type Conversions

Meyer and Knight (2003) suggest the proportion of the BNF in forested vegetation has almost doubled since the late 1800s – from 35% in 1898 to 62% at present (Fig. M10-7). They attribute this change to forest encroachment into meadows and shrublands, and natural reforestation after fire and timber harvesting. However, the accuracy of estimates by Town (1899) and Jack (1900) is probably low from that time period. It is unlikely that forested cover types regrew on 9% of the BNF between 1898 and 1900, or that sagebrush and shrubland did not exist. Instead, the difference probably represents error in those early estimates. However, other evidence (e.g., stand ages) supports that much of the forested lands were burned in 1898 (and then classified as grassland). As shown in Figure M4C-3, vegetation succession since that time has increased the forest percentage to the higher numbers today. Meyer and Knight (2003) noted with high confidence that, even though the variability is high, the present ratio of forest to grassland/shrubland is most likely within the historic range of variability on high-elevation landscapes. Their conclusion suggests that perhaps there has not been a significant degree of type conversions.

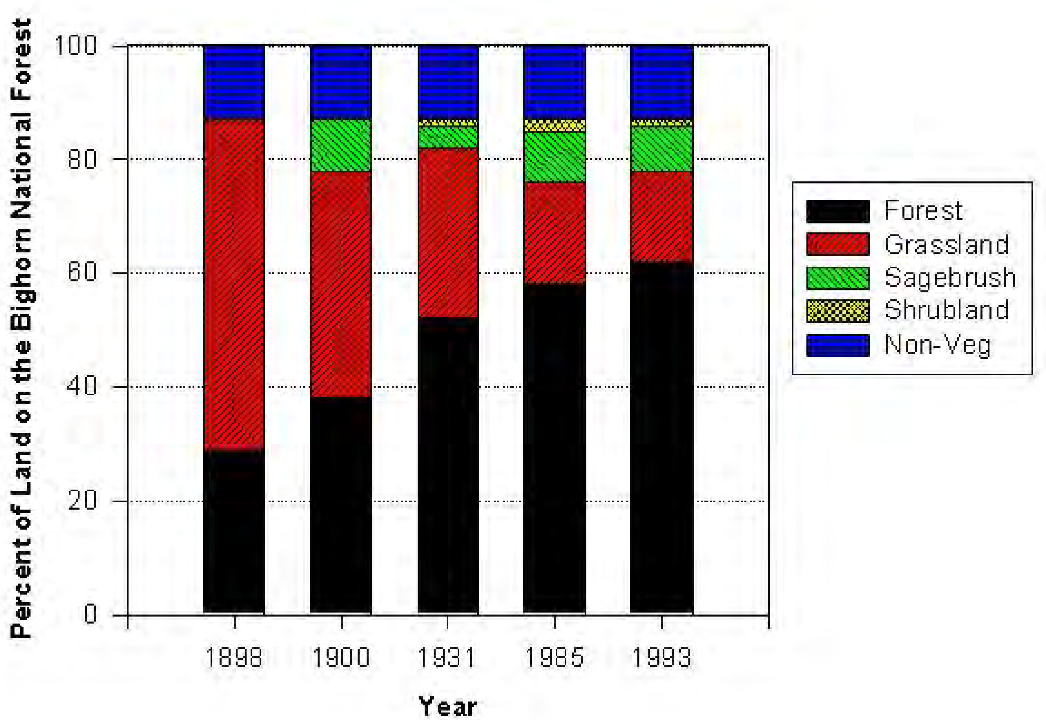


Figure M4C-3. Vegetation percentages for the Bighorn National Forest from 1898 to 1993 (USDA Forest Service 1994), adjusted so non-vegetation (non-veg) is always 13% *(source: Meyer and Knight 2003*).

Summary of Key Findings

Livestock Grazing

Stocking Rate

- Currently, the BNF supports just over a quarter of the livestock animal units stocked near the turn of the century. However, current stocking rates on BNF appear to be high when expressed as acres of capable range per Animal Unit Month.
- The number of sheep using the Forest has declined dramatically.

Season of Use

- Compared to the animal units grazed on Forest near the turn of the century, current grazing seasons have decreased by more than half.

Range Condition

- Most rangeland is categorized as fair range condition.

Type Conversions

- Forested vegetation has increased from 35% in 1898 to 62% at present. However, this forest encroachment into meadows and shrublands is characteristic of HRV

Significant Information Gaps

How do human disturbances, such as livestock grazing, affect the frequency and severity of natural disturbance?

Literature Cited

CEEM 2002

Dyksterhuis, E.J. 1949. Condition and management of rangeland based on quantitative ecology. Journal of Range Management. 2:1-4-115.

Jack 1900

Meyer, C.B., and D.H. Knight. 2003. Historic variability for upland vegetation in the Bighorn National Forest, Wyoming. Unpublished report on file at Bighorn National Forest Supervisor's Office, Sheridan, WY.

Murray 1980

Town 1899

Appendix M4C-A: Permitted Livestock by Allotment on the Bighorn National Forest.

Permitted livestock by allotment on the Bighorn National Forest (*source: Bighorn National Forest range allotment permit data*).

No.	ALLOTMENTS	Livestock Permitted	Number of Permittees	Total acres	Capable acres	Forest Plan watershed	Permitted Season	Season in days	Acres/ AUM
1	Crooked Cr. C&H	110 C/C	1	2,462	1,359	Shell	7/11-9/20	82	3.4A/AUM
2	Granite Cr. C&H	454 C/C 70 Y	2	7,090	6,313	Shell	7/8-10/7	92	2.3A/AUM
3	Salt Creek C&H	640 C/C: 95 Y	3	15,999	7,621	Shell	6/16-10/15	122	1.4A/AUM
4	Shell Basin C&H	300 C/C	2	21,748	7,696	Shell	7/11 to 9/20	72	8.1A/AUM
5	Shell Creek C&H	695 Y	1	11,462	4,626	Shell	7/1-10/10	102	2.8A/AUM
6	Clear Creek C&H	875 C/C; 144 Y	3	15,910	6,073	Clear/Crazy	7/1-9/30	92	1.2A/AUM
7	Doyle/Upper Doyle C&H	266 C/C	1	14,336	2,264	Clear/Crazy	7/16 - 9/15	72	2.7A/AUM
8	Grommund/Sourdough Creek C&H	331 C/C	2	11,475	3,409	Clear/Crazy	7/7-9/30	86	2.7A/AUM
9	Muddy Creek/Crazy Woman C&H	740 C/C	10	46,373	8,302	Clear/Crazy	6/25-9/25	93	2.7A/AUM
10	Poison Creek C&H	330 C/C	1	2,848	1,299	Clear/Crazy	7/7 - 9/21	77	1.2A/AUM
11	Powder River C&H	303 C/C; 650 Y	2	9,245	3,468	Clear/Crazy	7/16-9/30	77	1.3A/AUM
12	Devils Canyon C&H/Little Mountain C&H	959 C/C	1	42,312	19,867	Medicine Mountain/Little Bighorn	7/01 - 10/09	101	4.7A/AUM
13	Medicine Mountain C&H	1087 C/C	7	17,775	9,611	Medicine Mountain/Little Bighorn	6/26 - 10/10	107	2.9A/AUM
14	Lodge Grass C&H	119 C/C	1	4,965	1,649	Little Bighorn	7/1-10/15	107	2.9A/AUM
15	Amsden C&H	81 C/C; 75 Y	1	2,660	1,294	Tongue	7/4 - 10/10	99	2.5A/AUM
16	Copper Cr/Upper Dry Fork C&H	900 Y	1	14,576	2,187	Tongue	6/20 - 9/15	86	1.2A/AUM
17	Freezeout C&H	1369 C/C; 102 Y	7	27,090	9,165	Tongue/Little Bighorn	6/16 - 10/10, 6/16 - 9/10	117 87	1.3A/AUM
18	Little Tongue C&H	375 C/C	2	25,650	5,616	Tongue	6/21 to 10/5	107	3.2A/AUM
19	Lower Tongue C&H	1278 C/C 240 Y	5	13,440	7,937	Tongue	6/16 to 10/10 6/16 - 9/10	117 87	1.1A/AUM
20	Nicklemine C&H	172 C/C; 479 Y	2	6,319	2,424	Tongue	6/16 to 10/10; 7/1 - 10/10	117 102	1.2A/AUM

Permitted livestock by allotment on the Bighorn National Forest (*source: Bighorn National Forest range allotment permit data*).

No.	ALLOTMENTS	Livestock Permitted	Number of Permittees	Total acres	Capable acres	Forest Plan watershed	Permitted Season	Season in days	Acres/ AUM
21	Pass Creek C&H	310 C/C; 100 Y	1	13,440	2,883	Little Bighorn/Tongue	6/26 to 10/5; 7/20 - 10/5	102 78	1.8A/AUM
22	Prospect Cedar C&H	169 C/C	1	4,699	3,402	Shell & Tongue	7/6 to 10/5	92	5.0A/AUM
23	Upper Tongue C&H	710 C/C	2	7,168	3,328	Tongue	6/16 to 10/10	117	0.91A/AUM
24	Wolf Creek C&H	338 C/C	2	6,344	1,788	Tongue	6/21 to 9/25	97	1.2A/AUM
25	Bull Creek S&G	Variable Season NTE 2078 AUM'S	1	16,921	11,725	Tongue	7/1 - 9/30	92	5.6A/AUM
26	Fishhook/FOOL CREEK S&G	1200 S	1	9,467	4,222	Tongue	7/6 to 9/18	75	5.3A/AUM
28	Lookout Mtn. S&G	VACANT	0	8,317	4,248	Tongue/Little Bighorn	VACANT		
29	Owen Creek S&G	1450 S; 320 Y	1	3,930	2,304	Tongue	7/4 to 9/5; 7/7 - 9/5	64 61	1.8A/AUM
30	Pole Creek S&G	1200 S	0	2,558	1,877	Tongue	7/6 to 9/15	72	2.2A/AUM
31	Spring Creek S&G	1200 S	1	2,500	1,345	Tongue	7/6 to9/5 (30 DAYS)	30	4.2A/AUM
32	Wallrock/Hidden Teepee S&G	1500 S	1	7,840	4,850	Tongue	7/1 -9/15	77	4.8A/AUM
33	Southside C&S	VARIABLE # & KIND	1	9,080	4,041	Shell	4/30 - 11/ 7 690 AUM		5.8A/AUM
34	Paintrock C&H	C/C VARIABLE SEASON & #'S	2	42,925	8,048	Paintrock	7/10-9/2	3000 AUMS	2.7A/AUM
35	Forks C&H	467 C/C; 99 Y	3	11,168	3,913	Paintrock	7/11-10/10	92	1.9A/AUM
36	Trapper C&H	422 C/C	1	17,276	10,517	Paintrock/Shell	7/11-9/30	82	6.9A/AUM
37	Dry Fork Medicine Lodge S&G	2500 S	1	12,378	6,381	Paintrock/Shell	7/10 - 9/2	55	4.6A/AUM
38	Battlepark C&H	1445 C/C	7	27,380	15,764	Paintrock	6/26-10/25	122	2.0A/AUM
39	Misty Moon S&G	VACANT	0			Paintrock/Tensleep			
40	Piney C&H	264 C/C	1	9,593	1,822	Piney/Rock	7/10 -9/30	83	1.9A/AUM
41	Little Piney C&H	67 C/C	1	9,518	1,446	Piney/Rock	6/16 - 9/30	107	4.6A/AUM
42	Rock Cr. C&H	300 C/C	1	30,720	6,073	Piney/Rock/Clear/Crazy	7/1-9/26	88	5.2A/AUM
44	Whaley S&G	1030 S	1	6,396	2,744	Shell	6/26 -9/7	72	3.6A/AUM
45	Hunt Mtn. S&G	VACANT	0			Shell			

No.	ALLOTMENTS	Livestock Permitted	Number of Permittees	Total acres	Capable acres	Forest Plan watershed	Permitted Season	Season in days	Acres/ AUM
46	Red Canyon S&G	VACANT	0			Shell			
47	Red Canyon C&H	100 C/C	1	6,405	2,792	Shell	6/29 - 10/11	107	6.0A/AUM
48	Sunlight Mesa C&H	238 C/C	1	10,643	5,899	Shell	6/21-10/15	117	4.8A/AUM
49	Grouse Cr. C&H	56 C/C	1	3,169	2,212	Shell	5/16 - 8/30	106	8.5A/AUM
51	Wiley Sundown /Finger Creek C&H	334 C/C	1	6,929	4,264	Shell	7/6-9/23	80	3.6A/AUM
53	Walker Prairie C&H	329 C/C	3	33,392	3,213	Goose Creek/Tongue	6/25 -9/25	93	2.4A/AUM
54	Rapid Creek C&H	449 C/C	2	13,760	2,615	Goose Creek	6/26-9/25	92	1.4 A/AUM
55	Stull C&H	VACANT	0			Goose Creek			
56	Big Goose C&H	175 C/C	1	11,196	1,213	Goose Creek	6/21 - 9/20	92	1.7 A/AUM
57	Little Goose C&H	415 C/C	3	28,599	2,061	Goose Creek	7/1-9/5	67	1.7 A/AUM
58	Little Goose Canyon C&H	34 C/C	1	1,235	471	Goose Creek	7/1 - 9/30	92	3.4 A/AUM
59	Willow Park C&H	91 C/C	1	6,710	444	Piney/Rock	7/10 - 9/15	68	1.6A/AUM
60	Dry Tensleep C&H	387 C/C	4	5,466	3,495	Tensleep	6/23-10/8	108	1.9A/AUM
61	Tensleep Canyon C&H	175 C/C	1	2,671	1,470	Tensleep	7/1 - 9/30	92	2.1A/AUM
62	South Canyon C&H	465 C/C	3	14,097	6,459	Tensleep	7/1-10/1	93	3.4A/AUM
63	Monument C&H	250 C/C	1	3,643	1,495	Tensleep	7/1-9/30	92	1.5A/AUM
64	North Canyon C&H	800 C/C	1	13,384	6,644	Tensleep	7/1-10/5	97	1.9A/AUM
65	Leigh Creek S&G	VACANT	0			Tensleep			
66	Garnet S&G	1250 S	1	5,157	2,965	Tensleep	7/8 - 9/12	67	3.2A/AUM
67	Willow/Upper Meadows S&G	1200 S	1	18,417	4,376	Tensleep	7/1 - 8/23	54	6.7A/AUM
68	McLain S&G	VACANT	0			Tensleep			
70	Baby Wagon S&G	520 S	0	6,737	1,498	Tensleep	7/11 - 8/31	52	5.5A/AUM
71	Hazelton S&G	1000 S	1	5,954	1,978	Tensleep	7/6 - 9/5	62	3.2A/AUM
72	Fisher Mtn. C&H	10 H	1	1,485	390	Little Bighorn	5/1 -10/31	184	5.3A/AUM
73	Red Springs C&H	46 C/C	2	21,039	5,696	Little Bighorn	7/1-10/5	97	29.0A/AUM
74	Sage Basin C&H	200 C/C	1	5,489	1,630	Little Bighorn	6/26-9/20	87	2.1A/AUM

Permitted livestock by allotment on the Bighorn National Forest (*source: Bighorn National Forest range allotment permit data*).

Permitted livestock by allotment on the Bighorn National Forest (*source: Bighorn National Forest range allotment permit data*).

No.	ALLOTMENTS	Livestock Permitted	Number of Permittees	Total acres	Capable acres	Forest Plan watershed	Permitted Season	Season in days	Acres/ AUM
75	Little Horn C&H	819 C/C	4	12,567	5,866	Little Bighorn	6/28-10/14	109	1.5A/AUM
76	Wyoming Gulch C&H	225 C/C	1	8,285	5,238	Little Bighorn/Medicine Mountain	7/6-9/30	87	6.1A/AUM
77	Antelope Ridge, Bear Crystal, Beaver, Creek S&G	3000 S	1	15,410	6,638	Little Bighorn	7/1 - 9/10	72	3.1A/AUM
78	Dry Fork Ridge C&H	148 C/C	1	7,257	877	Little Bighorn	7/1 - 9/30	92	1.5A/AUM
79	West Pass C&H	166 C/C	1	2,088	1,363	Little Bighorn	6/16 - 9/30	107	1.7A/AUM
80	Lower Dry Fork C&H	313 C/C	2	7,472	3,227	Little Bighorn	6/21 - 9/30	102	2.3A/AUM
81	Little Horn S&G	1200 S	1	5,243	2,684	Little Bighorn	6/27 - 9/20	86	2.6A/AUM
82	Lake Creek C&H	171 C/C	2	14,469	4,048	Little Bighorn	6/26 - 10/10	107	5.0A/AUM
83	Mathew's Ridge	52 C/C	1	1,928	385		7/1 - 9/15	77	2.2A/AUM
84	South Park	100 C/C	1	1,105	687		7/1 - 9/15	77	2.0A/AUM

C/C for 1 month = 1.32 AUM
1 Yearling fo 1 month = 0.7 AUM
5 E/L for 1 month = 1.32 AUM

Module 4D - Non-Native Plant Species

Objectives

Identify current concerns regarding the distribution of non-native plant species. Depending on the availability of current systematic inventory data, map known locations of non-native plant species. Identify and map invasibility (vulnerability of a site to non-native plant establishment and spread). Identify and map dispersal vectors (risk). Identify and map areas most likely to be invaded by non-native plants (hotspots). Discuss the interaction of non-native plant species with disturbance. Address the ecological consequences of the current condition and probable trends.

Introduction

Non-native plant species have the potential to change the composition of natural communities, threaten native biodiversity, and alter ecosystem functions such as nutrient cycling and disturbance regimes (Mack *et al.* 2000; Vitousek *et al.* 1997; Wilcove *et al.* 1998). For example, non-native plants are known to alter the natural fire regime in some ecosystems (D'Antonio and Vitousek 1992). Non-native plants may be especially problematic in rangelands, where they out-compete native species and reduce forage for wildlife and livestock. Human activities that disturb native plant communities and alter natural disturbance regimes may promote the spread of non-native species. Climate change and habitat fragmentation may exacerbate the spread of non-native species (Mooney and Hobbs 2000). The impact of non-native species introductions on our ability to conserve native species is illustrated by the fact that almost half of the threatened and endangered species listed under the Endangered Species Act are so listed because of competition with or predation by non-native species (Pimentel *et al.* 2000).

Non-native species have the potential to disrupt the ecological integrity of the Big Horn Mountains (Fig. M4-1). The current situation does not appear to be severe, but invasive species monitoring and inventory on the Bighorn National Forest is so limited that occurrence data are available only with relatively low confidence for the entire Forest. In addition, lands adjacent to the Forest are showing increases in non-native species that increase the risk of non-native plant invasion on the Forest.

<u>Invasive Species of Concern on the Bighorn National Forest</u>

Data to evaluate current distributions of invasive and non-native plant species in the assessment area were extremely limited. However, we present some findings that should be considered preliminary and tentative given the inventory limitations. The most common non-native plant species found within the Bighorn National Forest is Canada thistle (*Cirsium arvense*). A total of 128-point occurrences of Canada thistle were recorded across the Forest, and its presence was noted across at least 3,300 acres (1,336 ha). Canada thistle has rapidly spread in western North America in the last 50 years. It prefers moist habitats such as road right-of-ways, riparian bottoms, aspen stands, and coniferous and deciduous riparian types. Its common proximity to water poses problems for chemical control. In fact, the combination of its rapid expansion and the difficulty to control it have led many weed and pest organizations to declare it a naturalized species, similar to Kentucky bluegrass (*Poa pratensis*) or dandelion (*Taraxicum officiale*). Livestock and transportation corridors are its main sources of dispersal.

Houndstongue (*Cynoglossum officinale*) is far less well established in the Bighorns, but is thought to occur across approximately 4,700 acres (1,903 ha). It spreads rapidly along deciduous stream courses, cottonwood bottoms, and mountain big sagebrush vegetation types, mainly because its sticky seed is widely dispersed by livestock and recreationists. This species is poisonous to livestock.

Whitetop (*Cardaria draba*), or hoary cress, is present at 37-point occurrences and across at least 200 acres (81 ha) of the Forest. It is a major invasive in pastures, cultivated lands, and disturbed sites in the Big Horn Basin. It spreads rapidly along low elevation moist river bottoms and meadows.

Yellow toadflax (*Linaria vulgaris*) has been recorded at 18 point occurrences and on 250 acres (101 ha) in the Big Horn Mountains. It has the ability to expand its range rapidly, and prefers mid- to high-elevation wet meadows and grasslands. This species is a major problem in the subalpine grasslands in the Flat Tops Wilderness in Colorado, and similar growing conditions exist in the Bighorn Section. Chemical control is extremely difficult and expensive.

Musk thistle (*Carduus nutans*) has become a problem in portions of the Bighorn and Wind River basins, although it has not yet become well established in the Forest (one point occurrence, < 100 acres/40 ha). Areas at highest risk are non-forested and at generally lower elevations (< 8500 feet/2591 m) within the Big Horn Mountains Section. Biological control and chemical efforts are successful if they are initiated quickly and prudently.

Although Russian knapweed (*Acroptilon repens*) has yet become well established on the Forest (one point occurrence, < 50 acres/20 ha), it exhibits strong allelopathy and has rapidly invaded cottonwood bottomlands and agricultural pasturelands on the east side of the Big Horn Basin and in the Wind River Basin over the last 10 years. Chemical control has been very difficult. Spotted knapweed (*Centaurea maculosa*) is well established in Montana and in some areas is at the point that control is economically questionable. Its distribution is rapidly expanding in the Big Horn Basin and is one of the highest priorities for treatment for county weed and pest organizations.

Several other species are not yet known in the Bighorn National Forest, but are of concern due to their high propensity for invading, their success on sites similar to those found in the Bighorns, or their location very near the Forest. Russian olive (*Elaeagnus angustifolia*) is still commonly used as a shelterbelt species around agricultural properties and landscaping. It is bird-dispersed, and has spread along river bottoms, out-competing native cottonwood and willow species in the Shoshone, Bighorn, Nowood, and GreyBull River drainages over the last 50 years. Lower fringes of the Section are particularly susceptible to invasion.

Leafy spurge (*Euphorbia esula*) is a considerable problem to the north and to the east of the Big Horn Mountains Section. This species rapidly out compete native species, and it has greatly expanded its range along the Yellowstone River drainage in Montana and Powder River basin over the last 10 years. Chemical treatment has proven difficult, but biological control with leaf beetles has been shown to be effective. This species may appear along the lower fringes of the Big Horn Mountains Section.

Tamarisk (*Tamarisk ramossisima, T. parviflora,* and *T. chinesis*) is an increasing problem along river drainages in the Big Horn Basin. This species out-competes salt-intolerant native species by increasing salt levels in the soil. The Bureau of Land Management in the Big Horn Basin is beginning to treat this species aggressively, but chemical control is difficult due to its proximity to water.

Dalmatian toadflax (*Linaria dalmatica*) is rapidly expanding from points along the Shoshone River drainage to the west. Many acres of critical bighorn sheep habitat have been affected in the upper South Fork of the Shoshone River, and similar habitat conditions occur within the Big Horn Mountains Section. In the Big Horn Mountains, areas of concern are on the west side along Shell Creek and in the Owl Creek Mountains. This species spreads rapidly in Wyoming big sage and bluebunch wheatgrass vegetation types. Chemical control is extremely difficult and expensive.

Other species of concern but not currently known to occur in the Bighorns include common mullein (*Verbascum thapsus*), cheatgrass (*Bromus tectorum*), and Kentucky blue grass. Common mullein, a species native to the plains, usually colonizes disturbed or rocky lands along transportation corridors. It has gained rather high densities on winter ranges along the Main and Middle Forks of the Salmon River in Idaho. Wyoming big sage and bluebunch wheatgrass vegetation types in the Bighorns are susceptible to this species. Cheatgrass has increased in the intermountain basins of the West over the last 50 years, and is common along low-elevation road corridors and in dry bluebunch wheatgrass, buffalo grass, and Wyoming big sage types where it spreads rapidly after fire. Kentucky bluegrass is an invader of moist grasslands and riparian areas, but is now considered to be a naturalized species. Its shallow rooting system allows it to out-complete other more preferred wetland grasses. High densities of this species usually indicate past heavy grazing pressure.

Known Occurrences of Invasive Plants in the Bighorn National Forest

Although invasive species mapping on the Forest is underway, it is far from complete. The known occurrences of invasive plants on the Forest were gathered from fewer than 50 sample points as part of the Forest Service's Forest Health Monitoring and Forest Inventory and Analysis database; other known occurrences were determined using non-standardized methodology by other local, state, or federal agencies.

Available data indicate invasive plants are currently most common in the northern portion of the Forest (Fig. M4D-1) in grasslands, prairies, and subalpine meadows, although some have been found in coniferous forests, particularly lodgepole pine, and in recent (<20 years) clearcuts. Such patterns should be viewed in the context of the limited data available, however, rather than as long-term trends or affinity for any vegetation cover type.

Although limited, known occurrence data are useful in identifying the most common vectors of non-native plant invasion, particularly since human disturbances are often an important influence. Some of the most common vectors include roads, campgrounds, trailheads, stock driveways, livestock, and recreationists. Some of the most susceptible landscapes include low-elevation grasslands, shrub lands, and riparian bottoms, although grasslands and woodlands at any elevation are also susceptible to plant invasion.

Known occurrences of various non-native plant species in each LTA and FPWS are shown in Tables M4D-1 and M4D-2, respectively. LTAs in the Big Horn Mountains Sedimentary Subsection (M331Ba) have the most diverse infestation of non-native plant species compared with those in the Big Horn Mountains Granitic/Gneiss Subsection (Fig. M4D-1; Table M4D-1) Canada thistle and houndstongue are the most broadly distributed non-native species, occurring in ten and seven out of the 11 LTAs, respectively. Yellow toadflax and field bindweed have the most limited distribution, with only one occurrence each and both of those on Sedimentary Mountain Slopes, Limestone/Dolomite (M331Ba-03). Four of the FPWS units have three or four species of non-native plant occurrences, while three FPWS units have only one occurrence (Table M4D-2). Canada thistle is found in all FPWS units. Because these data were not collected in a statistically rigorous design, further interpretation and any conclusions would need proper validation.

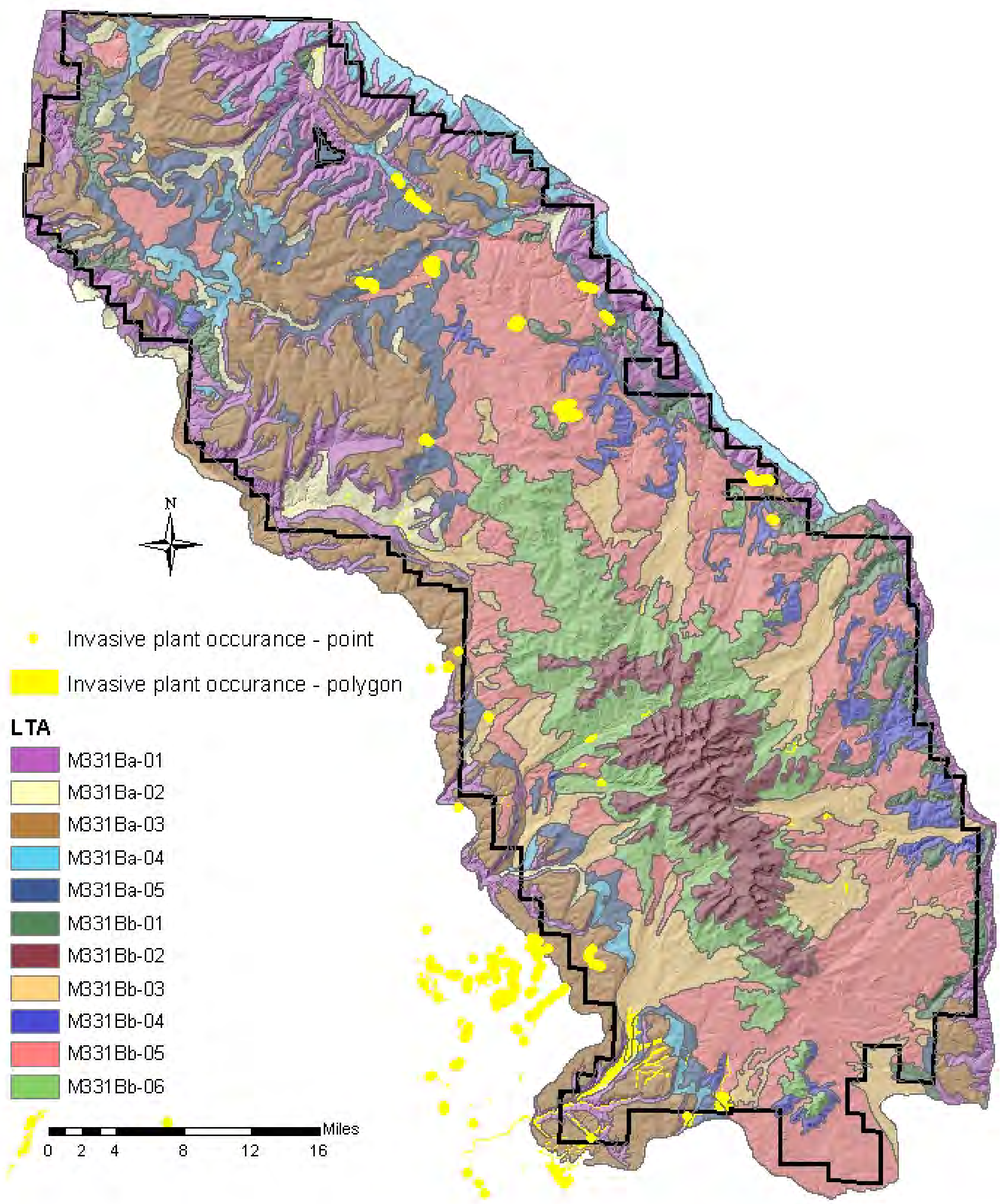


Figure M4D-1. The known locations of invasive plant occurrences in and near the Bighorn National Forest.

Table M4D-1. Distribution of known occurrences of invasive plant species by Landtype Association (LTA). NN = No name, CT = Canada thistle, WT = whitetop, YT = yellow toadflax, MT = musk thistle, HT = houndstongue, KW = knapweed, FB = field bindweed.

LTA	LTA description	NN	CT	WT	YT	MT	HT	KW	FB
Big Horn Mountains Sedimentary Subsection									
M331Ba-01	Sedimentary Breaklands	X	X	X		X	X	X	
M331Ba-02	Landslide/Colluvial Deposits	X	X	X		X	X	X	
M331Ba-03	Sedimentary Mountain Slopes, Limestone/Dolomite	X	X		X		X	X	X
M331Ba-04	Sedimentary Mountain Slopes, Shale/Sandstone (Calcareous)	X	X			X	X	X	
M331Ba-05	Sedimentary Mountain Slopes, Shale/Sandstone (Noncalcareous)		X			X	X		
Big Horn Mountains Granitic/Gneiss Subsection									
M331Bb-01	Granitic Breaklands		X				X		
M331Bb-02	Glacial cirquelands								
M331Bb-03	Glacial/Tertiary Terrace Deposits		X	X			X		
M331Bb-04	Granitic Mountain Slopes, Steep		X						
M331Bb-05	Granitic Mountain Slopes, Gentle		X						
M331Bb-06	Alpine Mountain Slopes and Ridges		X						

Table M4D-2. Distribution of known occurrences of invasive plant species by Forest Plan Watershed Unit (FPWS). CT = Canada thistle, WT = whitetop, YT = yellow toadflax, MT = musk thistle, HT = houndstongue, KW = knapweed.

FPWS	CT	WT	YT	MT	HT	KW
Clear/Crazy Woman Creek	X					
Devil's Canyon	X			X	X	
Goose Creek	X					
Little Bighorn	X			X	X	
Paintrock Creek	X	X	X			
Piney/Rock Creek	X					
Shell Creek	X	X		X		X
Tensleep Creek	X		X		X	
Tongue River	X					X

Probable Invasive Species Distributions on the Bighorn National Forest

Factors Related to Risk of Non-native Plant Establishment

Risk is the probability of a non-native species becoming established. The risk of non-native species establishment increases when dispersal vectors provide for the continued introduction of non-native plant species into a given area (Fig. M4D-2). For example, an area has higher risk when dispersal vectors such as roads and trails (see Module 4E), recreation areas (campgrounds, picnic areas, ski areas—see Module 4F), areas of livestock concentration (corrals, watering areas, and stock driveways—see Chapter 5 Module B), and other areas of human concentration (private landholdings, summer homes, and agency administration sites—see Module 4E) are nearby. Similarly, risk is greater for non-native species establishment for areas that are in close proximity to already invaded areas.

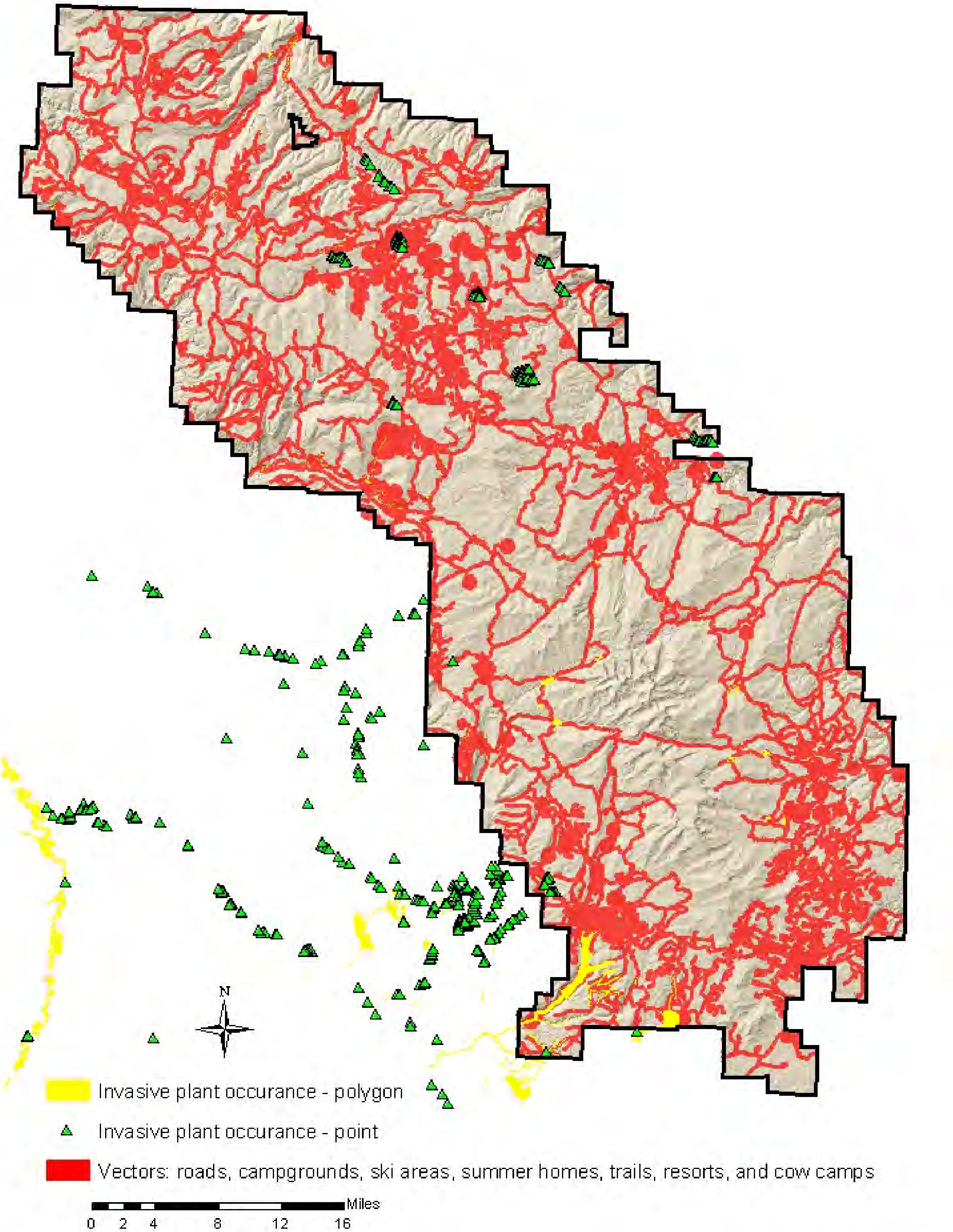


Figure M4D-2. Delineation of areas at risk of invasion on the Bighorn National Forest.

Geographic Areas of Probable Invasibility in the Bighorn National Forest

Physiographic Invasibility Model

Influences on invasibility (i.e., vulnerability to invasion) are often difficult to characterize, because species-specific factors that determine how quickly a non-native plant may spread or how well a given species may survive across environmental gradients are widely variable from plant to plant. However, when assessing the invasibility of a given land area, several factors are typically consistent in their importance to plant spread and survival. In western North America, moisture and nutrient availability is often the most limiting factor to plant distribution. In addition, most non-native plant species show a preference for high light conditions, such that invasion occurs most frequently in cover types with low or no canopy cover. Finally, non-native plant invasion appears to be most successful where temperatures are higher and growing seasons are longer.

Because occurrence data for invasive plant species on the Bighorn National Forest are limited, this assessment focuses mainly on describing areas of probable invasibility based on the biophysical factors described above. The following data are based on a qualitative model (see Protocol for complete description) developed to draw attention to potentially vulnerable areas on the Forest based upon other studies of invasive species. The model has not been validated, and inventory and occurrence data for invasive species on the National Forest are greatly needed.

The model suggests the majority of the Bighorn National Forest appears to be at relatively low risk for plant species invasion (Fig. M4D-3). Of the 1.1 million acres of the Bighorn National Forest, 52% (approximately 578,000 acres/ 234,000 ha) are considered to be at low or very low invasibility. Areas with very low invasibility are generally concentrated at the highest elevations on the Forest (> 10,000 feet/3,048 m) where native plants tend to have a competitive advantage due to colder temperatures and shorter growing season. Low-invasibility areas tend to be more evenly distributed across all elevations and geographic locations (Fig. M4D-4). Less than 20% (approximately 210,000 acres/ 85,000 ha) are considered to be at very high or high invasibility; most areas of very high invasibility are located within drainages or valley bottoms at the northern end of the Forest (Fig. M4D-4). High-invasibility areas, as well as those considered to be at moderate invasibility (322,000 acres/130,000 ha), are generally located on north-facing slopes and relatively flat sites and at lower elevations (<8,000 feet/2,438 m), particularly those around the margin of the Forest.

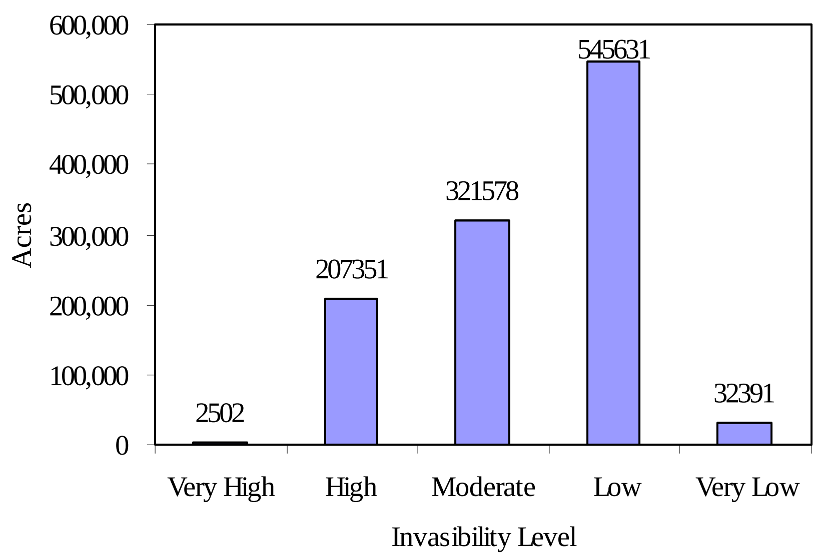


Figure M4D-3. Number of acres assigned to each invasibility category for non-native plant invasion in the Bighorn National Forest.

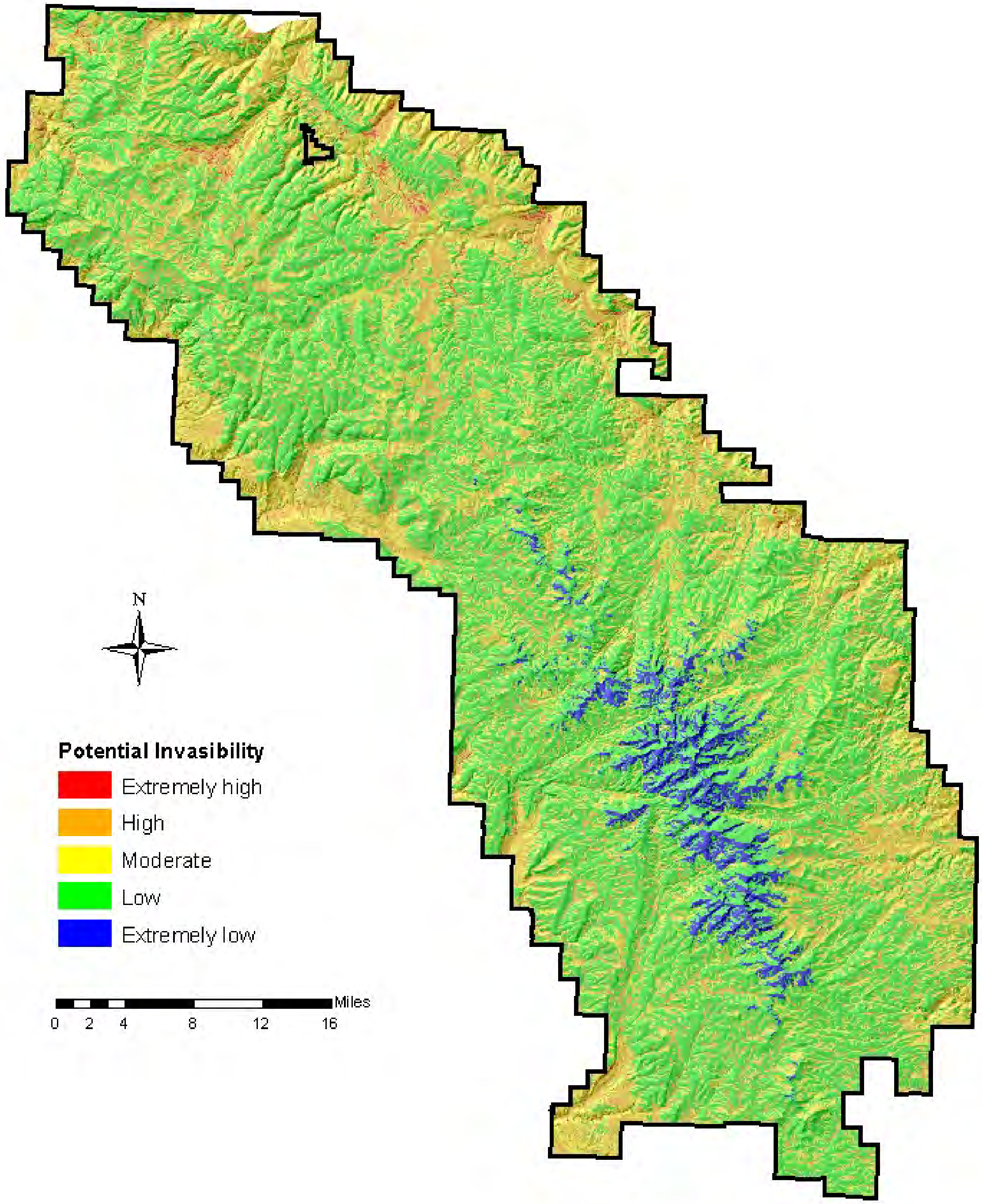


Figure M4D-4. Potential invasibility to non-native plant species invasion on the Bighorn National Forest.

Probable Invasibility by Vegetation Type

The affinity of invasive species for certain broad vegetation types (Table M4D-4) is another factor in the invasibility of an area. For example, using the CVU database as a reference, shrubby vegetation or open woodlands occupy 90% of the land area classified as being at very high invasibility is dominated by grass or forb species, 1%, and 9% is dominated by forests. Forests are often classified as having high invasibility; 57% of the land area classified as being at high invasibility is forested, 9% is occupied by shrubby vegetation or open woodlands, and 31% is dominated by non-woody vegetation. In contrast, 71% of the area considered to be at low invasibility is forested, 5% is shrubby or open woodland vegetation, and grasses and/or forbs dominate 13%. Interestingly, mainly areas of bare rock and soil dominate the "very low invasibility" category. Grasses and forbs occupy less than one percent of this total land area, and only two percent is forested (Table M4D-3). Such patterns are in part a consequence of model construction, which considered areas of high light and low canopy coverage to be more likely to support non-native plant invasion. However, grasslands and areas dominated by non-woody vegetation are considered areas of high invasibility due to their occurrence at lower elevations, their likelihood to be grazed, and their easier access by humans. Thus many factors act in concert in determining the invasibility of any given site on the Forest to non-native plant establishment and spread.

Probable Invasibility by Landtype Association

Within the Bighorn National Forest, invasibility of specific physiographic features may be inferred by examining the invasibility of Landtype Associations (LTAs). LTAs in the Sedimentary Subsection have a greater proportion of their land area in the very high and high categories of invasibility compared with those of the Granitic/Gneiss Subsection (Table M4D-4). Specifically, Landslide/ Colluvial Deposits (M331Ba-02) has 41% of its land area in the very high and high invasibility categories, making this relatively small LTA an important management concern. Interestingly, this conclusion that the Sedimentary Subsection has greater probability of invasion coincides with the noted occurrences pattern seen above in Figure M4D-1 and Table M4D-1.

It is likely that topographic influences, for example, slope percentage and elevation, may have more influence on plant species invasibility than soil type. Notably, a high proportion of the land area for Glacial Cirquelands (M331Bb-02) and Alpine Mountain Slopes and Ridges (M331Bb-06; Table M4D-4) is in the low and very low invasibility categories, where topography is very steep and temperature and growing season are not favorable for generalist species. Glacial Cirquelands is of particular interest for its small land area in the high and very high invasibility categories.

Table M4D-3. Acres of land (hectares are in parentheses) and proportion within the Bighorn National Forest by vegetation cover type within each invasibility category for non-native plant invasion. VH = very high, H = high, M = moderate, L =low, VL = very low invasibility.

Cover Type	VH		H		M		L		VL	
	acres (ha)	%	acres (ha)	%	acres (ha)	%	acres (ha)	%	acres (ha)	%
Bluegrass scabland	23 (9)	4	270 (109)	45	242 (98)	41	59 (24)	10		
Mountain mahogany	3 (1)	21	11 (4)	79						
Idaho fescue/bluebunch wheatgrass	12 (5)	1	642 (260)	53	539 (218)	45	12 (5)	1		
Rabbitbrush/sagebrush			1,855 (751)	24	2,163 (875)	29	3,569 (1,444)	47		
Aspen	4 (2)	<1	5,560 (2,250)	54	2,345 (949)	23	2,375 (961)	23	6 (2)	<1
Bare			94 (38)	1	3,018 (1,221)	24	5,433 (2,199)	43	3,968 (1,606)	32
Bare litter duff					4 (2)	40	6 (2)	60		
Bare rock			2,858 (1,157)	3	7,252 (2,935)	8	51,882 (20,996)	58	27,660 (11,194)	31
Bare rock/soil indistinguishable			736 (298)	12	1,847 (747)	31	3,344 (1,353)	56		
Bare soil			553 (224)	24	910 (368)	40	834 (338)	36		
Bare wood (logging debris)			116 (47)	9	503 (204)	39	664 (269)	52		
Big sagebrush	6 (2)	<1	13,575 (5,494)	29	14,363 (5,813)	30	19,500 (7,891)	41		
Curl leaf mountain mahogany	6 (2)	<1	898 (401)	26	2,434 (985)	72	62 (25)	2		
Cottonwood			305 (123)	78	75 (30)	19	13 (5)	3		
Deschampsia/wet sedge			580 (235)	34	523 (212)	30	619 (251)	36	2 (1)	<1
Douglas-fir	15 (6)	<1	23,737 (9,606)	24	39,355 (15,926)	39	36,906 (14,935)	37		
Forb	1,509 (611)	2	22,214 (8,990)	36	19,105 (7,732)	31	19,466 (7,878)	31		
Grass	704 (285)	1	41,073 (16,621)	32	39,242 (15,881)	31	45,807 (18,537)	36	7 (3)	
Ice/snow							89 (36)	57	66 (27)	43
Idaho fescue			1,059 (429)	17	1,446 (585)	23	3,701 (1,498)	60		
Juniper			58 (23)	32	20 (8)	11	102 (41)	57		
Limber pine	33 (13)	<1	3,265 (1321)	23	6,520 (2,639)	47	4,169 (1,687)	30		
Lodgepole	53 (21)	<1	47,979 (19,416)	14	98,340 (39,797)	28	199,692 (80,813)	58	8 (3)	<1
Pinyon/juniper	10 (4)	<1	1,148 (465)	39	1,733 (701)	59	55 (22)	2		
Ponderosa	45 (18)	<1	5,225 (2,114)	29	9,129 (3,694)	50	3,908 (1,582)	21		
Shrub	2 (1)	<1	1,001 (405)	37	758 (308)	28	956 (387)	35		

Table M4D-3. Acres of land (hectares are in parentheses) and proportion within the Bighorn National Forest by vegetation cover type within each invasibility category for non-native plant invasion. VH = very high, H = high, M = moderate, L =low, VL = very low invasibility.

Cover Type	VH		H		M		L		VL	
	acres (ha)	%	acres (ha)	%	acres (ha)	%	acres (ha)	%	acres (ha)	%
Skunkbrush			17 (7)	49	18 (7)	51				
Spruce/Fir	74 (30)	<1	27,458 (11,112)	12	67,094 (27,152)	29	139,454 (56,435)	59	658 (266)	<1
Water			12 (5)	80			3 (1)	20		
Willow			5,051 (2,044)	48	2,593 (1,049)	24	2,942 (1,191)	28	16 (6)	<1
Total	2,502 (1,013)	<1	207,347 (83,910)	19	321,573 (130,136)	29	545,619 (220,804)	49	32,391 (13,108)	3

Table M4D-4. Acres (hectares) and proportion of land within the Bighorn National Forest by Landtype Association (LTA) within each invasibility category for non-native plant invasion. VH = very high, H = high, M = moderate, L =low, VL = very low invasibility. Hectares are in parentheses.

LTA	VH		H		M		L		VL	
	acres (ha)	%	acres (ha)	%	acres (ha)	%	acres (ha)	%	acres (ha)	%
Big Horn Mountains Sedimentary Subsection										
Sedimentary Breaklands	500 (202)	<1	32,786 (13,268)	25	57,488 (23,265)	43	41,898 (16,956)	32	16 (6)	<1
Landslide/Colluvial Deposits	683 (276)	2	13,839 (5,600)	39	10,920 (4,419)	31	9,835 (3,980)	28		
Sedimentary Mountain Slopes; Limestone/Dolomite	360 (146)	<1	27,917 (11,298)	17	46,753 (18,920)	28	91,016 (36,833)	55	1 (0.5)	<1
Sedimentary Mountain Slopes; Shale/Sandstone (Calcareous)	164 (66)	1	7,567 (310)	29	9,246 (3,742)	36	9,031 (3,655)	35		
Sedimentary Mountain Slopes; Shale/Sandstone (Non-calcareous)	303 (12)	<1	19,141 (7,746)	23	24,888 (10,072)	30	37,279 (15,086)	46		
Big Horn Mountains Granitic/Gneiss Subsection										
Granitic breaklands	133 (54)	<1	11,068 (4,479)	28	14,988 (6,065)	38	13,091 (5,298)	33		
Glacial cirquelands			899 (364)	1	3,878 (1,569)	6	34,623 (14,011)	54	25,018 (10,124)	39
Glacial/Tertiary Terrace Deposits	57 (23)	<1	20,922 (8,467)	21	28,154 (11,394)	28	49,932 (20,207)	50	71 (29)	<1
Granitic Mountain Slopes; Steep	20 (8)	<1	8,074 (3,267)	19	14,740 (5,965)	35	18,932 (7,662)	45		
Granitic Mountain Slopes; Gentle	281 (114)	<1	49,633 (20,086)	16	83,435 (33,765)	28	169,714 (68,681)	56	177 (72)	<1
Alpine Mountain Slopes and Ridges	2 (1)	<1	15,500 (6,273)	13	27,085 (10,961)	23	70,278 (28,441)	59	7,109 (2,877)	6

Probable Invasibility by Forest Plan Watershed Unit

Based on the model predictions, Shell Creek (30,086 acres/12,181 ha) and Tongue River (36,815 acres/14,905 ha) contain the highest area of very high and high invasibility (Fig. M4D-5), likely because of relatively high proportions of low-elevation terrain and, at least in the case of Tongue River, the high number of known infestations already present. In contrast, Devil's Canyon (13,202 acres/5,345 ha) contains the least area of very high and high invasibility. In addition, Clear/Crazy Woman Creek (86,007 acres/34,821 ha) and Tongue River (84,918 acres/34,380 ha) contain the highest area of very low and low invasibility (Fig. M4D-5); such a result is not surprising for Tongue River, which is the largest FPWS on the Bighorn National Forest. Devil's Canyon contains (29,177 acres/11,813 ha) the least area of very low and low invasibility. Thus, Devil's Canyon and Tongue River appear to be dominated by areas of moderate invasibility.

Weighting the FPWS by area, Little Bighorn has the highest proportion of land area considered very highly or highly vulnerable (25%), and Piney/Rock Creek and Paintrock Creek exhibit the lowest proportion (14% each). Paintrock Creek (66%) and Tensleep Creek (60%) exhibit the highest proportion of land area with invasibility considered to be very low or low, and Little Bighorn exhibits the lowest proportion (38%). Paintrock Creek, with the lowest proportion of highly vulnerable land and the highest proportion of land with low invasibility, might be considered to be the "safest" FPWS on the Forest in terms of invasibility. Notably, however, much of Paintrock Creek lies at relatively low elevations, making it susceptible to grazing and other human activities, and the FPWS already contains several known occurrences of invasive plant species (Fig. M4D-5).

Areas Most Likely to be Invaded by Non-Native Plants (Hotspots)

Intersecting a map of very high and high invasibility with the vector or risk map may result in a map of areas that are most likely to be invaded by non-native plants (Fig. M4D-4). Landtype Associations having the highest proportion of very high or high invisibility and high risk are the Landslide/Colluvial Deposits; Sedimenatry Mountain Slopes, Shale/Sandstone (Calcareous); and Sedimentary Mountain Slopes, Shale/Sandstone (Non-calcareous) (Table M7-3). All three are in the Big Horn Mountains Sedimentary Subsection. Landtype Associations with the lowest proportion of very high or high invisibility and high risk are the Glacial Cirquelands; Alpine Mountain Slopes and Ridges; and the Granitic Breaklands in the Big Horn Mountains Granitic/Gneiss Subsection and the Sedimentary Breaklands in the Big Horn Mountains Sedimentary Subsection (Table M4D-6, Fig. M4D-5).

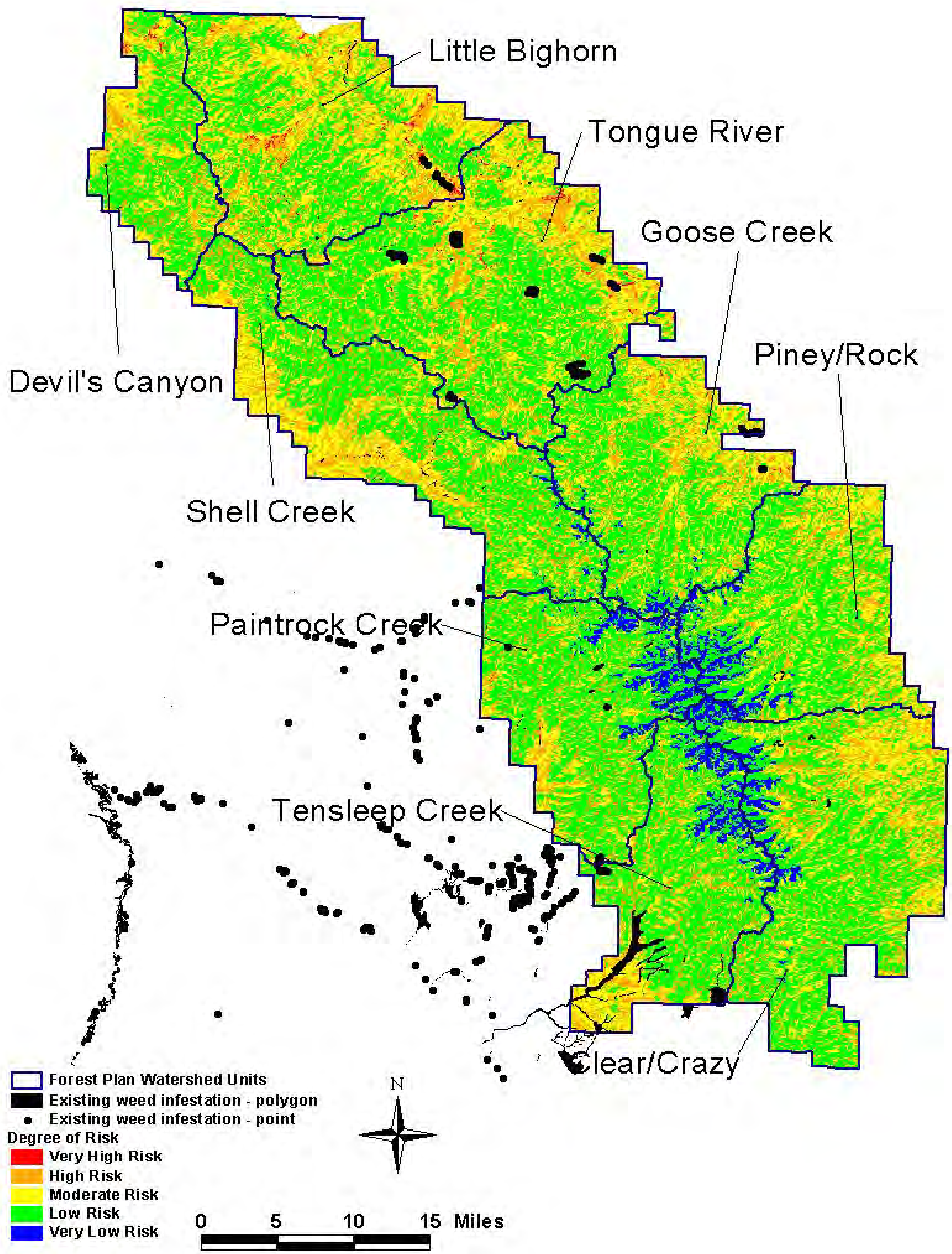


Figure M4D-5. Geographical distribution of known locations of invasive plant occurrences in the Bighorn National Forest, shown by forest plan watershed units.

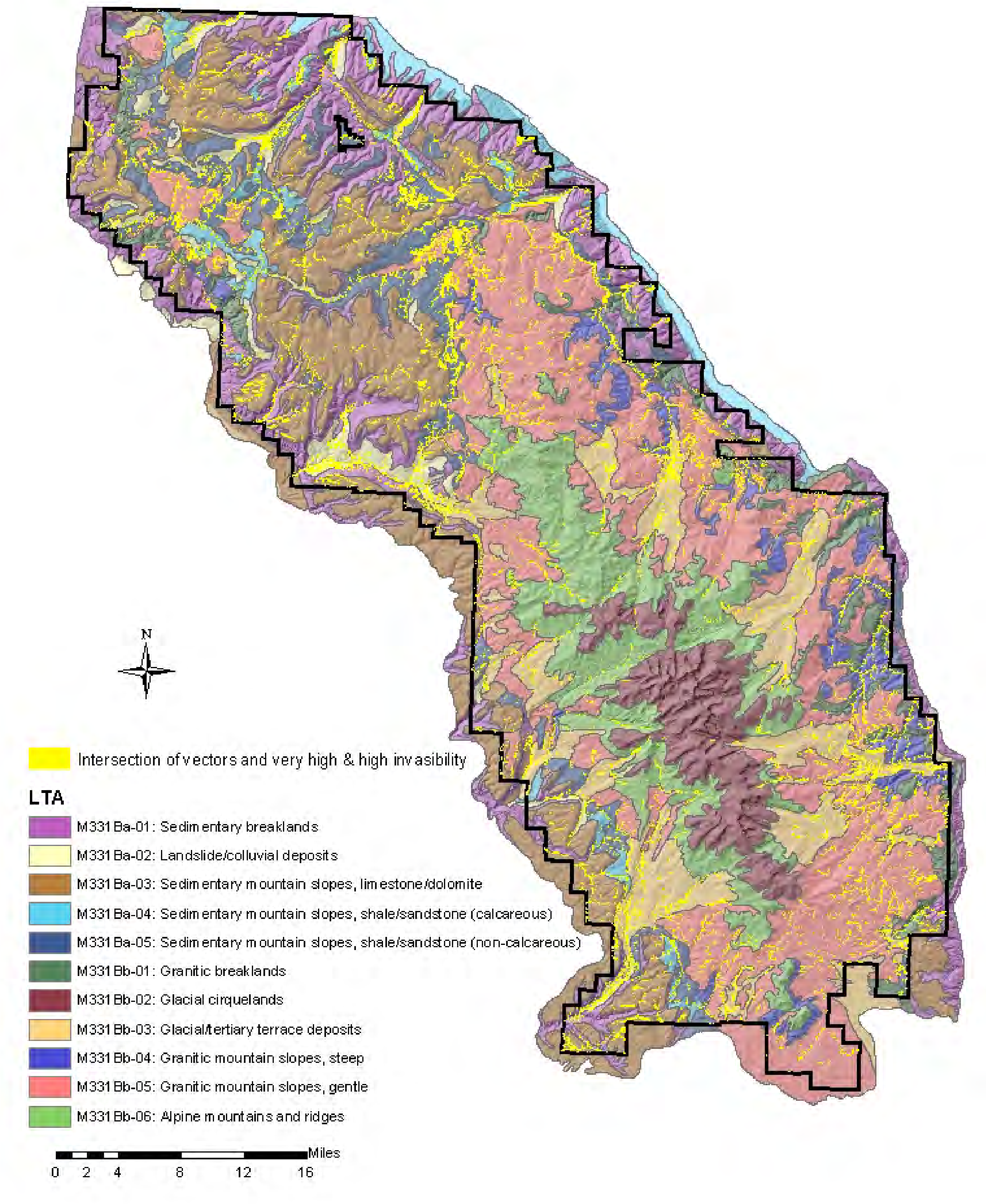


Figure M4D-6. The intersection ("hotspots") of vectors from Figure M4D-2 and very high and high invasibility categories from Figure M4D-3 by LTA**.**

Table M4D-5. Acres (hectares) and proportion of the total that each Landtype Association represents. Acres (hectares) and proportion of the total acres in each LTA of the intersection of very high and high invisibility (invasibility map) with high risk of non-native plant establishment (vector map).

LTA	Total		VH & H Invasibility & High Risk	
	acres (ha)	LTA% of Total	acres (ha)	%
Sedimentary Breaklands	133,995 (54226)	12.05	6,237 (2524)	4.65
Landslide/Colluvial Deposits	35,294 (14283)	3.17	7,031 (2845)	19.92
Sedimentary Mountain Slopes; Limestone/Dolomite	166,069 (67206)	14.94	12,414 (5024)	7.48
Sedimentary Mountain Slopes; Shale/Sandstone (Calcareous)	27,019 (10934)	2.43	4,132 (1672)	15.29
Sedimentary Mountain Slopes; Shale/Sandstone (Non-calcareous)	81,616 (33029)	7.34	11,736 (4749)	14.38
Granitic Breaklands	39,278 (15895)	3.53	2,271 (919)	5.78
Glacial Cirquelands	64,417 (26069)	5.79	178 (72)	0.28
Glacial/Tertiary Terrace Deposits	99,140 (40121)	8.92	12,501 (5059)	12.61
Granitic Mountain Slopes; Steep	41,767 (16903)	3.76	3,236 (1310)	7.75
Granitic Mountain Slopes; Gentle	303,241(122718)	27.27	25,633 (10373)	8.45
Alpine Mountain Slopes and Ridges	119,975 (48552)	10.79	3,604 (1458)	3.0

Natural and Anthropogenic Influences

Although environmental variables such as moisture availability, light availability, and temperature create the ecological template for invasibility of an area, invasibility is greatly increased when environmental conditions are altered by natural and human events. For example, when both non-native and native plant species have access to the site, areas disturbed by recent (< 20 years) fires or timber harvests are more vulnerable for non-native plant invasion. Due to the relatively unpredictable temporal and spatial occurrence of these influences, the only way to include these influences is to use past occurrences (i.e., previous fires and timber harvests) rather than the current risk and invisibility factors presented in the previous section.

Wildfire

Most areas burned in recent large wildfires on the Bighorn National Forest appear to have occurred in areas having relatively low invasibility for non-native plant species. Of the 19,400 acres (7,800 ha) recently burned on the Bighorn National Forest, approximately 48% are considered to be at low or very low invasibility.

Less than 24% are considered to be at very high or high invasibility, and 29% are considered at moderate invasibility. Interestingly, most areas burned by recent wildfires exhibit high spatial heterogeneity in terms of invasibility (Fig. M4D-7); in particular, the larger the wildfire, the more heterogeneous the invasibility within the area of the burn. Such heterogeneity may reflect either the variability in canopy cover resulting from burn severity or the variability of site factors within the burned perimeter. In addition, only one recently burned area at the northern end of the Forest appears to be dominated by areas at high or even moderate invasibility (Fig. M4D-7).

Association Between Wildfire High Hazard and Non-native Plant Very High and High-Invasibility Areas

Given that stand-replacing disturbances such as wildfires may provide an avenue for invasion by non-native, invasive plants, a description of the intersection between areas having high/very high invasibility with areas of high wildfire hazard is warranted here.
Granitic Breaklands (M331Bb-01; 14.8%); Granitic Mountain Slopes, Gentle (M331Bb-05; 12.5%); and Sedimentary Breaklands (M331Ba-01; 11.1%) Landtype Associations have the greatest proportion of overlap of areas rated high in wildfire hazard with areas rated very high/high for invasibility of non-native plants (Fig. M4D-8). Glacial Cirquelands (M331Bb-02; 0.2%); Sedimentary Mountain Slopes, Shale/Sandstone (Calcareous) (M331Ba-04; 0.2%); Alpine Mountain Slopes and Ridges (M331Bb-06; 1.8%); Sedimentary Mountain Slopes, Shale/Sandstone (Non-calcareous) (M331Ba-05; 2%); and Glacial/Tertiary Terrace Deposits (M331Bb-03; 2.3%) Landtype Associations have a very small proportion of area rated high for wildfire hazard that intersect with areas rated very high/high for invasibility of non-native plants (Fig. M4D-9).

Timber Harvest

Recent timber harvesting activities within the Forest have affected more than 4.5 times as much area (92,743 acres/37,548 ha) as wildfires. Like wildfire, most of the area affected by timber harvesting is considered to be at very low or low invasibility (less than 59%). Less than 17% is considered to be at very high or high invasibility, and about 27% is considered at moderate invasibility. Timber harvesting activities are much more widespread across the Forest than are recent burned areas (Fig. M4D-10), and appear to have occurred at middle elevations and outside of drainages, where invasibility is relatively low based on outputs from the physiographic invasibility model. It remains difficult to determine the risk associated with timber harvesting to non-native plant invasion.

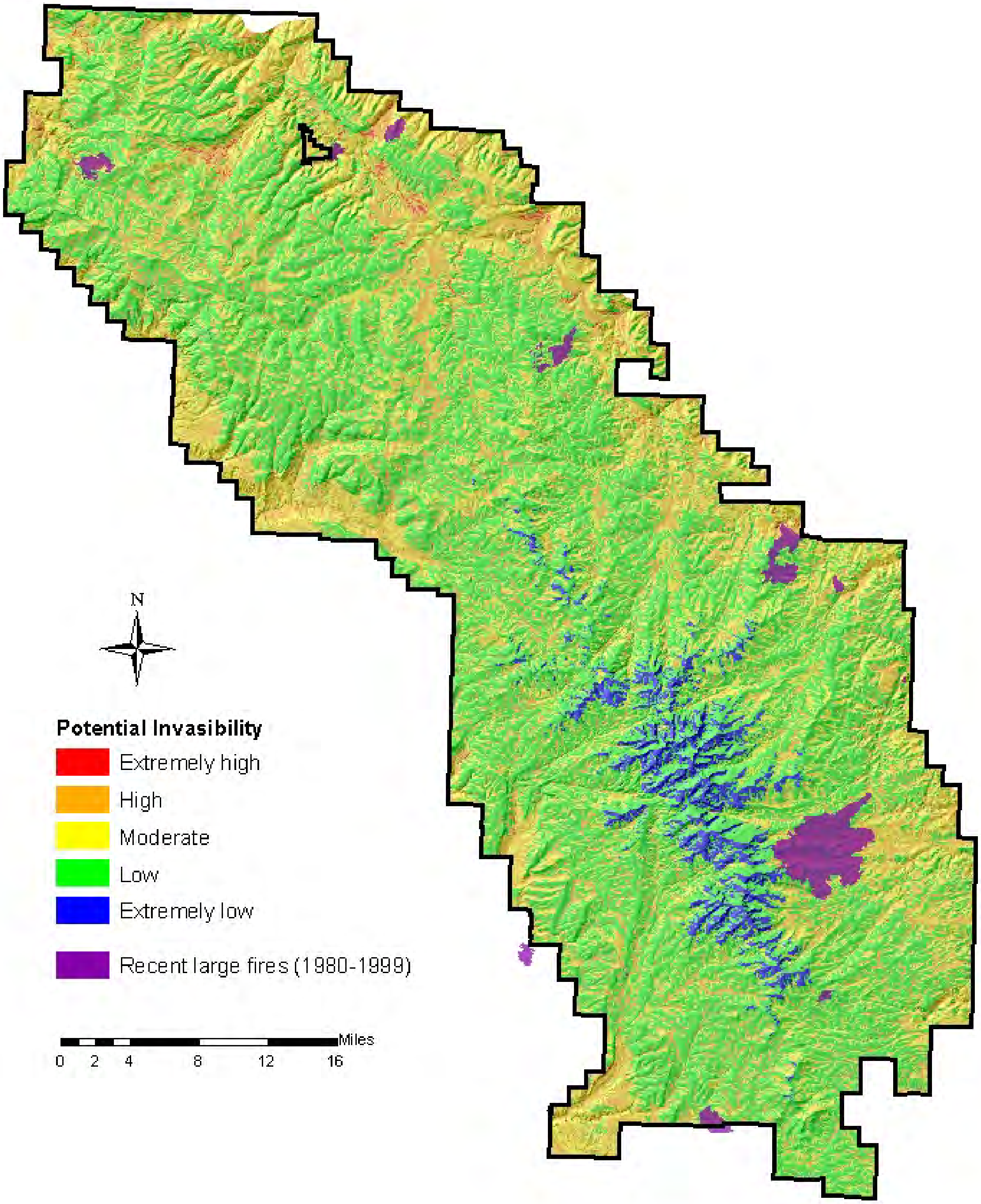


Figure M4D-7. Potential invasibility to non-native plant species on the Bighorn National Forest associated with recent (< 20 years) wildfires.

