USDA United States Department of Agriculture

Forest Service

Rocky Mountain Research Station

General Technical Report RMRS-GTR-104

June 2003

Indicators of Rangeland Health and Functionality in the Intermountain West

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Abstract

O'Brien, Renee A.; Johnson, Curtis M.; Wilson, Andrea M.; Elsbernd, Van C. 2003. **Indicators of rangeland health and functionality in the Intermountain West**. Gen. Tech. Rep. RMRS-GTR-104. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 13 p.

Rangelands comprise about 42 percent of the land area of the United States and provide vital land functions such as watershed, multiple-use, recreation, and other amenities. Currently, we do not know the status and trends of many of our nation's rangelands, and consistent protocols for describing rangeland system dynamics across land management agencies are lacking. Various Federal land management agencies have responsibility for rangeland inventory and assessments that characterize the health of the nation's rangelands. Many efforts have been initiated to standardize an approach to large-scale monitoring and assessment of rangelands, but none are universally accepted.

This paper describes four rangeland health indicators and interpretation criteria that can be used to characterize rangeland health and functionality. The four indicators tested in this study—noxious weeds, ground cover, species composition, and shrub cover—proved to be viable indicators of rangeland health and functionality. The paper recommends that these indicators can be used at many scales, from the site level for local planning, to State and national levels for strategic planning.

Keywords: rangeland health, functionality, indicators, bare ground, noxious weeds, species composition

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Acknowledgments

The authors gratefully acknowledge the cooperation between the Interior West Forest Inventory and Analysis Program and the Intermountain Region of the USDA Forest Service to make this technical reference possible. The authors especially thank Doug Myers (retired), Forest Inventory and Assessment Group Leader at the Intermountain Region, for encouraging indicator development. Appreciation is also extended to Levi Broyles of the Bridger-Teton National Forest rangeland and timber staff and Dave Tart, Intermountain Region Ecologist, for input and review of indicator development. Special thanks also go to Dr. John Mitchell, Dr. Phillip L. Simms, Tom Roberts, Dr. Chris Lauver, Larry De Blander, and Sharon Woudenberg for their reviews.

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Introduction

Rangelands provide vital watershed, multiple-use, and amenity land functions. An estimate of the area of rangeland in 1992 in the continental United States is 801 million acres (Mitchell 2000), which is about 42 percent of the total land area. Currently, we do not know the status and trend of many of our nation's rangelands, and we lack consistent protocols for describing rangeland system dynamics across land management agencies. Various Federal land management agencies have responsibility for rangeland inventory and assessments that characterize the health of the nation's rangelands. Several efforts have been initiated by these agencies to standardize an approach to large-scale rangeland monitoring, but none are universally accepted. There is a need for a rangeland inventory and assessment protocol that is consistent, quantitative, relatively inexpensive, repeatable, systematic, statistically sound, and can be accomplished with minimal technical skills.

Qualitative, descriptive rangeland health concepts have been described in range health checklists developed by the National Research Council (1994) and the USDI Bureau of Land Management (BLM) (2000). Taking a more quantitative approach, a study of rangeland health indicators was conducted on the Bridger-Teton National Forest by the Interior West Forest Inventory and Analysis (IW-FIA) Program within the Rocky Mountain Research Station of the USDA Forest Service. Forest Inventory and Analysis (FIA) is a national program that conducts inventories for large-scale planning and monitoring on all forest land in the United States, including both public and private ownerships. FIA sampling procedures for forest lands are well documented and standardized nationally (USDA Forest Service 2001). IW-FIA is one of five regional FIA programs and conducts inventories in eight Interior West States as part of its national FIA responsibilities.

IW-FIA conducted an inventory on the Bridger-Teton during 1998 through 2001. FIA has not traditionally sampled nonforested lands, those with less than 5 percent tree canopy cover or less than 10 percent stocked by trees of any size. However, as much as 30 percent of National Forest System lands are classified as nonforest. Nonforest land is often referred to as rangeland, but rangeland is not restricted to nonforest types. Therefore, all cover types on the Bridger-Teton, both forest and nonforest, were included in this study using the systematic FIA sample selection grid and the portion of the FIA protocols that were relevant to rangelands. An analysis was completed to determine if the information collected on all Bridger-Teton plots could be used to summarize the health and functionality of the Bridger-Teton rangelands. For this pilot study, the interpretation criteria for functionality were that a site was either in proper functioning condition, or functioning at risk. Functioning at risk means health and sustainability are threatened. A nonfunctioning category was not used in this pilot because that threshold has not yet been defined. The threshold for functioning at risk was based on data collected on rangelands in the Intermountain Region, combined with professional judgment (appendix B; Johnson and Elsbernd 1997; USDA Forest Service 1996).

Riparian areas occupy a small proportion of a landscape (usually less than 2 percent) and are typically linear landscape features. Riparian areas are often missed using the systematic FIA sample grid and therefore were not included in this study. Because they are not adequately sampled with the FIA grid, they must be sampled using other methods. One such procedure that handles riparian area monitoring and analysis is outlined in Winward (2000).

Study Objectives

1. Develop indicators of rangeland health and functionality.
2. Test the value of FIA data for evaluating the indicators, and demonstrate use of the FIA grid and data collection protocol for rangeland health.

