Chapter 5
Biological Category

Key Findings

1. Most occurrences of invasive plants were found in the northern portion of the Bighorn National Forest (BNF) and the southwestern portion of the landscape scale.
2. Canadian thistle (*Cirsium arvense)* the most common invasive plant found, and it is often found in riparian areas and wetlands where it can out compete native plants.
3. Roads were identified as the most likely activity to have the highest potential of spreading invasive plants. A direct relationship between the density of roads and the density of roads within valley bottoms was found to exist. Therefore, there is a high risk of invasive plant colonization in riparian areas where they traverse valley bottoms.
4. The highest risk for invasive plants in riparian areas and wetlands appears to be in 6th level HUBs in the northern portion of the BNF.
5. Native Yellowstone cutthroat trout (*Oncorhynchus clarkii bouvieri*) occupy a limited portion of their historic range at the landscape scale, with most, if not all current populations managed within the BNF boundary.
6. Historic populations of Yellowstone cutthroat trout are generally found in 6th level HUBs intersecting the BNF. These HUBs are located at moderate elevations with generally higher production capabilities than most of the HUBs where introduced populations are found.
7. There are a few 6th level HUBs that are entirely within the BNF (2 of 74) that contain characteristics, which would be considered high production areas for Yellowstone cutthroats. These HUBs could be managed as key habitats for this subspecies.
8. While there is a risk of introduction through several different pathways, whirling disease (*Myxobolis cerebalis*) is currently not found within the BNF. Management that results in increased water temperatures and sedimentation could increase the habitat for the intermediate tubifex worm host.
9. Beavers are a major influence on aquatic, riparian, and wetland form and function, and on plants and animals that rely on them. Most beavers were removed from the Rocky Mountains in the 1800s.
10. There are only limited populations of beavers in the BNF, and their reestablishment could result in increased aquatic, riparian, and wetland function throughout the Forest.

Influence of Invasive Plant Species

The majority of the information in this section is taken directly from Regan et al. (2003). Invasive plants in Region 2 are a very high concern for both aquatic, riparian, and wetland ecosystems and terrestrial ecosystems therefore we combined our analysis and efforts for this anthropogenic influence. Specific reference to aquatic, riparian, and wetland resources are included in this section.

Invasive species introduction and spread has an extremely high potential to disrupt the ecological integrity of the Big Horn Mountains and the Bighorn National Forest, although there is limited inventory information on their locations (fig. 5.1). Currently, there appears to be a very low occurrence of invasive species on the Forest; however, invasive species monitoring and inventory on the Bighorn National Forest is currently limited, therefore occurrence data is available only with relatively low confidence for the entire Forest. In addition, lands adjacent to the National Forest are showing increases in invasive species that may place the Bighorn National Forest lands at risk in the very near future.

Known Occurrences of Invasive Plants

Although invasive species mapping on the National Forest is underway, it is far from complete, and known occurrences represent only a very limited sample of the area. For example, the known occurrences of invasive plants on the National Forest were gathered from fewer than 50 sample points as part of the Forest Service's Forest Health Monitoring and Forest Inventory and Analysis data; other known occurrences were recorded using non-standardized methodology by other local, state, or federal agencies (fig. 5.1). Clearly, there is a paucity of known occurrence data for invasive plants on the Bighorn National Forest; therefore this section of the assessment is not described at the various scales (e.g., basin, landscape, management, and reach/site scales).

Based on limited available data, invasive plants are currently most common in the northern portion of the National Forest (fig. 5.1) in grasslands, prairies, and subalpine meadows, although known occurrences are also in coniferous forests, particularly lodgepole pine forests, and in recent clear cuts. 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 upon invasibility. Some of the most common vectors include roads, campgrounds, trailheads, stock driveways, livestock, and recreationists. Some of the most susceptible landscapes include low elevational grasslands, shrub lands, and riparian bottoms, although grasslands and/or woodlands at any elevation are also very susceptible to plant invasion. These lands are commonly part of wildlife winter ranges that could face diminished habitat quality.

Invasive Plant Species of Concern at the Management Scale

Based on available data, the most common invasive plant species found within the Bighorn National Forest is the Canada thistle (*Cirsium arvense*). A total of 128-point occurrences of Canada thistle were recorded across the National Forest, and its presence was noted across at least 3,300 acres. Canada thistle has rapidly spread in western North America in the last 50 years. Canada thistle 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 its difficulty to control have lead 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 Big Horn Mountains compared to Canada thistle, but it is thought to occur across approximately 4,700 acres. It rapidly spreads along deciduous stream courses, cottonwood bottoms, and mountain big sagebrush vegetation types, mainly due to its sticky seed, which provides wide dispersal 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 of the National Forest. It is a major invasive species in pastures, cultivated lands, and disturbed sites in the Bighorn Basin. It rapidly spreads along low elevation moist river bottoms, and meadows.

Yellow toadflax (*Linaria vulgaris*) populations occur in the Big Horn Mountains, and have been recorded at 18-point occurrences on 250 acres. It has the ability to rapidly expand its range, 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 Basin. Chemical control is extremely difficult and expensive.

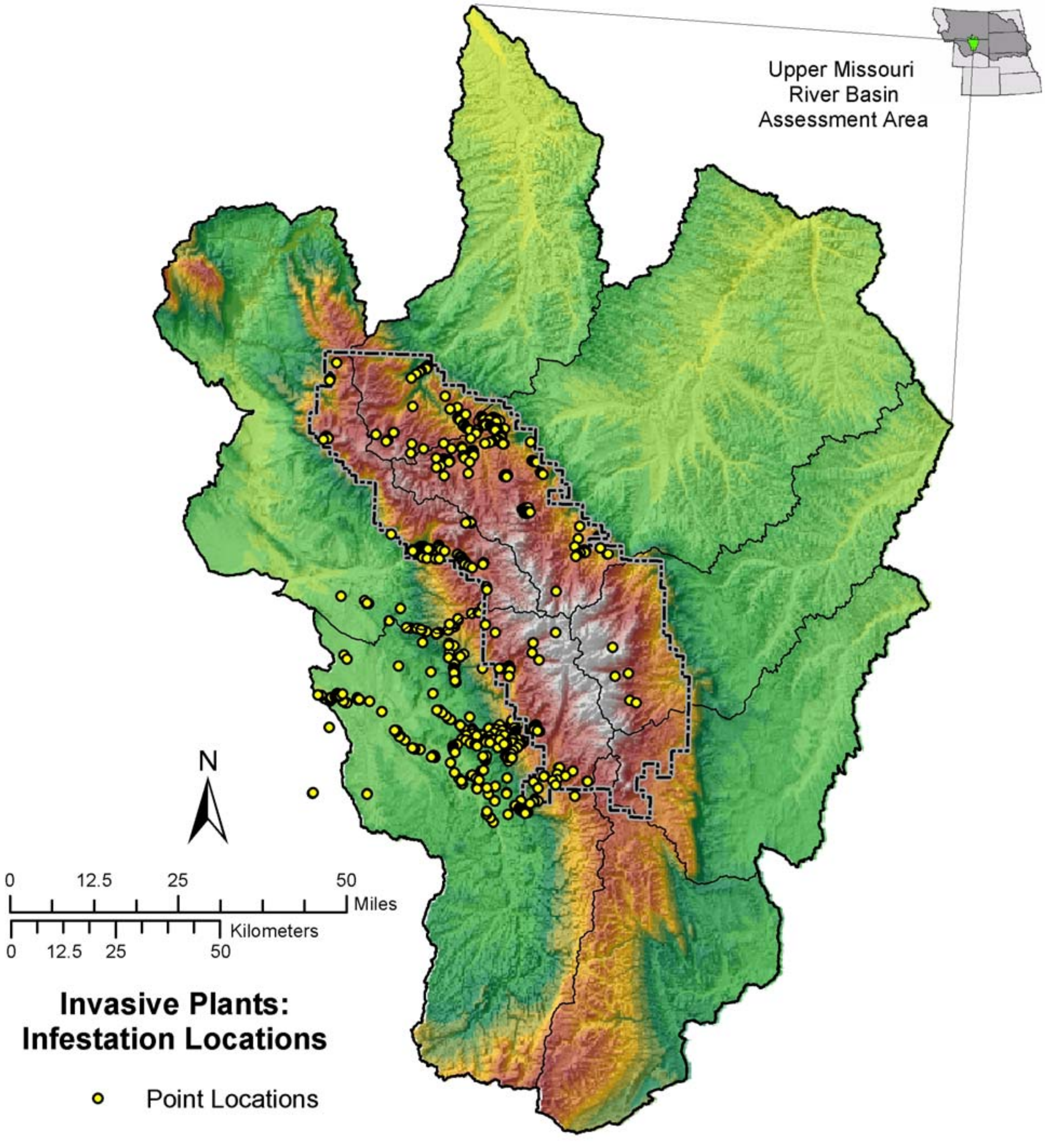

Figure 5.1. Known locations of invasive plant occurrences in and near the Bighorn National Forest.

Musk thistle (Carduus nutans) has become a problem in portions of the Big Horn and Wind River Basins, although it has not yet become well established in the National Forest (1 point occurrence, < 100 acres). Areas at highest risk are non-forested and at generally lower elevations (< 8,500 feet) within the Big Horn Mountains. Biological control and chemical efforts are successful if they are initiated quickly and prudently.

Russian knapweed (*Acroptilon repens*) has also not yet become well established on the National Forest (1 point occurrence, < 50 acres). However, it exhibits strong allelopathic properties 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 ten years. Chemical control of this species 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 Bighorn Basin and is one of the highest priorities for treatment for county weed and pest organizations.

The following species currently have no known occurrences in the Bighorn National Forest, but are species of concern due to their high propensity for invasibility, their success on sites similar to those found in the Bighorns, or their location very near the National 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 Bighorns 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. This species rapidly out competes native species, and it has greatly expanded its range along the Yellowstone River drainage in Montana and Powder River Basin over the last ten years. Chemical treatment has been proven to be difficult, but biological control has shown to be effective using leaf beetles. This species may appear along the lower fringes of the Big Horn Mountains.

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 Bighorn Basin is beginning to aggressively treat this species, but chemical control is difficult due to its proximity to water.

Dalmatian toadflax (*Linaria dalmatica*) is not currently known to occur in the Big Horn Mountains, but it 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. In the Big Horn Mountains, areas of concern are found along the west side of the Forest 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 Big Horn Mountains include Common mullein (*Verbascum thapsus*), Cheatgrass (*Bromus tectorum*), and Kentucky bluegrass (*Poa pratensis*). 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 already showing increases of 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 rapidly spreads 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 compete other more preferred wetland grasses. High densities of this species usually indicate past heavy grazing pressure.

Biophysical Influences and Anthropogenic Influences on Invasibility

Influences on invasibility 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, in assessing and/or predicting the risk of invasion of a given land area, several factors are typically consistent in their importance to plant spread and survival. Environmentally, moisture availability, light availability, and temperature are the three most important factors influencing the invasibility of an area. In western North America, moisture availability is often the most limiting factor to plant distribution; on the Bighorn National Forest, riparian areas and valley bottoms are considered to be at the highest risk for non-native plant invasion, and north-facing slopes and relatively flat sites are likely more susceptible than other aspects. In addition, most non-native plant species show a preference to high light conditions, such that invasion occurs most frequently in cover types with low or no canopy cover. On the National Forest, cover types such as grasslands and alpine meadows show the highest incidence of non-native species, and forests with low canopy closure (< 20%) are considered to be at the highest risk. Finally, non-native plant invasion appears to be most successful where temperatures are higher and growing seasons are longer. These environments typically occur at low-elevation sites (< 8,000 feet) in the Bighorn National Forest, especially since native plants tend to have a competitive advantage at high elevations (> 10,000 feet), where temperatures are colder and growing seasons are shorter.

Although environmental variables such as moisture availability, light availability, and temperature create the ecological template for vulnerability of an area to plant invasion, invasibility is greatly increased when environmental conditions are altered by disturbance, both natural and human, and when dispersal vectors are provided for the continued introduction of non-native plants into a given area. 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 at high risk for non-native plant invasion. In addition, an area is most vulnerable to invasion nearest dispersal vectors such as roads, recreation areas (campgrounds, picnic areas, ski areas, trails, and trailheads), areas of livestock concentration (corrals, watering areas, stock driveways), and other areas of human concentration (private landholdings, summer homes, agency administration sites). For each of these vectors, vulnerability to plant invasion tends to decrease with increasing distance from the vector. Similarly, areas lacking heavy infestation by non-native species are most vulnerable to invasion when they are adjacent to a heavily infested area. In any case, invasive species usually have wide ecological amplitudes that can fluctuate by climatic conditions.

Specific geographic areas of probable vulnerability to invasive species are addressed in the Bighorn National Forest Terrestrial Ecosystems Assessment (Regan et al. 2003). Based on the model used by Regan et al. (2003) there appears to be a close relationship between road density and valley bottom area, in terms of risk of non-native plant establishment. In our transportation section, we analyzed the individual and additive effects of all transportation uses (including roads, trails, and OHV use). Since all of these factors result in similar ground disturbing and ultimately bare soil conditions (albeit in different degrees), we chose to use this analysis as a measurement of "risk of invasion" of non-native plants to aquatic, riparian, and wetland resources.

While other activities such as grazing and development can also spread non-native plants, transportation activities most likely have the potential to influence aquatic, riparian, and wetland resources and non-native plants. Figure 5.2 illustrates the general relationship between road density and presence within the valley bottom. Roads within the valley bottom could be considered a "high risk" for establishment of non-native plants. Solar absorption on the flat valley floor, productive soils, and relatively high moisture content related to the water table all would contribute to the increased invasion capability in this area. Because road location is generally associated with the valley bottom within the Bighorn National Forest, the presence of invasive plants associated with roads is of concern.

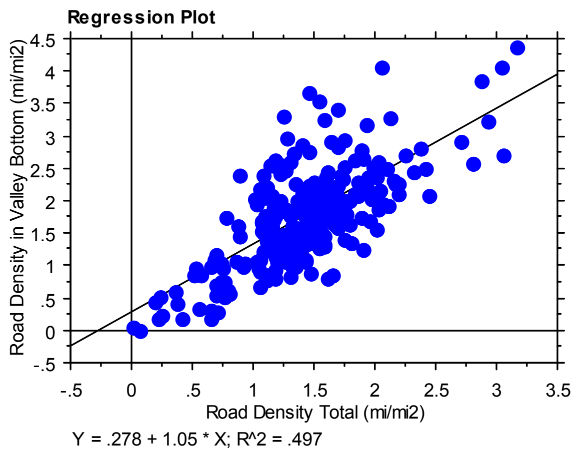

Figure 5.2. Relationship between road density and road density within the valley bottom for 6th level HUBs intersecting the Bighorn National Forest boundary.

Areas of invasive plant infestations have been mapped for certain areas within the Bighorn National Forest (fig. 5.1). However, as a result of limitations associated with dataset completeness, data collection methods and results interpretation, and the spatial analysis of exact invasive plant distribution analysis cannot be performed. Instead, an invasive plant risk model was implemented following the design of Regan et al. (2003). This model included the following variables: elevation, canopy closure, soil moisture content, proximity to roads, trails, livestock grazing areas, recent burn areas, recreation areas, private in-holdings and timber harvest areas (Regan et al. 2003). The risk model included five categories: Extremely High Risk, High Risk, Moderate Risk, Low Risk and Extremely Low Risk. (fig. 5.3). Each HUB was analyzed to identify the percentage of the HUB area incorporated in each category.

Each HUB was ranked by the percentage of the HUB area that was identified to be at either an extremely high or a high risk of invasive plant establishment (fig. 5.4). The HUBs were then grouped by percentiles, with the 0 – 24th percentiles constituting the group with the lowest risk, the 25th – 49th percentiles constituting the group with a low risk, the 50th – 74th percentiles constituting the group with moderate risk, and the 75th – 100th percentiles constituting the group with the highest risk. HUB 100800160109 had the highest percent (59.8%) of its area identified as a high risk, followed by 100800160107 (40.2%), 100800080406 (39.2%), and 100901010105 (36%) (fig. 5.4).

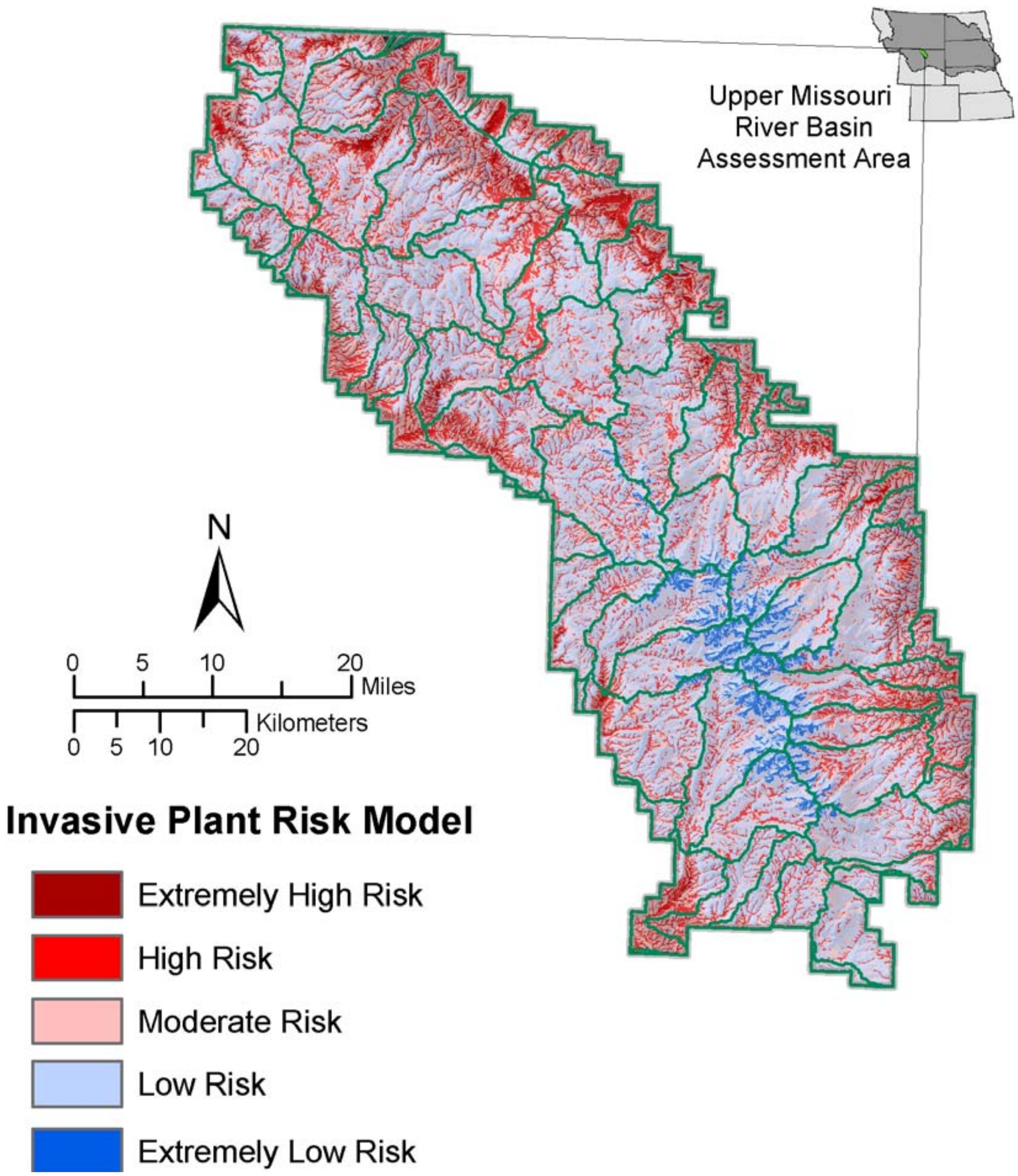

Figure 5.3. Invasive plant risk model.