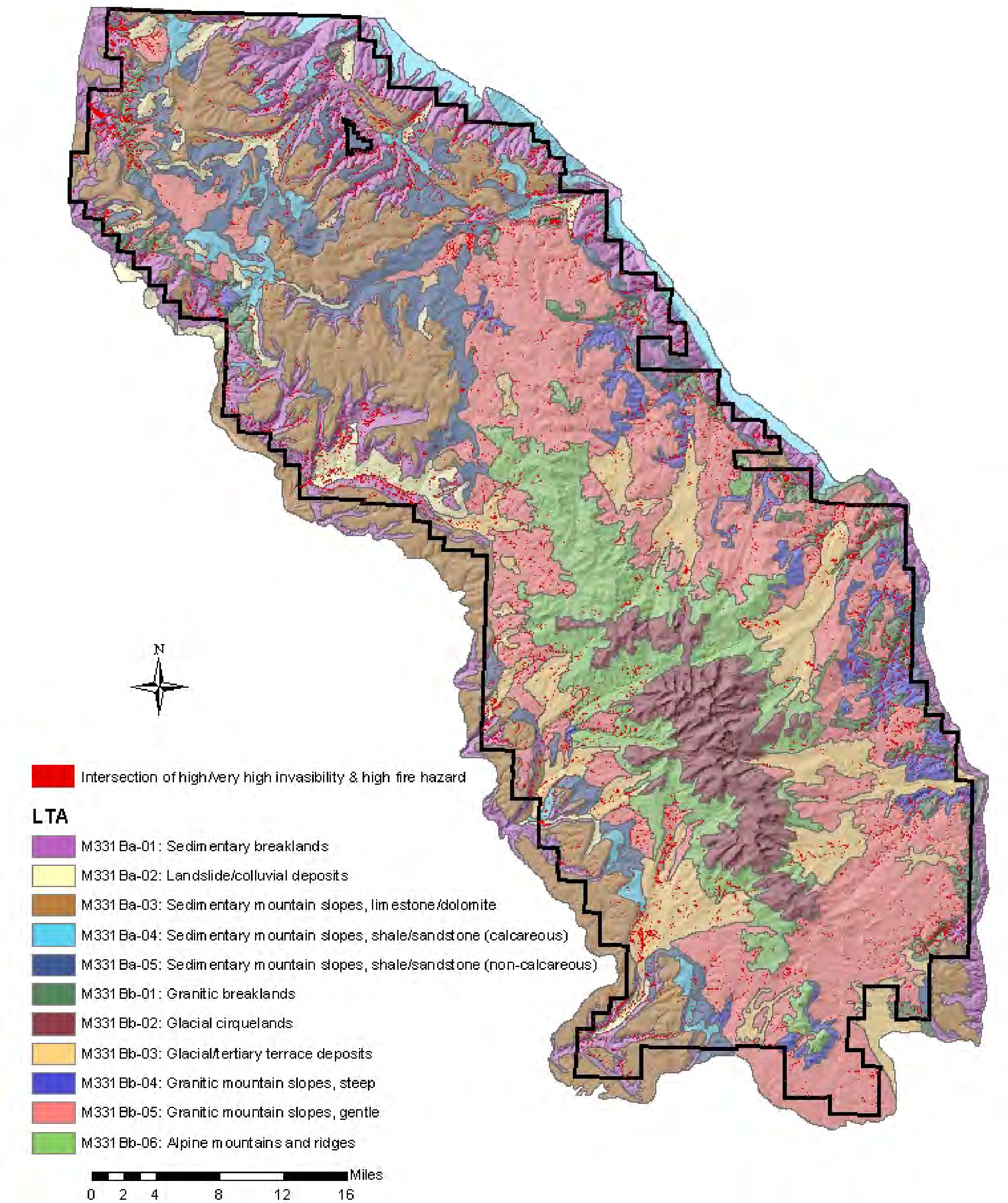


Figure M4D-8. Intersection of high/very high invasibility with high fire hazard on the Bighorn National Forest.

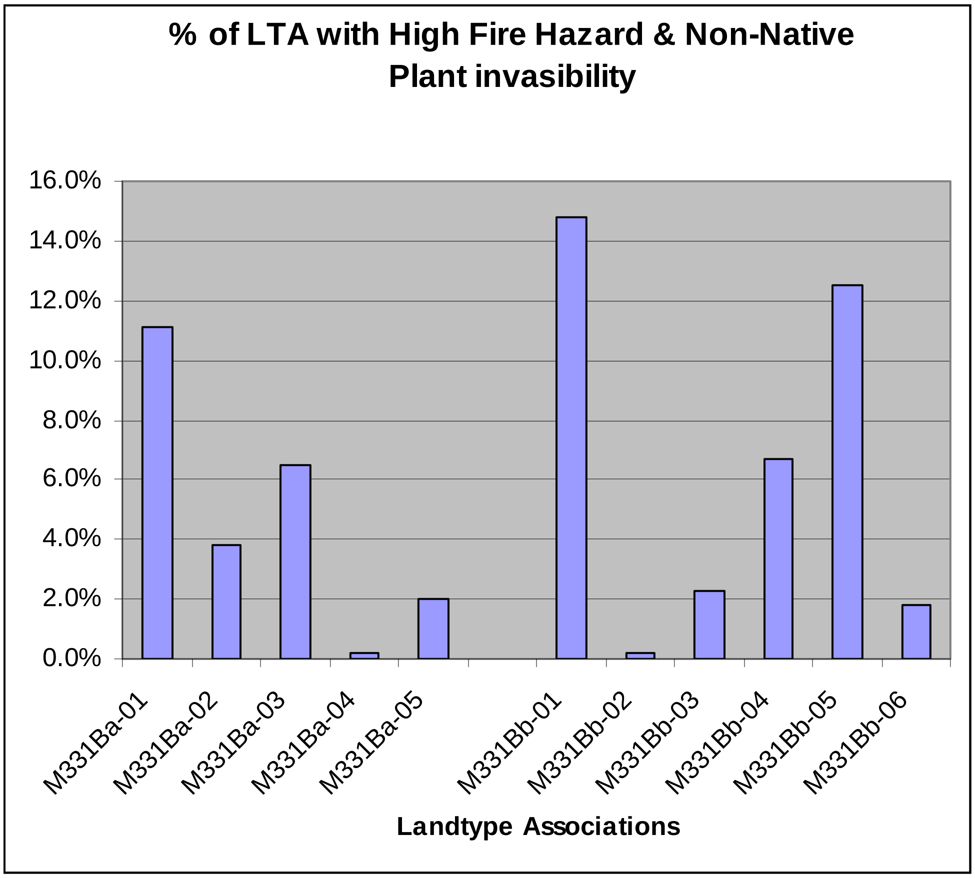


Figure M4D-9. Acreage representing the intersection of high wildfire hazard with areas having very high or high invasibility by non-native plant species by Landtype Associations.

Discussion of Ecological Consequences

Invasive species introduction and spread have more potential for disrupting the ecological integrity of the Bighorn National Forest and the Big Horn Mountains Section than almost any other factor in the next few decades. Known occurrence data suggest a relatively low occurrence of invasive species on the Forest, but limited monitoring and inventory in this region make invasive species exceedingly difficult to manage. The model results presented in this Module have not been validated, and represent only areas that may be identified as vulnerable based on studies conducted outside the region. If invasive species are not truly established in the Forest, proactive treatment is possible. The Bighorn National Forest may have a rare opportunity when viewed in a broader geographic context. Therefore, vigilant monitoring of invasive species on the Bighorn National Forest is a critical need, as is rapid treatment of new infestations when located. If these new infestations are ignored, the ecological costs and subsequent treatment costs will increase exponentially.

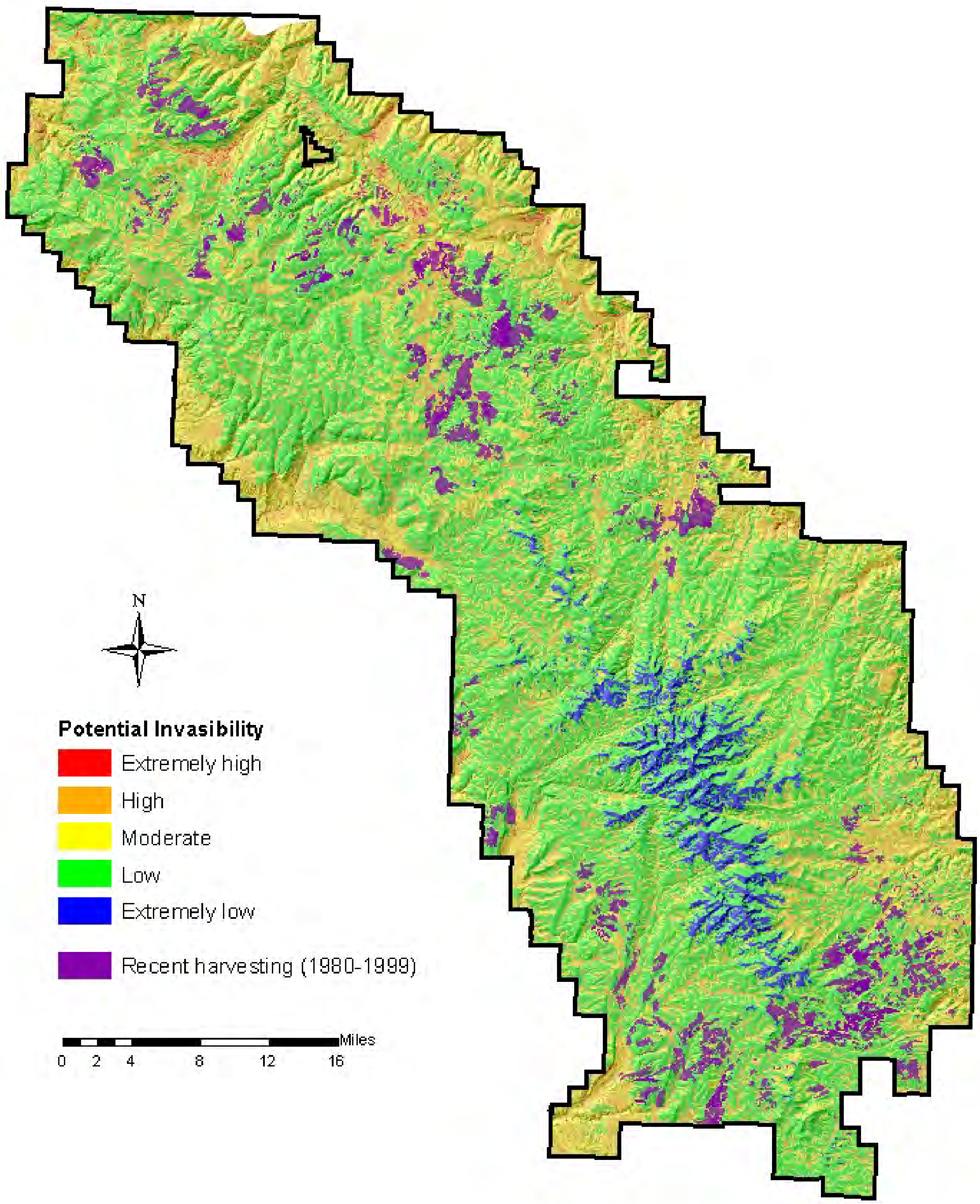


Figure M4D-10. Potential invasibility to non-native plant species on the Bighorn National Forest associated with recent (< 20 years) timber harvesting activities.

Significant Information Gaps

(1) Standardized, well-distributed sampling to describe the occurrence and coverage of invasive species across the Forest. Sampling should include roadside surveys, trailside surveys, etc. What are the known occurrences of invasive species across the entire Bighorn National Forest?

(2) Information to describe the relationships between land use history and the presence and spread of invasive species. Are invasive species more prevalent in disturbed areas? How long will the increased invasibility of disturbed areas to invasive species last?

(3) Specific ecological consequences of invasive species on communities similar to those in the Bighorns. Are certain communities or ecosystems (including plant composition and percent coverage) more affected by invasive species than others?

(4) Identification of areas of critical concern on the Bighorn National Forest – are there rare communities or species that may be most affected by invasive species?

(5) Information of the effects of specific management activities on invasive species responses.

(6) Validation of the invasive species invasibility model. With the paucity of known occurrence data on the Bighorn National Forest, the invasibility model used in this Module is still the primary means of assessing the extent of potential invasive species occurrence on the Forest. Its validation will enhance the management and control of invasive species.

Key Findings

Known Occurrences

(1) Although available data are extremely sparse for known occurrences of invasive plant species on the Bighorn National Forest, the Forest appears to have relatively few occurrences of invasive plants today.

(2) Canada thistle appears to be the most problematic of all invasive species on the Forest, with the highest and most widespread occurrences. However, the explosive nature of invasive species reproduction and spread forewarns that other species be closely monitored and controlled, where possible.

Invasibility

(1) Known occurrences are most typical in grasslands and subalpine meadows, where competition for light and with woody species is particularly low, and especially at low elevations (< 8,000 feet/2,438 m) and in drainages and valley bottoms.

Factors Influencing Invasibility

(1) Important factors influencing the invasibility of any given area include environmental factors (particularly moisture availability, light availability, growing season length, and temperature), disturbances (fires, timber harvesting, and grazing), and the presence of humans (along trails and roads and at various developments).

(2) These factors interact closely, such that no single factor necessarily determines the invasibility of a given area.

Literature Cited

D'Antonio, C.M. and P.M. Vitousek. 1992. Biological invasions of exotic grasses, the grass/fire cycle, and global change. Annual Review of Ecology and Systematics 23:63-97.

Mack, R.N., D. Simberloff, W.M. Lonsdale, H. Evans, M. Clout, F.A. Bazzaz. 2000. Biotic invasions: Causes, epidemiology, global consequences, and control. Ecological Applications 10(3):689-710.

Mooney, H. A. and R.J. Hobbs. 2000.Global change and invasive species: Where do we go from here? Pgs. 425-434 *in* Mooney, H.A. and R.J. Hobbs (*eds*). Invasive species in a changing world. Island Press. Washington, DC.

Pimental, D., L. Lach, R. Zuniga, D. Morrison. 2000. Environmental and economic costs of nonindigenous species in the United States. BioScience 50(1):53-65.

Vitousek, P.M., C.M. D'Anotonio, L.L. Loope, M. Rejmanek, and R. Westbrooks. 1997. Introduced species: A significant component of human caused global change. New Zealand Journal of Ecology 21:1-16.

Wilcove, D.S., D. Rothstein, D. Dubow, A. Philips, and E. Losos. 1998. Quantifying threats to imperiled species in the United States. BioScience 48:607-615.

Module 4E - Roads and Trails

Objectives

Describe the current patterns of the distribution of roads and trails in the assessment area. Evaluate the relative impacts of these patterns on the vegetation types in the assessment area. Identify and map ecological risks associated with the interaction of roads and trails with invasive plant species. To the extent possible, given the information limitations, discuss the ecological implications of the current condition

Introduction

Roads, trails, and associated bridges and parking lots together are referred to as travel routes. The Bighorn National Forest (BNF) of north-central Wyoming contains 2,791 mi (4,501 km) of travel routes, resulting in a travel route density of 1.63 mi/mi^2. Many roads within the BNF were originally constructed for access to timber or livestock grazing, but now provide human access to other National Forest amenities. Clearly, in addition to the human derived benefits, it is desirable to understand the potential consequences of travel route pattern and frequency to ecosystem structure and function.

To provide a contextual setting for the BNF, this Module first summarizes road data for the greater Bighorn Mountain Section (M331B) that includes the BNF as well as other land ownership categories. Because more detailed information is available for the land area comprising the BNF, the Forest is the focus of the majority of the report. Data on travel routes and vegetation dissected by the travel routes are summarized for the BNF as a whole, and then by Landtype Associations (LTA) and Forest Plan Watershed (FPWS) units within the BNF. Landscape level patterns of vegetation and physiography are contributing factors for road location, and it is the smaller sub-forest scale analysis that may show the specific vegetation types that are being most impacted by those choices of road placement. Because limited data are available for exurban development areas, these areas are only addressed for the BNF as a whole. Management implications, information gaps, and high-priority information needs are discussed.

There is some overlap between the data presented in this module and the Region 2 Roads Analysis Report in terms of road length and road density for the Forest as a whole and the FPWS units. This is because the Roads Analysis Report uses only classified roads (levels 1-5 within 6th level HUBs) for the determination of road length and density, whereas this module includes all roads identified by Forest Service data as existing on the BNF. However, this module treats all roads equally because the roads data set doesn't distinguish between different types of roads.

This module also includes trails in the determination of travel route densities, because it is clear that roads and trails have ecological ramifications in terms of the direct and indirect impacts on the vegetation the travel routes dissect and the habitat that vegetation provides. As with the discussion in this module, the Roads Analysis Report includes general comments about the potential direct and indirect impacts of roads on wildlife. To determine which species are of concern regarding road impacts users of this module will need to refer to the Species Assessment portion of the Species Conservation Project.

Bighorn Mountain Section M331B

The Bighorn Mountain Section encompasses a total land area of 4,412 mi^2 (ca. 2.8 million acres or 1.1 million ha). Gap Analysis Program (GAP) land ownership categories include: Bureau of Indian Affairs, Bureau of Land Management, Fish and Wildlife Service, Forest Service, Private, State, The Nature Conservancy, and Water (Fig. M4E-1). Road data for the Section is provided by the USGS in the form of TIGER road data, which are not as complete as the Forest Service road and trail data. Despite this shortcoming of the TIGER data, these data are all we have to provide a relevant context for discussion of roads within the BNF. Although the Forest Service manages the largest area of land (1,716 mi^2 or 444,632 ha; Table M4E-1) and has the second largest road length (1,498 mi or 2,416 km), its road density is among the lowest of the ownership categories (0.88 mi/mi^2 or 0.55 km/km^2). The low road density can be attributed to two causes: 1.) the BNF encompasses a large, roadless Wilderness Area; and 2.) the shortcoming of the TIGER road data discussed above. The end result is an artificially low road density for the BNF and most likely for the other GAP land ownerships. For instance, BNF total road length, which includes all roads but does not include trails, is 2,476 mi (3,994 km), and road density is 1.44 mi/mi^2 (0.89 km/km^2) or just over 1.5 times that calculated from the TIGER road data. Private land ownership has the second largest land area but has the highest road length and road density (Table M4E-1). Although The Nature Conservancy owns a relatively small area of land, its road density is the second highest.

A vast majority of the Section and the BNF, excluding the roadless Wilderness Area, has a road density of $\geq$ 0.9 mi/mi^2 (0.62 km/km^2; Fig. M4E-2) with potential impacts for both vegetation and animal species (see Discussion section).

Table M4E-1. Land area, road length, and road density by GAP land ownership category (s*ource: USGS TIGER road data*).

Ownership	Land Area (mi^2)	Proportion of Total Land Area (%)	Road Length* (mi)	Proportion of Total Road Length (%)	Road Density (mi/mi^2)
Bureau of Indian Affairs	575	13	482	10	0.84
Bureau of Land Management	764	17	764	17	1.01
U.S. Fish and Wildlife Service	<1	<1	0	0	na
U.S. Forest Service	1,716	39	1,498	32	0.88
Private	1,076	24	1,522	33	1.43
State of Wyoming	256	6	298	6	1.18
The Nature Conservancy	15	<1	18	<1	1.23
Unknown	na	na	42	1	na
Total	4,412	100	4,625	100	

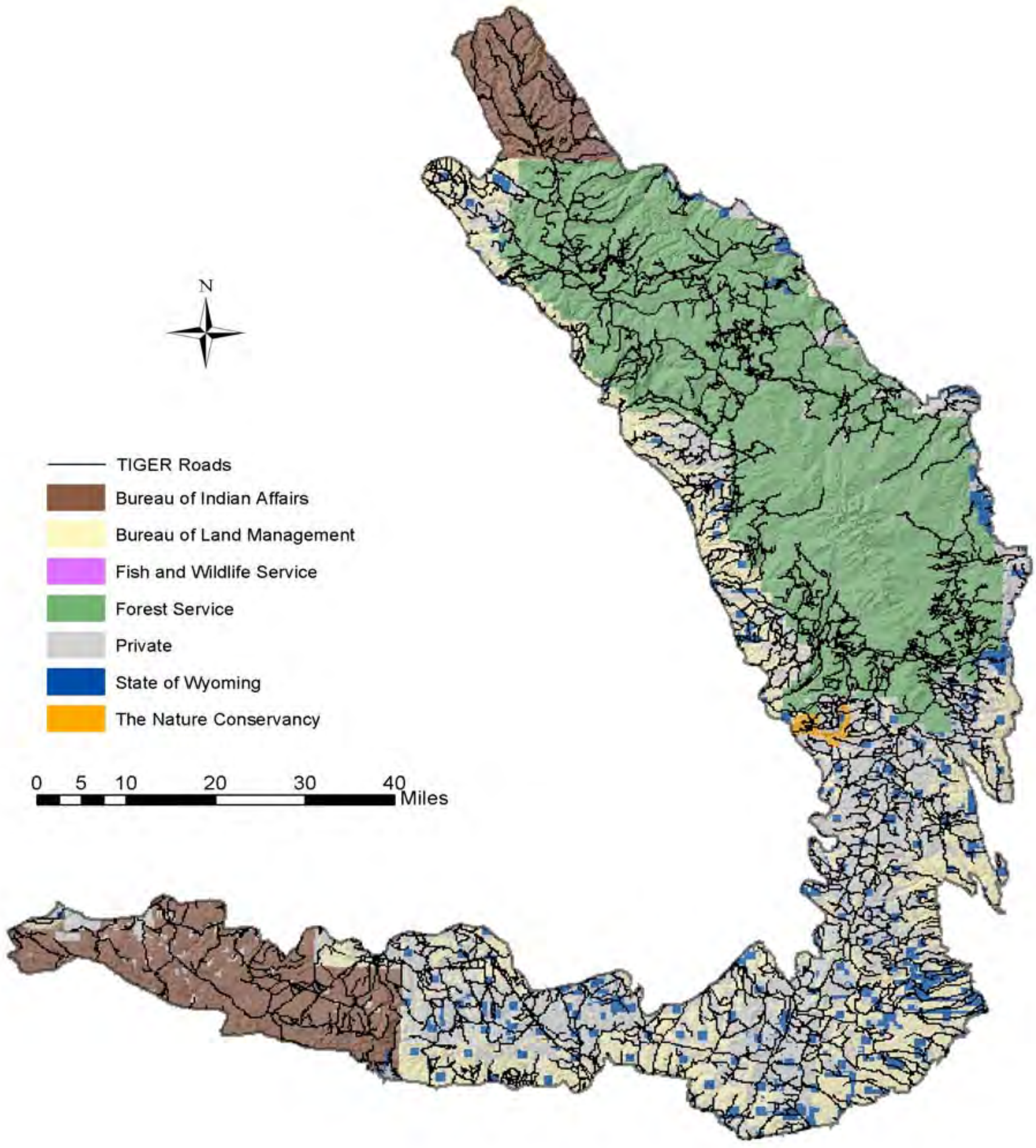


Figure M4E-1. The Bighorn Mountain Section (M331B) showing TIGER road classifications and land ownership areas.

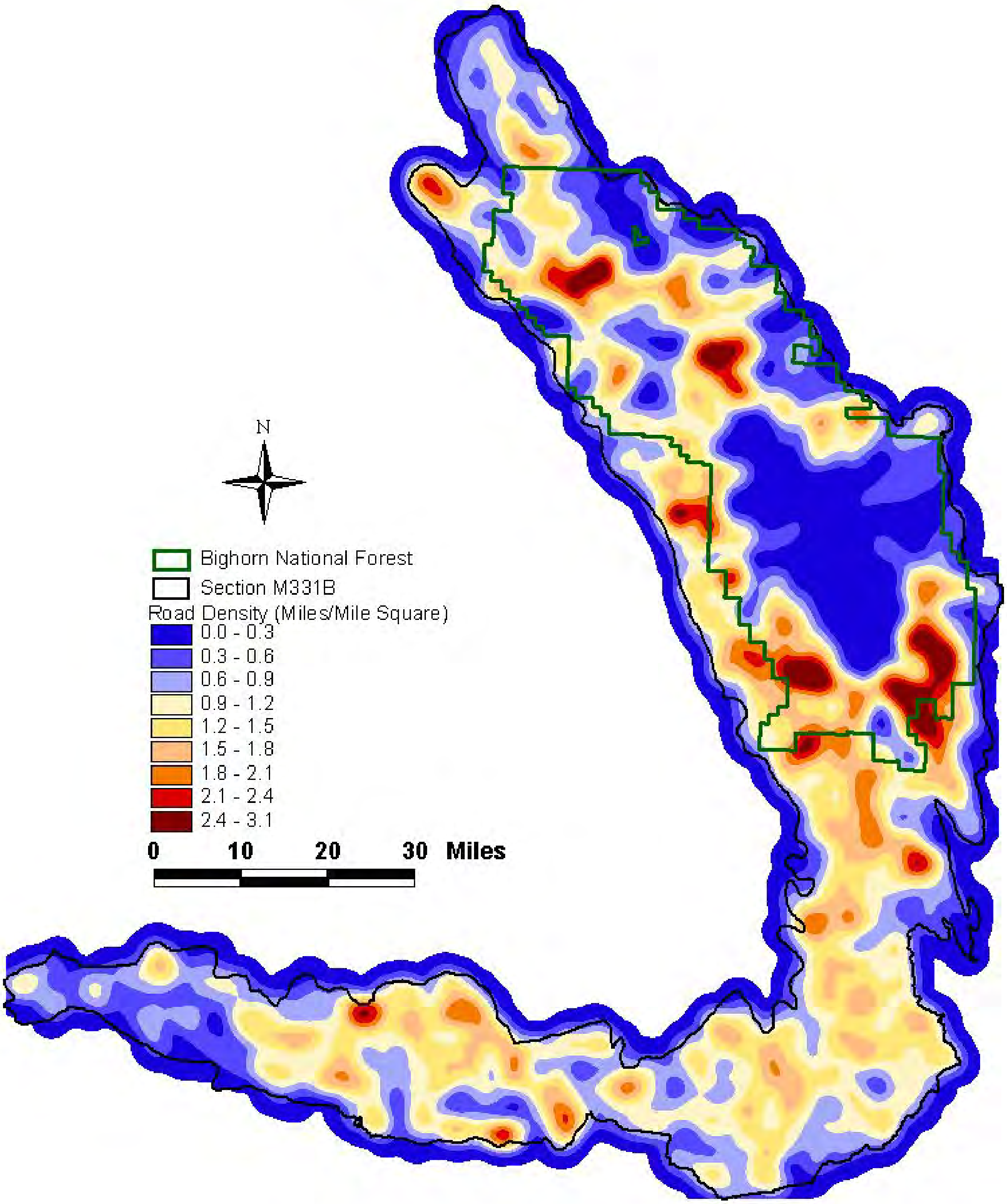


Figure M4E-2. Road density for Bighorn Mountain Section.

Relationship of Roads and Trails to Major Vegetation Types

Seven Common Vegetation Unit (CVU) cover types—lodgepole pine, spruce/fir, grass, Douglas-fir, rock, forb, and big sagebrush—comprise 90% of the total BNF land area (Table M4E-2). These same cover types are also the cover types most often influenced by travel routes (Table M4E-3). Despite this correlation, not all cover types within the BNF are affected in direct proportion to their areal coverage. Fourteen of the 32 cover types have proportionally more roads than would be predicted by the percentage of that cover type in the BNF (marked by an asterisk in the "% of travel routes" column of Table M4E-2). The following are several examples:

(1) Lodgepole pine comprises 31% of the National Forest but contains 35% of the travel routes. In this instance, the higher travel route density is most likely due to logging roads, given that lodgepole pine is a valuable timber species.

(2) Aspen comprises 1% of the Forest area, but contains 1.3% of the roads. Given that aspen is a high-diversity hotspot the impacts of these travel routes may be disproportionately high, making the reasons for these roads an important area to investigate.

(3) For skunkbrush, which occupies only a small proportion of the BNF land area, the percentage of travel routes dissecting it is inordinately high. Skunkbrush is important habitat area, albeit a minute area in the Forest; however, it is exactly for this reason—it is a minor species—that makes it potentially important to the diversity of the Forest as a whole. If skunkbrush is deemed a desirable species, this high travel route impact warrants some consideration.

(4) The higher % of travel routes dissecting grass and Idaho fescue relative to their % in the BNF is likely because building a road through a grassland is easier than through a forest, consequently, many roads within the BNF appear to follow grassland patches where possible (Fig. M5-4). Again, depending on their desirability, grass and Idaho fescue may warrant some consideration.

Table M4E-2. Common Vegetation Units (CVU) encompassed within the Bighorn National Forest, arranged in order of dominance.

CVU Cover Type	Area (acres)	Proportion of Total Area (%)	Proportion of Travel Routes (%)
Lodgepole pine	348,538	31	34.6*
Spruce/Fir	234,857	21	13.6
Grass	131,398	12	20.8*
Douglas-fir	99,926	9	3.8
Rock	90,218	8	1.0
Forb	63,045	6	9.3*
Big sagebrush	52,255	5	7.3*
Ponderosa pine	17,850	2	1.2
Limber pine	14,269	1	0.5
Barren	12,550	1	0.2
Willow	10,657	1	1.3*
Aspen	10,326	1	1.3*
Other sagebrush	9,764	1	1.0
Fescue grassland	6,510	1	0.2
Rock soil	6,103	1	0.6*
Curlleaf mountain mahogany	4,804	<1	0.1
Pinyon/juniper	3,574	<1	0.2
Shrub	2,838	<1	0.3*
Bare soil	2,296	<1	0.9
NO VEG DATA	1,967	x	0.3
Tufted hairgrass – sedge	1,855	<1	0.3*
Wood	1,283	<1	0.2*
Idaho fescue	1,204	<1	0.9*
Bluegrass scabland	593	<1	0.1
Cottonwood	494	<1	0.2*
Juniper	390	<1	Na
Permanent ice and snow	155	<1	Na
Oatgrass grassland	21	<1	Na
Water	16	<1	Na
True mountain mahogany	14	<1	Na
Litter / duff	10	<1	0.01*
Skunkbrush	2	<1	0.02*
Total (Does NOT include the NO VEG category)	1,127,815	100.00	100.00

* indicates that there are proportionally more miles of travel route than would be predicted by the percentage of cover type in the BNF.

Table M4E-3. Common Vegetation Units (CVU) cover types comprising five percent or more of each buffer width (200 m & 400 m) within the "JUST ROADS" and "JUST TRAILS" categories for the Bighorn National Forest.

	200 m Buffer		400 m Buffer	
CVU Cover Type	**Total Area (acres)**	**Proportion of Buffered Area (%)**	**Total Area (acres)**	**Proportion of Buffered Area (%)**
JUST ROADS				
Lodgepole pine	94,520	33	152,987	33
Grass	55,991	20	83,658	18
Spruce/Fir	38,530	14	69,136	15
Big sagebrush	26,741	9	42,147	9
Forb	22,588	8	33,325	7
Douglas-fir	na	na	28,423	6
TOTAL	238,370	84	409,677	88
JUST TRAILS				
Lodgepole pine	45,790	34	90,603	35
Spruce/Fir	22,322	17	44,588	17
Grass	18,845	14	32,255	13
Douglas-fir	10,623	8	21,861	9
Forb	8,585	6	14,637	6
Bare rock	na	na	na	na
Big sagebrush	na	na	na	na
TOTAL	106,164	80	203,944	80

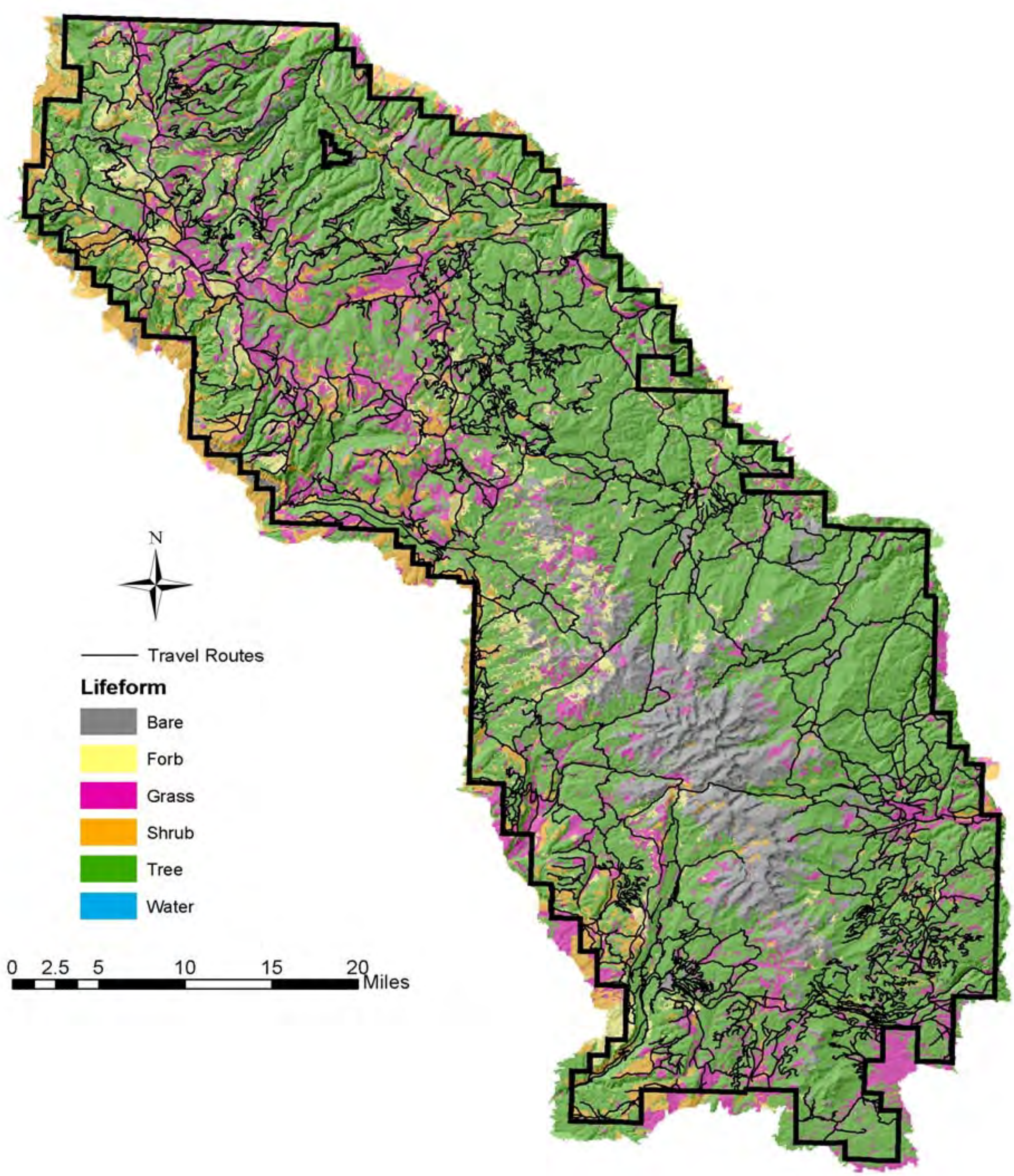


Figure M4E-3. Lifeform and travel route information within the Bighorn National Forest showing that roads often overlie grass corridors.

In the following analysis 200 and 400 meter buffer widths were used to provide more insight into the interaction of travel routes with vegetation and habitat. Actual buffer widths should be selected based on habitat needs of the species in question. Sources for this information are the individual species assessments currently in various stages of completion.

The comparison between buffer widths (i.e., 200 m & 400 m) and travel route types (i.e., "JUST ROADS" versus "JUST TRAILS") (Table M4E-3), show that lodgepole pine comprises 33% (94,520 acres) of all cover types falling within 200 m of all roads in the BNF. The biggest generalization about Table M5-3 is that there are not huge differences between the vegetation types impacted by roads versus trails.

However there are a few interesting, subtle differences. The most notable difference between roads and trails is the juxtaposition of spruce/fir and grass as the second most commonly dissected cover. For example, grass is the second most commonly impacted cover type for the 200 and 400 m road buffer widths, whereas spruce/fir is second for "JUST TRAILS" regardless of buffer width. This lends further support to the ease of constructing roads in grasslands versus forests, whereas trails can be constructed to weave around trees.

Mid-Level Planning Units

The BNF may be subdivided using two different classification systems: Landtype Association (LTA) and Forest Plan Watershed (FPWS) units. The LTA is an ecologically driven classification of land area based on similarities in soil, climate, and elevation (Fig. M4E-4). Because the LTA units extend slightly beyond the BNF boundary, thus including more land area and more travel route length, they cannot be directly compared with BNF data. The FPWS units are administrative units based on whole watersheds within the BNF (Fig. M4E-5).

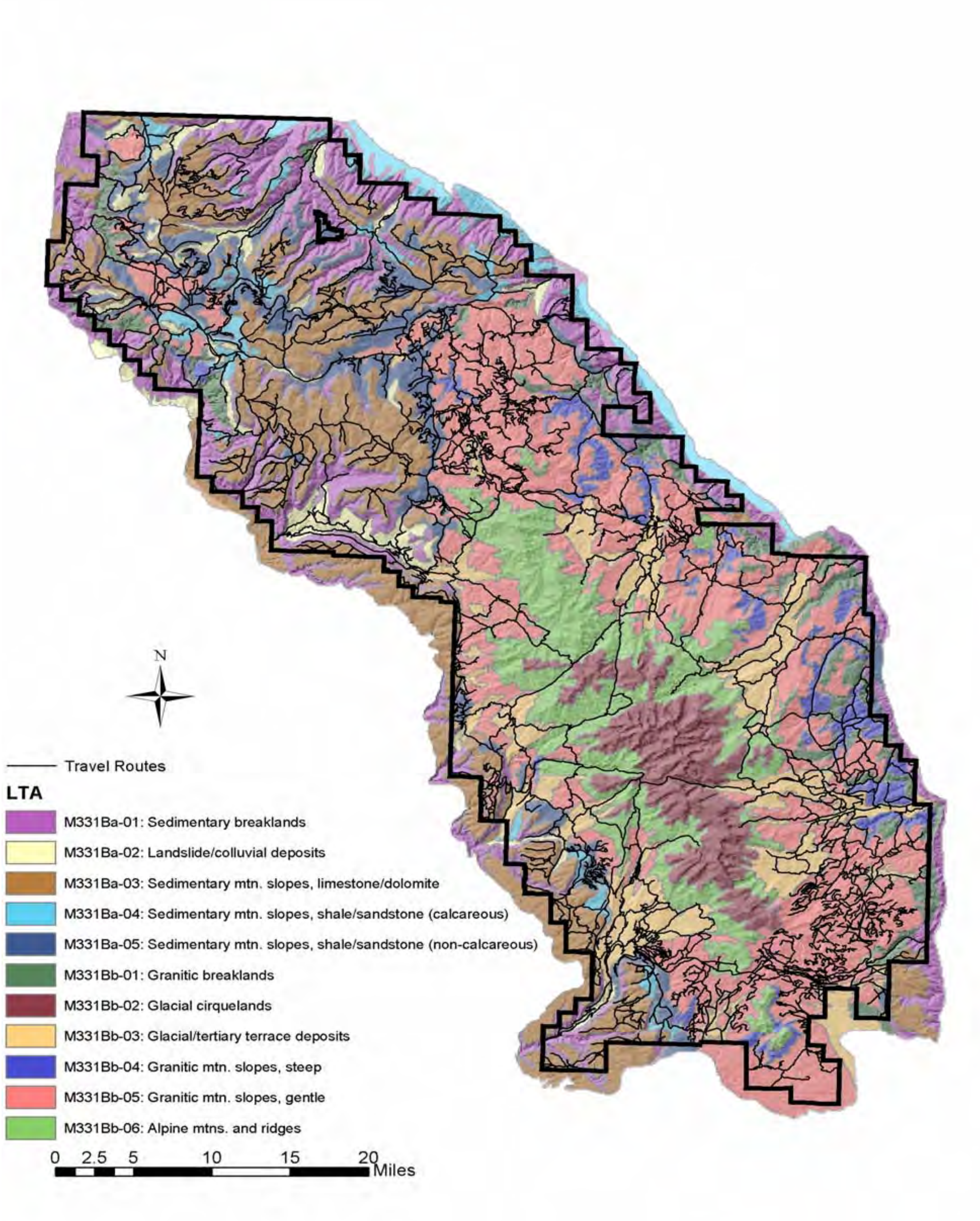


Figure M4E-4. The Landtype Association units and travel routes associated with the Bighorn National Forest.

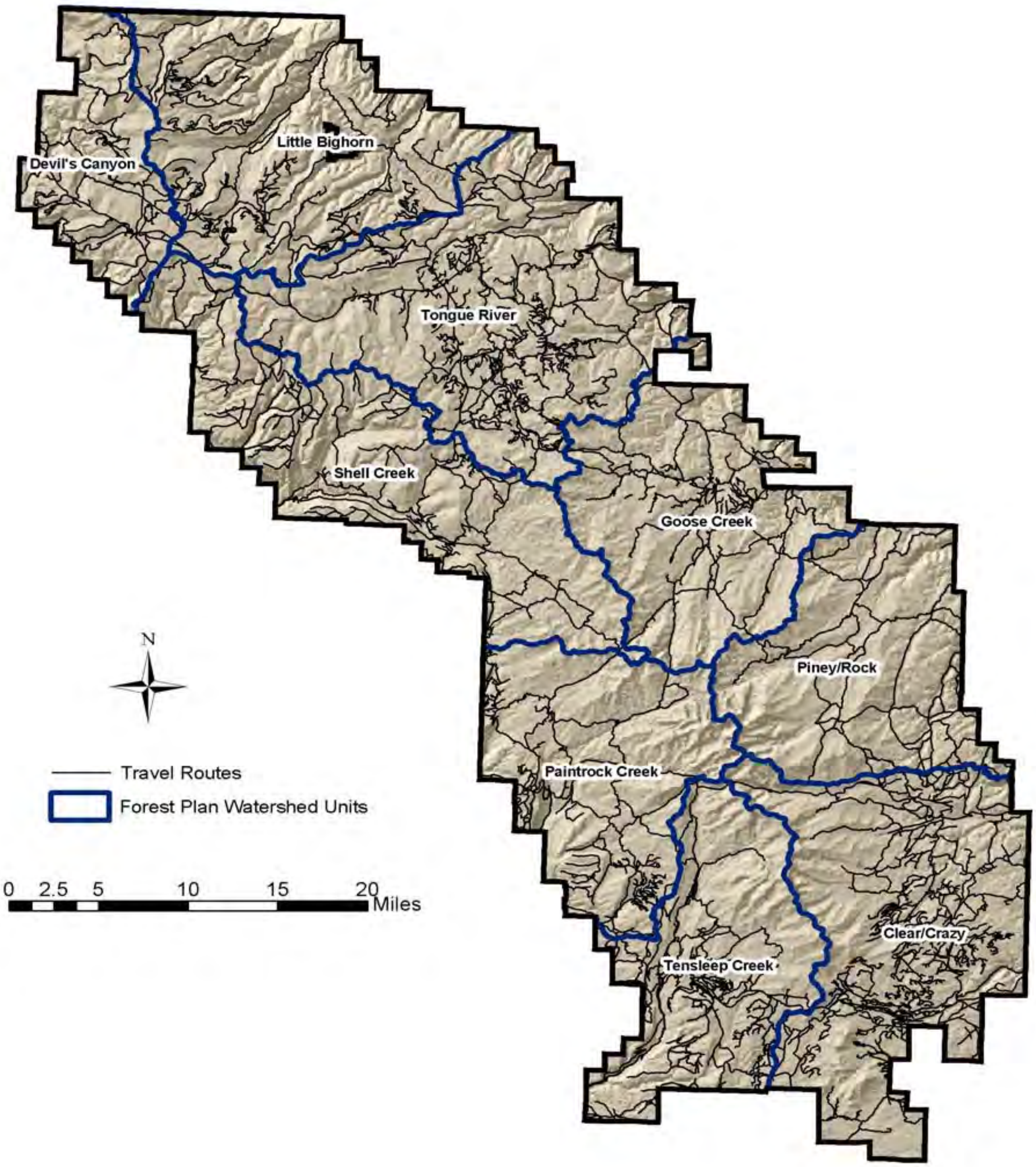


Figure M4E-5. The Forest Plan Watershed units and travel routes contained within the Bighorn National Forest.

Landtype Association Units

The 11 LTA units comprise a total land area of 1,736 mi² (452,923 ha) containing 2,728 mi (4981 km) of travel route length. Individual LTA areas are highly variable (1 to 32% of the total land area) as is the distribution of travel route length and density among them (Table M4E-4). The three largest LTA units (M331Bb-05, M331Bb-03, and M331Ba-05) have the greatest length of road but not necessarily the highest road density. The highest road density (6.83 mi/mi² or 4.2 km/km²) is within the smallest LTA unit (M331Ba-01).

Table M4E-4. Land area, travel route length, proportion of travel routes, and travel route density by Landtype Association (LTA) unit on the Bighorn National Forest.

LTA Unit		Land Area (mi²)	Travel Route Length (mi)	Proportion of Travel Routes in Total LTA Area (%) on the Bighorn National Forest	Travel Route Density (mi/mi²)
M331Ba-01	Sedimentary Breaklands	209	124	5	0.59
M331Ba-02	Landslide/Colluvial Deposits	55	104	4	1.89
M331Ba-03	Sedimentary Mountain Slopes, Limestone/Dolomite	259	517	19	1.99
M331Ba-04	Sedimentary Mountain Slopes, Shale/Sandstone (Calcareous)	42	96	4	2.28
M331Ba-05	Sedimentary Mountain Slopes, Shale/Sandstone (Noncalcareous)	126	323	12	2.56
M331Bb-01	Granitic Breaklands	61	43	2	0.70
M331Bb-02	Glacial Cirquelands	101	10	<1	0.10
M331Bb-03	Glacial/Tertiary Terrace Deposits	155	368	14	2.38
M331Bb-04		65	72	3	1.11
M331Bb-05	Granitic Mountain Slopes, Gentle	474	970	36	2.05
M331Bb-06	Alpine Mountain Slopes and Ridges	187	101	4	0.54
TOTAL		1,736	2,728	100	1.57

Besides an “unidentified road category” which consists of 45% of the travel routes within the LTA units, the top three travel route types by length are “road, unimproved”, “road, 4-wheel drive”, and “trail”, consisting of 23, 13, and 11% of the total travel route lengths for both LTA and FPWS units. Table M5-5 displays the most commonly dissected cover types by travel routes within each LTA. These cover types coincide with the most common cover types by areal coverage in the BNF (compare with Table M4E-2). There is only slight variation among the LTA units with grass being among the top three for 9 of the 10 LTA units, and bare rock only making an appearance in one of the LTA units. The ponderosa pine in LTA M331Ba-01 has the highest travel route density (1.93 mi/mi² or 1.20 km/km²) of any individual CVU within all the LTA units, followed by that of Douglas-fir within that same unit (Table M4E-5). Both of these high travel route densities may be a result of logging, but given their extremity the travel routes associated with these cover types should be investigated.

Table M4E-5. Travel route length, proportion of travel route length and travel route density for the three cover types most commonly dissected by travel routes within individual Landtype Association (LTA) units.

LTA unit	CVU Cover Type	Road Length (mi) within one Vegetation Type and one LTA	Percent of LTA (road length of each veg/LTA combination/Total road length in LTA)	Road Length Density (mi/mi^2) within one Vegetation Type and one LTA
M331Ba-01	Ponderosa pine	18	15	0.09
	Douglas-fir	45	36	0.22
	Grass	14	11	0.06
M331Ba-02	Grass	27	26	0.50
	Big sagebrush	27	26	0.49
	Forb	12	12	0.22
M331Ba-03	Grass	132	26	0.51
	Big sagebrush	107	21	0.41
	Spruce/fir	101	19	0.39
M331Ba-04	Grass	39	41	0.92
	Forb	23	24	0.54
	Big sagebrush	16	17	0.38
M331Ba-05	Lodgepole pine	83	26	0.66
	Grass	83	26	0.66
	Spruce/fir	59	18	0.47
M331Bb-01	Lodgepole pine	15	35	0.24
	Grass	5	12	0.09
	Douglas-fir	5	12	0.08
M331Bb-02	Bare rock	3	27	0.03
	Spruce/fir	2	24	0.03
	Grass	2	18	0.02
M331Bb-03	Lodgepole pine	176	48	1.13
	Grass	98	27	0.63
	Spruce/Fir	33	9	0.22
M331Bb-04	Lodgepole pine	41	57	0.63
	Spruce/fir	9	13	0.14
	Grass	8	11	0.12
M331Bb-05	Lodgepole pine	591	61	1.25
	Grass	129	13	0.27
	Spruce/fir	104	11	0.22
M331Bb-06	Spruce/fir	35	34	0.18
	Grass	34	33	0.18
	Forb	15	14	0.08

Although it is important to know the commonly impacted vegetation, what about the less common cover types that are being disproportionately impacted by travel routes? Table M4E-6 provides some insight into this question by providing those cover types that are less than 1% of the LTA and are within 400 m of a road. For example, skunkbrush in LTA M331 Ba-01 occupies less than 0.01% of the LTA but almost 57% of it is within 400 m of a road.

Table M4E-6. Covertypes that occupy <1% of the LTA and greater than 50% within 400m of a road.

LTA	LTA Code	Covertype	Acres	Percent of LTA	Acres of Covertype within 400m of Travel	Percent
Sedimentary Breaklands	M331Ba-01	Festuca idahoensis and Elymus spicata	12.449	0.01%	12.449	100.00
Sedimentary Breaklands	M331Ba-01	Idaho Fescue	23.272	0.01%	19.471	83.67
Sedimentary Breaklands	M331Ba-01	Skunkbrush	12.468	0.01%	7.089	56.86
Landslide/Colluvial Deposits	M331Ba-02	Cottonwood	191.565	0.50%	141.368	73.80
Sedimentary Mountain Slopes, Limestone/Dolomite	M331Ba-03	Deschampsia/wet sedge	130.256	0.07%	107.501	82.53
Sedimentary Mountain Slopes, Limestone/Dolomite	M331Ba-03	Shrub	853.788	0.43%	512.315	60.00
Sedimentary Mountain Slopes, Limestone/Dolomite	M331Ba-03	Willow	220.487	0.11%	185.559	84.16
Sedimentary Mountain Slopes, Shale/Sandstone (Calcareous)	M331Ba-04	Blue grass scabland	238.002	0.62%	169.399	71.18
Sedimentary Mountain Slopes, Shale/Sandstone (Calcareous)	M331Ba-04	Idaho Fescue	143.849	0.38%	120.931	84.07
Sedimentary Mountain Slopes, Shale/Sandstone (Calcareous)	M331Ba-04	Skunkbrush	63.488	0.17%	63.375	99.82
Sedimentary Mountain Slopes, Shale/Sandstone (Calcareous)	M331Ba-04	Willow	235.811	0.61%	132.567	56.22
Sedimentary Mountain Slopes, Shale/Sandstone (Non-calcareous)	M331Ba-05	Deschampsia/wet sedge	303.865	0.35%	302.594	99.58
Sedimentary Mountain Slopes, Shale/Sandstone (Non-calcareous)	M331Ba-05	Festuca idahoensis and Elymus spicata	456.26	0.53%	438.95	96.21
Sedimentary Mountain Slopes, Shale/Sandstone (Non-calcareous)	M331Ba-05	Rabbitbrush, sagebrush	802.005	0.94%	567.838	70.80

Sedimentary Mountain Slopes, Shale/Sandstone (Non-calcareous)	M331Ba-05	Shrub	101.764	0.12%	70.785	69.56
Granitic Breaklands	M331Bb-01	Cottonwood	5.911	0.01%	5.911	100.00
Granitic Breaklands	M331Bb-01	Deschampsia /wet sedge	14.725	0.03%	11.43	77.62
Granitic Breaklands	M331Bb-01	Rabbitbrush, sagebrush	59.666	0.14%	33.42	56.01
Glacial Cirquelands	M331Bb-02	Rabbitbrush, sagebrush	44.795	0.07%	32.635	72.85
Glacial/Tertiary Terrace Deposits	M331Bb-03	Cottonwood	69.718	0.07%	54.02	77.48
Glacial/Tertiary Terrace Deposits	M331Bb-03	Deschampsia /wet sedge	242.407	0.23%	173.451	71.55
Glacial/Tertiary Terrace Deposits	M331Bb-03	Idaho Fescue	315.59	0.30%	286.16	90.67
Glacial/Tertiary Terrace Deposits	M331Bb-03	Rabbitbrush, sagebrush	196.554	0.19%	184.075	93.65
Glacial/Tertiary Terrace Deposits	M331Bb-03	Shrub	6.282	0.01%	4.549	72.41
Granitic Mountain Slopes, Steep	M331Bb-04	Forb	273.496	0.64%	164.24	60.05
Granitic Mountain Slopes, Steep	M331Bb-04	Willow	47.974	0.11%	47.959	99.97
Granitic Mountain Slopes, Gentle	M331Bb-05	Bare rock	2968.985	0.94%	1533.419	51.65
Granitic Mountain Slopes, Gentle	M331Bb-05	Big sagebrush	2779.022	0.88%	2110.827	75.96
Granitic Mountain Slopes, Gentle	M331Bb-05	Deschampsia /wet sedge	436.823	0.14%	348.435	79.77
Granitic Mountain Slopes, Gentle	M331Bb-05	Festuca idahoensis and Elymus spicata	735.462	0.23%	526.458	71.58
Granitic Mountain Slopes, Gentle	M331Bb-05	Idaho Fescue	1001.535	0.32%	726.357	72.52
Granitic Mountain Slopes, Gentle	M331Bb-05	Limber pine	2.314	0.00%	2.314	100.00
Granitic Mountain Slopes, Gentle	M331Bb-05	Rabbitbrush, sagebrush	328.101	0.10%	262.014	79.86
Granitic Mountain Slopes, Gentle	M331Bb-05	Shrub	80.194	0.03%	56.887	70.94
Alpine Mountain Slopes and Ridges	M331Bb-06	Idaho Fescue	261.113	0.22%	166.003	63.58

LTA unit M331Bb-05 contains 7 of the 10 cover types with more than 50% of their total LTA area being impacted by travel routes. The majority of these seven cover types are most likely related to logging (e.g., bare litter duff, bare, rock/soil indistinguishable, bare wood--usually logging debris, and lodgepole), indicating that this specific LTA most likely has had a lot of logging activity. However, "bluegrass scabland", aspen, and willow appear to be disproportionately affected as well, perhaps as a result of this logging activity. The reason for high travel route impact on these three cover types would need on-site investigation. The cover types may need to be evaluated for restoration, if they are deemed desirable.

Forest Plan Watershed Units

The 9 FPWS units cover a land area of 1,738 mi^2 (449,814 ha) with 2,791 miles (4,502 km) of roads and trails. Unlike the LTA units, FPWS areas are far more consistent in size (6 to 16% of total BNF area) with a more even distribution of travel routes and travel route densities (Table M4E-7). Generally, the larger FPWS units have more travel route length and higher travel route densities (e.g., Tongue River, Clear Crazy, and Little Big Horn).

Table M4E-7. Land area, travel route length, proportion of travel routes in total Forest Plan Watershed (FPWS), travel route density by FPWS unit.

FPWS unit	Land Area (mi^2)	Travel Route Length (mi)	Proportion of Travel Routes in Total FPWS Area (%)	Travel Route Density (mi/mi^2)
Clear/Crazy	244	521	19	2.14
Devil's Canyon	96	162	6	1.70
Goose Creek	183	228	8	1.25
Little Big Horn	222	353	13	1.59
Paintrock Creek	169	231	8	1.37
Piney/Rock	172	161	6	0.94
Shell Creek	219	330	12	1.51
Tensleep Creek	158	302	11	1.91
Tongue River	277	502	18	1.82
Total	1,738	2,791	100	

The three most often dissected cover types for each of the FPWS units include only five cover types (compared with eight for the LTA units): lodgepole, grass, spruce/fir, forb, and big sagebrush (listed in order from high to low miles of travel route dissection; Table M4E-8). As with the travel route impacts on LTA cover types (Table M4E-5) and those of the BNF as a whole (Table M4E-2), the most commonly impacted cover types by travel routes in FPWS units are correlated with their areal coverage. The question then arises, particularly for lodgepole, grass, and forbs, whether the travel routes are encouraging their growth over time. Because these three species tend to be shade intolerant, the additional light environment created by road and trail corridors may be beneficial. Additionally, the site disturbance created by road construction may also encourage grass and forbs, given the decreased competition for belowground resources (e.g., water and nutrients). This type of question could only be answered via analysis of areal coverage through time (e.g., using GIS, repeat photography, or careful on-site repeated sampling).

Table M4E-8. Travel route length, proportion of travel route length and travel route density for the three cover types most commonly dissected by travel routes within individual Forest Plan Watershed (FPWS) units.

FPWS Unit	CVU Cover Type	Travel Route Length (mi)	Proportion of Travel Route in FPWS (%)	Travel Route Density (mi/mi^2)
Clear/Crazy	Lodgepole pine	302	58	1.24
	Grass	130	25	0.54
	Spruce/Fir	32	6	0.13
Devil's Canyon	Spruce/Fir	36	22	0.38
	Forb	33	20	0.35
	Big sagebrush	32	20	0.33
Goose Creek	Lodgepole pine	135	59	0.74
	Spruce/Fir	32	14	0.17
	Grass	26	11	0.14
Little Big Horn	Spruce/Fir	103	29	0.47
	Grass	83	23	0.37
	Forb	51	14	0.23
Paintrock Creek	Lodgepole pine	68	29	0.40
	Grass	57	25	0.34
	Big sagebrush	33	14	0.19
Piney/Rock	Lodgepole pine	86	53	0.50
	Spruce/Fir	30	18	0.17
	Grass	17	11	0.10
Shell Creek	Grass	106	32	0.48
	Big sagebrush	62	19	0.28
	Forb	45	14	0.21
Tensleep Creek	Lodgepole pine	113	37	0.71
	Grass	57	19	0.36
	Big sagebrush	30	10	0.19
Tongue River	Lodgepolepine	187	37	0.67
	Grass	86	17	0.31
	Forb	64	13	0.23

As with the LTA units, there are several cover types within a given FPWS unit that have more than 50% of their total BNF area impacted by travel routes (Table M4E-9; see LTA discussion of Table M4E-6 for interpretation of Table M4E-9). Because of the differing land subdivisions between LTA and FPWS units, different cover types are highlighted with this analysis of less common cover types impacted by travel routes. For example, travel routes within the Clear/Crazy FPWS unit dissect more than 50% of the tufted hairgrass/wet sedge covertype for the entire BNF. Given that these wetland cover types comprise only a small proportion of the BNF (0.16 %; Table M4E-2), a possible explanation for having a high road impact is that roads are often placed along stream channels for ease of road construction. Five of the ten cover types with high travel route impacts are within the Tongue River FPWS. The travel route density for Tongue River is the third highest of all the FPWS units. Based on the large area of lodgepole impacted in this unit (Table M4E-8), the large number of travel route impacts to less common cover types may be a consequence of logging roads. Tongue River coincides with much the area of LTA unit M331Bb-05 (compare Figs. M4E-5 with M4E-4), which also appeared to have a lot of logging activity. If any of the less common cover types in Table M4E-9 are deemed desirable, it may be necessary to investigate the extent of the impacts to ascertain whether any mitigation is required.

Table M4E-9. Travel route length, proportion of travel route length, proportion of CVU impacted by travel routes in total Bighorn National Forest (BNF) area, and travel route density for cover types within a Forest Plan Watershed (FPWS) unit where more than 50% of that cover type for the total BNF area is being impacted by travel routes.

FPWS Unit	CVU Cover Type	Travel Route Length (mi)	Proportion of Travel Routes in LTA (%)	Proportion of CVU Impacted by Travel Routes in BNF (%)	Travel Route Density (mi/mi^2)
Clear/Crazy	Bare litter duff	<1	<1	100	0.00
	Tufted hairgrass/wet sedge	4	1	50	0.02
Shell Creek	Curl leaf mountain mahogany	2	1	60	0.01
Tensleep Creek	GOAT	<1	<1	100	0.00
	Pinyon juniper (juniper here)	4	1	68	0.03
Tongue River	Bare	3	1	59	0.01
	"Blue grass scabland" (only 15 polygons, 593 acres)	1	<1	85	0.01
	Festuca idahoensis and *Elymus spicata* (7poly, 615 acres)	7	1	100	0.02
	Idaho fescue	17	3	72	0.06
	Skunkbrush (*Rhus trilobata*)	1	<1	100	0.00

Discussion

Roads and trails not only impact the vegetation they dissect, but also wildlife associated with the vegetation. The potential impacts on vegetation include: decreased vegetation patch size, increased edge-affected area and subsequent loss of interior environment, and increased homogeneity of patch characteristics (Baker and Knight 2000). Because forest cover types comprise 64% of the BNF land area, certain attributes of road fragmentation on forests may be particularly significant for the BNF, for instance, the increase in edge-affected area. The abrupt edge created by a new road dissecting a forest, not only alters the interior environment of the forest, but is also introducing previously protected trees to stressful environmental conditions such as strong winds and sudden changes in solar radiation. Interior environmental changes such as increased light and temperature extremes can alter nutrient cycling and increase aridity with ramifications for seedling survival and the potential for species conversions. Furthermore, abrupt edges can make trees vulnerable to windthrow and damage to foliage due to sudden changes in radiation. This can lead to alterations in leaf area and therefore gross productivity.

An additional road impact on vegetation is the potential for exotic and/or invasive species introduction along roadsides and the migration of such species along road corridors. For instance, Tyser and Worley (1992) found that fescue grasslands adjacent to roads in Glacier National Park, Montana have experienced invasion of many alien species. Grassland cover type has the second highest percentage of travel routes within the BNF, making the investigation of alien flora invasion into native grasslands an important monitoring priority. See Chapter 4 Module D for detailed discussion on invasive species.

Changes in landscape structure (e.g., increased edge, increased numbers of vegetation patches, and decreased patch size) caused by roads and trails have implications for wildlife populations. Wildlife species that avoid roads but have relatively large range requirements may not fair well in the BNF. This conclusion is based on two pieces of information: an overall road density of 1.44 mi/mi^2 and a landscape where all areal coverage of a majority of the cover types (including important habitat species such as lodgepole, spruce/fir, aspen, willow, etc.) fall within two miles of a travel route. A road density of approximately 0.95 mi/mi^2 (0.6 km/km^2) has been identified as a threshold "above which natural populations of certain large vertebrates decline" (quoted from Forman *et al.* 1997 in Baker and Knight 2000). For the conterminous 48 States, 97 percent of all land area is within 5000 m (3.1 mi) of a road (Ritters and Wickham 2003). Therefore, the BNF is no different from the rest of the U.S. Given that the pattern on public lands is similar to that on private lands, public land managers are not in a position to argue that public lands are meeting the needs of road sensitive species.

Roads and trails have a direct impact on wildlife as well. Loss of habitat, road mortality, and pollution are some examples of direct negative effects (Mech 1989; Baker and Knight 2000). These effects are not limited to large vertebrates, but also include amphibians and reptiles, small forest mammals, and predators and scavengers attempting to feed on the road-killed animals (Baker and Knight 2000). Additionally, roads and trails can deter food use, when located too near to roads, and alter movement patterns for species such as black bear, deer, elk, grizzly, mountain goats, and wolves (Mladenoff *et al.* 1995; Baker and Knight 2000, but see McLellan and Shackleton 1989). Within the BNF, roads in the Clear/Crazy FPWS unit have dissected more than 50% of tufted hairgrass/wet sedge covertype area. Oat grass and pinyon/juniper have more 50% of their total area in the BNF dissected by roads in Tensleep FPWS unit. Because these species provide quality habitat and forage for a variety of species, avoidance of this cover type due to roads may be lowering species diversity within the BNF. To make a quantitative evaluation about the travel route impacts on species pertaining to the BNF, the Species Assessment portion of the Species Conservation Project would need to be consulted in conjunction with this module.

Exurban development areas may differ from travel routes in their impacts on wildlife and vegetation, given that they experience more constant human presence and heightened human activity levels (Theobald 2000). Additionally, cow camps carry a greater potential for alien species invasion due to the transportation of seed in cow manure brought in by cows. Very little information is available regarding development impacts (see point "5" of Information Gaps section below), but Theobald (2000) suggested that development areas be clustered near roads to aggregate potential impacts rather than dispersing them and affecting larger areas.

Roads differ in some respects from trails in terms of ecological impacts. Because roads are wider, they directly remove more habitat than trails, and vehicles kill wildlife. Although trails would certainly be responsible for some fragmentation of the landscape, roads with their larger gaps and more abrupt edges are by far a greater detriment to vegetation structure and function.

Several relevant suggestions for management and mitigation of current and future road effects are provided by Tyser and Worley (1992), Tinker *et al*. (1998), and Baker and Knight (2000). Some of the suggestions are: eliminating redundant roads; decreasing construction of new roads; when new roads are essential, placing them near existing clearcuts, edges, or other roads to avoid affecting more interior area; and establishing an effective management strategy to handle alien species invasion.

Significant Information Gaps

Several information gaps and high-priority information needs have been identified and grouped into the following five categories:

(1) Because of the ever-increasing potential for alien species invasions, better species classification is needed, particularly of forbs and grasses which may include exotic, invasive species. Early knowledge of alien species invasions would allow for proactive rather than reactive management strategies (Tyser and Worley 1992).

(2) A large number of travel routes in the BNF are grouped into a "no road category" (i.e. 43% of the travel routes within the FPWS units are not categorized). To better characterize potential travel route impacts, data for those uncategorized travel routes, and frequency of usage for all travel routes, would be very beneficial.

(3) Because of the lack of equivalency between TIGER road data and data provided by the USDA-Forest Service, it is impossible to compare travel routes within and outside the BNF. Yet these data are critical to make a proper assessment of landscape cover type impacts. For example, if the BNF is the last refuge for certain cover types in the region, such impact data would be essential to provide a context of how this species fits into the larger regional landscape.

(4) Road length and density do not provide a complete account of forest fragmentation and effects on wildlife. Spatial distribution of roads is an additional important metric, where clumping of roads is less of an impact on vegetation and wildlife than an even distribution of roads (Tinker *et al.* 1998). Spatial distribution data would be valuable to the analysis of potential road effects on landscape structure and wildlife (Tinker *et al.* 1988; Baker and Knight 2000).

(5) Exurban development areas are known to fragment habitat. However, long-term effects on population viability for broad assemblages of species have not been established (Theobald 2000) but are necessary for determining the degree of fragmentation and the mitigation possibilities to alleviate the fragmentation effects.

Key Findings

Road Density

(1) Of 27 GAP vegetation types in M331B, all areas of 21 of them are entirely within 2 miles of a road.

(2) The 2,791 miles (4502 km) of travel routes within 1,716 mi^2 (444,632 ha) of land base create an overall travel route density of 1.63 mi/mi^2 (1.01 km/km^2) for the BNF.

(3) LTA unit M331Ba-01 has an inordinately high travel route density of 6.83 mi/mi^2 (4.23 km/km^2).

Highly Impacted Cover Types

(1) Cover types most influenced by travel routes are lodgepole pine, spruce/fir, grass, Douglas-fir, rock, forb, and big sagebrush. These types comprise 90% of the total BNF area.

(2) Fourteen of 32 cover types, including several minor ones, have proportionately more travel routes than would be predicted by the percentage of the cover type in the BNF.

(3) Within the LTA unit areas, important wildlife habitat cover types that cover a limited area, but are heavily impacted by travel routes, include but are not limited to rabbitbrush, sagebrush, juniper, and skunkbrush.

(4) Within the FPWS unit areas, important wildlife habitat cover types that cover a limited area, but are heavily impacted by travel routes, include but are not limited to oatgrass, blue grass scabland, *Festuca idahoensis* and *Elymus spicata*, Idaho fescue, and skunkbrush.

Highly Impacted Areas

(1) Section M331Bb-05 contains a larger number of these highly impacted but minor cover types than any other single LTA unit.

(2) Tongue River FPWS unit contains a larger number of these highly impacted but minor cover types than any other single FPWS unit.

In conclusion, roads and trails are having potentially large and long-lasting effects on vegetation and wildlife within the BNF and greater Bighorn Mountain Section area. Travel route impacts vary widely across the area of the BNF. Travel routes heavily dissect important cover types in terms of areal extent, as well as less common but perhaps ecologically important cover types.

Literature Cited

Baker, L.W. and R.L. Knight. 2000. Chapter 5: Roads and forest fragmentation in the Southern Rocky Mountains. *In* Forest Fragmentation in the Southern Rocky Mountains, Knight, R.L., F.W. Smith, S.W. Buskirk, W.H. Romme, and W.L. Baker, eds. University Press of Colorado, Boulder, CO. pp 97-122.

Forman, R.T.T., D.S. Friedman, D. Fitzhenry, J.D. Martin, A.S. Chen, and L.E. Alexander. 1997. Ecological effects of roads: toward three summary indices and an overview for North America. *In* Habitat Fragmentation & Infrastructure, K. Canters, A. Piepers, and D. Hendricks-Heersma, eds. Proceedings of the international conference "Habitat fragmentation, infrastructure and the role of ecological engineering" 17-21 September 1995, Masstricht—The Hague, The Netherlands. Ministry of Transport, Public Works and Water Management, Directorate-General for Public Works and Water Management, Road and Hydraulic Engineering Division, Delft, The Netherlands, pp. 40-54.

McLellan B.N. and D.M. Shacketon. 1989. Grizzly bears and resource-extraction industries: Habitat displacement in response to seismic exploration, timber harvesting and road maintenance. Journal of Applied Ecology **26**:371-380.

Mech, L.D. 1989. Wolf population survival in an area of high road density. American Midland Naturalist **121**:387-389.

Mladenoff, D.J., T.A. Sickley, R.G. Haight, and A.P. Wydeven. A regional landscape analysis and prediction of favorable gray wolf habitat in the Northern Great Lakes Region. Conservation Biology **9**: 279-294.