3. Identify cover types currently in proper functioning condition or functioning at risk on the Bridger-Teton.

Indicators of Rangeland Health and Functionality

1. Noxious Weeds—These are plants that are designated as noxious weeds by the Secretary of Agriculture or by an appropriate State official. A comprehensive list of state and federally designated noxious weeds for Wyoming is presented in appendix A. For this paper, a potential new invader from adjacent States was added to the list. Noxious weeds generally possess one or more of the following characteristics: aggressive and difficult to manage, poisonous, toxic, parasitic, invasive, and new or not common to the United States.

Data collection focused on determining the presence or absence of a noxious weed on a sample location. The interpretation for this indicator was that if any noxious weed was found on a sample site the acres represented by that sample were determined to be at risk from both a health and sustainability viewpoint, even if the ground cover was adequate for a properly functioning watershed. This interpretation was made because of the aggressive nature of noxious weeds in both pristine and disturbed landscapes.

2. Ground Cover—A stable and sustainable soil base is needed for rangeland watersheds to yield a variety of multiple-use products, services, and amenities (Ellison and others 1951). The soil base, no matter what the soil classification, needs an adequate ground cover of vegetation, litter, and rock for protection from rain, erosion, and use. Qualitative rangeland health and functionality checklists in the literature have a majority of indicators and descriptors focusing on various aspects of ground cover. For example, in BLM (2000), 11 of the 17 indicators deal with some aspect of ground cover protection, such as rills, water flow patterns, bare ground, soil surface resistance to erosion, and litter amount. The other indicators in the literature deal with the vegetation on the site, addressed below in the species composition indicator tested in this pilot.

Using the Society for Range Management (SRM) cover types (Shiflet 1994) as the broad-scale vegetation classification base, ground cover threshold levels were developed to represent the threshold point at which a site in a particular cover type would begin to lose basic functionality defined by increased soil erosion and loss of site sustainability. Ground cover is defined as basal vegetation, litter, moss/lichen, or rock greater than ¾-inch diameter. The minimum ground cover needed for proper functioning sustainable watersheds for the four Bridger-Teton cover types used in this pilot are:

Cover type	Percent ground cover
Aspen	95
Alpine	90
Mountain big sagebrush	85
Tall forb	80

The ground cover threshold values for watershed protection used in this study were derived from baseline material collected throughout the Intermountain Region from healthy and functional rangelands (appendix B). The data were averaged across the Intermountain Region, modified for the Bridger-Teton, and summarized in Johnson and Elsbernd (1997). Cover types with ground cover levels below these minimum thresholds were determined to be functioning at risk for basic watershed protection.

A separate study conducted by Hardy (2002) assessed the applicability of using soil physical and plant cover categories to predict Erosion Condition Class for two major community types, mountain sagebrush and mountain grassland, at the broad scale of FIA. Erosion Condition Class is a tool developed by the BLM to quantify levels of erosion at a given site. Seventeen variables were tested for significance in predicting site scores for Erosion Condition Class. Of those 17 variables, percent bare ground was the only significant variable at the site level ($p < .001$).

3. Species Composition—Determining if the proper vegetation is present on a site is the most difficult question in the rangeland health discussion. A general evaluation of ecological status may be conducted using a basic species composition list; however, species lists would probably need to be revised to adequately assess a site's ability to meet more specific health or other management objectives. An attempt was made at describing the desired predominant species that should be present if the Society for Range Management cover type was in potential natural community ecological status, with the understanding that a potential natural community species composition would not meet all desired plant community compositions. For this first approximation, predominant species are defined as species present with at least 5 percent canopy cover. This was done because FIA protocols limit the field recording of species to those with 5 percent or greater cover. The desired potential natural community plant species components are listed for each cover type in appendix C.

A site was considered to be functioning at risk if at least one listed potential natural community plant species was not present with at least 5 percent cover. These interpretation criteria will change if the goal changes from meeting the potential natural community

criteria to species composition desirable for a specific purpose such as forage production, sage grouse habitat, low risk wildfire community, or a visually pleasing wildflower setting in a sagebrush community.

4. Shrub Cover—Many rangelands across the United States have a major shrub component. As an example, much of the Intermountain region is occupied by sagebrush (*Artemisia* spp.). Because of ecological processes such as fire, insects and disease, and normal life cycles, sagebrush ecosystems naturally have a broad range of self-sustaining communities with a variety of age classes and structures. Such a mix of components provides a variety of habitat and food that benefit an assortment of wildlife and domestic animals, along with a diversity of visual and watershed aspects across the landscape.

The approach taken with sagebrush cover is slightly different from the approach taken with the first three indicators. Instead of rating an individual site's health and aggregating those ratings to represent the health of the cover type, this indicator only assesses the properly functioning aspect of the entire cover type. It is essentially a landscape level indicator. The desired mix of cover classes for sustainable sagebrush ecosystems for all ecological purposes and needs (USDA Forest Service 1996) was determined to be:

- 10 percent of the sagebrush area has 0 to 5 percent shrub canopy cover
- 50 percent of the sagebrush area has 6 to 15 percent shrub canopy cover
- 40 percent of the sagebrush area has greater than 15 percent shrub canopy cover

If the mix of sagebrush cover is outside the desired cover class distribution, the cover type may be functioning at risk for the overall ecological health and diversity of a sustainable sagebrush community at a landscape level.