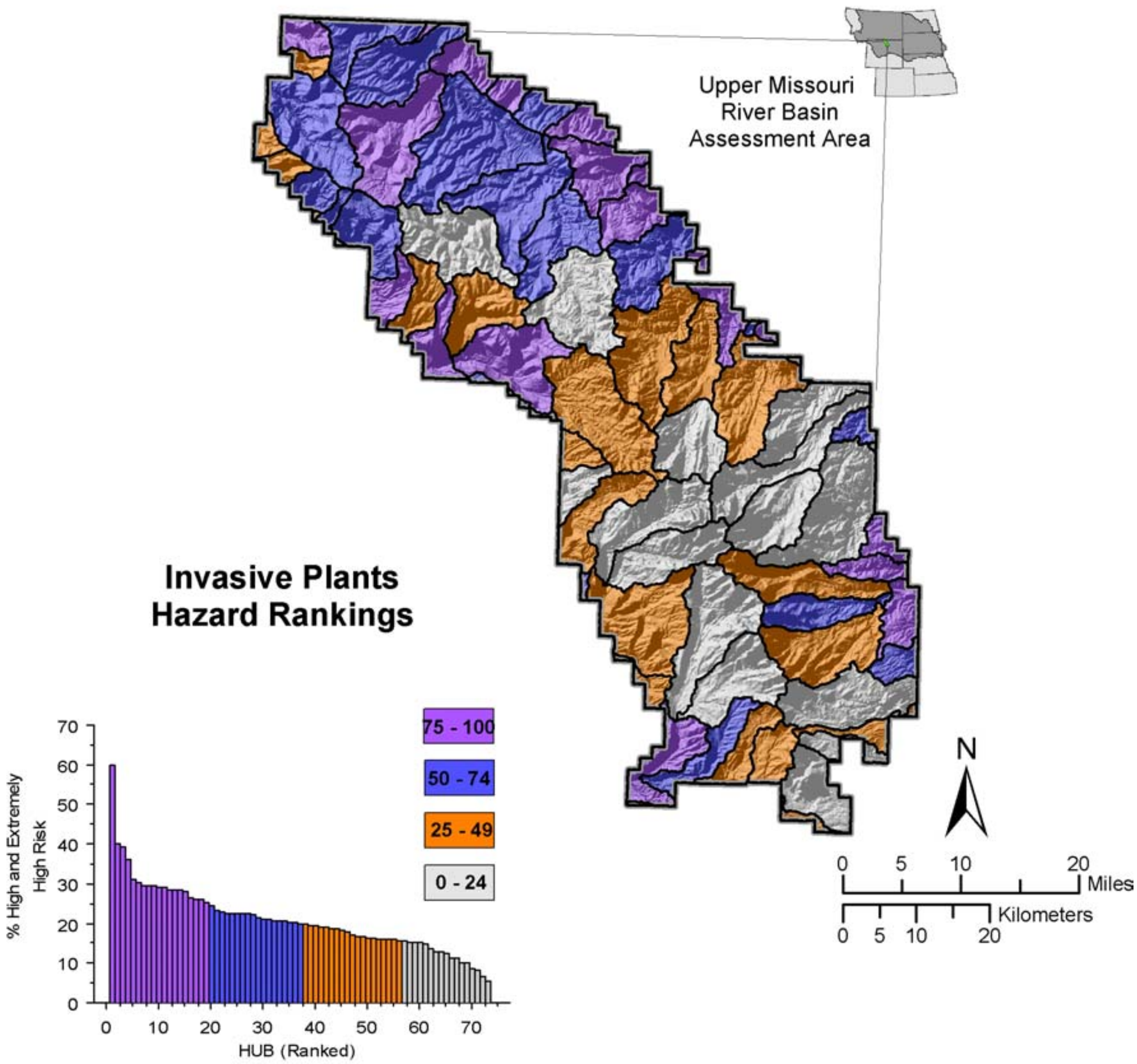

Figure 5.4. Invasive plant risk ranking categorized by percentiles.

Information Needs

Once invasive plants are established in riparian areas and or wetlands they are extremely difficult to remove. Probably the best way to analyze their presence and abundance in aquatic, riparian, and wetland resources is to prioritize areas with high potential and conduct thorough inventories of these areas. Specific questions that should be addressed are:

1. What species and what is the specific location of invasive species present in aquatic, riparian, and wetland resources?
2. Is there significant ground-disturbing activities occurring that would contribute to their establishment?
3. What is the mechanism that brought them to the area and contributed to their establishment?
4. What are the options for removal?
5. Are their rare plants and/or animals that would make this area a higher priority for recovery than others?

Management Implications and Relationship to Ecological Drivers

The ecological driver analysis identified areas with potentially abundant wetlands and the highest percentage of low gradient stream channels (see Chapter 2 in Report 1 of this assessment). The clusters derived from this analysis should identify 6th level HUBs with generally the most preferred habitat for invasive plant species. However, it does not include the mechanisms for dispersing them that were described above. Those clusters that exhibit relatively high percentages of low gradient stream channels and glaciated valleys and especially high road density should be considered the highest priority for inventories of invasive plants for aquatic, riparian, and wetland resources.

Influence of Non-Native Fish and Other Aquatic Organisms

Introduction

Ecological characteristics (ecological drivers) and management (anthropogenic) influences that can help identify planning, restoration and overall management factors that influence the distribution of non-native fish and other aquatic organisms at the appropriate scale are discussed in this section. Factors that may help in identifying restoration and key habitat areas are presented. The term "non-native species" is used for species such as brown trout which were in large part introduced into the Rocky Mountains as a management tool, while "invasive species" is defined as a subset of non-native species such as the whirling disease parasite (*Myxobolis cerebralis*) that was inadvertently introduced or has "invaded" the area and has no redeeming biological and/or social value.

<u>**Basin Scale**</u>

Dr. F. Rahel described the occurrence of native and non-native fish species in the Missouri River drainage in Wyoming (see Report 1 of this assessment, Tables 2.4 and 2.5). Rahel's review of existing information shows that of the 33 taxa of fish identified within the Missouri Basin in Wyoming, 20 are native and 13 are introduced, primarily for sport fishing purposes. In addition to fish, amphibians such as the bullfrog (*Bufo castesbeiana*) are also present at this scale. These effective predators compete with native amphibians, and are predaceous on larvae as well as adults. While they may have not been found in Wyoming yet, invasive species such as the zebra muscle and various carp (Cyprinidae, such as the bullhead strains appear to be expanding their range in the Mississippi and ultimately Missouri drainages. Because of the habitat, elevation and ultimately water and air temperature conditions found associated with the Big Horn Mountains, it is doubtful that many of these species will invade the relatively cold steep and relatively unproductive reaches of most of the Bighorn National Forest. The Bighorn National Forest occupies a rather unique position within the upper Missouri drainage, with conditions that would preclude the introduction of “warm water” species of aquatic organisms.

Thermal limitations may have a dramatic influence on the distribution of different invasive species. In their development of suitability index models for bullfrogs (*Bufo castesbeiana),* Graves and Anderson (1987) state that the range of mean water temperature values at mid-depth during summer need to be within a range from approximately 15 to 36 degrees centigrade. Suitability values of 1, ranged from 20 to over 30 degrees centigrade. While we do not have ranges of temperature values for bullfrog habitat on the Bighorn National Forest, it would appear that there is limited amount of habitat that would get this warm. The development of reservoirs and other impoundments such as stock ponds could facilitate movement at higher elevations. Obviously the higher in elevation one goes, the less their chance of invasion.

Keleher and Rahel (1996) found that salmonids were restricted to areas where mean July temperatures did not exceed 22 degrees centigrade. They found that relatively small changes in temperature due to global warming could have a dramatic effect on the available habitat for salmonid fish in Wyoming. Keleher and Rahel’s conclusion was that global warming could restrict the habitat available for native cutthroat and other salmonids by forcing them into smaller, headwater stream habitats. A preliminary analysis of the relationship between the climate ecological driver and the 22-degree limit revealed no significant difference between the temperature limit and the rain-and-snow – rain-driven hydrology boundary identified in this assessment (fig. 2.10 in Report 1). While some salmonid fish are more tolerant to warmer water conditions such as the brown trout, which may be found in larger streams exiting the Big Horn Mountains, it is doubtful that their distribution extends downstream into the plains under natural conditions. Conversely, warmwater fish may be able to migrate further upstream in Rocky Mountain streams if temperatures increased and habitat conditions were favorable. Even with increasing water temperatures however, most plains fish are limited to relatively low gradient habitats and would probably not be able to inhabit the steep stream channels in the Big Horn Mountains. Obviously there are limits to invasive aquatic species related to elevation, habitat, and temperature as there are to native species. These considerations are important when developing “long-term” strategies for managing native as well as non-native species.

Yellowstone cutthroat trout are also found within the Shoshone National Forest in the upper Missouri River Basin as well as other Forests in adjacent areas (fig. 5.5). Because of their locations within the mountainous areas of the landscape, Forest Service lands represent a considerable amount of the available habitat for this native trout, and thus are important for their future management.

Photo 5.1. The bullfrog (*Bufo castesbeiana*), an invasive species.

<u>Landscape Scale</u>

Within this scale, the Bighorn National Forest is restricted to the snow and rain-and-snow hydrologic portions of the landscape (fig. 2.10 in Report 1). This mountainous area generally receives more precipitation than the surrounding plains region (fig. 2.9 in Report 1), as well as exhibiting colder temperatures. As a result, the species of non-native fish and other vertebrates within this scale are generally representative of cool or warmwater species (e.g., walleye and largemouth bass), while the mountainous areas contain coldwater species. There is some overlap of species around the base of the Big Horn Mountains. However, it is doubtful that the Bighorn National Forest management can have a significant role in the viability of those species that are generally widespread across the plains (e.g., brassy minnow; *Hybognathus hankinsoni*). Those plant and animal species that are restricted to specific, often isolated habitats (e.g., springs and fens) may be identified as taxa that we may have an opportunity to address at the Forest level. Invasive species in these habitats could eliminate isolated populations of native species, effecting the distribution and ultimately population and species viability.

The cluster analysis for riparian ecological driver combinations shows a very dissimilar grouping of 6th level HUBs intersecting the Bighorn National Forest boundary as compared to the HUBs on the plains (fig. 2.15 in Report 1). Clusters 2r and 6-9r are located primarily in the low gradient stream channel and on the rain-driven hydrology portion of the landscape, indicating a plains environment. Several of the HUBs are partially located within the Bighorn National Forest boundary, but very little of their area is actually within the boundary. If an entire 6th level HUB were managed for a particular plains species, then the Forest Service would be a valuable partner in maintaining a specific species for management. However, without the bigger HUB managed appropriately, it is doubtful that the limited area within the National Forest boundary would constitute a priority for management of that species.

Bullfrogs are currently found from Nova Scotia to central Florida, from the East coast to Wisconsin, and across the Great Plains to the Rockies. The natural western limits of this species are now confused due to their introduction into places as far west as California and Mexico. It is known that bullfrogs were introduced to areas of California and Colorado in the early 1900s (www.invasivespecies.gov 2003). While bullfrogs are currently identified as being in Wyoming they are not currently found in the Big Horn Mountains (Baxter and Stone 1980). Baxter and Stone further described that while the bullfrog has spread up the North Platte and Laramie Rivers in the plains of eastern Wyoming, they are generally limited to that area unless warm springs are present. If bullfrogs become established in the Big Horn Mountains they could become a predator on the native amphibians (both frogs and the tiger salamander), effectively influencing their distribution and density.

The Yellowstone cutthroat trout (*Oncorhynchus clarki bouvieri*) is a native salmonid subspecies of cutthroat trout that is an important management species throughout its range in Wyoming, Montana, Idaho, and to a very limited degree in Utah and Nevada (Behnke 2002). While this cutthroat historically occupied the second largest area of any of the cutthroat subspecies (the coastal cutthroat having the largest distribution), its distribution and numbers have been compromised like all the other cutthroat subspecies. Within the landscape scale of this assessment, the Yellowstone cutthroat trout historically occupied the Bighorn Reservoir, Little Bighorn, Upper Tongue, and Nowood 4th level HUBs (fig. 5.6). Most of the adequate habitat conditions for this coldwater species are located within the northern and western portion of the Bighorn National Forest boundary, corresponding with their historic movements (Behnke 2002). The fact that most of the southern limit of the Yellowstone cutthroat trout range falls within the Bighorn National Forest would indicate that special management emphasis be placed on this important subspecies as part of the recovery process.

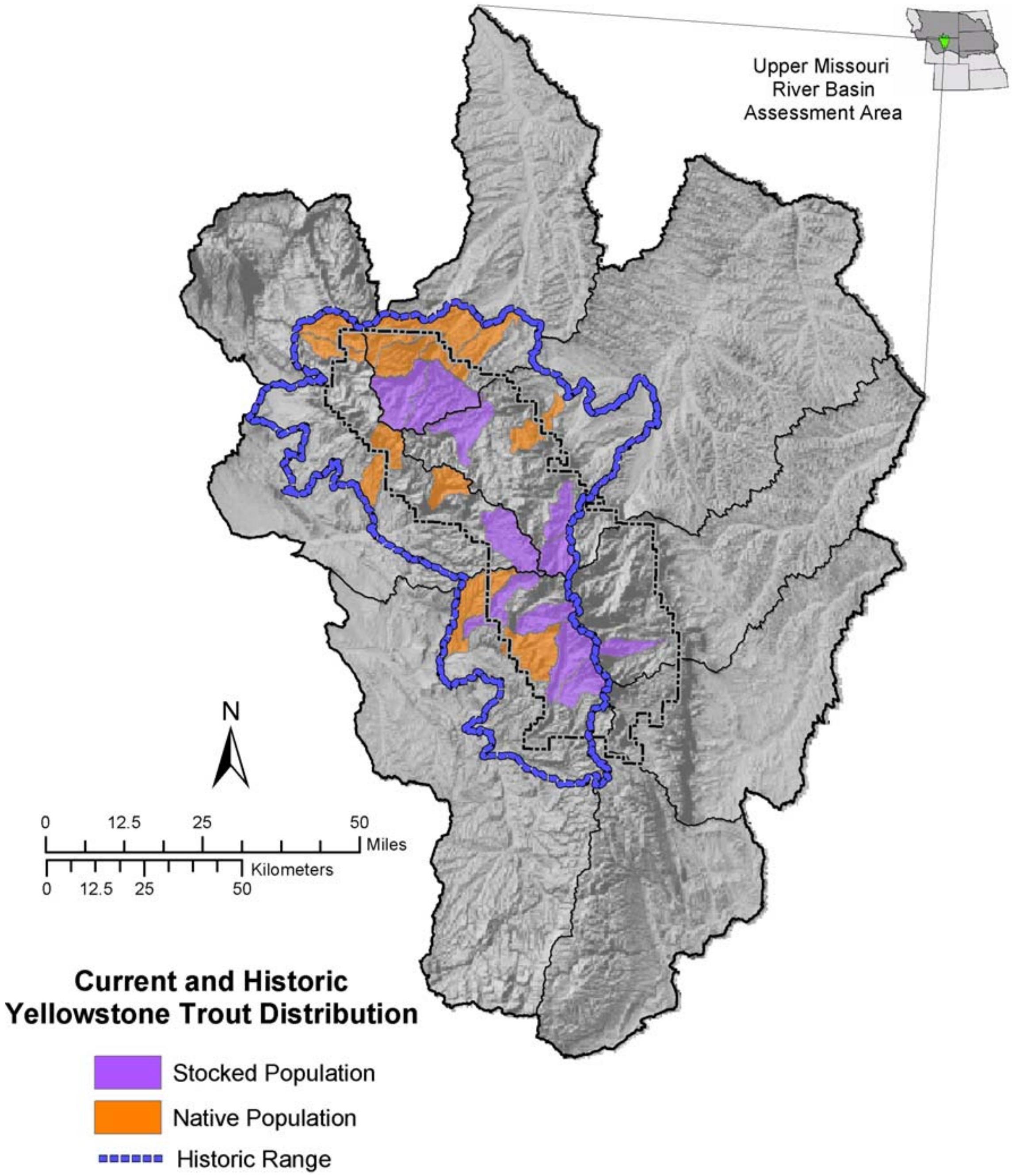

Figure 5.5. Historic boundary and currently occupied 6th level HUBs of Yellowstone cutthroat trout at the landscape scale. Yellowstone cutthroat trout do not occupy the entire HUB identified, and may be sympatric with other non-native salmonid species. The rest of the Bighorn National Forest is occupied by primarily non-native salmonids.

Management Scale

Non-native aquatic species introductions and management at this scale currently includes primarily non-native salmonids, although there does appear to be limited habitat capability for bullfrogs (*Bufo castesbeiana*). At this scale we can begin addressing the historic and current range of the Yellowstone cutthroat in relationship to the Bighorn National Forest and identifying landscape factors that may aide in prioritizing 6th level HUBs for management focus. Other more reach/site specific parameters are important in defining salmonid habitat, such as water temperature, the presence of migration barriers, habitat quality, etc. and are currently being addressed by USDA Forest Service and Wyoming Game and Fish Department biologists. In addition, social and economic values may play a role in reestablishing native populations that we cannot assess at this scale.