Ritters, K.H. and J.D. Wickham. 2003. How far to the nearest road? Frontiers in Ecology and the Environment **1**:125-129.

Theobald, David M. 2000. Chapter 8: Fragmentation by inholdings and exurban development. *In* Forest Fragmentation in the Southern Rocky Mountains, Knight, R.L., F.W. Smith, S.W. Buskirk, W.H. Romme, and W.L. Baker, eds. University Press of Colorado, Boulder, CO. pp. 155-174.

Tinker, D.B., C.A.C. Resor, G.P. Beauvais, K.F. Kipfmueller, C.I. Fernandes, and W.L. Baker. 1998. Watershed analysis of forest fragmentation by clearcuts and roads in a Wyoming forest. Landscape Ecology **13**:149-165.

Tyser, R.W. and C.A. Worley. 1992. Alien flora in grasslands adjacent to road and trail corridors in Glacier National Park, Montana (U.S.A.). Conservation Biology **6**:253-262.

Module 4F - Recreation and Exurban Development

Objectives

Describe the current patterns of the distribution of recreation and exurban development features in the assessment area. Evaluate the relative impacts of these patterns on the vegetation types in the assessment area. Identify and map ecological risks associated with the interaction of recreation and exurban development with invasive plant species. To the extent possible given the information limitations, discuss the ecological implications of the current condition

Introduction

Exurban development areas are conceptually and often physically linked to travel routes as another human influence within the National Forest System. Exurban development consists of campgrounds, cow camps, homes, resorts, ski areas, and utility corridors. These developments represent a more continual, less transient human impact on surrounding ecosystems compared with travel routes. Because of the more continuous presence of humans around these developments, their impacts are likely to represent a different set of challenges to those concerned with ecosystem management.

Recreational Uses and Trends

Recreation use on the Bighorn National Forest is steadily increasing. Not only is the number of visits increasing, the complexity of uses and user expectations are increasing. Increased and changing dispersed recreation use has heightened the issue of recreation and travel management that needs to be addressed as we enter into the next decade of management for the Bighorn National Forest.

Dispersed recreation use, especially motorized vehicle use such as snowmobiling and ATV (All Terrain Vehicle), has grown substantially since 1985 (Figure M4F-1). There were few if any ATVs on the Forest at that time and now there may be several hundred on any weekend day on the Forest. The use of ATVs is very popular for summer riding and camping and also during the fall hunting season. Because of this growth, there are more conflicts for those seeking a more primitive experience on the Forest.

The Forest currently has about 123,585 acres open to cross-country motorized travel. The miles of user created trails in these areas have increased. The current draft of the Revised Forest Plan proposes to eliminate cross-country travel except on designated routes.

Outdoor recreation and tourism are a major industry in north central Wyoming. Not only does providing services in recreation and tourism employ people, but this income also helps to diversify local economies. In a 1990 study on tourism by the Bighorn Mountain Country Coalition and the University of Wyoming, researchers identified that a major activity for the Bighorn National Forest visitor was viewing natural scenery and watching wildlife.

Since the Forest Plan was implemented in 1985, changes have occurred in recreation uses and patterns. There were many issues identified during public scoping meetings held during fall 2000 and letters received that related to recreation and travel management. Some of those issues are:

- Separating motorized and nonmotorized users.
- Resource damage concerns from increasing numbers of recreation users.
- Access should be provided.
- Motorized travel should be restricted to designated routes.
- Need to identify areas for winter nonmotorized use.

The Bighorn Mountains are a travel-through area for people between Mount Rushmore and Yellowstone National Park. In 1985 there were 2,226,159 visitors to Yellowstone and in 2000 there were 2,838,233, an increase of 9%. This is a representative growth number because use has fluctuated during the past fifteen years.

Figure M4F-1. Snowmobiling and hiking are two of the many popular recreation activities in the Bighorn Mountains.

Historical Summary

The 1985 Forest Plan provided for additional campgrounds and trails. Many of those campgrounds and trails were not built because of lack of recreation funding. Although travel management constraints have been applied on the travel map, this remains one of the most controversial facets of current management. Road closures have caused considerable controversy. Strong feelings have surfaced on both sides of the issue during public meetings held as part of the revision process. While many people want fewer closures to motorized vehicles, many others want more closure to motorized vehicles. Decisions are needed that seek to balance opportunities for the many modes of travel on the Forest.

Current Conditions (Supply)

Developed Recreation

Developed recreation opportunities are located primarily along existing travel-ways. Most developed campgrounds are managed through a concessionaire program. The season is from May to September and campgrounds are open only during a portion of May and September. Campground occupancy during 2000 was 20% in May, 40% in June, 87% in July, 84% in August and 46% percent in September.

There are 37 developed campgrounds on the Forest with a total of 496 campsites, 16 picnic grounds with several picnic sites, 22 trailheads and 3 warming huts for cross country skiers in the winter. In addition, there are several parking lots and areas that provide information services on the Forest. The Bighorn's major emphasis and effort for developed facilities is enhancement by reconstructing these facilities or expanding them where site conditions allow. The goal is to maintain a wide spectrum of quality facilities (campgrounds, picnic areas, interpretive sites and trailheads).

Three Scenic Byways are situated on the Forest. Direction for the Scenic Byways may be included in the plan revision. The Byways will be in a separate management area with standards and guidelines applicable to those areas.

Interpretive services are provided at three major sites: Burgess Visitor Center on US Highway 14, Shell Falls Visitor Center on US Highway 14 and Medicine Wheel Historic Preservation site on US Highway 14A.

Dispersed Recreation

Dispersed recreation continues to increase at rates exceeding Forest Plan projections. People continue to return to their favorite secluded site to enjoy it with their family and friends. There are 2,992 dispersed campsites on the Bighorn National Forest outside of wilderness that were identified and mapped in 1997 and updated in 2001. During summer 2002, campsite inventories for condition were conducted on each district.

There are an additional 1,387 dispersed campsites that were inventoried in the wilderness in the mid 1980s. The dispersed recreation program on the Bighorns has been directed in the past to the more popular traditional activities such as fishing, hunting, hiking, horseback riding, dispersed camping and winter activities such as snowmobiling and cross-country skiing. These activities will continue to be provided and managed. Nontraditional, dispersed recreation activities such as riding ATV's and mountain bikes and rock climbing are becoming more important in long term planning, not only to provide the opportunity but also to protect the resource.

Dispersed recreation direction will be improved by deciding forestwide standards and guidelines, management areas, ROS classes and scenery objectives.

Ski Areas

Antelope Butte and Bighorn Mountain Ski Area are located entirely on the forest. A review of past use at the ski areas shows an erratic pattern due to ski-lift capacity and snow conditions. The current ski-area capacity exceeds use. Antelope Butte has been expanded with further plans identified in the master plan for the area. Bighorn Mountain Ski Area has also expanded their skiing terrain and lift capacity.

Recreation Settings

Some people desire an emphasis on undeveloped, remote recreation settings, other people want a mix of developed and undeveloped settings and yet others are interested in seeing more developed facilities and easier access. The recreational opportunities and experiences associated with each setting are linked to the physical landscape (size of the area, remoteness and degree of human influences), social interaction (amount and types of contact) and managerial efforts (degree of regulation).

The Forest Service uses the ROS (Recreation Opportunity Spectrum) to describe different recreation experiences. These experiences are separated in ROS classes. The following ROS classes and acres have been identified on the forest (Figure M4F-2):

<u>Primitive</u> (181,232 acres) – These areas are characterized by an unmodified environment and have a very high probability of experiencing solitude, freedom, closeness to nature, tranquility, self-reliance, challenge and risk. There is very low interaction between recreation users. Access and travel is nonmotorized on trails or cross country.

<u>Semi-primitive nonmotorized</u> (278,105 acres) – Areas in a semi-primitive nonmotorized class are in a natural appearing environment with a high probability of experiencing solitude, closeness to nature, tranquility, self-reliance, challenge and risk. There is low interaction between users. Access and travel is nonmotorized on trails, some primitive roads or cross-country.

<u>Semi-primitive motorized</u> (372,549 acres) – There is a moderate probability of experiencing solitude, closeness to nature and tranquility. The setting is in a predominantly natural appearing environment. There is a low concentration of users, but often evidence of others on trails. Motorized vehicles are allowed for travel.

<u>Roaded modified</u> (106,532 acres) – In a roaded modified setting, there is opportunity to get away from others, but with easy access. There is moderate evidence of other users on roads and little evidence of others or interaction at camp sites. Conventional motorized access includes sedan, trailer, atv and motorcycle travel. These areas are located where concentrations of roads occur from past timber harvest.

<u>Roaded natural</u> (140,393 acres) – Self-reliance on outdoor skill is of only moderate importance to the recreation user with little

challenge and risk. The environment is mostly natural appearing. Access and travel is motorized including sedan and trailers. These areas are located along the major US Highways 14 and 14A corridors.

Rural (32,544 acres) – The opportunity to observe and affiliate with other users is important as is convenience of facilities and recreation opportunities. There is little challenge and risk. Interaction between users may be high as is evidence of other users.

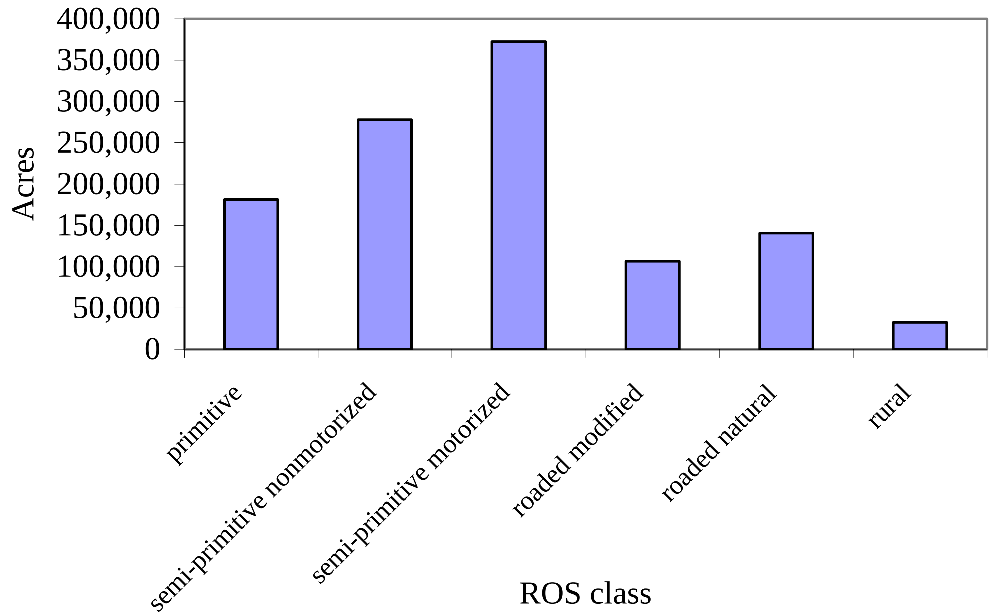


Figure M4F-2. Recreation Opportunity Spectrum Class Acres on BNF.

Recreation Special Uses

Currently there are 53 outfitter/guides providing services throughout the year on the Bighorn National Forest (Table M4F-1). Twenty-one of those outfitters provide service in the Cloud Peak Wilderness. The interest and demand for new outfitters and new uses increases yearly. As part of the plan revision, the Forest conducted a needs analysis to determine criteria if or when additional outfitter/guides or new uses will be authorized.

Table M4F-1. Outfitter/guide use on the Bighorn National Forest.

Activity by District	Tongue	Powder River	Medicine Wheel - Paintrock	Total
Spring				
Spring bear hunting	149	0	75	224
Summer				
Trail rides, camping, fishing	2,650	10,616	1,979	15,245
Fishing	80	172	206	458
Cattle drives	180		390	570
Rock climbing		160		160
Backpacking		660		660
Env. Educ ,backpacking			1,790	1,790
Fall				
Big game hunting	441	245	2,192	2,878
Winter				
Snowmobile guiding	1,600	1,750	790	4,140
Dog sledding			20	20
Lion hunting	40	40		80
TOTAL SERVICE DAYS PROVIDED ON THE BIGHORN NATIONAL FOREST*				**26,225**

*A service day is a day or any part of a day on the National Forest System lands for which an outfitter or guide provides goods or services, including transportation, to a client.

Demand Assessment

The demand for dispersed recreation opportunities is very high, putting increased pressure on existing road and trail facilities (Table M4F-2). Some shifts in the types of recreation use have been observed. In the 1980s, motorized recreation increased as tent camping changed to motorized RVs and trailers. Campers and day users also started using larger vehicles including the use of additional vehicles and ATVs. Because of the shift in types of vehicles, types of activities and demographics, existing designs do not always meet the needs of current users. Our future population will generally be older and less agile, which will require designs to make recreation use more enjoyable. Examples of these changes could be trail grades that are not as steep, more rest benches and interpretative signs that have larger print.

Use of developed recreation facilities and exploring scenic byways and the recreational opportunities found along these corridors will continue to attract and draw visitors to the forest. It is anticipated the current growth will continue in the long term.

With two ski areas on the Forest, there is sufficient capacity to meet skier demand over the next planning period. Even if skier demand should exceed the anticipated growth rate, it can be accommodated with the potential expansion capability within the existing permit areas.

Table M4F-2. Recreation use on the Bighorn National Forest. The percent column does not sum to 100 due to rounding.

Activity	Thousands of Recreation Visitor Days*	Percent
Camping, picnicking and swimming	323.0	19.6
Mechanized travel & viewing scenery	482.5	29.3
Hiking & horseback, mtn. climbing	213.8	13.0
Resorts, Cabins, organization camps	260.1	15.8
Winter sports (downhill skiing)	8.7	0.5
Winter sports (cross country skiing)	31.2	1.9
Winter – snowmobiling	52.3	3.2
Winter - other	17.9	1.1
Hunting	52.9	3.2
Fishing	85.0	5.1
Nature study	16.4	1.0
Other activities	105.0	6.4
Total	1,648.8	
Wilderness use (included in above)	70.1	4.6

* One recreation visitor day is one person spending twelve hours in the activity or it may also be two persons spending six hours each.

In 2001, the University of Wyoming conducted a social assessment in the four counties surrounding the Bighorns to help understand how people are connected to the Forest. Almost 19 out of every 20 respondents surveyed indicated they visited the Bighorn National Forest at least once during 2000 for the purpose of recreation.

Of those persons responding, the favorite activity was fishing. The top five favorite things were fishing, camping/picnicking, hunting, enjoying scenery and hiking/backpacking. When respondents had an opportunity to note all the recreation activities they participate in on the Forest, wildlife viewing was listed by 78.4% of all responding, fishing by 64% and picnicking by 60.2% of all respondents.

Recreation use nationwide is projected to increase for all activities. Recreation use on the Bighorn National Forest is projected to continue in a slow, but steady growth (Table M4F-3).

Table M4F-3. Projected recreation use on the Bighorn National Forest in Recreation Visitor Days* (see footnote of Table M4F-2 for definition).

	2000 -2010	2011 - 2020	2021 - 2030	2031 - 2040	2041 - 2050
Developed Recreation	507.0	543.9	584.0	627.4	674.5
Dispersed Recreation	1248.0	1339.0	1441.6	1557.5	1688.8
Downhill Skiing	8.8	8.9	8.9	9.0	9.1
Total	1763.8	1891.8	2034.5	2193.9	2372.4

* Numbers include wilderness use

The capability to manage the increased demand for traditional and nontraditional recreation opportunities and activities will be reflected in the management area allocations. The amount, location, and user distribution will need to be monitored.

Exurban Development

Exurban development within a 200 m buffer width (Figure M4F-3) impacts 13,452 acres (5,446 ha) or 1% of the BNF. By far, utility corridors affect the largest area (6,654 acres or 2,694 ha), with homes (2,103 acres or 851 ha) and ski areas (2,097 acres or 849 ha) a distant second and third, respectively. As with travel routes, lodgepole pine, grass, and spruce/fir are the three most frequently affected cover types (Data not shown). Utility corridors are the only area where spruce/fir is less than five percent of the 200 m buffer width; big sagebrush is more greatly affected instead.

Exurban development areas are scattered throughout the BNF with definite clumping of ski areas, resorts, residential homes, and utility corridors (Figure M4F-4). Cow camps are more evenly distributed across the BNF landscape.

Because exurban development areas consist, in part, of permanent structures (e.g., homes, resort buildings, cabins, etc.) intended for frequent human visitation if not year-round habitation, their direct and indirect impacts on surrounding vegetation and wildlife may be greater than those of travel routes (see Discussion of greater detail on potential wildlife impacts).

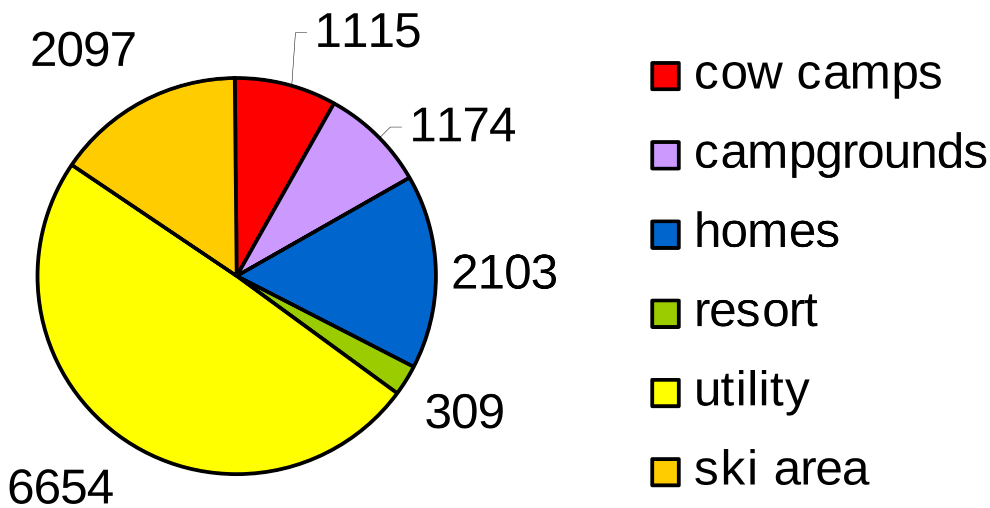


Figure M4F-3. The distribution of the total acreage within a 200 m from a development area among the six types of exurban development found in the Bighorn National Forest.

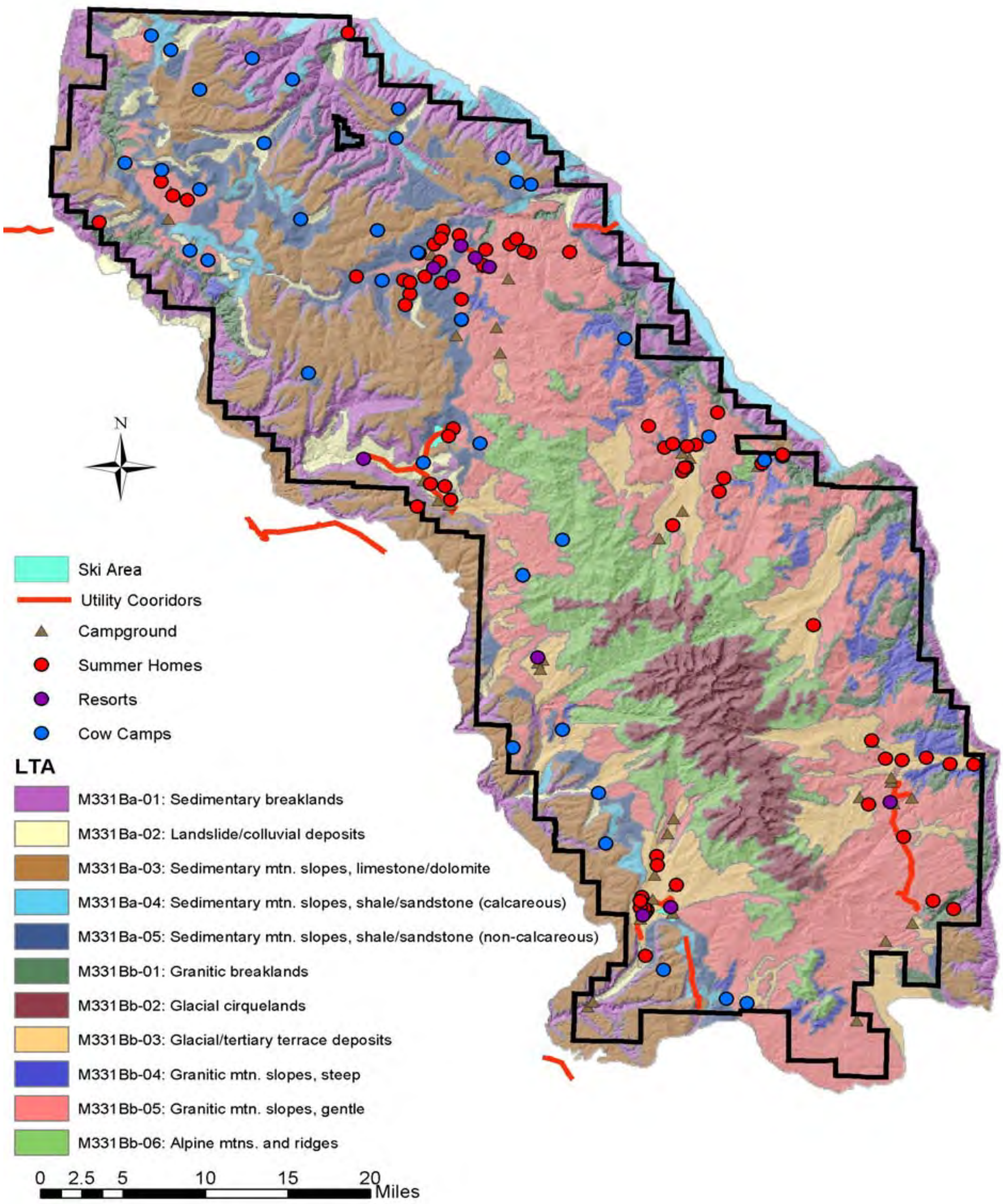


Figure M4F-4. Exurban development areas within the Bighorn National Forest.

Development

In many areas of western North America, the conversion of agricultural land and forested land into low-density residential development (referred to as *exurban*) has increased rapidly in recent decades (Theobald 2000). For example in the Front Range of Colorado, development increased exponentially during the 30 years between 1960 and 1990. Although developmental expansion in the Bighorn Mountains currently does not approach the rate of expansion in the Front Range, the occurrence of similar pockets of growth across the American West presents the potential for similar growth in the Bighorns. Numerous other associated human activities that result from demands on natural resources (e.g., water impoundments and diversions, mining, etc.) increase as development increases, and these activities permanently perforate landscape pattern.

Wildland Recreation

Outdoor recreation has grown ten-fold in the past 40 years in wilderness areas (Cole and Landers 1996). Winter sports activities tripled between 1966 and 1979 (Hammit and Cole 1987). Clearly, as regional human population increases, wildland areas experience increased use for various forms of recreation – and the forms of recreation available are evolving over time with technological advances (e.g., the availability and popularity of mountain bikes in the last two decades). Wildland recreation includes an enormous variety of human activities that vary at spatial and temporal scales as well as in numbers (Pomerantz *et al.* 1988), and the popularity of these recreation types changed between the period 1966 and 1979. For example, hunting and fishing have decreased in popularity, while winter camping and hiking and mountain climbing – which have benefited from improved technology and equipment – have increased. All of these activities may affect landscape pattern to varying degrees. The type, intensity, and frequency of recreation activity -- coupled with a site's inherent resistance to the activity -- are significant variables in how much impact the activity has on vegetation pattern (Hammit and Cole 1987).

Human Developments

Including a 400-meter buffer zone around campgrounds, summer homes, and resorts, human developments affect approximately 14,000 acres (5,700 ha) of the Bighorn National Forest. Summer homes account for 47% (6,600 acres/2,700 ha) of human developments; followed by campgrounds (28%), ski areas (21%), and resorts (5%). Less than one percent of the total area affected by human developments is considered to be at very high invasibility for non-native plant establishment and spread; 30 percent (4,264 acres/1,726 ha) is considered at high invasibility, 31 percent (4,384 acres/1,775 ha) at moderate invasibility, and 38 percent (5,385 acres/2,180 ha) shows low invasibility for non-native plant establishment and spread (Table M4F-4).

It is difficult to determine the impact of human developments independent from other factors, because human developments are often placed where non-native plant invasibility is high due to other factors or a combination of abiotic and human influences (Figure M4F-5). For example, although resorts affect only 702 acres (284 ha) of the Forest, a much higher percentage (61%) of the area affected by resorts is considered to be at very high or high invasibility compared to campgrounds (36%) or summer homes (31%). However, resorts and, in particular, summer homes appear to be most common at lower- to middle elevations or near major drainages or valleys where non-native plant establishment and spread is most common (Figure M4F-5). Only ski areas were located away from these areas of high invisibility with only 17% of the land affected by ski areas showed high invasibility for non-native plant establishment and spread, and none showed very high invasibility.

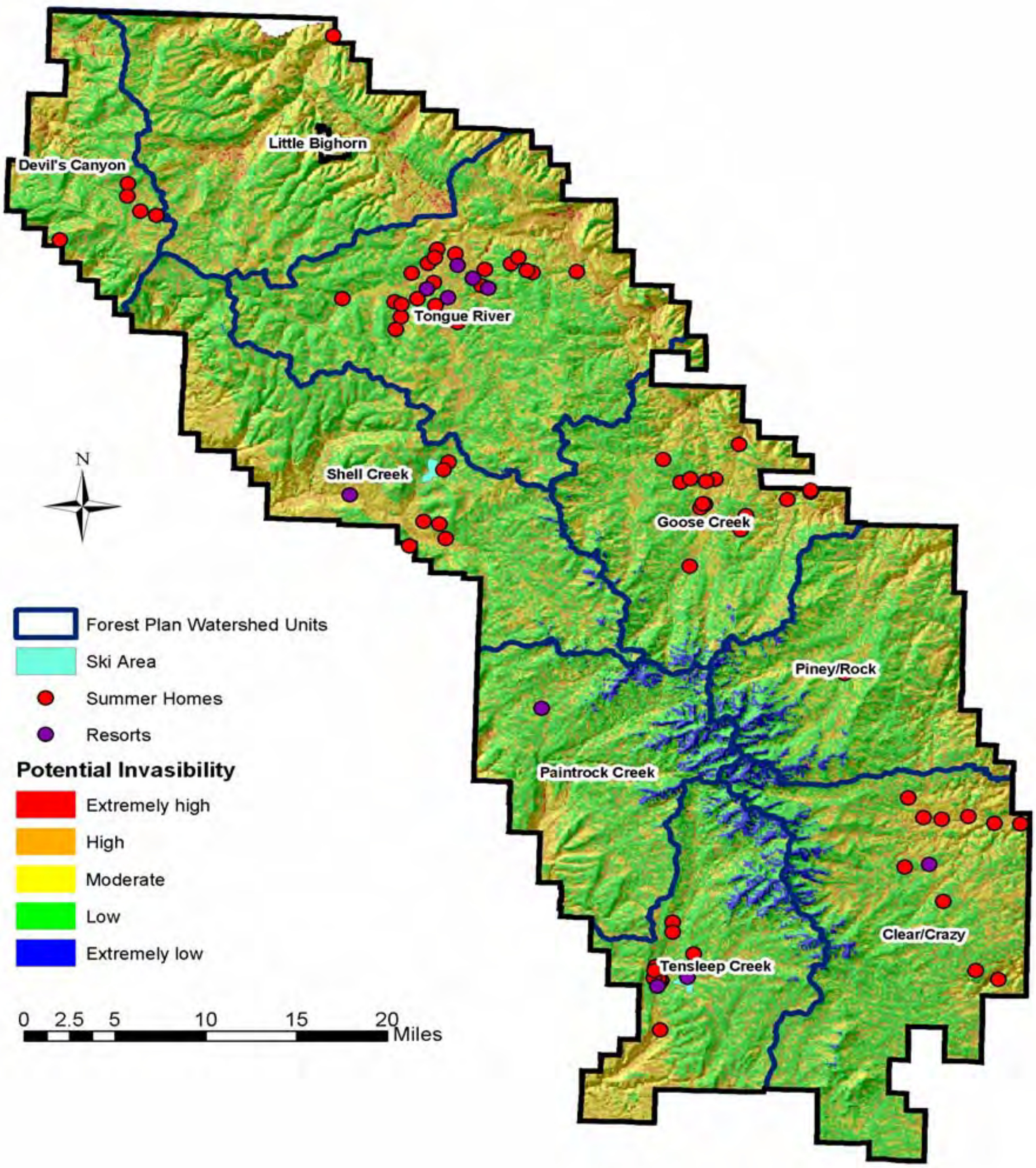


Figure M4F-5. Potential vulnerability to non-native plant species invasion on the Bighorn National Forest associated with human developments.

Table M4F-4. Acres of land within the Bighorn National Forest affected by human developments within each invasibility category for non-native plant establishment and spread. VH = very high, H = high, M = moderate, L =low, invasibility. Hectares are in parentheses. (400 yd buffer used for campgrounds, summer homes, and resorts)

	VH	H	M	L	Total
Campgrounds	26 (11)	1,379 (558)	1,279 (518)	1,210 (490)	3,893 (1,575)
Summer Homes	20 (8)	2,005 (811)	2,097 (849)	2,502 (1,013)	6,624 (2,681)
Resort	34 (14)	370 (150)	271 (110)		702 (284)
Ski Areas		484 (196)	738 (299)	1,673 (677)	2,894 (1,171)
Total	80 (32)	4,238 (1,715)	4,385 (1,775)	5,385 (2,179)	14,113 (5,711)

Significant Information Gaps and Key Findings

Recreational Uses and Trends

(1) Dispersed recreation continues to increase at rates exceeding Forest Plan projections.

(2) Dispersed recreational motorized vehicle use (snomobiling & ATV) has grown substantially since 1985.

(3) Nontraditional, dispersed recreation activities such as riding mountain bikes and rock climbing are increasingly more important.

(4) There are 2992 dispersed camp site on the BNF outside of wilderness were mapping in 1997 and 1387 dispersed campsites within the wilderness inventoried in the 1980s.

(5) Favorite activities are fishing, camping/picnicking, hunting, enjoying scenery and hiking/backpacking (U of Wyoming social assessment, 2001).

Exurban Development

(1) Utility corridors and homes with 200 m buffers and ski areas affect 1% of the BHF.

(2) Lodgepole pine, grass, and spruce/fir are the three most frequently affected cover types.

(3) Exurban development areas, in part, consist of permanent structures intended for year-round habitation and may have direct and indirect impacts on surrounding vegetation and wildlife greater than those of travel routes or dispersed recreation.

Non-native Plant Establishment and Spread

(1) Resorts and homes are more common at lower to middle elevations or near major drainages where non-native plant invasion is most common. Ski areas are located away from these areas of high invisibility.

Literature Cited

Cole, D.N., and P.B. Landers. 1996. Threats to wilderness ecosystems: Impacts and research needs. Ecological Applications 6:168-184.

Hammit, W. E., and Dn.N. Cole 1987. Wildland Recreation Ecology and Management. John Wiley & sons. New York. 341 p.

Pomerantz, G. A., D.J. Decker, G.R. Goff, and K.G. Purdy. 1988. Assessing impact of recreation on wildlife: A classification scheme. Wildlife Society Bulletin 16:58-62.

Theobald, D. M. 2000. Chapter 8: Fragmentation by inholdings and exurban development. In: Forest fragmentation in the Southern Rocky Mountains, Knight, R.L., F.W. Smith, S.W. Buskirk, W.H. Bomme, and W.L. Bakers, eds. University Press of Colorado, Boulder, CO. pp. 155-174.

Chapter 5 - Landscape Patterns

Introduction

Vegetation patterns across landscapes (i.e., landscape heterogeneity) vary over spatial and temporal scales (Daubenmire 1968; Forman and Godron 1986; Forman 1995), requiring the consideration of scale for evaluation. This module describes patterns at the scale of the relatively coarse-grained patchiness of aerial photos covering more than a thousand hectares. For example, the orthophotoquadrangle in Figure M5-1 shows vegetation patterns resulting from both human influences (roads, timber harvest, and livestock grazing) and natural landscape heterogeneity (intermixed grasslands and forested lands in undulating, dissected topography). In recent years, there has been an increasing focus on understanding the significance of vegetation pattern for ecosystems (Harris 1984; Hunter 1991; Knight *et al.* 2000), and the technology and tools for measuring landscape-scale patterns have also advanced (Baker and Cai 1992; Flather and MacNeal 1993; McGarigal and Marks 1995).

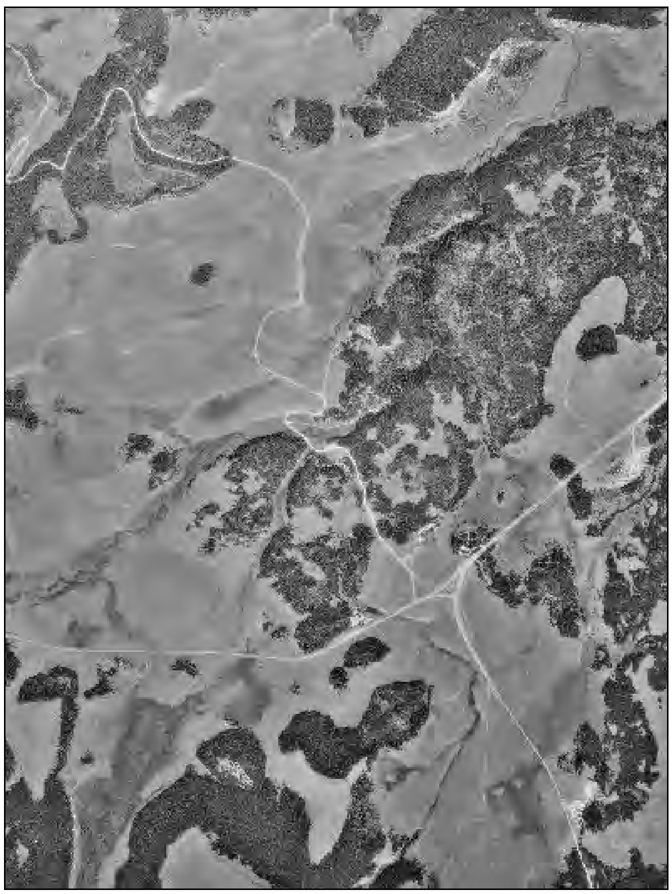


Figure M5-1. An example of landscape heterogeneity from a digital orthophoto of the Burgess Junction SE, WY quadrangle (*source: http://www.sdvc.uwyo.edu/doqq/search.html*).

Suggested improvement: Insert 1) a brief narrative defining pattern (i.e. pattern is more than just an analysis of landscape metrics as produced by something like Fragstats) and 2) list of our measures of landscape pattern (proportion or amount of cover type, proportion or amount of HSS, fragmentation/landscape structure).]

Factors Creating Pattern

The Rocky Mountains exhibit a broad climatic gradient influenced by physiographic features including topography and elevation. Geological features, parent materials, and subsequent soil conditions are highly heterogeneous across the region. In addition, species have evolved in response to and vegetation pattern has been shaped by various disturbance agents, in part creating the naturally patchy landscape seen today. Vegetation patterns such as those in the Rocky Mountains and the Big Horn Mountains (Fig. M5-2) likely results from the distribution of species along environmental gradients, as well as by patterns of disturbance and recovery within communities along these gradients (Romme and Knight 1981). Factors creating pattern can be segregated into two broad categories -- natural processes and anthropogenic influences, which are discussed in more detail below. The current broad vegetation pattern of the Big Horn Mountains Section (M331B) is influenced primarily by natural influences and, to a much lesser extent, by anthropogenic influences at this scale.

Chapter Organization

After introductory material on factors creating patterns in the Bighorn ecosystem, the chapter is partitioned into two modules. The first module focuses on forest and woodland ecosystem and identifies very broad patterns within an ecoregional context and describes the forest vegetation response to the ecological template by displaying how forest types are distributed among Subsections and Land Type Associations. The module then describes major land use influences on pattern. The second module focuses on grassland and shrubland ecosystem pattern as influenced by major land use influences and relies heavily on a GIS model due to limitations in data availability.

Major Influences on Landscape Pattern in the Big Horn Mountains

Abiotic template

Fundamentally, climate (including temperature, moisture, wind, and sunlight), topography, and soils underlie much of the natural landscape pattern seen in the Big Horn Mountains and in the Rocky Mountains in general (see Climate section in Chapter 2 for greater detail). Climate is a very strong control on vegetation patterns through the distribution of energy and water, and differs not only with latitude or regionally, but also with elevation. For example, the distribution of ponderosa pine forests, restricted to the eastern edge of the Section and Forest, corresponds with the region of highest rainfall (Fig. M5-2). The occurrence of ponderosa pine forests on the southwestern edges of the Section and Forest also corresponds with increased moisture carried by air masses that have navigated a physiographical gap in the northwest corner of Big Horn Basin (Despain 1973). Similarly, juniper woodlands occur only in the driest, western portion of the Section (Fig. M5-2).

Geomorphic features of the landscape, particularly topography and elevation, modify the effects of climate. These effects are reflected in the spatial distribution of the broad lifeform groups: rock and bare, grass and forb, shrub, tree, and water (Fig. M5-3). The Big Horn Mountains, and particularly the Bighorn National Forest, vary greatly in topography and elevation. However, mountainous landscapes express much more patchiness, especially in highly dissected terrain, than would be expressed by elevation alone (Knight and Reiners 2000) due to topographic features such as aspect and slope. Essentially, the environment is relatively warmer and drier on south- and west-facing slopes as compared to north- and east-facing slopes at the same elevation, which also produces spatial heterogeneity in soil developmental patterns. In addition, vegetation types generally change dramatically between contrasting aspects; for example, in the Big Horn Mountains, Douglas-fir may be found on a north-facing slope while a mountain big sagebrush shrubland may be present on the corresponding south-facing slope. In general, landforms and topographic features affect landscape patterns by: 1) affecting air and ground temperatures and the availability of moisture, nutrients, and other materials at a given site; 2) affecting the flow of organisms, propagules, and energy through a landscape; 3) affecting the frequency and spatial pattern of natural disturbances (see below); and 4) constraining the spatial pattern and rate/frequency of the mechanical transport of organic and inorganic material that alters biotic processes (Swanson *et al.* 1988).

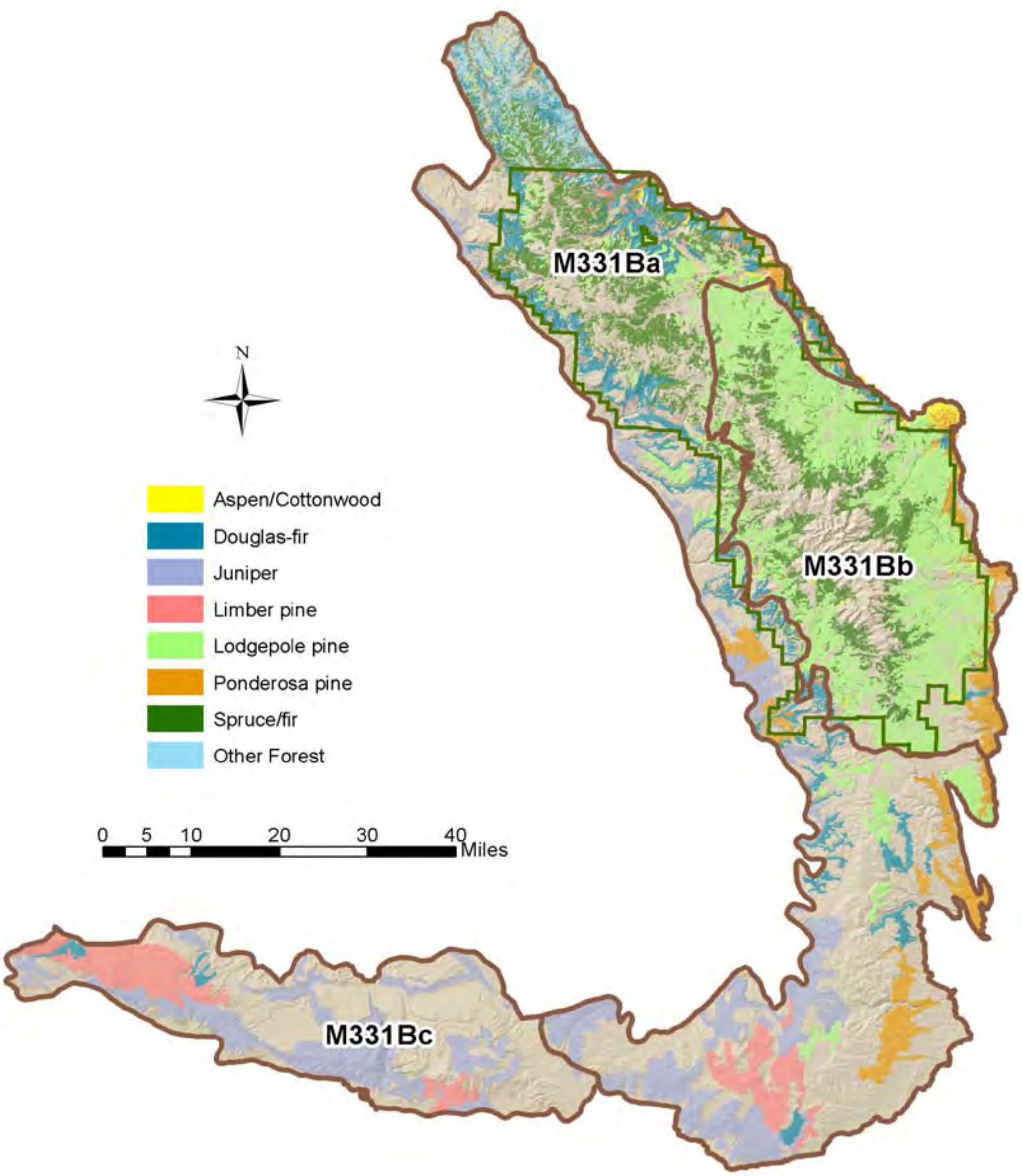


Figure M5-2. Forested areas in the Big Horn Mountains Section (M331B) using GAP data for the Section and CVU data for the Bighorn National Forest.

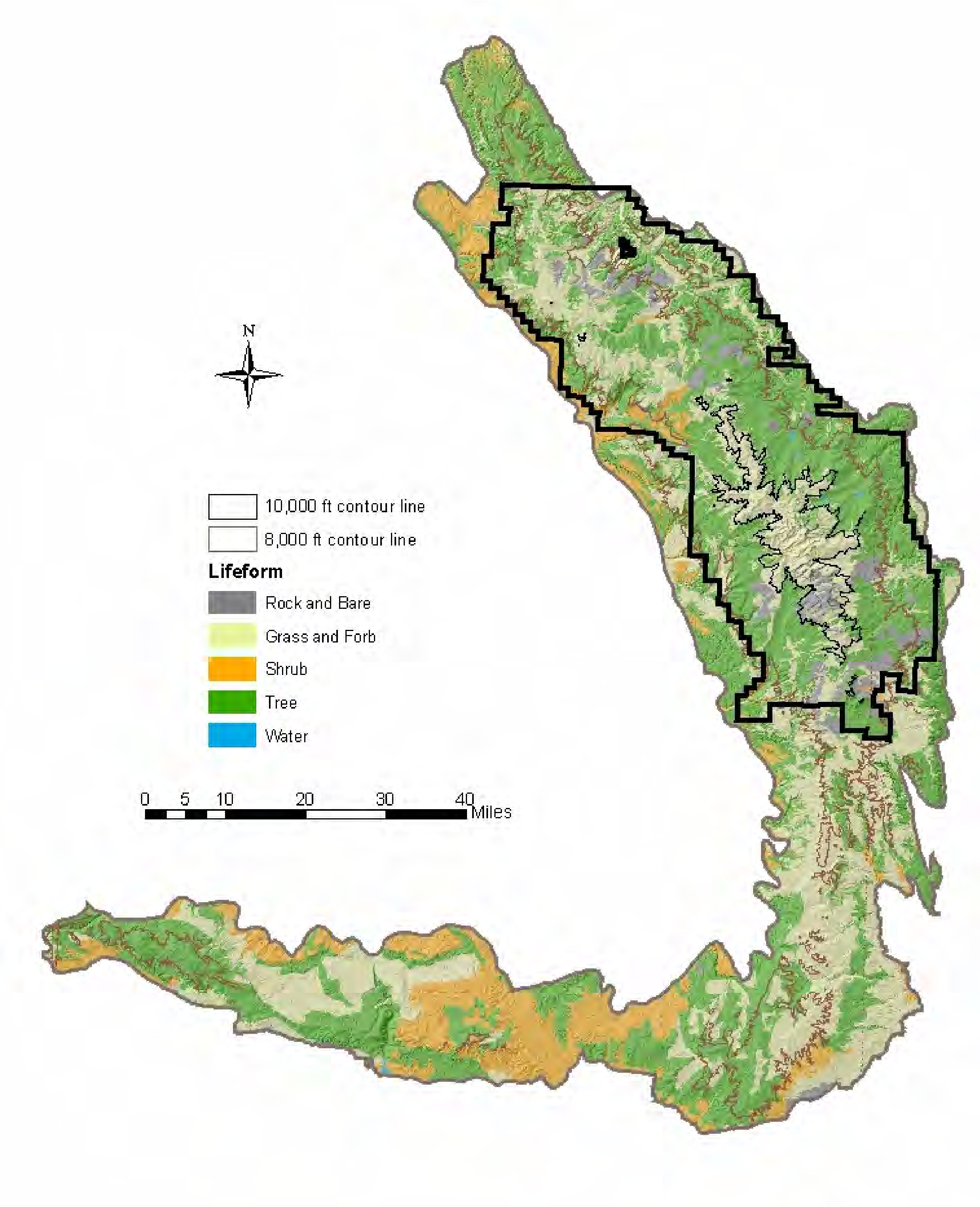


Figure M5-3. Relief map with associated vegetation lifeforms for the Big Horn Mountains Section (M331B) (*source: USGS DEM data*).

Finally, geology and soils combine to form an important feature in further defining landscape heterogeneity. For example, on the BNF, forest types such as lodgepole pine appear to be restricted mainly by the presence of granitic parent materials, and Douglas-fir is best developed on limestone- or dolomite-derived soils (Despain 1973; Fig. M5-4). About 90% of lodgepole pine forests occur on granitic substrates. In contrast, Douglas-fir (93%), limber pine (99%), ponderosa pine (80%), and juniper (99%) each are most common on sedimentary substrates. Spruce/fir and aspen forests show little preference for either parent material. While spruce/fir forests can occur on either substrate, they only occur on granite in cooler, more mesic environments, such as at high elevations, on north aspects, or along riparian areas. Another example of substrate patterns affecting vegetation pattern on the BNF is the association between geologic substrate and the occurrence of curl-leaf mountain mahogany communities (Table M5-1), where there is clearly a strong association of this community to limestone substrates. Although the association of vegetation types to a particular parent material or soil is not always evident, spatial heterogeneity in soil types and properties across a landscape has a profound influence on vegetation pattern.

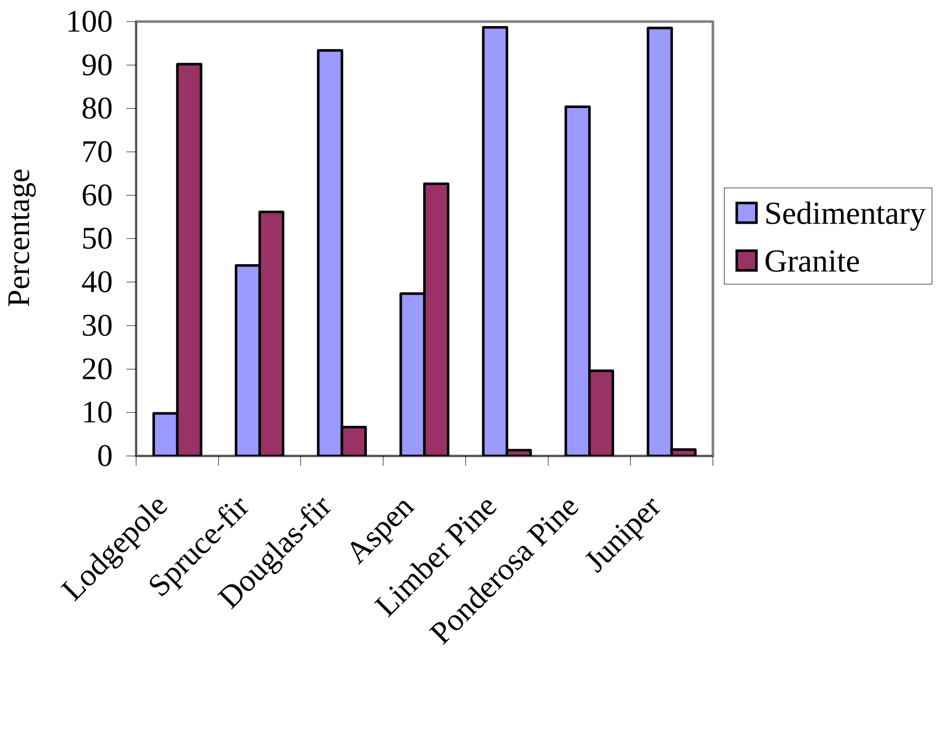


Figure M5-4. Correspondence of forest types in the Bighorn National Forest to parent material.

Table M5-1. Relationship between curl-leaf mountain mahogany and geology on the Bighorn National Forest. *Source: Bighorn NF Common Vegetation Unit data and Geology.*

Geology	Acres	Percent of Total
Limestone	5,972.71	88.34
Landslide Deposits	532.77	7.88
Granite	214.87	3.18
Alluvium	20.02	0.30
Sandstone	11.42	0.17
Mixed Sedimentary	8.97	0.13
TOTAL	6,760.75	100.00

Disturbance

Disturbance plays an integral role in shaping vegetation pattern. Veblen (2000) emphasizes that key to understanding disturbance is to comprehend the concept of disturbance regime, which is characterized by: 1) spatial distribution of the disturbance, 2) frequency of the disturbance, 3) size of area disturbed, 4) mean return interval, 5) predictability of the disturbance, 6) rotation period, 7) magnitude or severity, and 8) the synergistic interactions of different kinds of disturbances. Variations of these parameters are key determinants of landscape heterogeneity. Major disturbance agents are fire, insects, and windstorms, but diseases also are an important factor affecting vegetation (Forest Health Management Group 1994). Each of these disturbance agents is briefly discussed below; see Module 4A of this assessment for detailed descriptions.

Fire types vary significantly between the subalpine and montane zones (Romme and Knight 1981; Peet 1988). Historically, fires in open ponderosa pine forests of the lower montane zone experienced relatively frequent surface fires carried primarily by grass fuels. In contrast, the upper subalpine zone typically has continuous fuels within Engelmann spruce, subalpine fir, and lodgepole pine forests that historically burned relatively infrequently but resulted in widespread stand-replacing fires (Veblen 2000). Estimates of the average time between recurrent fires to the same stand is 5-40 years in open forests of the lower montane zone and 100-500 years in subalpine forests for Wyoming and Colorado (Clagg 1975; Rowdabaugh 1978; Romme and Knight 1981; Crane 1982; Romme 1982; Gruell 1985; Peet 1988).

Several insects may have significant impacts on forest stands over wide geographic areas. Important forest insects include mountain pine beetle (*Dendroctonus ponderosae*), Douglas-fir beetle (*Dendroctonus pseudotsugae*), spruce beetle (*Dendroctonus rufipennis*), and western spruce budworm (*Choristoneura occidentalis*) (Veblen 2000). The beetles tend to attack and typically kill large-diameter trees, while the western spruce budworm is a defoliator whose attacks may not be lethal to the tree but is considered to be the most destructive forest defoliator in the West (Furniss and Carolin 1977). Refer to Module 4A for detailed descriptions of insect disturbances.

Many diseases are well documented in forested environments, and can affect vegetation pattern. Three species of dwarf mistletoe (*Arceuthobium* spp.) infect species-specific hosts -- lodgepole pine, Douglas-fir, and ponderosa pine. Dwarf mistletoes cause the greatest disease losses in the Rocky Mountain Region. In Wyoming, they are widespread on the Bighorn and Shoshone National Forests (Forest Health Management Group 1994). Canker diseases (*Cytospora* spp.) are commonly found on aspen. Root pathogens (*Armillaria* spp.) are common in conifers, especially where tree harvesting leaves stumps, which become new food sources. Finally, a series of foliage diseases also periodically affect various hosts, including lodgepole pine, ponderosa pine, and aspen (Forest Health Management Group 1994). While diseases are common in forests of the Big Horn Mountains, few are likely widespread enough to affect forest landscape patterns.

Windstorms may be damaging, especially in the subalpine zone. Trees in this zone tend to be shallow rooted and, where dense stands have developed, are especially susceptible to blowdown (Alexander 1987). In 1987, a tornado blew down 15,000 ac (6,000 ha) of forest in the Teton Wilderness (Knight 1994). Small blowdowns of 0.5 acre to several acres (.2 ha +) are common in subalpine forests (Veblen *et al.* 1991). Effects of snow avalanches are much more localized and restricted to sites having significant snowfall and percent slope.

Anthropogenic Influences

Though perhaps far less important than modern influences for landscape pattern, pre-Euro-American settlement activities have left several legacies on the current forested landscape (Romme *et al*. 2000). Between 1500 and 1800, Native American tribes that occupied the area were hunter-gatherers and likely had little effect on forest landscape structure. Even during several "Indian Wars" between 1812 and 1860, impacts on forested areas were probably relatively minor, primarily because hostilities between tribes prevented long-term use of the area. In general, Native American influences on forests of the Bighorns were probably limited to small areas of harvest for sustenance, as well as an occasional intentional fire – although lightning fires were likely much more influential (Meyer and Knight 2003).

Between about 1860 and 1920 the West experienced a period of rapid population expansion, including extensive exploitation of natural and mineral resources (Smith 2000). Trees were harvested for mine timbers, railroad ties, and building construction. Large numbers of domestic livestock were allowed to graze over long seasons. Large fires occurred during this time as well. Some of these fires were a consequence of human activity – for example, railroading, miners, and livestock operators clearing land. A period of fire suppression followed the settlement era that continues through today.

Clearly, western landscapes are a reflection, to varying degrees, of past human actions since settlement, and humans have influenced forested landscape pattern. Some of the major human influences include timber harvest (see Module 4B), road and trail construction (see Module 4E), fire suppression (see Module 4B), and development (see Module 4F). All of these actions directly or indirectly influence vegetation pattern.

Summary of Biological and Anthropogenic Effects on Landscape Pattern

The Rocky Mountains are naturally patchy as a result of pronounced gradients and discontinuities in environmental factors such as soils and microclimate as well as persistent natural disturbances (Romme *et al*. 2000a). Thus, the significance of human-induced influences on the natural heterogeneity of Rocky Mountain landscapes appears to be the critical issue if changes in landscape patterns are of interest. Unfortunately, the issue is complex and much additional scientific study is needed. The next half-century may yield profound shifts in demographics, economics, and social expectations (Romme *et al*. 2000a), such that a review of past anthropogenic influences may not reflect the dominant future anthropogenic stresses. Yet, expansive recreation and exurban development in the next century have the potential to disrupt ecological function and native biological diversity on a large and significant scale.

The natural processes that affect landscape pattern often occur at large spatial and temporal scales, such that human actions are thought to have trivial effects within a larger landscape context. However, many human effects on landscape pattern may be cumulative over time. Moreover, the effects of large, infrequent events (flooding, wildfire, windstorms, etc.) that are beyond human control are often overlooked, though they may add enormous change in landscape pattern over very short time periods.

Module 5A
Forest and Woodland

Objectives

Describe key features of spatial pattern on the landscapes. Identify very broad patterns within an ecoregional context by displaying how forest types are distributed within the national forest compared to the Section and the broader ecoregion (Province). Describe the forest vegetation response to the ecological template by displaying how forest types are distributed among Subsections and Land Type Associations. Finally, describe major land use influences on pattern by displaying how forest types are proportionately influenced by land ownership and land use allocations, by summarizing major effects of roads and vegetation management on pattern, and by displaying probable departures in pattern from HRV. To the extent possible given information limitations, discuss the ecological implications of the current condition.

Geographic Context of Current Patterns of Forest and Woodland Distribution

Importance of Forest in Larger Eco-regional Landscape

Because forested habitats are relatively rare in the immediate region (see Chapter 2 for Biogeographic Significance), they represent an important source of heterogeneity across the landscapes of northern Wyoming and southern Montana, as well an important source of biodiversity for the region. In particular, the Bighorn National Forest contains the majority of the high-elevation ecosystems in the region that lie above 8,000 feet, emphasizing the importance of the National Forest in the greater ecological context of the area. The major forest and woodland vegetation types in the Section and the BNF (Fig. M5A-2 and Table M5A-1) are: spruce/fir forests, lodgepole pine forests, aspen forests, Douglas-fir forests, ponderosa pine forests, limber pine woodlands, and juniper woodlands (see Module 3A for detailed discussion of these cover types). This Module begins with a description of the forest types found within the Southern Rocky Mountain Province (M331) and the Big Horn Mountains Section (M331B) to provide a broad ecological context for and comparison with forest types found in the Bighorn National Forest (BNF).

Existing vegetation is described using primarily common vegetation unit (CVU) maps, GAP land cover types for Wyoming (Merrill *et al.* 1996) and Montana (Fisher *et al.* 1998), and a series of studies found in the ecological literature (especially Despain 1973).

Patterns of Distribution

Comparisons at the Province, Section, and Forest levels are made for seven vegetation types that occur in the Southern Rocky Mountain Province (M331) in Colorado and Wyoming. Lodgepole pine (24%) and Spruce/fir (23%) dominate the Southern Rocky Mountain Province (Table M5A-1). Ponderosa Pine (15%), Aspen/cottonwood (14%), and Juniper (15%) are close seconds. And Douglas fir (7%) and Limber Pine (1%) are the vegetation types with the least acreage in Province M331.

There is a slight increase in Lodgepole Pine (27%) in the Big Horn Mountains Section (M331B) as compared to the Province; and significant increases in Douglas fir, Juniper, and Limber Pine. The proportion of Spruce/fir, Ponderosa pine, and Aspen/cottonwood decreased in Section M331B as compared to Province M331. The northern half of Section M331B contains the largest area of forest, which lies between 4,900 and 10,000 feet (1,500 and 3,000 m) elevation. Much of the forest vegetation type distribution is due to elevational zonation (Despain 1973). A brief description of the distribution and area of each major forest type in the Section follows, arranged from high-elevation to low-elevation forest types. These summaries are based on GAP data, which differ in resolution and accuracy from CVU data. However, GAP data are the only vegetation cover data readily available Section-wide.

Spruce/Fir forests occur on north-facing slopes at the highest elevations (7,500 to 10,000 feet/2,300 to 3,000 m), mainly in the northern half of the Section (Fig. M5A-2). More than 92% of the approximately 256,724 acres (103,937 ha) of spruce/fir forests in the Section are located in the BNF (Table M5A-2).

Lodgepole pine forests comprise the largest forests in the Section, occupying 422,758 acres (171,157 ha) or 27% of the forested area. They occur mainly between 7,000 and 9,500 feet (2,100 and 2,900 m) in the northern half of the Section (Fig. M5A-2), just below the spruce/fir forests but just higher than Douglas-fir forests. Isolated pockets of lodgepole pine also occur further south in the Section. Nearly 46% of the forested area of the BNF is lodgepole pine, and the Forest includes 85% of all the lodgepole pine forests in the Section (Table M5A-2).

Aspen forests are described by Despain (1973) as being unimportant as a community type in the Bighorns, and occur mainly as small scattered patches in the northern end of the Section, often along the fringe of lodgepole pine forests (Fig. M5A-2). Aspen forests comprise 1% of the forested area in the Section; 60% of the Section's 20,935 (8,476 ha) of aspen is found in the Forest (Table M5A-2).

Douglas-fir forests occur mainly on the flanks of the Bighorns between 6,000 and 9,000 feet (1,800 and 2,700 m), particularly in the northern two-thirds of the Section (Fig. M5A-2). Despain (1973) notes that Douglas-fir forests on the eastern flank of the Bighorns form a band between lodgepole pine and ponderosa pine forests; on the western flank, Douglas-fir is the lowest forest type. Approximately 54% of the Douglas-fir forests in the Section are found in the BNF (Table M5A-2).

Ponderosa pine forests are found mainly on the eastern slope of the Bighorns at the lowest elevations of 5,000 to 6,000 feet (1,500 to 1,800 m), grading directly into grasslands outside the eastern edge of the Section. A small island of ponderosa pine forest grades into juniper woodlands in the west-central portion of the Section as well (Fig. M5A-2). The majority of the ponderosa pine forests lie just outside of the National Forest boundary; only 27% of the 137,588 acres (55,704 ha) of ponderosa pine forests are found within the BNF (Table M5A-2).

Limber pine woodlands are found interspersed with juniper woodlands mainly in three portions of the southern part of the Section (Fig. M5A-2). Despain (1973) hypothesized that limber pine may perform a similar ecological function as pinyon pine in these areas. The GAP data indicate no limber pine on the BNF, but CVU data indicate that limber pine occupies about 2% of the forested area in the BNF.

Juniper woodlands occur between 5,000 and 7,000 feet (1,500 and 2,100 m) along the western edge of the Section (Despain 1973), though not continuously; none are found on the eastern edge. Juniper woodlands are extensive and common along the southern third of the Section (Fig. M5A-2). Although juniper occupies 21% of the Section's forested area, juniper woodlands occupy less than 1% of the forested area of the BNF (Table M5A-2)

Although much of the forested area is located in the northern end of the Big Horn Mountains (Fig. M5A-2), the amount of each type encompassed within the BNF is not necessarily representative of the entire Section (Table M5A-2). For example, lodgepole pine and juniper are the two most extensive forest cover types across the Section and occupy 48% of the forested area. In contrast, 76% of the forested area of the BNF features lodgepole pine and spruce/fir cover types. Similarly, juniper and limber pine are relatively minor components of the BNF but are much more common across the Section, comprising much of the southern, east-west trending portion of the Section. The proportions of Douglas-fir, ponderosa pine, and aspen forests are similar in the Section and the BNF.

Table M5A-2. Comparison of forest types in the Big Horn Mountains Section (M331B) and Bighorn National Forest (*source: GAP combined with CVU data for the Section and only CVU data for the Forest)*.

GAP Forest Type	Section M331B			Bighorn National Forest		
	Acres	Hectares		Acres	Hectares	
Lodgepole	422,758	171,157	27%	359,354	145,426	46%
Spruce/Fir	256,724	103,937	17%	236,330	95,640	30%
Douglas-Fir	208,110	84,255	14%	113,198	45,810	14%
Ponderosa	137,588	55,704	9%	37,324	15,105	5%
Aspen/Cttnwd	20,935	8,476	1%	12,746	5,158	2%
Juniper	328,882	133,151	21%	6,308	2,553	<1%
Limber Pine	124,474	50,394	8%	16,235	6,570	2%
Other Forest	40,454	16,378	3%	N/A	N/A	N/A
TOTALS	1,539,924	623,451	100%	781,496	316,262	100%

GAP Forest Type	Province M331		
	Acres	Hectares	
Lodgepole Pine	6,139,783	2484692	24%
Spruce/Fir	5,708,468	2310144	23%
Douglas-Fir	1,870,366	756913	7%
Ponderosa Pine	3,685,422	1491443	15%
Aspen/Cottonwood	3,627,984	1468199	14%
Juniper	3,793,136	1535034	15%
Limber Pine	257,795	104326	1%
TOTALS	25,082,954	10150750	100%

Forest and Woodland Distribution on the Ecological Template

Currently the following is just a general discussion of habitat structural stage distribution. To achieve the objective of describing the pattern of forest distribution on the ecological template, revise this section to display 1) how cover types are distributed among subsections and LTAs and 2) how HSSs are similarly distribution. The data for this have been summarized and just need to be incorporated into the narrative. It might be important or useful to retain some of the existing general, forest wide discussion.

Current Habitat Structural Stage Distribution

In general, much of the landscape pattern on the Bighorn National Forest appears to be closely related to the variation in tree sizes and associated tree ages reflected by habitat structural stages (Fig. M5A-5). To some degree, habitat structural stages are stratified by location across the National Forest (see Module 3A for brief descriptions of habitat structural stages). Although some of the grass (Stages 1M and 1T) and shrub/seedling (Stages 2S and 2T) classes correspond to those areas recently clearcut or burned, several areas around the fringe of the National Forest are natural grasslands or are pine woodlands dominated by juniper or shrubs. For forests, a great deal of spatial heterogeneity in habitat structural Stages 3 and 4 exists across the

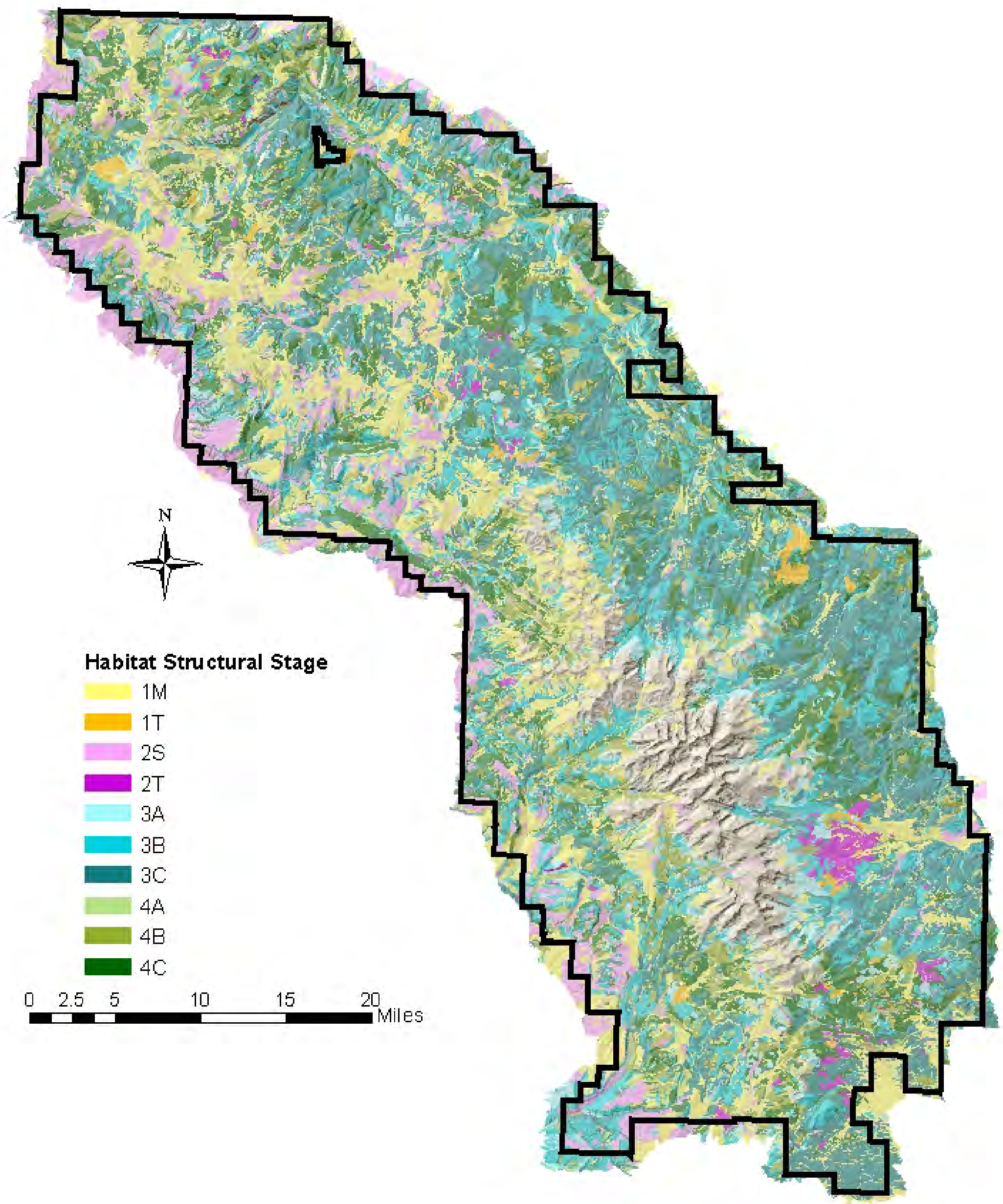


Figure M5A-5. Geographical distributions of habitat structural stages across the Bighorn National Forest.

landscape; while in some cases this variability in habitat structural stages is related to site factors (i.e., Stage 3B appears to be common in drainages and valley bottoms), much of it is likely due to past and recent disturbances.

For all forest types, 63% of the forested area is represented by Stages 3 and 4, and Stage 3B (180,636 acres/73,101 ha or 15%) and 3C (258,417 acres/104,578 ha, 21%) are the most common habitat structural stages on the Bighorn landscape (Fig. M5A-6). Stage 4 represents only 22% of the forested areas; Stage 4C areas, referred to here as "older" forest, represent 12% of the forested area alone (see *Distribution of older forests* section below). Interestingly, grassy areas (classified as Stage 1) represent 19% or 235,278 acres (95,214 ha) of the forested areas; because recent timber harvest and/ wildfire have not been this extensive, much of this area must reflect the grassy openings within and among forested areas.

Many forest types, including spruce-fir, lodgepole pine, Douglas-fir, and ponderosa pine are dominated (>70%) by habitat structural stages 3 and 4 (Fig. M5A-7). While the geographic distribution of habitat structural stages is described in detail in the Forest and Woodland Vegetation Types Module, a brief description of that variation is warranted here.

Much of the spruce-fir and lodgepole pine forests classified as Stage 4 appear to occur at the lower elevations of the subalpine zone, at least in the southern portion of the National Forest; Stage 4 lodgepole pine typically occurs as isolated pockets within larger matrices of Stage 3 vegetation. Douglas-fir forests classified as Stage 3 are often juxtaposed with those classified as Stage 4, but often show very clear boundaries between the two classes, suggesting that habitat structural stage for Douglas-fir may be heavily influenced by slope and aspect. In ponderosa pine forests, Stage 3 forests are more common at lower elevations than Stage 4 forests, likely as a result of increased historical harvesting pressure at lower elevations. Limber pine and aspen forests cover less area (60-70%) in Stages 3 and 4, and Stage 4 forests typically occur in small, contiguous patches in these forest types. For all forest types, Stage 3B and 3C lodgepole pine are most common on the Bighorn National Forest (Fig. M5A-7).