Methods

FIA inventories provide a statistical-based sample of forest resources across all ownerships that can be used for planning and analysis at a National Forest or BLM District; and State, regional, and national levels. The sample was designed to meet national standards for precision in State and regional estimates of forest attributes. IW-FIA uses a two-phase sampling procedure. Field crews normally conduct the field phase of the inventory only on forest land, but for this study, plots were established on all grid points, including nonforest. The sampling intensity is one field plot every 5,000 m, or about every 3 miles.

The Bridger-Teton is located in the Greater Yellowstone Ecosystem in western Wyoming. It is the largest National Forest in the continental United States, with 3.4 million acres, of which approximately 30 percent is nonforest. IW-FIA sample grid plots were established on the Bridger-Teton between 1998 and 2001. There were 557 plots, of which 382 were classified with a forest location center, 159 were classified with a nonforest location center, 15 were inaccessible, and one was water. Each sample on the grid represents approximately 6,000 acres of land.

Data from both forest and nonforest plots were used to evaluate the rangeland health indicators, with the exception of the shrub cover indicator that only used the mountain big sagebrush cover type. The cover types chosen for the pilot study included aspen, alpine, mountain big sagebrush, and tall forb. Plots were assigned to the aspen type based on the FIA forest type classification. Field crews assigned the plots on nonforest types to Society for Range Management cover types based on the general descriptions available in Shiflet (1994). These four types were selected for this study based on adequate sample size. Forest procedures were adapted to the nonforest (rangeland) plots by using a subset of FIA measurement variables (USDA Forest Service 1998) that were relevant to nonforest conditions. These included physiographic variables (elevation, slope, and aspect), understory vegetation, and ground cover. The layout of the field plot, which comprises four subplots, is shown in figure 1.

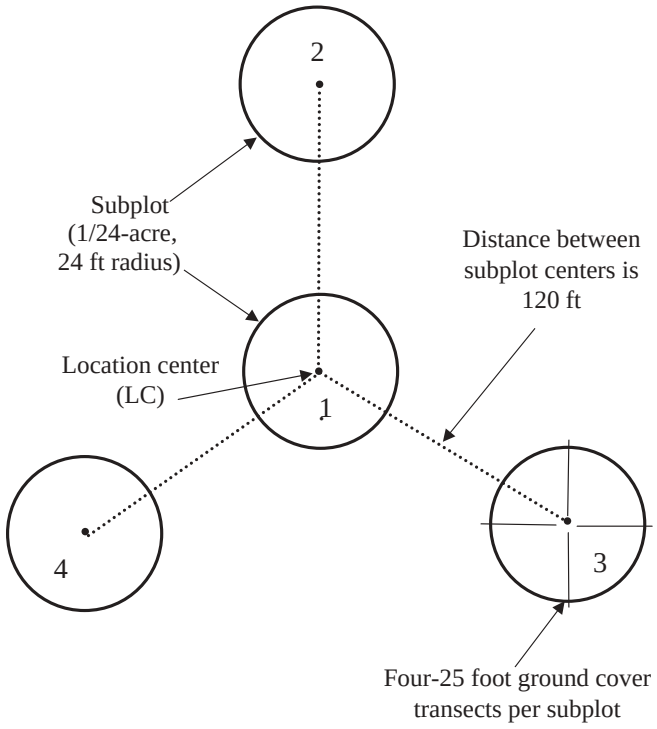

Figure 1—Field plot layout.

Noxious Weeds—Field crews were trained in the identification of plants listed as noxious or invasive in the State of Wyoming and surrounding States. The presence of any noxious weeds was recorded by species and subplot.

Ground Cover—Ground cover was identified on 400 points per plot. Using a tape measure, 25-foot transects were laid out in the four cardinal directions for each of the four subplot centers. Beginning at the 1-foot mark, the tip of a plot stake or sharply pointed staff was placed on the ground surface along the side of the tape at each 1-foot mark, and ground cover was recorded at each point by category of cover. The categories were bare ground, pavement (pebbles between $\frac{1}{8}$ and $\frac{3}{4}$ inches diameter), rocks ($\frac{3}{4}$ inches diameter or greater), litter, moss/lichens, basal vegetation, and other. For this study, pavement cover percentages were combined with bare ground because material between $\frac{1}{8}$ and $\frac{3}{4}$ inch does not impede raindrop erosional impact. The transect layout was chosen for efficiency for field crews and was similar to other FIA protocols. The fact that transects radiate out from the center of the subplot may oversample the center of the subplot (see "Recommendations" section for more discussion of the transect configuration). For each plot, the percent ground cover was estimated by dividing the number of points not on bare ground by the total number of sampled points on each plot. The estimate was then averaged over all the plots in the cover type to obtain the final estimate. The standard error of the final estimate was calculated using the assumption that the plot level estimates were normally distributed.

Species Composition and Shrub Cover—For each subplot (four per location), up to four species that had 5 percent cover or greater were listed within each life form (tree seedlings/saplings, shrubs, forbs, or graminoids). Percent cover for each species listed was ocularly estimated and recorded. Total percent cover was also ocularly estimated and recorded for each life form that occurred on each subplot. A maximum of four species were recorded on each subplot per life form, so it is possible that some species with 5 percent or greater cover were present on a subplot yet not recorded. For this study, all the species on all four subplots were combined into one list for each location.