The current distribution of Yellowstone cutthroat trout at the management scale is presented in Figure 5.6. It is important to note that none of the 6th level HUBs identified as containing Yellowstone cutthroat trout are entirely managed for that subspecies, and several have populations of other nonnative species as well.

While there are a number of physical, biological and socio/economic considerations typically used for addressing management of native cutthroat subspecies, we will focus our results on the following factors:

1. Habitat size as measured by 6th level HUB.
2. Habitat quality as measured by the percentage of low gradient stream channels that result in a higher percentage of pool habitat.
3. Potential growth as measured by climate values of snow, rain-and-snow, and rain-driven hydrology.
4. Anthropogenic influences measure by those influences most commonly associated with the influence on salmonid habitat (e.g., transportation).

These factors were identified and grouped into watersheds with "similar" ecological driver characteristics. Dr. Frank Rahel and Dr. N. LeRoy Poff identified in Chapter 2 in Report 1 of this assessment combinations of calcareous geology, high percentage of low gradient stream channels, and rain-and-snow hydrology as being "preferred" drivers for fish and aquatic invertebrate and algae production at this scale. Table 5.1 identifies each cluster into the following three categories of management consideration:

1. High, cold-water fish and aquatic production potential
2. Moderate cold-water production potential
3. Low cold-water production potential

Table 5.2 illustrates the number of 6th level HUBs that are currently managed within the historic range of Yellowstone cutthroat trout in relationship to the production ranges described above. The diversity of values presented is mostly the result of other "values" influencing the reintroduction efforts for Yellowstone cutthroats. For example, while a relatively high percentage of 6th level HUBs in Cluster 1r contain reintroduced populations, it is also considered "low" in terms of productivity. Further examination reveals that most of the populations in this cluster are located within the Cloud Peak Wilderness boundary, which emphasizes native species management. In addition, relatively few management activities occur in the wilderness areas, making it more efficient to manage for native fish. Cluster 5r is the other cluster with the highest percentage of 6th level HUBs with Yellowstone cutthroat populations and is located around the periphery of the Bighorn National Forest. It contains predominantly remnant populations of native (as opposed to reintroduced) populations.

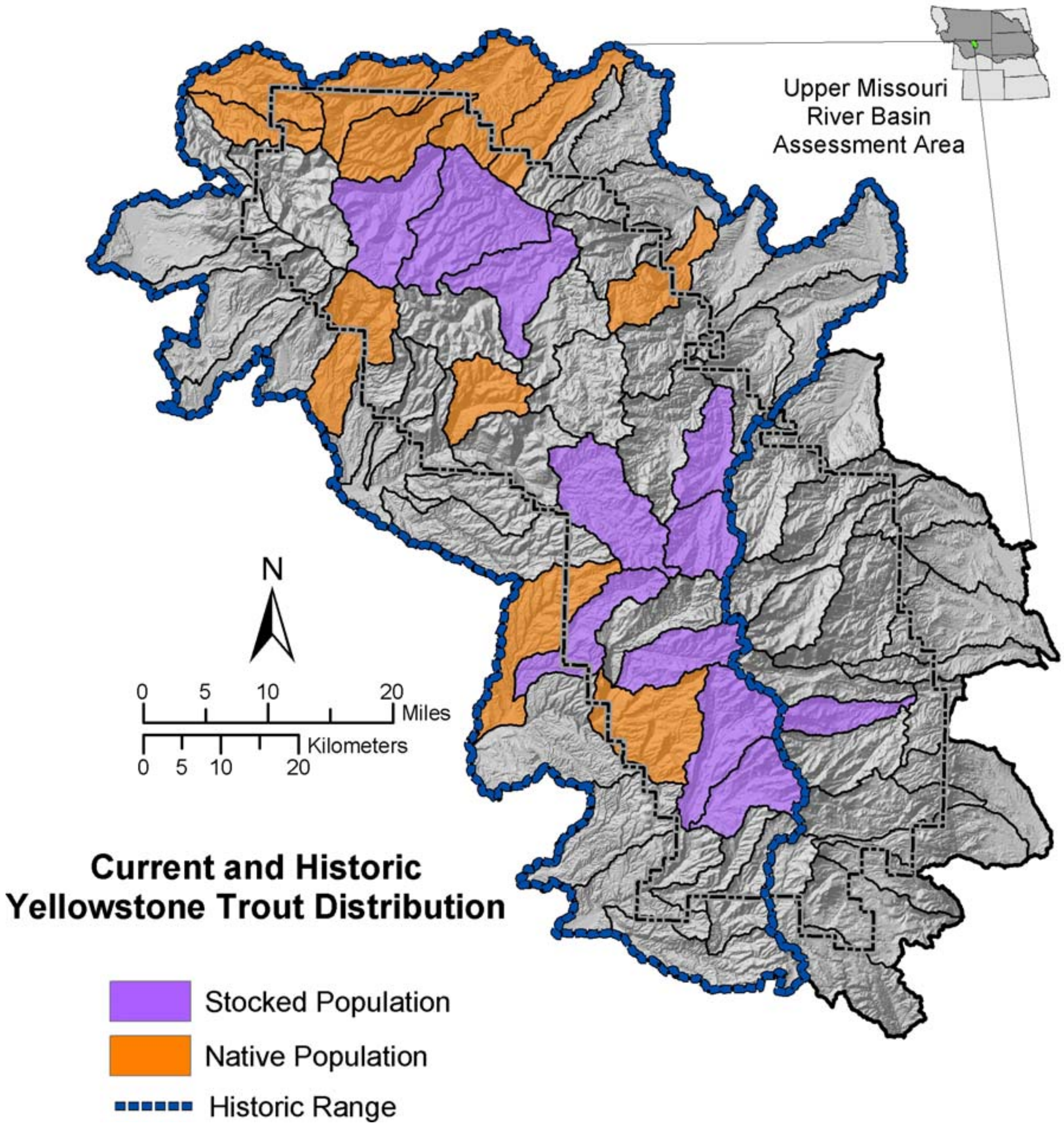

Figure 5.6. Historic range and HUBs currently occupied by Yellowstone cutthroat on the 74 6th level HUBs intersecting the Bighorn National Forest boundary. All other watersheds are assumed to have primarily non-native salmonid species. (Information courtesy of Dan Scaife, Bighorn National Forest). It is important to note that populations in occupied HUBs represent a relatively small amount of the habitat within them.

Table 5.1. Cluster results for 6th level HUBs intersecting the Bighorn National Forest boundary with associated coldwater production ratings. Ratings are based on interpretation of cluster results from Dr. F. Rahel, (see Chapter 2 in Report 1).

Cluster ID # for Riparian Analysis	Percentage Calcareous Geology %	Percentage Climate % (Precipitation Zone)	Percentage Low Gradient Stream Channels %	Production Rating
1r	11	79 – snow	11	Low
2r	53	53 – snow	21	High
3r	10	66 – rain/snow	30	Low
4r	59	70 – snow	7	Moderate
5r	77	54- -rain/snow	20	High
6r	17	77 – rain	40	Low

Table 5.2. Relationship between predicted coldwater fish production and current population distribution of Yellowstone cutthroat trout at the management scale.

Cluster ID # for Riparian Analysis	Production Rating	Total Number of 6th Level HUBs	Total Number of 6th Level HUBs with Yellowstone Cutthroat Trout	Percentage (%)
1r*	Low	19	8	42
2r	High	7	2	29
3r	Low	11	0	0
4r	Moderate	3	1	33
5r	High	18	8	44
6r	Low	16	1	6
Total		74	20	27

**Seven of the 8 6th level HUBs are either totally within or intersect the Cloud Peak Wilderness Area boundary.*

There is one noticeable exception, which is a HUB that is totally within the Bighorn National Forest boundary (HUB 100800160102, Dry Fork. Little Big Horn River) and has a reintroduced population. In Cluster 2r, which also has a high productivity rating, one of the two HUBs is within the National Forest boundary (HUB 100901010102, Fool Creek), and the other (having a native population) intersects the Forest boundary.

The ability to manage Yellowstone cutthroat populations on lands being under federal jurisdiction has obvious benefits for state and federal agencies. While some private landowners are willing to manage stream resources for native trout species, there are obvious management implications that many are not willing to sacrifice. As a result, information from the Bighorn National Forest reveals that of the 6th level HUBs with native populations of Yellowstone cutthroats, 1 of 11 are entirely within the Forest boundary. Eight of these HUBs are identified as being within "high production" HUBs. Of the reintroduced populations, 10 of 11 are located entirely within the Bighorn National Forest boundary, and 3 of the 11 are within 6th level HUBs considered "high production" areas. These results indicate three important management considerations:

1. It is extremely difficult to reintroduce Yellowstone cutthroat trout where private land ownership must be considered, even if native populations are present.
2. As a result, reintroductions within historic ranges of the Bighorn National Forest have generally occurred in wilderness areas, which identify native species management as important, although production may be relatively low.
3. 6th level HUBs totally within the Bighorn National Forest with high production ratings are relatively rare (e.g., 2 of 74 HUBs within or intersecting the Forest boundary). Both currently have reintroduced populations of Yellowstone cutthroat introductions within them.

These results indicate that a strategy of protecting native populations and focusing management efforts on the rare but most productive watersheds could be a future consideration. Managing in less productive watersheds is also valuable for extending the range of Yellowstone cutthroats back to their original range.

<u>Reach/Site Scale</u>

The Bighorn National Forest Aquatics team and Wyoming Game and Fish Department monitor populations and habitat of native as well as non-native species (B. Bohn oral. commun., 2003 BNF Aquatics Program Manager). In addition, reintroduction of native Yellowstone cutthroat trout is a major management consideration for aquatics management. Increased recreation and overall use of the Bighorn National Forest could result in inadvertently introducing species as well as "planned" introductions of non-native species by the public, which has been a problem in many parts of the west.

Identification of invasive species, either naturally or from introductions can best be controlled if they are identified early, before they become well established. Monitoring of key habitats for species like the bullfrog will often identify their early "arrival". Other species like the whirling disease parasite are not as easily found. Since the mechanism that distributes them and their resting stages are varied, the risk of infection is relatively high. Stocking of non-infected salmonids is critical, although maintenance of instream habitat conditions associated mainly with low gradient streams and reaches to minimize erosion and over-wide channels, and maintaining riparian vegetation to reduce stream temperatures may limit its distribution. Specific questions that could be addressed include:

1. What aquatic invasive species is an immediate and long-term threat to Bighorn National Forest?
2. What implications do forest management activities have on increasing the chance of providing invasive species with suitable habitat?
3. Are native species being managed to meet the needs of populations and the species?
4. Are native species management objectives being "balanced" with other resource values?

Management Implications and Relationship to Ecological Drivers

Non-native, invasive species are not as pervasive on the Bighorn National Forest as in other regions of the country (Abell 2000). However, native Yellowstone cutthroat trout populations have been compromised in their historic range due primarily to competition and hybridization with non-native salmonids. Influences of anthropogenic activities are also an important factor in reducing Yellowstone cutthroat populations. There is currently no evidence of bullfrogs within the Bighorn National Forest boundary, although habitat is potentially present and populations could compromise populations of native amphibians.

It appears that there is a limited amount of highly productive habitats for Yellowstone cutthroat trout. Sixth level HUBs have been identified as being a logical scale for addressing the long-term management of this subspecies. While protection of historic populations (and population fragments) are important in maintaining genetic material. Long-term management and survivability of Yellowstone cutthroat trout may involve addressing management within identified 6th level HUBs and focusing efforts on the highest priority watersheds. Management prescriptions could be developed for these watersheds, where the primary focus of management is for the health of Yellowstone cutthroat trout. Other management action would be allowed in these watersheds, however, like current management prescriptions the primary focus would be on cutthroat trout management. By default, this strategy appears to be happening within the Cloud Peak Wilderness area where one of the goals is native species management. However, more productive watersheds are present in lower elevations, with higher percentages of low gradient stream channels and calcareous geology.

General Conclusions

1. Aquatic non-native and invasive species are limited in the Bighorn National Forest due to the inability of many "warmwater" or habitat-limited vertebrates to invade the mountainous environment.
2. Currently, non-native salmonids are the most important numerous aquatic species and has no doubt compromised the distribution and abundance of native Yellowstone cutthroat trout.
3. Whirling disease is currently not found within the Bighorn National Forest, there is the potential for its introduction through several pathways, especially in lower elevations where habitat conditions for the intermediate host (tubifix worms) is more abundant.
4. Increasing sedimentation, nutrient input and water temperature through poor management practices on the Bighorn National Forest could increase habitat for tubifix worms.
5. Although highly productive, coldwater habitats are present within the Bighorn National Forest, and most intersect the Forest boundary making it difficult to manage them on a watershed basis.
6. HUBs are rare within the Bighorn National Forest with high production ratings (e.g., 2 of 74 intersecting the Forest boundary) and could be managed primarily for Yellowstone cutthroat trout to ensure long-term sustainability.

Influence of Pesticide Use

Historical Content

Pesticides have been used on the Bighorn Assessment Area for decades although there is no way of determining just what has been used and in what quantities. In general, uses would fall into the following categories: urban/household; agriculture; natural resources.

Households in the assessment area have used pesticides in their homes, lawns, and businesses for a very long time. A tracking of pesticides used would show many that are no longer permitted by the EPA were used to varying degrees in the past (e.g., DDT). Households and urban areas are major users of pesticides ranging from; herbicides for control of weeds and other unwanted vegetation; insecticides for control of garden and tree insects, lawn insects, mosquitoes, and household insects such as spiders, roaches, etc.; rodenticides to control rodent populations (mice, rats, gophers, etc.); algaecides or fungicides to control mildew and mold, and so forth. Overall, urban uses of pesticides are believed to account for a very large percentage of the pesticides actually used within the assessment area. Other urban uses have long included right of way clearing and maintenance for highways, county roads, railroads, power lines, and so forth. These uses can, and have accounted for a fairly significant percent of the overall pesticide use across the landscape.

Agricultural uses also have traditionally accounted for a significant portion of the pesticide use in the assessment area. Usages over the past decades have primarily focused on control of competing vegetation in crop or hay/pasture production. On the National Forest, and quite probably on some private or BLM lands, herbicides were historically used to control sagebrush in order to favor the production of forage species for livestock and wildlife. These practices are believed to have involved several hundreds of acres during the 1940s or 1950s and continuing possibly into the 1970s (R. Stellingwerf, oral. commun., 2002). For the most part, this practice involved aerial or ground application of herbicides that were approved for use at that time (but which may not be approved currently). Few records are readily available to indicate herbicides or rates applied or to show effects of the treatments.

On the Forest, pesticide uses have been tracked for a number of years via the Pesticide Use Report. Records are sketchy and have only recently begun to be collected via a corporate database. Little to no information is available regarding any monitoring of the effects of the applications to non-target species or to water quality. This is a significant data gap. Table 5.3 displays the available information regarding herbicide use on the Bighorn National Forest.

Current Context

Use of pesticides on the Bighorn National Forest is believed to be quite limited when compared to the potential applications on private lands, including especially urban and agricultural uses. Reports for the past three fiscal years (Pesticide Use Reports USFS unpublished) show only herbicide applications with no other pesticides uses. This may or may not be accurate as the reporting may be incomplete. But in any case, the amount of herbicides used is quite low. Incomplete records show from 0.25 to about 0.75 pounds per acre of active ingredient being applied depending on the specific herbicide being used. With a three-year average of 536 acres being treated, and assuming an average of 0.5 pounds per acre of active ingredient (probably a high estimate), this would give only 268 pounds being applied Forest-wide across approximately 1.1 million acres within the Bighorn National Forest. BLM lands are believed to show similar rates of use and similar trends. Amounts and trends on private lands are unknown. An important question might be "what is the percentage of herbicides being used on sensitive aquatic, riparian, and wetland resources?"

The dominant herbicide used on the National Forest is Picloram. This herbicide has the potential for limited residual effect and for limited translocation but when applied according to label restrictions has minimal potential for unintended effects. It is used because of its effectiveness on a number of noxious weed species. Other herbicides are used but are not as frequently employed as Picloram. In noxious weed management, it is necessary to tailor the specific chemical to the specific weed species if effective treatment is to be achieved.

There have been no documented instances of problems occurring with the use of pesticides on the Forest that have resulted in significant impact to non-target species. Pesticide applicators on the Forest are licensed and trained and are required to follow EPA standards for the use and application of all pesticides. The predominant use of pesticides on the Forest in recent years is for the use of herbicides to manage noxious weeds.

Over the past four years an average of 678 acres of noxious weeds have been treated annually (R. Stellingwerf, oral commun., 2002). Most of the treatment is via herbicide use with some acres treated by biological means and a few sites treated by manual or mechanical. Application is primarily by backpack sprayer and vehicle mounted sprayers. All herbicides used on the Forest are approved by the EPA for use on noxious weeds and are applied according to label restrictions.

Only very limited applications of other pesticides occurs on the Forest. Some rodenticides are probably applied on an irregular basis at work centers to control mice and rats. Some limited application of herbicides occurs at campgrounds and work centers to manage unwanted vegetation. The potential exists for the use of insecticides to manage insects but no such use is currently foreseen.

The Pesticide Use Report for fiscal years 1999-2001 shows only herbicide applications and only for noxious weed management purposes. No other pesticide uses are reported for those years.

Information Needs

Significant gaps exist in our tracking and knowledge regarding the application and unintended effects of pesticide use. There is little tracking completed on the major uses by urban areas other than possibly in the tracking of chemicals sold. Most chemicals sold for urban use do not require a special license for application and are not tracked as to when, when, and how much is applied. Much may be misapplied by untrained applicators operating in their yards. Commercial or agricultural users may apply chemicals that require a special license and these may be tracked. This information would be helpful in determining the overall extent of pesticide use in the assessment areas but we lacked the time to track the information down.

On National Forest System lands, tracking has begun to employ a corporate database for reporting pesticide use. The future use of this database will help to provide valuable information, but more detailed and site-specific information on uses is needed. Corporate database tracking of actual application via Terra (or other database), when developed, will help to fill this need.

Monitoring and assessment is needed regarding unintended effects associated with application of pesticide. Specifically, information is needed on non-target species (plants or animals) and on effects on water quality. Little to no information currently exists for the Bighorn National Forest and therefore any assessment of the potential effects of pesticide use is very incomplete.