It remains difficult to discern the contributing factors to the current geographical distribution of habitat structural stages on the landscape. Several factors may have contributed to current landscape structure, and likely differ among forest types. For example, although high-elevation, subalpine forests (spruce-fir and lodgepole pine) have been somewhat affected by 20^{th} century timber clearcutting activities, they likely have also been affected by large, infrequent wildfires, especially during the 19th century. These fires have created much of the differences in age structure and habitat structural stages across the landscape. In contrast, the landscape structures of lower- and middle-elevation forests (particularly Douglas-fir and ponderosa pine) have likely been most affected by historical timber harvesting (Despain 1973) and more recently by fire suppression (Meyer and Knight 2003).

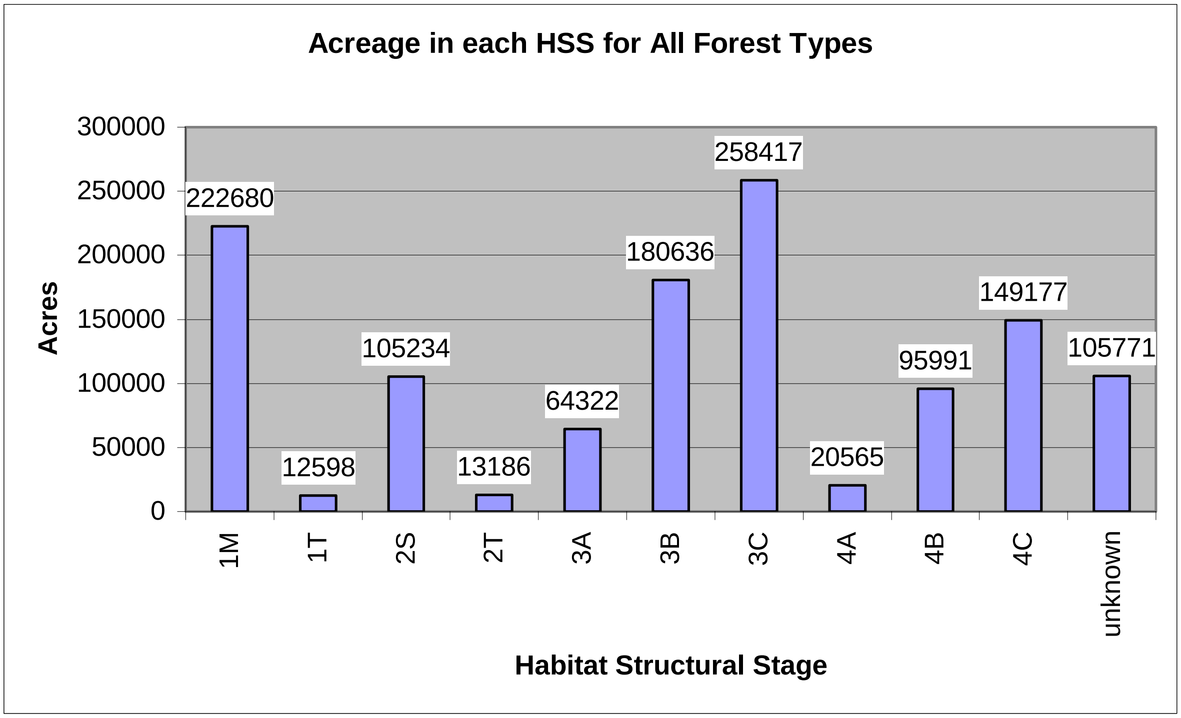


Figure M5A-6. Area found in each habitat structural stage for all forest types on the Bighorn National Forest.

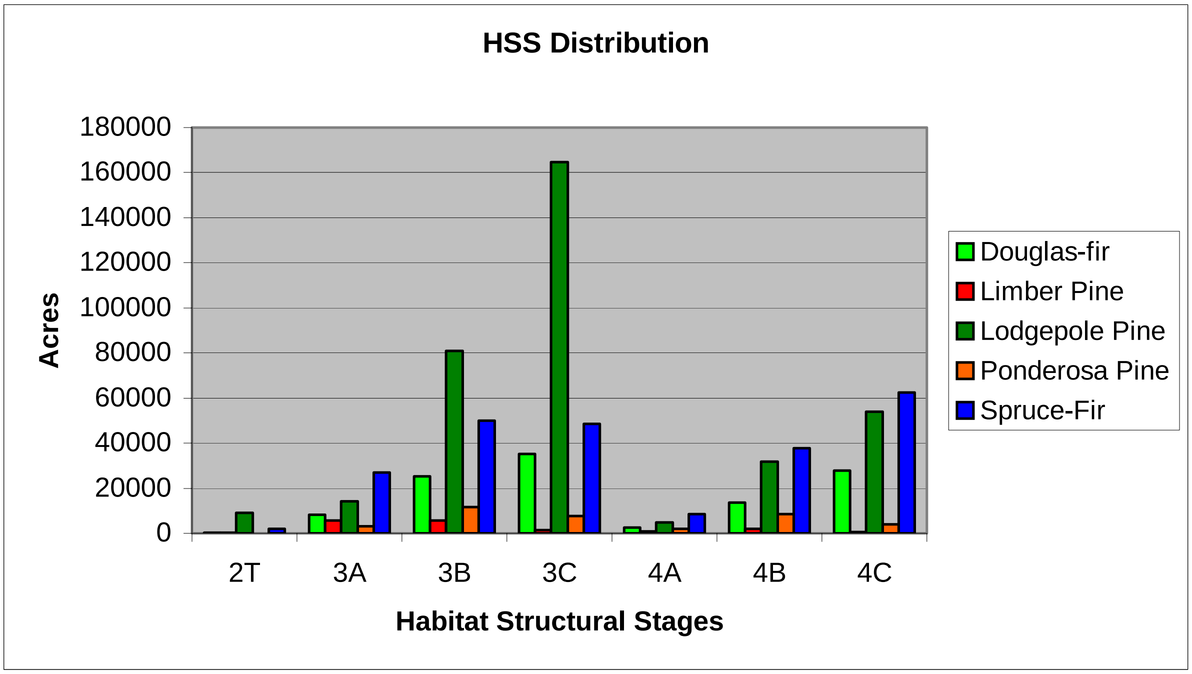


Figure M5A-7. Area found in each habitat structural stage by major forest type on the Bighorn National Forest.

Land Use Influences on Forest and Woodland Pattern

Land Ownership

In the same manner that understanding the ecological context of the National Forest is critical to comprehending the natural processes that influence landscape pattern, summarizing land ownership is critical to understanding anthropogenic influences. For the Big Horn Mountains Section (M331) as a whole, the Forest Service manages the majority of the landscape (1,098,579 acres or 39% of the Section), followed by private landowners (24%) and the Bureau of Land Management (17%) (see Land Ownership Pattern in Chapter 2 for more detail).

In terms of forest types within the Section, the Forest Service manages approximately one-half of the 1.5 million acres of forested area (based on GAP data) within the Big Horn Mountains. Thus, the Bighorn National Forest exerts overwhelming influence on the forests of the entire ecological region. In particular, the Bighorn National Forest encompasses much of the high- and middle-elevation habitat within the Section, including 77% of the spruce-fir forests, 87% of the lodgepole pine forests, and 47% of the Douglas-fir forests (Fig. M5A-3, Table M5A-3). In contrast, private landowners, the State of Wyoming, and the BLM own and manage the majority of the lower-elevation forests in the Section. BLM manages a large percentage of ponderosa pine forest (40%) and juniper woodlands (30%) in the Section. The State of Wyoming manages 17% of ponderosa pine forests and 18% of aspen forest. Private landowners own a large proportion of juniper woodlands (32%), limber pine woodlands (42%), and aspen forests (50%). The ownership of low-elevation forests is especially significant to their ecological sustainability, given that most forests in this zone have relatively short fire return intervals such that their disturbance regimes may be drastically changed by fire suppression.

Land Use Allocations

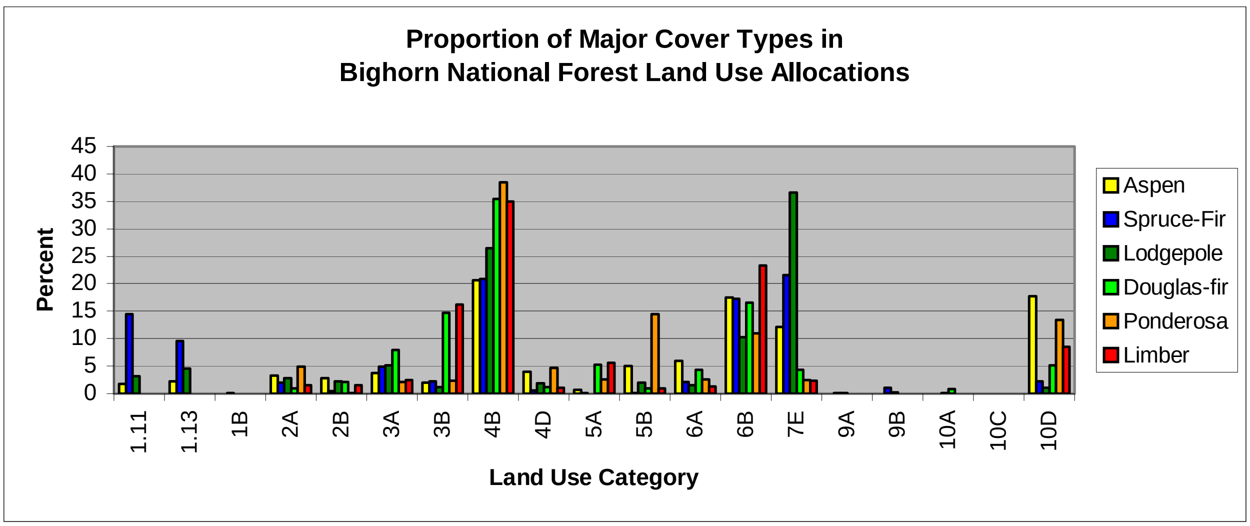
The following discussion of land use allocations is based on the existing Forest Plan. Evaluating allocations is a key feature of analzing pattern and should be relevant to revisions of allocations. The current plan represents the most current allocation information available for assessment purposes. It should be noted that allocations are very generalized assignments to land uses and often the designated land use does not occur on every acre with the allocation

The overwhelming land use allocations on the National Forest are wildlife habitat, livestock grazing, and wood fiber production (Fig. M5A-8). Wildlife habitat represents a significant proportion of each of the dominant forest cover types on the National Forest, reflecting $\geq$ 35% of low-elevation forests including Douglas-fir, ponderosa pine, and limber pine, approximately 26% of lodgepole pine, and nearly 20% of spruce-fir and aspen forests. Wood fiber production is dominated by high-elevation forests including lodgepole pine, nearly 37% of which is managed for this land use, and by spruce-fir (23%). Surprisingly, at least 10% of all forest types are managed for livestock grazing; 24% of limber pine forests are managed for livestock grazing, as are 15-20% of aspen, spruce-fir, and Douglas-fir forests (Fig. M5A-8).

The dominant forest cover types on the National Forest are disproportionately affected by broad land uses (Table M5A-4), and the intensity of the disturbance created by each land use may have implications for its effect on landscape structure. For example, a larger proportion of the two most dominant forest types on the National Forest (spruce-fir and lodgepole pine) are potentially affected by vegetation management than by any other land use. Such a trend is important because these land uses, particularly timber harvesting, have the potential to affect landscape structure. A large proportion of low-elevation forests such as Douglas-fir, ponderosa pine, and limber pine, are managed for wildlife habitat. Very little area is permanently reserved from vegetation mangement in these forest types (Table M5A-4). A higher proportion of lower-elevation forests (particularly Douglas-fir and limber pine) is managed for recreational purposes, although significant proportions of all forest types are managed for recreation.

Table M5A-3. Percentage of forest cover types in the Big Horn Mountains Section by ownership based on GAP data.

Landowner	Spruce/Fir	Lodgepole pine	Douglas-fir	Ponderosa pine	Juniper	Limber pine	Aspen
U.S. Forest Service	76.6	86.8	46.5	17.3	1.1	0.0	9.1
Bureau of Land Mgmt.	1.6	3.2	13.8	40.0	29.5	15.1	0.8
Wyoming State	0.0	1.3	3.8	16.9	8.6	5.2	18.0
Indian Reservation	21.4	0.7	16.4	1.8	27.6	38.0	22.0
Private	0.1	7.4	17.7	23.9	32.4	41.8	50.0
Other	0.3	0.5	1.8	0.1	1.0	0.1	0.1



1.11 Wilderness – Pristine management
1.13 Wilderness – Semi-primitive management
1B Ski areas
2A Semi-primitive motorized recreation
2B Rural and roaded natural recreation
3A Semi-primitive non-motorized recreation
3B Primitive recreation
4B Wildlife habitat
4D Aspen management
5A Wildlife winter range – non-forested
5B Wildlife winter range – forested
6A Livestock forage improvement
6B Livestock grazing
7E Wood fiber production
9A Riparian area management
9B Water yield enhancement
10A Research natural areas
10B Special interest areas
10D

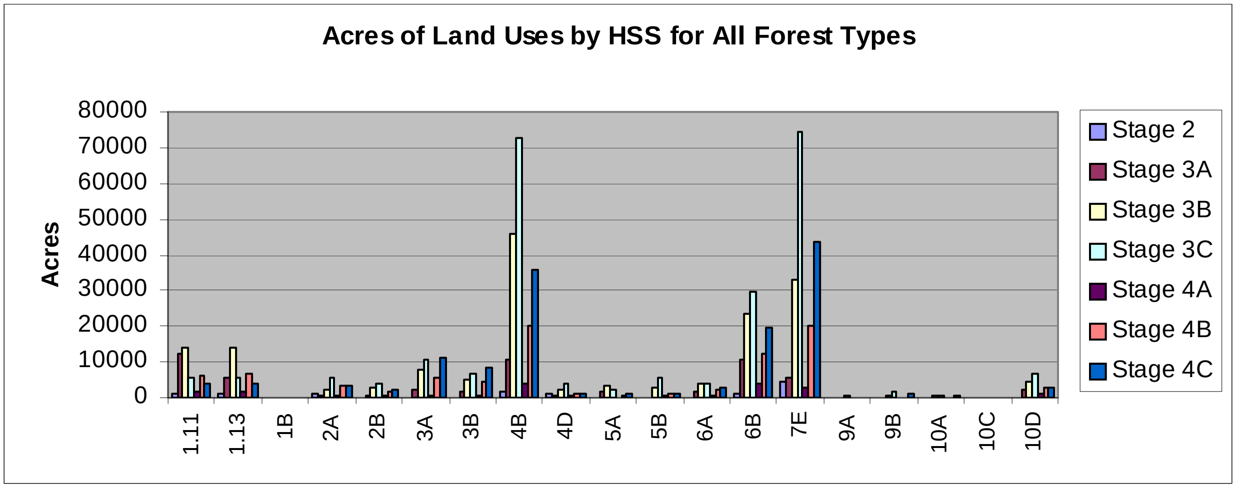
Figure M5A-8. Proportion of dominant forest types under land uses on the Bighorn National Forest.

Table M5A-4. Proportion of each dominant forest type found in selected broad land uses on the Bighorn National Forest.

	Aspen	Spruce-fir	Lodgepole pine	Douglas-fir	Ponderosa pine	Limber pine
Permanent protection from timber harvest	4%	25	8	1	0	0
Recreation	12	10	11	26	9	21
Wildlife/aspen	31	22	30	42	60	43
Livestock/timber	36	41	49	25	16	6

As described above, land use allocations for wildlife habitat, livestock grazing, and wood fiber production are most common on the National Forest; land managed for wildlife habitat occupies 26% of the forested area of the Forest (190,880 acres/77,247 ha), wood fiber production occupies 25% (183,479 acres/74,251 ha), and livestock grazing occupies 14% (100,569 acres/40,699 ha). For wildlife habitat, 38% of the area is in Stage 3C of the habitat structural stages, 24% is in Stage 3B, and 19% is in Stage 4C, suggesting that mature forests with larger trees and closed canopies provide quality wildlife habitat (Fig. M5A-9). It also suggests that large amounts of forests with these characteristics will not likely be instrumental in changing landscape structure, given that management of wildlife habitat often requires that forest structure be left alone.

For wood fiber production, 41% is classified as Stage 3C, and 24% is classified as Stage 4C, reflecting the use of larger trees in timber production. In contrast to wildlife habitat, this acreage has the potential to create large changes in landscape pattern, as timber harvesting typically changes vegetation structure across the landscape (Fig. M5A-9). For livestock grazing, land use allocation is much more evenly spread across the habitat structural stages, although Stages 3C (23%) and 4A (29%) appear to be the most affected (Fig. M5A-9). The distribution of livestock grazing across structural stages is more likely related to the geographical distribution of structural stages than any particular characteristic of the structure itself.



1.11	Wilderness – Pristine management	5A	Wildlife winter range – non-forested
1.13	Wilderness – Semi-primitive management	5B	Wildlife winter range – forested
1B	Ski areas	6A	Livestock forage improvement
2A	Semi-primitive motorized recreation	6B	Livestock grazing
2B	Rural and roaded natural recreation	7E	Wood fiber production
3A	Semi-primitive non-motorized recreation	9A	Riparian area management
3B	Primitive recreation	9B	Water yield enhancement
4B	Wildlife habitat	10A	Research natural areas
4D	Aspen management	10B	Special interest areas
		10D	

Figure M5A-9. Proportion of habitat structural stages under land uses on the Bighorn National Forest.

<u>Roads</u>

Insert a summary of roads influences on pattern.

<u>Vegetation Management</u>

Insert a summary of vegetation management influences on pattern.

<u>Departures from HRV</u>

Given that subalpine forests dominate the Bighorn National Forest, a comparison of their historical range of variability with current subalpine landscape structure is appropriate. Such a comparison must be done in the context of the fire regime of subalpine forests of the Big Horn Mountains. Large, infrequent fires that have likely shaped landscape structure over millennia characterize these subalpine forests. Between these large fires, relatively small fires have characterized the Forest during the latter half of the twentieth century (Meyer and Knight 2003). Notably, fire suppression may only be effective during the interval between large fires; large fires probably cannot be prevented because they are controlled overwhelmingly by broad-scale weather phenomena (Bessie and Johnson 1995; Weir *et al*. 1995; Agee 1997).

A comparison of current and hypothesized historical subalpine landscape structure is facilitated by the hypothesized range of variability in landscape structure proposed by Romme (Appendix F, summarized in Table M5A-5), although these comparisons should be made only in a very general sense (see Appendix F). The proportions of successional stages covering the subalpine landscape of the Big Horn Mountains prior to 1900 exhibit very high variance, which is common to high-elevation ecosystems in the Rocky Mountains. In comparison, much of the current landscape appears to fit within the landscape under "ordinary" climate conditions (Table M5a-5), with a few important exceptions. The percent of the current landscape in Stages 3B, and 3C fit within the historical range of variability; however, the current landscape appears to contain lower proportions of grasslands (<1 %) than were present historically (5-15%). Such a result is difficult to explain, since fire suppression that would promote invasion of grasslands by forest is likely unimportant in the subalpine zone. More notably, the current landscape contains smaller areas of forests containing older, larger trees (Stages 4B and 4C), which may be related to the propensity for timber harvesting activities to occur within forests having these characteristics (Table M5a-5).

Table M5A-5. Estimated range of natural variability in landscape structure on the Bighorn National Forest, Wyoming, prior to 1900 (modified from Appendix F).

Habitat Structural Stage	Percent of the landscape: current	Percent of the landscape: ordinary climatic conditions*	Percent of the landscape: several decades after extreme fire events **	Percent of the landscape: near the end of long fire-free periods ***
Stage 1: Grass/Forb	0%	5 - 15 %	50 % maximum	3 % minimum
Stage 2: Shrub/Seedling	3%	5 - 15 %	50 % maximum	3 % minimum
Stage 3A: Sapling/Pole (<40% crown cover)	4%	5 – 45 %	50 % maximum	3 % minimum
Stage 3B: Sapling/Pole (40-70% crown cover)	23%	15 - 45 %	50 % maximum	5 % minimum
Stage 3C: Sapling/Pole (>70% crown cover)	46%	15 - 45 %	50 % maximum	5 % minimum
Stage 4A: Trees >9" DBH (<40% crown cover)	1%	N/A ****	N/A ****	N/A ****
Stage 4B: Trees >9" DBH (40-70% crown cover)	9%	15 - 50 %	15 % minimum	50 % maximum
Stage 4C: Trees >9" DBH (>40% crown cover)	15%	15 - 50 %	15 % minimum	50 % maximum

* "Ordinary" climatic conditions are those that prevail most of the time.
** "Extreme" fire events are exemplified by the 1988 Yellowstone fires or by the extensive fires that occurred in YNP in the early 1700s and 1860s.
*** Very long fire-free periods occur naturally high-elevation Rocky Mountain forest systems, e.g., from the late 1700s – mid 1800s in YNP, and from the late 1700s – early 1800s in Colorado. "Fire-free" in this context refers only to the absence of *large* fires.

Although several caveats regarding the hypothesized historical proportions of successional stages on the Big Horns make these comparisons quite tenuous, such a comparison does provide insight into the potential effects of future management on the Bighorns landscape, especially considering the potential for very large, uncontrollable wildfires in the future and global climate change.

Distribution of Older Forests

Given that the current area of older subalpine forests may be less or at the minimum of the natural range of variability (Table M5A-5), analysis of the current distribution of older forests on the National Forest may be important in understanding how future management may affect landscape structure. The BNF inventory contains no forest type with Habitat Structural Stage 5 classification, which is "old-growth" because there is no old-growth inventory available for the Bighorn National Forest. So HSS 4C is used to approximate old forests. There are limitations to this approach so these should be considered preliminary findings until an old-growth inventory is available. The Bighorn National Forest currently encompasses 149,137 acres (60,354 ha) of forests classified as Habitat Structural Stage 4C (hereafter referred to as "older" forest). Of the dominant forest types, spruce-fir (62,322 acres/25,221 ha or 42% of all older forests) and lodgepole pine (54,008 acres/21,856 ha, 36%) contribute the most area to the total acreage of older forest on the Bighorn National Forest (Fig. M5A-10). Douglas-fir (27,881 acres/11,283 ha or 19%) and ponderosa pine (3,976 acres/1,609 ha, 3%) also contribute significantly to the amount of older forest on the National Forest; aspen (514 acres/208 ha) and limber pine (435 acres/176 ha) each contribute less than 1% of the total older forest.

Notably, the highest proportion of a cover type in an older condition is found in both high-elevation forests such as spruce-fir (26%) and lodgepole pine (15%) as well as middle- to low-elevation forests such as Douglas-fir (25%) and ponderosa pine (10%) (Fig. M5A-10). Much of the older forest in the Big Horn Mountains is located in high-elevation forests with fire regimes featuring large, uncontrollable fires that may easily destroy large tracts of older forests in the near future, and where the majority of timber harvesting occurs on the Forest. However, a similar amount of older forest is located in low-elevation forests historically characterized by frequent fires, where fire suppression has been most effective and where fire regimes may be furthest from their historical range of variation.

In terms of geographic distribution of older forests, forests classified as Stage 4C are widely distributed across the Bighorn National Forest (Fig. M5A-11). Older spruce/fir forests are most heavily concentrated towards the northern half of the Forest, whereas lodgepole pine older forest is more common towards the southern end. Douglas-fir older forest is located around nearly the entire fringe of the Forest, although it is least common at the southeastern boundary. Older ponderosa pine forest is found exclusively on the eastern boundary of the Forest (Fig. M5A-11).

Older forests are similar among forest types in their allocations to different land uses (Table M5A-6), but some important differences may affect the sustainability and/or functioning of older forests. For example, most forest types contain substantial proportions of older forest in wildlife habitat, livestock grazing, and wood fiber production. Wood production, in particular, will certainly affect the sustainability of older forests, and livestock grazing may affect the ecosystem functioning of these forests, at least at lower elevations. Low-elevation forests (ponderosa pine and limber pine) also contribute a large portion of their older stands to wildlife winter range, which is likely a relatively low-impact land use for older forests. Other older stands in forest types at middle to lower elevations, including aspen and Douglas-fir, are characterized by low-impact recreation activities, although 12% of older aspen forests include motorized recreation (Table M5A-6).

It may be worthwhile to maintain older forest proportions near the maximum levels in Table M5A-5, rather at or above the minimum levels, for several reasons: 1) current older forests appear to be at or below minimum levels, 2) young forests on the landscape are always attainable through harvesting or other disturbances, but older forests must develop slowly over very long time periods without major disturbance, and 3) fire frequency and fire extent are likely to increase over the next several decades, as the climate warms overall and extreme weather conditions (including droughts) become more frequent (Overpeck *et al.* 1990; Balling *et al.* 1992; Flannigan and Van Wagner 1991; Gardner *et al.* 1996). Since controlling wildfires in the 21st century is not likely to be as effective as in the 20th century, much of the current older forest may be lost to uncontrollable fires. Younger forests on the current landscape will increase the significance of future fire losses in this critical forest type (see Appendix F).

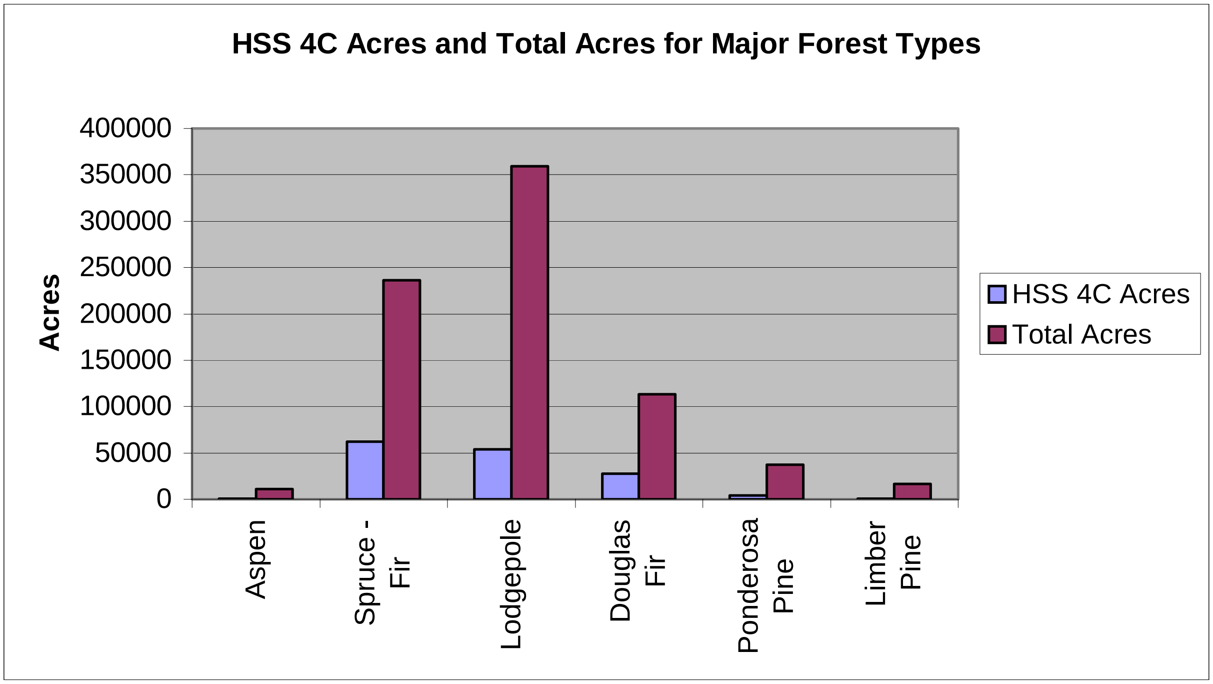


Figure M5A-10. Acreage of older forests (Habitat Structural Stage 4C) and total area for each forest cover type on the Bighorn National Forest.

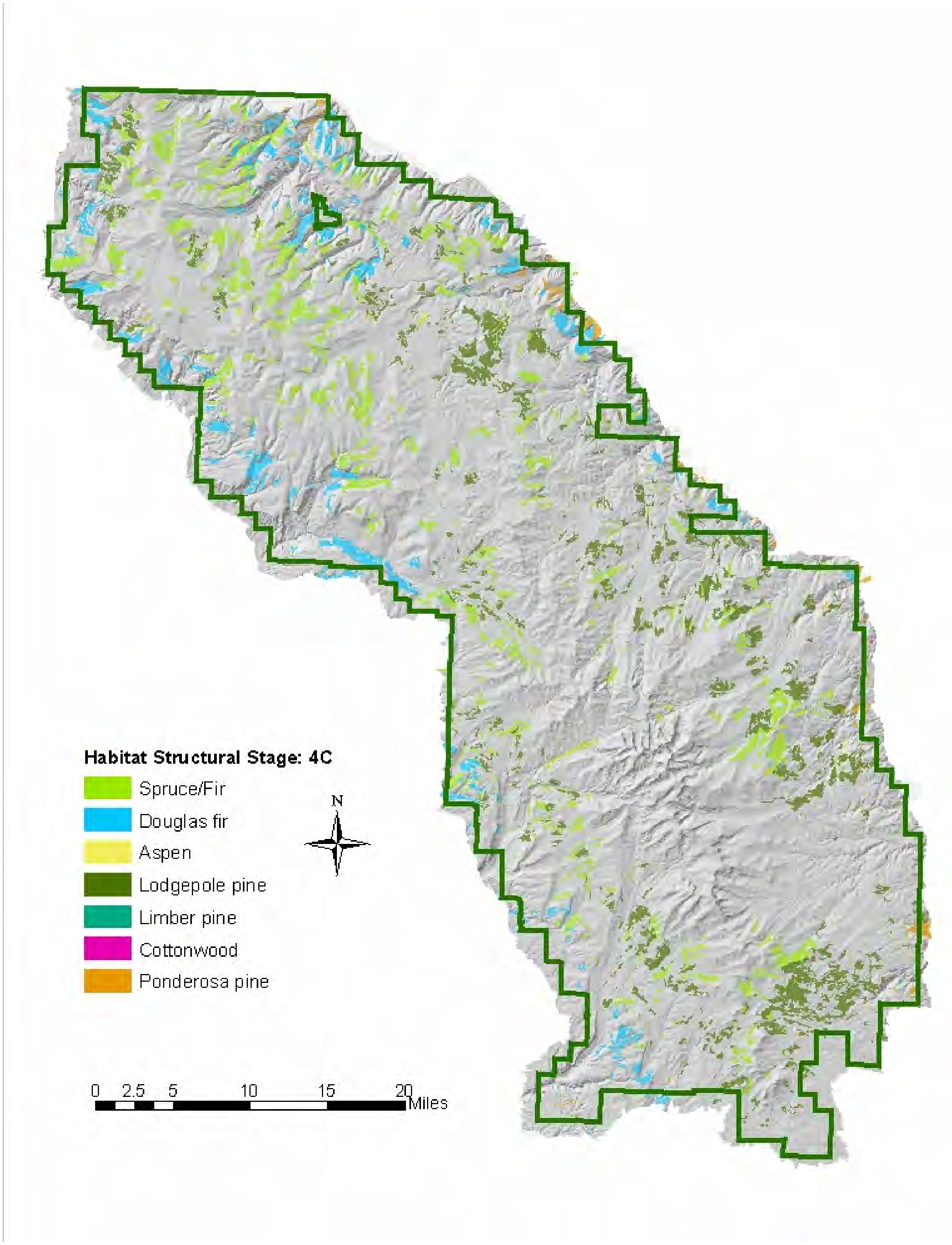


Figure M5A-11. Geographical distribution of older forests on the Bighorn National Forest.

Table M5A-6. Proportions of total area in older forest for each dominant forest type among land use allocations on the Bighorn National Forest.

Land use*	Aspen	Spruce-fir	Lodgepole pine	Douglas-fir	Ponderosa pine	Limber pine
1.11	0	4.6	2.0	0	0	0
1.13	1	4.9	1.8	<1	0	0
1B	0	<1	<1	0	0	0
2A	11.5	2.6	2.9	1	7.9	0
2B	0	<1	3.1	1.1	0	0
3A	4.3	7.1	6.9	12.8	0	0
3B	0	4.1	2.2	17.7	5.8	0
4B	20.4	23.9	19.7	38.7	27.1	18.3
4D	2.7	<1	1	1	4.2	0
5A	0	<1	<1	2.9	<1	17.2
5B	0	<1	1	1.3	19.7	0
6A	4.7	2.3	1.1	4	1	1
6B	17.8	18.0	11.0	9.4	1.8	27.1
7E	37.2	28.1	45.8	6.0	10.3	9.2
9A	0	<1	<1	0	0	0
9B	0	1.2	<1	0	0	0
10A	0	0	<1	1.2	0	0
10C	0	<1	0	0	0	0
10D	0	1.8	1	3.2	0	0

*Land use codes:

1.11 Wilderness – Pristine management
1.13 Wilderness – Semi-primitive management
1B Ski areas
2A Semi-primitive motorized recreation
2B Rural and roaded natural recreation
3A Semi-primitive non-motorized recreation
3B Primitive recreation
4B Wildlife habitat
4D Aspen management
5A Wildlife winter range – non-forested
5B Wildlife winter range – forested
6A Livestock forage improvement
6B Livestock grazing
7E Wood fiber production
9A Riparian area management
9B Water yield enhancement
10A Research Natural Areas
10B Special interest areas
10D

Areas Permanently Reserved from Timber Harvest

As much as clearcutting may fragment or perforate the landscape in influencing landscape pattern, the persistence of forest unaffected by anthropogenic disturbances (mainly timber harvest), which forms the matrix within which human-disturbed stands exist on the landscape, will also have an important affect on landscape pattern. Several areas are permanently reserved from timber harvest as part of management prescription (mainly wilderness) within the National Forest, as Research Natural Areas, or as Conservation Areas (Fig. M5A-12). The majority of areas reserved from timber harvest are found in the Cloud Peak Wilderness Area, within the Goose Creek, Piney/Rock, Clear/Crazy Woman Creek, Tensleep Creek, and Paintrock Creek FPWS.

Approximately 25% of spruce-fir forests in the National Forest are permanently reserved from timber harvest; 8 % of lodgepole pine, 4% of aspen, and 1% of Douglas-fir forests are also permanently reserved from timber harvest (Table M5A-7). Goose Creek contains the largest amount of reserved area (27,147 acres/10,986 ha), which is dominated by spruce-fir forest. Several other FPWS also have significant amounts of reserved area, each of which is dominated by high-elevation forest types that are found within the Cloud Peak Wilderness: Clear/Crazy Woman Creek (16,424 acres/6,647 ha), Piney/Rock Creek (13,099 acres/5,301 ha), Paintrock Creek (12,587 acres/5,094 ha), Shell Creek (10,711 acres/4,335 ha), and Tensleep Creek (9,226 acres/3,734 ha). Those FPWS that do not include portions of the Cloud Peak Wilderness generally have little or no reserved area: Little Bighorn, Devil's Canyon, and Tongue

River. Notably, however, Little Bighorn and Devil's Canyon (as well as Shell Creek) contain significant proportions of the limited Douglas-fir forests that fall within reserved areas, and Little Bighorn contains the only area of reserved limber pine forest (Table M5A-7). The majority of reserved aspen forests are found in Tensleep Creek.

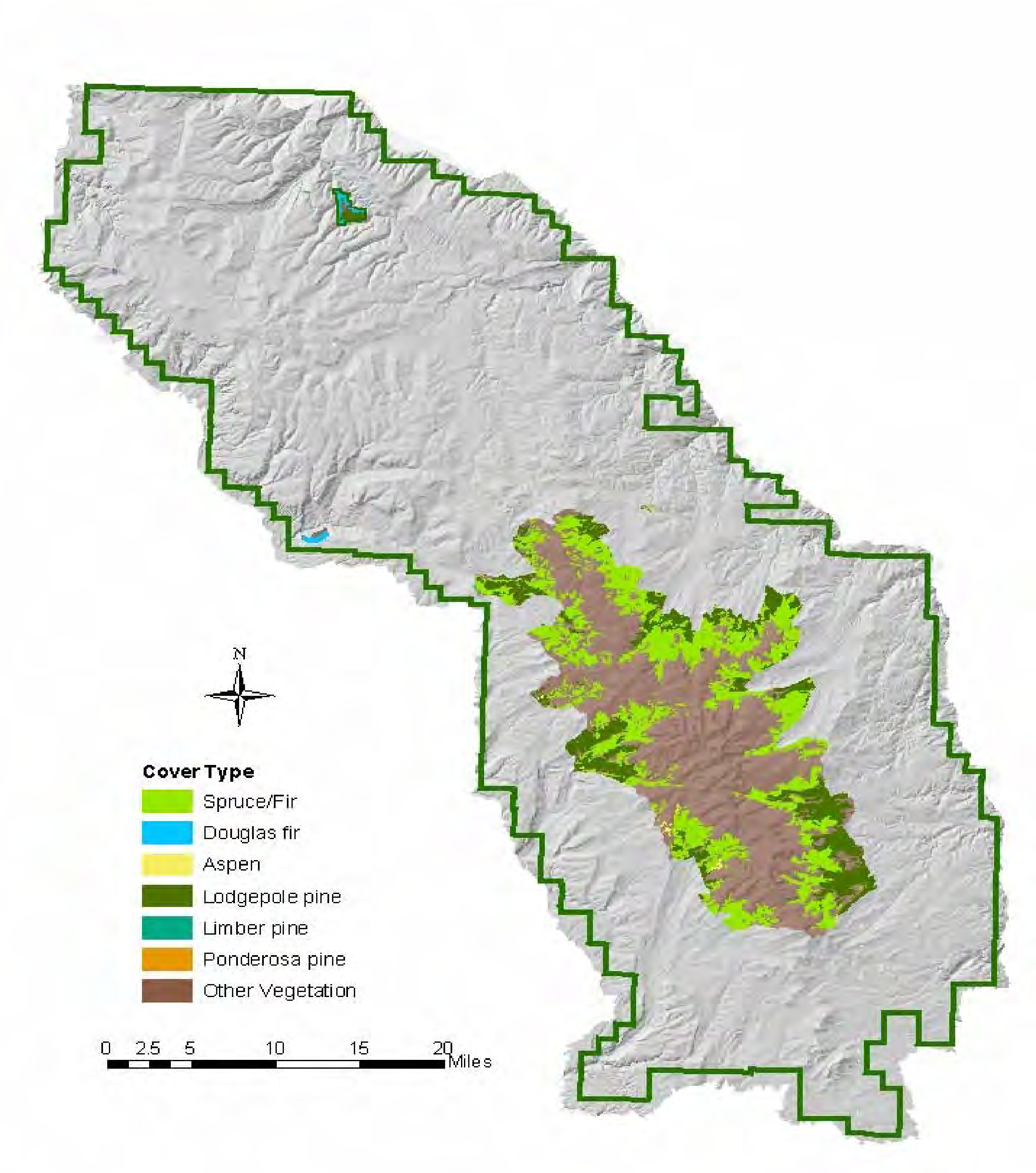


Figure M5A-12. Forest type composition of areas permanently reserved from timber harvest in the Bighorn Natural Forest.

Table M5A-7. Acreage of areas within FPWS reserved from timber harvest by forest type in the Bighorn National Forest. Proportion of area within each forest type is shown in parentheses.

FPWS	Aspen	Spruce-fir	Lodgepole pine	Douglas-fir	Limber pine
Clear/Crazy Woman Creek	7 (2)	7107 (13)	9310 (34)	0	0
Devil's Canyon	0	<1 (<1)	0	22 (3)	0
Goose Creek	0	16004 (28)	6145 (23)	0	0
Little Bighorn	0	0	453 (2)	439 (51)	6 (100)
Paintrock Creek	46 (11)	7437 (13)	5104 (19)	0	0
Piney/Rock Creek	0	10838 (19)	2261 (8)	0	0
Shell Creek	12 (3)	7611(13)	2684 (10)	404 (47)	0
Tensleep Creek	339 (84)	7625 (14)	1262 (5)	0	0
Tongue River	0	0	0	0	0

Forest Fragmentation

Fragmentation is defined here as an increase in the number of abrupt changes between forest and non-forest, or between developing and older forests, that reduces interior forest area and increases the amount of forest edge (Meyer and Knight 2003). Timber harvesting, particularly clearcutting, is a primary agent of change of landscape pattern in the Big Horn Mountains, at least at higher elevations. Natural wildfires typically produce either few very large patches as a result of large, infrequent fires, or many small patches resulting from the smaller, more frequent fires that burn between the large fires. The primary result of large fires is to produce large, continuous even-aged stands across the landscape. In contrast, clearcuts tend to produce many middle-sized patches, such that timber harvesting in this manner acts to perforate and fragment the larger patches of even-aged forests produced by historical large fires.

On the Bighorn National Forest, clearcuts affect a relatively small area of the landscape as compared to the historical large, high-intensity fires that characterize the area. Since landscape pattern is affected by past as well as recent silvicultural activities, however, timber harvesting effects are cumulative on the landscape. Such a trend not only helps to explain the effects of clearcutting on landscape pattern, but it also predicts the potential effect of future clearcutting on landscape patterns. Clearcutting is far less common on the National Forest today than it was during the 1950s into the 1970s, the potential of clearcutting to affect landscape pattern and fragmentation is minimal but still should not be ignored.

Although seemingly less important in terms of area affected, roads also appear to be an important agent of landscape pattern change on the Bighorn National Forest (Tinker *et al*. 1998). Roads fragment the landscape, particularly by increasing the amount of edge and reducing the amount of interior forest, and road-building is often associated with timber harvesting.

Tinker *et al.* (1998) measured changes that occur in landscape pattern due to roads and clearcuts in high-elevation forests (spruce-fir and lodgepole pine) that dominate the Bighorn National Forest (see Module 4E for the description of road pattern on the landscape). They noted that both roads and clearcuts contributed to increased fragmentation, with a reduction in interior forest (edge depth of 50 m) and mean patch size, and an increase in edge density, patch density, and patch diversity. They analyzed landscape pattern at the scale of watersheds, however, and did not include the Cloud Peak Wilderness in their analysis because it is reserved from timber harvesting and contains no roads. Inclusion of this relatively pristine portion of the Bighorn landscape would decrease the effects of clearcuts and roads on landscape pattern, especially if the National Forest is analyzed as a whole. In any case, however, Meyer and Knight (2003) note that the Forest is already characterized by a high amount of natural edge and low amount of interior forest due to the numerous meadows present at higher elevations. Thus the landscape may be especially sensitive to additional fragmentation caused by timber harvesting and road-building. In terms of factors affecting landscape pattern, it is important to distinguish between the dominant high-elevation forests (spruce-fir, lodgepole pine) and middle- to low-elevation forests (Douglas-fir, ponderosa pine, limber pine) on the Bighorn National Forest. Clearcutting of Douglas-fir forests in the 1960s probably affected the landscape occupied by this forest type in a similar way as in high-elevation forest (Meyer and Knight 2003). However, because fire is more easily suppressed in these and other forests at lower elevations, many low-elevation forests are probably more homogenous and dense as a result of suppression. Thus, the trend during the last century actually has not been forest fragmentation in low-elevation forests so much as coalescence and homogenization of formerly patchy forests as a result of fire exclusion and early timber harvest practices (Romme *et al.* 2000a).

Although current descriptions of landscape condition and analysis rely on descriptive information and data and on published materials, future opportunities are forthcoming to quantitatively analyze forest pattern as part of the Rocky Mountain Landscape Simulator (RMLANDS). See Appendix G for a full description of the model and its potential application for this assessment.

Ecological Indicators and Key Findings

<u>Primary Influences on Pattern</u>

(1) Natural influences affecting forested landscape pattern in the Bighorn National Forest include climate, topography, elevation, soil, and disturbance (primarily fire, but also insects, pathogens, and wind).

(2) Anthropogenic influences affecting patterns include prehistoric activities, timber harvesting, roads and trails, fire suppression, development, and recreation.

<u>Land ownership</u>

(1) The Bighorn National Forest covers 39% of the Big Horn Mountains Section, and it therefore can contribute significantly to the ecological sustainability of the area. Secondary owners include private landowners (24%) and the Bureau of Land Management (17%), with whom collaboration is essential for forest management at a landscape scale.

(2) The majority of the high- and middle-elevation forests (spruce-fir, lodgepole pine, Douglas-fir) in the Big Horn Mountains are managed by the Forest Service, but the majority of the low-elevation forests (ponderosa pine, limber pine, and juniper) are managed by private landowners, the State of Wyoming, and the BLM.

(3) The majority of land use allocations on the Bighorn National Forest are directed toward wildlife habitat, livestock grazing, and wood fiber production.

<u>Habitat Structural Stage Distribution</u>

(1) Approximately 63% of the National Forest is represented by Habitat Structural Stages 3 (sapling/pole) and 4 (trees > 9" DBH); Stages 3B and 3C are the most common stages on the landscape. These stages dominate many but not all forest types.

(2) In the subalpine zone, the proportions of Stage 3 appear to fit within the natural range of variability for the Bighorn landscape, but the current landscape contains lower proportions of grasslands (Stage 1) and shrub/seedlings (Stage 2)

and proportions of older forests (Stages 4B and 4C) at or below the minimum of the natural range of variability.

Distribution of Older Forest

(1) The National Forest includes nearly 150,000 acres (60,703 ha) of older forest, mainly in spruce-fir and lodgepole pine forests. Spruce-fir, lodgepole pine, Douglas-fir, and ponderosa pine all have significant proportions of their respective cover types in older forest.
(2) Currently, older forests appear to be most affected by livestock grazing and wood fiber production.

Timber Harvesting Activities

(1) Timber has been harvested on the National Forest since the late 1940s; clearcutting activites peaked in the 1960s and declined thereafter.
(2) Lodgepole pine forests are affected by silviculture more than any other forest type, while spruce-fir forests include more area permanently reserved from timber harvest.

Forest Fragmentation

(1) Fragmentation of the current landscape, at least at high elevations, appears to be affected by the number of clearcuts and roads present, which acts to perforate large stands created in the aftermath of large, infrequent, historical fires.

Fire Suppression Effects

(1) Lower elevation forests also appear to be affected by clearcutting, but fire suppression is an equally important factor in those forests. Fire suppression tends to homogenize the landscape rather than fragment it.

Significant Information Gaps

(1) A more thorough literature search that investigates the implications of natural and anthropogenic influences on landscape pattern for this region. Currently, all factors are listed, but not tied together very well. How are vegetation types stratified by climate, topography, etc? How are these patterns specifically influenced by natural and anthropogenic disturbances?
(2) Time-specific analyses of human influences in the Bighorns: How did the landscape look in the 50s, 60s, 70s, etc? How has it changed, and what are the causes for these changes?
(3) Actual landscape pattern analyses specific to various questions at hand. Currently, pattern addresses the effects of clearcuts and roads. What about human developments? Trails? Fires? Other disturbances? Or perhaps analyses related to the distribution of age classes within forest types, or the distribution of forest types themselves? Much of this will be addressed with RMLANDS, but these analyses would be useful in the interim, and relatively easy to run.
(4) Solid literature background on the effects of various land uses on landscape pattern. How is livestock grazing affecting landscape pattern relative to wood fiber production, or wildlife habitat?
(5) Good data on future management planning, especially for older forests, including projections of each habitat structural stage based on future harvesting plans.
(6) Ecological responses to landscape pattern.

Inventory information on old-growth forest characteristics and distributions.

Literature Cited

Agee, J. K. 1997. Fire management for the 21st century. Pp. 191-201. *In*: Kohm, K. A., and J.F. Franklin, (eds.). Creating a forestry for the 21st century: the science of ecosystem management. Island Press, Washington, D.C. 475 p

Alexander, R.R. 1987. Ecology, silviculture and management of Engelmann spruce-subalpine fir type in the central and Southern Rocky Mountains. USDA Forest Service, Agricultural Handbook No. 659. Washington, DC.

Aplet, G., R. Laven, and F.W. Smith. 1988. Patterns of community development in Colorado Engelmann spruce-subalpine fir forests. Ecology 69:312-319.

Baker, W.L., and R.L. Knight. 2000. Roads and Forest Fragmentation in the Southern Rocky Mountains. *In*: Forest Fragmentation in the Southern Rocky Mountains. Knight, R., F. Smith, S. Buskirk, W. Romme, and W. Baker (eds.). University Press of Colorado. Boulder, CO. 474 p.

Baker, W.L., and Y. Cai. 1992. The r.le programs for multiscale analysis of landscape structure using the GRASS geographical system. Landscape Ecology 7:291-302.

Balling, R.C. Jr., G.A. Meyer, and S.G. Wells. 1992. Climate change in Yellowstone National Park: Is the drought-related risk of wildfires increasing? Climatic Change 22:35-45.

Bessie, W. C., and E. A. Johnson. 1995. The relative importance of fuels and weather on fire behavior in subalpine forests. Ecology 76:747-762.

Clagg, H.B. 1975. Fire ecology in high-elevation forests in Colorado. Colorado State University, Fort Collins, CO. Thesis.

Cole, D.N., and P.B. Landers. 1996. Threats to wilderness ecosystems: impacts and research needs. Ecological Applications 6:168-184.

Crane, M.F. 1982. Fire ecology of Rocky Mountain Region forest habitat types. Final Report. Contract from USDA Forest Service, Rocky Mountain Region with Department of Botany, U. of Montana, Missoula, MT. Purchase Order No. 43-82X9-1-884.

Daubenmire, Rexford. 1968. Plant Communities: A Textbook of Plant Synecology. Harper & Row Publishers. New York, NY. 300 pp.

Flannigan, M.D., and C.E. VanWagner. 1991. Climate change and wildfire in Canada. Canadian Journal of Forest Research 21: 66-72.

Flather, C. H., and R. MacNeal. 1993. DISPLAY spatial analysis computer program. US Forest Service, Rocky Mountain Research Station, Fort Collins, CO.

Forest Health Management Group. 1994. Forest Insect and Disease Conditions in the Rocky Mountain Region 1994. USDA Forest Service. Renewable Resources, Forest Health Management. Rocky Mountain Region, Denver, CO.

Forman, R.T.T. 1995. Land Mosaics: The Ecology of Landscapes and Regions. Cambridge University Press, Cambridge, UK.

Forman, R.T.T., and Michel Godron. 1986. Landscape Ecology. John Wiley & Sons, Inc. New York. 619p.

Furniss, R.L., and V.M. Carolin. 1977. Western Forest Insects. USDA Forest Service. Misc. Publication 1339.

Gardner, R.H., W.W. Hargrove, M.G. Turner, and W.H. Romme. 1996. Global change, disturbances and landscape dynamics. Pp. 149-172. In: Walker, B., and W. Steffen (eds.), Global Change and Terrestrial Ecosystems: The first GCTE Science Conference, 23-27 May 1994, Woods Hole, MA. Cambridge University Press, Cambridge, UK.

Gruell, G.E. 1985. Indian fires in the Interior West: a widespread influence. In: Proceedings: Symposioum and Workshop on Wilderness Fire. Edited by J.E. Lotan. USDA Forest Service, Gen. Tech. Report INT-182. Intermountain Forest and Range Experiment Station, Ogden, UT.

Hammitt, W.E., and D.N. Cole. 1987. Wildland Recreation Ecology and Management. John Wiley & Sons. New York. 341p.

Harris, L.D. 1984. The Fragmented Forest: Island Biogeographic Theory and the Preservation of

Biotic Diversity. The University of Chicago Press. Chicago, IL. 211p.

Hunter, M.L., Jr. 1991. Coping with ignorance: the coarse-filter strategy for maintaining biodiversity. *In*: Balancing on the Brink of Extinction: the Endangered Species Act and Lessons for the Future. K.A. Kolm (ed.). Island Press, Washington, D.C.

Knight, Dennis H. 1994. Mountains and Plains: The Ecology of Wyoming Landscapes. Yale University Press. New Haven, CT.

Knight, Dennis H., and William A. Reiners. 2000. Natural patterns in southern Rocky Mountain landscapes and their relevance to forest management. *In*: Forest Fragmentation in the Southern Rocky Mountains. Knight, R., F. Smith, S. Buskirk, W. Romme, and W. Baker (eds.). University Press of Colorado. Boulder, CO. 474 p.

Knight, R.L. 2000. Forest fragmentation and outdoor recreation in the Southern Rocky Mountains. *In*: Forest Fragmentation in the Southern Rocky Mountains. Edited by R. Knight, F. Smith, S. Buskirk, W. Romme, and W. Baker. University Press of Colorado. Boulder, CO. 474 p.

Knight, R.L., F.W. Smith, S.W. Buskirk, W.H. Romme, and W.L. Baker (eds). 2000. Forest Fragmentation in the Southern Rocky Mountains. University Press of Colorado. Boulder, CO. 474p.

Mast, J.N., T.T. Veblen, and Y.B. Linhart. 1998. Disturbance and climatic influences on age structure of ponderosa pine at the pine/grassland ecotone, Colorado Front Range. Journal of Biogeography 25:743-767.

McGarigal, K. and B.J. Marks. 1995. FRAGSTATS: spatial pattern analysis program for quantifying landscape structure. PNW-GTR-351, US Forest Service, Pacific Northwest Research Station, Portland, OR.

Meyer, C. B., and D. H. Knight. 2001. Historic variability of upland vegetation in the Bighorn National Forest, Wyoming. Draft report, November 30, 2001.

Overpeck, J.T., D. Rind, and R. Goldberg. 1990. Climate-induced changes in forest disturbance and vegetation. Nature 343:51-53.

Peet, R.K. 1988. Forests of the Rocky Mountains. *In*: North American Terrestrial Vegetation. Barbour, M.B., and W.D. Billings (eds.). Cambridge University Press, Cambridge, UK.

Pomerantz, G.A., D.J. Decker, G.R. Goff, and K.G. Purdy. 1988. Assessing impact of recreation on wildlife: a classification scheme. Wildlife Society Bulletin 16:58-62.

Romme, W.H. 1982. Fire and landscape diversity in Yellowstone National Park. Ecological Monographs 52:199-221.

Romme, W.H., and D.G. Despain. 1989. Historical perspective on the Yellowstone fires of 1988. BioScience 39:695-699.

Romme, W.H., and Dennis H. Knight. 1981. Fire frequency and subalpine forest succession along a topographic gradient in Wyoming. Ecology 62:319-326.

Romme, W.H., R.L. Knight, W.L. Baker, F.W. Smith, and S.W. Buskirk. 2000a. What have we learned about forest fragmentation in the Southern Rocky Mountains. *In*: Forest Fragmentation in the Southern Rocky Mountains. Knight, R., F. Smith, S. Buskirk, W. Romme, and W. Baker (eds.). University Press of Colorado. Boulder, CO. 474 p.

Romme, W.H., M.L. Floyd, D. Hanna, and J.S. Redders. 2000b. Using natural disturbance regimes as a basis for mitigating impacts of anthropogenic fragmentation. *In*: Forest Fragmentation in the Southern Rocky Mountains. Knight, R., F. Smith, S. Buskirk, W. Romme, and W. Baker (eds.). University Press of Colorado. Boulder, CO. 474 p.

Rowdabaugh, K.M. 1978. The role of fire in the ponderosa pine-mixed conifer ecosystem. Colorado State University, Fort Collins, CO. Thesis.

Smith, F.W. 2000. Forestry practices and forest fragmentation in the Southern Rocky Mountains. *In*: Forest Fragmentation in the Southern Rocky Mountains. Knight, R., F. Smith, S. Buskirk, W. Romme, and W. Baker (eds.). University Press of Colorado. Boulder, CO. 474 p.

Swanson, F.J., T.K. Kratz, N. Caine, and R.G. Woodmansee. 1988. Landform effects on ecosystem patterns and processes. Bioscience 38:92-98.

Theobald, D.M. 2000. Fragmentation by inholdings and exurban development. *In*: Forest Fragmentation in the Southern Rocky Mountains. Knight, R., F. Smith, S. Buskirk, W. Romme, and W. Baker (eds.). University Press of Colorado. Boulder, CO. 474 p.

Tinker, D.B., C.A.C. Resor, G.P. Beauvais, K.F. Kipfmueller, C.I. Fernandes, and W.L. Baker. 1998. Watershed analysis of forest fragmentation by clearcuts and roads in a Wyoming forest. Landscape Ecology 13:149-165.

Veblen, Thomas T. 2000. Disturbance patterns in Southern Rocky Mountain Forests. *In*: Forest Fragmentation in the Southern Rocky Mountains. Knight, R., F. Smith, S. Buskirk, W. Romme, and W. Baker (eds.). University Press of Colorado. Boulder, CO. 474 p.

Veblen, T.T. and D.C. Lorenz. 1991. The Colorado Front Range: a century of ecological change. University of Utah Press, Salt Lake City, UT.

Veblen, T.T., K.S. Hadley, and M.S. Reid. 1991. Disturbance and stand development of a Colorado subalpine forest. Journal of Biogeography 18:707-716.

Weir, J. M. H., K. J. Chapman, and E. A. Johnson. 1995. Wildland fire management and the fire regime in the southern Canadian Rockies. Pp. 275-280. *In*: Brown, J. K. *et al.* (tech. cords.), Proceedings: symposium on fire in wilderness and park management. USDA Forest Service General Technical Report INT-GTR-320. Intermountain Research Station, Ogden, UT.

Module 5B
Grassland and Shrubland

Objectives

Describe key features of spatial pattern on the landscape. Identify the effects of land uses and management activities on landscape pattern. Due to the limited availability of data to describe and map grassland and shrubland patterns, Livestock Preference and Rangeland Resilience Models were developed to approximate existing patterns of rangeland condition. Discuss the dynamic nature of pattern and probable ecological implications of varying patterns. To the extent possible given information limitations, discuss the ecological implications of the current condition.

Introduction

Available data for grassland/shrubland vegetation are relatively generalized (both for vegetation mapping and the accompanying descriptions), therefore this narrative will be necessarily broad in scope. Module 5B will cover the following topics: 1) current grassland/shrubland upland landscape condition; 2) cultural and biological influences on these landscapes, with an emphasis on livestock grazing; 3) Livestock Preference and Rangeland Resilience Modeling approach; and 4) proportion of major vegetation types permanently reserved from livestock grazing. The Module concludes with a discussion of information gaps and analysis limitations for grassland/shrubland landscape condition on the Bighorn National Forest (BNF).

Current Grassland/shrubland Upland Landscape Condition

This section describes: a) importance of the Bighorn National Forest in the larger eco-regional landscape, and b) land ownership and land use allocation summary for the Big Horn Mountains Section (M331B).

Importance of the Bighorn National Forest in the Larger Eco-Regional Landscape

The existing dominant grassland and shrubland plant dominance types on the Forest were previously discussed in Module 3B. Although the dominance types discussed in Module 3B are common within the Province, at finer geographic scales their importance undoubtedly increases due to their spatial isolation in the Big Horn Mountains. Welp *et al.* (2000) listed the following vegetation as being rare (based on Natural Heritage Program methodologies):

- *Pseudoroegneria spicata* Herbaceous Vegetation – rank G2?
- *Festuca idahoensis – Festuca kingii* Herbaceous Vegetation Plant Association – rank G2?
- *Festuca idahoensis* Herbaceous Vegetation Plant Association – rank G2?

Rareness needs to be qualified since it may be related to a lack of documented occurrences. Unquestionably, the BNF would benefit from a description of grassland/shrubland vegetation at finer levels of geographic resolution. Its role in the larger ecological context would be more accurately articulated and new conservation priorities could become evident. However, the current Integrated Resource Inventory-Common Vegetation Unit (IRI-CVU) data for grassland/shrubland vegetation limits further interpretation.

Table M5B-1. GAP vegetation types and ownership – Forest Service lands in bold (source: WY and MT GAP data).

GAP Vegetation Type	Acres	Hectares	Percent
Mixed grass prairie			
National Wildlife Refuge	0	0	0
USDA Forest Service Research Natural/Special Interest Area	**127**	**52**	**<1**
USDA Forest Service Wilderness Area /Scenic River	**178**	**72**	**<1**
State Park	271	110	<1
Nature Conservancy Preserve	3,448	1,395	1
State Wildlife Habitat Management Area	8,234	3,332	1
Wyoming State Land	48,966	19,816	8
Indian Reservation	84,368	34,143	13
USDA Forest Service National Forest	**105,747**	**42,794**	**16**
Bureau of Land Management	137,046	55,461	21
Private Lands	254,391	102,949	40
TOTAL	642,963	260,199	100
Subalpine meadows			
Nature Conservancy Preserve	2	1	<1
Wyoming State Land	2,765	1,119	1
Bureau of Land Management	3,587	1,451	1
Private Lands	26,234	10,616	10
USDA Forest Service Wilderness Area /Scenic River	**75,106**	**30,394**	**30**
USDA Forest Service National Forest	**142,422**	**57,636**	**57**
TOTAL	250,652	101,436	100
Very Low Cover Grasslands			
Indian Reservation	3,243	1,312	100
TOTAL	3,243	1,312	100
Dry-land Crops			
Nature Conservancy Preserve	15	6	1
Bureau of Land Management	31	12	1
State Wildlife Habitat Management Area	48	19	2
USDA Forest Service National Forest	**228**	**92**	**9**
Wyoming State Land	364	147	14
Private Lands	1,766	715	70
TOTAL	2,533	1,025	100

Mesic shrub associations	**Acres**	**Hectares**	**Percent**
Wyoming State Land	90	37	4
Bureau of Land Management	93	38	4
Private Lands	935	379	38
USDA Forest Service National Forest	**1,328**	**538**	**54**
TOTAL	2,447	990	100
Sagebrush -includes WY big and MTN big			
USDA Forest Service Wilderness Area /Scenic River	**101**	**41**	**<1**
Nature Conservancy Preserve	182	73	<1
State Wildlife Habitat Management Area	201	81	<1
State Park	425	172	<1
USDA Forest Service National Forest	**22,007**	**8,906**	**7**
Wyoming State Land	26,259	10,627	8
Indian Reservation	30,009	12,144	9
Bureau of Land Management	113,108	45,773	34
Private Lands	136,709	55,324	42
TOTAL	329,031	133,155	100
Xeric shrub associations			
USDA Forest Service Research Natural/Special Interest Area	**1**	**0**	**<1**
National Wildlife Refuge	87	35	<1
State Wildlife Habitat Management Area	213	86	<1
State Park	246	99	1
Indian Reservation	2,373	960	6
Wyoming State Land	4,099	1,659	10
USDA Forest Service National Forest	**5,894**	**2,385**	**14**
Private Lands	6,476	2,621	15
Bureau of Land Management	23,286	9,424	54
TOTAL	42,838	17,336	100
Rock			
Indian Reservation	6	2	<1
Private Lands	688	278	3
Wyoming State Land	1,235	500	6
USDA Forest Service National Forest	**2,144**	**868**	**10**
Bureau of Land Management	4,351	1,761	20
USDA Forest Service Wilderness Area /Scenic River	**13,380**	**5,415**	**61**
TOTAL	21,950	8,883	100
Snowfields or ice			
USDA Forest Service National Forest	**1**	**0**	**<1**
USDA Forest Service Wilderness Area /Scenic River	**686**	**278**	**100**
TOTAL	687	278	100

Land Ownership and Land Use Allocation Summary for the Big Horn Mountains Section (M331B)

Table M5B-1 lists the ownership for each GAP vegetation type in Section M331B. The Bighorn National Forest has the following GAP types: 1) subalpine meadows, 2) mesic shrub associations, 3) snowfields or ice, and 4) rock, typically the higher elevational areas within the section. Lower elevational plant communities (i.e., below roughly 8,000 feet (2,440 m) are in mixed ownership (Fig. M5B-1).

On a finer geographic scale, the BNF is a significant owner of the following plant community dominance types (as identified in Module 3B): *Pseudoroegneria spicata, Festuca idahoensis, Carex elynoides, Artemisia tridentata* ssp. *vaseyana*, *Cercocarpus ledifolius*, and *Artemisia nova*. *Artemisia tridentata* ssp. *wyomingensis* was not listed here since it is assumed to be prominent on lower elevational lands adjacent to the Bighorn National Forest. Because of the relative coarseness of the IRI-CVU data, other plant community types may be important but have not been identified.

Cultural and Biological Influences on Landscapes with an Emphasis on Livestock Grazing

Historical to Present Day Perspective

Meyer and Knight (2003) summarized the historical cultural and biological influences on the BNF. The following attempts to recap pertinent points relevant to grassland/shrubland upland vegetation.

Meyer and Knight (2003) argue that Native American influences were typically minor and less severe than those of European-Americans, who came mostly after the 1890s. Native Americans may have started fires that burned over large areas, probably their greatest influence on the landscape. These fires are assumed to have burned grassland/shrubland vegetation adjacent to forested stands.

By the 1870s, most of the bison were gone, and the Bozeman and Oregon Trails brought cattle and sheep ranching into the plains surrounding the Big Horn Mountains. Small settlements such as Sheridan, Story, Buffalo, and Tensleep developed. Minor grazing did not begin inside the present Bighorn National Forest until the mid-1880s (Martarano *et al.* 1985). European-Americans settled in the area in large numbers from 1890 to 1945. In the 1890s, livestock grazing increased rapidly (Martarano *et al.* 1985).

It appears that the frequency of human-caused fires may have increased soon after the arrival of European-Americans, probably due to accidental fires associated with sawmills and wood-burning stoves. Town (1899) estimated that 70,000 acres (28,000 ha) of the federal Bighorn Reserve burned during the summer of 1898, a year after the Reserve was established. The Reserve later became the Bighorn National Forest. About 30,000 acres (12,000 ha) of that total were purportedly caused by a sheepherder's campfire on the divide between Prairie Dog Creek and the north Fork of Piney Creek. The causes of other fires that year are unknown, although Town (1899) reported rumors that Indians had set them.

Important information about historic livestock and wildlife numbers summarized by Meyer and Knight (2003) is reported verbatim below:

From 1890 to the early 1900s, the native herbivores (elk, deer, bighorn sheep, pronghorn antelope, and bison) and furbearers (pine marten, beaver) were hunted for eastern markets and sport (Dary 1986). Some species were driven to near extinction and the elk population disappeared. Populations of the native predators, such as wolves, mountain lion, lynx, and grizzly bear, were also decimated during this time by poisoning and shooting. Simultaneously, domestic livestock grazing was extensive and uncontrolled until 1899. Town (1899) estimated 3,000 cattle and 450,000 sheep on the Forest Reserve in 1898. In 1900, Jack (1900) observed that the Bighorn National Forest south of the 13th standard parallel was badly overgrazed.

Concerns about adverse effects of grazing and timber harvest practices on the land brought about the third period of human occupancy, the period of national forest administration. This period began in 1897, with the establishment of the Bighorn Forest Reserve by President William McKinley, and continues to the present. Land uses were regulated and more careful attention was given to finding the *best ways to avoid depleting and destroying valuable natural resources (Pinchot 1907). Because fire was personified as the "enemy" to forest managers, fire suppression became a primary objective (Conner 1940; Town 1899). Grazing permits also were required, and sheep grazing declined from 450,000 to 150,500 head in 1899. However, the number of sheep permitted to graze on the Reserve increased again to 374,734 in* 1904. *The number of cattle permits increased from 3,000 to over 30,000 during the same period. Notably, the number of sheep often exceeded permitted levels, and uneven livestock distribution led to overgrazing near streams while some rangelands were left mostly unused. In 1907, approximately 16,000 ha [40,000 acres] of the Forest (22% of grasslands) were used by cattle and 24,000 ha [60,000 acres] (34% of grasslands) were used by sheep (Conner 1940, Martarano et al. 1985). The Reserve became a National Forest in 1905, but it took over a decade before grazing became more tightly controlled and various kinds of range improvement were attempted (including fencing and the provision of water). Grazing continued to increase due to pressures during World War I, until 1919 when grazing recommendations were reduced to about 117,000 sheep and between 36,000 to 48,500 cattle. By 1931, actual sheep use was about 126,765 head for a 2.5-month season and cattle use had declined to 32,352 head for 3.5 months.*

Domestic grazing has declined in the region during the last 60 years, largely due to a reduction in sheep grazing (Cochrane et al. 1988). In the 1980s, the number of cattle grazing on the Bighorn National Forest was similar to the 1930s (33,000), but sheep grazing declined from about 127,000 to 58,000 head on the Forest (134,000 animal unit months in the 1980s, USDA Forest Service 1985) with the decline in the market for wool. Wild herbivores such as deer and elk increased during this period [Figure M5B-3]. Bighorn sheep have been re-introduced periodically [Figure M5B-3], but in 1999 their population was down to 20, probably due to disease transmission from domestic sheep (B. Bornong, personal communication). Moose were introduced in the 1950s, reaching a population of over 400 by 1994 (USDA Forest Service 1994). Deer peaked in the 1960s and then declined, possibly caused by lower winter habitat quality resulting from fire suppression, forest encroachment, and other habitat alterations (Hobbs and Spowart 1984; B. Jellison, Wyoming Game and Fish Biologist, personal communication; Leege and Hickey 1971). In 1984, winter carrying capacity on the Forest for deer and elk was estimated to be only 1,053 and 544, respectively (USDA Forest Service 1985). Winter rather than summer habitat tends to limit the ungulate populations in the region (Davis 1977); many animals migrate off the Bighorn National Forest during the winter.