Results and Discussion

The objectives of this study were to (1) develop indicators of rangeland health and functionality, (2) test the value of FIA data for evaluating the indicators, and demonstrate use of the FIA grid and data collection protocol for rangeland health, and (3) identify cover types currently in proper functioning condition, or functioning at risk on the Bridger-Teton.

Develop Indicators of Rangeland Health and Functionality

The four indicators of rangeland health and functionality presented in this paper were shown to be useful for describing rangelands in the Intermountain West and could be applicable across the United States. Used together, the four indicators can describe the health and functionality of rangelands at many scales.

Noxious Weeds—The noxious weed indicator was applied to all the cover types on the Bridger-Teton, including all the coniferous forest types. Three percent of the sampled locations (14 of 542 plots) had at least one noxious weed species present. Five of the locations with noxious weeds present were in the spruce-fir cover type, four were in the Douglas-fir type, two were in the aspen type; and one each were in the lodgepole, tall forb, and mountain big sagebrush types. Weed occurrence is typically associated with roads and trails, and is not spread uniformly across the landscape. It is therefore probably not reasonable to expand these plot-based detections in the same way that FIA expands other forest attributes to get population estimates. A separate inventory of noxious weeds conducted by Bridger-Teton personnel in 2001 indicated that about 6,712 acres had noxious weeds present.

One noxious weed, Canada thistle, often occurs as a disturbance component in many coniferous forest types. Its occurrence fluctuates with canopy closure, and therefore "risk" may not be indicated just by its presence.

Tracking the trend of noxious weed plant spread through number of plot occurrences could indicate a trend in rangeland sustainability. Figure 2 shows the rough location of FIA plots having weed species on the Forest, and table 1 lists the noxious weed species found by number of plots.

Ground Cover—The percent ground cover results for the four cover types analyzed on the Bridger-Teton are compared to the desired ground cover thresholds in figure 3. The results of the FIA estimates of bare ground are presented with a 95 percent confidence range on the estimated mean. The estimated average ground cover for the aspen type on the Bridger-Teton is 90 percent, plus or minus 5, compared to the 95 percent ground cover needed for the type to be considered healthy and properly functioning for watershed protection and soil sustainability and recovery. The estimated average ground cover for the alpine cover type is 68 percent, plus or minus 10, compared to the threshold value of 90. The estimated average ground cover for the tall forb type is 67 percent, plus or minus 6,