Management Implications and Relationship to Ecological Drivers

As mentioned previously, pesticides are often treated from vehicle-mounted applicators. This procedure is based on the need to treat areas along roadways where invasive weeds are brought in from vehicle tires and colonize disturbed areas along the right-of-way. A simple regression reveals that there is a direct relationship between road density and roads in the valley bottom in 6th level HUBs intersecting the Bighorn National Forest boundary (fig. 5.2). These results indicate that many of the acres treated by the Forest may be also within the valley bottom, and should be treated even more carefully than the upland areas because of the proximity of the groundwater and sensitive riparian vegetation.

Clusters that exhibit a relatively high potential for wetlands (Clusters 1-4r) and stream/riparian areas (Clusters 2r, 3r, and 6r) should be given special consideration because of the potential for establishment of invasive plants and the potential effects of herbicides on aquatic, riparian, and wetland ecosystems.

Table 5.3. Herbicides used on the Bighorn National Forest for 1999-2001.

Fiscal Year			Herbicide Used									
			Picloram	Metsulfuron-methyl	Amitrol	Clopyralid	Banvel	Dicamba	Escort	2,4-D	Curtail	Triclopyr
1999	Acres	627	X	X	X	X						
	# AI	N/A										
	Purpose	Noxious Weeds										
2000	Acres	472	X	X			X	X	X	X	X	
	# AI	N/A										
	Purpose	Noxious Weeds										
2001	Acres	508	X	X		X		X		X		X
	# AI	N/A										
	Purpose	Noxious Weeds										

#AI refers to pounds of active ingredient. Data reports mix pounds per acre with gallons (of mix or of chemical) and therefore are not useful. N/A means information is incomplete or not available. 2002 information was not available at this time.

Influence of Beaver Removal

Basin Scale

The fur trade played a very large role in the exploration and development of the Upper Missouri River Basin.

In 1807, Manuel Lisa built a trading post, Fort Raymond, at the mouth of the Big Horn River in Montana. This fort was the center of the Upper Missouri beaver trade from 1807 until the War of 1812, and also served as the main trading post with the Crow Indians. However, none of the traders using this fort are known to have come into present day Wyoming. Fort Raymond was abandoned in 1811-1812 because of poor economic conditions (Murray 1980).

During the early part of the fur trade, several expeditions passed through the area on their way to and from the Columbia River Basin to the west. Difficult terrain made passage through the Bighorns undesirable. In 1812, Robert Stuart led a small party east from the Columbia River across the Continental Divide through what is now called "South Pass", that provided an ideal location for east-west travel. With much of the subsequent transcontinental travel occurring to the south of the Bighorn National Forest, the Upper Missouri River Basin became one of the last regions in the West to become settled (Murray 1980).

For the next ten years, the frequency of fur traders visiting the Upper Missouri River Basin increased. However, the primary travel routes tended to be south of the mountains or via the Bighorn Basin on the west side of the mountains, because these routes provided access to beaver-rich streams and avoided encounters with Native American tribes. Although much of the travel apparently bypassed the Big Horn Mountains themselves, it is almost certain that small trapping parties worked the streams in and around the Big Horn Mountains (Murray 1980).

Landscape Scale

Fur trappers and traders explored the areas around the Big Horn Mountains beginning in the early 1800s. In 1810-1811, the Hunt (Astor) party traveled from St. Louis to the base of the Big Horn Mountains. During the summer of 1811, they traveled up the Little Powder River into what is now Johnson County on the east side of the mountains. They intended to cross the mountains and made their first attempt a little southwest of where the city of Buffalo now stands, but failed in this attempt. They eventually located a suitable passage and emerged on the west side of the range on one the tributaries of the Big Horn River. It is believed that the party traveled up the Middle Fork of the Powder River to the pass at the head of that stream which leads into the Nowood River watershed. This is the first account of the crossing of the Big Horn Mountains by beaver traders (Conner 1940).

Removal of beaver would likely have significant effects on aquatic, riparian, and wetland resources in low order streams (1-4), habitats where beaver typically build dams. However, although they cannot build dams in middle (5-8) or high (9 or greater) streams, beaver still affect them by cutting riparian trees, accumulating debris and creating small islands, and altering floodplain and backwater habitats (Naiman et al. 1988). In addition, they build dams in side channels of larger streams, creating additional habitat along the edges. Thus, beaver removal may have affected aquatic, riparian, and wetland resources throughout the drainage networks in the 4^{th} level HUBs.

Habitat available for beaver in the Forest is substantial, so reintroduction or expansion of beaver populations again might exert a large influence on aquatic, riparian, and wetland resources, particularly where beaver might be expected to reach high densities. Suitable habitat is defined as areas with perennial streams of order ≤4, valley gradient ≤3%, valley floor width ≥60 m, and within 150 m of aspen/willow (common vegetative unit coverage).

At the landscape level, 'suitable' beaver habitat is not evenly distributed among the 4th level HUBs, whether expressed as a percentage of total stream length within the Forest or absolute stream length (fig. 5.7). For example, up to 0.65% of Forest stream inside Crazy Woman Creek (10090205) is suitable beaver habitat, whereas the same value for Clear Creek (10090206) is <0.1%. Nearly 42% of the suitable habitat in the Forest (11.94 of 28.46 miles) is found in a single HUB, Big Horn Reservoir (fig. 5.7; HUB 10080010).

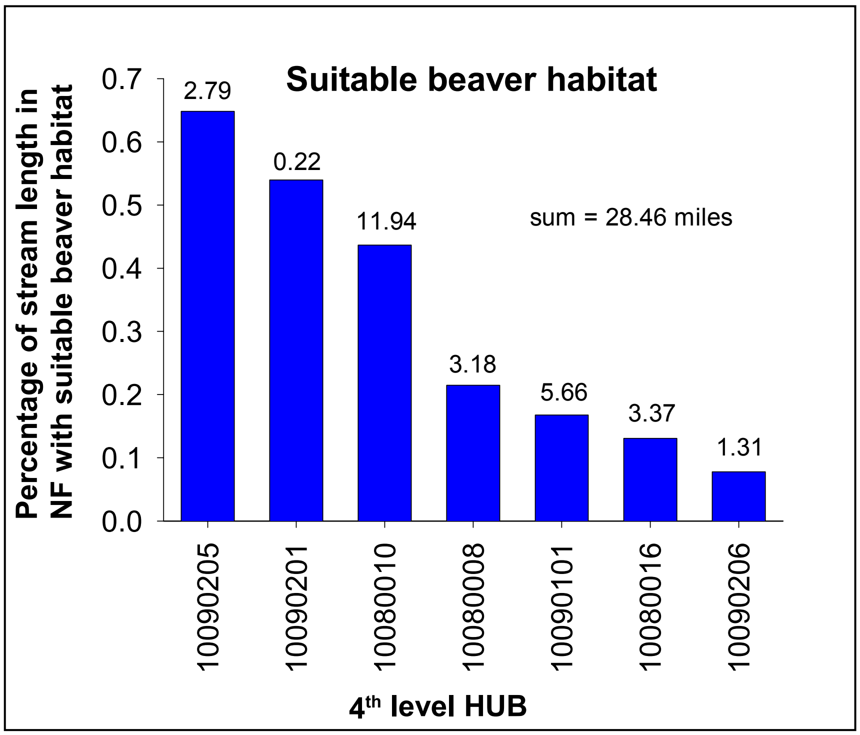

Figure 5.7. Distribution of suitable beaver habitat among 4th level HUBs intersecting Bighorn National Forest. Bars express percentage of the total stream length within the Forest that is suitable beaver habitat, and values above bars are length of suitable beaver habitat in that HUB. Suitable habitat is defined as areas with perennial streams of order ≤4, valley gradient ≤3%, valley floor width ≥60 m, and within 150 m of aspen/willow (common vegetative unit coverage).

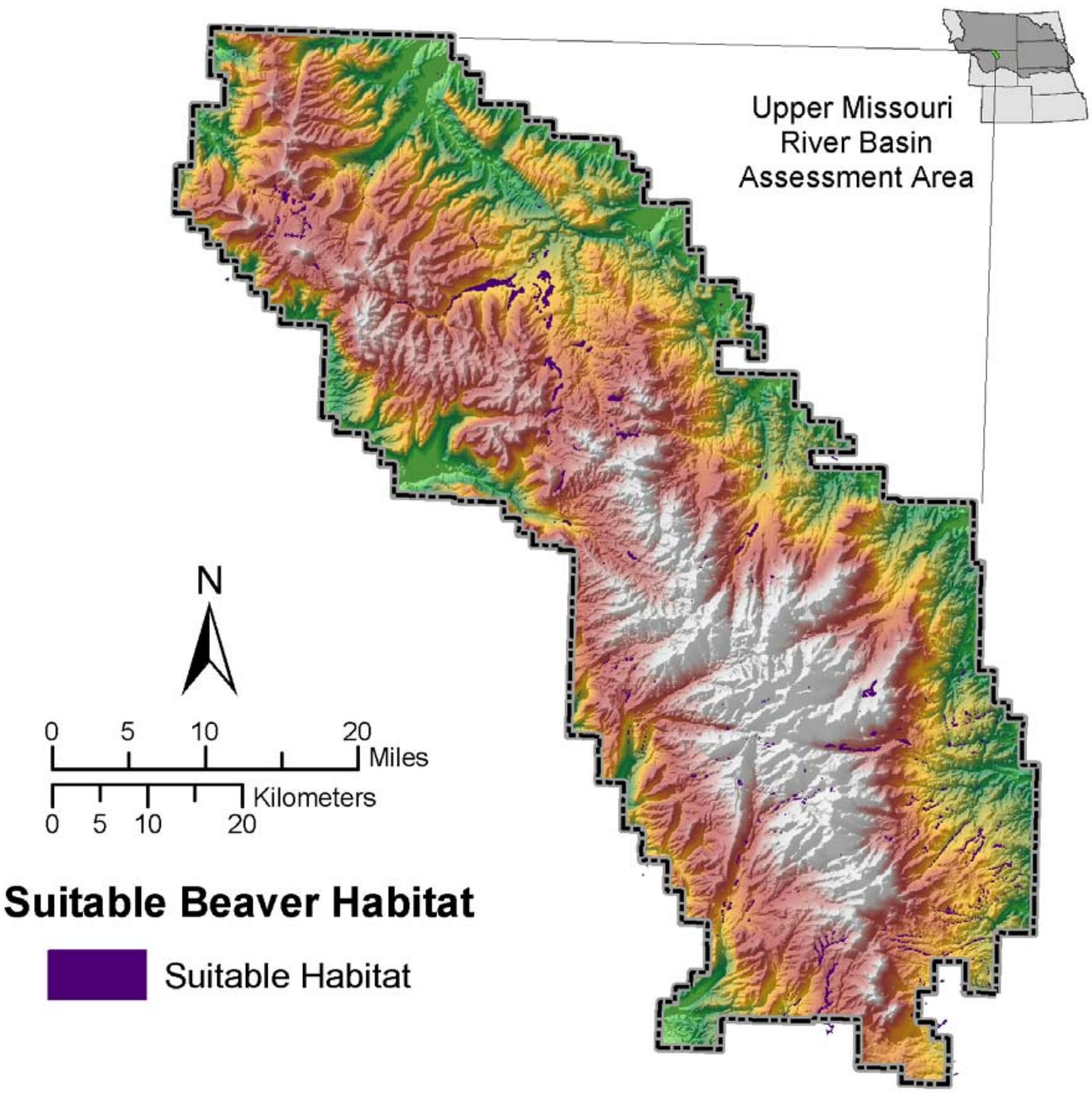

Figure 5.8. Highly suitable beaver habitat in the Bighorn National Forest.

Management Scale

Historic over-trapping caused a sharp decline in beaver populations, but they are presently making a comeback in the Big Horn Mountains and colonizing new habitats. In addition to trapping restrictions, translocation efforts by Wyoming Game and Fish and improved riparian conditions resulting from better livestock management practices may be contributing to increased beaver abundance. The effect of beaver colonization is immediately recognizable. For example, higher water tables and slow backwater habitats are evident in the headwaters of the North Tongue and Crazy Woman watersheds that have recently been colonized by beaver.

Exploitation of beaver in the 19th and early 20th century likely had a negative impact on aquatic, riparian, and wetland resources in the Forest. Reduction or near extirpation of beaver would be expected to result in: 1) a loss of pond habitat for fishes, amphibians, and waterfowl; 2) decreased nutrient retention and water temperatures which might reduce overall productivity; and 3) decreased water storage and loss of 'buffering' flow during drought.

As mentioned above, there are over 28 miles of highly suitable beaver habitat in Bighorn National Forest as defined by the suitability criteria (fig. 5.7). It should be noted that this analysis provides information on the most "preferred habitat" for beavers; they also will inhabit less desirable areas with higher gradients and absence of preferred vegetation. Beavers inhabit these less desirable areas especially when densities are high and young are pushed out of the preferred areas. In addition, higher gradient, less desirable habitat constitutes migration corridors for them moving throughout the watershed, so fragmentation of those habitats is important. At the management level, this habitat is distributed among 54, 6th level HUBs (table 5.4; fig. 5.8). Over half of this suitable beaver habitat is found in five different watersheds, three of which are inside the Big Horn Reservoir HUB. The average and median percentage of stream length in a given HUB that is suitable beaver habitat is generally low, with a few exceptions (fig. 5.9).

Table 5.4. Length of suitable beaver habitat in Bighorn National Forest per 6th level HUB.

6th Level HUB Code	6th Level HUB Name	Stream length (miles)
100800100601	Upper Porcupine Creek	4.457
100800100203	Upper Beaver Creek	2.902
100901010104	Lower South Tongue River	2.762
100800160101	Little Big Horn River-Wagon Box Creek	2.312
100800100102	Shell Creek-Granite Creek	1.981
100902050101	Upper North Fork Crazy Women Creek	1.635
100901010103	Upper Tongue River	0.985
100800080603	Paint Rock Creek-South Paint Rock Creek	0.895
100800160102	Dry Fork Little Big Horn River	0.872
100800080405	Upper Canyon Creek	0.758
100800100309	Crystal Creek	0.518
100800080404	Leigh Creek	0.504
100902050102	Middle North Fork Crazy Women Creek	0.407
100800100604	Trout Creek	0.396
100902050106	Up. Middle Fork Crazy Women Creek	0.385
100901010101	North Tongue River	0.384

6th Level HUB Code	6th Level HUB Name	Stream length (miles)
100800100107	Horse Creek	0.382
100800080402	East Tensleep Creek	0.382
100800100305	Upper Bear Creek	0.361
100901010203	West Fork Big Goose Creek	0.296
100902050103	Muddy Creek	0.267
100902060104	Clear Creek-Grommund Creek	0.255
100902060201	North Rock Creek	0.241
100901010202	Lower East Fork Big Goose Creek	0.237
100901010102	Fool Creek	0.234
100901010105	Tongue River-Sheep Creek	0.229
100902060101	South Clear Creek	0.221
100800100204	Lower Beaver Creek	0.217
100902010301	Upper North Fork Powder River	0.217
100902060301	South Piney Creek	0.211
100800100101	Shell Creek-Willett Creek	0.204
100800080502	Brockenback Creek	0.200
100800080403	Lower Tensleep Creek	0.187
100800100105	White Creek	0.173
100901010109	Upper Quartz Creek	0.170
100902060103	Seven Brothers Creek	0.163
100800160108	East Pass Creek	0.158
100800100401	Five Springs Creek	0.155
100800080606	Lower Medicine Lodge Creek	0.138
100901010107	Little Tongue River	0.113
100902060107	French Creek	0.104
100901010204	Upper Big Goose Creek	0.097
100902060102	Middle Clear Creek	0.096
100902050107	Poison Creek	0.096
100901010106	Tongue River-Columbus Creek	0.090
100800100106	Trapper Creek	0.079
100800100104	Shell Creek-Cottonwood Creek	0.079
100800080605	Upper Medicine Lodge Creek	0.064
100901010206	Upper Little Goose Creek	0.063
100800080401	Upper Tensleep Creek	0.055
100800100402	Big Horn River-Willow Creek	0.026
100800160107	West Pass Creek	0.024
100902060302	Kearny Creek	0.018
100800100103	Cedar Creek	0.008

<u>Reach/Site Scale</u>

Inventory and monitoring at the reach/site scale is important to understand how past removal and future recolonization of beaver will affect aquatic, riparian, and wetland resources in the Forest.

Beavers are rightly considered ecosystem engineers, capable of drastically modifying the physical structure of their preferred habitats, and consequently influencing the ecological processes occurring in and around these habitats. Thus, any change in their abundance or distribution will likely produce major habitat changes at a variety of scales. Specific questions related to changes in beaver populations are, but are not limited to:

1. Is past beaver removal or the prospect of beaver recolonization likely to result in:
   a. Altered hydrology (e.g., increased water table, increased water retention)?
   b. Changes in water quality (e.g., temperature, clarity)?
   c. Changes in sediment yield (e.g., sediment retention in recent ponds or sediment release in senescent ponds)?
   d. Channel alteration (e.g., changes in channel profile, decreased water velocity)?
   e. Direct changes to aquatic, riparian, and wetlands habitat (e.g., loss or creation of pools and wetlands, removal of riparian vegetation)?
2. What is the present distribution of beaver (at both landscape and management scales)?
3. Are particular locations amendable to reintroduction or translocation of beaver?
4. How is beaver distribution likely to affect the abundance of other aquatic or wetland fauna (e.g., waterfowl, amphibians, and fish)?

Information Needs

A major information need is to establish the distribution and abundance of beaver in the Forest, as their presence will likely result in major changes to physical habitat at the reach/site scale. Another major challenge will be to validate that the 'suitable' habitat criteria is correlated to presence or colonization of beaver. A list of specific measurements that can be made at the reach/site scale include:

1. Presence or absence of beaver.
2. Age and condition of current beaver structures (e.g., presently maintained or senescent dams).
3. Area of beaver ponds and associated wetland habitat.
4. Thermal regime in stream reaches with beaver versus without beaver.
5. Abundance and diversity of fish and amphibian fauna in sites with beaver versus without beaver.