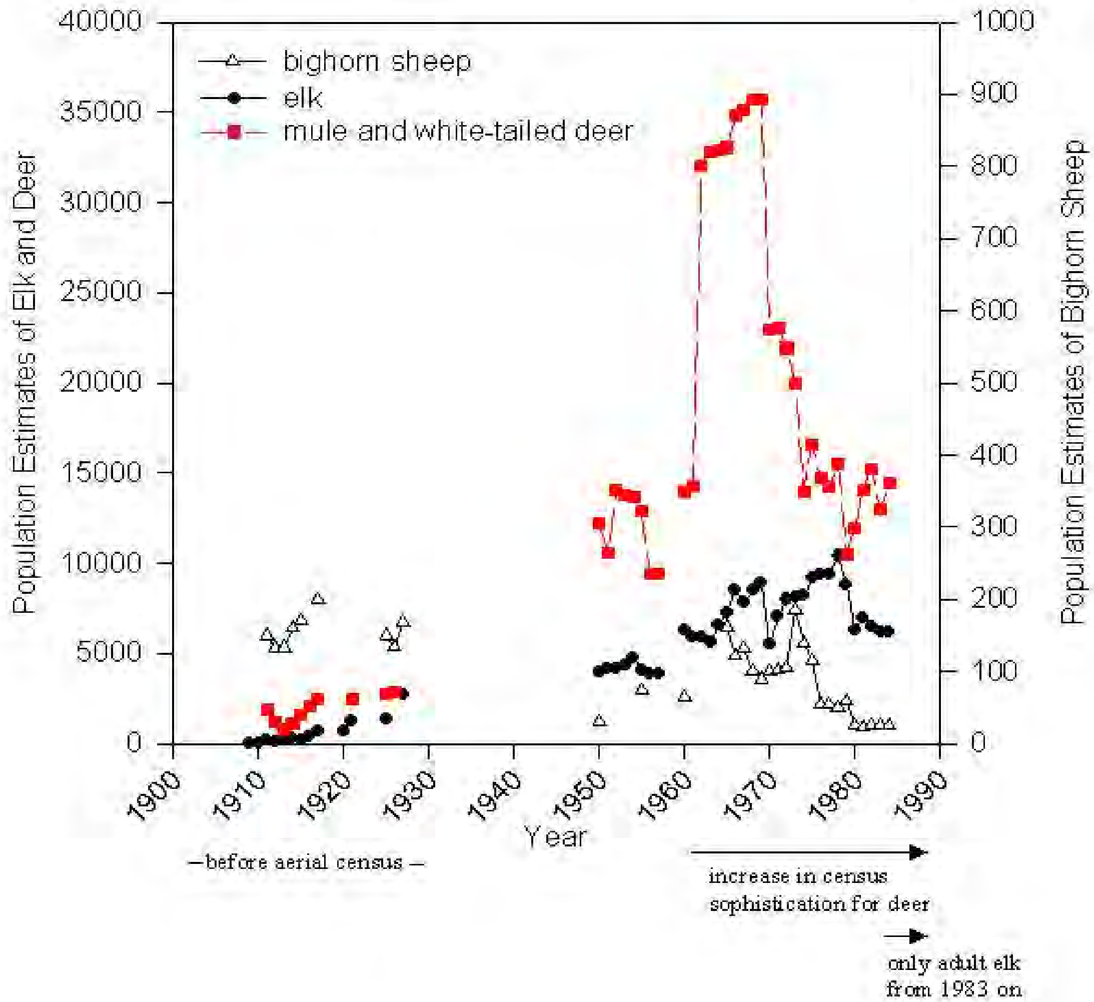


Figure M5B-1. Population estimates for elk and deer (left axis), and bighorn sheep (right axis) on the Bighorn National Forest (data from USDA Forest Service 1985, 1994, and from 1909-1929 Annual Fish and Game Reports for the Forest; *source: Meyer and Knight 2003*).

Currently, elk number approximately 7,100 animals – similar to what was believed to be pre-settlement levels. Deer numbers are also believed to be close to pre-settlement population numbers, with about 15,000 present on the Bighorn National Forest for part of the year (Wyoming Game and Fish Department 1999).

Livestock Preference and Rangeland Resilience – A Modeling Approach

IRI-CVU vegetation data for grassland/shrubland communities does not afford rigorous analysis due to the generalizations made in the grass and shrub layers. Instead, we developed a Livestock Preference and Rangeland Resilience Model (Quimby 2002). Livestock preference has to do with understanding where livestock might tend to concentrate. Rangeland resilience relates to understanding which areas are more likely to be susceptible to livestock impacts.

Livestock Preference Model

The Livestock Preference Model assesses the distribution of permitted livestock across the landscape and the areas most likely to experience livestock grazing. This model is based on current permitted livestock use and can be run at any time to assess changes in permitted use. The model first uses the forest planning suitability and capability determination process to determine areas across the landscape where livestock grazing could be allowed, while ensuring the long-term health and sustainability of the ecosystems. It further refines the determination by eliminating any areas where livestock grazing has been determined to be inappropriate.

The model then takes this suitability determination and overlays it with allotment status (as active, vacant, or non-allotment), permitted livestock kind (cattle or sheep), and assesses livestock preference in terms of three factors that are key indicators of livestock preference for an area (slope, distance to water, and canopy cover). Although other factors could be locally important, the model was run using these three as a reasonable means of arriving at a general assessment across the entire landscape. The end result is a map, with associated data tables, showing where livestock use could be expected, expressed in terms of high, moderate, low, or no preference.

The findings of this modeling across the BNF indicate that a very large part of the landscape is in the "Non-Allotment", "Non-suitable", and preference rating of "None" categories. This means that of the total 1,107,670 acres (448,450 ha) of the Forest (USDA Forest Service 1985), 190,000 acres (76,900 ha) are in non-allotment status, and of the active and vacant cattle and sheep allotments, approximately 798,000 acres (323,000 ha) would be expected to show little to no effects from current livestock management activities (e.g. they are either non-suitable or show a preference of "None"). Approximately 28% of the BNF landscape would be expected to have current livestock management activities present to any degree greater than none to incidental use. Since we lack information for private lands, it was not possible to assess impacts outside of National Forest lands.

Only 12% of the acres within active cattle allotments would be expected to show measureable effects of livestock management (Table M5B-2; Fig. M5B-2). In general, the low preference acres would be expected to have only minimal livestock activity and therefore limited potential for effects. The areas identified as high or moderate are where livestock activity is most likely to occur and where the risk of effects is potentially the greatest. Because the landscape model cannot account for small local differences, actual local effects may be quite different from the potential.

On the vacant cattle allotments (Table M5B-2), which could potentially be stocked but are not currently under term permit, only a total of 569 acres (230 ha; 2%) of the total would be considered to have a potential for measurable livestock effects if the area is ever permitted (Fig. M5B-2).

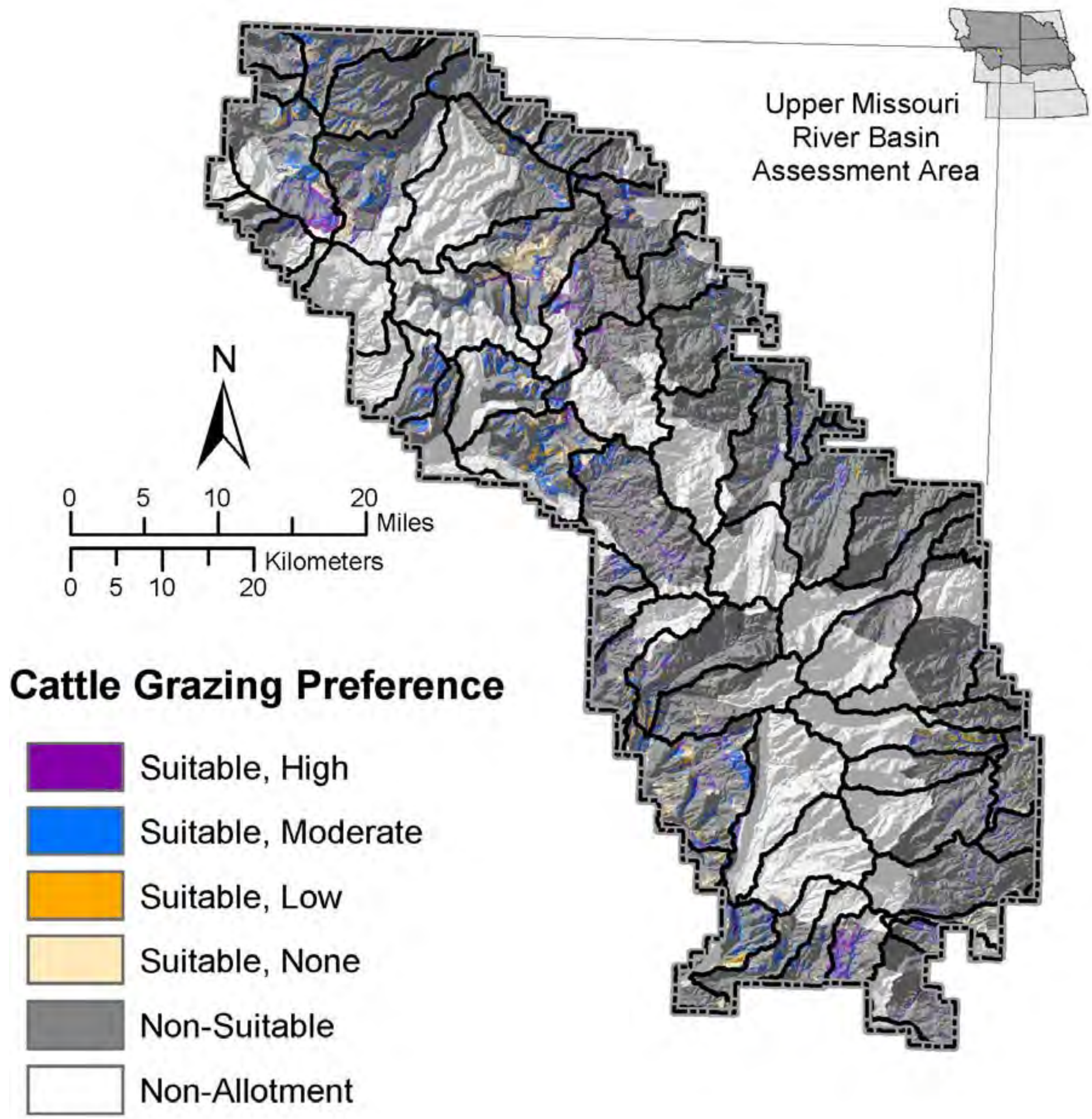


Figure M5B-2. Livestock preference ratings for cattle on the Bighorn National Forest (*source: Bighorn National Forest resource data).*

Table M5B-2. Livestock preference ratings for active and vacant allotments for cattle on the Bighorn National Forest**.**

	Non-suitable	None	Low	Moderate	High	Total
	Active Allotment Livestock Preference Ratings					
Acres	588,533	43,050	12,195	50,363	24,143	718,284
Percent	82	6	2	7	3	100
	Vacant Allotment Livestock Preference Ratings					
Acres	25,646	327	36	418	115	26,542
Percent	97	1	T	2	T	100

Only 21% of the acres within active sheep allotments would be expected to show measureable effects of livestock management (Table M5B-3; Fig. M5B-3). About 15% of the total acres within vacant sheep allotments would be predicted to have a potential for livestock effects if the area is ever placed under permit.

Table M5B-3. Livestock preference ratings for active and vacant allotments for sheep on the Bighorn National Forest.

	Non-suitable	None	Low	Moderate	High	Total
	Active allotment Livestock Preference Ratings					
Acres	115,558	2,467	621	5,918	25,703	150,267
Percent	77	2	T	4	17	100
	Vacant allotment Livestock Preference Ratings					
Acres	22,573	165	54	734	3,203	26,729
Percent	85	T	T	3	12	100

The predictions above indicate that livestock effects are relatively localized, and that much of the BNF is not likely to be significantly affected by current management. It is highly likely, however that impacts did occur during the historical era of heavy stocking and limited management.

Obviously, preference ratings are not evenly distributed across the Bighorn National Forest's landscapes. Some areas—particularly open, low-gradient riparian areas, meadows, aspen types, and grasslands—tend to be ranked as high preference, while areas that are steep or have dense conifer canopy are ranked low to none. Figures M5B-2 and M5B-3, along with their accompanying tables, should provide a useful tool in assessing the potential for effects across the landscape. They should also provide a focus for more intensive investigation into specific areas, especially the areas ranked high or moderate preference.

Rangeland Resilience Model

Rangeland Resilience is meant to represent, on a relative and subjective basis, how well a site is capable of tolerating livestock impacts without experiencing significant degradation, as well as how quickly a site recovers from livestock impact. In general, this model predicted that areas of shallow soil and southern exposures would be least resilient to livestock effects (Fig. M5B-4). Conversely, areas of deeper soil and better moisture would be more resilient.

The Rangeland Resilience Model was then run in conjunction with the Livestock Preference Model detailed above. Rangeland resilience was examined for those areas showing high, moderate, and low livestock preference (Table M5B-4). Finally, separate displays were developed for cattle and sheep (Figs. M5B-5 and M5B-6).

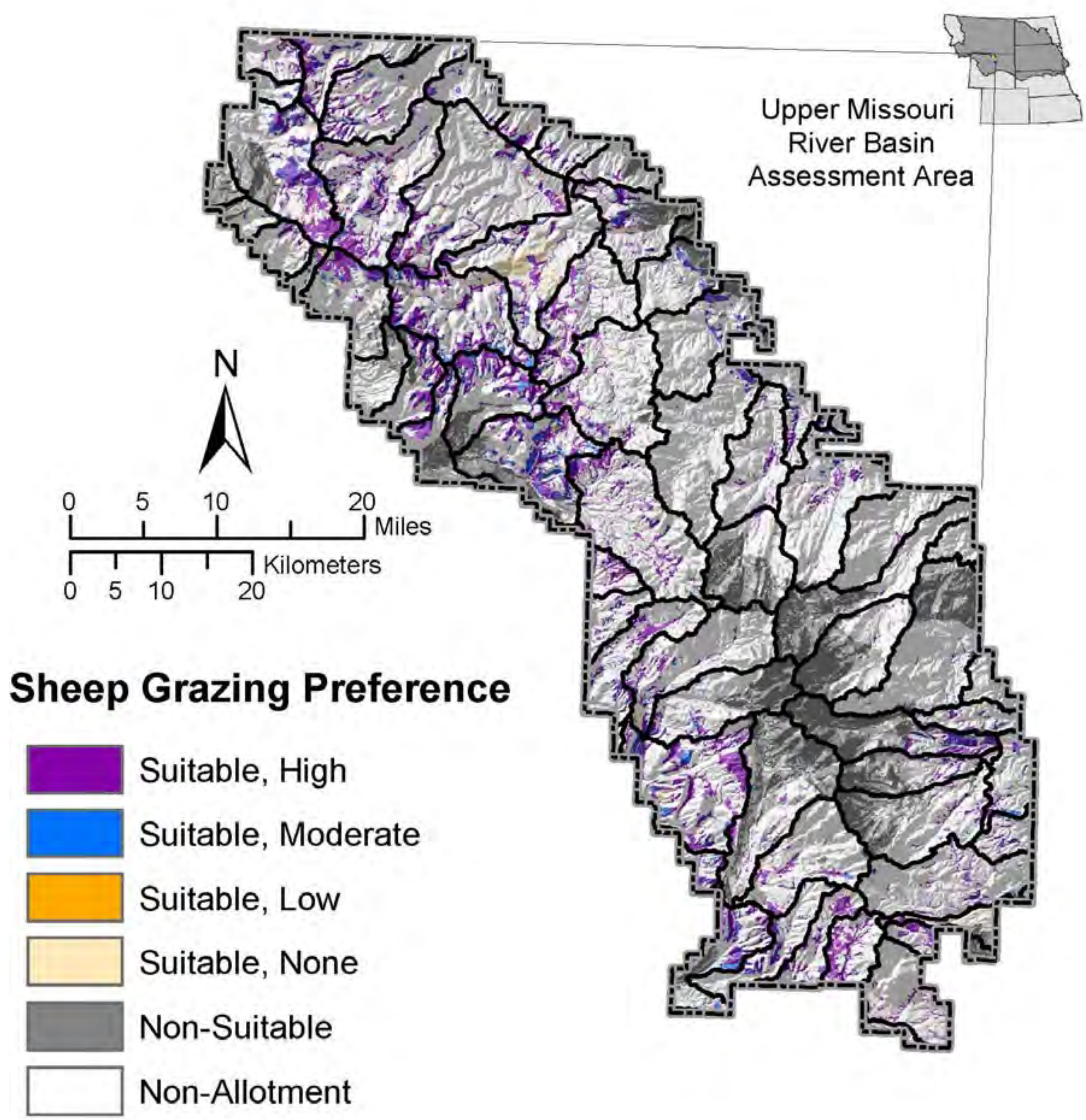


Figure M5B-3. Livestock Preference Ratings for sheep on the Bighorn National Forest (*source: Bighorn National Forest resource data).*

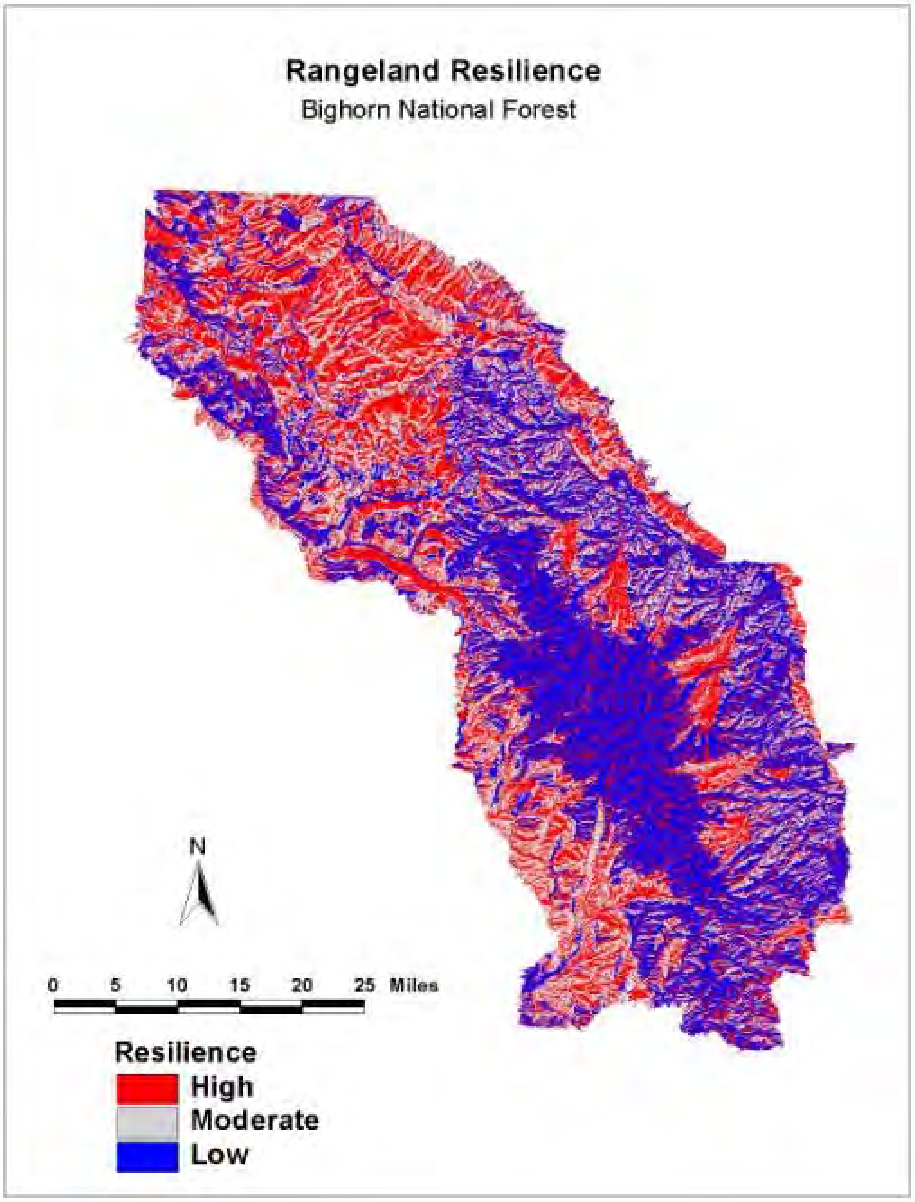


Figure M5B-4. Rangeland resilience on the Bighorn National Forest (source: Bighorn National Forest resource data).

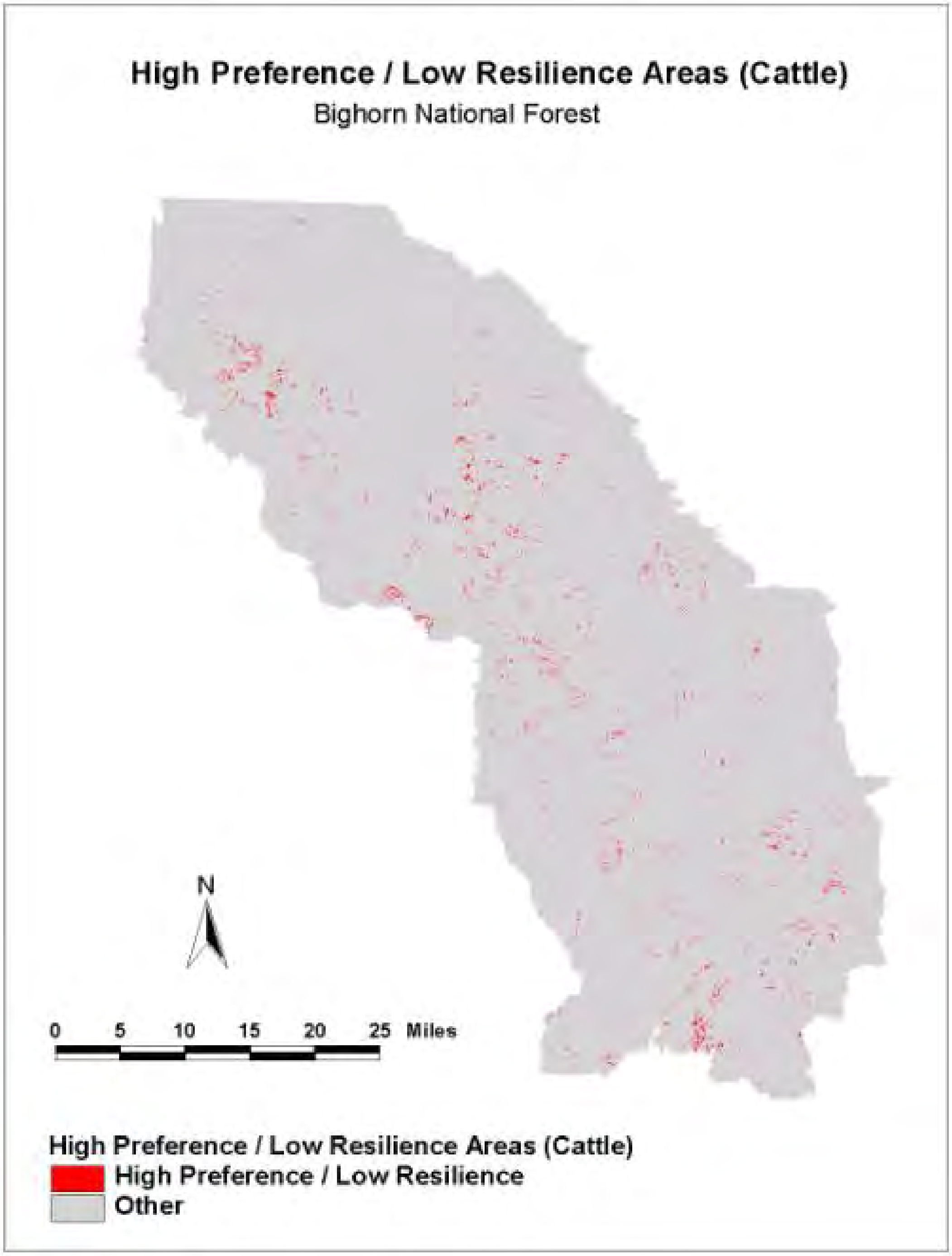


Figure M5B-5. High livestock preference and low rangeland resilience for cattle on the Bighorn National Forest (*source: Bighorn National Forest resource data*).

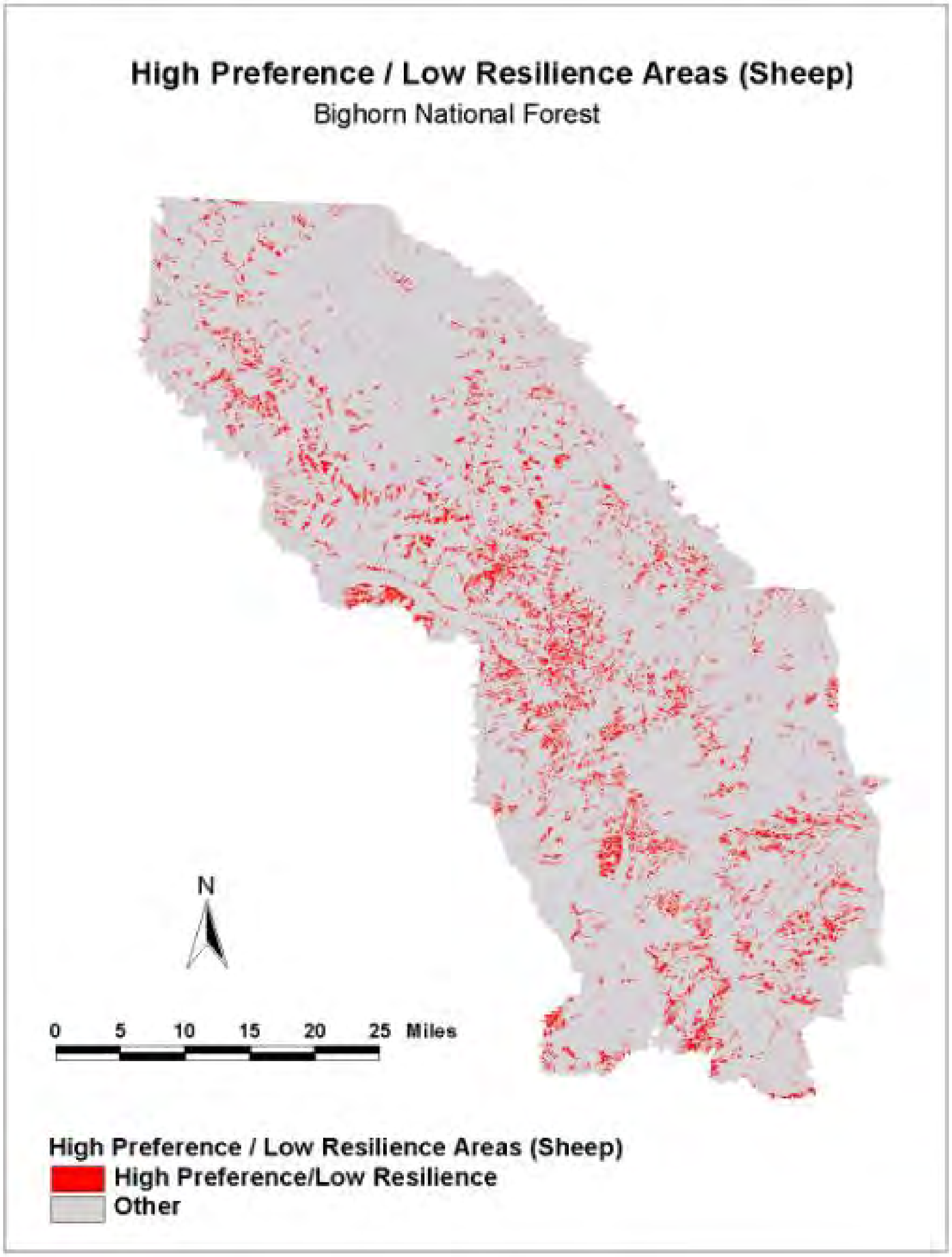


Figure M5B-6. High livestock preference and low rangeland resilience for sheep on the Bighorn National Forest (*source: Bighorn National Forest resource data*).

Table M5B-4. Livestock preference – rangeland resilience acreage by kind of stock (*source: Bighorn National Forest resource data*).

Preference	High Resilience Acres	Moderate Resilience Acres	Low Resilience Acres
	Cattle		
High	42,153	17,108	13,337
Moderate	67,286	62,923	57,322
Low	348,485	284,463	336,790
	Sheep		
High	140,182	107,841	94,437
Moderate	44,210	49,246	57,730
Low	273,535	207,409	255,282

This model shows that the majority of areas of highly preferred by cattle also have high to moderate resilience. The key areas of concern would be those areas mapped as high preference and low resilience (Fig. M5B-5). The moderate and low preference areas are relatively evenly distributed between the three resilience classes. This makes any assessment difficult, but Figure M5B-5 may prove valuable as a planning tool, especially when combined with local knowledge of a specific area.

For sheep, there is a relatively even distribution among all preference ratings and resilience classes. Again, the key areas of concern would be those areas mapped as high preference and low resilience (Fig. M5B-6). If both cattle and sheep are considered simultaneously, approximately 64,000 acres (25,900 ha) of the BNF are modeled as high preference and low resilience (Fig. M5B-7).

Finally, we wanted to investigate whether the predicted potential conflicts illustrated above (Figs. M5B-5 and M5B-6) were disproportionately attributed to any particular cover type. Table M5B-8 displays the High Preference – Low Rangeland Resilience acres, by IRI-CVU cover type, and by kind of livestock. Common "Grass" and "Forb" types are heavily used by cattle and sheep. Because grassland/shrubland IRI-CVU data are generalized, it is difficult to point out any obvious concerns. However, this tool may be a useful as the resolution of vegetation mapping and description improve over time.

Combining stocking rates by allotment (Fig. M5B-8 from Module 3C) with high livestock preference (Fig. M5B-4) and low rangeland resilience (Fig. M5B-5), will identify potential areas of concern. Again, combining this information with local knowledge should be valuable. Highly productive meadows would be expected to be capable of supporting relatively high stocking rates while maintaining long-term health and sustainability (under proper management). In contrast, low-productivity grasslands on shallow soils or low-productivity conifer types would be expected to be capable of maintaining only a relatively low stocking rate.

Because stocking rates on the Forest appear to be high, it is important to identify areas of high stocking that intersect with areas of high preference and low resilience (Fig. M5B-9) as areas of concern for rangeland management and sustainability. Currently, the Forest includes approximately 20,000 acres (8,100 ha) meeting this condition, most of which is fairly well distributed. Notably, 19% of this area is considered to have high fire hazard (see Module 8). Similary, 59,500 acres (24,100 ha) of the Forest includes high potential for invasion by non-native plant species (see Module 7) as well as high preference and high stocking by cattle and/or sheep. Such patterns may be important for identifying grassland/shrubland landscapes requiring careful monitoring and/or restoration.

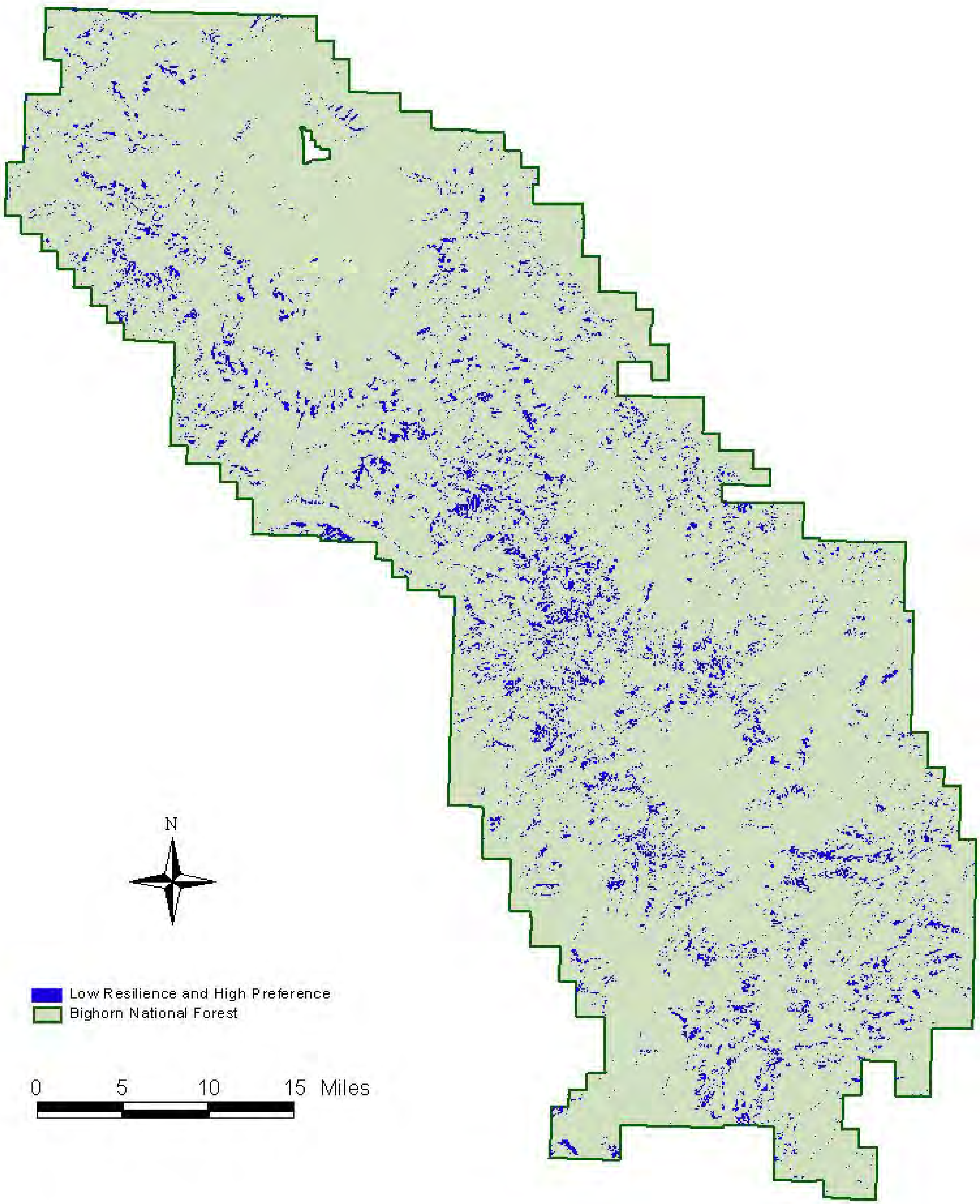


Figure M5B-7. High livestock preference and low rangeland resilience for both cattle and sheep on the Bighorn National Forest (*source: Bighorn National Forest resource data*).

Table M5B-5. High Livestock Preference – Low Rangeland Resilience acres, by IRI-CVU cover type and kind of livestock on the Bighorn National Forest (*source: Bighorn National Forest resource data)*.

IRI CODE	Description	Cattle		Sheep	
		Acres	Hectares	Acres	Hectares
W	Water	1	0	1	0
B	Bare	3	1	150	61
BBS	Bare Soil	32	13	220	89
BIC	Ice/snow	0	0	0	0
BLD	Bare litter duff	0	0	0	0
BRO	Bare rock	93	37	3,058	1,238
BRS	Bare rock/soil indistinguishable	10	4	146	59
BWO	Bare wood (usually logging debris)	16	7	88	36
F	Forb	2,191	887	12,417	5,025
G	Grass	4,942	2,000	25,503	10,321
G106	Blue grass scabland	6	3	84	34
G304	Idaho fescue and bluebunch wheatgrass	25	10	184	74
G313	Tufted hairgrass/wet sedge	30	12	226	92
G613	Idaho Fescue	94	38	369	149
G0AT	Oatgrass	0	0	0	0
S	Shrub	19	8	399	161
S209	Skunkbrush	0	0	6	2
S322	Curl-leaf mountain mahogany	8	3	161	65
S401	Big sagebrush	680	275	6,637	2,686
S408	Rabbitbrush, sagebrush	301	122	1,545	625
S412	Juniper	0	0	0	0
S416	Mountain mahogany	0	0	0	0
S921	Willow	256	104	1,207	488
T	Tree	0	0	0	0
T206	Spruce fir	1,449	586	16,643	6,735
T210	Doug fir	106	43	1,730	700
T217	Aspen	111	45	869	352
T218	Lodgepole	2,711	1,097	19,935	8,067
T219	Limber pine	48	20	657	266
T235	Cottonwood	2	1	32	13
T237	Ponderosa	148	60	1,600	647
T239	Pinyon juniper (juniper here)	54	22	558	226
	TOTAL	13,335	5,397	94,424	38,212

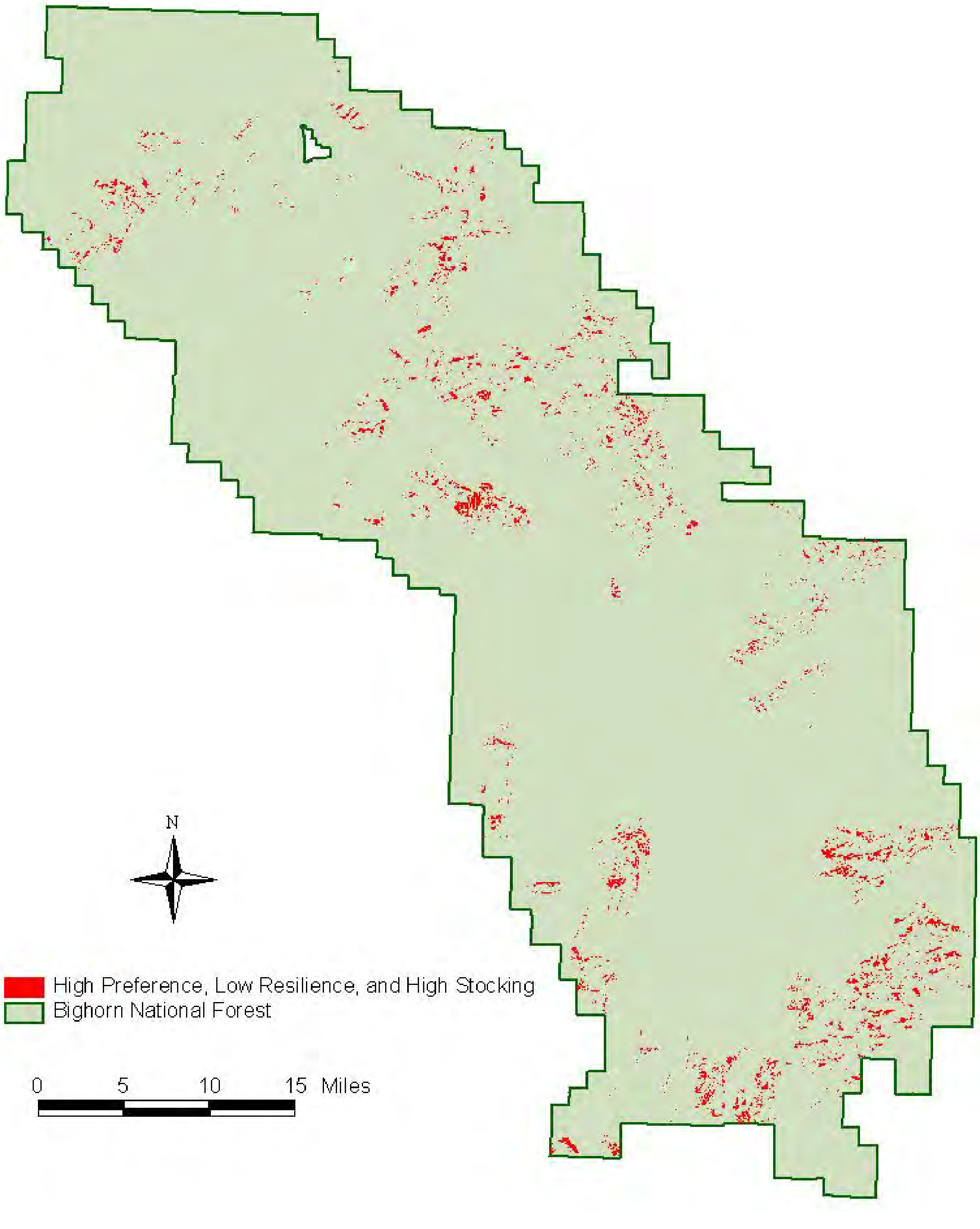


Figure M5B-9. Areas of high cattle and/or sheep stocking on the Bighorn National Forest intersecting with areas of high livestock preference and low rangeland resilience for both cattle and sheep.

Grazing and livestock activities (primarily by cattle and sheep) are the anthropogenic disturbances that have affected the largest total area (310,798 acres/125,829 ha) in the Bighorn National Forest. Because of its widespread effects, and due to its higher occurrence at lower elevations, within drainages and valley bottoms, and where canopy closure is naturally low, grazing likely has the strongest influence on vulnerability of an area to non-native plant invasion (Fig. M5B-10). Approximately two percent of the total area affected by grazing, primarily in drainages and valley bottoms at the northern portion of the Forest, is considered to be at very high risk for plant invasion. Likewise, nearly 32% is considered to be at high risk, and 27% is considered to have moderate vulnerability; approximately 40% is considered to be at very low or low risk.

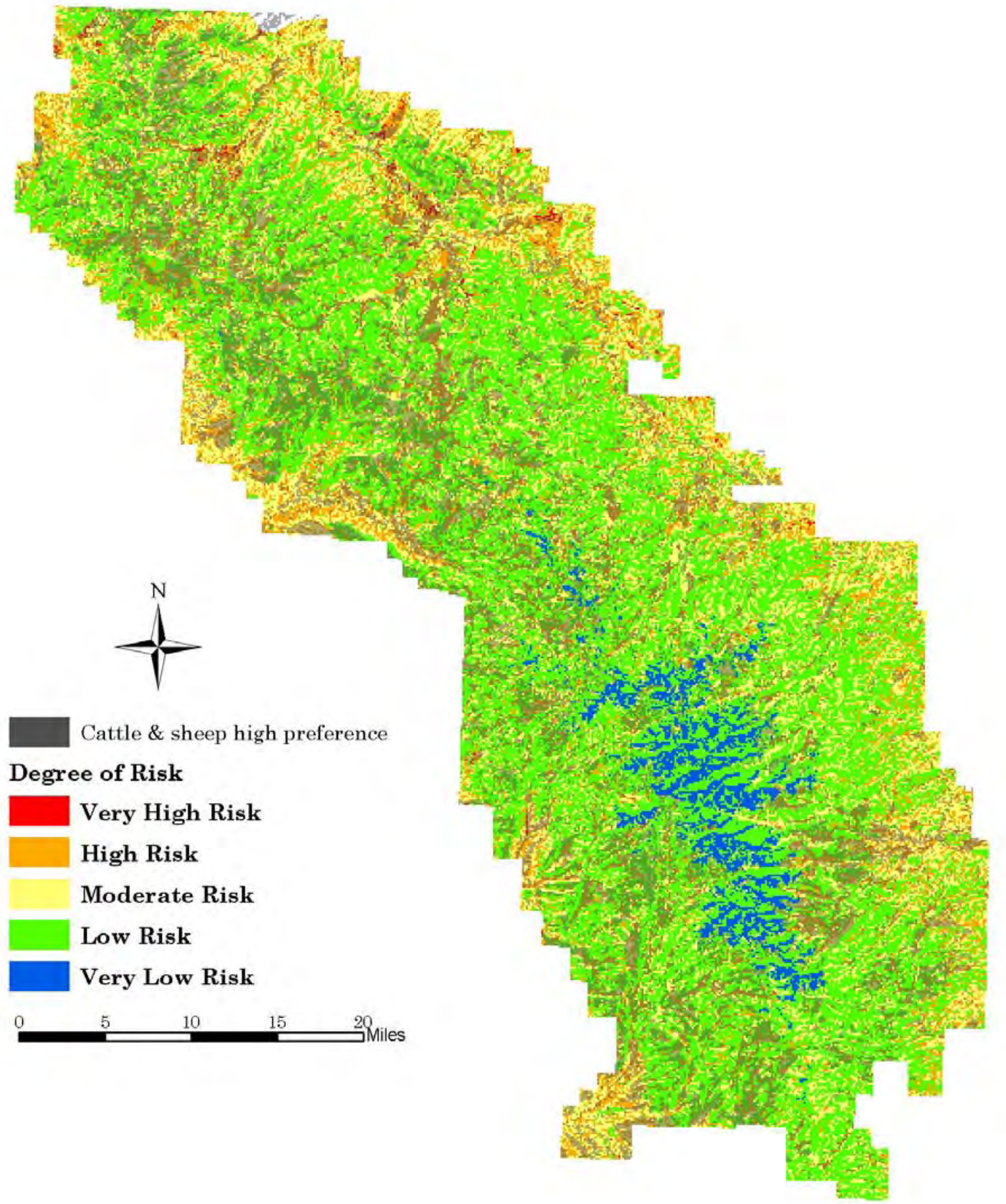


Figure M5B-10. Potential vulnerability to non-native plant species invasion on the Bighorn National Forest associated with recent grazing and/or livestock activities (<20 years).

Proportion of Major Vegetation Types Permanently Reserved from Livestock

The only management prescription on the BNF that specifically restricts livestock grazing is for Research Natural Areas (RNA; 10A; USDA Forest Service 1985). See Chapter 6 for a more detailed description of RNAs. Most other management prescriptions allow livestock grazing on the Bighorn National Forest. A tally of the IRI-CVU cover types represented in established RNAs, and the result is displayed in Table M5B-6. It appears that the RNAs on the Bighorn National Forest are primarily representing forested cover types with minor amounts of general "Grass" cover type followed by big sage cover type.

Table M5B-6. Cover types represented by Research Natural Areas on the Bighorn National Forest (*source: Bighorn National Forest resource data*).

Code	Cover Type	Polygon Count	Acres	Hectares
BRO	Bare Rock	1	2	1
BRS	Bare rock/soil indistinguishable	1	3	1
G	Grass	8	178	72
S322	Curl leaf mountain mahogany	1	6	2
S401	Big sagebrush	2	48	20
T210	Doug-fir	29	821	332
T218	Lodgepole pine	11	453	183
T219	Limber pine	1	6	2
T239	Juniper	2	101	41
	TOTALS	56	1,618	655

Information Gaps and Needs for Grassland/shrubland Upland Vegetation

More detailed data on rassland/shrubland vegetation are needed in order to better assess landscape condition and better understand how the landscapes of the BNF contribute to species conservation. The information gaps identified from this module are:

(1) The plant communities listed as "rare" by the Wyoming Heritage Program need further verification as to whether they are truly rare, or simply suffer from meager occurrence documentation.
(2) The Bighorn National Forest is a significant owner of the following plant dominance types (as identified in Module 4): 1) *Pseudoroegneria spicata,* 2) *Festuca idahoensis,* 3) *Carex elynoides,* 4) *Artemisia tridentata* ssp. *vaseyana*, 5) *Cercocarpus ledifolius*, and 6) *Artemisia nova*. Because of the relative coarseness of the IRI-CVU data, other plant community types may be important but have not been identified.
(3) Additional information is needed to identify seral status of key plant communities.
(4) High Livestock Preference – Low Rangeland Resilience areas could be better refined by more resolute IRI-CVU cover type data. The current data for grassland/shrubland areas are generalized, so it is difficult to point out meaningful patterns or risks.
(5) Data on ecotones are limited (i.e., forest, shrubland, and grassland expansion or decline). An improvement in our knowledge of these changes, and where they occur spatially, would help us better understand the natural dynamics of these types.

Chapter 6 - Areas of Special Biodiversity Significance

Objectives

Plant communities of special concern or other unique habitats of biodiversity significance will be described in this chapter. Discussion of their ecological significance, a display of the spatial distributions of these habitats, identification of anthropogenic influences or risk factors, and evaluation of the ecological implications of the current condition is included. And an evaluation of the relationships among vegetation of these special areas and vegetation of assessment area is presented.

Introduction

The identification of areas of special biodiversity significance may contribute to a total, whole-landscape approach to ecological and species conservation planning (TNC citation, Groves *et al.* citation). A place-based approach is consistent with island biogeography theory, once the prevailing paradigm guiding the design of conservation reserves (MacArthur and Wilson 1967). Although contemporary ecological theory (e.g. metapopulation theory, Levins references) suggests the need for more complex approaches to ensure conservation, these early ideas remain important in conservation planning. More recently, Hunter (1991) has proposed that the protection of areas representing characteristic ecosystems and processes may ensure the protection of biodiversity (Hunter's coarse-filter approach). These areas might be similar to reference landscapes. An analysis of these areas may be helpful in understanding what components should be encompassed in reference landscapes, or which may actually serve as reference landscapes. It may also help identify habitats known to constrain the distribution and abundance of species, and contribute to regional persistence of rare species by identifying local habitats that need protection (Duerksen *et al.* 1997).

This module describes plant communities of special concern, unique habitat features, WYNDD conservation sites, and existing and potential Research Natural Areas (RNAs) within the Bighorn National Forest (BNF). In addition, we discuss the ecological significance of these special places, display their spatial distributions, identify anthropogenic influences or risk factors, and evaluate the ecological implications of the current condition.

Plant Communities of Special Concern

The Wyoming Natural Diversity Database (WYNDD) described 26 vegetation types on the BNF (Table 6-1; Anderson *et al.* 1998; WYNDD 2000). These are dominance types, recognized by the dominant species in the tallest vegetation layer. The forest vegetation types are essentially equivalent to Society of American Foresters forest cover types (Eyre 1980). Each type corresponds to at least one alliance from the new National Vegetation Classification (Anderson *et al.* 1998). While this list of vegetation types is not exhaustive, it encompasses most of the vegetation found on the Forest.

One of the 26 types, the mountain willow *(Salix eastwoodiae)* shrub type, is represented solely by rare or uncommon associations. Two vegetation types, the redosier dogwood (*Cornus sericea)* riparian shrub type and curl-leaf mountain mahogany (C*ercocarpus ledifolius)* upland shrub type, are listed as only located within the BNF.

Table 6-1. Vegetation types identified on Bighorn National Forest by Wyoming Natural Diversity Database.

Vegetation Type	Distribution	Physical Environment	Vegetation Description	Management Considerations
<u>Carex elynoides</u>	Pete's Hole area in Crystal Creek drainage (Welp *et al.* 1998); probably occurs mainly on northern end of Forest	Windswept slopes (Welp *et al.* 1998)	Sparse vegetation with high proportion of cushion plants (Welp *et al.* 1998)	No information
Abies lasiocarpa - Picea engelmannii	North and south of Cloud Peak Wilderness Area (Hoffman and Alexander 1976); locations at northern and northwestern boundaries of Forest (Jones and Fertig 1998; Welp *et al.* 1998a, 1998b, 1998c)	Slopes with a variety of aspects (Hoffman and Alexander 1976); "best-developed" stands on north facing slopes atop Gros Vetntre Shale bedrock	Primarily equal densities of *P. engelmannii* and *A. lasiocarpa*, with former species larger (Despain 1973, Hoffman and Alexander 1976); Seral specis is *P. contorta* on granitic rock; and *P. menziesii* on limestone; scattered shrubs	Many stands were being logged (Despain 1973)
Picea engelmannii upland	Central third of Bighorns, at eleveations of 6600 to 8600 feet (Hoffman and Alexander 1976); Mann Creek area at elevations of 8000 to 8800 feet (Jones and Fertig 1998); northwest of Powder River Pass at 10000 feet (Welp *et al.* 1998)	Level sites or on north- to northwest-facing slopes with granitic bedrock, grantici moraine, and limestone bedrock (Hoffman and Alexander 1976, Jones and Fertig 1998); More mesic sites than *P. contorta* stands (Hoffman and Alexander 1976)	*P. engelmannii* forms overstory, which may also contain substantial amounts of *P. contorta*; *V. scoparium* dominates undergrowth at higher elevations, while *P. monogynus, S. betulifolia, C. colubiana* var, *tenuiloba,* and *T. occidentale* occur at lower elevations	No information
Picea engelmannii riparian	Primarily from central part of Bighorns at 74400 to 9280 feet (Girard *et al.* 1997); Mann Creek between 6400 and 6800 feet	Granitic and sedimentary alluvium (Girard *et al.* 1997, Jones and Fertig 1998); in narrow valley bottoms with high-gradient streams and cobbly substrates	*P. engelmannii* dominates overstory; *P. contorta* may co-dominate in drier stands; overstory may be dense with few shrubs or sparse over a shrub layer of *C. sericea* or *S. boothii*; undergrowth dominated by forbs	No information
Pinus contorta	Nearly continuous on granitic central third of range at 69900 to 9515 feet (Despain 1973)	Well-developed on granite, limited on sandstone, rare on shale and limestone (Despain 1973); primarily upland, but can occur on riparian sites	Stands vary widely in structure; dnese overstories nearly pure *P. contorta*; open overstories are mix of *P. contorta, P. engelmannii,* and *A. lasiocarpa* with shrub layers of *J. communis* and *R. lacustre*.	By early 1970s, the most important timber tree on Bighorns; clearcutting was common harvest method; large barren areas with poor regeneration (Despain 1973)

Populus tremuloides	Major cover type for only one isolated area in Bighorns	On deep soils with more moisture available than surrounding sites dominated by conifers (Hoffman and Alexander 1976)	*P. tremuloides* dominates overstory; *L. argenteus, A. alnifolia, P. virginian, C. canadensis,* or *P. pratensis* may dominate understory (Hoffman and Alexander 1976, Girard *et al.* 1997, Welp *et al.* 1998a-b)	Not very valuable for timber; high forage production if not overgrazed; sprouts are important browse source for big game; valuable as fall scenery (Hoffman and Alexander 1976)
Salix boothii	Common at elevations from 7800 to 9080 feet (Girard *et al.* 1997)	Along low-gradient streams and in sediment-filled beaver ponds, on sedimentary- and granitic-derived alluvium; occupies wetter soils than other willow types	*S. boothii* dominates or co-dominates with *S. planifolia* ssp. *planifolia*; undergrowth on wet sites include *Carex* spp; on drier sites undergrowth includes *D. cespitosa, C. praegracilis,* and *T. officinale.*	Heavy use of stands with wet soils causes compaction of soil and may increase erosion rates (Girard *et al.* 1997)
Salix eastwoodiae	One stand at 9000 feet in northwest part of Forest; may occur elsewhere at higher elevations	Narrow valley on limestone substrate	*S. eastwoodiae* dominates shrub layer; *C. scopulorum, D. cespitosa* and *T. wofii* occur in undergrowth	Sampled stand had been disturbed, causing decline in *C. scopulorum* and some forbs, and increase in *D. cespitosa* and *T. wolfii* (Girard *et al.* 1997)
Salix geyeriana	Uncommon at elevations of 7600 to 8680 feet, in central part of mountains (Girard *et al.* 1997)	Primarily occur on granitic substrates, but may occur on sedimentary substrates; rarely occur next to stream channel	*S. geyeriana* dominates or co-dominates with *S. planifolia* ssp. *planifolia*; undergrowth of wet sites dominated by *C. rostrata* and few forbs; undergrowth of dry sites dominated by *C. canadensis* and more forbs	Stands receive light use by wildlife and livestock (Girard *et al.* 1997)
Salix planifolia	Throughout Forest at elevations from 7530 to 9360 feet; in riparian zones with other willow shrub types and with herbaceous meadows	Soils developed from granitic- or sedimentary derived alluvium that are moist throughout growing season, but flooded only during spring	In lower and middle parts of elevation range *S. planifolia* ssp. *planifolia* dominates; in higher elevations *S. planifolia* ssp. *monica* dominates; common undergrowth plants are *Carex* spp. and *C. canadensis* on wet sites, and *D. cespitosa* and *P. pratensis* on drier sites	Palatable to livestock and wildlife; many stands have been heavily browsed, producing shorter shrub layers and increasing cover of *S. wolfii* (Girard *et al.* 1997)

Salix wolfii	Common at moderate and high elevations throughout Forest; forms transition between riparian and upland areas	Soils derived from granitic and sedimentary rocks in drier parts of riparian zones	At higher elevations, *S. wolfii* co-dominates with *S. planifolia* ssp. *monica* and *C. scopulorum* is major undergrowth species; in lower-elevation stands, *S. wolfii* co-dominates with *S. planifolia* ssp. *planifolia*	Trampling and grazing decrease cover of sedges (Girard *et al.* 1997)
Calamagrostis canadensis	Southeastern half of Forest from approximately 7400 to 8200 feet; in riparian areas with *P. tremuloides, S. geyeriana,* and *S. planifolia* ssp. *monica*; usually small stands	Alluvium derived from granitic rock (Girard *et al.* 1997, Welp *et al.* 1998)	In addition to *C. canadensis, Juncus* spp. and *Phleum pratense* may contribut substantial amounts of cover	No Forest-specific information
Carex aquatilis	Throughout Bighorns above 8100 feet; more common in southeast	Valley bottoms along low-gradient, meandering streams; often behind sediment filled beaver ponds; soils are developed in alluvium and saturated for most of growing season (Girard *et al.* 1997)	*C. aquatilis* dominates or co-dominates; sedges and grasses contribute bulk of canopy cover	No Forest-specific information
Carex rostrata	Throughout Forest from 7500 to 9360 feet; occurs as narrow bands along stream channels and in swales in willow vegetation	Soils are developed in granitic and sedimentary substrates; soils generally saturated	*C. rostrata* dominates; other species include *P alpinum, D. cespitosa* (more in drier sites), *C aquatilis,* and *A. foliaceus*	No Forest-specific information
Deschampsia cespitosa	Northern and central parts of Bighorns; most common as meadow vegetation in subalpine stream valleys (Girard *et al.* 1997)	Sedimentary and crystalline bedrock (Girard *et al.* 1997); soils on floodplains may be saturated most or all of growing season; soils on upland slopes saturated for shorter periods following snowmelt	*D. cespitosa* and *Carex microptera* dominate canopy cover	Concentrated livestock use caused soil to dry and species composition to change (Girard *et al.* 1997)

Pinus ponderosa	Common along eastern slopes; can be found on southwestern slopes (Merrill *et al.* 1996, Despain 1973)	On coarse-textured soils at lowest elevation (Hoffman and Alexander 1976)	Climax community at lower elevations; seral to *P. menziesii* at higher elevations; understory dominants include *E. spicatus, F. idahoensis, S. betulifolia, P. monogynus, J. communis* (Hoffman and Alexander 1976)	Stands on mesic sites better for timber harvesting; Hoffman and Alexander (1976) suggest stands be kept open for forage production, despite timber reduction; also important for recreation and big game habitat
Pinus flexilis	Not common to Bighorns; seral to *Pseudotsuga-Abies* vegetation type; several stands identified in potential Research Natural Areas	No Forest-specific information	No Forest-specific information	No Forest-specific information
Pseudotsuga menziesii	Lower elevations on eastern and western slopes	Between 6100 and 8600 feet on soils derived from limestone or dolomite; on eastern slopes, more likely found on mesic sites; on western slopes, more likely found on drier sites	*P menziesii* dominates overstory; *P. ponderosa* and *P. flexilis* found at lower elevations; *A. lasiocarpa* and *P. engelmannii* found at higher elevations; understory dominants include *M. repens, J. communis, P. monogynus,* and *S. betulifolia*	Can be harvested for timber, but site indexes low (Hoffman and Alexander 1983); most stands with merchantable timber were cut during time of settlement (Despain 1973); does not support livestock grazing, but provides browse for wildlife
Populus angustifolia	Common at lower elevations	Along high gradient streams in narrow canyons; some stands also occur on low to medium-gradient streams (Girard *et al.* 1997)	Overstory dominated by *P. angustifolia*; common understory dominants include *P. virginiana, A. rubra, and R. woodsii*	An important part of the mosaic in the calving ground for elk in Tensleep Canyon
Betula occidentalis	Minor type occurring at low elevations	In narrow valleys on alluvium derived from tranitic bedrock (Girard *et al.* 1997)	Dominated by *B. occidentalis;* also relatively high cover of *C. sericea, Rosa* spp., *S. betulifolia*	No Forest-specific information
Cornus sericea	Isolated pockets in southern portion of Forest (Merrill *et al.* 1996)	Along narrow riparian corridors surrounding Leigh and Tensleep Creeks (Welp *et al.* 1998)	*C. sericea* dominates; other shrubs include *P. virginiana, R. cereum,* and *A. glabrum*	No Forest-specific information

Festuca idahoensis	Widespread in meadows throughout montane zone	On soils overlying granitic and sedimentary rock; climate is humid to subhumid	Canopy cover ranges from 65% to 91%; grasses and sedges comprise 54% above ground biomass; *F. idahoensis* dominant, constituting larger portion of cover on granitic soils than sedimentary	Most important source of forage for grazers; overgrazing can be problematic as it allows establishment of exotics
Artemisia nova	Major cover type at Shell Canyon Research Natural Area (Ryan *et al.* 1994) and at Elephant Head potential RNA (Welp *et al.* 1998); commonly found on western slopes	On benches and gentle to steep slopes (Ryan *et al.* 1994, Welp *et al.* 1998); 10-50% exposed rock and bare soil at surface (Welp *et al.* 1998)	*A. nova* dominates shrub layer; *E. spicatus* dominates grass layer	No Forest-specific information
Artemisia tridentata ssp vaseyana	Along central portion of western slopes; in isolated areas in southeastern and northwestern portions of Forest	In open meadows, dry slopes, near drainages; considerable amount of bare ground and gravel common in stands ; occupies more mesic sites than *A. nova* (Welp *et al.* 1998d-e)	Stands may be fragmented forming a mosaic of shrub-dominated and grass-dominated vegetation (Welp *et al.* 1998); *Juniperus* spp., *P. menziesii*, and *P. pratensis* found in this type	*P. menziesii* sometimes found, suggesting that this type might be seral; fire needed for eventual regeneration
Cercocarpus ledifolius	Along eastern and western boundaries of Forest	On steep, dry slopes with shallow soils derived from limestone; found on limestone cliffs (Welp *et al.* 1998c); common, but not restricted to south facing slopes	*C. ledifolius* ssp. *ledifolius* dominates; presence of *B. japonicus* and *P. pratensis* indicates exotic invasion on Forest	No Forest-specific information
Elymus spicatus	More common on western slopes, but does occur on eastern (Despain 1973)	No Forest-specific information	Important associates on western slopes include *C. filifolia, S. comata, O. polycantha, P. hoodii*; on eastern slopes, associates are *A. scoparius* and *Y. glauca*	Stands dominated by exotic *P. pratense* in Tongue River potential RNA

Within the 26 vegetation types, 61 different plant associations were identified (Table 6-2). There is likely a far greater diversity in plant communities, and possibly more rare or unique types, than is currently reflected in the literature. The current state of knowledge is limited by the sampling effort on the BNF. For example, the riparian classification (Girard *et al*. 1997) is based on several years of sampling, but few of the samples were taken from above 9,000 feet (274 m; Welp *et al*. 2000). While the forest vegetation has been well classified (Hoffman and Alexander 1976), no classification of upland non-forest habitat types is available. Given greater sampling efforts throughout the Forest, more alpine and foothills vegetation associations would likely be recognized (Welp *et al*. 2000).

Table 6-2. Plant Associations identified by the Wyoming Natural Diversity Database on the Bighorn National Forest as occurring in the 26 vegetation types of special concern.

ECOSYSTEM VEGETATION TYPE Plant Association	Presence	Rank
ALPINE		
CAREX ELYNOIDES		
Carex elynoides / Geum rossii	X	G4
SUBALPINE		
ABIES LASIOCARPA – PICEA ENGELMANNII		
Abies lasiocarpa / Arnica cordifolia	X	G5
Abies lasiocarpa / Vaccinium scoparium	X	G5
PICEA ENGELMANNII UPLAND		
Picea engelmannii / Vaccinium scoparium	X	G3G5
PICEA ENGELMANNII RIPARIAN		
Picea engelmannii / Caltha leptosepala	?	G3
Picea engelmannii / Carex disperma	?	G2
Picea engelmannii / Cornus sericca	X	G3
Picea engelmannii / Equisetum arvense	X	G4
Picea engelmannii / Linnaea borealis	X	G3
PINUS CONTORTA		
Pinus contorta / Arctostaphylos uva-ursi	X	G5
Pinus contorta / Calamagrostis canadensis ?	?	G5Q
Pinus contorta / Juniperus communis	X	G5
Pinus contorta / Vaccinium scoparium	X	G5
POPULUS TREMULOIDES		
Populus tremuloides / Calamagrostis canadensis	X	G3
Populus tremuloides / Lupinus argenteus	X	G2?
SALIX BOOTHII		
Salix boothii / Carex rostrata	?	G4
Unknown association	X	
SALIX EASTWOODIAE		
Salix eastwoodiae Association	?	G1?

Table 6-2. Plant Associations identified by the Wyoming Natural Diversity Database on the Bighorn National Forest as occurring in the 26 vegetation types of special concern.

ECOSYSTEM VEGETATION TYPE Plant Association	Presence	Rank
SALIX GEYERIANA		
Salix geyeriana / Calamagrostis canadensis	X	G3
Salix geyeriana / Carex rostrata	X	G5
Salix geyeriana / Deschampsia cespitosa	X	G4
SALIX PLANIFOLIA		
Salix planifolia / Calamagrostis canadensis	X	G3
Salix planifolia / Carex aquatilis	X	G5
Salix planifolia / Carex scopulorum	?	G4
Salix planifolia / Deschampsia cespitosa	X	G2G3
SALIX WOLFII		
Salix wolfii / Carex scopulorum	?	G4
Salix wolfii / Deschampsia cespitosa	X	G3
Unknown	X	
CALAMAGROSTIS CANADENSIS		
Calamagrostis canadensis Western Herbaceous Vegetation		G4Q
CAREX AQUATILIS		
Carex aquatilis	X	G5
Carex aquatilis / Carex rostrata	X	G3G4
CAREX ROSTRATA		
Carex rostrata	X	G5
DESCHAMPSIA CESPITOSA		
Deschampsia cespitosa / Carex microptera	?	G2G3
MONTANE		
PINUS PONDEROSA		
Pinus ponderosa / Cornus sericea		G3
Pinus ponderosa / Festuca idahoensis	X	G4
Pinus ponderosa / Juniperus communis	X	G4?
Pinus ponderosa / Physocarpus monogynus	X	G3
Pinus ponderosa / Spiraea betulifolia	X	G2?
PINUS FLEXILIS		
Pinus flexilis / Cercocarpus ledifolius	X	G3G4
Pinus flexilis / Festuca idahoensis	X	G5
Pinus flexilis / Juniperus communis	X	G5
PSEUDOTSUGA MENZIESII		
Pseudotsuga menziesii / Arnica cordifolia	X	G4
Pseudotsuga menziesii / Juniperus communis	X	G4
Pseudotsuga menziesii / Mahonia repens	X	G5
Pseudotsuga menziesii / Physocarpus monogynus	X	G4

Table 6-2. Plant Associations identified by the Wyoming Natural Diversity Database on the Bighorn National Forest as occurring in the 26 vegetation types of special concern.

ECOSYSTEM VEGETATION TYPE Plant Association	Presence	Rank
Pseudotsuga menziesii / Symphoricarpos oreophilus	X	G5
POPULUS ANGUSTIFOLIA		
Populus angustifolia / Cornus sericea	X	G4
Populus angustifolia / Prunus virginiana	X	G2G3
Populus angustifolia / Rosa woodsii	X	G2G3
BETULA OCCIDENTALIS		
Betula occidentalis / Cornus sericea	X	G2G3
CORNUS SERICEA		
Cornus sericea (Provisional)	X	G4Q
FESTUCA IDAHOENSIS		
Festuca idahoensis / Carex obtusata	?	G3
Festuca idahoensis / Deschampsia cespitosa	X	G3
Festuca idahoensis / Festuca kingii	X	G2?
Festuca idahoensis / Pseudoroegneria spicata	X	G4
Festuca idahoensis	X	G2?
FOOTHILLS		
ARTEMISIA NOVA		
Artemisia nova / Pseudoroegneria spicata	X	G4G5
ARTEMISIA TRIDENTATA SSP *VASEYANA*		
Artemisia tridentata ssp. *vaseyana / Festuca idahoensis*	X	G5
Artemisia tridentata ssp. *vaseyana / Pseudoroegneria spicata*	X	G5
CERCOCARPUS LEDIFOLIUS		
Cercocarpus ledifolius / Pseudoroegneria spicata	X	G4Q
ELYMUS SPICATUS		
Pseudoroegneria spicata ?	X	G2?

Within ten of the vegetation types, there are 12 plant associations located within the Bighorn National Forest with a G1, G2 or G2G3 conservation rank (highlighted in Table 6-2). This rank is based upon The Nature Conservancy's Natural Heritage Network system to assess the global and statewide conservation status of a species or community. A G1 code indicates that throughout its range, the community is critically imperiled because of extreme rarity (often known from five or fewer extant occurrences or very few remaining individuals) or because some factor of a species' life history makes it vulnerable to extinction. A G2 code indicates the community is imperiled throughout its range because of rarity (often known from 6-20 occurrences) or because of factors demonstrably making a species vulnerable to extinction.

Potential distributions of these types, as inferred from the Gap Analysis Project (Merrill *et al.* 1996) mapping, are indicated in Figure 6-1 and Table 6-3. However, the distribution of these types in Wyoming is not well known, and the GAP map is only an estimate.

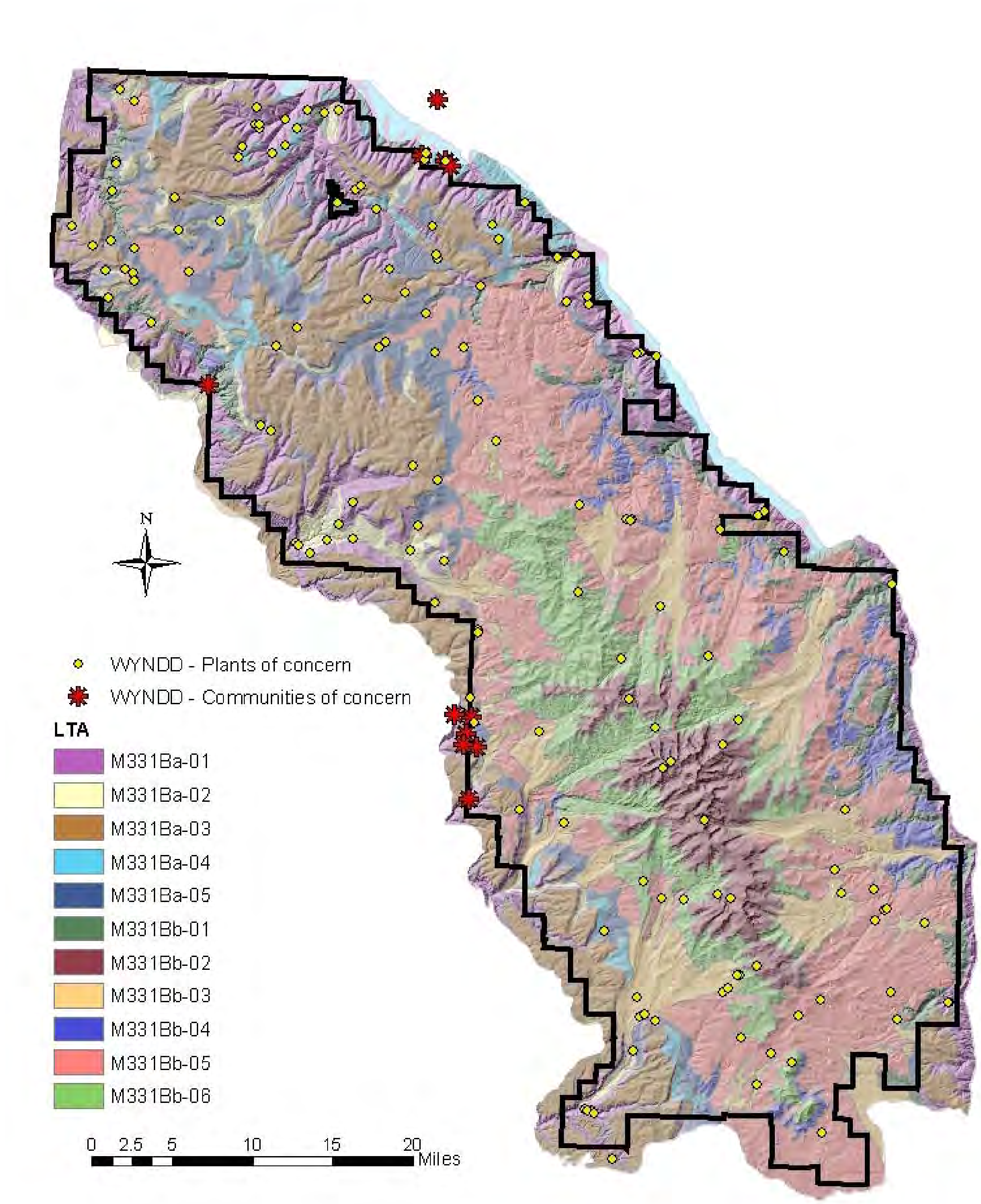


Figure 6-1. Distribution of plants and communities of special concern. Map is developed by the Wyoming Natural Diversity Database (WYNDD) with crosswalks from WYNDD vegetation types to GAP cover types.