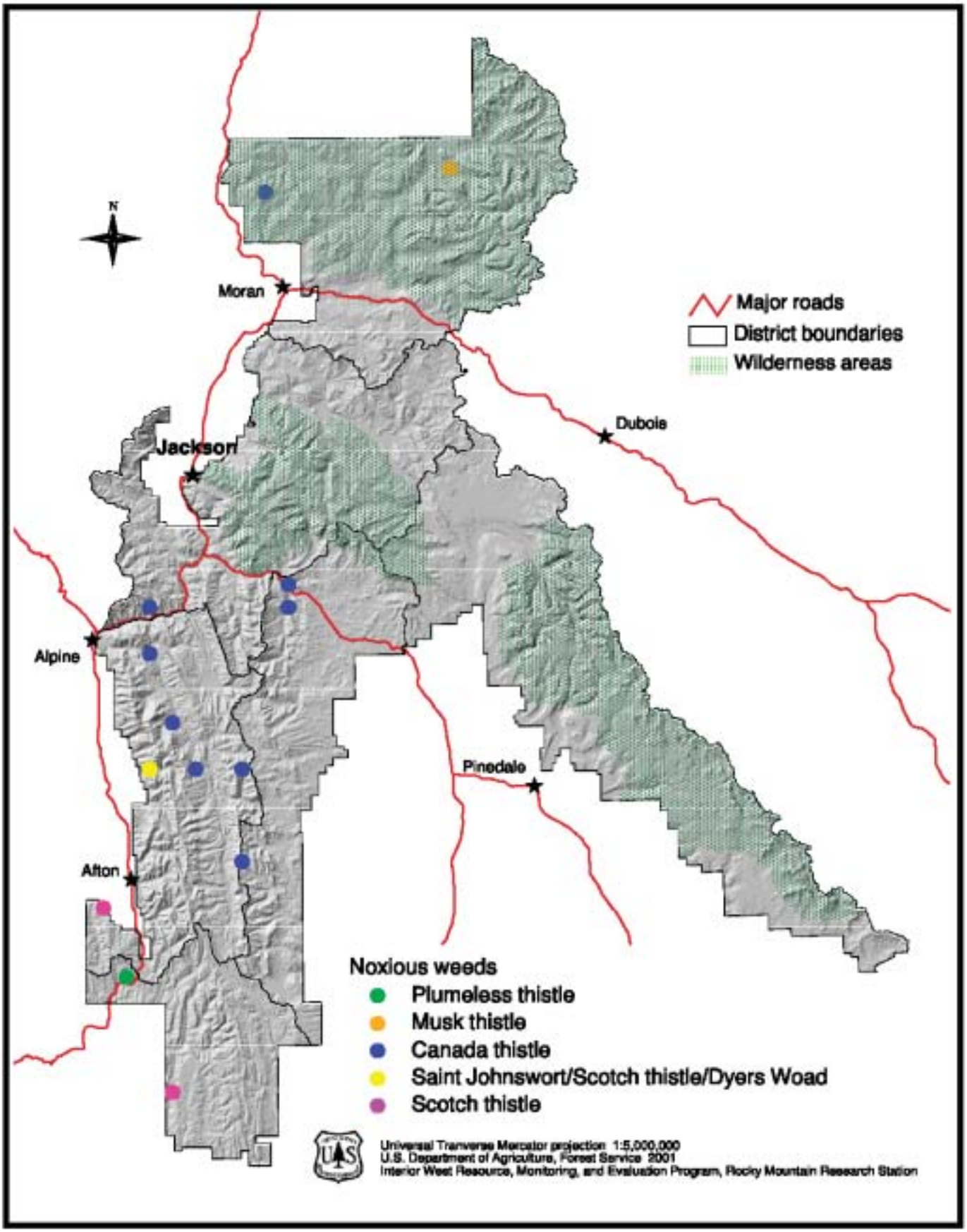

Figure 2—Noxious weeds on FIA sample locations on the Bridger-Teton National Forest.

Table 1—Noxious weed species found by number of locations on the Bridger-Teton National Forest. The 14 plots represent 3 percent of the total 542 sample plots.

Noxious weed species found	Number of locations
Canada thistle (*Cirsium arvense*)	9
Scotch thistle (*Onopordum acanthium*)	3
Plumeless thistle (*Carduus acanthoides*)	1
Musk thistle (*Carduus nutans*)	1
Common St. Johnswort (*Hypericum perforatum*)	1
Dyer's Woad (*Isatis tinctoria*)	1

compared to the threshold value of 80. The estimated average ground cover for the mountain big sagebrush type is 77 percent, plus or minus 5, compared to the threshold value of 85. The range of ground cover estimates for the alpine, tall forb, and mountain big sagebrush types were all below the desired thresholds, portraying that ground cover might not be high enough for adequate watershed and soil protection over a long period, which may threaten the sustainability of these types on a Forestwide scale.

Species Composition—Table 2 depicts the results of the Bridger-Teton plant species sample. These results are based on a comparison of the total species list for each location, aggregated over all subplots, with the list of potential natural community species. To be counted as occurring on the plot, a potential natural community species had to have at least 5 percent cover on at least one subplot. The results show that 77 percent of aspen sites had at least one of the potential natural community species present, 42 percent had at least two species present, 25 percent had at least three potential natural community species present, and 4 percent had at least four species present. There were no aspen type plots with more than five species from the list. Of the alpine sites, 63 percent had at least one potential natural community species present, and 7 percent had two species present. No alpine plots had more than two species from the list. Of the mountain big sage sites, 95 percent had at least one of the potential natural community species present, 69 percent had at least two species present, 24 percent had at least three species present, and 7 percent had at least four species present. No mountain big sage plots had more than five listed species present. Only 37 percent of tall forb communities had at least one of the potential natural community species present, 4 percent had at least two potential natural community species present, and no