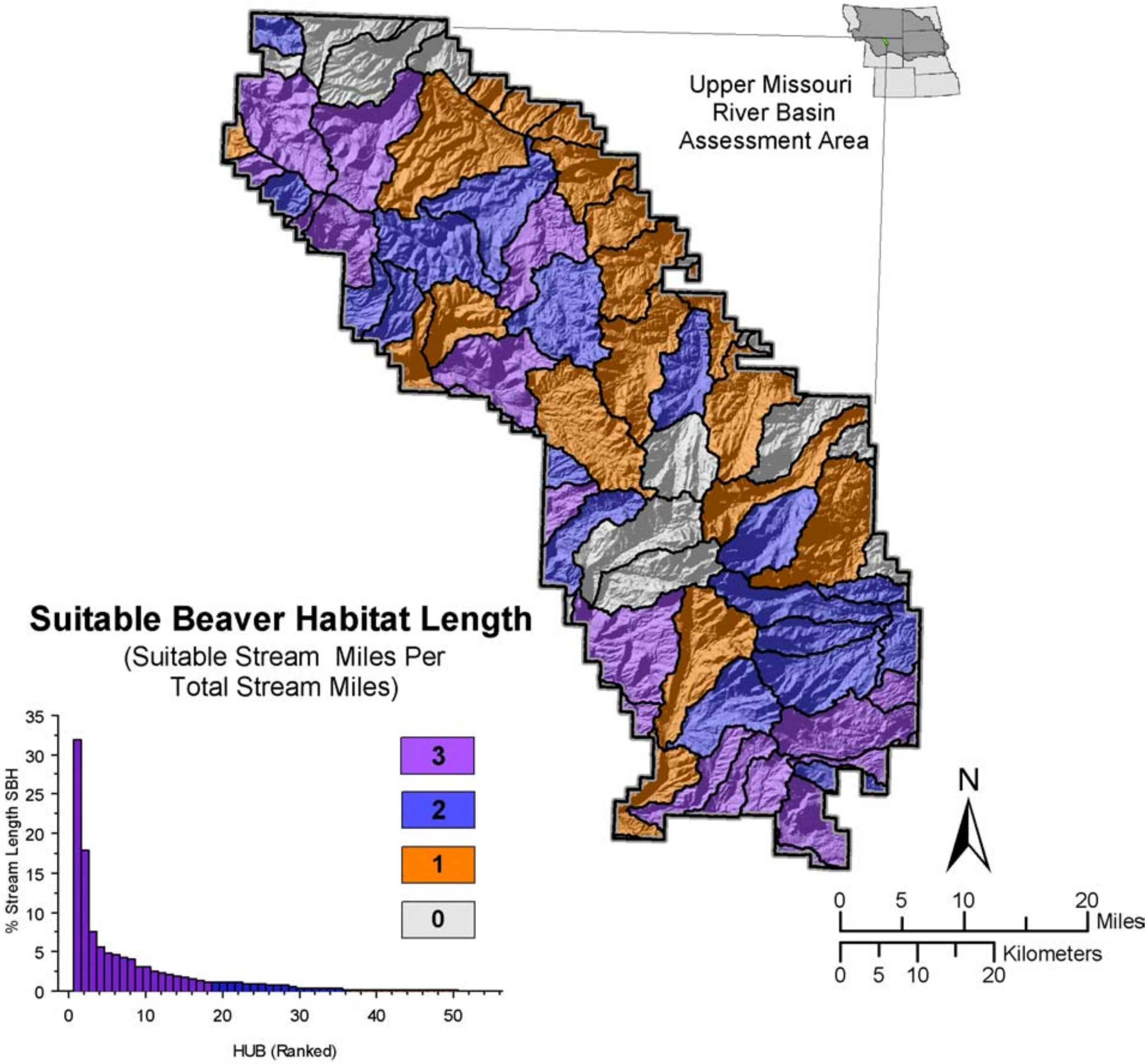

Figure 5.9. Percent of stream length in Bighorn National Forest that is suitable beaver habitat per 6th level HUB inside or intersecting the Forest. See Table 5.4 for actual length of suitable beaver habitat (miles) per 6th level HUB.

Management Implications and Relationship to Ecological Drivers

Beavers have a natural predisposition for low gradient stream channels and wetlands. The cluster analysis revealed that there are relatively few 6th level HUBs with the characteristics required for abundant beaver populations (fig. 5.9).

From a wetland perspective, Cluster 1w contains the highest percentage of glaciated valleys, and resulting wetlands. The clusters surrounding this high elevation area also contain a noticeable percentage of glaciated valleys (>4%). These clusters, associated with the Cloud Peak area of the Bighorn National Forest would be expected to have the biggest influence from beavers, from a wetlands perspective.

From a stream/riparian cluster perspective, Clusters 2r, 3r, and 6r exhibit the highest percentage of low gradient stream channels. Most of these HUBs intersect the Bighorn National Forest boundary, and may be influenced considerably by areas outside of the National Forest boundary (especially Cluster 6r. There is relatively little area available for highly suitable beaver habitat in the Bighorn National Forest, which is probably true for most Rocky Mountain streams. However, beavers have been well adapted to utilize the available habitat and historically proliferated throughout the region (Wohl 2001). Cluster analysis results indicating relatively high percentage of low gradient stream channels in mid to high elevation areas would probably be most conducive to beaver populations.

In order to manage for beaver populations, focus could be made on the 6th level HUBs with the highest suitability values. While beaver populations appear to be expanding somewhat in the Rocky Mountains after almost becoming extinct, they are still restricted by lack of adequate habitat and migration barriers. If habitat conditions were made available in these identified watersheds and possible reintroductions were conducted, a healthy "core" population could be created which would expand into less desirable locations. No doubt there would be some of the management problems associated with beavers and infrastructure located in valley bottom locations. However, the gain in riparian and wetland plant and animal communities, recreational viewing and fishing activities and sorting and maintenance of sediment in stream channels would be highly beneficial to the Bighorn National Forest.

Chapter 6
Mineral Extraction Category

Key Findings

1. At the landscape scale, mineral extraction is far higher outside of the Bighorn National Forest boundary than within the Forest.
2. Most mining sites within the Forest are limited to historic prospect sites.

Influence of Hardrock and Placer Mining

Basin Scale

Prospectors in the late 19th and 20th centuries searched most western US states for valuable ore bodies and placer deposits of gold, silver, and other precious minerals. In the Big Horn Mountains these efforts proved largely unsuccessful (Murray 1980). To date only a handful of prospects and largely nominal claims have been made within the boundaries of the Bighorn National Forest. However, recent demand for non-precious minerals has led to discovery and development of clay, coal, gypsum, sand, gravel, uranium, and building stone deposits or quarries near the Big Horn Mountains. Nearly all of this recent activity has occurred outside Bighorn National Forest boundary in the sedimentary plains along and beyond the mountains front.

Overall, the impact of mining in the Big Horn Mountains on local and downstream systems is limited because of minimal activity in the Forest, which contains the headwaters for the Bighorn, Powder, and Tongue Rivers.

Landscape Scale

Trends in economics, environmental regulations, and land ownership tend to dictate the scope of mining activities (e.g., operations, sites, prospects, claims) on a regional setting. New discoveries and the closing of unprofitable mines also factor into these patterns. Such complexity makes it difficult to precisely characterize the mining activity in a given area, even though the ecological effects of these activities are apparent and quantifiable.

Records describing the historical mining activities in the Big Horn Mountains are rare or non-existent. The U.S. Geological Survey provides three important data sources that approximate historic and current mining activity in the Big Horn Mountains and the region. These include: the active mineral sites/operations database ('active sites database'; U.S. Geological Survey 1998); the minerals availability system database (Causey 1998); and mining claim density plots (Hyndman and Campbell, 1999). These databases provide information on the spatial and temporal distribution of mining activities and what type of mineral is or was being extracted (e.g., commodity type), but they do not describe impacts on aquatic, riparian, and wetland resources. Characterizing these impacts thus requires site-specific measurements.

The active sites database provides a useful snapshot of the current minerals development setting. This database identifies three active bentonite (a clay-type mineral) mines within the assessment area, and five additional mines (two each bentonite and lime, one gypsum) just outside the assessment area. These latter five mines indicate the importance of sedimentary deposits at the margins of the Big Horn Mountains. The database did not identify any active mines within the boundaries of the Bighorn National Forest.

The minerals availability system (MAS) database provides a temporally comprehensive view of mining activity, and shows 762 mine sites within the Bighorn assessment area (fig. 6.1). These 762 sites can be categorized in four classes based on their presumed level of activity. These classes are:

1. *Historic* – indicating active mineral development in the past;
2. *Prospect* – site with prospecting but no development;
3. *Recent* – indicating active development currently or at least recently; and
4. *Unknown* – indicating the possibility of either prospecting and/or development.

Under this classification scheme, nearly 70% are considered historic or inactive, 20% are unknown, 7% are recent or currently active, and the remaining 3% are prospect sites.

Spatial characterization of the 762 MAS sites show they are all located outside the boundaries of the Bighorn National Forest (fig. 6.1). The relatively small number of sites in the Forest illustrates that both local and overall mineral development potential is less significant in this Forest than in other western National Forests. The comparatively high number of sites outside the Forest boundaries (compared with inside) reflects an increase in both readily exploited deposits and local demand. For example, highly valued deposits of clay, coal, gypsum, and uranium are found in the sedimentary terrain adjacent to the Big Horn Mountains Lower-valued deposits, such as sand and gravel, tend to be developed in concert with demand for road building materials or general construction projects.

The 762 sites can also be classified into 28 'commodity categories' based on the most important mineral extracted from that mine. Six of these twenty-eight commodity categories stand out for the Bighorn assessment area: clay, coal, gypsum, sand and gravel, stone, and uranium (table 6.2). These six comprise over 91% of the total sites (e.g., 694 of 762). Many of the remaining 68 sites, classified as 'OTHER' in Table 6.2, are undeveloped prospects having no current or historic production and thus have minimal disturbance associated with them. Table 6.2, lists these 68 sites by commodity classes listed in Table 6.1.

Table 6.1. Principal commodities for the 762 minerals sites in the aquatic, riparian, and wetland assessment area. Source: U.S. Geological Survey, 1997 Mineral Availability System Database (Causey, 1998). Clay, coal, gypsum, sand & gravel and uranium constitute over 91 percent of the sites.

Commodity	Count	Percent of Total
CLAY	161	21.1
COAL	206	27.0
GYPSUM	88	11.6
SAND & GRAVEL	77	10.1
STONE	16	2.1
URANIUM	146	19.2
OTHER	68	8.9
Total	762	100.00

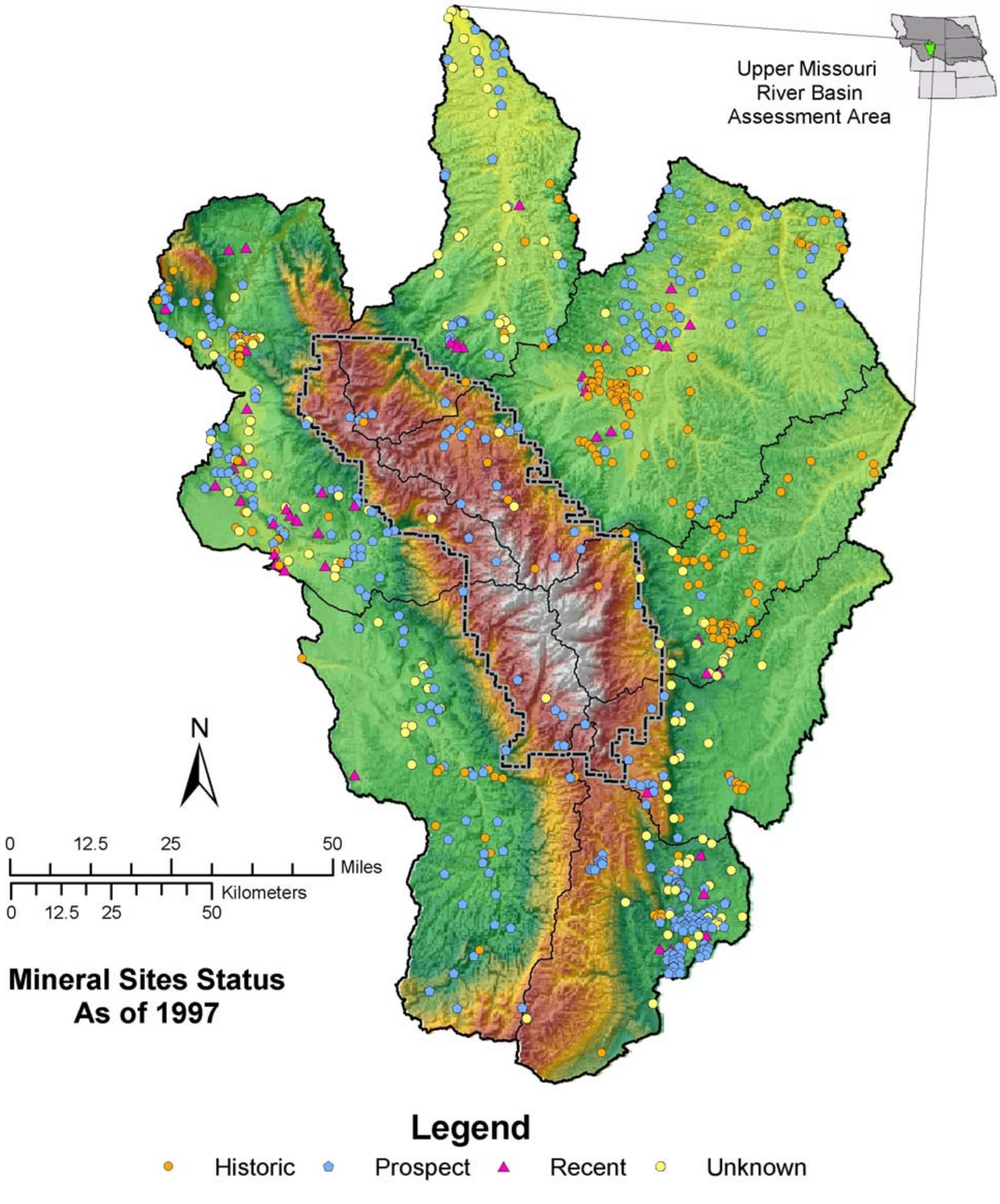

Figure 6.1. Distribution of mine sites at the landscape scale. See text for description of legend categories. Source: U.S. Geological Survey, Minerals Availability System, 1997 (Causey 1998). Note: in the assessment the 4th level HUB 'Prospect's are lumped into the 'Historic' category while 'Unknown' are lumped into the 'Recent' category.

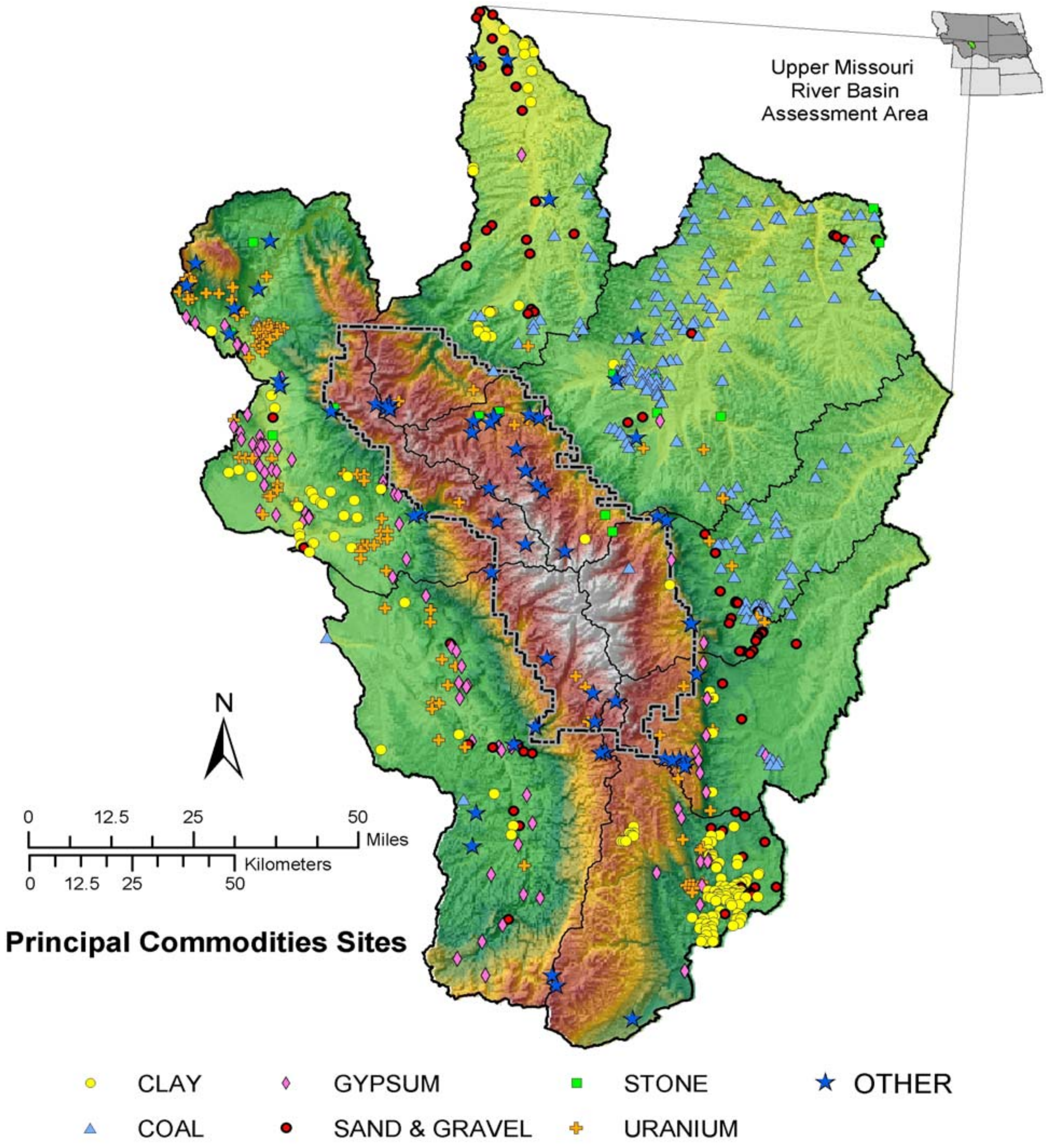

Figure 6.2. Mineral sites for principal commodities at the landscape scale. Source: U.S. Geological Survey, Minerals Availability System, 1997 (Causey 1998). Those sites classified as "OTHER" are largely prospects and are summarized in Table 6.2.

Table 6.2. Sixty-eight of the 762 minerals sites at the landscape scale are classified as "OTHER" in both Table 6.1 and Figure 6.2. Here, these sixty-eight are listed by commodity. Most are historic prospects and they typically represent the search for minerals rather than their development. Source: U.S. Geological Survey, 1997 Mineral Availability System Database (Causey 1998).