Table 6-3. Distribution of Wyoming Natural Diversity Database vegetation communities across Landtype Associations (LTAs) and Forest Plan Watershed (FPWS) units.

Vegetation Community	LTA	FPWS
Pinus contorta / Vaccinium scoparium	M331Ba05	Paintrock Creek
Pseudotsuga menziesii / Arnica cordifolia	M331Ba03	Paintrock Creek – off
Pseudotsuga menziesii / Arnica cordifolia	M331Ba01	Paintrock Creek
Pseudotsuga menziesii / Physocarpus monogynus	M331Ba01	Little Bighorn – off
Pinus flexilis / Juniperus communis	M331Ba03	Paintrock Creek
Pinus ponderosa / Juniperus communis	M331Ba01	Little Bighorn – off
Pinus ponderosa / Pseudoroegneria spicata	Off LTA	Little Bighorn – off
Artemisia tridentata ssp. *vaseyana / Pseudoroegneria spicata*	M331Bb01	Shell Creek – off
Betula occidentalis /	M331Ba01	Little Bighorn – off
Betula occidentalis	M331Ba01	Little Bighorn – off
Artemisia tridentata ssp. *vaseyana / Festuca idahoensis*	Off LTA	Paintrock Creek – off
Artemisia tridentata ssp. *vaseyana / Festuca idahoensis*	M331Ba03	Paintrock Creek – off

Plant Species of Special Concern

The WYNDD described 44 individual plant species on the BNF (Table 6-4; WYNDD 2000). These species appear on Region 2's Sensitive Species list and/or WYNDDs Species of Special Concern list. For more detailed information, refer to the Plant Abstracts in the WYNDD Report.

Each abstract contains:
- status
- abundance
- trends
- distribution
- highest quality occurrence
- management
- description and taxonomy
- habitat and ecology
- distribution map

Table 6-4. Individual plant species of concern on the Bighorn National Forest (WYNDD 2000). Species with an asterisk (*) are on the R2 Sensitive Species list.

Species	Common Name
Adoxa moschatellin	Moschatel
Agoseris lackschewitzii *	Pink agoseris
Anemone narcissiflora var zephyra	Zephyr windflower
Antennaria aromatica	Aromatic pussytoes
Antennaria monocephala	Single-headed pussytoes
Arnica lonchophylla *	Northern arnica
Asplenium trichomanes-ramosum	Green sleenwort
Aster mollis *	Soft aster
Botrychium crenulatum	Crenulate moonwort
Botrychium lanceolatum	Lance-leaved grapefern
Botrychium minganense	Mingan Island moonwort
Botrychium virginianum	Rattlesnake fern
Carex limosa	Mud sedge
Carex misandra	Short -leaved sedge
Celtis occidentalis	Common hackberry
Cirsium foliosum	Leafy thistle
Cryptogramma stelleri	Fragile rockbrake
Cymopterus williamsii	Williams'waferparsnip
Cypripedium calceolus var. pubescens	Large yellow lady's-slipper

Table 6-4. Individual plant species of concern on the Bighorn National Forest (WYNDD 2000). Species with an asterisk (*) are on the R2 Sensitive Species list.

Species	Common Name
Cypripedium montanum	Mountain lady's-slipper
Draba fladnizensis var pattersonii	White artic witlow-grass
Equisetum sylvaticum	Woodland horsetail
Erigeron allocotus	Bighorn fleabane
Erigeron humilis	Low fleabane
Eriophorum chamissonis	Russet cotton-grass
Eritrichium howardii	Howard forget-me-not
Festuca hallii *	Hall's fescue
Juncus triglumis var triglumis	Three-flower rush
Leptodactylon watsonii	Watson's prickly-phlox
Listera convallarioides	Broad-leaved twayblade
Musineon vaginatum	Sheathed musineon
Papaver kluanense	Alpine poppy
Pedicularis contorta var ctenophora	Coil-beaked lousewort
Pedicularis parryi var mogollonica [reported but not confirmed]	Mogollon lousewort
Pedicularis pulchella	Mountain lousewort
Penstemon caryi *	Cary beardtongue
Physaria lanata	Woolly twinpod
Potamogeton amplifolius	Large-leaved pondweed
Pyrrocoma clementis	Tranquil goldenweed
Rubus acaulis *	Northern blackerry [Nagoonberry]
Sambucus cerulea [reported but not confirmed]	Blue elderberry
Stanleya tomentosa var tomentosa	Hairy prince's-plume
Sullivantia hapemanii var hapemanii *	Hapeman's sullivantia
Triodanis leptocarpa [reported but not confirmed]	Slim-pod Venus' looking-glass
Utricularia minor	Lesser bladderwort

Distribution of the R2 sensitive plant species from Table 6-4 by Landtype Association is tabulated in Table 6-5. Of the eleven LTAs on the Forest, these rare plants occur on all but M331Bb02 and M331Bb04. Greatest concentration of occurrences is on LTAs M331Bb05, M331Ba01, and M331Ba03. At least four of the seven R2 sensitive plant species occur on M331Ba01, 02, 03, 05, and M331Bb05. It should be noted that there is only one occurrence of *Festuca hallii* and two of *Rubus acaulis* on the Forest, and they both can be found on LTA M331Bb05. This LTA also contains six of the seven species of concern as well as the greatest number of occurrences.

Distribution of the R2 sensitive plant species of special concern by Forest Plan Watershed Units is shown in Table 6-6. Greatest concentration of rare plants occurs on the Tongue River and Little Bighorn Units. The Paintrock Creek Unit contains only two of the seven species of concern. *Festuca hallii* and *Rubus acaulis* both can be found on the Clear/Crazy watershed unit.

Table 6-5. Number of occurrences of R2 plant species of special concern on Landtype Associations on the Bighorn National Forest.

Species	M331Ba01	M331Ba02	M331Ba03	M331Ba04	M331Ba05	M331Bb01	M331Bb03	M331Bb05	M331Bb06
Agoseris lackschewitzii	0	1	1	0	3	0	4	13	2
Arnica lonchophylla	2	1	0	1	1	0	0	1	1
Aster mollis	2	4	9	3	5	1	2	4	0
Festuca hallii	0	0	0	0	0	0	0	1	0
Penstemon caryi	2	5	2	0	1	0	0	0	0
Rubus acaulis	0	0	0	0	0	0	1	1	0
Sullivantia hapemanii var. *hapemanii*	9	1	1	1	1	1	0	1	0
Total occurrences	15	12	13	5	11	2	7	21	3

Table 6-6. Number of occurrences of R2 plant species of special concern on Forest Plan Watershed Units on the Bighorn National Forest.

Species	Clear/Crazy	Devil's Canyon	Goose Creek	Little Bighorn	Paintrock Creek	Shell Canyon	Tensleep Canyon	Tongue River
Agoseris lackschewitzii	5	4	3	0	3	1	4	4
Arnica lonchophylla	2	0	1	2	0	1	1	1
Aster mollis	2	4	1	8	2	5	3	5
Festuca hallii	1	0	0	0	0	0	0	0
Penstemon caryi	0	4	0	2	0	2	1	1
Rubus acaulis	2	0	0	0	0	0	0	0
Sullivantia hapemanii var. *hapemanii*	1	1	1	4	0	2	1	5
Total occurrences	13	13	6	16	5	11	10	16

Unique Features – Caves, Cliffs, and Canyons

Caves

The Big Horn Mountains have one of the highest concentrations of known caves in the western United States. Caves in this report are defined as >50 feet in extent or continuing to total darkness. This broad definition includes several thousand karst features on the BNF.

The Bighorn-Dolomite formation is considered the most important rock formation in terms of caves in the Big Horns , containing many large cave systems, as well as hosting most of the fissure type caves found extensively near Medicine Wheel and Boyd Ridge.

The climatic history of the Big Horn Mountains during the last 2 million years has determined the locations and types of caves formed. Pleistocene climates were much wetter than those at present. Glacial run-off may have enlarged caves or debris from glaciers may have plugged previously formed caves.

Humans have more recently exerted influence on cave and cavern development. Activities such as building dams and roads have the most serious impacts on cave systems. More subtle activities, such as logging, grazing and recreational uses can increase sediment loads in streams, thereby potentially filling passageways with debris and sediment or directly changing cave formations or openings.

There are five major caves on the Big Horn Landscape: Tongue River, Cliff Dweller, Torech Ungol Pit, P-Bar, and Eaton's Cave. The Big Horn area also has the deepest cave in the United States (Great X Cave) and one of the best paleontological sites in North America (Natural Trap Cave). Just west of the BNF on the northern end, is the Horsethief-Bighorn Cave system, which is the longest cave system in Wyoming.

The three types of caves on the BNF are: 1) areas of shallow dipping, high altitude caves, usually in the Big Horn Dolomite, 2) active stream cave systems, and 3) caves not currently being enlarged. Caves known as fissure pits represent the first type of cave, which often have greater vertical than horizontal extent. Bones of various animals, predominately small mammals, are relatively common, with some caves containing bison bones. Caves of this type include: Torech Ungol Pit, Medicine Wheel, and MacCaskey Bottomless Pit. These caves are located primarily in the northern part of the Big Horn Mountains near the Medicine Wheel and Boyd Ridge.

Active stream caves are found scattered along the flanks of the Big Horn Mountains. These caves are usually located in or near valley bottoms, exhibiting stream sinks, rise, and stream flowing through part or all of their lengths. These caves are often subject to flooding, and contain a great amount of organic debris. As such they support a greater variety of cave life than other types of caves. Typical active stream caves on the Big Horn landscape include P-Bar and Tongue River Caves.

Inactive caves include caves that may have been active stream caves in the past, but have been isolated through the process of erosion such as Cliff Dweller's Cave. Slow-moving underground waters created other caves, and subsequent surface erosion has exposed entrances to these caves, such as Eaton's Cave.

Evidence of animal use of cave habitats includes many small mammal bones, nesting materials, bat guano, bison bones, bear and coyote scat, and trout.

Cliff and Canyons

Within the BNF, there are extensive uplift areas on the fringe of mountains, and smaller cliff and canyon formations throughout (Fig. 6-2 and Tables 6-7 and 6-8). Nearly 4000 acres of cliffs and canyons occur on Glacial Cirquelands and Sedimentary Breaklands landtype associations. The Clear/Creek, Piney/Rock, and Paintrock Creek watershed units contain the highest coverage of cliffs and canyons. These formations range from short rock bands to cliffs that extend more than 100 feet high. In some cliff habitats there are important plant microsites due to higher moisture. Notable canyons include Tensleep, Tongue, Crazy Woman, Shell, and Devil's

Canyon. Caves are also sometimes associated with the canyons.

Canyons and cliffs can be important migration corridors for avifauna and big game, as well as for nesting raptors. White-throated swifts are generally found foraging for flying insects around cliff habitats. Peregrine falcon and bighorn sheep have historically occupied Shell and Devil's Canyons, but both have been extirpated from the area in the past. Recently, these two species have been restored to the ecosystem, but are at lower population levels than have historically occurred.

Some recreational impacts can occur to these cliff and canyon habitats from activities such as rock climbing, rappelling, road mortality, falconry (actual trapping of raptors) and accidental disturbance. Generally, no other management activities take place in these habitats, except for road construction/upgrading in the larger canyons. Wildfire and prescribed fire may also take place in canyons with enough vegetation to carry a fire. Fires usually improve bighorn sheep habitat, since sheep require early successional stages of vegetation for their needs.

Important Conservation Areas

WYNDD Conservation Sites

The WYNDD delineated 16 Conservation Sites within the BNF that contain a high concentration of important taxa or representative vegetation communities (Fig. 6-3; Table 6-9). Sites are based on any of several factors, such as a high-quality occurrence of a National Forest-Sensitive species, a concentration of several rare species, or the presence of important habitat or vegetation communities. Biological information is used to prioritize the sites according to the rarity of the species within them, the quality of each population, and the urgency of protection. These are areas that may be considered for special management designation, or they may be used to identify areas that are sensitive to certain management activities. For more detailed information, refer to Biological Area Abstracts in the WYNDD report (2000). Each abstract contains:

- Area rank
- Area purpose and significance, including the conservation importance of the species in the site.
- Site description (including counties, quad maps, and acres)
- Management information
- Other considerations
- Information needs
- List of species found at the site and their conservation ranks

Although many of the Biological Area Abstracts do not list wide-ranging animals in their species lists, it should be understood that species such as marten, fisher, and bighorn sheep will be found in many places on the BNF in varying densities, including many of the WYNDD conservation sites.

Two Conservation Sites have a ranking of B2/B3 (very high significance to high significance, respectively): Leigh Canyon and Virginia Creek. Leigh Canyon has good to excellent populations of five rare plants (*Erigeron allocotu*s, *Sullivantia hapemanii* var. *hapemanii,Asplenium trichomanes-ramosum,Adoxa moschatellina,Leptodactylon watsonii;*see (WYNDD 2000). The high quality of these populations derives in part from their inaccessibility and large degree of natural protection. Leigh Canyon overlaps with Tensleep Canyon potential RNA and is near the Nature Conservancy's Tensleep Preserve.

Virginia Creek area contains a wide variety of relatively low impacted alpine and subalpine habitats, unique geological features and populations of rare plant species, including three Region 2 Sensitive Species (*Agoseris lackschewitzii,Symphyotrichum molle,Arnica lonchophyll*a; (WYNDD 2000). The Cloud Peak Wilderness Area lies just to the north of this site and the Virginia Creek drainage overlaps with McClain Lake potential RNA.

Four of the Conservation Sites (CS) overlap with potential RNAs (Fig. 6-3): Cedar Creek CS overlaps with the Elephant Head potential RNA; Dry Fork CS with Dry Fork potential RNA; Mann Creek CS with Mann Creek potential RNA and Medicine Mountain CS with Devil's Canyon potential RNA

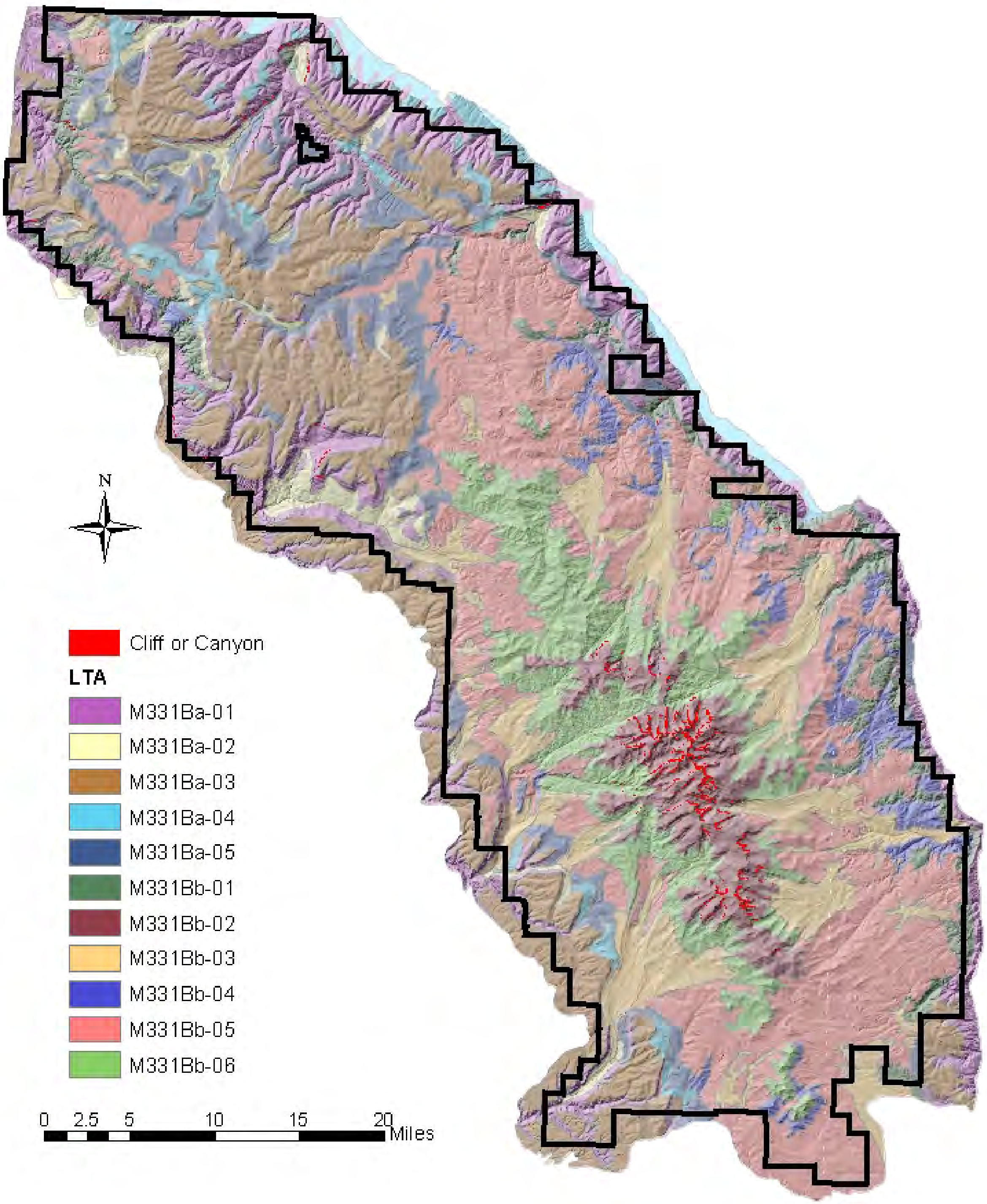


Figure 6-2. Cliff and canyon locations within the Bighorn National Forest.

Table 6-7. Distribution of Cliffs and Canyons across Landtype Associations (LTAs) on Bighorn National Forest.

LTA	LTA Description	Acres of Cliffs and Canyons
M331Bb-02	Glacial Cirquelands	**3485**
M331Ba-01	Sedimentary Breaklands	**503**
M331Bb-06	Alpine Mountain Slopes and Ridges	**126**
M331Bb-01	Granitic Breaklands	**116**
M331Ba-03	Sedimentary Mountain Slopes, Limestone/Dolomite	**16**
M331Ba-02	Landslide/Colluvial Deposits	**15**
M331Ba-05	Sedimentary Mountain Slopes, Shale/Sandstone (Noncalcareous)	**7**
M331Bb-04	Granitic Mountain Slopes, Steep	**4**
M331Bb-05	Granitic Mountain Slopes, Gentle	**3**
M331Ba-04	Sedimentary Mountain Slopes, Shale/Sandstone (Calcareous)	**2**

Table 6-8. Distribution of Cliffs and Canyons across Forest Plan Watershed Units on Bighorn National Forest.

Forest Plan Watershed Unit	Acres of Cliffs and Canyons
Clear/Crazy	1102
Piney/Rock	1064
Paintrock Creek	922
Tensleep Creek	313
Goose Creek	273
Little Bighorn	249
Shell Creek	184
Devil’s Canyon	108
Tongue River	61

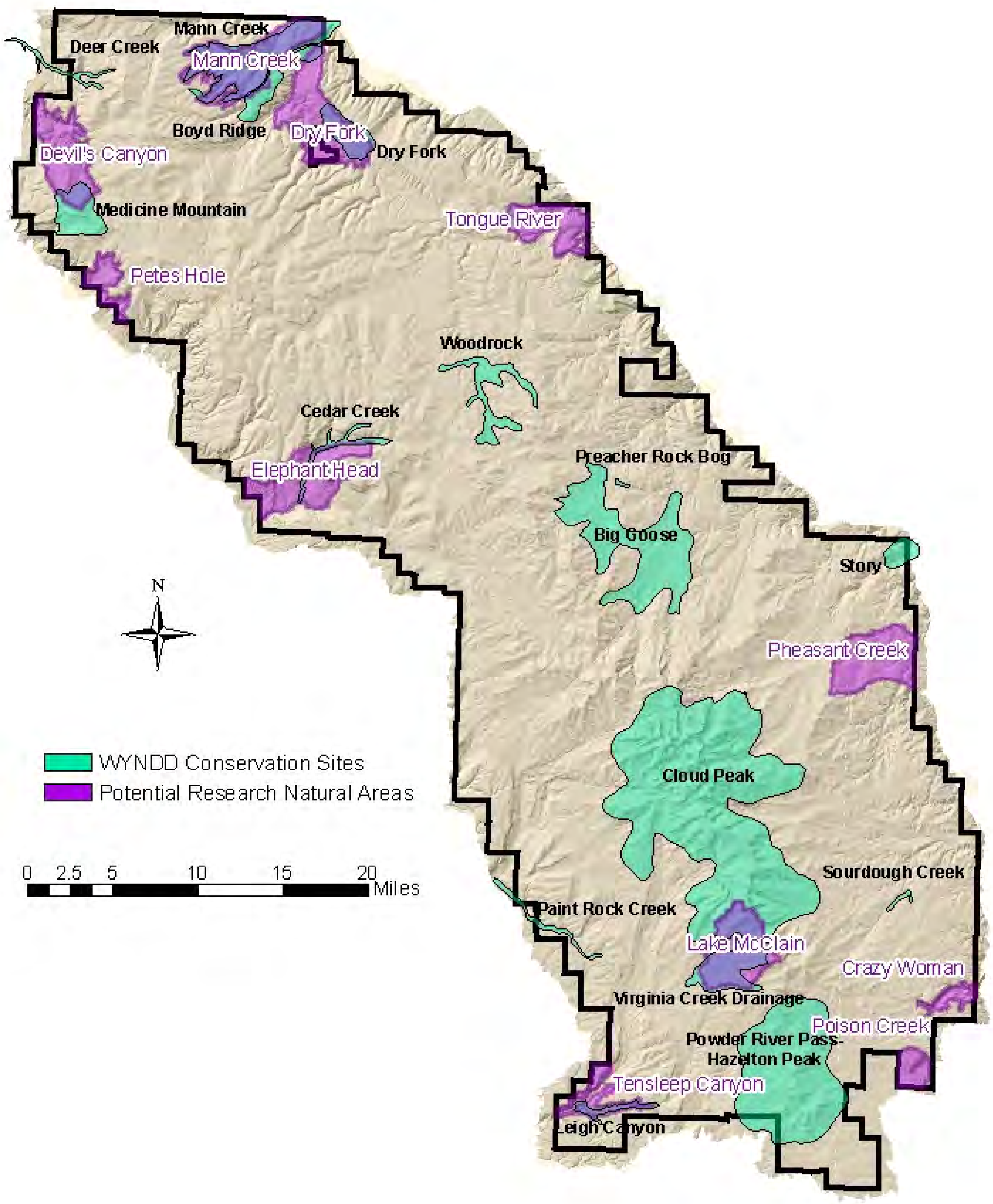


Figure 6-3. Location and names of WYNDD conservation sites and potential Research Natural Areas (RNAs) and their overlap across the Bighorn National Forest.

Table 6-9. A list of WYNDD Conservation Sites, acres, ranking code, and predominate cover type (forest and non-forest), site species tracked, site species G/S ranks and primary area purpose/significance for the Bighorn National Forest.

Conservation Site	Acres	Ranking Code	Predominant Cover Type: Forest (%)/Non-forest (%)	Species Tracked	Site Species G/S Ranks	Primary Area Purpose/Significance
Big Goose	18,849	B4	Lodgepole (70%)/ bare ground (5%)	Common loon Water Vole N. Leopard frog Wood frog Mill Creek agoseris	G5/S2B G5/S2S3 G5/S3 G5/S2 G4/S3	One of only 2 mountain ranges with wood frogs. This site contains largest, best-quality populations currently known in this mountain range. Wetland communities around Dome Lake Reservoir are in excellent condition.
Boyd Ridge	3,108	B3	Douglas fir (18%)/ Grass (36%)	Soft aster Greater yellow lady's slipper Big Horn fleabane Howard's alpine forget-me-not Sheathed wild parsley	G3/S3 G5/S1S2 G3/S2S3 G4/S1 G3?/S2	This site captures open meadows and ridge tops on Boyd Ridge and a small portion of the steep slopes of Little Bighorn Canyon. Provides habitat for soft aster, populations of three regionally endemic species and 1 disjunct species.
Cedar Creek	1,613	B3	Douglas fir (60%)/ Grass (13%)	Yellowstone cutthroat trout	G4T2/S2	Population of YCT, which is within the historic native range of the species, is genetically pure.
Cloud Peak	69,635	B2	Spruce/Fir (14%)/ Bare rock (64%)	Golden-crowned kinglet Narcissa windflower Singlehead pussytoes Austrian draba Artic alpine fleabane Threeflower rush Rooted poppu Coiled lousewort Moutain lousewort	G5/S3 G5T4/S1 G4G5/S1 G4T2T3/S2 G4/S2 G5T5/S1 G3?/S2 G5T3/S2 G3/S2	Area contains nine tracked species, most of which are only moderately rare.
Deer Creek	948	B4	Douglas fir (25%)/ Deer Creek (22%)	Yellowstone cutthroat trout	G4T2/S2	Boundary captures occurrence of YCT and the stream reaches above and below it.
Dry Fork	3,356	B3	Douglas fir (45%)/ Big sagebrush (17%)	Soft aster Bighorn fleabane Hapeman's coolwort	G3/S3 G3/S2S3 G3T3/S3	This site is based on part of a long, relatively inaccessible calcareous ridge with populations of Big Horn fleabane, Hapeman's coolwort and large, almost continuous populations of soft aster

Leigh Canyon	1,263	B2/B3	Douglas fir (56%)/ Big sagebrush (1.9%)	Muskroot Brightgreen spleenwort Big Horn fleabane Watson's prickly phlox Hapeman's coolwort	G5/S1 G4/S2 G3/S2S3 G3?/S1 G3T3/S3	Has good to excellent populations of five rare plants.
Mann Creek	10,755	B3	Douglas fir (30%)/ Grass (12%)	Rubber boa Yellowstone cutthroat trout Longleaf arnica Soft aster Mingan moonwort Rattlesnake fern Fragile rockbrake Cary's beardtongue Hapeman's colwort	G5/S2S2 G4T2/S2 G4/S2 G3/S3 G4/S1 G5/S1 G5/S1 G3/S2 G3T3/S3	Site rank is based on the presence of high quality occurrences of six rare plant species. In addition, YCT was found in the area. Site also includes occurrences of plant associates typical of the lower elevations of the Bighorn Mountains.
Medicine Mountain	4,337	B3	Spruce/Fir (41%)/ Big Sagebrush (22%)	Mill Creek agoseris Scented pussytoes Soft aster Coiled lousewort Cary's beardtongue Common tyinpod	G4/S3 G4/S2S3 G3/S3 G5T3/S2 G3/S2 G5T2/S2	This area contains an unusual concentration of six rare plants, three of which are Region 2 sensitive species.
Paint Rock Creek	1,208	B3	Douglas fir (52%)/ Grass (20%)	Yellowstone cutthroat trout	G4T2/S2	Genetically pure population of YCT within historic native range.
Powder River Pass-Hazelton Peak	26,565	B3	Lodgepole (52%)/ Grass (15%)	Short-eared owl Three-toed woodpecker Golden-crowned kinglet Mill Creek agoseris Longleaf arnica Coiled lousewort	G5/S2S3 G5/S3 G5/S3 G4/S3 G4/S2 G5T3/S2	Area has good populations of Mill Creek agoseris and other species being tracked.
Preacher Rock Bog	116	B4	Lodgepole (62%)/ Grass (27%)	Mill Creek agoseris Woodland horsetail Chamisso's cottongrass	G4Q/S3 G5/S1 G5/S1	One of few bogs in the Bighorn Range and contains the only occurrence of woodland horsetail and Chimisso's cottongrass in these mountains.
Sourdough Creek	280	B3	Lodgepole (61%)/ Grass (22%)	Mill Creek agoseris Lanceleaf grapefern Dwarf raspberry	G4Q/S3 G4/S1 G5/S1	The Sourdough Creek watershed is the only know extant location of the Bighorns for dwarf raspberry.
Story	1,580	B3	Ponderosa (47%)/ shrub (1%)	Greater yellow lady's slipper Mountain lady's slipper Broadlipped twayblade	G5/S1S2 G4G5/S1 G5/S1	This site contains good to excellent occurrences of mountain lady's slipper and several other species that are rare in the state.

Virginia Creek Drainage	5,305	B2/B3	Spruce/Fir (42%)/ Grass (22%)	Mill Creek agoseris Longleaf arnica Soft aster Shortleaved sedge Coiled lousewort	G4/S3 G4/S2 G3/S3 G4/S1 G5T3/S2	This area contains a wide variety of relatively unimpacted alpine and subalpine habitats, unique geological features, and populations of rare plant species, including 3 Region 2 sensitive species.
Woodrock	4,395	B3	Lodgepole (54%)/ Forb (%)	Common loon Columbia spotted frog Wood frog Mill Creek agoseris Soft aster	G5/S2B,SZN G4/S2S3 G5/S2 G4/S3 G3/S3	Wood frog is known from four locations scattered throughout the site, and there are two locations of Columbian spotted frog. These occurrences represent rare subpopulations of the two vertabrate species of highest conservation concern in the Bighorn Range.

Research Natural Areas

There are currently two Research Natural Areas (RNAs) on the BNF (Table 6-10). The *Festuca idahoensis/Festuca kingii* plant community, which has a conservation rank of G2, is known to occur on the Bull Elk Park RNA. A more complete description of these and other RNAs in Forest Service Region 2 can be found in Ryan *et al.* (1994).

Table 6-10. Selected features of Bighorn National Forest Research Natural Areas.

Name	Acres	Date Established	Special Features
Bull Elk Park	728	1952	201 acres of disjunct Palouse Prairie Climax; *Agropyron-Festuca* association. Remainder of area is primarily lodgepole pine montane forests.
Shell Canyon	738	1987	Primary reason for establishment is Rocky Mountain juniper community. Most other sites have been seriously disturbed, and Shell is considered to be in good condition.

Initial identification of additional areas for potential RNA (pRNA) designation began about 1994, when several forest resource specialists met to identify areas on the BNF that met the RNA selection criteria (USFS Region 2). Eleven areas were selected (Fig. 6-3): Crazy Woman Canyon, Devil's Canyon, Dry Fork, Elephant Head, Leigh Creek, Mann Creek, McClain Lake, Pete's Hole, Pheasant Creek, Poison Creek, Tongue River.

The BNF contracted with the WYNDD to conduct ecological evaluations. The ecological evaluations included: field review by WYNDD botanists, ecologists, and/or wildlife biologists; interaction with Forest Service and Wyoming Game and Fish specialists; and review of pertinent vegetation and animal databases. National Forest and Wyoming Game and Fish specialists reviewed initial drafts of the ecological evaluations. Upon receipt of the ecological evaluations, most of the pRNAs were field reviewed by Tom Andrews (former Region 2 RNA ecologist), Bernie Bornong (Bighorn National Forest RNA coordinator), and usually the appropriate district ranger. Key information about each pRNA from the ecological evaluations is summarized in Table 6-11. The ecological evaluations are 30 to 50 pages long and contain detailed information about the pRNAs; they are available at the Forest Service office in Sheridan.

Lodgepole is the predominate cover type in the Crazy Woman, Pheasant Creek, and Poison Creek pRNAs at 58, 76 and 65 percent, respectively. Douglas fir is the predominant cover type in the Devil's Canyon (51 percent), Dry Fork (61 percent), Elephant Head (36 percent), Mann Creek (30 percent), Pete's Hole (61 percent), and Tensleep (51 percent) pRNAs. Ponderosa pine is the predominant cover type for the Tongue River pRNA at 46 percent and spruce-fir at 38 percent for Lake McClain. Short narratives describing each pRNA including locator maps and CVU cover type by acreage and percentage are in Appendix A.

Table 6-11. Size, cover types, soil, quality, condition, viability, and defensibility of potential Research Natural Areas on the Bighorn National Forest.

Potential RNA	Size (acres)	Major Cover Types	Soil Substrate	Quality	Condition	Viability	Defensibility
Crazy Woman Creek	1,589	Lodgepole pine, ponderosa pine, cottonwood, shrub	50% Sedimentary 50% Granite	Types quite variable; not in RNAs	Slopes good; riparian bottom is poor	Fire needed in ponderosa pine	Road in bottom bisects area; not defensible.
Devil's Canyon	8,286	Spruce/Fir, Douglas-fir, limber pine, aspen, grassland, sage	75% Sedimentary 25% Granite	Wide variety of ecosystem types	Most is "remarkably undisturbed"; trail	Medicine Wheel NHL boundary may affect south portion	Canyon good; south end poor.
Dry Fork	11,419	Douglas-fir, grassland, sage, limber pine	Sedimentary	Wide variety of ecosystem types	Many types have exotics present; timothy up to 15% in grass/shrub	Douglas-fir "stable seral", so may persist; exotics may lead to change	Most of area "easily protected"
Elephant Head	9,550	Grassland, spruce/fir, sage, Rocky Mountain juniper, cottonwood	Sedimentary	Wide variety of ecosystem types	Exotics are sometimes dominant along trail	Exotics may continue to increase	Cliffs secure; Beef Trail may be indefensible
Leigh Creek (Tensleep)	3,124	Douglas-fir, cottonwood, shrub/sage	Sedimentary	Types are not represented in RNAs	Largely pristine	Likely to remain viable	Highly defensible; almost inaccessible
Mann Creek	11,368	Douglas-fir, grassland, ponderosa pine, limber pine, shrub	Sedimentary	Good representation of limestone canyon habitats	Exotics present, major in only a few mesic grasslands; needs fire	No immediate threats noted; will need fire; trout protection	Steep rough terrain; little access
McClain Lake	9,533	Alpine, lodgepole pine, spruce-fir	Granite	Variety of upper subalpine and alpine ecosystems	Little alteration from pre-settlement conditions	Baby Wagon meadow is human access point; little influence now	4-wheel drive access to south end; snowmobile trail through SW corner.
Pete's Hole	2,842	Spruce/Fir, sage, Douglas-fir, limber pine	80%+ Sedimentary <20% Granite	Types are variable and not represented in RNAs	Exotics and human impacts in meadows	Forests stable; grasslands impacted	Relatively defensible; difficult access.
Pheasant Creek	9,403	Lodgepole pine	90%+ Granite <10% Sedimentary	Large and least impacted Lodgepole Pine/vaccinium type; very homogeneous; may not define range	Good; minimal human impacts	Lodgepole pine seral to spruce-fir? Natural processes appear intact	Difficult access; impacts primarily along trails
Poison Creek	2,328	Lodgepole pine, grassland, aspen	85% Granite 15% Sedimentary	Good lodgepole pine/vaccinium community	Poor; high evidence of human use	Poor; exotic species, roads, grazing, logging	"Poorly suited for research"
Tongue River	5,909	Douglas-fir, grassland, ponderosa pine, cottonwood, limber pine	80% Sedimentary 20% Granite	Wide variety of ecosystem types	7% impacted by exotics; trails	Heavy human use and evidence of past use	Probably indefensible with trails

Natural Disturbance Risk on Conservation and Research Natural Areas

All of the 16 Conservation Sites identified by WYNDD on the BNF contain areas of high wildfire hazard, high departure from historical fire regimes, and/or high insect risk (Fig. 6-4, Table 6-12). Of the 16 sites, Powder River Pass/Hazelton Creek has the most area in each of the three categories. Big Goose and Mann Creek also contain large acreages of ecosystems in the three categories. In contrast, Preacher Lake Bog and Sourdough Creek have the fewest acres in the three categories.

In terms of wildfire hazard, Powder River Pass/Hazelton Creek exhibits the highest acreage with high wildfire hazard under dry conditions. Big Goose and Mann Creek also exhibit large areas with high wildfire hazard, while Preacher Rock Bog and Paintrock Creek exhibit the fewest acres with high wildfire hazard (Table 6-12). Powder River Pass/Hazelton Creek has the largest area at high risk to insect damage, as do Mann Creek, Big Goose, and the Virginia Creek Drainage. Notably, although it has relatively few acres with high wildfire hazard or at high departure from historical fire regimes, Story has a relatively large area at high risk to insects. Cloud Peak and Medicine Mountain also have relatively large acreage in all three disturbance categories, although this may be in part due to differences in site area.

Of the 11 potential NRAs, Elephant Head has the largest area extremely departed from its historical fire regime (Table 6-13, Fig. 6-5). Mann Creek, Dry Fork, and Devil's Canyon have the highest total acreage of ecosystems in the three high-risk categories. In contrast, Poison Creek, Clear/Crazy Woman Creek, and Petes Hole had the fewest total acres in the three high-risk categories.

For wildfire hazard, Devil's Canyon exhibits the highest acreage with high wildfire hazard under dry conditions, as does Elephant Head. Pheasant Creek and Dry Fork also exhibit large areas high wildfire hazard. Poison Creek has the fewest acres with high wildfire hazard (Table 6-13). Mann Creek has the largest area at high risk to insect damage, as do Dry Fork and Devil's Canyon. Poison Creek has very few acres at high risk to insect damage.

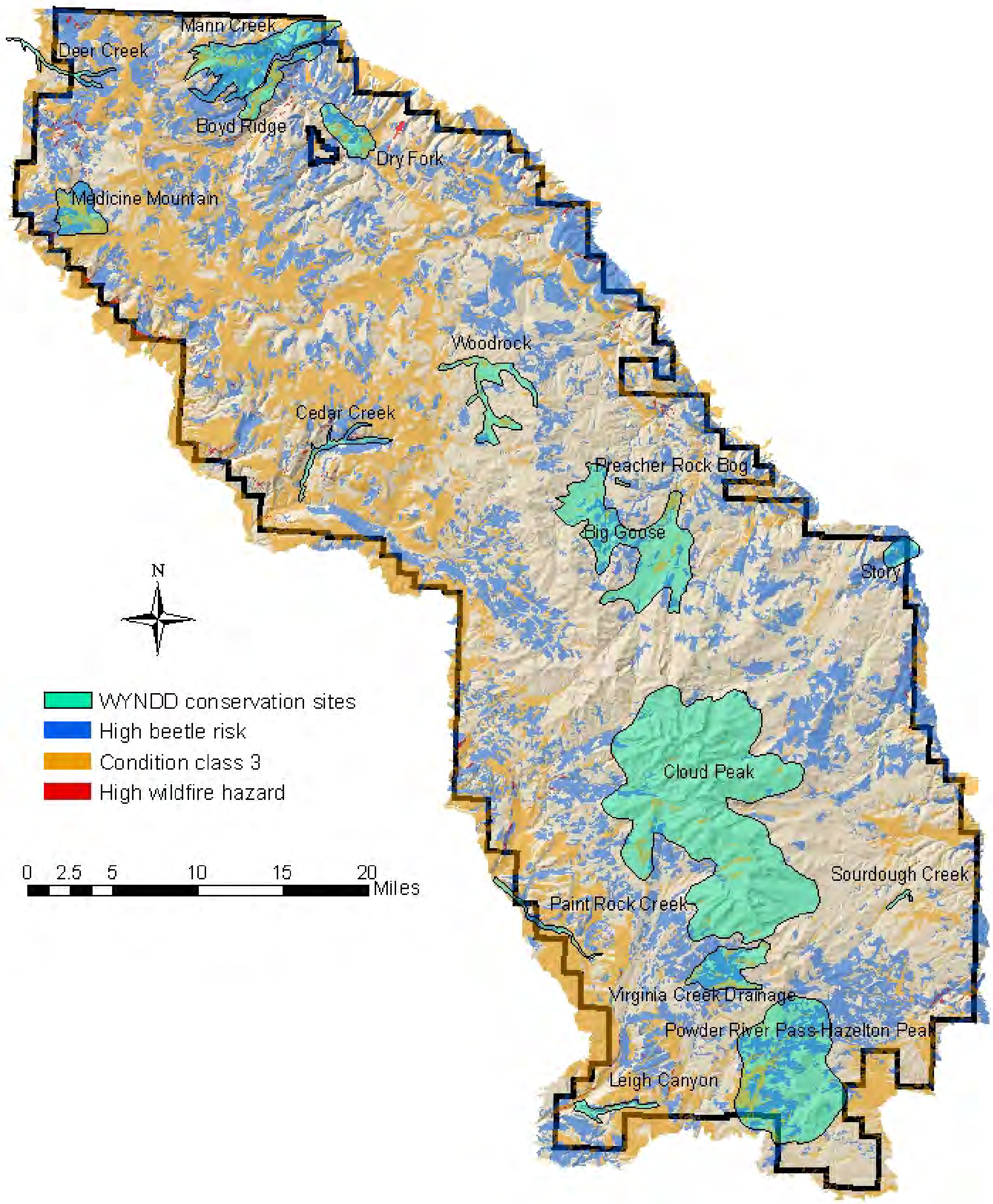


Figure 6-4. Geographic location of WYNDD Conservation Sites in relation to areas of high wildfire hazard under dry conditions, high departure from historical fire regimes (Condition Class 3), and high insect damage risk.

Table 6-12. Acreage of WYNDD Conservation Sites showing high departure from historical fire regimes or at high risk to wildfires and/or insect damage on the Bighorn National Forest. Hectares are in parentheses.

WYNDD Conservation Site	High Departure from Historical Regime	High Wildfire Hazard	High Insect Damage Risk
Big Goose	1,341 (543)	4,975 (2,013)	3,465 (1,402)
Boyd Ridge	1,209 (489)	589 (238)	954 (386)
Cedar Creek	240 (97)	780 (316)	554 (224)
Cloud Peak	1,705 (690)	1,643 (665)	1,921 (777)
Deer Creek	235 (95)	316 (128)	291 (118)
Dry Fork	834 (338)	813 (329)	1,068 (432)
Leigh Canyon	25 (10)	794 (321)	377 (153)
Mann Creek	1,490 (603)	2,075 (840)	5,850 (2,367)
Medicine Mountain	1,809 (732)	1,101 (446)	1,990 (805)
Paintrock Creek	396 (160)	97 (39)	262 (106)
Powder River Pass/Hazelton Creek	2,892 (1,170)	9,046 (3,661)	9,496 (3,843)
Preacher Rock Bog	45 (18)	14 (6)	7 (3)
Sourdough Creek	62 (25)	113 (46)	0
Story	9 (4)	484 (196)	1,178 (477)
Virginia Creek Drainage	1,020 (413)	1,842 (745)	2,586 (1,047)
Woodrock	825 (334)	1,758 (711)	323 (131)

Table 6-13. Acreage of current and potential Research Natural Areas showing high departure from historical fire regimes or at high risk to wildfires and/or insect damage on the Bighorn National Forest. Hectares are in parentheses. RNA 10A is the only current research natural area on the Forest with high departure or at high hazard or risk acreage.

Current/Potential Research Natural Area	High Departure from Historical Regime	High Wildfire Hazard	High Insect Damage Risk
10A (Current)	232 (94)	225 (91)	46 (19)
Crazy Woman Creek	137 (55)	1,083 (438)	690 (279)
Devil's Canyon	1,132 (458)	4,253 (1,721)	4,058 (1,642)
Dry Fork	1,170 (473)	3,490 (1,412)	4,293 (1,737)
Elephant Head	2,383 (964)	4,162 (1,684)	1,331 (539)
Lake McClain	816 (330)	2,312 (936)	2,918 (1,181)
Mann Creek	1,734 (702)	2,347 (950)	5,998 (2,427)
Petes Hole	226 (91)	864 (350)	972 (393)
Pheasant Creek	133 (54)	3,911 (1,583)	2,642 (1,069)
Poison Creek	223 (90)	511 (207)	20 (8)
Tensleep Canyon	654 (265)	1,634 (661)	482 (195)
Tongue River	870 (352)	1,681 (680)	3,018 (1,221)

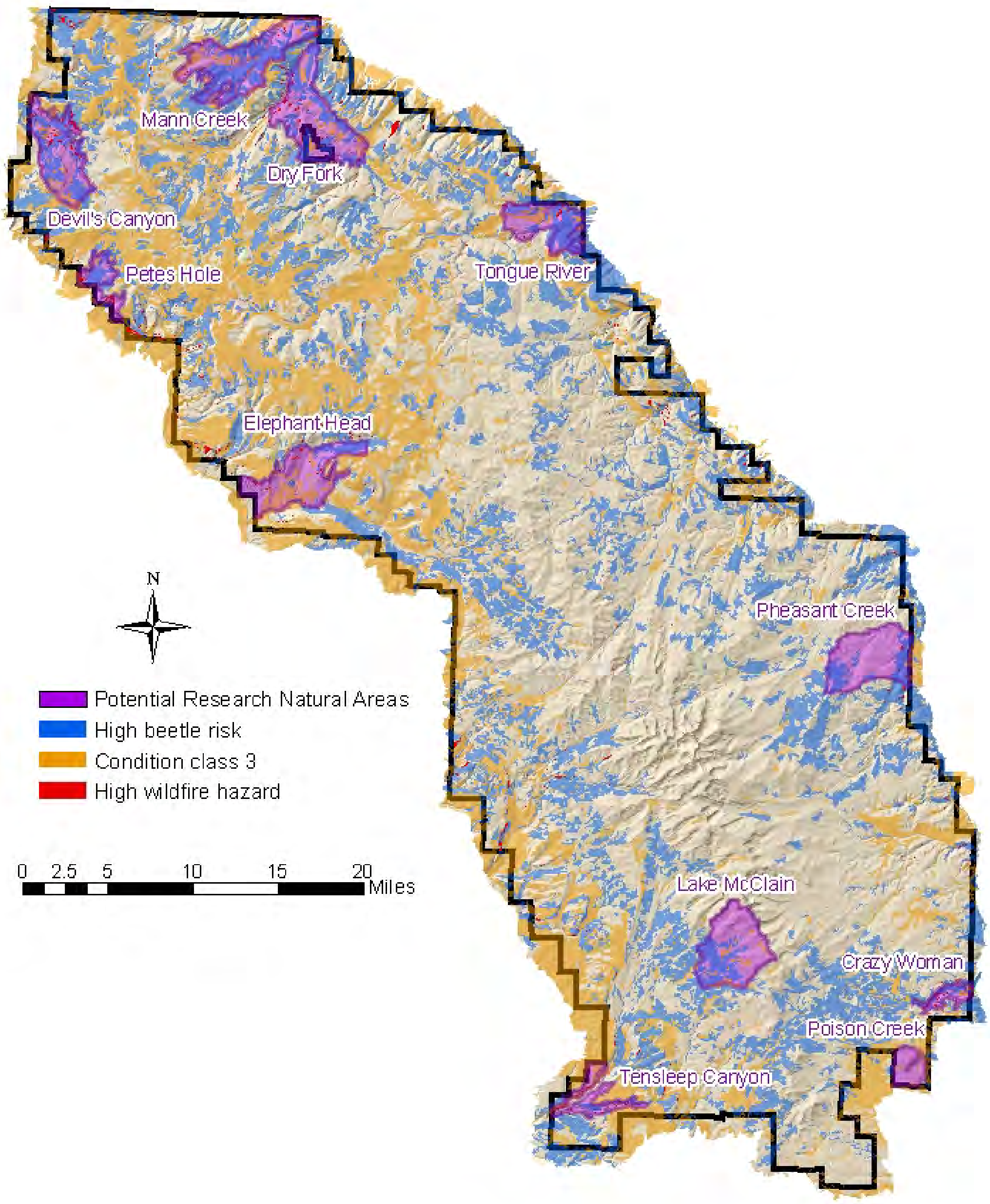


Figure 6-5. Geographic location of current and potential Research Natural Areas in relation to areas of high wildfire hazard under dry conditions, high departure from historical fire regimes (Condition Class 3), and high insect damage risk.

Representation of Bighorn National Forest Vegetation

The vegetative composition of the total pRNA network differs from that on the entire Bighorn National Forest (Fig. 6-6). The lodgepole pine and grassland communities tend to be underrepresented in the pRNA network. However, the existing Bull Elk Park RNA is over 25% grassland and may compensate for the limited amount on the pRNAs. The Douglas-fir community is overrepresented on the pRNAs, occupying 30% of the pRNA network, but only 9% of the Bighorn National Forest. The proportions of other plant communities on the Forest are approximately equivalent to their respective proportions on the Forest.

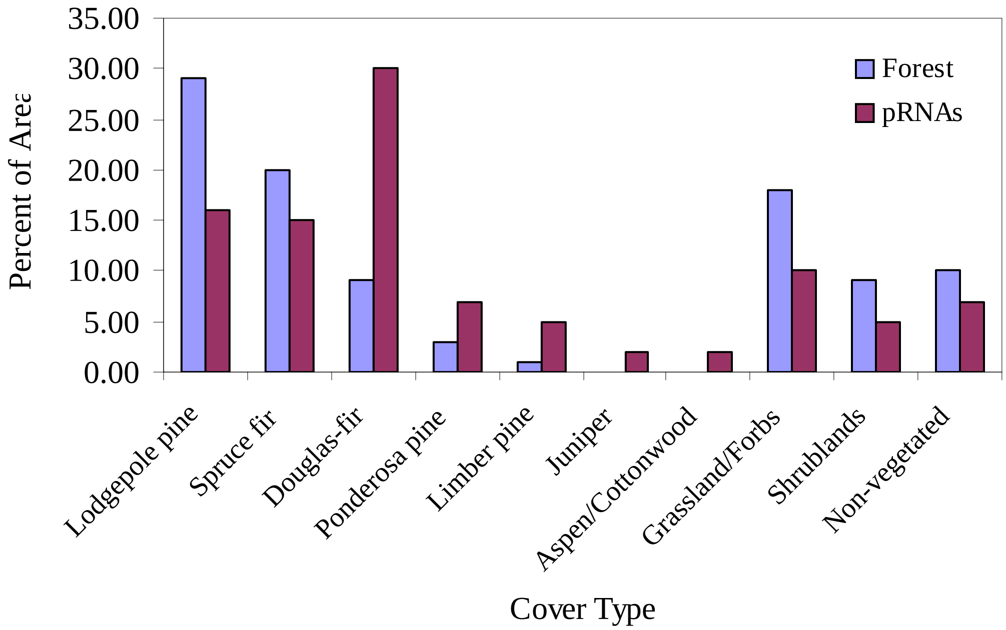


Figure 6-6. Vegetation composition comparison between the total BNF and total pRNA area.

Representation of Plant Species of Special Concern

Of the seven Region 2 Plant Species of Special Concern, all except *Festuca hallii* have been recorded on a Conservation Site (Table 6-14). *Rubus acaulis* was found only on the Sourdough Creek Area, while *Penstemon caryi* was found on Mann Creek and Medicine Mountain areas. *Agoseris lackshewitzii* and *Aster mollis* are fairly well represented, occurring on seven and six of the areas, respectively.

Table 6-14. Occurrence of Plant Species of Special Concern on Conservation Site network.

Species	Big Goose Creek Area	Boyd Ridge Area	Cedar Creek Area	Cloud Peak Area	Deer Creek Area	Dry Fork Area	Leigh Canyon Area	Mann Creek Area	Medicine Mountain Area	Paint Rock Area	Powder River Pass-Hazelton Area	Preacher Rock Area	Sourdough Creek Area	Story Area	Virginia Creek Area	Woodrock Area
Agoseris lackschewitzii	X								X		X	X	X		X	X
Arnica lonchophylla								X			X				X	X
Aster mollis		X				X		X	X						X	X
Festuca hallii																
Penstemon caryi								X	X							
Rubus acaulis													X			
Sullivantia hapemannii var. *hapemanii*						X	X	X								

Representation of Plant Communities of Special Concern

Of the 26 vegetation types identified by WYNDD as being of special concern, 20 may be found within the pRNA system (Table 6-15). Those not represented include:

Carex elynoides
Salix boothii
Salix eastwoodiae
Salix geyeriana
Salix wolfii
Carex rostrata

Mann Creek and McClain Lake contain eight and seven types, respectively. Devil's Canyon, Dry Fork, and Elephant Head each contain six vegetation types, while Tensleep Canyon and Tongue River both contain five.

Table 6-15. Occurrence of the 20 vegetation types present on the potential Research Natural Areas.

	Crazy Woman Creek	Devil's Canyon	Dry Fork	Elephant Head	Mann Creek	McClain Lake	Pete's Hole	Pheasant Creek	Poison Creek	Tensleep Canyon	Tongue River
SUBALPINE											
Abies lasiocarpa – Picea engelmannii		X			X	X	X				
Picea engelmannii (upland / riparian / both?)						X	X				
Pinus contorta	X		X	X		X		X	X		
Populus tremuloides		X	X		X				X		
Salix planifolia						X					
Calamagrostis canadensis									X		
Carex aquatilis						X					
Deschampsia cespitosa						X		X			
MONTANE											
Pinus ponderosa	X				X			X			X
Pinus flexilis		X	X		X		X			X	X
Pseudotsuga menziesii		X	X		X					X	X
Populus angustifolia	X			X				X			X
Betula occidentalis					X						
Cornus sericea										X	
Festuca idahoensis		X		X	X	X			X		
FOOTHILLS											
Artemisia nova				X							
Artemisia tridentata ssp. *vaseyana*		X	X	X	X		X			X	
Cercocarpus ledifolius	X			X						X	X
Elymus spicatus			X								
Total	4	6	6	6	8	7	4	4	4	5	5

Of the seven Region 2 Plant Species of Special Concern, all except *Festuca hallii* and *Rubus acaulis* are found on a pRNA (Table 6-16). *Agoseris lackshewitzii* is only found at McClain Lake. *Aster mollis* is best represented, occurring on 8 of the 11 areas.

Table 6-16. Occurrence of Plant Species of Special Concern on the potential Research Natural Area network.

Species	Crazy Woman Creek	Devil's Canyon	Dry Fork	Elephant Head	Mann Creek	McClain Lake	Pete's Hole	Pheasant Creek	Poison Creek	Tensleep Canyon	Tongue River
Agoseris lackschewitzii						X					
Arnica lonchophylla	X				X	X					
Aster mollis		X	X	X	X	X	X		X		X
Festuca hallii											
Penstemon caryi				X	X					X	
Rubus acaulis											
Sullivantia hapemannii var. *hapemanii*	X		X	X	X					X	X

Significant Information Gaps

Several information gaps and high-priority information needs have been identified:

(1) There is a lack of information on management activities and their relationship to plant communities of special concern on the Forest.

(2) There are no data available on the location of caves despite the importance of caves in this region.

(3) Data on existing RNAs is limited.

(4) There is data discrepancy between WYNDD Plant Associations and GAP data used for tables and maps.

Key Findings

Vegetation Types or Species of Special Concern

(1) The mountain willow *(Salix eastwoodiae)* shrub vegetation type is represented solely by rare or uncommon associations.

(2) The redosier dogwood (*Cornus sericea)* riparian shrub type and curl-leaf mountain mahogany (C*ercocarpus ledifolius)* upland shrub type are listed as only located within the BNF.

(3) Of the seven Region 2 Plant Species of Special Concern, all except *Festuca hallii* and *Rubus acaulis* are found on a potential RNA. *Agoseris lackshewitzii* is only found at McClain Lake. *Aster mollis* is best represented, occurring on 8 of the 11 areas.

Areas with High Concentration of Plant Species of Special Concern

(1) The greatest concentration of the occurrences of Plant Species of Special Concern are on gentle granitic mountain slopes, granitic breaklands, and limestone/dolomite sedimentary mountain slopes on Tongue River and Little Big Horn Watershed Units.

(2) The rarest species of concern, *Festuca hallii* and *Reubus acaulis*, occur on the gentle granitic mountain slopes on the Clear/Crazy Watershed Unit.

(3) Of the seven Region 2 Plant Species of Special Concern, all except *Festuca hallii* have been recorded on a Conservation Site. *Rubus acaulis* was found only on the Sourdough Creek Area, while *Penstemon*

caryi was found on Mann Creek and Medicine Mountain areas. *Agoseris lackshewitzii* and *Aster mollis* are fairly well represented, occurring on seven and six of the areas, respectively.

(4) Leigh Canyon Conservation Site has good to excellent populations of five rare plants (*Erigeron allocotu*s, *Sullivantia hapemanii* var. *hapemanii, Asplenium trichomanes-ramosum, Adoxa moschatellina, Leptodactylon watsonii;*see (WYNDD 2000). The high quality of these populations derives in part from their inaccessibility and large degree of natural protection.

(5) Virginia Creek area contains a wide variety of relatively lightly impacted alpine and subalpine habitats, unique geological features and populations of rare plant species, including three Region 2 Sensitive Species (*Agoseris lackschewitzii, Symphyotrichum molle, Arnica lonchophyll*a).

(6) The *Festuca idahoensis/Festuca kingii* plant community, which has a conservation rank of G2, is known to occur on the Bull Elk Park RNA.

(7) The lodgepole pine and grassland communities tend to be underrepresented in the pRNA network. However, the existing Bull Elk Park RNA is over 25% grassland and may compensate for the limited amount on the pRNAs. The Douglas-fir community is over-represented on the pRNAs, occupying 30% of the pRNA network, but only 9% of the Bighorn National Forest.

Unique Landscape Features of Concern

(1) There are five major caves on the Big Horn Landscape: Tongue River, Cliff Dweller, Torech Ungol Pit, P-Bar, and Eaton's Cave. The Big Horn area has the deepest cave in the United States (Great X Cave) and one of the best paleontological sites in North America (Natural Trap Cave). Just west of the BNF on the northern end, is the Horsethief-Big Horn Cave system, which is the longest cave system in Wyoming.

(2) Nearly 4000 acres of cliffs and canyons occur on Glacial Cirquelands and Sedimentary Breaklands landtype associations. The Clear/Creek, Piney/Rock, and Paintrock Creek watershed units contain the highest coverage of cliffs and canyons.

Conservation Sites and Research Natural Areas

(1) Several areas fall within the boundaries of WYNDD Conservation Sites or current and/or potential Research Natural Areas.

Literature Cited

Anderson, M., P. Bourgeron, M.T. Bryer, R. Crawford, L. Engelking, D. Faber-Langendoen, M. Gallyoun, K. Goodin, D.H. Grossman, S. Landaal, K. Metzler, K.D. Patterson, M. Pyne, M. Reid, L. Sneddon, and A.S. Weakly. 1998. International Classification of Ecological Communities: Terrestrial Vegetation of the United States, Volume II The National Vegetation Classification System: List of Types. The Nature Conservancy.

Girard, Michele, David L. Wheeler, and Stephanie B. Mills. 1997. Classification of riparian communities on the Bighorn National Forest. USDA Forest Service, Rocky Mountain Region, R2-RR097-02.

Hoffman, George R. and Robert R. Alexander. 1976. Forest vegetation of the Bighorn Mountains, Wyoming: a habitat type publication. USDA Forest Service Research Paper RM-170. Rocky Mountain Forest and Range Experiment Station, Fort Collins CO. 38 pp.

Hunter, M.L., Jr. 1991. Coping with ignorance: the coarse-filter strategy for maintaining biodiversity. *In* K.A. Kohm, editor, Balancing on the Brink of Extinction: the Endangered Species Act and Lessons for the Future. Island Press, Washington D.C. 266-281 pp.

MacArthur, R.H. and E.O. Wilson. 1967. The Theory of Island Biogeography. Princeton University Press, Princeton, N.J. 203 p.

Ryan, Michael G., Linda A. Joyce, Tom Andrews, and Kate Jones. 1994. Research Natural Areas in Colorado, Nebraska, South Dakota, and Parts of Wyoming. Gen. Tech. Rep. RM-251. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 57p.

Uhl, Peter J. 1980. An Inventory and Evaluation of the Cave Resources on the Bighorn National Forest. Unpublished Report.

USDA Forest Service. 1993. Research Natural Area Guide for the Rocky Mountain Region, USDA Forest Service, review draft. Rocky Mountain Region, Lakewood, CO. 38p.

Crazy Woman Creek and Poison Creek

The Crazy Woman Creek pRNA is 1,589 acres (643 ha) and is located within the Clear/Crazy Forest Plan Watershed (FPWS) unit on the Buffalo Ranger District (Fig. A-1). Eighty-seven percent of this pRNA consists of forested cover types (Table A-1). Principle distinguishing vegetation types are lodgepole pine, ponderosa pine, narrowleaf cottonwood, and curl-leaf mountain mahogany. This area includes types that are quite variable and not found in existing RNAs on the Forest. Riparian bottom areas in the pRNA are considered poor.

The 2,328-acre (943-ha) Poison Creek pRNA is also located within the Clear/Crazy FPWS unit on the Buffalo Ranger District (Fig. A-1). Eighty-five percent of this pRNA consists of forested cover types (Table A-1). Principle distinguishing vegetation types are lodgepole pine, quaking aspen, bluejoint (*Calamagrostis canadensis*), and Idaho fescue. This pRNA also has a good lodgepole pine/vaccinium community but has heavy human use and evidence of past use.

Table A-1. Cover type area for Crazy Woman Creek and Poison Creek potential Research Natural Areas (pRNA).

pRNA	Cover Type	Acres	Percent
Crazy Woman	Lodgepole pine	926	58
Crazy Woman	Ponderosa pine	255	16
Crazy Woman	Grasslands	149	9
Crazy Woman	Douglas-fir	118	7
Crazy Woman	Aspen	74	5
Crazy Woman	Bare rock	62	4
Crazy Woman	Cottonwood	6	0
TOTAL		***1,590***	***100***
Poison Creek	Lodgepole pine	1,531	66
Poison Creek	Aspen	453	19
Poison Creek	Grasslands	344	15
TOTAL		***2,329***	***100***

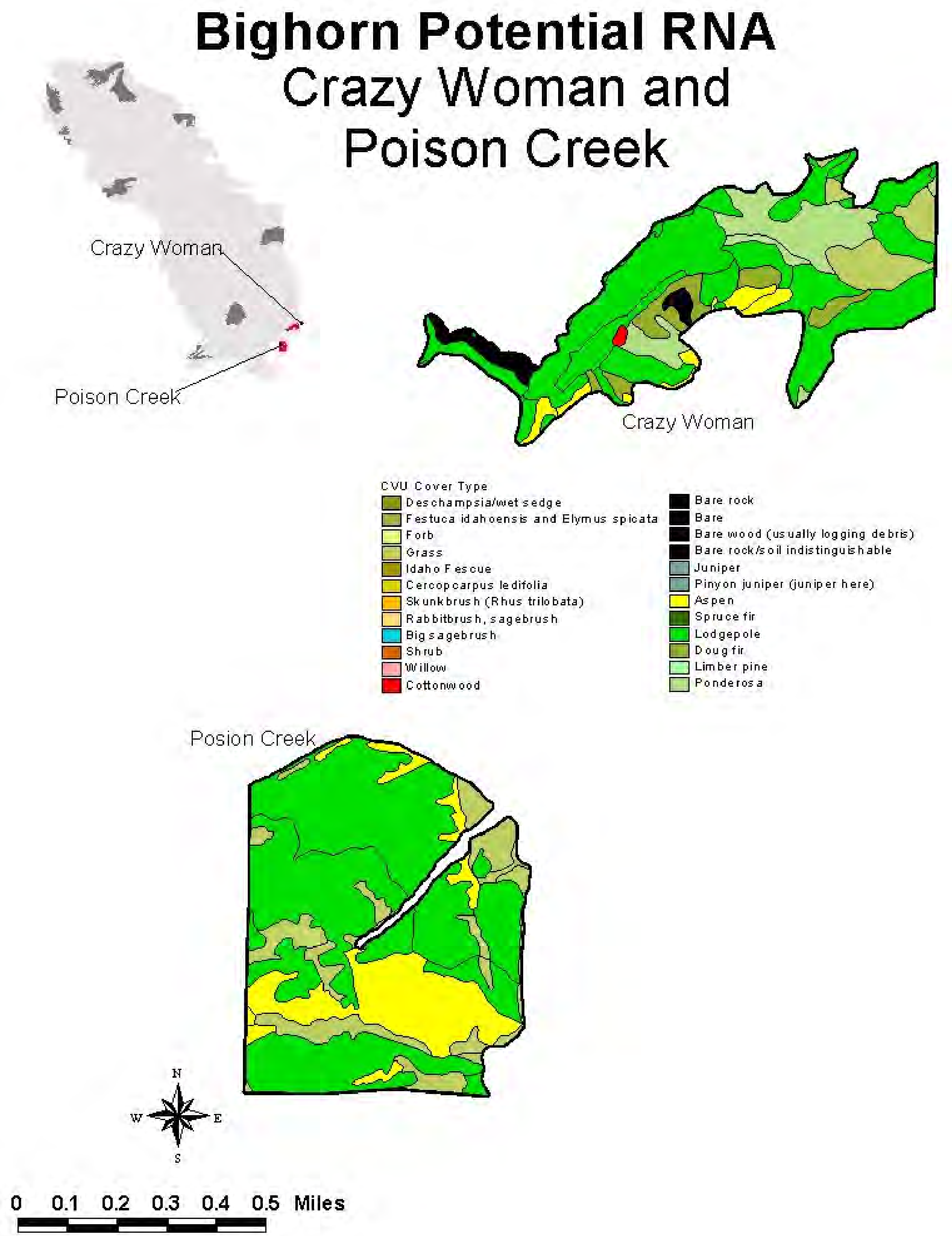


Figure A-1. *Location of Crazy Woman Creek and Poison Creek potential RNAs within the BNF.*

Dry Fork and Mann Creek

The Dry Fork pRNA is 11,419 acres (4,623 ha) and is located within the Little Bighorn FPWS unit on the Tongue Ranger District (Fig. A-2). Eighty-seven percent of the area is of forested cover types (Table A-2). The principle distinguishing vegetation types of this pRNA are Douglas-fir woodlands (61 percent of cover type for this area), limber pine woodlands, lodgepole pine woodlands, ponderosa pine woodlands, aspen woodlands and some spruce-fir woodlands. Big sagebrush, shrubs, forbs, grasses contribute to the variety of non-forested cover types. Bare rock and bare rock with soil indistinguishable make up approximately 5.5 percent of this pRNA. Dry Fork pRNA provides a wide variety of ecosystem types. The Dry Fork pRNA encompasses the current Bull Elk Park RNA, with special features that include 201 acres of disjunct Palouse Prairie Climax, *Agropyron-Festuca* association.

The 11,368-acre (4,620-ha) Mann Creek pRNA is located within the Little Bighorn FPWS unit on the Medicine Wheel Ranger District (Fig. A-2). Forested cover types for this pRNA occupy 82 percent of the area (Table A-2). The principle distinguishing vegetation types of the pRNA are predominately Douglas fir and Spruce/Fir woodlands (approximately 30 percent and 29 percent, respectively). Other woodlands include limber pine, ponderosa pine, and lodgepole pine. Remaining major cover types for this area consist of grassland and shrubs. The Mann Creek pRNA provides a good representation of limestone canyon habitats for the Bighorn National Forest. Mann Creek has steep, rough terrain with very little access to the site.

Table A-2. Cover type area for Dry Fork and Mann Creek potential Research Natural Areas (pRNA).

pRNA	Cover Type	Acres	Percent
Dry Fork	Douglas-fir	6,990	61
Dry Fork	Limber pine	913	8
Dry Fork	Lodgepole pine	654	6
Dry Fork	Big sagebrush	613	5
Dry Fork	Spruce/Fir	413	4
Dry Fork	Bare rock/soil indistinguishable	345	3
Dry Fork	Grasslands	319	3
Dry Fork	Bare rock	277	2
Dry Fork	Forb	252	2
Dry Fork	Aspen	218	2
Dry Fork	Ponderosa pine	202	2
Dry Fork	Shrub	197	2
Dry Fork	Rabbitbrush, sagebrush	25	0
TOTAL		***11,420***	***100***
Mann Creek	Douglas-fir	3,448	30
Mann Creek	Spruce/Fir	3,258	29
Mann Creek	Limber pine	2,094	18
Mann Creek	Grasslands	1,467	13
Mann Creek	Ponderosa pine	527	5
Mann Creek	Curl leaf mountain mahogany	353	3
Mann Creek	Bare rock	89	1
Mann Creek	Rabbitbrush, sagebrush	76	1
Mann Creek	Idaho Fescue	26	0
Mann Creek	Shrub	16	0
Mann Creek	Lodgepole pine	12	0
Mann Creek	Forb	1	0
TOTAL		***11,368***	***100***

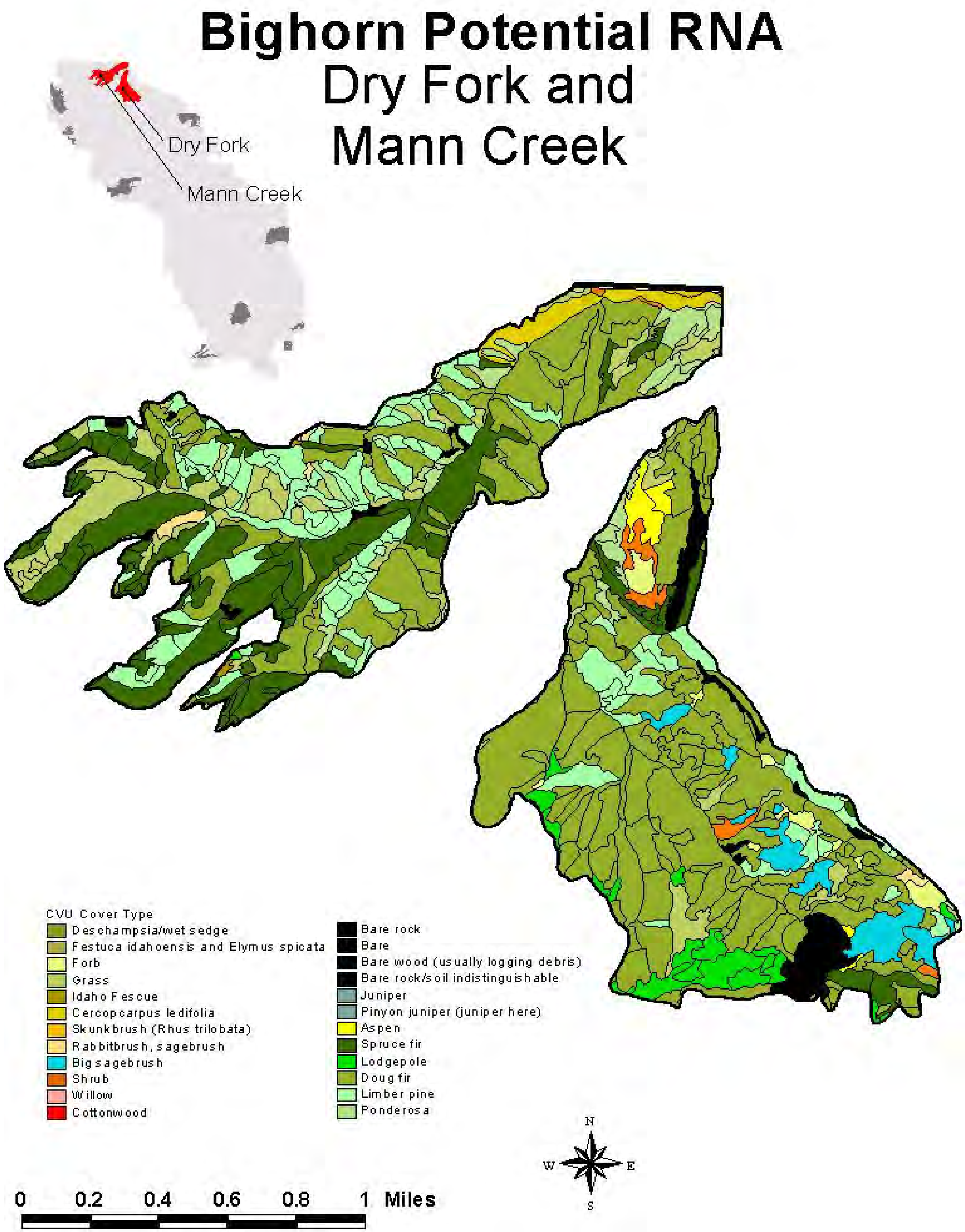


Figure A-2. *Location of Dry Fork and Mann Creek potential RNAs within the BNF.*

Elephant Head

The 9,550-acre (3,866-ha) Elephant Head pRNA is located in the Shell Creek FPWS unit on the Paintrock Ranger District (with some overlap on the Medicine Wheel Ranger District; Fig. A-3). Sixty-three percent of the area is forested cover types with Douglas-fir at 36.5 percent (Table A-3). Other distinguishing vegetation types are Rocky Mountain juniper, lodgepole pine, narrowleaf cottonwood, black sagebrush, mountain big sagebrush, curl-leaf mountain mahogany (*Cercocarpus ledifolius*), and Idaho fescue. This pRNA is immediately north of the existing Shell Canyon RNA and provides for a wide variety of ecosystem types.