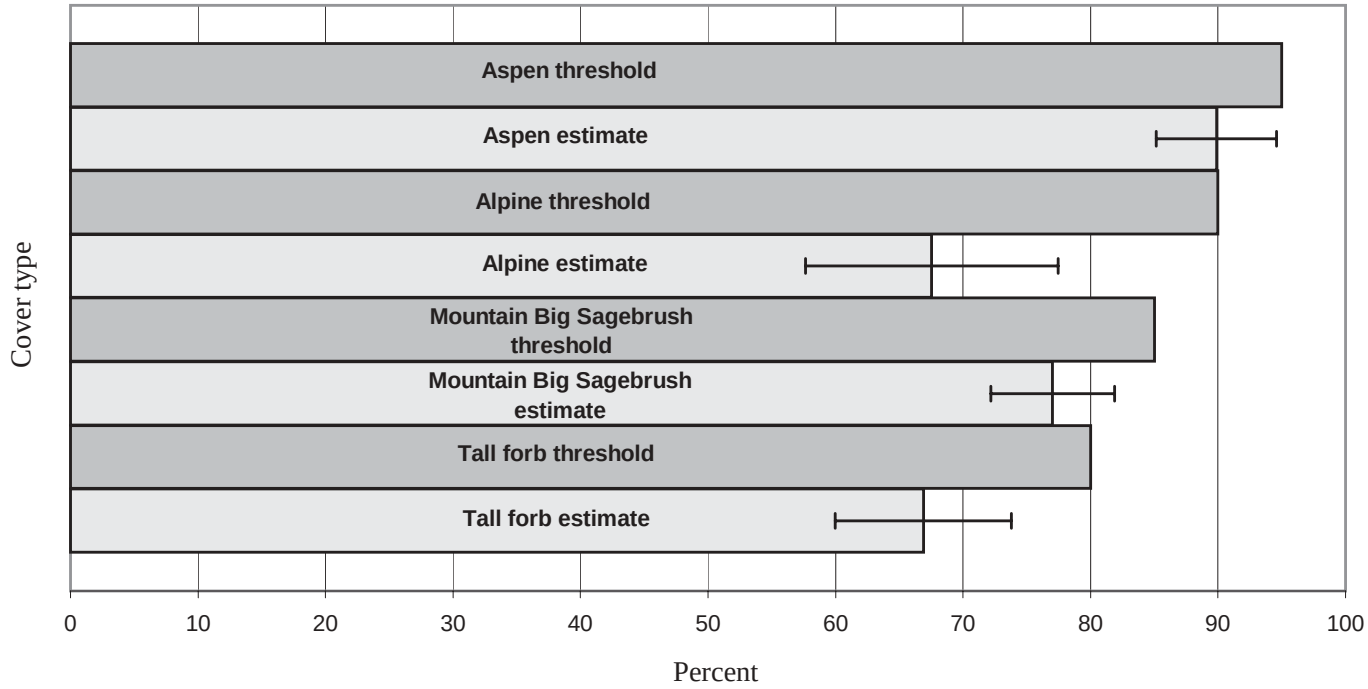

Figure 3—Estimated percent ground cover compared to proper physical functioning threshold by cover type, Bridger-Teton National Forest, 1999.

Table 2—Number of potential natural community (PNC) species present on four cover types on the Bridger-Teton National Forest, listed as a percentage.

Cover type	Percent of plots with at least 1 PNC species present	Percent of plots with at least 2 PNC species present	Percent of plots with at least 3 PNC species present	Percent of plots with at least 4 PNC species present	Percent of plots with at least 5 PNC species present
Aspen	77	42	25	4	2
Alpine	63	7	0	0	0
Mountain big sage	95	69	24	7	4
Tall Forb	37	4	0	0	0

plots had more than two species. According to the study criteria, all of the types may be functioning at risk from a species composition point of view. The mountain big sage appears to be in the best health based on list species present with 5 percent cover or greater. The interpretation of this indicator is problematic, however, and needs more work.

Shrub Cover—Shrub cover results for the mountain big sagebrush cover type on the Bridger-Teton is given in figure 4. The desired distribution of the mountain big sagebrush cover type is a cover class mix of 10 percent with 0 to 5 percent canopy cover, 50 percent with 6 to 15 percent canopy cover, and 40 percent over 15 percent canopy cover. The estimated amount of the mountain big sage type that is in the medium class is lower than desired, and the amount in the high cover class is higher than desired. The confidence interval for estimates of percent shrub cover for the Bridger-Teton at the 95 percent level is plus or minus 5. These proportions indicate that the mountain big sagebrush landscape does not meet the desired distribution and may be functioning at risk for sustainable rangeland sagebrush diversity.

Value of FIA Data and Grid for Evaluating Rangeland Health

All four indicators used in this determination of the health and functionality of the Bridger-Teton rangelands can be monitored using FIA protocols. One criterion cannot stand alone as an ultimate judgment of any rangeland's sustainable health or functionality because of the diversity of rangelands and the complexity of the question. These indicators can be used at the project scale by Forest Service Ranger Districts and BLM field offices for site-specific analyses, at broader scales for Forest and BLM District planning efforts, or at the State or national scale for broad strategic-level assessments.

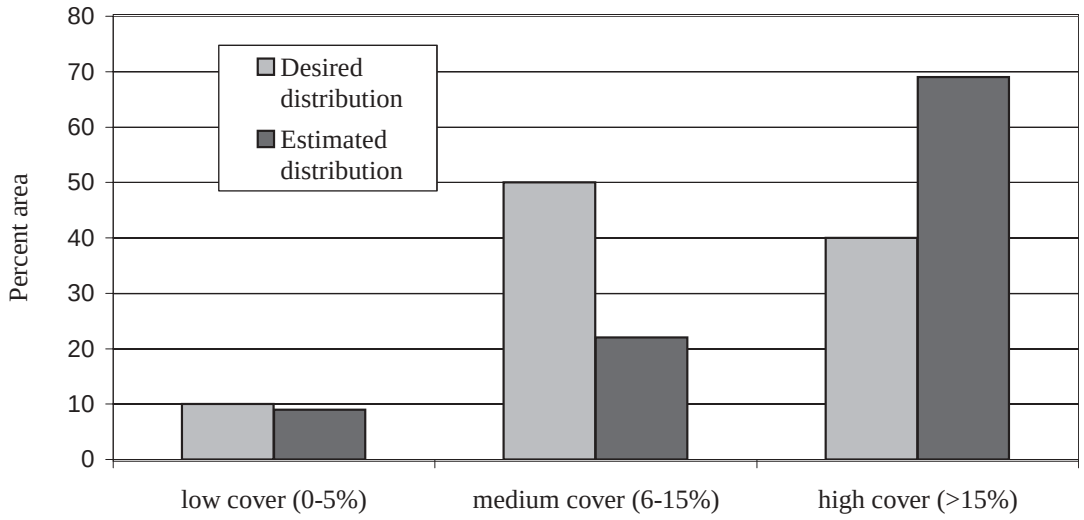

Figure 4—Estimated area of shrub cover by cover class compared with desired area of shrub cover by cover class for the mountain big sagebrush cover type.