Commodity	Count	Percent of Total
ASBESTOS	1	0.13
CALCIUM	5	0.66
COPPER	7	0.92
GEMSTONE	3	0.39
GOLD	9	1.18
IRON	9	1.18
LEAD	1	0.13
MAGNESIUM	4	0.52
MANGANESE	5	0.66
NICKEL	1	0.13
NITROGEN	1	0.13
PETROLEUM	2	0.26
POTASH	1	0.13
PUMICE	6	0.79
SILICON	1	0.13
TALC	2	0.26
THORIUM	2	0.26
TITANIUM	1	0.13
TUNGSTEN	4	0.52
VANADIUM	1	0.13
VERMICULITE	1	0.13
UNKNOWN	1	0.13
Total	68	8.92

In general, both the historic and recent mineral activities in the landscape fall within site distributions that reflect the geologic setting and geologic pattern. Table 6.3 shows that of 762 sites, nearly 75 percent may be classified as historic. Of these 558 sites, 91 percent are located outside of the Bighorn National Forest leaving just 9 percent within the Forest. Conversely, about 25 percent of the 762 sites are classified as recent. Echoing the historic distributions, 97 percent of the recent sites fall outside of the Forest. In both cases, the distributions show that most mineral activity is concentrated outside the Forest in the sedimentary formations surrounding the Big Horn Mountains.

Table 6.3. Historic and recent mining sites relative to the Bighorn National Forest. From U.S. Geological Survey, 1997 Mineral Availability System (MAS) database (Causey 1998). Note: the provenance for *'Prospect and Unknown'* is not clear in the source data. Here, 'Historic' includes also 'Prospects' and 'Recent' includes 'Unknown'.

	Historic		Recent		
4th Level HUB Name	Inside BNF	Outside BNF	Inside BNF	Outside BNF	Total
Nowood River	7	51	1	15	74
Big Horn Reservoir	4	106	3	72	185
Little Big Horn River	7	35	0	31	73
Upper Tongue River	22	139	2	13	176
Middle Fork Powder R.	1	100	0	30	131
Crazy Woman Creek	1	24	0	20	45
Clear Creek	5	56	0	17	78
Total	47	511	6	198	762

Management Scale

Density of mining sites was zero or very low in approximately half of the 74 6th level HUBs intersecting the Forest (fig. 6.3). Many of the HUBs are influenced to a large degree by minerals activity outside of the National Forest boundary (e.g. recent gypsum, clay, sand and gravel sites). And, in the remainder (e.g., HUBs and sites within the Forest boundary), concerns are driven mostly by historic prospecting and minor development. These relationships are amplified by display of site counts by 6th level HUB by historic and recent time periods in Figures 6.3 and 6.4 respectively.

In other words, prospecting and mining activity in the Big Horn Mountains was greater historically than in recent times (figs. 6.4 and 6.5). Currently, there is more exploration and activity in the watersheds beyond the mountains and largely beyond the boundaries of the National Forest (fig. 6.5).

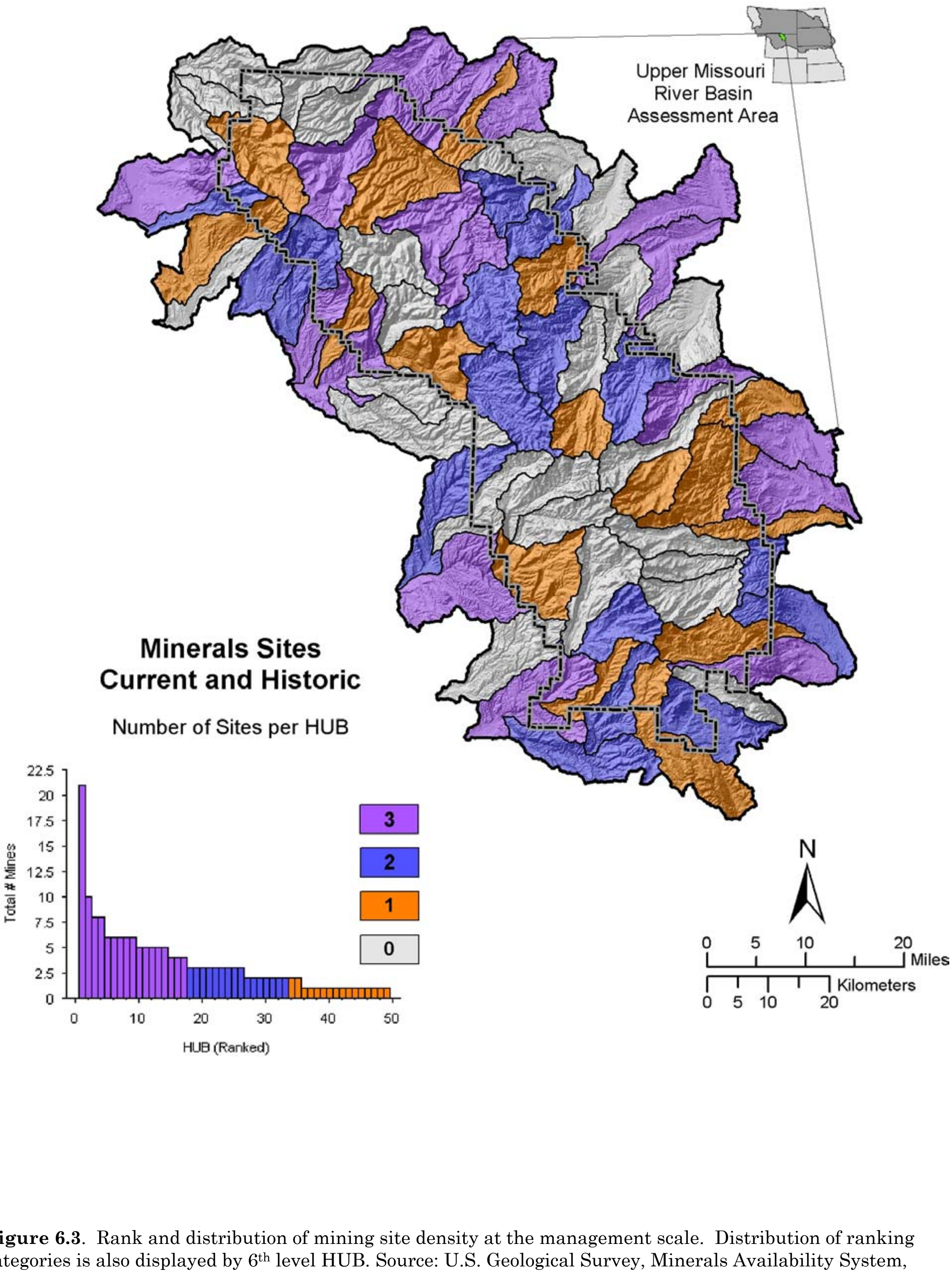

Figure 6.3. Rank and distribution of mining site density at the management scale. Distribution of ranking categories is also displayed by 6th level HUB. Source: U.S. Geological Survey, Minerals Availability System, 1997 (Causey 1998).

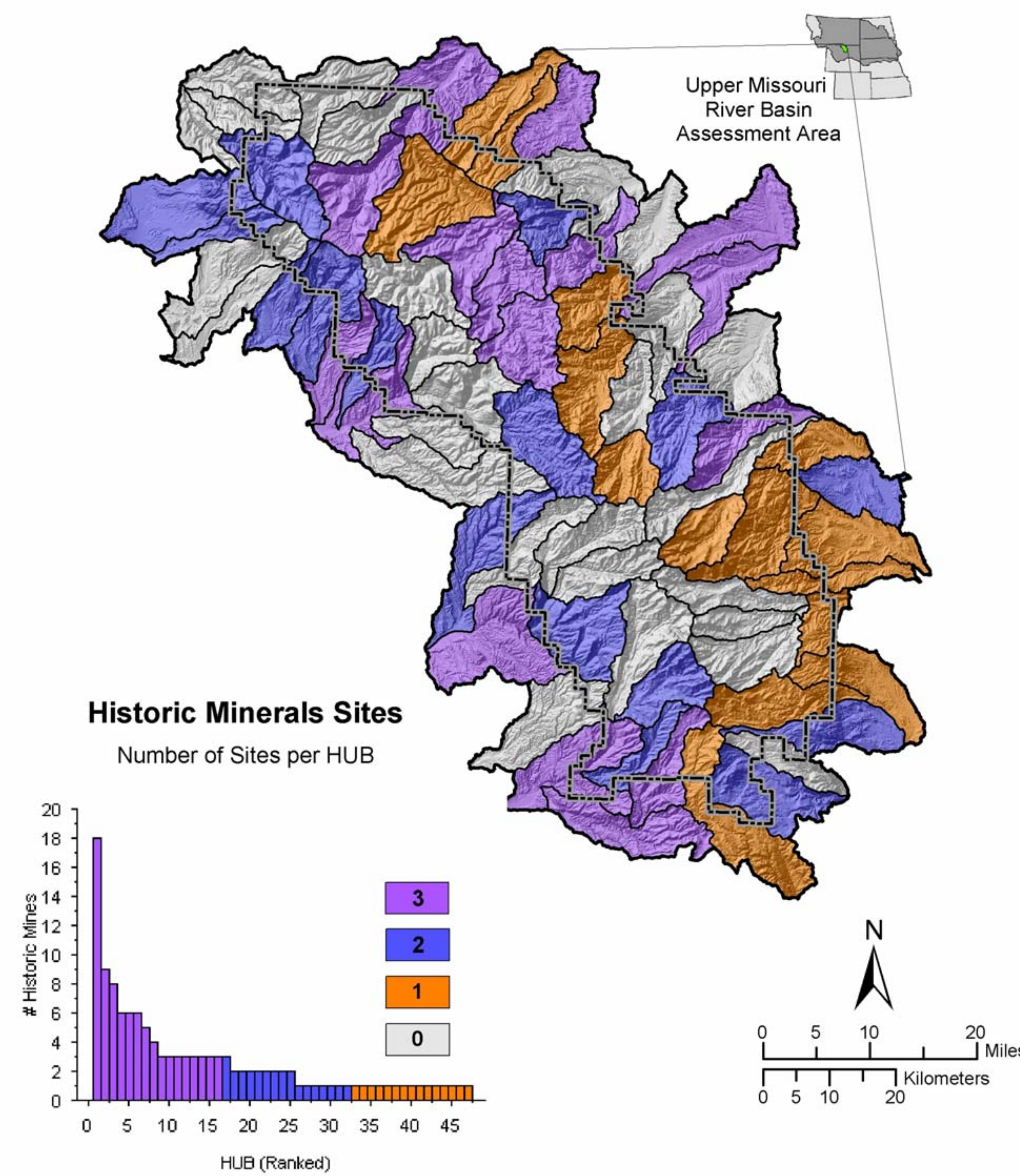

Figure 6.4. Rank and distribution of the density of historic mines at the management scale. "Historic" sites include both the "historic" and "prospect" sites shown in Figure 6.1. Source: U.S. Geological Survey, Minerals Availability System, 1997 (Causey 1998).

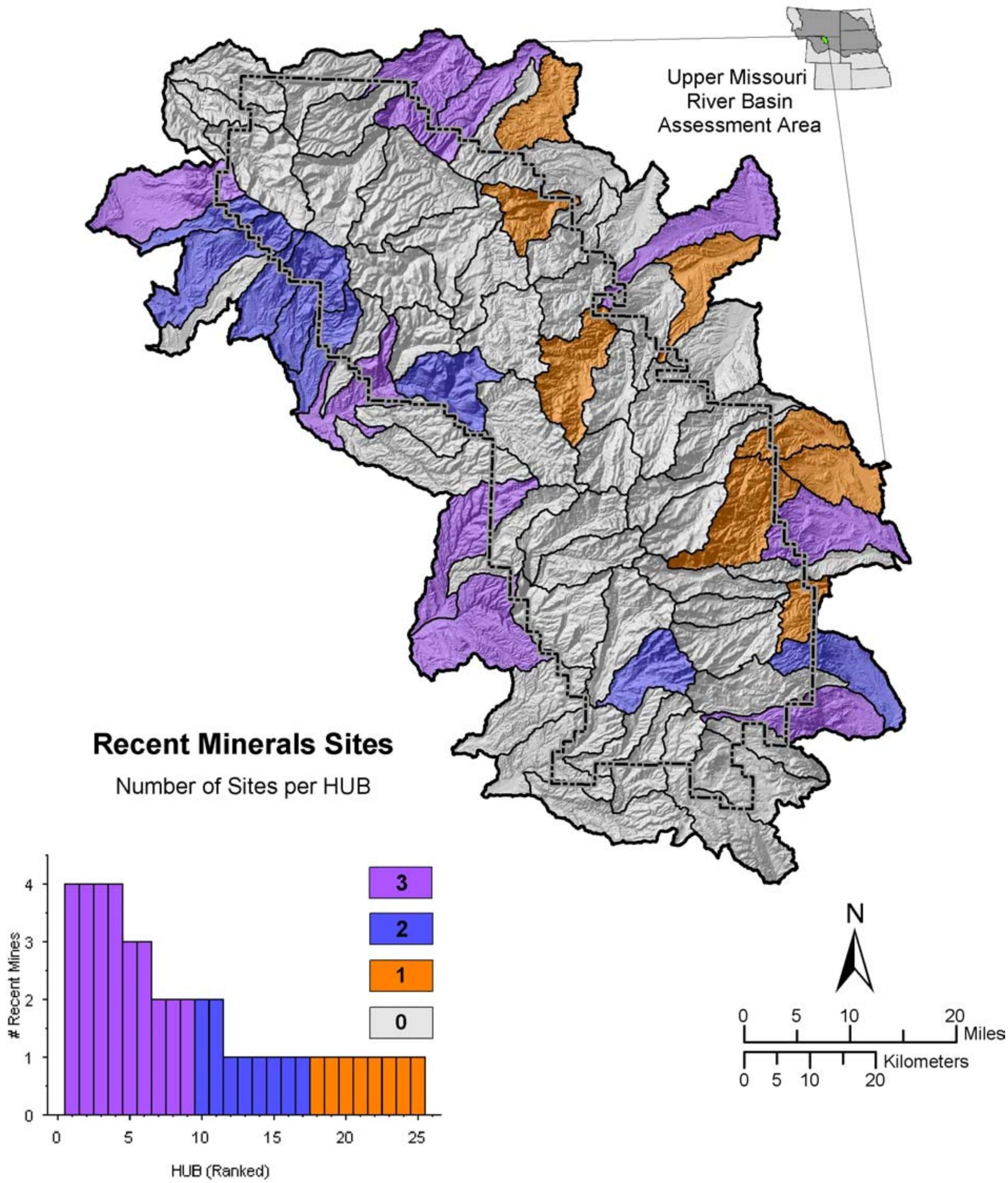

Figure 6.5. Rank and distribution of the density of recent mines at the management scale. “Recent” sites include both the “recent” or “unknown” sites shown in Figure 6.1. Source: U.S. Geological Survey, Minerals Availability System, 1997 (Causey 1998).

Reach/Site Scale

Mining influences and impacts generally depend on the specific type of mining activity. For example, gravel mining and suction dredging have directly affects on aquatic, riparian, and wetland resources by removing vegetation removal and disturbing stream substrate. In addition, this type of mining can fill wetland habitat and increased sedimentation in streams. Hardrock mining often does not have the surface disturbance as gravel mining, but can severely impact water quality for significant distances downstream and also in adjacent wetland ecosystems. The first step in addressing influences of mining at the reach/site scale is to identify the type of activity, the types of influences associated with it, and the resources affected.

Specific questions that should be addressed for mining influences on aquatic, riparian, and wetland resources include:

1. What types of activities are being conducted?
2. Are groundwater and/or surface water being influenced?
3. What biological communities are potentially being influenced?
4. What trophic levels (e.g., periphyton, benthic macroinvertebrates) are being affected? What is the best way to monitor changes in population dynamics?
5. How far downstream or in the groundwater are influences being realized?
6. What aquatic, riparian, and wetland habitats are being modified as a result of sedimentation, removal and deposition of soils and bedrock?
7. How is water quality affected, and how do these changes influence life-history characteristics of plants and animals? Are Clean Water Act standards being met?

Information Needs

Locations of active mining operations are found in databases maintained by the Bighorn National Forest and other federal agencies. However, their direct influences on aquatic, riparian, and wetland resources, both currently and from historic activities could be addressed on a more site-specific nature. Determining where areas of potential commercial value (for mining) correspond important aquatic, riparian, and wetland resources will be a key data need.

Management Implications and Relationship to Ecological Drivers

Mineral exploration and extraction does not currently appear to be a significant risk to aquatic, riparian, and wetland resources within the Bighorn National Forest. There are no streams listed as impaired under section 303d of the Clean Water Act, which also indicates that mining effluent is not contaminating downstream reaches. The long lasting effects of mining operations should be considered, if future development is proposed. Some of these impacts are probably irreversible, or are at least extremely expensive, as is the case of effluent treatment operations.

Dredging and gravel mining operations may be identified more often in the future as the population and resulting road development and maintenance increases. While the impact from these activities is not as strong as hard-rock mining, consideration of the impact to aquatic, riparian, and wetland resources should be investigated because many of these mining operations occur in floodplains.

Influence of Energy Development

Oil, gas, and coal development are key components of the Wyoming economy, but these activities have generally been confined to areas outside the boundary of the Bighorn National Forest.

Coal is not an important resource in the Big Horn Mountains (fig. 6.2). The region's developed coal deposits are instead found beyond the mountain front in the adjacent basins, especially to the east. Similarly, oil and gas deposits are also found in the basins adjacent to the Big Horn Mountains.

However, there is some potential for development of oil and gas deposits along the margins of the Big Horn Mountains where overthrust belts of older basement rock over younger sediments may form traps for the accumulation of oil and gas.

Management Implications

Increasing oil and gas prices may spur greater interest in exploring the overthrust belts within the Bighorn National Forest that are most likely to contain petroleum resources. Although the initial phases of oil and gas exploration (e.g., surface mapping) may be fairly benign with respect to aquatic, riparian, and wetland resources, later phases (e.g., drilling or seismic investigations) are more invasive.