Table A-3. Cover type area for Elephant Head potential Research Natural Area (pRNA).

pRNA	Cover Type	Acres	Percent
Elephant Head	Douglas-fir	3,491	37
Elephant Head	Grasslands	1,986	21
Elephant Head	Pinyon juniper	1,131	12
Elephant Head	Spruce/Fir	977	10
Elephant Head	Curl-leaf mountain mahogany	619	6
Elephant Head	Bare rock/soil indistinguishable	371	4
Elephant Head	Bare rock	207	2
Elephant Head	Limber pine	196	2
Elephant Head	Juniper	180	2
Elephant Head	Rabbitbrush/sagebrush	108	1
Elephant Head	Big sagebrush	98	1
Elephant Head	Aspen	69	1
Elephant Head	Willow	58	1
Elephant Head	Lodgepole pine	36	0
Elephant Head	Cottonwood	28	0
TOTAL		***9,555***	***100***

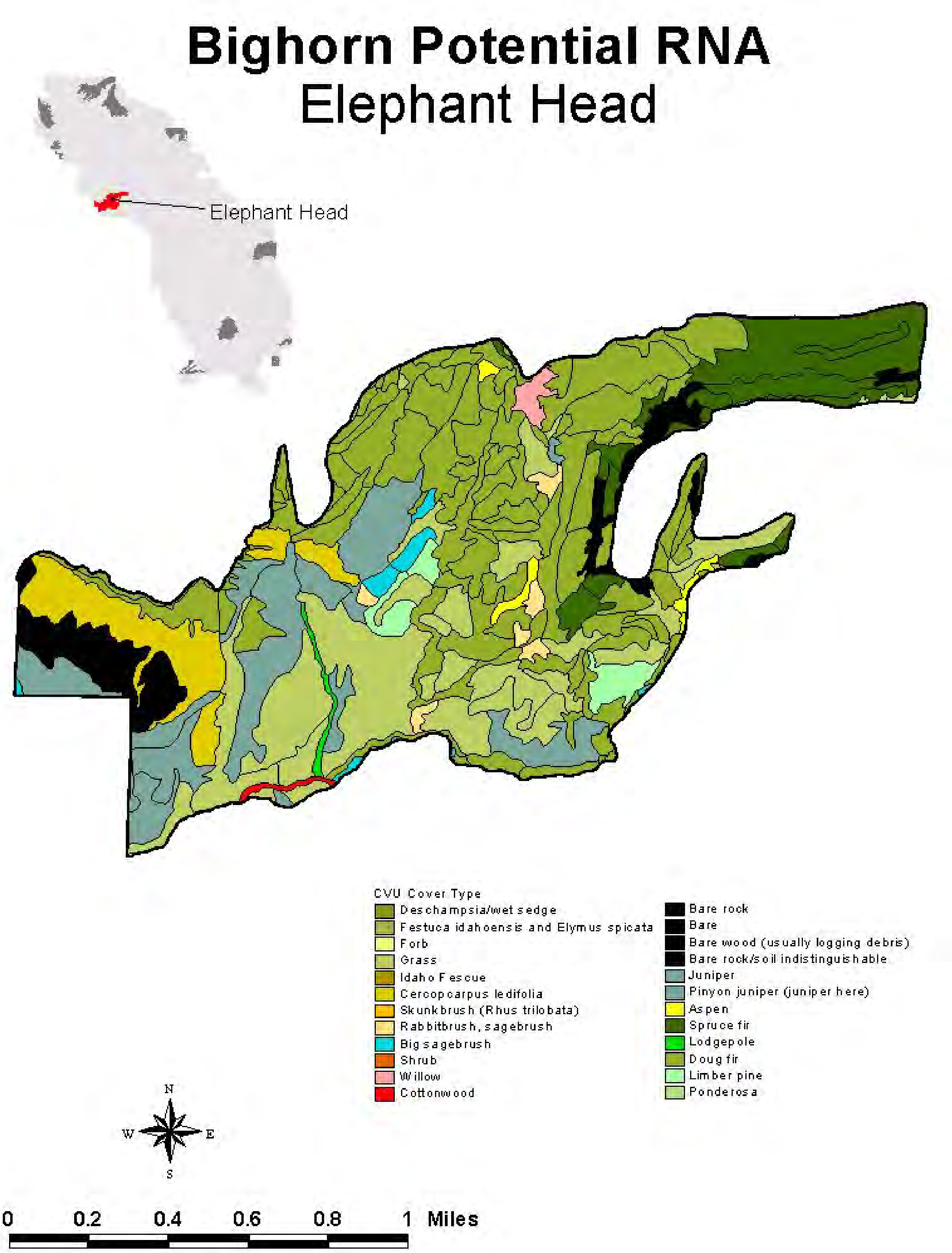


***Figure A-3**. Location of Elephant Head potential RNA within the BNF.*

Lake McClain

The 9,533-acre (3,860-ha) Lake McClain pRNA is located within the Tensleep Creek FPWS unit on Tensleep Ranger District (Fig. A-4) and overlaps with the Virginia Creek Drainage WYNDD Conservation Site (Fig. 6-3). Forested and non-forested cover types each occupy close to 50 percent of the area (45 percent and 55 percent, respectively; Table A-4). Major cover types for this area are alpine habitat, lodgepole pine woodlands and spruce-fir woodlands. The Lake McClain pRNA provides a variety of upper subalpine and alpine ecosystems. This site has had little alteration from pre-settlement conditions. It is the only pRNA that has occurrences for diamondleaf willow (*Salix planifolia*) and water sedge (*Carex aquatilis*), a plant community of special concern identified by the Wyoming Natural Diversity Database.

Table A-4. Cover type area for Lake McClain potential Research Natural Area (pRNA).

pRNA	Cover Type	Acres	Percent
Lake McClain	Spruce/Fir	3,642	38
Lake McClain	Bare	3,529	37
Lake McClain	Grasslands	914	10
Lake McClain	Lodgepole pine	652	7
Lake McClain	Deschampsia/wet sedge	406	4
Lake McClain	Bare rock	245	3
Lake McClain	Willow	132	1
Lake McClain	Shrub	13	0
TOTAL		***9,533***	***100***

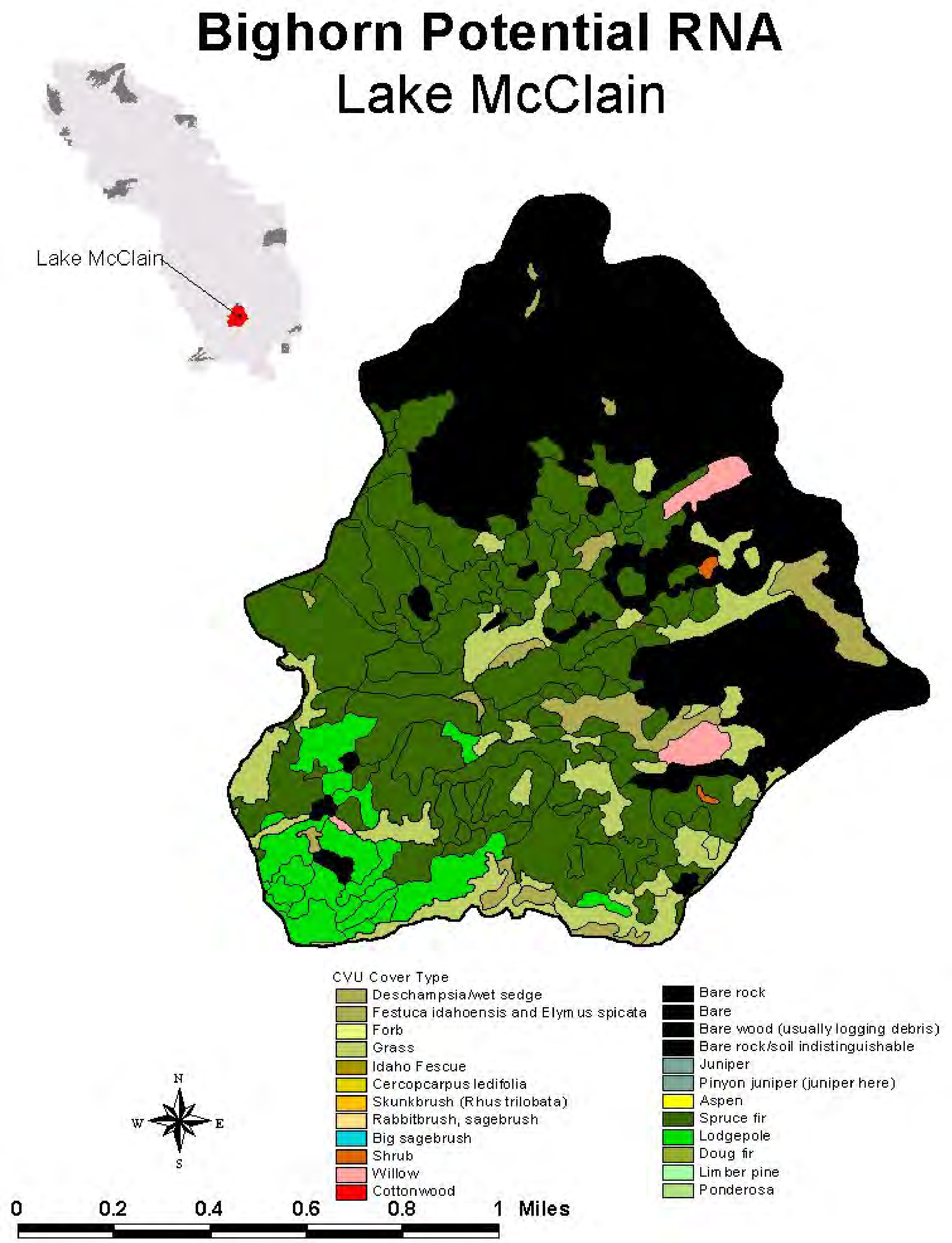


Figure A-4. *Location of Lake McClain potential RNA within the BNF.*

Pete's Hole and Devil's Canyon

The 2,842-acre (1,151-ha) Pete's Hole pRNA is located within the Devil's Canyon FPWS unit on the Medicine Wheel Ranger District (Fig. A-5) and is located near Medicine Mountain Conservation Site (Fig. 6-3). Eighty-eight percent of this pRNA consists of forested cover types (Table A-5). Principle distinguishing vegetation types for this area are subalpine fir, Engelmann spruce, limber pine, mountain big sagebrush, and curly sedge (*Carex rupestris*). While this area may be difficult to access, exotics and human impacts are evident in meadows. This area also provides cover types that are not represented in current RNAs on the Forest.

The Devil's Canyon pRNA is 8,286 acres (3,355 ha) in size, is also located within the Devil's Canyon FPWS unit, Medicine Wheel Ranger District (Fig. A-5), and overlaps with the Medicine Mountain Conservation Site (Fig. 6-3). Eighty-four percent of this pRNA consists of forested cover types (Table A-5). Principle distinguishing vegetation types are subalpine fir-Engelmann spruce, limber pine, quaking aspen, Douglas fir, mountain big sagebrush, and Idaho fescue (*Festuca idahoensis*). This pRNA provides a wide variety of ecosystem types and most of the area is considered "remarkably undisturbed."

Table A-5. Cover type area for Pete's Hole and Devil's Canyon potential Research Natural Areas (pRNA).

pRNA	Cover Type	Acres	Percent
Petes Hole	Doug fir	1,743	61
Petes Hole	Lodgepole	304	11
Petes Hole	Pinyon juniper (juniper here)	224	8
Petes Hole	Spruce/Fir	150	5
Petes Hole	Bare rock	104	4
Petes Hole	Rabbitbrush, sagebrush	87	3
Petes Hole	Curl leaf mountain mahogany	82	3
Petes Hole	Big sagebrush	52	2
Petes Hole	Aspen	41	1
Petes Hole	Limber pine	30	1
Petes Hole	Cottonwood	20	1
Petes Hole	Grass	4	0
Petes Hole	Willow	0	0
TOTAL		***2,842***	***100***
Devil's Canyon	Doug fir	4,239	51
Devil's Canyon	Spruce/Fir	2,455	30
Devil's Canyon	Forb	461	6
Devil's Canyon	Big sagebrush	355	4
Devil's Canyon	Grass	243	3
Devil's Canyon	Lodgepole	183	2
Devil's Canyon	Rabbitbrush, sagebrush	167	2
Devil's Canyon	Bare rock	91	1
Devil's Canyon	Limber pine	75	1
Devil's Canyon	Bare wood (usually logging debris)	11	0
Devil's Canyon	Curl leaf mountain mahogany	6	0
TOTAL		***8,287***	***100***

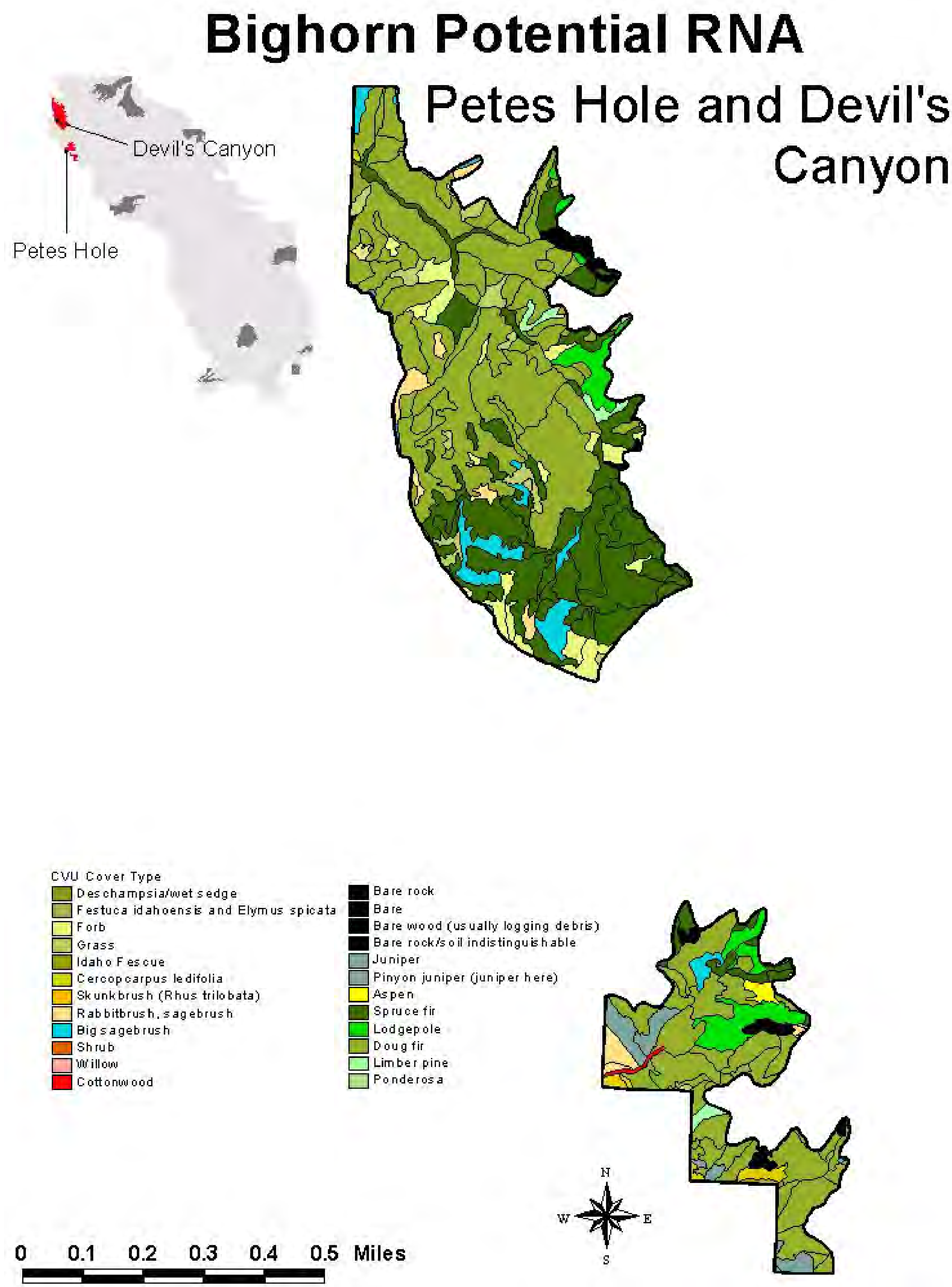


***Figure A-5**. Location of Pete's Hole and Devel's Canyon potential RNAs within the BNF.*

Tensleep Canyon

The 3,124-acre (1,265-ha) Tensleep Canyon pRNA is located within the Tensleep Creek FPWS unit on the Tensleep Ranger District (Fig. A-6), overlaps with the Leigh Creek Conservation area (Fig. 6-3), and is in the vicinity of the Nature Conservancy's Tensleep Preserve. Seventy-six percent of this pRNA consists of forested cover types (Table A-6). Principle distinguishing vegetation types are Rocky Mountain juniper, limber pine, Douglas-fir, mountain big sagebrush, curl-leaf mountain mahogany, and redosier dogwood (*Cornus sericea*). This area provides cover types not currently represented in existing RNAs on the Forest. The area is considered largely pristine and almost inaccessible.

Table A-6. Cover type area for Tensleep Canyon potential Research Natural Area (pRNA).

pRNA	Cover Type	Acres	Percent
Tensleep Canyon	Douglas-fir	1,621	52
Tensleep Canyon	Ponderosa pine	450	14
Tensleep Canyon	Big sagebrush	300	10
Tensleep Canyon	Curl leaf mountain mahogany	242	8
Tensleep Canyon	Forb	192	6
Tensleep Canyon	Pinyon juniper	172	5
Tensleep Canyon	Limber pine	128	4
Tensleep Canyon	Cottonwood	12	0
Tensleep Canyon	Bare rock	6	0
Tensleep Canyon	Grass	1	0
TOTAL		***3,124***	***100***

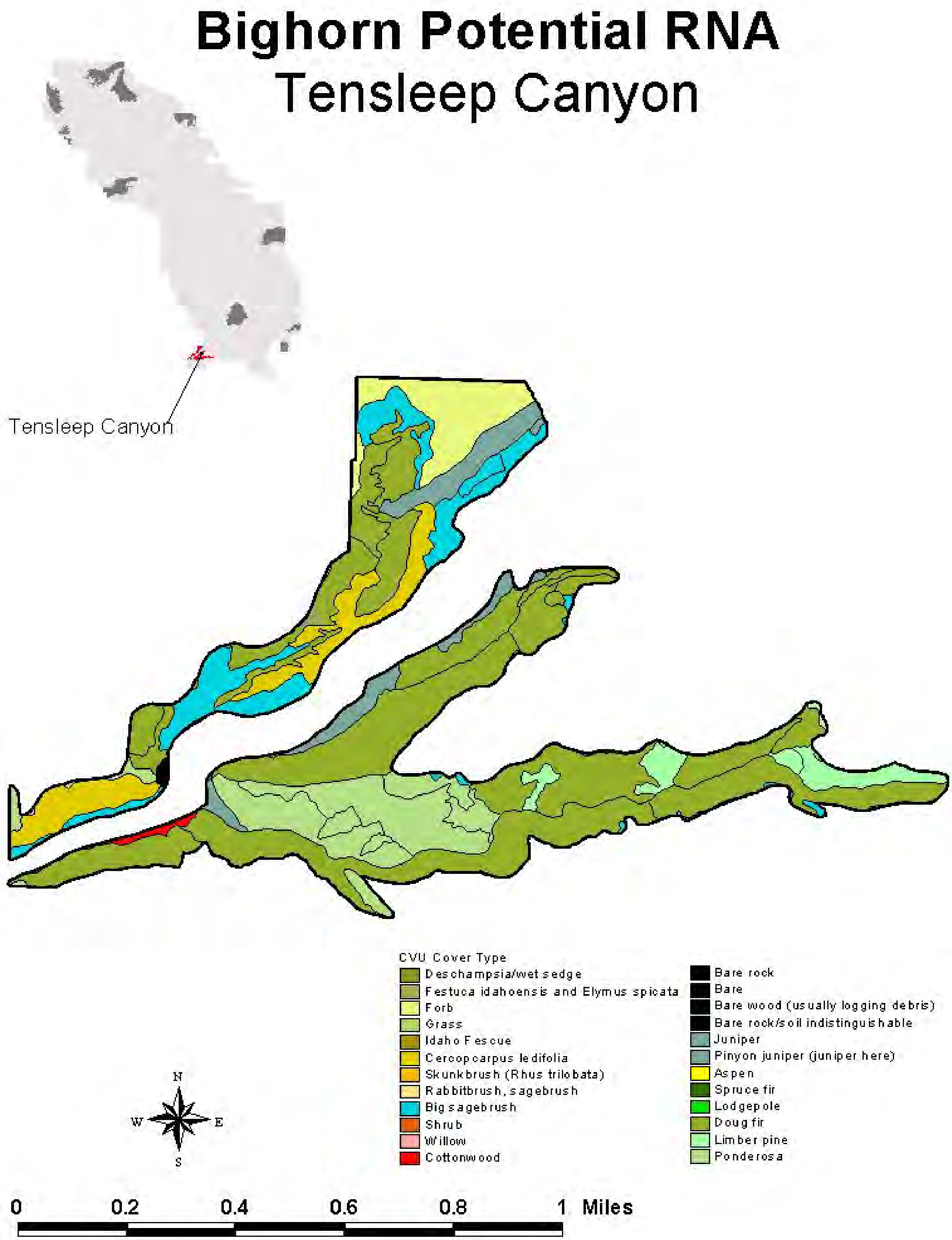


Figure A-6. *Location of Tensleep Canyon potential RNA within the BNF.*

Tongue River

The 5,909-acre (2,392-ha) Tongue River pRNA is located within the Tongue River FPWS unit on the Tongue River Ranger District (Fig. A-7). Eighty percent of this pRNA consists of forested cover types (Table A-7). Principle distinguishing vegetation types are limber pine, ponderosa pine, narrowleaf cottonwood, Douglas-fir, curl-leaf mountain mahogany, and bluebunch wheatgrass (*Pseudoroegneria spicata*). This area provides a wide variety of ecosystem types.

Table A-7. Cover type area for Tongue River potential Research Natural Area (pRNA).

pRNA	Cover Type	Acres	Percent
Tongue River	Ponderosa	2,751	47
Tongue River	Doug fir	777	13
Tongue River	Forb	743	13
Tongue River	Lodgepole	568	10
Tongue River	Aspen	502	8
Tongue River	Bare rock	234	4
Tongue River	Limber pine	122	2
Tongue River	Big sagebrush	82	1
Tongue River	Shrub	77	1
Tongue River	Grass	45	1
Tongue River	Skunkbrush (Rhus trilobata)	7	0
Tongue River	Festuca idahoensis and Elymus spicata	1	0
TOTAL		***5,909***	***100***

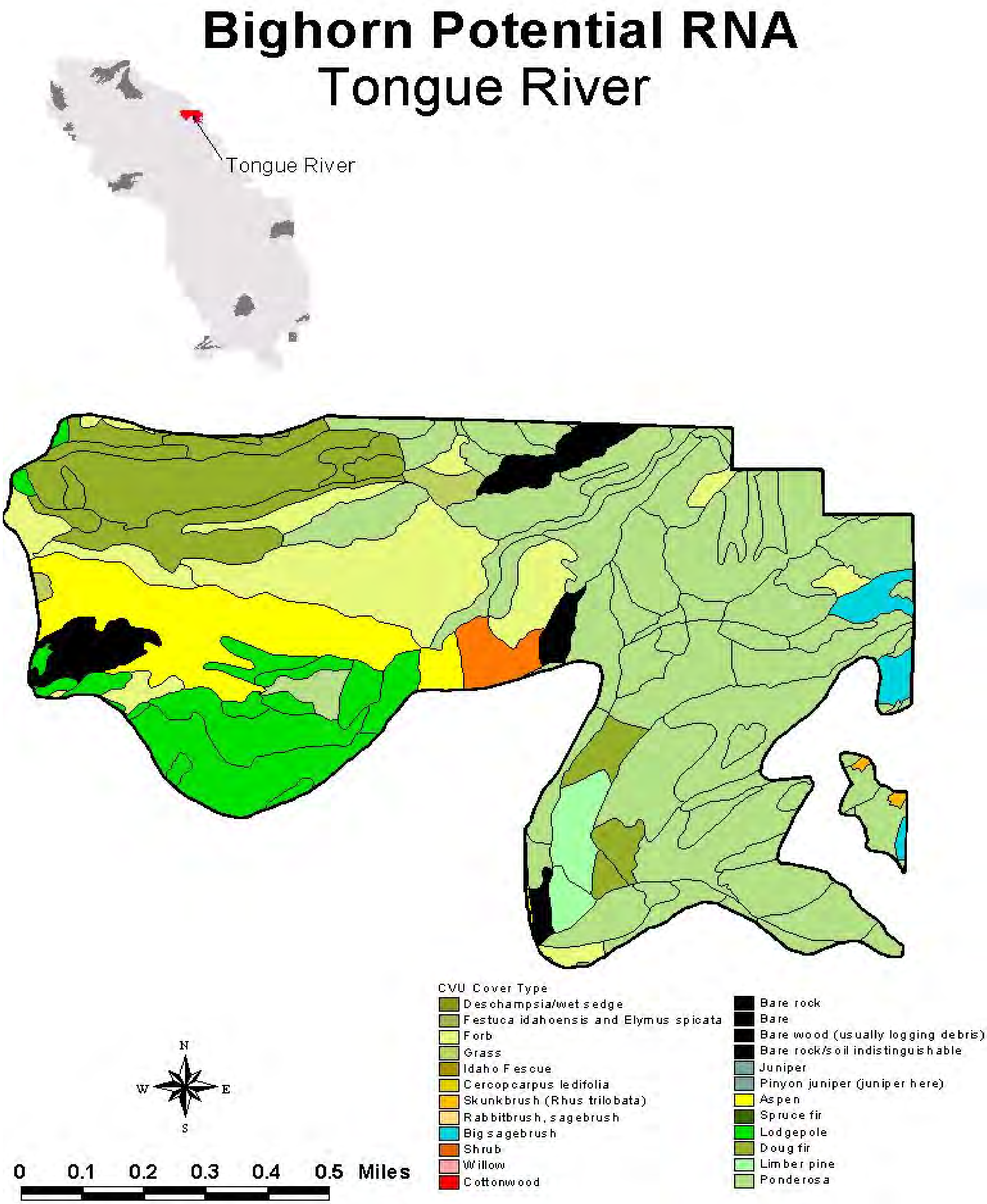


Figure A-7. *Location of Tongue River potential RNA within the BNF.*

Pheasant Creek

The Pheasant Creek pRNA is 9,403 acres (1,985 ha) and is located within the Piney/Rock FPWS unit on the Buffalo Ranger District (Fig. A-8). Ninety-eight percent of Pheasant Creek pRNA consists of forested cover types (Table A-8). Principle distinguishing features are lodgepole pine, ponderosa pine, narrowleaf cottonwood, and tufted hairgrass (*Deschampsia caespitosa*). The pRNA has one of the largest and least impacted lodgepole pine/vaccinium community. Condition of this site is good, with minimal human impacts and difficult accessibility.

Table A-8. Cover type area for Pheasant Creek potential Research Natural Area (pRNA).

pRNA	Cover Type	Acres	Percent
Pheasant Creek	Lodgepole	7,183	76
Pheasant Creek	Ponderosa	1,269	13
Pheasant Creek	Spruce/Fir	757	8
Pheasant Creek	Grass	122	1
Pheasant Creek	Cottonwood	51	0
Pheasant Creek	Aspen	22	0
TOTAL		***9,403***	***100***

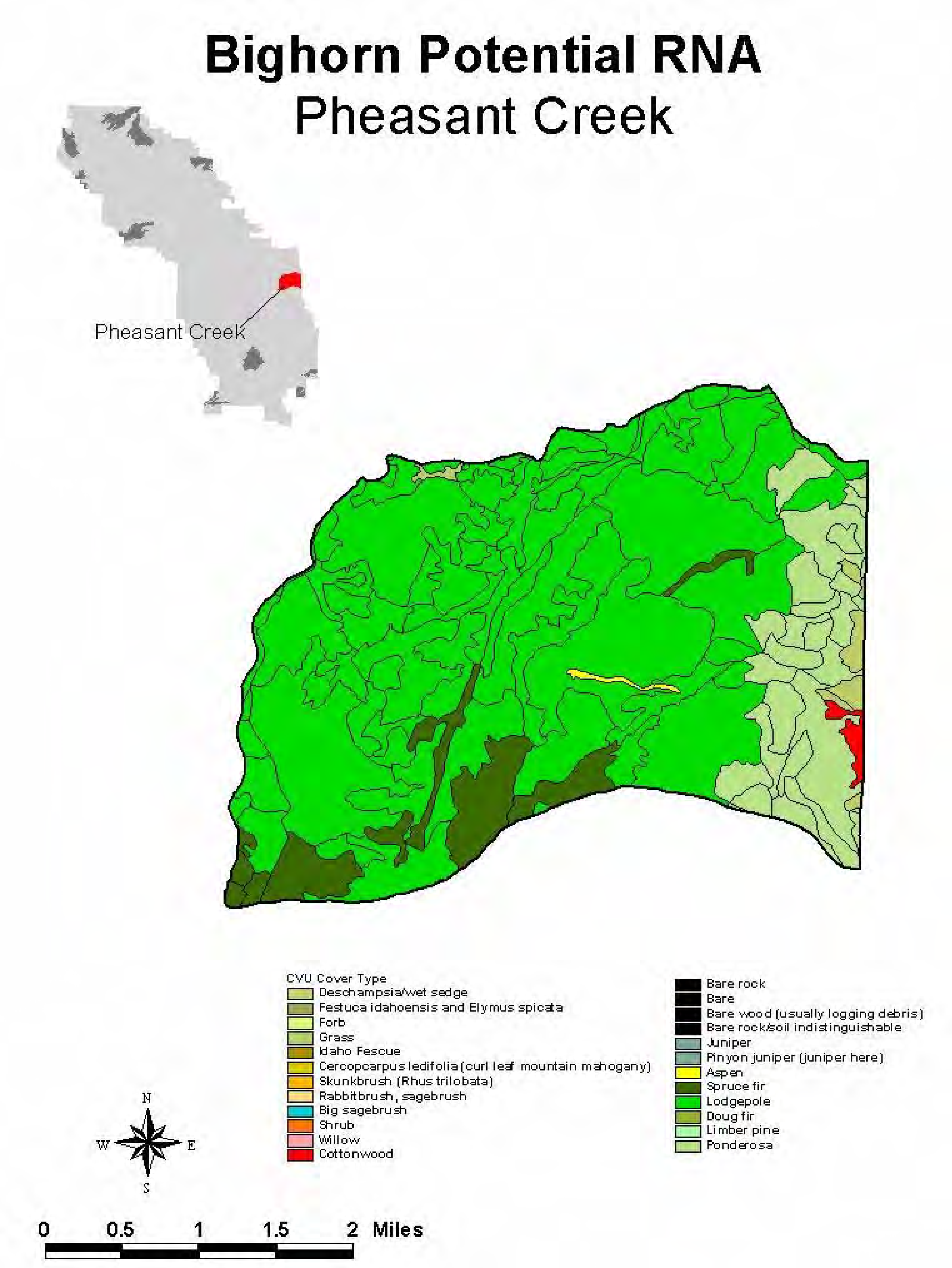


Figure A-8. *Location of Pheasant Creek potential RNA within the BNF.*

Chapter 7 – Synthesis

Objectives

Summarize the key findings of the assessment by major land uses and by ecological land units. Develop a synthetic understanding of ecological integrity and ecological sustainability concerns of the assessment area. Examine the cumulative impacts of anthropogenic influences and ecological disturbance across the assessment area. Map "high integrity" and "low integrity" landscapes. Identify places that may serve as reference for developing ecological restoration approaches and monitoring. Identify the opportunities and needs for ecological restoration, including places of concern. Identify and prioritize information gaps, inventory needs, and research needs and provide suggestions for applying and maintaining the assessment.

Findings Summarized by Major Land Uses

The key findings of this assessment are summarized into the following four broad categories that reflect major management influences on the BNF: forest management, rangeland management, fire, and areas reserved from extractive uses.

Forest Management

The Big Horn Mountains form a large forested island in the midst of extensive grassland. The region represents a source of heterogeneity across the landscapes of northern Wyoming and southern Montana that likely helps to maintain the biodiversity of the region (Turner 1989, Hunter 1999). Two-thirds of the BNF is forested, resulting in a landscape pattern of large isolated forest patches interspersed with relatively small grassland areas (Merrill *et al.* 1996, Fisher *et al.* 1998). The BNF contains the majority of the high-elevation areas (> 8,000 ft/2,438 m) in the Bighorn Mountains, and most of its high-elevation forests, characterized by lodgepole pine and spruce-fir. Douglas-fir forests occupy the middle elevations of the BNF; ponderosa pine forests and limber pine and juniper woodlands occupy the lower elevations. Aspen stands are generally rare and scattered across most elevations (Module 3A; Despain 1973).

The Forest currently appears to be relatively free of invasive plant species, but this conclusion is based mainly on predictive, yet-unvalidated models. These models integrate the influence of physiographic factors and disturbances with the presence of vectors that may introduce invasive species to an ecosystem (forest vegetation management, grazing, or the presence of humans along trails and roads and at various developments). To predict the potential invasibility accurately, however, such models demand systematic sampling and monitoring for invasive species and on-the-ground validation of the model itself (Module 4D).

Generally, all forest types on the BNF appear to be at risk for invasion by non-native species if the appropriate vectors for invasion are present. High-elevation forests (lodgepole pine and spruce-fir types) are generally at lower risk for invasion, and low-elevation forests are at higher risk. Aspen is disproportionately high in terms of invasibility, but covers only 1% of the BNF. Although some areas subjected to recent forest vegetation management may be highly susceptible to invasive species, 59% of the area affected by timber harvesting since 1980 on the BNF is at low or very low risk (Module 4D).

While human activities undoubtedly have affected the majority of the BNF to some extent over the last century, only a relatively small area (less than 20%) of the forested area) has been affected by silvicultural activities between 1946 and 2000. In addition, clearcut harvesting, considered to have the highest immediate and long-term impact on forest ecosystem processes and structure (Barnes *et al.* 1998), has occurred on only 5% of the forested area of the BNF during that period. Silvicultural activities have been concentrated in the high-elevation lodgepole pine and spruce-fir forests that dominate the BNF, and include commercial thinning and shelterwood cuts as well as clearcutting (Meyer and Knight 2003). Aspen is the only forest type relatively limited in distribution that has been affected by timber harvest, and less than 5% of the aspen on the BNF has been harvested (Module 4B).

Although the BNF contains a fair amount of timber suitable for harvesting, much of this suitable timber may be at risk to natural disturbances, particularly wildfire and insect outbreaks. Over 90% of the suitable timber on the BNF is in lodgepole pine and spruce-fir cover types. These forest types are characterized by large though infrequent wildfires (Romme and Despain 1989, Johnson 1992, Meyer and Knight 2003), and are particularly susceptible to outbreaks of the mountain pine beetle and spruce bark beetle (Veblen *et al.* 1994, Schmid and Mata 1996, Meyer and Knight 2003). In the BNF, approximately 44% of the suitable timber is currently at high risk of wildfire under normal climatic conditions, nearly 29% is at high risk to insect outbreaks, and 15% is at high risk of both wildfire and insect outbreaks. These predictive models are hardly precise, but they do highlight the inherent risk of natural disturbances to potential timber commodities in high-elevation coniferous forests (Module 4A and 4B).

Although silvicultural activities have been relatively limited on the BNF, the effects of past timber harvesting are nevertheless notable. Clearcutting is currently not extensive enough on the BNF to fragment the landscape, but it affects landscape pattern by perforating large, even-aged stands created by the large, infrequent, historical fires that characterized high-elevation landscapes (Franklin and Forman 1987, Barnes *et al.* 1998). Roads used or built for timber harvest create unnatural corridors, barriers, and edges for the facilitation or prevention of plant and animal dispersal (Forman 1995). Tinker *et al.* (1998) suggest that roads on the BNF may be a greater fragmenting influence than the timber harvests themselves. Indeed, no location on the BNF is further than two miles (3.2 km) from a road or trail, suggesting a major influence of travel routes on faunal movement on the Forest (Module 4E). However, this suggestion assumes that all roads, including logging roads, two-tracks, improved gravel roads, and paved highways, and trails have an equal influence on land fragmentation, which is improbable (Forman 1995).

Approximately 23% of areas subjected to silvicultural activities exhibit high wildfire hazard, 22% are highly susceptible to insect outbreaks, and 10% exhibit both high wildfire hazard and high risk for insect outbreaks. Clearcutting represents 22%, 28%, and 25% of each of these scenarios, respectively, which suggests that logging debris may at least be partially responsible for fire and/or insect outbreaks in some forest stands (Smith *et al.* 1997, Barnes *et al.* 1998). It is important to realize, however, that the majority of silvicultural activities occur in high-elevation forests on the BNF, and that the large, infrequent fires that characterize high-elevation forests generally are controlled by weather phenomena rather than fuel characteristics (Romme and Despain 1989, Bessie and Johnson 1995, Wier *et al.* 1995, Agee 1997) (Modules 4A and 4B).

There are fewer older spruce/fir and lodgepole pine forests on the current BNF landscape than may be expected within the historical range of variability under a natural disturbance regime. Although such a pattern may be due in part to the discriminatory harvest of older stands, the reduced number of older forests may also be the result of past disturbances including fire and insects. However, given that future timber harvests are likely to be concentrated within older forests of these types, this distribution may be important to consider when implementing landscape-scale forest planning (Module 5A).

While 20% of the forested area of the BNF has been affected by silvicultural activities, approximately 12% of the forested area is permanently unavailable for timber harvesting activities, mostly within the Cloud Peak Wilderness. In particular, 25% of spruce/fir, 8% of lodgepole pine, 4% of aspen, and 1% of the Douglas-fir forests are permanently unavailable for timber harvest. Notably, based on the proportional distribution of these forest types on the BNF, a larger area of spruce-fir forests is reserved, and a smaller area of lodgepole pine and Douglas-fir forest is reserved. Lodgepole pine represents 46% of the BNF, yet only 32% of the total area reserved from timber harvest is lodgepole pine; similarly, Douglas-fir represents 14% of the BNF, but only 1% of all reserved areas are in Douglas-fir. In contrast, 67% of all reserved areas are in spruce-fir, which represents only 32% of the BNF (Module 5A).

Rangeland Management

Grasslands are relatively common and widely distributed within the Bighorn Mountains, while croplands are relatively rare. Shrublands are less common relative to grasslands, are generally found at lower elevations, and appear to be most prevalent along the western flank of the Big Horn Mountains and in the southern portion of the Section. Shrublands, grasslands, forblands, and rock/bare ground areas make up 8%, 13%, 6%, and 9% of the cover types, respectively, on the BNF. Because much of the data in this assessment is based upon vegetation mapping protocols completed at multiple scales, relatively little information regarding non-forested community composition of the BNF is available. For example, 94% of the grasslands on the BNF are mapped simply as "grass". However, three grassland communities -- dominated by bluebunch wheatgrass, Idaho fescue, or blackroot sedge -- are delineated for the BNF. Shrublands are dominated by big sagebrush (65% of all shrublands), rabbitbrush/sagebrush (14%), and willow (10%), but also include mountain mahogany, skunkbrush, and curl leaf mountain mahogany (Module 3B).

Similar to forested ecosystems, the non-forested vegetation in the BNF currently appears to be relatively free of invasive plant species, at least based on available data of known occurrences. However, known occurrences are most common in grasslands and subalpine meadows, where competition for light availability and with woody species is minimal. Most invasive species tend to be found at lower elevations in drainages and valley bottoms, often non-forested, where accessibility for humans is highest and the growing season is longest. Once again, in the absence of systematic sampling and monitoring for invasive species, such trends should be interpreted with great care (Module 4D).

All grassland and shrubland types on the BNF appear to be at risk for invasion by non-native species, and these non-forested types are generally at higher risk than forested types. Grassland types having the largest proportions of their area at very high or high risk of invasion include Idaho fescue/bluebunch wheatgrass, bluegrass scablands, and Deschampsia/wet sedge. Shrubland types include curl leaf mountain mahogany, skunkbrush, and willow. Notably, 90% of the land area modeled as very high risk for invasibility is dominated by grass and/or forb cover types, while only 13% of the low risk is grass or forb (Module 4D).

As much as forest vegetation management and silviculture affect forested areas, grazing is the most important human disturbance to non-forested areas. Approximately 5% of the Forest includes high potential for invasion by non-native invasive plant species as well as high preference and high stocking by cattle and/or sheep. Currently, approximately 30,000 domestic animal units are present on the BNF, and livestock stocking rates appear to be relatively high. Despite these high stocking rates, there has been a dramatic decrease in the number of sheep using the BNF over time, from a peak of nearly 75,000 animal units in 1904 to 3,300 units today. Including both sheep and cattle, the BNF only has a little over 25% of the livestock animal units as compared to the animal units grazing near the turn of the century. Furthermore, the grazing season has decreased by more than half over this time period. Elk and deer numbers are currently similar to probable pre-settlement levels (Wyoming Game and Fish Department 1999) (Module 5B). Grazing activities are very likely associated with areas of high risk to invasibility; 34% of all areas considered to be high preference areas for grazing are modeled as high or very high invasibility.

Because livestock grazing is prominent on the BNF, the effects of grazing are important to consider both for future rangeland management and in evaluating the ecological effects on non-forested ecosystems. Grazing also affects forests by removing understory and changing fire regimes in low elevation forests. Over 70% of the Tensleep Assessment Area (Powder River Ranger District) is in fair or lower range condition. This area covers only a portion of the southern part of the BNF, so these data cannot be applied Forest-wide. However, they suggest the need for similar kinds of evaluations across the Forest. High livestock preference is found on 3% of active cattle allotments and 17% of the active sheep allotment acres. Areas of high livestock preference combined with low rangeland resilience for cattle and sheep were 13,300 and 94,400 acres (5,400 and 38,000 ha), respectively (Module 5B).

Other human activities also affect the grassland and shrubland types in the BNF. Grasslands and shrublands occupy over 25% of the BNF, but contain over 32% of the travel routes (roads and trails). Grasslands and some minor shrubland types, such as skunkbrush, have disproportionately higher proportions of travel routes than would be expected based on their distribution across the BNF. Such a pattern is likely due at least in part to the accessibility and increased use of low-elevation ecosystems by humans over the past century (Meyer and Knight 2003). However, the disproportionate presence of travel routes in grassland and shrubland ecosystems is also important because these cover types are most susceptible to invasive species, and travel routes provide an important conduit for plant species dispersion (Wace 1977, Wilcox and Murphy 1989) (Module 4E).

In addition, grassland and shrubland types were generally most affected by fire suppression during the 20th century, mainly because they are characterized by relatively short fire intervals (most often < 100 years) that typically operate over the same temporal scale as fire suppression, and they are most accessible to humans (e,g., Cooper 1960, Veblen *et al.* 2000, Meyer and Knight 2003). The relatively high departure from the historical range of variability in fire regimes for these types confirms the effect of fire suppression on grasslands and shrublands, although direct fire history data for non-forested areas is scanty (Meyer and Knight 2003). The largest effect of fire suppression on grassland communities is often the invasion of exotic and woody species (Cook *et al.* 1994, Knight 1994, Morgan *et al.* 1996), although relatively little evidence of encroachment is found on the BNF (Meyer and Knight 2003) (Modules 4C and 5B).

While a large proportion of the BNF has been affected by grazing activities, the only present management prescription on the BNF that specifically restricts livestock grazing is for Research Natural Areas, of which only two (10A) have been officially designated. This allocation represents a very small proportion (0.1%) of the BNF, however.

<u>Wildfire History and Hazard</u>

Fire, both historically and currently, is the predominant natural disturbance in the Rocky Mountains and in the BNF (Despain and Romme 1991). In the BNF, fire intervals generally are shorter at lower elevation, and fires are generally most frequent in grasslands (Despain 1973, Meyer and Knight 2003). Because the majority of the BNF is forested and most of the forests are higher elevation, 64% of the area historically burned with a frequency greater than 100 years, almost exclusively in middle- to high-elevation forests. One third of the BNF is occupied by spruce-fir and lodgepole pine forests, which are characterized by infrequent (100- to 300-year return interval) large fires that may approach the size of those that burned in Yellowstone National Park in 1988 (Module 4A). Virtually no fire history data exist for the BNF, and all fire regimes have been interpolated from nearby forest, shrubland, and grassland ecosystems (Meyer and Knight 2003).

The majority of the ecosystems on the BNF (62%) show little or no departure from their historical fire regime, but 23% of the Forest shows departures, most likely as a result of over 100 years of fire suppression. Grasslands and shrublands are most significantly altered by fire suppression because they have the shortest fire-return intervals and are generally found at lower elevation where they are most accessible to management (e,g., Cooper 1960, Veblen *et al.* 2000, Meyer and Knight 2003). Thus, 79% of all the grasslands and shrublands on the BNF are considered to have departure from the historic regime, while most forest types show little departure from the historic regime. These departures from historical fire regimes were subjectively estimated based on the number of expected disturbance events that have not occurred since the U.S. Forest Service has managed the BNF. Given the lack of on-site fire history data and on-the-ground validation, such trends should be interpreted with great care (Module 4A).

Since approximately 1910, only 61 fires larger than 50 acres (20 ha) have burned on the Forest, representing only 7% of the entire BNF. Fire size during this period ranged up to 18,300 acres (7 and 7,400 ha), and mean fire size was 1,300 acres (540 ha). Although such statistics are strongly influenced by the quality of the record keeping that likely varied since 1910 (Meyer and Knight 2003), fires on the BNF appear to burn far less frequently and over smaller areas than in Yellowstone or areas with similar forests and fire regimes. Although the fire record suggests no event similar to the 1988 Yellowstone fires, a large event is very likely to occur in the spruce-fir and lodgepole pine forests of the BNF in the future because large fires are driven primarily by weather phenomena (Romme and Despain 1989, Bessie and Johnson 1995, Wier *et al.* 1995, Agee 1997). Thus future fire suppression may become more difficult if droughts become more frequent (Overpeck *et al.* 1990, Flannigan and VanWagner 1991, Gardner *et al.* 1997). For the BNF, fire activity has been variable among decades: more fires occurred between 1910 and 1919 than any other decade, but fewer, larger fires occurred in the 1920s (Module 4A).

Given the predominance of fire on the BNF and concerns about future climate change, an assessment of wildfire hazard is essential for future management planning. Wildfire hazard was estimated in this assessment for differing weather conditions using a GIS model to predict potential wildfire characteristics. Because such a model is difficult to validate, the hazard condition trends listed here should be interpreted with care. Under average weather conditions, about 13% of the Forest is at high hazard for wildfire, and about 29% is at high hazard under drought conditions. Most vegetation types (95%) having high wildfire hazard under drought conditions are forested (mainly lodgepole and spruce/fir), but 87% of the vegetation types having high wildfire hazard under average conditions are dominated by grass and forbs. Grassland types have the highest coincidence with high fire hazard and/or departure from the historic disturbance regime and high or very high weed invasibility, suggesting that future wildfires in grassland types will have increased unpredictability in behavior and ecological effects (Module 4A).

<u>Areas Reserved from Extractive Uses</u>

For a generalized summary of conservation status, it is useful to describe how vegetation types and estimated associated species richness are currently distributed among ecological threats and broad land use allocations. For example, a higher proportion of spruce-fir forest is reserved from extractive uses than any other vegetation type (mostly as part of the Cloud Peak Wilderness) although it has relatively low species richness (Table M7-1). In contrast, grasslands have the highest risk of non-native plant invasion, the highest departure from historical fire regimes, high road densities, and high grazing activity, but only a very small proportion of grasslands are reserved from extractive uses on the BNF. In general, vegetation types most threatened by non-native plant invasion and departure from fire regimes are those having the highest species richness and the smallest proportion reserved. In contrast, those types least threatened by these factors generally have the lowest species richness yet the highest proportion reserved (Table M7-1). It is important to note that extractive uses are not necessarily in conflict with conservation goals. In some instances, active vegetation management may enhance meeting conservation objectives. However, the information is important to consider in attempting to accommodate conservation objectives for species and ecological characteristics that are known to be negatively affected or for which affects are unknown.

Ecological Integrity of the Bighorn Ecosystem

Defining Ecological Integrity

Ecological integrity has received increasing attention by land managers over the past few decades. For example, the Canadian National Parks Act requires that maintenance of ecological integrity be a top priority when developing a park management plan (Woodley 1993). Aldo Leopold stated over 50 years ago "A thing is right when it tends to preserve the integrity, stability, and beauty of the biotic community. It is wrong when it tends otherwise" (Leopold 1949). Unfortunately, as noted by Noss (1995), Leopold did not describe the meaning behind "integrity", and the ambiguous nature of the term remains troublesome to this day, even as scores of ecologists have long placed heavy value on the reference.

At its most superficial level, ecological integrity may describe an ecosystem untouched or at least unaffected by humans. Indeed, ecological integrity has been used as a basis for public policy and decision-making primarily due to the concern of scientists and others about the threats of human activities to ecosystems and species (Lemons and Westra 1995).

Table 7-1. Summary of species richness, proportion permanently reserved, and ecological threats by vegetation type on the Bighorn National Forest. Rankings are relevant to other areas within the Bighorn National Forest.

Vegetation Type	Species Richness	Proportion in Permanently Reserved Areas	Non-native Plant Invasibility	Fire Regime Departure	Road Density	Extractive Resource Use (Livestock or Timber)
Grasslands	High	< 1%	Very High	High	High	High
Shrublands	Moderate to Low	< 1%	Moderate	High	High	High to Moderate
Juniper Woodland	Low	16%	Low	Low	Low	Low
Limber Pine Woodland	Low to Moderate	< 1%	Moderate to Low	Moderate to Low	Low	Low
Ponderosa Pine Forest	Moderate	0%	Moderate to High	Moderate to Low	Moderate	Moderate to Low
Aspen Forest	High to Moderate	4%	High	Low	High	Moderate
Douglas-fir Forest	Low to Moderate	2%	Moderate	Moderate to Low	Moderate	Moderate
Lodgepole Pine Forest	Low	9%	Low	Low	High	High
Spruce-fir Forest	Low	25%	Low	Low	Moderate	High

However, the notion of ecological integrity is ambiguous even in the conservation literature. Ecological integrity may in some sense correspond to a natural or pristine ecosystem condition, but the concept is made even vaguer when "natural" is defined as a condition existing prior to human influence. It is unlikely that any ecosystems exist that have not been or are not being affected by humans (Lemons and Westra 1995). Moreover, ecological integrity must apply to more than "pristine" areas, as managed ecosystems surely maintain some level of ecological integrity so long as their ecological functioning is not disrupted (Westra 1994).

What, then, are the attributes of an ecosystem having high integrity? An ecosystem having high integrity is generally assumed to have several characteristics (Westra 1994, Karr and Chu 1995). First, ecological integrity refers to an ecosystem that will function successfully and optimally under conditions characteristic of the locale (Cairns 1977, Karr and Dudley 1981, Woodley 1993, Westra 1994, Kay and Schneider 1995). Thus, in addition to including optimal levels of energy flow, an ecosystem of high integrity should maintain a balanced, adaptive community having species composition, biodiversity, and functional processes naturally characteristic of the area (Karr and Dudley 1981, Woodley 1993).

Secondly, ecological integrity assumes an ecosystem's ability to withstand stress or exhibit resilience in the face of unexpected future perturbations to environmental conditions (Westra 1994, Kay and Schneider 1995). This "resilience" implies the ecosystem's ability to resume functioning following perturbation. In part, ecological integrity has not been precisely defined because of the dynamic nature of ecosystems, which often change chaotically and unpredictably over time due to natural, non-anthropogenic factors. For example, understanding that a continuously varying, frequently-disturbed, unstable landscape may have high integrity requires a point of view that includes the change itself as a necessary process of the ecosystem (Noss 1995).

Finally, and perhaps most notably, ecological integrity is defined by the values of society. Regier (1995) has stated that ecological integrity exists when an ecosystem is perceived to be in a state of well-being, and that a precise definition of ecological integrity is dependent on peoples' perspectives of what constitutes complete ecosystems, and must reflect social and ethical values as well as scientific concerns. Indeed, many agree that ecological integrity is simply the maintenance of the community structure and function characteristics deemed satisfactory to society (Cairns 1977). Rolston (1994) has been critical of the concept of ecological integrity, suggesting that "Integrity can mean anything you choose it to mean; it has begun to slip around as soon as we start to think about it." In any case, the attributes of an ecosystem with integrity are inherently qualitative rather than absolute, but most often include ecosystem health, biodiversity, stability, sustainability, naturalness, wildness, and beauty (Noss 1995b). For this assessment, we define "sustainability" as the ability to sustain ecological integrity over the long term, and leave the task of evaluating sustainability to the forest managers, who must do so within the context of their actions.

Noss (1995) argues that ecological integrity can be made operational by first selecting indicators that correspond to the ecological qualities associated with integrity, then measuring and quantifying those indicators within a system or set of systems. Indicators are especially helpful in inventory and identification, where the distributions of biological and environmental entities are assessed and areas that should be conserved are identified or selected. They are also helpful where the effects of management treatments are monitored as part of the adaptive management process, so that practices can be adjusted if warranted (Holling 1978, Walters 1986). Such an approach has been applied in other assessments (Canadian Model Forest Network 2000) and is the method used here.

The following are commonly considered indicators of sustainability and/or ecological integrity for terrestrial ecosystems (Quigley *et al.* 1997, Canadian Model Forest Network 2000):

- Area of each vegetation type by age class or structural condition relative to the expected distributions under historic range of variation
- Area of each vegetation type departed from historic range of variation in terms of disturbance hazard
- Area of permanent vegetation type conversions
- Forest fragmentation and connectedness
- Landscape diversity relative to that expected under historic range of variation
- Patch size distributions relative to that expected under historic range of variation
- Amount of interior forest
- Area of ground disturbance or significant soil disturbance
- Changes in soil nutrient status or soil productivity
- Changes in physical structure of soils
- Site productivity relative to potential
- Habitat quality and quantity for selected species

- Number of known species that occupy only a small portion of the former range
- Diversity of bird populations
- Area occupied by exotic species
- Percent of watershed in logged condition or area of total clear-cut logging
- Area in artificial vs. natural regeneration
- Intensive land use activities in rare or sensitive ecosystems
- Density of roads
- Proportion of each vegetation type in a status protected from resource extraction or intensive land uses

For the CLC assessment, we determined activities or characteristics that may have an influence on the measurable traits commonly used as indicators. This was done in order to simplify the task of mapping integrity (i.e. we mapped using nine attributes that affect the 20 indicators). The integrity maps are not verified and are not related to any known measures of ecosystem function. We simply used the nine attributes as a surrogate for mapping *possible* ecological integrity conditions. We defined areas of high ecological integrity as having at least some of the following attributes (see Appendix I for details):

- Low road density
- Limited timber harvest activity
- Limited livestock use
- Limited occurrences of invasive species
- Low departure from historical disturbance regimes
- Limited high-impact recreation
- No utility corridors
- Limited exurban development
- Limited mineral extraction activities.

Because the BNF does not have extensive exurban development or mineral extraction activities, these attributes were not considered. Each attribute was not necessarily given equal weight in determining ecological integrity, but areas having more of these attributes have higher ecological integrity than those having fewer of these attributes. When defining a landscape within the assessment area having high ecological integrity, it should represent the range of vegetation that occurs on the assessment area and be large enough to incorporate the characteristic natural disturbance regimes.

Areas of High Ecological Integrity

A particular location on the BNF was considered to have high ecological integrity if it was characterized by at least six of the seven high-integrity components listed above. Similarly, we considered a particular location to have moderately high ecological integrity if it was characterized by at least four of the seven high-integrity components. Nearly 94% of the BNF is characterized by high or moderately high ecological integrity (Fig. M7-1). Over 40% of the BNF includes at least 6 components of high integrity, and 54% includes 4 or 5 components. The largest and most contiguous areas of high integrity appear to occur in the interior of the BNF, particularly the Cloud Peak Wilderness. Areas with the fewest high-integrity indicators occur at the lowest elevations, on the fringes of the BNF (Fig. M7-1). All areas on the BNF contain at least one component of high integrity.

Areas of High Ecological Integrity by FPWS

All nine Forest Plan Watershed units were dominated by areas having at least four components of high integrity; only Tensleep Creek had less than 90% of its area characterized by at least four high-integrity components (Table M7-2). In addition, all of the area encompassed by the Piney/Rock Creek FPWS was characterized by at least four high-integrity components. Such a trend reflects the relatively high integrity of the BNF as a whole, and suggests that relatively few areas on the Forest may be considered highly degraded. Areas near the northern end of the BNF characterized by fairly high road density, grazing activity, and some silvicultural activities had lower integrity ratings (Fig. M7-1).

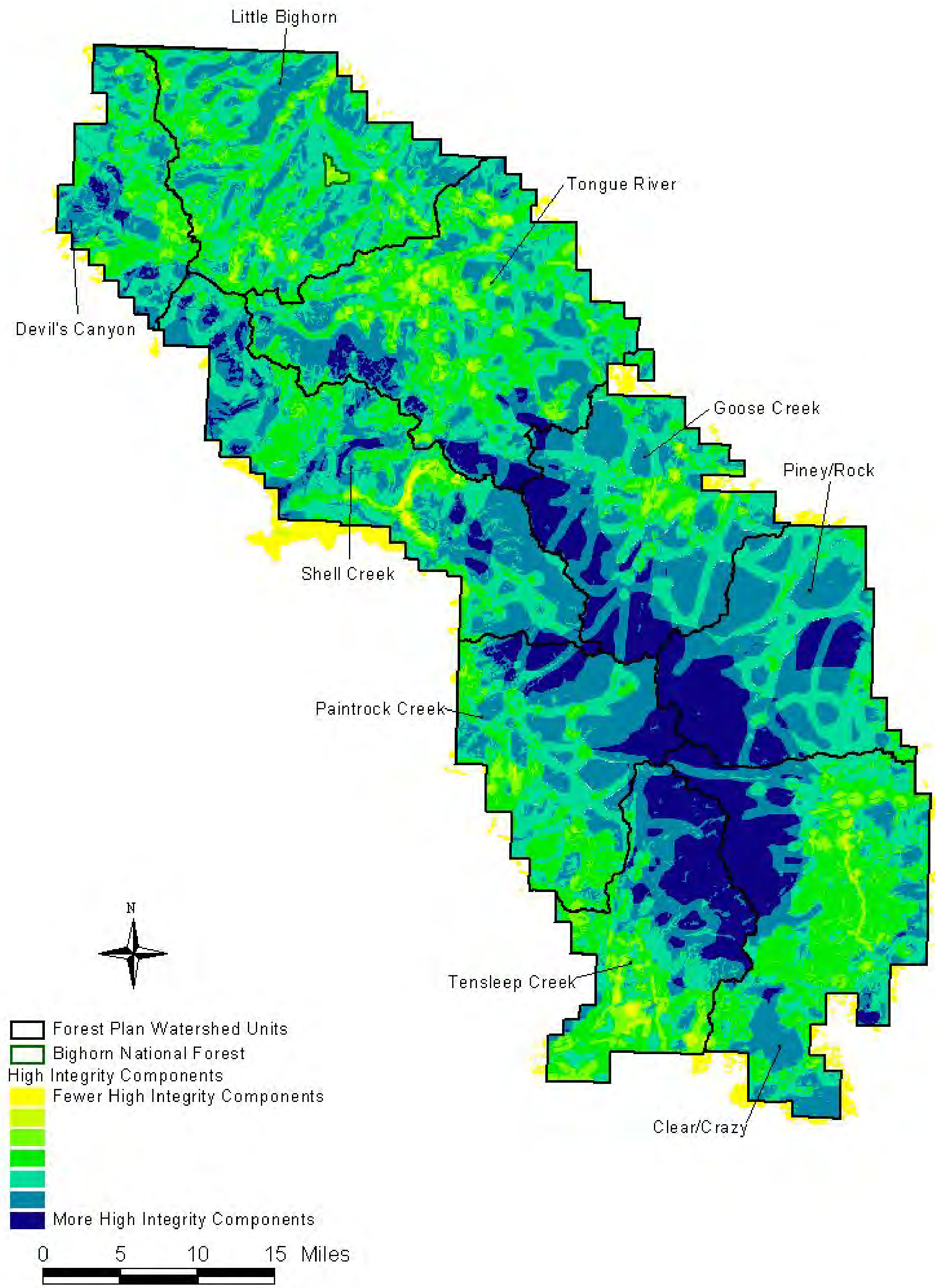


Figure 7-1. Areas of high ecological integrity on the Bighorn National Forest. Cooler colors represent areas having more indicators of high ecological integrity.

Ecological Integrity Characteristics of Conservation Sites and Potential RNAs

Sixteen sites on the BNF, based on specific locations of high natural biodiversity and/or threatened or endangered species have been recommended for conservation by the Wyoming Natural Diversity Database (WYNDD; Fig. M7-1). Of these 16 sites, all but 2 include at least 80% of their area as having high or moderately high ecological integrity (Boyd Ridge and Leigh Canyon have 75 and 70%, respectively; Table M7-3). Generally, those sites in the south-central portion of the BNF appear to have the most components of ecological integrity (Fig. M7-1).

Nearly all areas proposed for designation as Research Natural Areas (RNAs) exhibit very high proportions of their land area characterized by at least 4 high-integrity indicators (Table M7-4, Fig. M7-1). The entirety of potential RNAs including Devil's Canyon, Elephant Head, Lake McClain, Petes Hole, Pheasant Creek, and Poison Creek are of moderately-high or high ecological integrity, likely because encompassing high-integrity areas is a primary objective of RNA designation. Lake McClain, Pheasant Creek, and Poison Creek contain very high proportions of land area characterized by at least six high-integrity indicators, which confirms the importance of protecting these specific locations. Tongue River, Tensleep Canyon, Dry Creek, and Crazy Woman Creek, all of which are located at lower elevations or in areas more accessible to humans, contain much lower proportions of land area having at least six indicators

Areas of Ecological Concern

Similar to our criteria for identifying high-integrity areas, we considered a particular location on the BNF to have low ecological integrity (and thus to be a potential "area of concern") if it was characterized by six or seven of the following negative components: high road density; extensive silvicultural activity; a coincidence of low rangeland resilience, high preference, and high livestock stocking; high invasibility or occurrence of invasive species; high departure from historical disturbance regimes; high-impact recreation; or the presence of utility corridors. We considered a particular location to have moderately low ecological integrity if it was characterized by four or five of the seven low-integrity indicators.

Table 7-2. Area of each Forest Plan Watershed unit having high and moderately high ecological integrity. Proportion of each FPWS is shown in parentheses.

FPWS	Acres/ha Having 6-7 Components	Acres/ha Having 4-5 Components	Total Acres/ha
Clear/Crazy Woman Creek	57,947/23,450 (37.2)	88,992/36,014 (57.1)	146,940/59,465 (94.3)
Devil's Canyon	18,073/7,314 (29.6)	39,898/16,146 (65.3)	59,771/24,188 (94.9)
Goose Creek	66,194/26,788 (56.6)	46,768/18,926 (40.0)	112,962/45,714 (96.6)
Little Bighorn	30,476/12,333 (21.5)	101,627/41,127 (71.8)	132,103/53,460 (93.3)
Paintrock Creek	48,828/19,760 (45.2)	55,453/22,441 (51.4)	104,281/42,201 (96.6)
Piney/Rock Creek	69,659/28,190 (63.2)	40,579/16,422 (36.8)	110,238/44,612 (100.0)
Shell Creek	57,571/23,298 (41.1)	77,033/31,174 (55.0)	134,604/54,472 (96.1)
Tensleep Creek	48,058/19,448 (47.5)	40,635/16,444 (40.2)	88,693/35,893 (87.9)
Tongue River	51,585/20,876 (29.1)	108,931/44,083 (61.5)	160,515/64,958 (90.6)

Relatively little of the BNF (less than 2%) may be considered an area of concern, or is characterized by low or moderately low ecological integrity (Fig. M7-2). Only 38 acres (15 ha) of the entire BNF includes at least 6 components of low integrity, and 1.5% (10,965 acres/4,437 ha) includes 4-5 components. Most areas of concern appear to occur in the north-central portion of the BNF, where much silvicultural activity has occurred, and along the southern fringe, which is essentially surrounding the Cloud Peak Wilderness. Areas of concern occur at all elevations on the BNF (Fig. M7-2) and all locations on the BNF contained at least one component of low ecological integrity.

Areas of Concern by FPWS

Consistent with the Forest-wide pattern, all nine Forest Plan Watershed units contained very small proportions of areas characterized by low ecological integrity (Table M7-5, Fig. M7-2). Only two of the nine FPWS (Tongue River and Clear/Crazy Woman Creek) show greater than 2% of their land area having at least four low-integrity components, and none of the FPWS approached 1% of their areas having six components. The absence of large areas of concern confirms the relatively high integrity of the BNF as a whole. Tongue River and Clear/Crazy Woman Creek contained the largest area having at least six low-integrity components and the largest area having at least four low-integrity components (Table M7-5).

Areas of Concern within Conservation Sites and Potential RNAs

Only one of the 16 WYNDD sites has more than 3% of its area exhibiting low or moderately low ecological integrity characterized by at least 4 low-integrity components (Table M7-6). Similarly, no WYNDD site contains more than 5 acres (2 ha) having six or more low-integrity components. Most WYNDD sites appear to have relatively few areas of ecological concern (Fig. M7-2). The specific ecological threats to each WYNDD conservation site are discussed in detail in a later section of this chapter. The eleven potential RNAs contain essentially no land area having four or more components of low integrity (Fig.M7-2, Table M7-7).

Table 7-3. Area of each WYNDD conservation site having high and moderately high ecological integrity. Proportion of each site is shown in parentheses.

WYNDD Site	Acres/ha Having 6-7 Components	Acres/ha Having 4-5 Components	Total Acres/ha
Big Goose	10,609/4,293 (56.3)	7,500/3,035 (39.8)	18,110/7,329 (96.1)
Boyd Ridge	468/189 (15.0)	1,848/748 (59.5)	2,316/937 (74.5)
Cedar Creek	831/336 (51.5)	782/316 (48.5)	1,613/653 (100)
Cloud Peak	65,762/26,612 (94.4)	3,890/1,574 (5.5)	69,652/28,187 (99.9)
Deer Creek	190/77 (31.9)	387/157 (65.0)	578/234 (96.9)
Dry Fork	157/64 (4.7)	3,052/1,235 (91.0)	3,209/1299 (95.7)
Leigh Canyon	0	883/357 (69.8)	883/357 (69.8)
Mann Creek	5,428/2197 (52.1)	4,641/1,878 (44.6)	10,068/4,074 (96.7)
Medicine Mountain	1,714/694 (39.5)	2,573/1,041 (59.3)	4,287/1,735 (98.8)
Paintrock Creek	43/17 (5.1)	607/246 (72.9)	650/263 (98.0)
Powder River Pass	9,754/3947 (37.6)	15,034/6,084 (57.9)	24,788/10,031 (95.5)
Preacher Rock Bog	0	116/47 (100)	116/47 (100)
Sourdough Creek	65/26 (23.1)	175/71 (62.5)	240/97 (85.6)
Story	17/7 (1.5)	1,131/458 (98.5)	1,148/465 (100)
Virginia Creek Drainage	4,723/1,911 (89.0)	582/236 (11.0)	5,305/2,147 (100)
Woodrock	410/166 (9.3)	3,361/1,360 (76.5)	3,772/1,526 (85.8)

Current Ecological Threats to Identified Conservation Sites

Because the WYNDD conservation sites were specifically selected as areas of importance to the protection and maintenance of biodiversity and/or species persistence on the BNF, the presence and magnitude of current ecological threats to those sites are examined and described in this section. We examined the following potential threats: high fire hazard, which also implies departure from historical fire regimes and changes in ecosystem structure; high livestock preference and stocking; high road density, which implies

Table 7-4. Area of each potential Research Natural Areas (RNA) having high and moderately high ecological integrity. Proportion of each site is shown in parentheses.