Noxious Weeds—The presence of noxious weeds determines whether a rangeland site, landscape, or watershed is at risk from both a functioning and a sustainable point of view. The magnitude of the noxious weed problem would influence the questions of sustainability. The IW-FIA survey is not a census of noxious weeds but rather a systematic sample that can provide trend over time.

Ground Cover—This indicator shows which cover types are properly functioning by providing enough cover to protect watersheds and soils above an erodibility threshold, and which ones are at risk because of inadequate surface cover that does not absorb water and reduce surface impacts. This rangeland watershed health and functionality measurement could be used at all scales.

Species Composition—The most difficult rangeland health criterion to collect and analyze is species composition. Whether or not the appropriate plants are present over a landscape, watershed, or ecosystem depends on the purpose or objective that is defining a health or determination call. For this study, referencing each potential natural community's plants with 5 percent canopy cover or greater answers only the ecological status question. If the question centers on health for a threatened, endangered, or sensitive plant that may need an early seral ecological status to remain viable and sustainable, the criterion may be quite different or even the opposite of what was used in this study. IW-FIA data collection protocols provide data sufficient for some general ecological status evaluation.

The species composition list in appendix C was developed through examination of ecological scorecards, and community and habitat type classification references. This study is intended to be a first approximation. More work is needed to refine the species composition lists for each type and to define desired thresholds for different objectives. Another approach would be to develop a total cover percentage for a specific group of species.

Shrub Cover—Shrub cover arranged in a mosaic of varying densities over a landscape indicates shrub health regarding sustainability and diversity for a multitude of habitat values and uses. Shrub cover can be a primary rangeland health and functionality indicator in the Interior West (especially in the sagebrush ecosystem) and among some places in the West Coast and Plains ecosystems. In the national picture it could certainly indicate health and functionality of a large percentage of the Western rangelands.

The use of these indicators for the purpose of determining rangeland health and functionality was demonstrated at the National Forest scale. The indicators can be monitored in the field using FIA protocols. Although not demonstrated, the authors believe these indicators could be aggregated for rangeland health determination at a State or national level, and could also be utilized for more intensive, smaller scale determinations, such as watersheds, landscapes, or rangeland management units.

Reliability and Precision of the Indicators

Sample estimates are subject to variation. How much they vary depends on the inherent variability of the population and on the size of the sample. The FIA sample was designed to meet national standards for State and regional estimates of forest attributes. Standard errors, which denote the precision of an estimate, are presented in table 3 for ground and shrub cover estimates, along with the number of plots from which data for each cover type was obtained. The standard errors of the estimates were calculated using the assumption that plot level estimates were normally distributed. A system of computing and reporting quality assurance of all FIA variables is currently under development.

Noxious Weeds—The results of this indicator were reported as noxious weeds being either present or not. The reliability and precision of this indicator is based on the ability of FIA field crews to recognize the plant

Table 3—Average cover, standard errors, and number of plots for four cover types on the Bridger-Teton National Forest.

Cover type		Average shrub cover	Average forb cover	Average grass cover	Average ground cover	Number of plots
Aspen		12.54	20.57	17.76	89.89	48
	SE	*1.69*	*2.4*	*2.1*	*2.36*	
Alpine		1.65	18.52	19.31	67.54	28
	SE	*.81*	*4.04*	*3.5*	*4.95*	
Mountain big sagebrush		26.20	17.96	19.11	77.03	56
	SE	*2.44*	*1.82*	*1.82*	*2.42*	
Tall forb		3.48	41.01	18.32	66.89	27
	SE	*.94*	*4.2*	*3.25*	*3.21*	

species of concern. In Wyoming, field crews went through 2 days of training on plant identification, which included recognition of noxious species. They were also provided a weed handbook, with color photos and detailed description of each plant.

Ground Cover and Shrub Cover—Confidence in the ground and shrub cover estimates is presented by the standard error of the mean. Standard errors for ground and shrub cover are presented in table 3. A confidence interval on the mean was set by multiplying the standard error by a "t" value, in this case 1.96 or 2.0 (depending on sample size) for the 95 percent confidence level.

Species Composition—As with the noxious weed indicator, the reliability of this indicator is based on the ability of field crews to correctly identify the common species on FIA plots. The variability within the estimates of cover is presented with standard errors for each lifeform in table 3.

Bridger-Teton Cover Types at Risk

Aspen—Noxious weeds were present on two aspen locations. Ground cover averaged 90 percent (plus or minus 5), which barely encompassed the proper functioning condition threshold of 95 percent for sustained health and functionality. Of aspen sites, 77 percent met the minimum species composition requirements for potential natural community. The results of this pilot indicate slight risk to health and functionality of the aspen type on the Bridger-Teton.

Alpine—None of the alpine sample locations had any presence of noxious weeds. Ground cover averaged 68 percent, plus or minus 10, compared with the proper functioning condition threshold of 90 percent. Of the alpine sites, 63 percent met the minimum species composition requirements for potential natural community. This type is also at risk based on the ground cover and species composition indicators.

Mountain Big Sagebrush—Noxious weeds were present on one mountain big sagebrush location. Ground cover averaged 77 percent, plus or minus 5, which is lower than the proper functioning condition threshold of 85 percent. Of the mountain big sagebrush sites, 95 percent met the minimum species composition requirements for potential natural community. Based on the shrub cover indicator, there is some risk to the health of the mountain big sagebrush plant community. To achieve the highest sustainable diversity for multiple uses, the amount of area in the 6 to 15 percent canopy cover class needs to increase, and the amount of area in the greater than 15 percent class needs to decrease.