Chapter 7
Vegetation Management Category

Key Findings

1. The percentage of clear-cut boundaries (conducted within the last 40 years) within 6th level HUBs ranged from 18% (1 HUB) to 0% (40 HUBs), with the highest concentration being in the southern portion of the BNF. The percentage of valley bottoms within clear-cut boundaries shows similar results.
2. The percentage of wetlands within clear-cut boundaries per 6th level HUB ranged from slightly more than 35% (1 HUB) to 0 (for 30 HUBs).
3. The Clear Creek 4th level HUB exhibits the highest percentage of fire burn in the last 40 years (only 1.9% of the HUB) and the highest percentage of valley bottom burned also (2.8%of the HUB).
4. At the management scale, 34 6th level HUBs do not show any measurable natural fire since 1910. Four HUBs show 25% or more of their area being burned since 1910.
5. The percentage of valley bottoms for each 6th level HUB burned since 1960 ranged from approximately 85% (1 HUB) to 0 (for 54 HUBs). Sixth level HUBs with higher percentages of valley bottoms burned since 1960, in clusters sensitive to erosion, could be considered highly probable for influences still being realized in terms of sedimentation and stream habitat reduction.
6. A total of five 6th level HUBs exhibited more than 10% of their wetland area being burned since 1960.
7. The added effects of anthropogenic influences could dramatically impede the recovery of aquatic, riparian, and wetland resources from fire if they contribute significant amounts of sediment, restrict riparian and wetland vegetation growth, and/or stop movement of species into recovering areas.
8. Historic tie drives were located in the Tongue and Goose Creek watersheds, and are most likely still affecting channel stability and aquatic and riparian habitat where they occur. These areas could be considered for restoration, especially where cluster analysis reveals a high potential for aquatic, riparian, and wetland production.
9. The 6th level HUBs associated with tie drives include a relatively high percentage of the HUBs in the highest category for total acres burned since 1910. These results indicate that there may be a relationship between old tie drives, vegetation regeneration, and subsequent fires.
10. Domestic livestock numbers have decreased since the late 1800s, with increased efforts placed on active management of individual allotments. The influence of early, unregulated grazing is most likely being realized today in riparian areas and wetlands.
11. Today, approximately 83% of the area within the BNF is in active allotments, with only 11% having a moderate to high preference value. Current estimates indicate that 22% of riparian areas meet Land Management Plan objectives, 20% are not meeting objectives, and 58% are of undetermined status.
12. The preference model we used indicates that there is a close correlation between livestock preference and certain riparian and wetland areas within habitat characteristics preferred by livestock.
13. While results are highly variable, there are several 6th level HUBs that have a relatively high percentage of the valley bottoms and wetlands in high density (less than 3 acres per animal unit month (AUM)) grazing allotments.
14. Wild ungulates have increased considerably since 1900, although pre-Euro-American settlement numbers are difficult to estimate.

15. The additive effects analysis indicates that 31 6th level HUBs within or intersecting the BNF boundary have limited or no presence of vegetation management and fire.
16. There were 43 6th level HUBs, which exhibit various levels of all the vegetation management activities, and most are located in the northeastern and southern portions of the BNF.

Influence of Commercial Timber Harvest

Basin Scale

Until the late 1800s, timber harvesting in and around the mountains of the Upper Missouri River Basin was unregulated. Much of the timber harvested then, as now is associated with the mountainous areas of the basin, typically associated with USDA Forest Service administered lands, and to a lesser degree BLM and private land. Timber harvest has occurred in the vicinity of the Bighorn National Forest since the late 1800s, when the U.S. Army was establishing and expanding military forts (Murray 1980). The first sawmill of record, for example, was established on Piney Creek in 1866 to provide lumber for Fort Phil Kearney. Logging continued to increase with Euro-American settlement, and primary uses for the harvested timber included construction of dwellings, fuel for heating and cooking, fence materials for ranchers, railroad ties, and props for coal mine shafts (Murray 1980).

Logging was basically unregulated in the area until the Bighorn Forest Reserve, a precursor to the National Forest, was established in 1897 because of public concerns over future wood supplies. Despite federal management of timber resources on these federal lands, changes in timber harvest tactics may have accelerated impacts on aquatic, riparian, and wetland resources. For example, beginning in the 1960s clearcutting was frequently used to harvest timber, and more roads were being built into the basin to bring the wood to market and support the increasing demand for timber.

Landscape Scale

Much of the commercially valuable timber at the landscape scale or within 4th level HUBs are found on federal lands (e.g., Bighorn National Forest) (table 7.1). Past timber harvest strategies have lead to challenges to silviculture management in later years. For example, timber harvest for railroad ties was a major activity in the Forest at the end of the 19th century. However, tie hacks generally removed larger, 'high value' trees, leaving 'poorer quality' trees to reproduce. Subsequent management often emphasized clearcutting to reverse effects of tie hacking and to increase tree production. These past harvest activities continue to influence present aquatic, riparian, and wetland resources. Trends in clearcut timber harvest per 4th level HUB in the Forest are shown on Table 7.2.

Commercially important timber covers a substantial proportion of Bighorn National Forest, and suitable timber follows criteria outlined in the existing Bighorn National Forest Plan (USDA 1985). For example, the proportion of suitable timber (hereafter, timber) covering the National Forest area within a given 4th level HUB ranged from 0.16-0.68 (e.g., 16-68%), and averaged approximately 0.39 (fig. 7.1). Overall, the total amount of suitable timber found inside 4th level HUBs intersecting Bighorn National Forest is 566.1 mile^2 (362,334 acres) (table 3.38) with 35% of this total coming from a single HUB (HUB 10090101, Upper Tongue River). The density of timber per stream distance ranged from 0.022-0.261 (mean = 0.089, median = 0.052; fig. 7.2), and was greatest in Middle Fork Powder River (HUB: 10090201). The high values for the Middle Fork Powder River reflect the fact this HUB has only a small percentage of its area within the Forest boundary, despite having the lowest total area of timber of any 4th level HUB.

Table 7.1. Area of Bighorn National Forest associated 4th level HUBs with commercially suitable timber (USDA 1985).

4th Level HUB Name and Code	NF Lands (mile²)	Suitable Timber Inside NF (mile²)	Percent of Total HUB Area with Suitable Timber
Big Horn Reservoir 10080010	314.6	59.26	3.3
Nowood River 10080008	328.1	51.84	2.6
Crazy Woman Creek 10090205	98.06	66.87	7.0
Little Big Horn River 10080016	221.5	89.65	6.9
Upper Tongue River 10090101	458.2	200.00	7.9
Middle Fork Powder River 10090201	19.6	10.51	1.1
Clear Creek 10090206	298.2	88.02	7.6
Total	1,738.2	566.15	

Table 7.2. Trends in clearcut timber harvest per 4th level HUB in Bighorn National Forest.

	Clearcut Area (mile²) by Decade					
4th Level HUB Name and Code	**1950s**	**1960s**	**1970s**	**1980s**	**1990s**	**Total**
Nowood River 10080008	0.06	2.29	2.46	1.71	1.39	7.90
Big Horn Reservoir 10080010	1.10	0.10	1.79	3.69	0.00	6.69
Little Big Horn 10080016	0.00	0.00	1.35	1.99	1.29	4.63
Upper Tongue 10090101	0.00	7.60	2.01	0.65	2.59	12.86
Middle Fork Powder 10090201	0.00	1.16	0.01	0.41	0.00	1.58
Clear Creek 10090206	0.38	0.20	0.91	0.99	0.50	2.98
Crazy Woman 10090205	0.12	6.70	6.32	1.22	0.25	14.60
Total	1.66	18.07	14.85	10.65	6.03	51.25

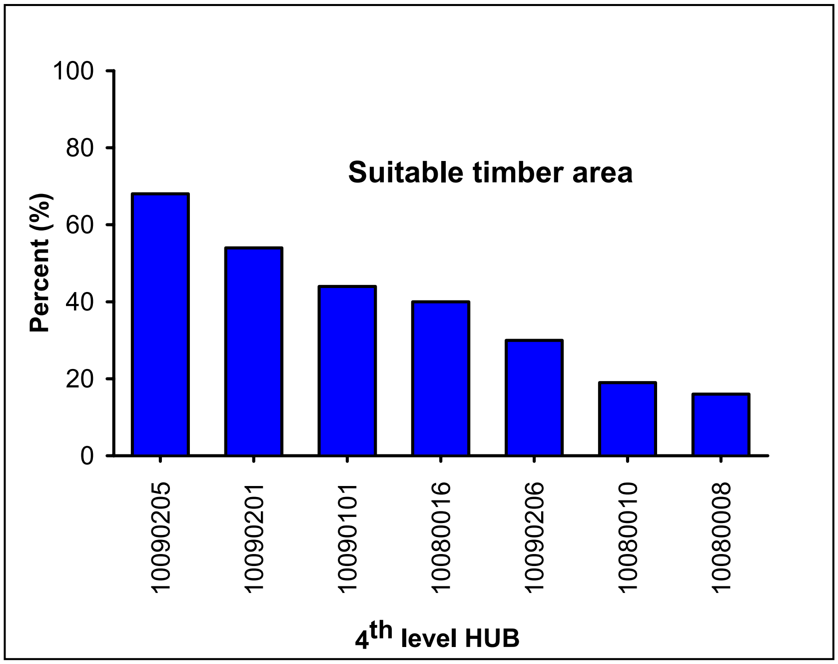

Figure 7.1. Area of suitable timber expressed as a percentage of the Bighorn National Forest area within that 4th level HUB.

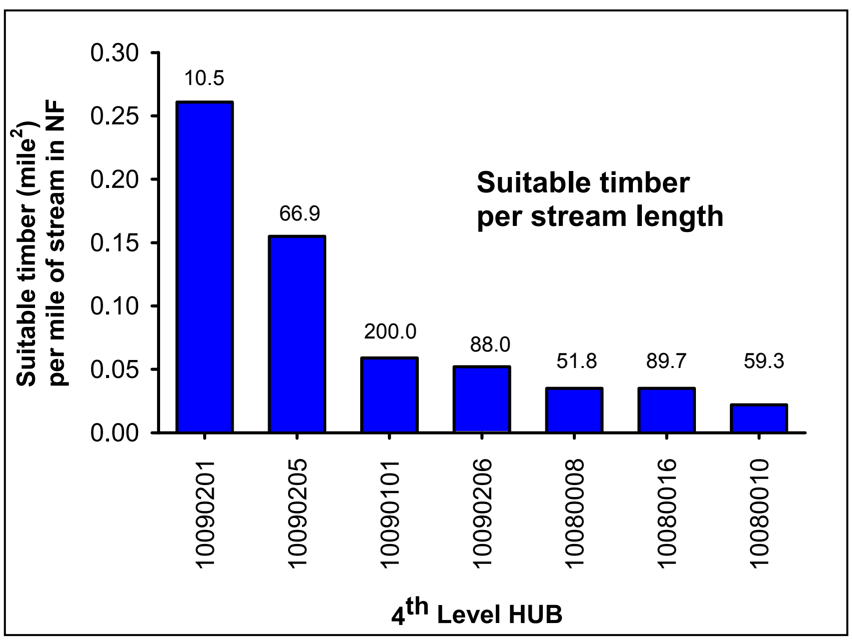

Figure 7.2. Area of suitable timber per mile of stream in Bighorn National Forest per 4th level HUB. Numbers above bars indicate timber area (per mile^2) in a given HUB. Note that order of HUBs along x-axis differs from previous figure.

Commercial timber harvest may continue to be an important land use activity in the Bighorn National Forest, depending upon economic demand and harvest regulations. The Big Horn Mountains represent the area's most substantial timber resources, and would likely be the location of future timber harvest in the region. Furthermore, the position of this timber on the landscape, whereby it is found in the headwaters of the 4th level HUBs, can set the stage for downstream influences in addition to those for areas immediately adjacent to logging sites. Given the myriad of direct and indirect influences timber harvest can have on aquatic, riparian, and wetland resources (Chamberlin et al. 1991), HUBs that have a high amount of commercially suitable timber (e.g., Upper Tongue River) or relatively high amount of timber per stream length (e.g., Middle Fork Powder or Crazy Woman Creek) should be initial targets for assessment. Overall, the biophysical effects of land use practices such as logging are well known, but their extent and significance at larger scales (e.g., basins and sub-basins or regions) are not (Ralph et al. 1994; McIntosh 2000).

Management Scale

At the management scale, the most important questions to ask concerning commercial timber harvest in relation to aquatic, riparian, and wetland resources are: 1) what is the extent of past harvest; 2) where has most of the past timber harvest occurred; and 3) where would future harvest be predicted to occur?

Within the past 40 years, timber harvest has been low to moderate in the Bighorn National Forest, but a number of watersheds have been subjected to relatively extensive harvest. Nearly 50% of the logging during this period has involved clearcutting, a trend that peaked in the 1960s and 70s (figs. 7.3 and 7.4). However, overall timber sale volume on the Bighorn National Forest has decreased from 38 to 3 millions of board feet in the past two decades.

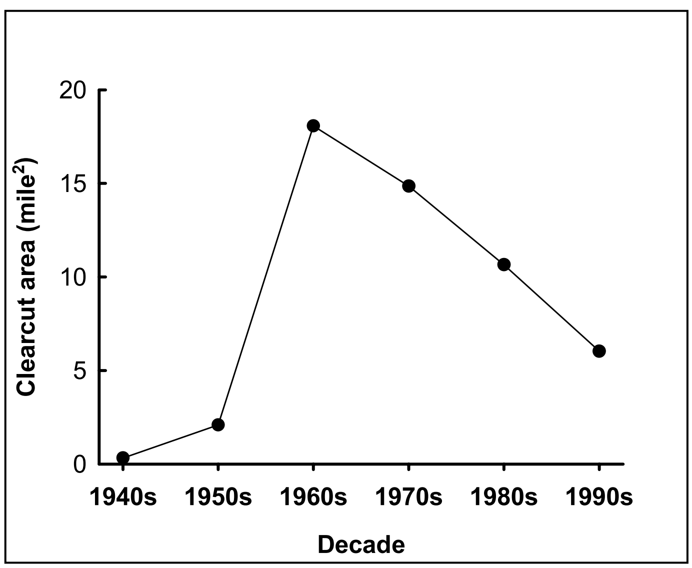

Figure 7.3. Trends in clearcut timber harvest by decade for 6th level HUBs in the Bighorn National Forest.

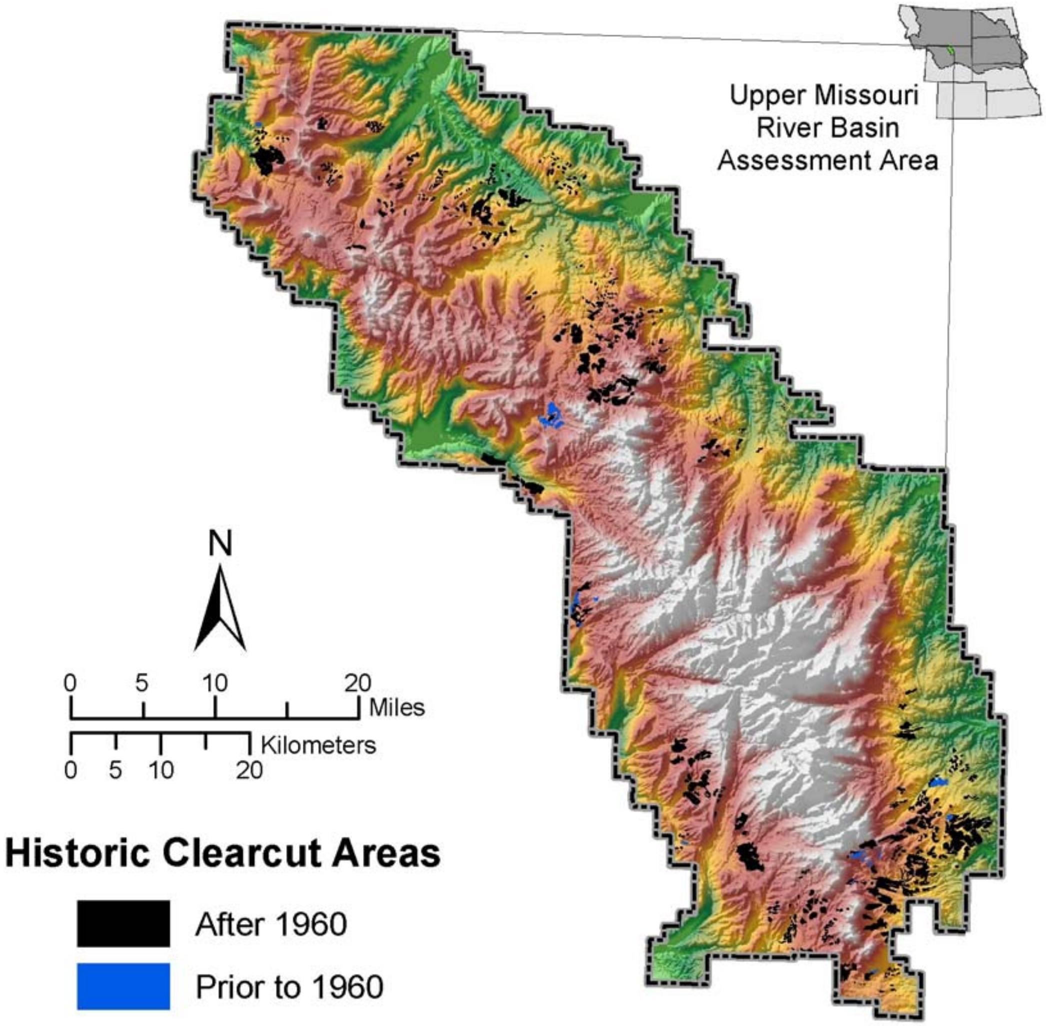

Figure 7.4. Historic clearcut areas shown before and after 1960 in the Bighorn National Forest.

Nearly half (36 of 74 HUBs; fig. 7.5) of the 6th level HUBs intersecting the Forest have been subjected to clearcutting and associated activities, which is generally regarded as the timber harvest strategy most damaging to aquatic, riparian, and wetland resources (Chamberlin et al. 1991). The severity of clearcutting varied widely among these 36 HUBs. For example, up to 18% of the total area in one HUB (e.g., Upper North Fork of Crazy Woman Creek - 100902050101) was clearcut, four HUBs had clearcuts of at least 10% of their area, but the average was around 4% (fig. 7.5). Nowood River HUB: Lower Medicine Lodge Creek (100800080606) has the greatest amount of stream length per clearcut area, and the next four most potentially affected watersheds are within the Crazy Woman Creek HUB (100902050101, -0103, -0106, and -0107; fig. 7.6).