Potential RNA	Acres/ha Having 6-7 Components	Acres/ha Having 4-5 Components	Total Acres/ha
Crazy Woman Creek	374/151 (23.5)	1,214/491 (76.4)	1,588/643 (99.9)
Devil's Canyon	4,249/1,720 (51.3)	4,037/1,634 (48.7)	8,287/3,354 (100)
Dry Creek	1,355/548 (11.9)	8,605/3,482 (75.3)	9,960/4,031 (87.2)
Elephant Head	5,161/2,089 (54.0)	4,390/1,777 (46.0)	9,551/3,865 (100)
Lake McClain	9,274/3,753 (97.3)	259/105 (2.7)	9,533/3,858 (100)
Mann Creek	5,929/2,399 (51.9)	5,294/2,142 (46.4)	11,223/4,542 (98.3)
Petes Hole	1,682/681 (59.2)	1,160/469 (40.8)	2,842/1,150 (100)
Pheasant Creek	7,460/3,019 (79.3)	1,944/788 (20.7)	9,403/3,805 (100)
Poison Creek	1,684/681 (72.3)	645/261 (27.7)	2,329/943 (100)
Tensleep Canyon	319/129 (10.2)	2,007/812 (64.2)	2,326/941 (74.4)
Tongue River	446/180 (7.5)	4,940/1,999 (83.6)	5,386/2,180 (91.1)

a direct impact from travel routes as well as facilitating human accessibility; high recreation, which includes the presence of human settlements; and high potential for invasion by non-native plant species.

Of the 16 WYNDD sites, Cloud Peak is the least affected by the five threats listed above (Table M7-8), having less than 15% of its area affected by any one threat. Deer Creek, although it experiences a higher threat from fire hazard and road density than Cloud Peak, is also relatively unthreatened; this observation is interesting, given the very different locations and ecological setting of the two sites (Fig. M7-2).

Several sites experience moderate ecological threat due to the high proportion of land area affected by one or a few threats. For example, the Virginia Creek Drainage receives little threat from grazing or human activities, but nearly 35% of its area is characterized by high fire hazard, over 50% by high road density, and nearly 22% by high invasibility (Table M7-8). Story is also threatened by similar activities at similar magnitudes as the Virginia Creek Drainage, and Mann Creek encompasses two cow camps and a permanent residence in addition to these threats.

At least four sites exhibit very high proportions of their area affected by at least two ecological threats: Big Goose, Boyd Ridge, Cedar Creek, and Preacher Rock Bog (Table M7-8). Of the 16 WYNDD sites, Woodrock and Sourdough Creek appear to be the most highly affected by the five ecological threats. Thus although most WYNDD sites are characterized by relatively high ecological integrity, various ecological threats may affect integrity of these locations in the future. Careful monitoring and continuous assessment are thus required if conservation and maintenance of biodiversity at these sites is a management objective for the BNF.

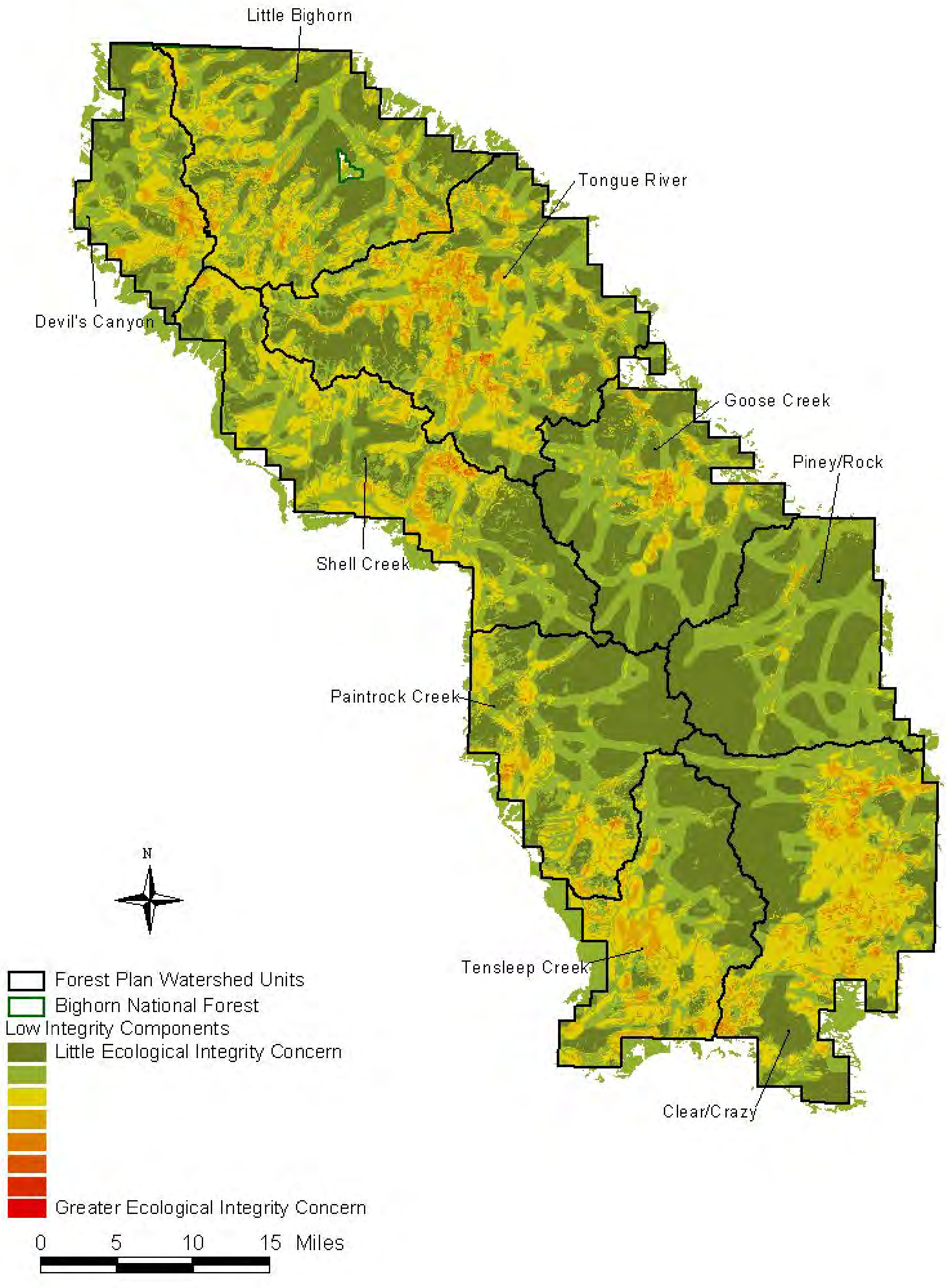


Figure 7-2. Areas of concern (low ecological integrity) on the Bighorn National Forest. Warmer colors represent areas having more components of low ecological integrity.

Table 7-5. Area of each FPWS unit having low and moderately low ecological integrity. Proportion of each FPWS is shown in parentheses.

FPWS	Acres/ha Having 6-7 Components	Acres/ha Having 4-5 Components	Total Acres/ha
Clear/Crazy Woman Creek	9/4 (<1)	3,046/1,233 (2.8)	3,055/1,236 (2.8)
Devil's Canyon	4/2 (<1)	678/274 (1.5)	682/276 (1.5)
Goose Creek	6/2 (<1)	820/332 (1.3)	826/334 (1.3)
Little Bighorn	<1/<1 (<1)	699/283 (0.7)	699/283 (0.7)
Paintrock Creek	1/<1 (<1)	680/275 (1.1)	680/275 (1.1)
Piney/Rock Creek	0	32/13 (<1)	32/13 (<1)
Shell Creek	3/1 (<1)	821/332 (0.8)	824/333 (0.8)
Tensleep Creek	1/<1 (<1)	779/315 (1.1)	779/315 (1.1)
Tongue River	15/6 (<1)	3,410/1,380 (2.7)	3,425/1,386 (2.7)

Table 7-6. Area of each WYNDD conservation site having low and moderately low ecological integrity. Proportion of each site is shown in parentheses.

WYNDD Site	Acres/ha Having 6-7 Components	Acres/ha Having 4-5 Components	Total Acres/ha
Big Goose	1/<1 (<1)	369/149 (2.5)	369/149 (2.5)
Boyd Ridge	0	0	0
Cedar Creek	0	1/< 1 (<1)	1/< 1 (<1)
Cloud Peak	0	2/1 (<1)	2/1 (<1)
Deer Creek	0	0	0
Dry Fork	0	1/< 1 (<1)	1/< 1 (<1)
Leigh Canyon	0	< 1/< 1 (<1)	< 1/< 1 (<1)
Mann Creek	0	0	0
Medicine Mountain	0	3/1 (< 1)	3/1 (< 1)
Paintrock Creek	0	3/1 (0.5)	3/1 (<0.5)
Powder River Pass	1/< 1 (< 1)	286/116 (2.7)	287/116 (2.7)
Preacher Rock Bog	0	< 1/< 1 (0.4)	< 1/< 1 (0.4)
Sourdough Creek	0	0	0
Story	0	< 1/< 1 (< 1)	< 1/< 1 (< 1)
Virginia Creek Drainage	0	0	0
Woodrock	5/2 (0.1)	415/168 (10.0)	420/170 (10.1)

Table 7-7. Area of each potential RNA having low and moderately low ecological integrity. Proportion of each site is shown in parentheses.

Potential RNA	Acres/ha Having 6-7 Components	Acres/ha Having 4-5 Components	Total Acres/ha
Crazy Woman Creek	0	0	0
Devil's Canyon	0	0	0
Dry Creek	0	< 1/< 1 (< 1)	< 1/< 1 (< 1)
Elephant Head	0	0	0
Lake McClain	0	0	0
Mann Creek	0	0	0
Petes Hole	0	0	0
Pheasant Creek	0	0	0
Poison Creek	0	0	0
Tensleep Canyon	0	0	0
Tongue River	0	< 1/< 1 (< 1)	< 1/< 1 (< 1)

Table M7-8. Proportion of WYNDD conservation sites currently affected by selected ecological threats.

WYNDD Site	High Fire Hazard	High Stocking & Preference	High Road Density	High Recreation*	High Invasibility
Big Goose	26.4	12.9	76.1	4CG, 5H	18.5
Boyd Ridge	19.0	2.6	74.1	1C	42.3
Cedar Creek	48.3	6.1	48.2	0	40.7
Cloud Peak	2.4	3.3	14.1	0	3.7
Deer Creek	25.9	0	27.2	0	16.1
Dry Fork	24.2	3.5	75.3	1C	29.8
Leigh Canyon	62.8	3.6	45.7	1CG	34.4
Mann Creek	19.2	0	34.8	2C, 1H	25.8
Medicine Mountain	25.4	11.5	71.7	1C	12.7
Paintrock Creek	8.0	26.3	41.8	0	24.4
Powder River Pass	31.4	24.4	61.1	1C	11.6
Preacher Rock Bog	12.5	54.9	100	0	28.1
Sourdough Creek	40.1	0	69.6	0	44.2
Story	30.2	7.5	49.5	0	16.5
Virginia Cr. Drainage	34.7	0	50.4	0	21.6
Woodrock	40.0	40.2	97.2	3CG	15.6

* C = cow camp, CG = campground, H = private home

Reference Landscapes for Ecological Integrity

Using our definitions of ecological integrity described above, we identified five reference landscapes on the Forest having high ecological integrity. These large reference landscapes may be useful as a baseline for management where ecological integrity is an issue.

Reference landscapes (RLs) were chosen using a minimum size requirement that reflects the natural disturbance regime for that landscape. For example, since subalpine areas are dominated by large (>100,000 acres/40,500 ha), infrequent disturbances (Romme and Despain 1989, Bessie and Johnson 1995, Agee 1997) and montane areas are characterized by smaller (<10,000 acres/4,050 ha), more frequent disturbances (Cooper 1960, Veblen *et al.* 2000, Meyer and Knight 2003), we defined high-integrity reference landscapes as having at least 6 components of high ecological integrity and as being >5,000 acres (2,000 ha) in area. A description of the vegetation included within each reference area follows.

Of the five landscapes, only RL 1 was larger than 100,000 acres (Table M7-9); this landscape is centered on the Cloud Peak Wilderness, at high elevations, and consists mainly of subalpine forest (spruce-fir and lodgepole pine), alpine meadows, and bare rock or soil (Fig. M7-3). RL 1 is likely the most representative area for high-integrity subalpine landscapes, given its large size and relatively pristine condition. RL 2 is similar to RL one in composition, although it is heavily dominated by spruce-fir forests and is much smaller. RLs 4 and 5 occur at slightly lower elevations, include a large (>20%) Douglas-fir component, are dominated by spruce-fir, and are smaller than 10,000 acres. Finally, RL 3 is most representative of montane landscapes (Table M7-9). It is slightly less than 10,000 acres, is dominated by Douglas-fir forests, includes fairly extensive shrublands and low-elevation woodland communities (limber pine and juniper), and is the only RL located at lower elevations.

No RL contains ponderosa pine forest, and only one is located at low elevation. Although selection of reference areas was determined in part by minimum size requirements, this distribution of RLs suggests that ecological integrity is relatively limited at low elevations on the Forest, at least across large landscapes.

Findings Summarized by Ecological Land Units

The Bighorn Mountains Section (M331B) is subdivided into three Subsections. The Bighorn National Forest occurs on two of these Subsections. The Bighorn Mountains, Granitic/Gneiss Subsection (M331Bb) is further subdivided into six Landtype Associations and the Bighorn Mountains, Sedimentary Subsection (M331Ba) are divided into five Landtype Associations. The Subsection and the Landtype Association levels of the National Hierarchy of Ecological Units will be used in this synthesis to help present the spatial variability of key ecological findings of this assessment. Differences in Land Type Associations are highlighted by summarizing the following ecological measures:

- Vulnerability to invasive plant species
- Resilience in response to livestock grazing
- Preference to livestock grazing
- Ecological integrity
- Reference area representation

Geologic Subsection Setting

The Granitic/Gneiss Subsection (GGS) is embedded within the Bighorn Mountains Sedimentary Subsection (SS). The GGS is generally higher, more rugged, and has thinner soils derived from granite and/or gneiss with considerably more rock outcrops than the SS.

Figure 7-3. Vegetation cover types included within Reference Landscapes for high ecological integrity on the Bighorn National Forest.

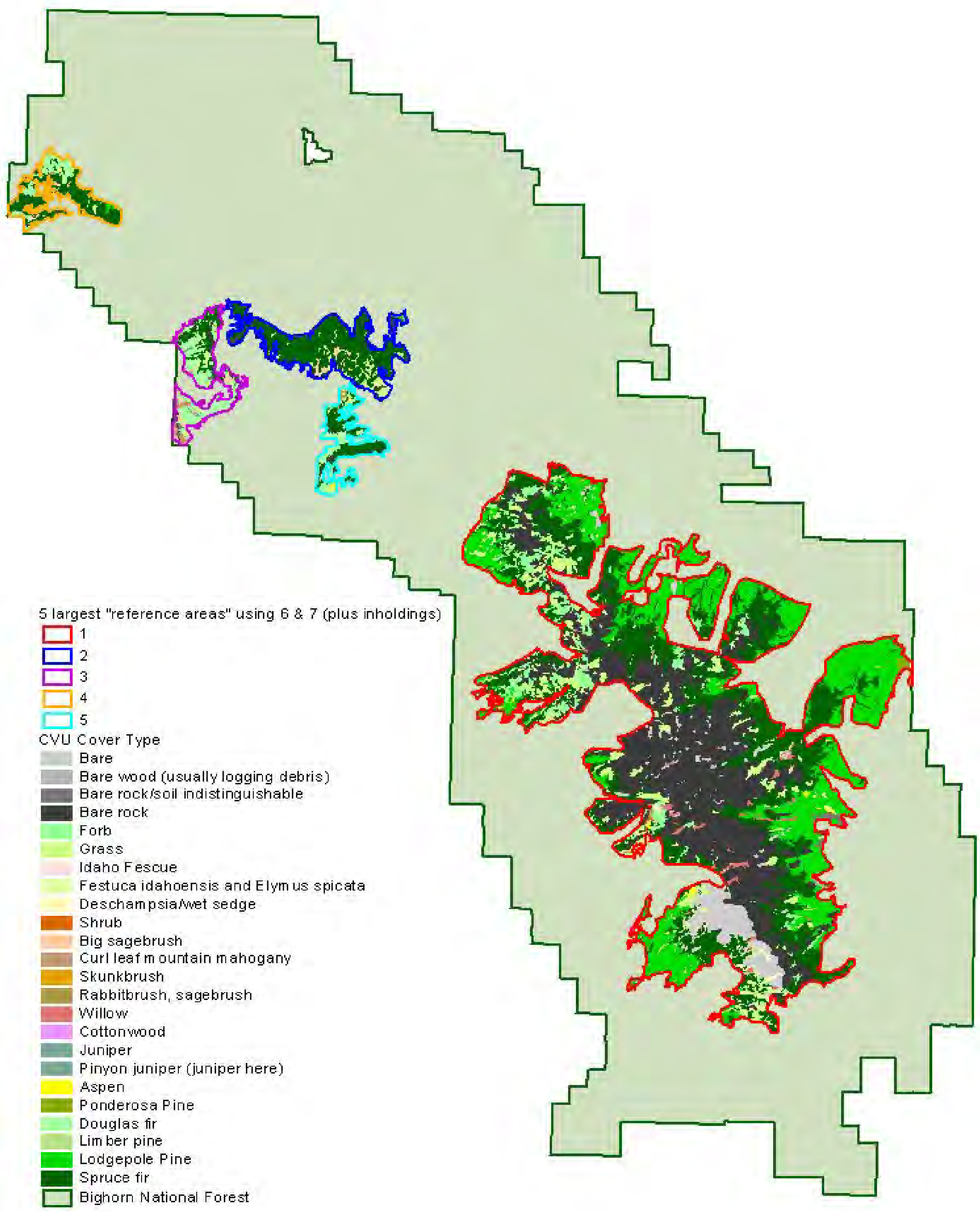


Table 7-9. Area (acres/ha) of major vegetation types (CVU) within reference landscapes on the Bighorn National Forest. Proportion of each vegetation type for each landscape is in parentheses.

CVU Cover Type	Reference Landscape 1	Reference Landscape 2	Reference Landscape 3	Reference Landscape 4	Reference Landscape 5
Bare rock/soil/wood	79,865/32,320 (35.9)	1,039/420 (6.8)	631/255 (6.8)	101/41 (1.3)	470/190 (7.2)
Forb	9,666/3,912 (4.4)	17.7/7 (< 1)	538/218 (5.8)	101/41 (1.3)	0
Grass	14,551/5,889 (6.5)	1,361/551 (8.9)	476193 (5.1)	129/52 (1.6)	598/242 (9.1)
Big sagebrush	0	573 (3.7)	570/231 (6.1)	174/70 (2.2)	28/11 (< 1)
Curl-leaf mtn. mahogany	0	0	656/266 (7.0)	2/1 (< 1)	0
Juniper	0	0	187/76 (2.0)	0	0
Limber pine	0	0	265/107 (2.9)	142/57 (1.8)	9/4 (< 1)
Douglas-fir	0	0	3,526/1427 (37.9)	1,714/694 (21.5)	1,604/649 (24.5)
Lodgepole pine	53,748/21,751 (24.2)	247/100 (1.7)	0	112/45 (1.4)	0
Spruce-fir	60,542/25,500 (27.2)	12,099/29,897 (78.8)	2,402/972 (25.8)	5,489/2,221 (68.8)	3,606/1,459 (55.1)
Other	4,047/1,638 (2.2)	40.5/16 (< 1)	48/19 (1.0)	22/9 (< 1)	229/93 (3.5)
TOTAL AREA	222,419/9,073	15,349/6,212	9,297/3,762	7,984/3,231	6,544/2,648

Vegetation Subsection Differences

90% of the lodgepole pine forests occur within the GGS (on granitic parent material) vs. 93% of limber pine, 80% of ponderosa pine, and 99% of juniper forests occur within the SS (on limestone or dolomite sedimentary parent material). 77% of all silviculture activities and 71% of all clearcut harvesting between 1935 and 2000 took place within the GGS.

Table 7- 10. Vegetation types within Sedimentary and Granitic/Gneiss Subsections.

	Sedimentary Subsection	Granitic/Gneiss Subsection
Most Common PNV Types		
	Spruce/Subalpine fir (164,827 acres; 31%)	Spruce/Subalpine fir (300,722; 44%)
	Idaho fescue (117,851 acres; 22%)	Lodgepole pine (159,159; 23%)
	Douglas-fir (97,443 acres; 18%)	Alpine tundra (75,973; 11%)
Most Common CVU Types	Douglas-fir (105,275; 20%)	Lodgepole pine (323,633; 47%)
	Spruce/fir (103,598; 19%)	Spruce/fir (132,733; 19%)
	Grass (81,059; 15%)	Bare rock (78,998; 11%)

Land Use

34 out of 38 campgrounds and 7 out of 10 resorts are located within the GGS. This preference for the higher and more rugged landscape found in GGS is also evident in the summer home statistics. 199 summer homes are in the GGS and 73 are in the SS.

Ecological Measures

75% of the GGS is in Condition Class I, 4% is in CC II, and 14% is in CC III in contrast to 34% in CC I, 24% in CC II, and 40% in CC III for the SS.

Vulnerability to mortality from insects is lower in the Granitic/Gneiss Subsection where 69% of the Subsection is classified as low vulnerability vs. 54% classified as low in the Sedimentary Subsection.

Invasibility to non-native plant establishment and spread is higher in the Sedimentary Subsection where 23% of the landscape is classified as high, 34% as moderate, and 43% as low invasibility. The Granitic/Gneiss Subsection is classified as 16% high, 26% moderate, 53% low and 5% extremely low for invasibility for non-native plant establishment and spread.

Differences in fire regimes correspond to differences in major vegetation types. The SS has 39% of its landscape classified as having fire regimes <35 yrs reflecting a greater proportion of grass and shrub lands. This is in contrast to 15% for the GGS. The GGS has 78% of its landscape classified as having fire regimes >125 yrs corresponding to subalpine forests of spruce, fir, and lodgepole pine. This contrasts with the SS with only 38% of its landscape classified as having fire regimes >125 yrs.

The Granitic/Gneiss Subsection is higher in elevation and has more alpine tundra and rock reducing its overall wildfire hazard from that of the Sedimentary Subsection.

Table 7-11a. Differences in fire regimes and major vegetation types.

Fire Regimes	Sedimentary Subsection	Granitic/Gneiss Subsection
10-35 years; mixed intensity	85,227 (16%)	24,455 (4%)
35-100 years; mixed intensity	121,736 (23%)	24,575 (4%)
125-300 years; low intensity	393 (<1%)	40 (<1%)
125-300 years; mixed intensity	1,401 (<1%)	3,334 (<1%)
125-300 years; high intensity	76,985 (14%)	157,418 (23%)
>300 years; low intensity	18 (<1%)	75,972 (11%)
>300 years; high intensity	106,923 (20%)	302,491 (44%)
N/A; Doesn't burn	14,860 (3%)	50,620 (7%)

Table 7-11b. Wildfire hazard and subsection information.

		Sedimentary Subsection	Granitic/Gneiss Subsection
Wildfire Hazard 90th Percentile	High	73,826 (17%)	84,096 (13%)
	Medium	253,257 (58%)	297,425 (45%)
	Low	92,177 (21%)	152,488 (23%)
	None	17,093 (4%)	123,938 (19%)

Landtype Associations add another level of spatial resolution to the analysis of key ecological findings of this assessment. The Landtypes that comprise the Granitic/Gneiss and the Sedimentary Subsections will be discussed by Subsection.

Granitic/Gneiss Subsection

The LTAs will be discussed beginning with the highest and ending with the lowest in mean elevation.

The **Glacial Cirqelands LTA** is unique to the BNF having no counterpart in the Sedimentary Subsection. It totals 64,417 acres or 10% of the Granitic/Gneiss Subsection.

Geologic LTA Setting
This LTA is comprised of glacial cirque headwalls, cirque basins, and periglacial rubble and talus.

Vegetation/Cover
Landscape PNV cover is Alpine Tundra (62%) and Rock/Soil (21%).

Land Use
This LTA has the lowest travel route density of all the LTAs within the Granitic/Gneiss Subsection (0.1 mi/mi2). It is within the Cloud Peak Wilderness. It hasn't any developments (homes, resorts, cow camps, utility corridors, ski areas, or campgrounds).

Ecological Measures
- Seventy-eight percent of the Glacial Cirqelands LTA is classified as having low resilience.
- Less than 1% of the LTA has high preference for cattle and only 8% has high preference for sheep.
- Thirty-nine percent of the LTA has extremely low and 54% has low invasibility for non-native plant establishment and spread.
- Ecological integrity values are1 – 7. The more areas of concern within the LTA, the

higher the low integrity indicator number. Ninety-two percent of the Glacial Cirque LTA has a low integrity indicator number of 0. Another 8% has a low integrity indicator number of 1.
- Reference Values are 1 – 7. The higher the reference value, the more indicators of high integrity present. Seventy-six percent of the LTA has a reference value of 7 and 23% has a reference value of 6.

The **Alpine Mountains and Ridges LTA** is topographically lower than and surrounds the Glacial Cirquelands LTA. It totals 119,975 acres or 18% of the Granitic/Gneiss Subsection.

Geologic LTA Setting
This LTA is comprised of mountainsides, alpine ridges, and glacial trough valleys.

Vegetation/Cover
Landscape PNV cover is Subalpine fir (40%), Alpine Tundra (27%), and Rock/Soil (17%). Less than 1% of this LTA had any kind of harvest between 1935 and 2000.

Land Use
This LTA has the second lowest travel route density of all the LTAs within the Granitic/Gneiss Subsection (0.54 mi/mi2). It is partially within the Cloud Peak Wilderness. It has four developments consisting of two summer homes and two cow camps.

Ecological Measures
- Sixty-eight percent of the Alpine Mountains and Ridges LTA is classified as having low resilience.
- Less than 5% of the LTA has high preference for cattle and 34% has high preference for sheep.
- Six percent of the LTA has extremely low and 62% has low invasibility for non-native plant establishment and spread.
- Ecological integrity values are1 – 7. The more areas of concern within the LTA, the higher the low integrity indicator number. Sixty-three percent of the Alpine Mountains and Ridges LTA has a low integrity indicator number of 0. Another 33% has a low integrity indicator number of 1.
- Reference Values are 1 – 7. The higher the reference value, the more indicators of high integrity present. Thirty-six percent of the LTA has a reference value of 7, 48% has a reference value of 6, and 14% has a reference value of 5.

The **Glacial/Tertiary Terrace Deposits LTA** is topographically lower than the Alpine Mountains and Ridges LTA. It totals 99,140 acres or 15% of the Granitic/Gneiss Subsection.

Geologic LTA Setting
This LTA is composed of glacial moraines and Tertiary terraces that are in the form of discontinuous patches radiating out from the topographically higher Glacial Cirquelands and Alpine Mountains and Ridges LTAs.

Vegetation/Cover
Landscape PNVcover is lodgepole pine (30%), spruce (23%), and Subalpine fir (19%). Eleven percent of the LTA or 11,293 acres had some type of harvest between 1935 and 2000. Of the acreage harvested, 2,588 acres were clearcut harvest between 1946 and 2000.

Land Use
This LTA has the highest travel route density of all the LTAs within the Granitic/Gneiss Subsection (2.38 mi/mi2). It is also one of the most developed LTAs on the BNF consisting of 16 campgrounds, 2 cowcamps, 3 resorts, and 117 summer homes. It also has 330 acres of developed ski areas, and 6.91 miles of utility corridor.

Ecological Measures
- Only 17% of the Glacial/Tertiary Terrace LTA is classified as having low resilience.
- Less than 15% of the LTA has high preference for cattle and 37% has high preference for sheep.
- Fifty percent of the LTA has low, 28% moderate, and 21% has high invasibility for non-native plant establishment and spread.
- Ecological integrity values are1 – 7. The more areas of concern within the LTA, the higher the low integrity indicator number. Eighteen percent of the Glacial/Tertiary Terrace LTA has a low integrity indicator

number of 0. Forty-five percent have a low integrity indicator number of 1; 24% have a low integrity indicator number of 2; and 12% have low integrity indicator number of 3.
- Reference Values are 1 – 7. The higher the reference value, the more indicators of high integrity present. Eighteen percent of the LTA has a reference value of 6, 35% has a reference value of 5, and 37% has a reference value of 4.

The **Granitic Mountain Slopes, Gentle LTA** is topographically lower than and surrounds the Alpine Mountains and Ridges LTA. It is in a topographic position similar to and dissected by the Glacial/Tertiary Terrace Deposits LTA. It dominates the Granitic/Gneiss Subsection with a total of 303,241 acres or 45% of the Subsection.

Geologic LTA Setting
This LTA is composed of mountainsides, fans, and outwash plains. Floodplains and wetlands are common.

Vegetation/Cover
Landscape PNV cover is lodgepole pine (34%), subalpine fir (29%), and spruce (20%). Thirty-three percent of the LTA or 99,284 acres had some type of harvest between 1935 and 2000. Of the acreage harvested, 21,754 acres (7%) were clearcut harvest between 1946 and 2000. Eighty-eight percent of all harvest between 1935 and 2000 and 88% of all clearcut harvest between 1946 and 2000 that occurred in the Granitic/Gneiss Subsection occurred in this LTA.

Land Use
This LTA has the second highest travel route density (2.05mi/mi2) of all the LTAs within the Granitic/Gneiss Subsection. It is also one of the most developed LTAs on the BNF consisting of 18 campgrounds, 8 cow camps, 4 resorts, and 62 summer homes. It also has 257 acres of developed ski areas, and 15.8 miles of utility corridor.

Ecological Measures
- Forty-two percent of the Granitic Mountain Slopes, Gentle LTA is classified as having low resilience.
- Less than 7% of the LTA has high preference for cattle and 23% has high preference for sheep.
- Fifty-six percent of the LTA has low, 28% has moderate, and 16% has high invasibility for non-native plant establishment and spread.
- Ecological integrity values are 1 – 7. The more areas of concern within the LTA, the higher the low integrity indicator number. Twenty-eight percent of the Granitic Mountain Slopes, Gentle LTA has a low integrity indicator number of 0. Thirty-five percent have a low integrity indicator number of 1; 29% have a low integrity indicator number of 2; and 7% have low integrity indicator number of 3.
- Reference Values are 1 – 7. The higher the reference value, the more indicators of high integrity present. Twelve percent of the LTA has a reference value of 6, 31% has a reference value of 5, 42% has a reference value of 4 and 12% has a reference value of 3.

The **Granitic Mountain Slopes, Steep LTA** consists of steeper sloping patches embedded within the lower portion of the Granitic Mountain Slopes, Gentle LTA. It is the second smallest LTA with a total of 41,767 acres comprising only 6.25% of the Granitic/Gneiss Subsection.

Geologic LTA Setting
This LTA is composed of steep mountainsides.

Vegetation/Cover
Landscape PNV cover is spruce (34%), lodgepole pine (25%), and subalpine fir (21%). Less than 1% of this LTA had any kind of harvest between 1935 and 2000.

Land Use
This LTA has a travel route density of 1.11 mi/mi2, 2 cow camps, and 12 summer homes.

Ecological Measures
- Forty-seven percent of the Granitic Mountain Slopes, Steep LTA is classified as having low resilience.
- One percent of the LTA has high preference for cattle and 9% has high preference for sheep.

- Forty- five percent of the LTA has low, 35% has moderate, and 19% has high invasibility for non-native plant establishment and spread.
- Ecological integrity values are1 – 7. The more areas of concern within the LTA, the higher the low integrity indicator number. Forty-four percent of the Granitic Mountain Slopes, Steep LTA has a low integrity indicator number of 0. Forty-four percent has a low integrity indicator number of 1 and 9% has a low integrity indicator number of 2.
- Reference Values are 1 – 7. The higher the reference value, the more indicators of high integrity present. Forty-four percent of the LTA has a reference value of 6, 41% has a reference value of 5, and 9% has a reference value of 4.

The **Granitic Breaklands LTA** is topographically the lowest LTA in the Bighorn Mountains, Granitic/Gneiss Subsection. It is the smallest LTA with a total of 39,278 acres comprising only 5.88% of the Granitic/Gneiss Subsection.

Geologic LTA Setting
This LTA is composed of steep mountainsides, escarpments, and canyon walls. Rock outcrop and rubble land are common.

Vegetation/Cover
Landscape PNV cover is spruce (25%), subalpine fir (19%), Douglas fir (19%), ponderosa pine (15%), and lodgepole pine (12%). Three percent of the LTA or 1,122 acres had some type of harvest between 1935 and 2000. Of the acreage harvested, 385 acres were clearcut harvest between 1946 and 2000.

Land Use
This LTA has the third lowest travel route density (0.70 mi/mi2) of all the LTAs within the Granitic/Gneiss Subsection. It has seven developments consisting of 1cow camp, and 6 summer homes.

Ecological Measures

- Seventy percent of the Granitic Breaklands LTA is classified as having low resilience.
- One percent of the LTA has high preference for cattle and 9% has high preference for sheep.
- Thirty-three percent of the LTA has low, 38% has moderate, and 28% has high invasibility for non-native plant establishment and spread.
- Ecological integrity values are1 – 7. The more areas of concern within the LTA, the higher the low integrity indicator number. Fifty-four percent of the Granitic Breaklands LTA has a low integrity indicator number of 0. Thirty-six percent has a low integrity indicator number of 1 and 9% has a low integrity indicator number of 2.
- Reference Values are 1 – 7. The higher the reference value, the more indicators of high integrity present. Eleven percent of the LTA has a reference value of 7, 36% has a reference value of 6, 38% has a reference value of 5, and 13% has a reference value of 4.

Sedimentary Subsection

The LTAs will be discussed beginning with the highest and ending with the lowest in mean elevation.

The **Sedimentary Mountain Slopes, Limestone/Dolomite LTA** is topographically lower than and surrounds the Granitic/Gneiss Subsection. It totals 166,069 acres or 37% of the Sedimentary Subsection. It shares the highest topographic position in the Sedimentary Subsection with the Sedimentary Mountain Slopes, Shale/Sandstone (Non-calcareous).

Geologic LTA Setting
This LTA is comprised of mountainsides, ridges, toeslopes, and fans.

Vegetation/Cover
Landscape PNV cover is Subalpine fir (28%), Idaho Fescue (28%), and Mountain Sagebrush (12%) and Wyoming Sagebrush (9%). Less than 1% of this LTA had any kind of harvest between 1935 and 2000.

Land Use
This LTA has a travel route density of 1.99 mi/mi2. It has twenty-seven developments consisting of twenty summer homes and seven cow camps. It also has 1.48 miles of utility corridors and 405 acres of developed ski areas.

Ecological Measures

- Nineteen percent of the Sedimentary Mountain Slopes, Limestone/Dolomite LTA is classified as having low resilience.
- Six percent of the LTA has high preference for cattle and 46% has high preference for sheep.
- Fifty-five percent of the LTA has low, 28% has moderate, and 17% has high invasibility for non-native plant establishment and spread.
- Ecological integrity values are1 – 7. The more areas of concern within the LTA, the higher the low integrity indicator number. Eighteen percent of the Sedimentary Mountain Slopes, Limestone/Dolomite LTA has a low integrity indicator number of 0. Twenty-eight percent has a low integrity indicator number of 1, 40% has a low integrity indicator of 2 and 6% has a low integrity indictor of 3.
- Reference Values are 1 – 7. The higher the reference value, the more indicators of high integrity present. Eighteen percent of the LTA has a reference value of 6, 35% has a reference value of 5, 37% has a reference value of 4 and 6% has a reference value of 3.

The **Sedimentary Mountain Slopes, Shale/Sandstone (Non-calcareous) LTA** is topographically lower than the Granitic/Gneiss Subsection and shares the highest topographic position in the Sedimentary Subsection with the Sedimentary Mountain Slopes, Limestone/Dolomite. It totals 81,616 acres or 18% of the Sedimentary Subsection.

Geologic LTA Setting
This LTA is composed of mountainsides, toeslopes, and fans.

Vegetation/Cover
Landscape PNV cover is subalpine fir (34%), Idaho Fescue (30%), lodgepole pine (9%), and spruce (9%). Twenty-one percent of the LTA or 17,031 acres had some type of harvest between 1935 and 2000. Of the acreage harvested, 4742 acres (6%) were clearcut harvest between 1946 and 2000. Fifty-one percent of all harvest between 1935 and 2000 and 48 % of all clearcut harvest between 1946 and 2000 that occurred in the Sedimentary Subsection occurred in this LTA.

Land Use
This LTA has the highest travel route density (2.56 mi/mi2) of all the LTAs within the Sedimentary Subsection. It is also one of the more developed LTAs in the Sedimentary Subsection consisting of 1 campgrounds, 5 cowcamps, 2 resorts, and 31 summer homes. It also has 225 acres of developed ski areas, and 1.43 miles of utility corridor.

Ecological Measures

- Nine percent of the Sedimentary Mountain Slopes, Shale/Sandstone (Non-calcareous) LTA is classified as having low resilience.
- Nine percent of the LTA has high preference for cattle and 34% has high preference for sheep.
- Forty-six percent of the LTA has low, 31% has moderate, and 23% has high invasibility for non-native plant establishment and spread.
- Ecological integrity values are1 – 7. The more areas of concern within the LTA, the higher the low integrity indicator number. Fourteen percent of the Sedimentary Mountain Slopes, Shale/Sandstone (Non-calcareous) LTA has a low integrity indicator number of 0. Thirty-one percent have a low integrity indicator number of 1; 38% have a low integrity indicator number of 2; and 14% have low integrity indicator number of 3.
- Reference Values are 1 – 7. The higher the reference value, the more indicators of high integrity present. Eighteen percent of the LTA has a reference value of 6, 35% has a reference value of 5, 37% has a reference value of 4 and 6% has a reference value of 3.

The **Sedimentary Mountain Slopes, Shale/Sandstone (Calcareous) LTA** is topographically lower than the Sedimentary Mountain Slopes, Limestone/Dolomite and the Sedimentary Mountain Slopes, Shale/Sandstone (Non-calcareous) LTAs. It shares this topographic position in the Sedimentary Subsection with the Sedimentary Breaklands LTA. It is the smallest LTA in the Subsection with a total of 27,000 acres comprising 18% of the Sedimentary Subsection.

Geologic LTA Setting
This LTA is composed of mountainsides, toeslopes, and fans.

Vegetation/Cover
Landscape PNV cover is Idaho fescue (39%), mountain sagebrush (12%), subalpine fir (10%), Douglas fir (9%) and ponderosa pine (7%). Two percent of the LTA or 621 acres had some type of harvest between 1935 and 2000. Of the acreage harvested, 38 acres were clearcut harvest between 1946 and 2000

Land Use
This LTA has a travel route density of 1.99 mi/mi2. It is one of the less developed LTAs in the Sedimentary Subsection consisting of 5 cow camps, and 4.48 miles of utility corridor.

Ecological Measures
- Sixteen percent of the Sedimentary Mountain Slopes, Shale/Sandstone (Calcareous) LTA is classified as having low resilience.
- Eight percent of the LTA has high preference for cattle and 52% has high preference for sheep.
- Thirty-five percent of the LTA has low, 36% has moderate, and 29% has high invasibility for non-native plant establishment and spread.
- Ecological integrity values are1 – 7. The more areas of concern within the LTA, the higher the low integrity indicator number. Eight percent of the Sedimentary Mountain Slopes, Shale/Sandstone (Calcareous) LTA has a low integrity indicator number of 0. Thirty percent have a low integrity indicator number of 1; 49% have a low integrity indicator number of 2; and 12% have low integrity indicator number of 3.
- Reference Values are 1 – 7. The higher the reference value, the more indicators of high integrity present. Nine percent of the LTA has a reference value of 6, 32% has a reference value of 5, 43% has a reference value of 4 and 13% has a reference value of 3.

The **Landslide/Colluvial Deposits LTA** is found in positions similar to that of the Glacial/Tertiary Terrace Deposits LTA in the Granitic/Gneiss Subsection. It totals 35,294 acres or 8% of the Sedimentary Subsection.

Geologic LTA Setting
This LTA is composed of moderately stable to stable landslide deposits.

Vegetation/Cover
Landscape PNV cover is Idaho fescue (29%), Douglas fir (15%) subalpine fir (13%), mountain sagebrush (13%), and spruce (6%). Less than 1% of this LTA had any kind of harvest between 1935 and 2000.

Land Use
This LTA has a travel route density of 1.89 mi/mi2. It has twenty-five developments consisting of 2 campgrounds, 4 cow camps, 1 resort, 18 summer homes, and 8.48 miles of utility corridor.

Ecological Measures
- Ten percent of the Sedimentary Breaklands LTA is classified as having low resilience.
- Four percent of the LTA has high preference for cattle and 41% has high preference for sheep.
- Twenty-eight percent of the LTA has low, 31% has moderate, and 39% has high invasibility for non-native plant establishment and spread.
- Ecological integrity values are1 – 7. The more areas of concern within the LTA, the higher the low integrity indicator number. Fourteen percent of the Granitic Breaklands LTA has a low integrity indicator number of 0. Thirty-eight percent has a low integrity indicator number of 1, 36% has a low integrity

indicator number of 2, and 11% has a low integrity number of 3.
- Reference Values are 1 – 7. The higher the reference value, the more indicators of high integrity present. Fifteen percent of the LTA has a reference value of 6, 40% has a reference value of 5, 32% has a reference value of 4, and 8% has a reference value of 3.

The **Sedimentary Breaklands LTA** is topographically the lowest LTA in the Bighorn Mountains, Sedimentary Subsection. It is similar to the Granitic Breaklands in the Granitic/Gneiss Subsection. It totals 133,995 acres or 30% of the Sedimentary Subsection.

Geologic LTA Setting
This LTA is composed of steep mountainsides, escarpments, canyon walls, and steep colluvial slopes.

Vegetation/Cover
Landscape PNV cover is Douglas fir (38%) subalpine fir (20%), spruce (11%), and ponderosa pine (7%). Two percent of the LTA or 2,460 acres had some type of harvest between 1935 and 2000. Of the acreage harvested, 1,694 acres were clearcut harvest between 1946 and 2000.

Land Use
This LTA has the lowest travel route density (0.59 mi/mi2) of all the LTAs within the Sedimentary Subsection. It has six developments consisting of 1 cow camp, 1 campground, 4 summer homes, and 2.57 miles of utility corridor.

Ecological Measures
- Twenty-six percent of the Sedimentary Breaklands LTA is classified as having low resilience.
- One percent of the LTA has high preference for cattle and 6% has high preference for sheep.
- Thirty-two percent of the LTA has low, 43% has moderate, and 25% has high invasibility for non-native plant establishment and spread.
- Ecological integrity values are 1 – 7. The more areas of concern within the LTA, the higher the low integrity indicator number. Fifty-two percent of the Granitic Breaklands LTA has a low integrity indicator number of 0. Thirty-nine percent has a low integrity indicator number of 1 and 8% has a low integrity indicator number of 2.
- Reference Values are 1 – 7. The higher the reference value, the more indicators of high integrity present. Thirty-three percent of the LTA has a reference value of 6, 44% has a reference value of 5, and 17% has a reference value of 4.

Relative Productivity of Land Units

For the purposes of evaluating ecological condition, particularly from a species conservation perspective, it is of interest to evaluate ecological condition according to relative ecosystem productivity. To accomplish this, we qualitatively ranked land type associations by probable productivity (Tommy John, Region 2 soil scientist, personal comm.). There are no data available to quantitatively rank productivity so we stress that this representation is tentative. There would be tremendous value in developing inventory information to establish productivity relationships. Bighorn ecosystem landtype associations were qualitatively ranked (Fig. M7-4).

Bighorn National Forest Landtype Associations

Ranked in terms of productivity (highest to lowest)

Big Horn Mountains, Sedimentary Subsection (M331Ba)

1. M331Ba-05 Sedimentary Mountain Slopes, Shale/Sandstone (Non-calcareous)
2. M331Ba-03 Sedimentary Mountain Slopes, Limestone/Dolomite
3. M331Ba-02 Landslide/Colluvial Deposits
4. M331Ba-04 Sedimentary Mountain Slopes, Shale/Sandstone (Calcareous)
5. M331Ba-01 Sedimentary Badlands

Big Horn Mountains, Granitic/Gneiss Subsection (M331Bb)

1. M331Bb-05 Granitic Mountain Slopes, Gentle

2. M331Bb-03 Glacial/Tertiary Terrace Deposits
3. M331Bb-04 Granitic Mountain Slopes, Steep
4. M331Bb-01 Granitic Breaklands
5. M331Bb-06 Alpine Mountains and Ridges
6. M331Bb-02 Glacial Cirquelands

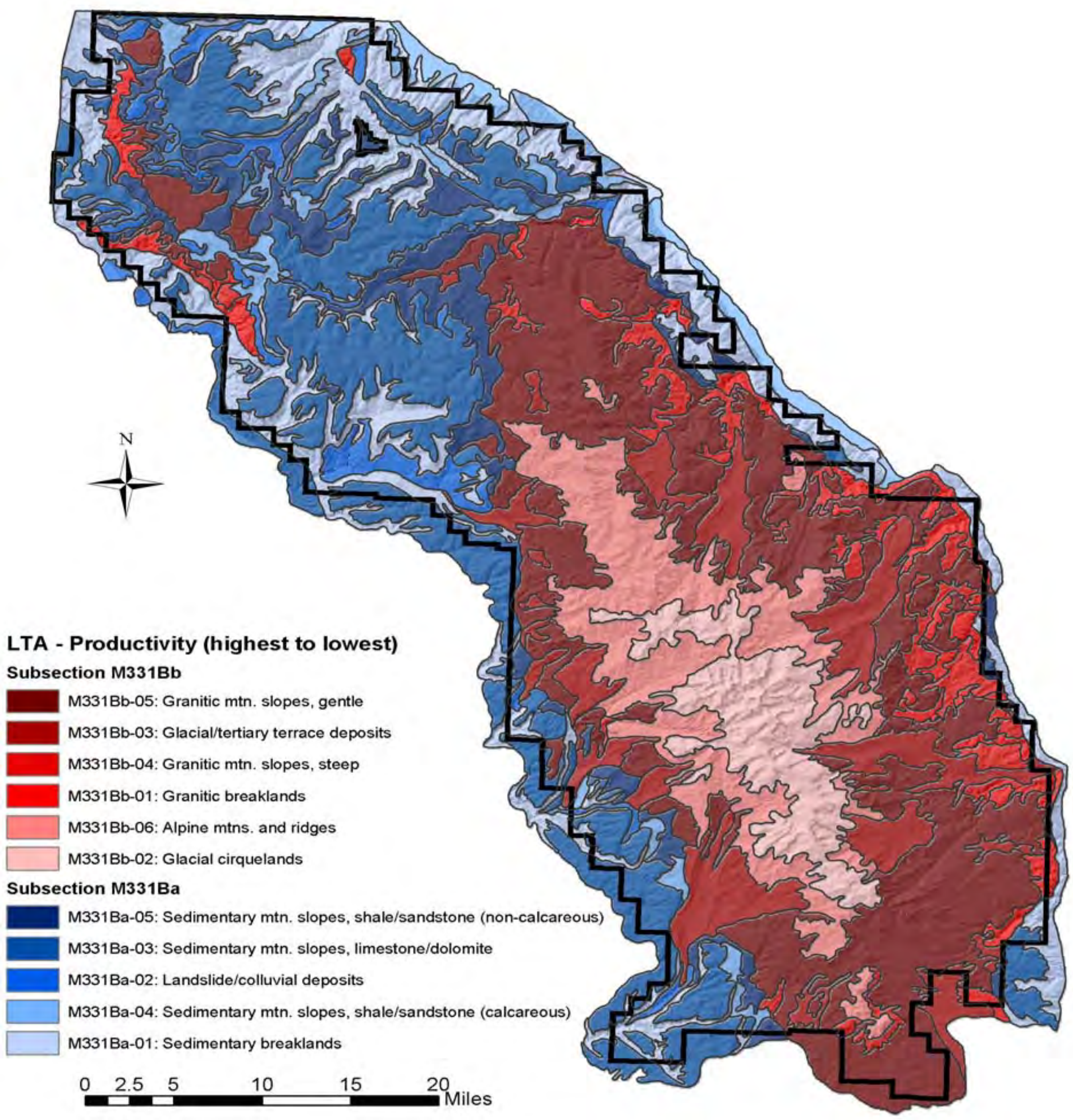


Figure 7-4. Productivity relationships for the Bighorn ecosystem land type associations.

Comparison of Ecological Measures among Land Units

Vulnerability to Invasive Plant Species

Within the Sedimentary Subsection (M331Ba), the LTAs most influenced by high or extremely high vulnerability to invasive plant species are those of relatively moderate to lower productivity. Within the Granitic/Gneiss Subsection (M331Bb), the areas most negatively affected by invasive species vulnerability are in the relatively higher productivity LTAs. An overall comparison indicates that vulnerability concerns may be greatest in the sedimentary subsection LTAs which are likely those that generally have the greatest potential productivity, with greater than 25% of three of the five LTAs showing vulnerability concerns (Fig. M7-5).

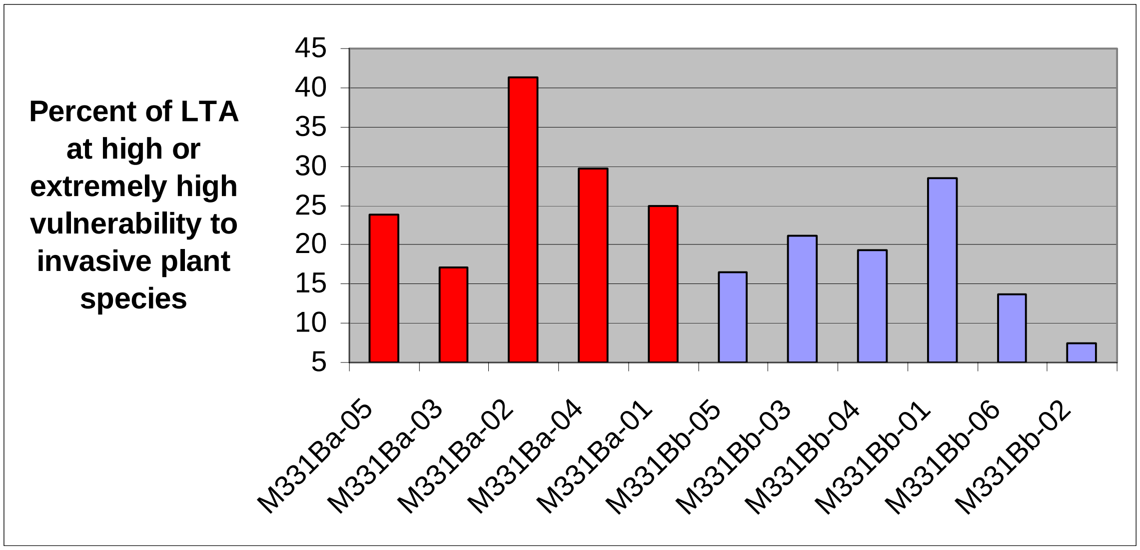


Figure 7-5. Percent of LTA at high or extremely high vulnerability to invasive plant species. LTAs are ordered on the x-axis from highest to lowest productivity based on a qualitative evaluation of LTA map unit descriptions. LTAs indicated by red bars are in the Big Horn Mountains, Sedimentary Subsection (M331Ba) and LTAs indicated by blue bars are in the Big Horn Mountains, Granitic/Gneiss Subsection (M331Bb).

Preference for and Resilience to Livestock Grazing

In this analysis, we are representing relative potential negative influence by livestock grazing as those areas of high grazing preference and low resilience to grazing. Again, we emphasize that this is a modeled representation of relative conditions. Representing absolute field conditions requires field data. Within the Sedimentary Subsection (M331Ba), the LTA that is potentially most negatively influenced by livestock grazing is one of relative higher productivity. Within the Granitic/Gneiss Subsection (M331Bb), the areas potentially most negatively affected by livestock grazing are in a relatively lower productivity LTA. An overall comparison indicates no clear pattern in potential negative livestock grazing influences and suggests that only a small portion of any LTA is potentially negatively affected (Fig. M7-6).

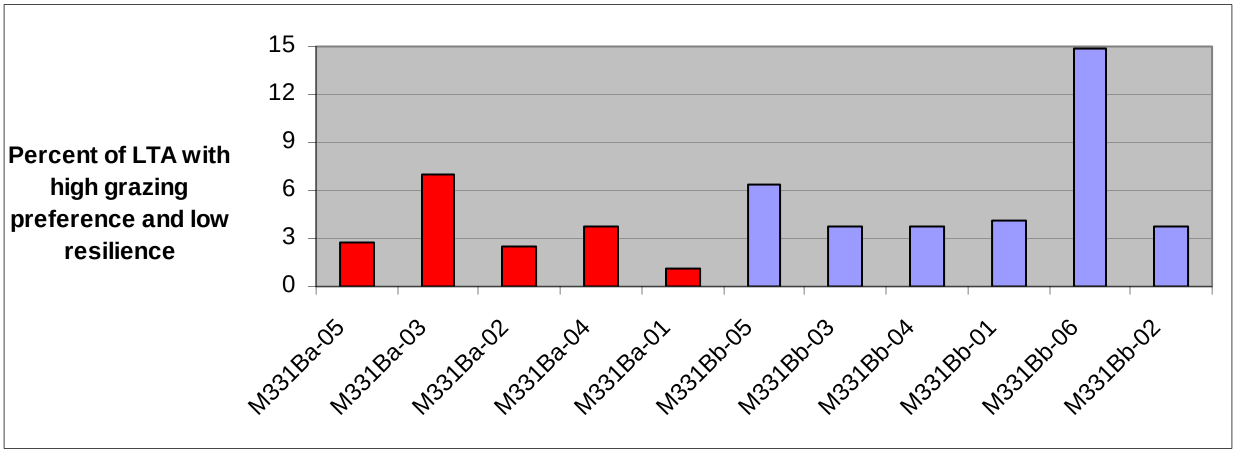


Figure 7-6. Percent of LTA with high grazing preference and low resilience. LTAs are ordered on the x-axis from highest to lowest productivity based on a qualitative evaluation of LTA map unit descriptions. LTAs indicated by red bars are in the Big Horn Mountains, Sedimentary Subsection (M331Ba) and LTAs indicated by blue bars are in the Big Horn Mountains, Granitic/Gneiss Subsection (M331Bb).

Relative Proportion of High Integrity

In this analysis, we are representing current LTA condition by the relative proportion with a high integrity ranking. Again, we emphasize that this is a modeled estimate and has not been ground verified. Within the Sedimentary Subsection (M331Ba), only one LTA (M331Ba-01) is characterized by high integrity rankings over a third or greater of the area. This LTA is expected to be relatively low in productivity compared to the other LTAs within the subsection. The most productive LTAs within this subsection are characterized by 20% or less of the area in a modeled high integrity ranking. Within the Granitic/Gneiss Subsection (M331Bb), modeled integrity rankings are generally much higher and range from greater than 30% to nearly 100% in a high integrity condition. An overall comparison again indicates the greatest integrity concerns are in the sedimentary subsection which is probably comprised of the most productive LTAs on the Bighorn landscape (Fig. M7-7).

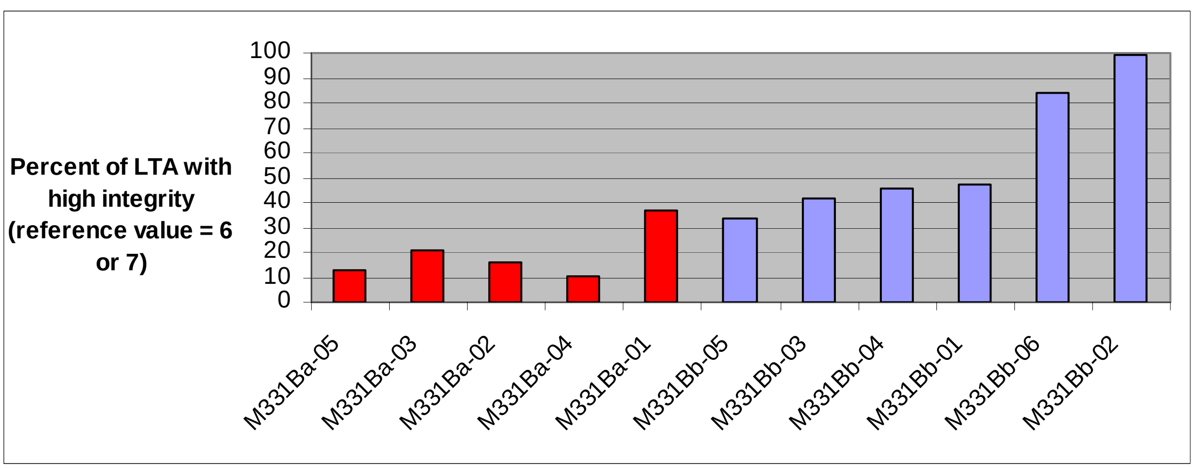


Figure 7-7. Percent of LTA with high integrity ranking. LTAs are ordered on the x-axis from highest to lowest productivity based on a qualitative evaluation of LTA map unit descriptions. LTAs indicated by red bars are in the Big Horn Mountains, Sedimentary Subsection (M331Ba) and LTAs indicated by blue bars are in the Big Horn Mountains, Granitic/Gneiss Subsection (M331Bb).

Relative Proportion of Acres in Reference Areas

In this analysis, we are representing the distribution of LTAs among reference areas as modeled in this assessment and described earlier in this chapter. Again, we emphasize that this is a modeled estimate and has not been ground verified. The Sedimentary Subsection (M331Ba) is underrepresented in modeled reference areas, with no LTA showing greater than a 10% representation. Within the Granitic/Gneiss Subsection (M331Bb), modeled reference area representation is generally much higher. However, the LTAs within this subsection that are expected to be most productive are characterized by the lowest representation in reference areas (Fig. M7-8).

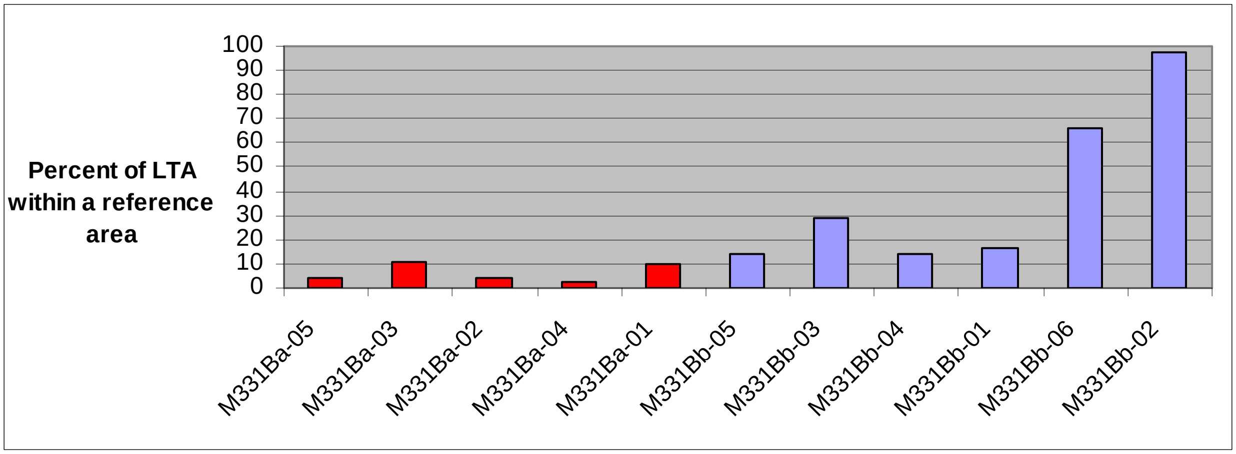


Figure 7-8. Percent of LTA within a reference area. LTAs are ordered on the x-axis from highest to lowest productivity based on a qualitative evaluation of LTA map unit descriptions. LTAs indicated by red bars are in the Big Horn Mountains, Sedimentary Subsection (M331Ba) and LTAs indicated by blue bars are in the Big Horn Mountains, Granitic/Gneiss Subsection (M331Bb).

Significant Information Gaps

In assessing the existing condition of the Bighorn National Forest, several information needs have become evident that are categorized here as inventory and assessment, monitoring, and research. Acquisition of these information or data may help to fulfill future regional or corporate management needs, but the need for such data should not be misconstrued as critical in a manner that will direct an unrealistic burden on the BNF**.**

Inventory and Assessment Needs

Additional stand-level data would be helpful to describe variation in characteristics of each cover type (i.e., areas affected by past management, stand age, coarse woody debris, snag-density, distribution of old-growth, vertical complexity). In particular, given our level of understanding of old-growth forests, an inventory for old-growth may be warranted for areas where silvicultural activity is planned. Basic stand and ecological data, including those listed above, are necessary for the minor forest types of BNF (ponderosa pine, limber pine, and juniper).

- For non-forest vegetation, greater detail in species identification is critically needed in vegetation mapping to accurately identify dominant plant community cover types. Similarly, there is a need for comprehensive non-forested vegetation historic range of variability (HRV) assessment to summarize what is known or not known about these cover types.

- For each plant community type, but particularly for non-forest vegetation, an ecological classification is necessary to, in part determine the present dominant seral status of each community on the landscape.

- Standardized, well-distributed sampling is required to describe the occurrence and coverage of invasive species across the BNF in different forest types, human activity areas, and areas of natural and anthropogenic disturbances.

Monitoring Needs

- Monitoring is required to determine changes in site productivity and in carbon/nutrient cycling and pools. In particular, it may be useful to develop standards for residual wood per acre in silviculturally treated areas.

- Given the explosive nature of invasive species dispersal and spread, it is critical that a monitoring program be developed to document the known occurrences and changes in invasive species distribution across the BNF.

- Monitoring is required to assess the dominant seral status in different rangeland communities, as well as to determine possible management concerns based on the dominant seral status.

- To ensure efficient and effective monitoring of rangelands, it would be useful if range utilization data were translated to electronic format.

Research Needs

- Additional stand-level data are needed to describe effects of natural, non-stand-replacing disturbances on forest stand productivity, structure, and function.

- Research is needed to document the status of soil productivity and carbon/nutrient cycling in this region to properly monitor the effects of human activities on site productivity.

- Given that the BNF is relatively undisturbed compared to other forests; there is a need for descriptive research to document the characteristics of old-growth forests for the Bighorn Mountains ecosystem. Currently, most information is inferred from similar ecosystems well outside the Bighorn Mountains Section.

- It is critical that on-site fire history data be collected for each forest type in the Bighorn Mountains, and that an HRV specific to the Big Horn Mountains be developed. Such data are crucial to understanding historical disturbance regimes and landscape patterns in the BNF, and may be useful in guiding future forest management.

- Research is needed to determine the successional relationship of each current non-forest vegetation type relative to the potential natural vegetation, as well as to determine how this status might affect species associated with the type.

- In lieu of a monitoring program to determine the distribution and abundance of invasive species across the BNF, field validation of the invasibility model presented in this assessment is necessary if accurate predictability and subsequent effective exotic species management is an objective for the BNF.

Literature Cited

Agee, J. K. 1997. Fire management for the 21st century. Pp. 191-201 *In*: Kohm, K. A., and J.F. Franklin (eds.). Creating a Forestry for the 21st Century: the Science of Ecosystem Management. Island Press, Washington, D.C. 475 pp.

Barnes, B.V., D.R. Zak, S.R. Denton, and S.H. Spurr. 1998. Forest Ecology. 4th ed. John Wiley and Sons, New York.

Bessie, W.C., and E.A. Johnson. 1995. The relative importance of fuels and weather on fire behavior in subalpine forests. Ecology 76: 747-762.

Cairns, J. 1977. Quantification of biological integrity. Pp. 171-187 *In*: Ballentine, R.K., L.J. Guarraia (eds.). The Integrity of Water. U.S. Environmental Protection Agency Office of Water and Hazardous Materials, Washington, D.C.

Canadian Model Forest Network. 2000. A user's guide to local level indicators of sustainable forest management. Natural Resources Canada, Ottawa, Ontario, Canada.

Cook, J.G., T.J. Hershey, and L.L. Irwin. 1994. Vegetative response to burning on Wyoming mountain-shrub big game ranges. Journal of Range Management 47: 296-302.

Cooper, C.F. 1960. Changes in vegetation, structure, and growth of southwestern pine forests since white settlement. Ecological Monographs 30: 129-164.

Despain, D.G. 1973. Vegetation of the Big Horn Mountains, Wyoming, in relation to substrate and climate. Ecological Monographs 43: 329-355.

Despain, D., and W.H. Romme. 1991. Ecology and management of high-intensity fires in Yellowstone National Park. Tall Timber Fire Ecology Conference 17.

Fisher, F.B., J.C. Winne, M.M. Thornton, and others. 1998. Montana land cover atlas. Unpublished report. Montana Cooperative Wildlife Research Unit, University of Montana, Missoula. 50 pp.

Flannigan, M.D., and C.E. VanWagner. 1991. Climate change and wildfire in Canada. Canadian Journal of Forest Research 21: 66-72.

Forman, R.T.T. 1995. Land Mosaics: The Ecology of Landscapes and Regions. Cambridge University Press, Cambridge, UK.

Franklin, J.F., and R.T.T. Forman. 1987. Creating landscape patterns by forest cutting: ecological consequences and principles. Landscape Ecology 1: 5-18.

Gardner, R.H., W.W. Hargrove, M.G. Turner, and W.H. Romme. 1997. Climate change, disturbances, and landscape dynamics. *In*: Walker, B.H., and W.L. Steffen (eds.). Global change and terrestrial ecosystems. IGBP Book Series No. 2. Cambridge University Press, Cambridge.

Holling, C.S. (ed.). 1978. Adaptive Environmental Assessment and Management. John Wiley and Sons, New York.

Hunter, M.L. Jr. 1999. Biological diversity. Pp. 3-21 *In*: Hunter, M.L. Jr. (ed.). Maintaining Biodiversity in Forest Ecosystems. Cambridge University Press, Cambridge.

Johnson, E.A. 1992. Fire and vegetation dynamics. Cambridge University Press, New York. 129 pp.

Karr, J.R., and E.W. Chu. 1995. Ecological integrity: reclaiming lost connections. Pp. 34-48 *In*: Westra, L., and J. Lemons (eds.). Perspectives on Ecological Integrity. Kluwer Academic Publishers, The Netherlands.

Karr, J.R., and D.R. Dudley. 1981. Ecological perspective on water quality goals. Environmental Management 5: 55-68.

Kay, J.J., and E. Schneider. 1995. Embracing complexity: the challenge of the ecosystem approach. Pp. 49-59 *In*: Westra, L., and J. Lemons (eds.). Perspectives on Ecological Integrity. Kluwer Academic Publishers, The Netherlands.

Knight, D.H. 1994. Mountains and Plains: the Ecology of Wyoming Landscapes. Yale University Press, 338 pp.

Lemons, J., and L. Westra. 1995. Introduction to perspectives on ecological integrity. Pages 1-11 *In*: Westra, L., and J. Lemons (eds.). Perspectives on Ecological Integrity. Kluwer Academic Publishers, The Netherlands.

Leopold, A. 1949. A sand county almanac. Oxford University Press, New York.

Merrill, E.H., T.W. Kohley, M.E. Herdendorf, and others. 1996. Wyoming gap analysis: a geographic analysis of biodiversity. Final report, Wyoming Cooperative Fishery and Wildlife Research Unit, University of Wyoming, Laramie, WY.

Meyer, C.B., and D.H. Knight. 2001. Historic variability for upland vegetation in the Bighorn National Forest, Wyoming. Unpublished report on file at Bighorn National Forest Supervisor's Office, Sheridan, Wyoming.

Morgan, P., S.C. Bunting, A.E. Black, T. Merrill, and S. Barrett. 1996. Fire regimes in the Interior Columbia River Basin: past and present. Report submitted to Intermountain Fire Sciences Laboratory, Intermountain Research Station, Missoula, MT.

Noss, R.F. 1995a. Ecological integrity and sustainability: buzzwords in conflict? Pp. 60-76 *In*: Westra, L., and J. Lemons (eds.). Perspectives on Ecological Integrity. Kluwer Academic Publishers, The Netherlands.

Noss, R.F. 1995b. Maintaining ecological integrity in representative reserve networks. World Wildlife Fund Canada and World Wildlife Fund-U.S., Toronto, Ontario, and Washington, D.C.

Overpeck, J.T., D. Rind, and R. Goldberg. 1990. Climate-induced changes in forest disturbance and vegetation. Nature 343:51-53.

Rolston, H. 1994. Foreword. Pp. xi-xiii *In*: Westra, L. An environmental proposal for ethics: the principle of integrity. Rowman and Littlefield, Lanham, MD.

Romme, W.H., and D.G. Despain. 1989. Historical perspective on the Yellowstone fires of 1988. Bioscience 39: 695-699.

Schmid, J.M., and S.A. Mata. 1996. Natural variability of specific forest insect populations and their associated effects in Colorado. USDA Forest Service General Technical Report RM-GTR-275. Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO.

Smith, D.M., B.C. Larson, M.J. Kelley, and P.M.S. Ashton. 1997. The Practice of Silviculture: Applied Forest Ecology. John Wiley and Sons, New York.

Tinker, D.B., C.A.C. Resor, G.P. Beauvais, and others. 1998. Watershed analysis of forest fragmentation by clearcuts and roads in a Wyoming forest. Landscape Ecology 13:149-165.

Turner, M.G. 1989. Landscape ecology: the effect of pattern on process. Annual Review of Ecology and Systematics 20: 171-197.

Veblen, T.T., T. Kitzberger, and J. Donnegan. 2000. Climatic and human influences on fire regimes in ponderosa pine forests in the Colorado Front Range. Ecological Applications 10: 1178-1195.

Veblen, T.T., K.S. Hadley, E.M. Nel, and others. 1994. Disturbance regime and disturbance interactions in a Rocky Mountain subalpine forest. Journal of Ecology 82:125-135.

Wace, N.M. 1977. Assessment of dispersal of plant species - the carborne plants in Canberra. Proceedings of the Ecological Society of Australia 10: 167-86.

Walters, C.J. 1986. Adaptive management of renewable resources. McGraw-Hill, New York.

Westra, L. 1994. An Environmental Proposal for Ethics: the Principle of Integrity. Rowman and Littlefield, Lanham, MD.

Weir, J. M. H., K. J. Chapman, and E. A. Johnson. 1995. Wildland fire management and the fire regime in the southern Canadian Rockies. Pp. 275-280 *In*: Brown, J. K. and others. (tech. cords.), Proceedings: symposium on fire in wilderness and park management. USDA Forest Service General Technical Report INT-GTR-320

Wilcox, B.A., and D.D. Murphy. 1989. Migration and control of purple loosestrife (*Lythrium salicaria* L.) along highway corridors. Environmental Management 13: 365-70.

Woodley, S. 1993. Monitoring and measuring ecosystem integrity in Canadian National parks. Pp. 155-176 *In*: Woodley, S., J. Kay, and G. Francis. Ecological Integrity and the Management of Ecosystems. St. Lucie Press, Ottawa, Canada.