Tall forb—Noxious weeds were present on one tall forb location. Ground cover averaged 67 percent plus or minus 7, compared to the proper functioning condition threshold of 80 percent. Only 37 percent of tall forb sites met the minimum species composition requirements for potential natural community. Health and functionality indicators of ground cover and species composition identify this type as being at high risk on the Bridger-Teton.

Recommendations

The use of these indicators for the purpose of determining rangeland health and functionality was demonstrated at the National Forest scale. Health and functionality can be monitored using FIA protocols. Although not demonstrated, the authors believe these indicators can be aggregated for rangeland health determination at a State or national level and could also be utilized for more intensive, smaller scale determinations, such as watersheds, landscapes, or rangeland management units. The summary of these individual data into an analytical health and functionality judgment at any scale could give a management signal of the state of our rangelands.

Additional analyses of the ground cover point transects showed that fewer points may give essentially the same estimate of bare ground that was obtained with the 400-point sample, with only a slight decrease in confidence. A more thorough analysis of quantity of transects needed for estimating percent bare ground by cover type is under development (O'Brien and Wilson, in preparation).

The species composition indicator needs more work. Species lists need to be refined for specific scales and purposes. The general lists developed for the cover types used in this study were meant for use at a broad scale. More specific lists will be more useful at finer scales.

Additional work is needed to establish thresholds and properly functioning criteria for other types and other areas at many scales: other National Forests, watersheds, ecoregions, and so forth. More work is also needed to establish thresholds for "nonfunctioning" rangeland categories.

The sampling design used in this pilot represents an amalgamation of the Intermountain Region's standard rangeland assessment techniques and the FIA sampling protocols. More work is needed, which may include additional modifications to the design and validation of the statistical techniques. Subsequent to the inventory of the Bridger-Teton, to avoid oversampling the center of the subplot, the configuration of the ground-cover transects was changed in the FIA protocols to one straight line transect across each

subplot, instead of four short transects radiating out from the center. More work is also needed on the subject of adequate sample size. Sample size may need to be increased above the intensity of the FIA grid for some types at some scales in order to decrease variance and increase confidence in the precision of the estimate.

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Appendix A—Plant species designated as noxious weeds in Wyoming

Scientific name	Common name
Acroptilon repens	Russian knapweed
Ambrosia tomentosa	Skeletonleaf bursage
Arctium minus	Common burdock
Cardaria draba	Pepperweed whitetop
Carduus acanthoides	Plumeless thistle
Carduus nutans	Musk thistle
Centaurea biebersteinii	Spotted knapweed
Centaurea diffusa	Diffuse knapweed
Cirsium arvense	Canada thistle
Convolvulus arvensis	Field bindweed
Cynoglossum officinale	Houndstongue
Elytrigia repens var. repens	Quackgrass
Euphorbia esula	Leafy spurge
Isatis tinctoria	Dyer's woad
Lepidium latifolium	Perennial pepperweed
Leucanthemum vulgare	Oxeye daisy
Linaria dalmatica	Dalmation toadflax
Linaria vulgaris	Toadflax
Lythrum salicaria	Purple loosestrife
Onopordum acanthium	Scotch thistle
Sonchus arvensis	Perennial sowthistle
* Hypericum perforatum	St. Johnswort

*A new invader in the State but not yet listed as noxious in Wyoming.

Appendix B—References for ground cover criteria for threshold watershed protection in the Intermountain West as it relates to properly functioning condition for rangeland health

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Appendix C—Plants needed with at least 5 percent canopy cover in each Society for Range Management cover type to be at potential natural community ecological status

SRM cover type	Predominant associated species
Alpine	*Geum rossi* – Ross avens *Carex scirpoidea* – Canada single-spike sedge *Carex elynoides* – blackroot sedge *Festuca ovina* – Sheep Fescue *Deschampsia cespitosa* – Tuffed hairgrass *Danthonia intermedia* – Timber oatgrass
Aspen	*Symphoricarpos oreophilis* – Wolfberry *Juniperus communis* – Common juniper *Sheperdia canadensis* – Soapberry *Thalictrum fendleri* – Fendler meadowrue *Geranium viscosissium* – Sticky geranium *Lupinus argenteus* – Silvery lupine *Lathyrus* spp. – Sweetpea *Calamagrostis rubescens* – Pinegrass *Elymus carinatuss* – Mountain brome *Carex geyeri* – Elk sedge *Trisetum spicatum* – Spike trisetum
Tall Forb	*Geranium viscossimumi* – Sticky geranium *Ligusticum filicnum* – Fernleaf ligusticum *Helianthella uniflora* – Single flowered sunflower *Valeriana edulis* – Tobacco root *Bromus carinatus* – Mountain brome
Mountain Big Sagebrush	*Artemisia tridentate* var. *vaseyana* – Mountain big sagebrush *Symphoricarpos oreophilis* – Wolfberry *Purshia tridentate* – Bitterbrush *Elymus trachycaulus* – Slender wheatgrass *Festuca idahoensis* – Idaho fescue *Elymus spicatus* – Bluebunch wheatgrass

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