Much of the past clearcut activity has occurred in or near riparian areas. Of the 36

HUBs with measurable clearcutting (fig. 3.85), 34 of these (94%) have had clearcutting in valley bottoms (fig. 7.7). In these 34 HUBs with valley bottom clearcutting, up to 55% of the total clearcut area within that HUB was found in valley bottoms. Up to 17% of the total valley bottom area within a given HUB was clearcut (fig. 7.7), with a Nowood River HUB: Lower Medicine Lodge Creek (100800080606) having the greatest clearcut area in valley bottoms per stream length (fig. 7.8).

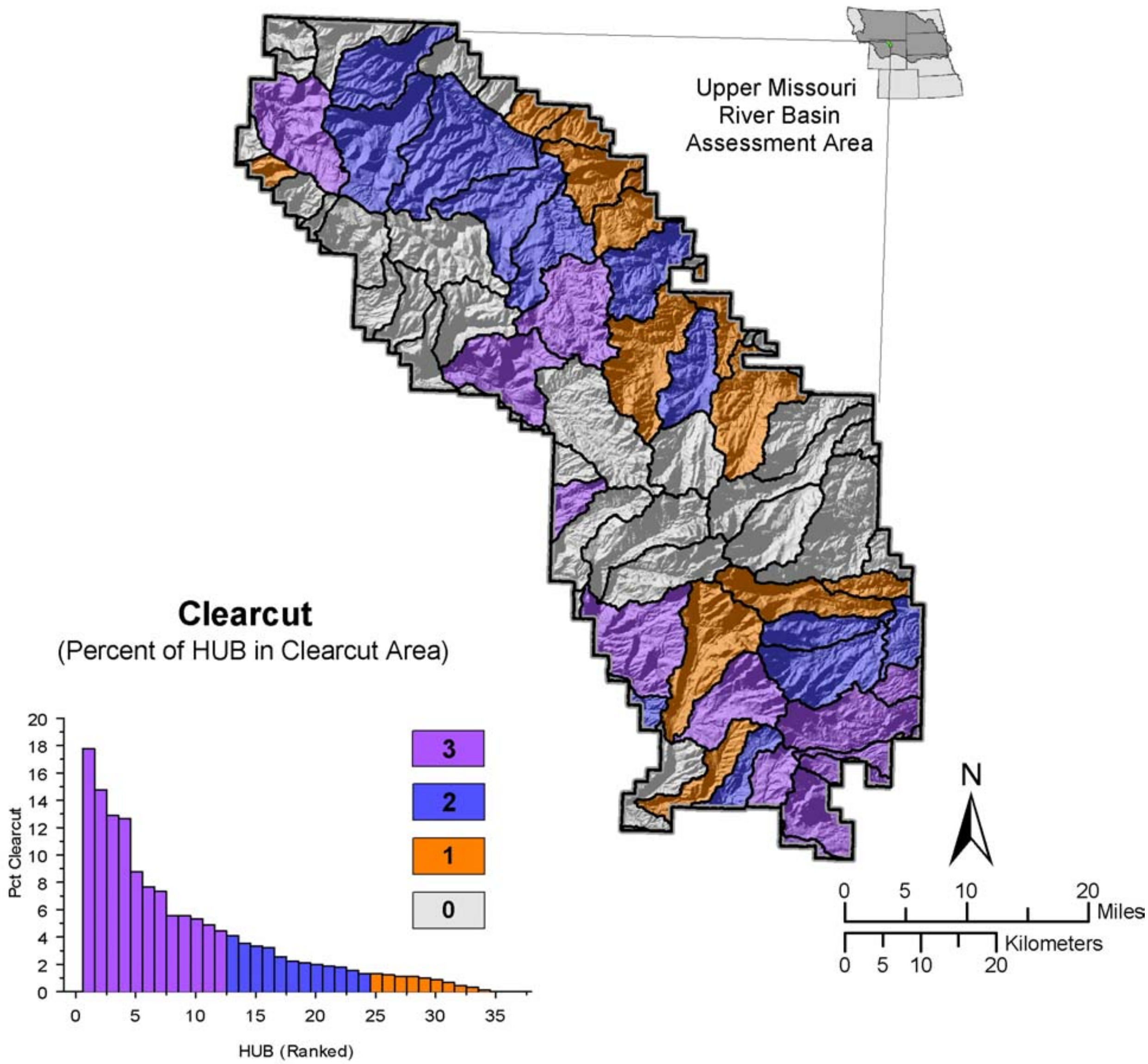

Figure 7.5. Percent of 6th level HUB area clearcut within 40 years (e.g., recent clearcut) in Bighorn National Forest.

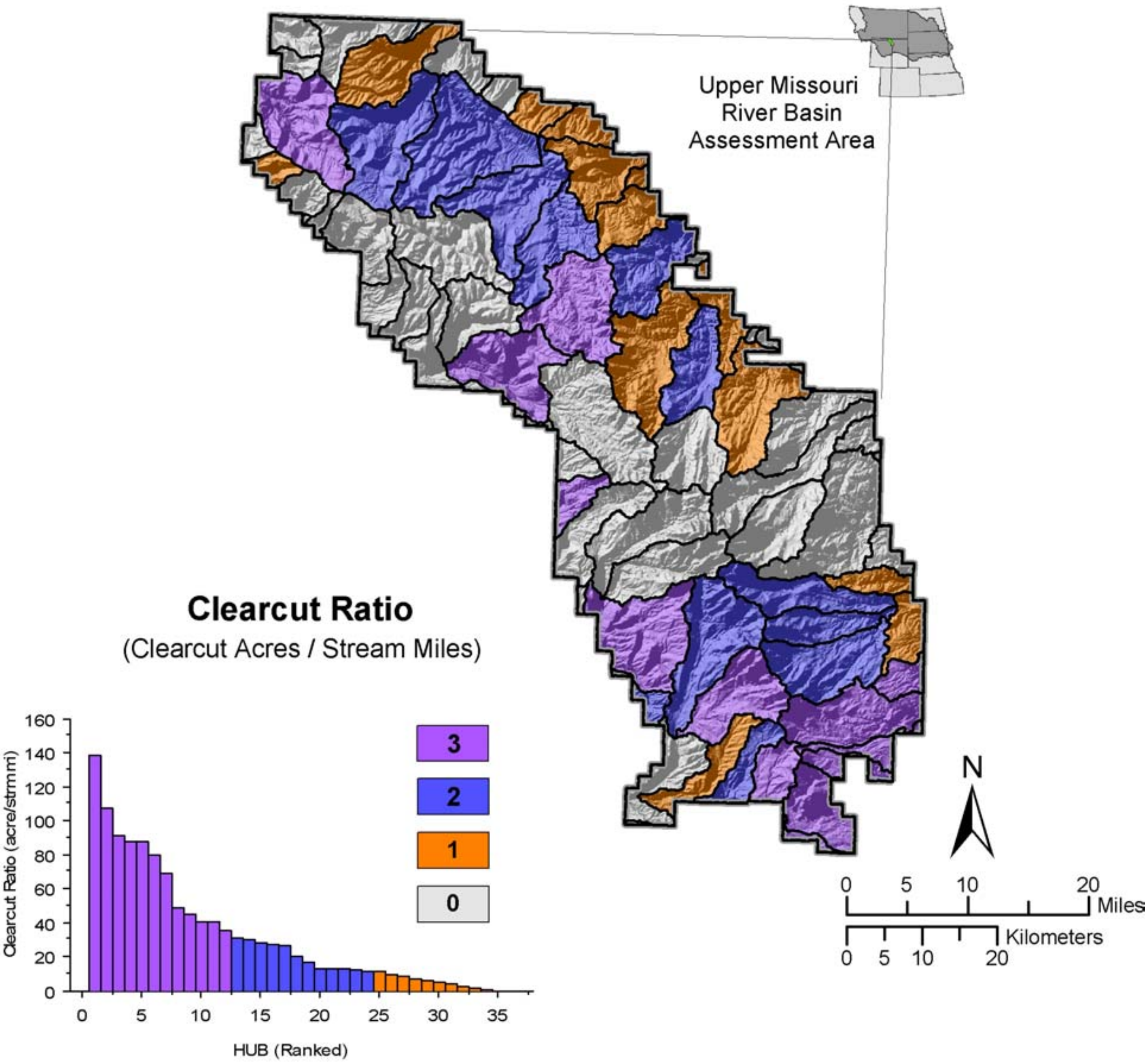

Figure 7.6. Area of recent clearcut per stream mile within 6th level HUBs in Bighorn National Forest.

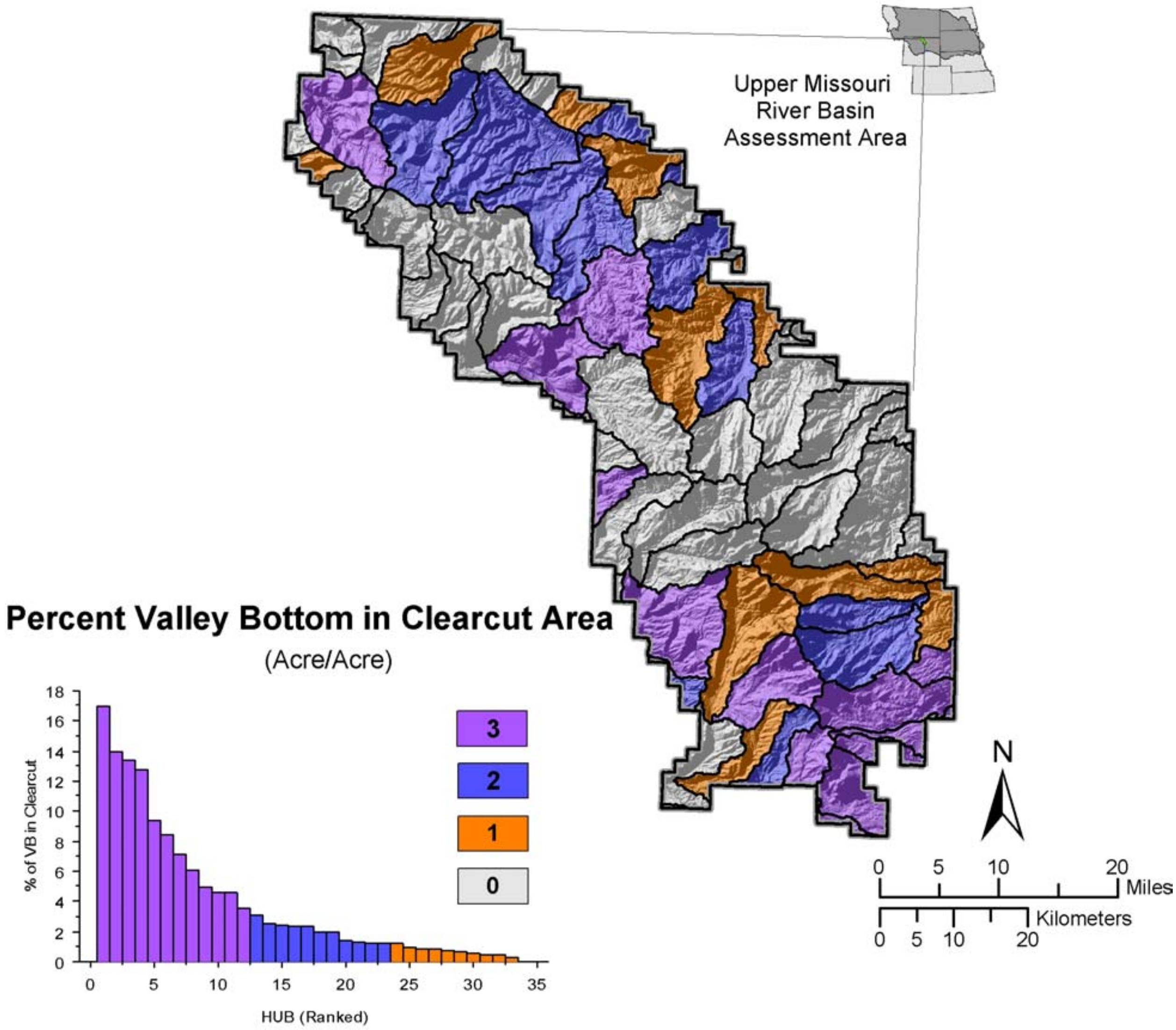

Figure 7.7. Percentage of valley bottom area of 6th level HUBs in Bighorn National Forest within clearcut timber sale boundaries.

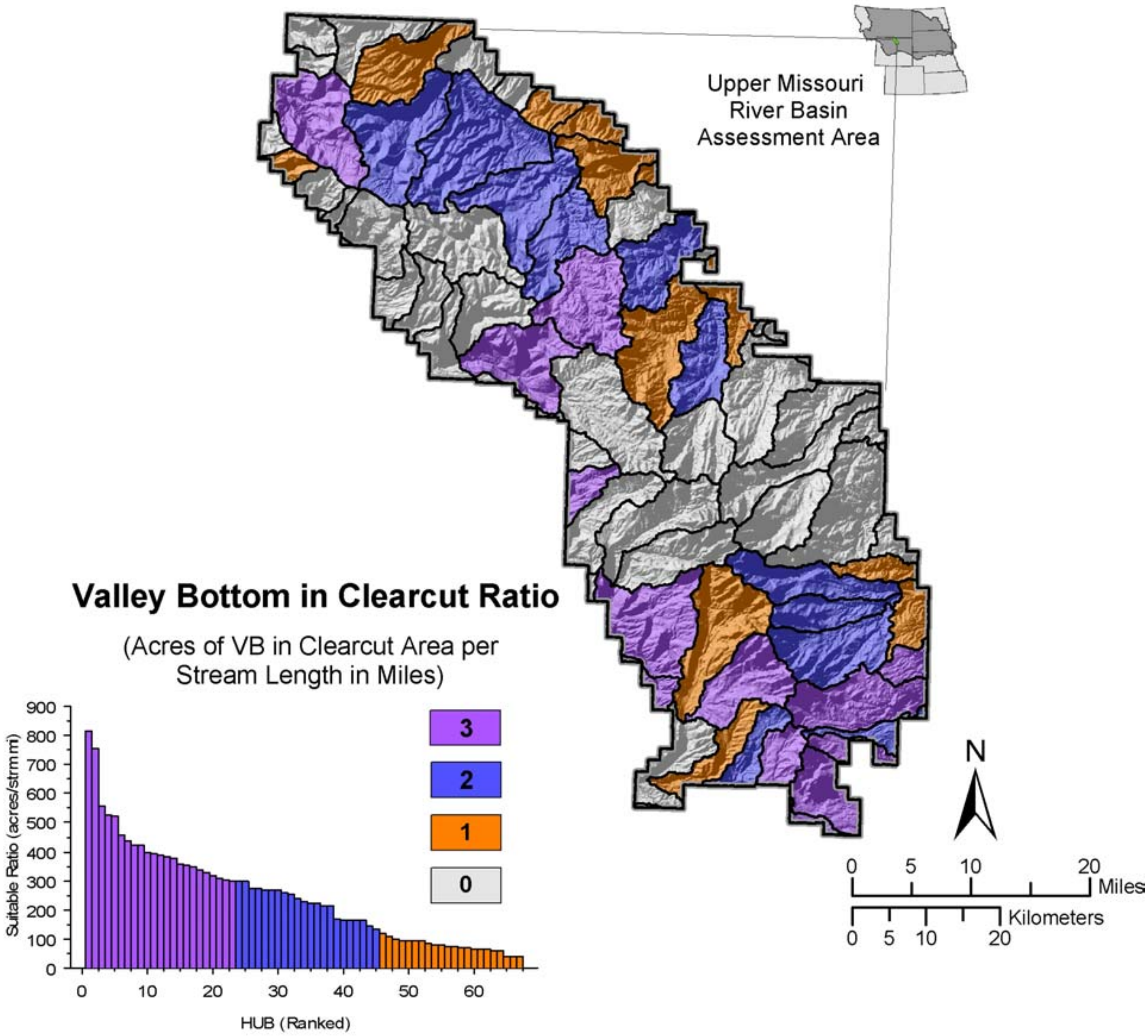

Figure 7.8. Area of valley bottom within the boundary of the clearcut timber sale per stream length in 6th level HUBs in Bighorn National Forest.

Clearcutting in HUBs with low gradient stream reaches does not appear to be widespread. Only four of 74 Forest HUBs have had any recent clearcutting where low gradient stream reaches were present, and these clearcut areas totaled only 0.0053 mile^2 (3.4 acres). However, low gradient stream habitats may be rare in these watersheds, and may contain pools and pool-riffle transitions which can be critical rearing and spawning habitats for resident fishes (Reiser and Wesche 1977; Bisson et al. 1992). In the Rocky Mountains, low-gradient stream reaches also tend to have higher biomass of native cutthroat trout compared to higher-gradient reaches (Herger et al. 1996). Thus, despite the small aerial extent of this clearcutting in these specific locations, the effects on aquatic biota may still be considerable. Further monitoring should identify the use and importance of these low gradient stream reaches to the population dynamics of resident fishes. Overall, this analysis demonstrates the importance of recognizing the extent that timber harvest occurs near habitats, like riparian, valley bottoms, or low-gradient stream reaches, which is closely linked with the integrity of aquatic, riparian, and wetland resources. These sites may be where the 'ghosts of clearcut past' may continue to influence aquatic, riparian, and wetland resources.

The current extent of timber suitable for commercial harvest suggests that logging may continue to be a significant land use activity in the Bighorn National Forest. Most of the timber in the high-elevation stands consist of pure lodgepole pine, Engelmann spruce and subalpine fir. At lower elevations, some Douglas fir has been logged, but very little cutting has occurred in the limber pine and ponderosa pine stands. Over 93% (69 of 74) of 6th level HUBs have 'suitable' timber (fig. 7.9), and almost all of these (e.g., 67) have some measurable stream habitat (fig. 7.10). Three of the top four top watersheds in percent of suitable timber area are in the Crazy Woman Creek HUB (100902050101, -0102, and -0106), having more than two-thirds of their area covered with suitable timber (fig. 7.9). Crazy Woman Creek HUB: Upper Middle Fork Crazy Women Creek (100902050106) and Nowood River HUB: Brockenback Creek (100800080502) both have values of suitable timber area per stream length of greater than 1.0, thus may be watersheds where future timber harvest can influence aquatic, riparian, and wetland resources (fig. 7.10).

Identifying watersheds where future timber harvest may occur, in relation to the presence of valuable ecological assets, such as populations of sensitive Yellowstone cutthroat trout, will be important to plan for sustainability of aquatic, riparian, and wetland resources. Ultimately, management emphasis and land allocation within a watershed will be essential to the integrity and sustainability of aquatic ecosystems (McIntosh et al. 2000).

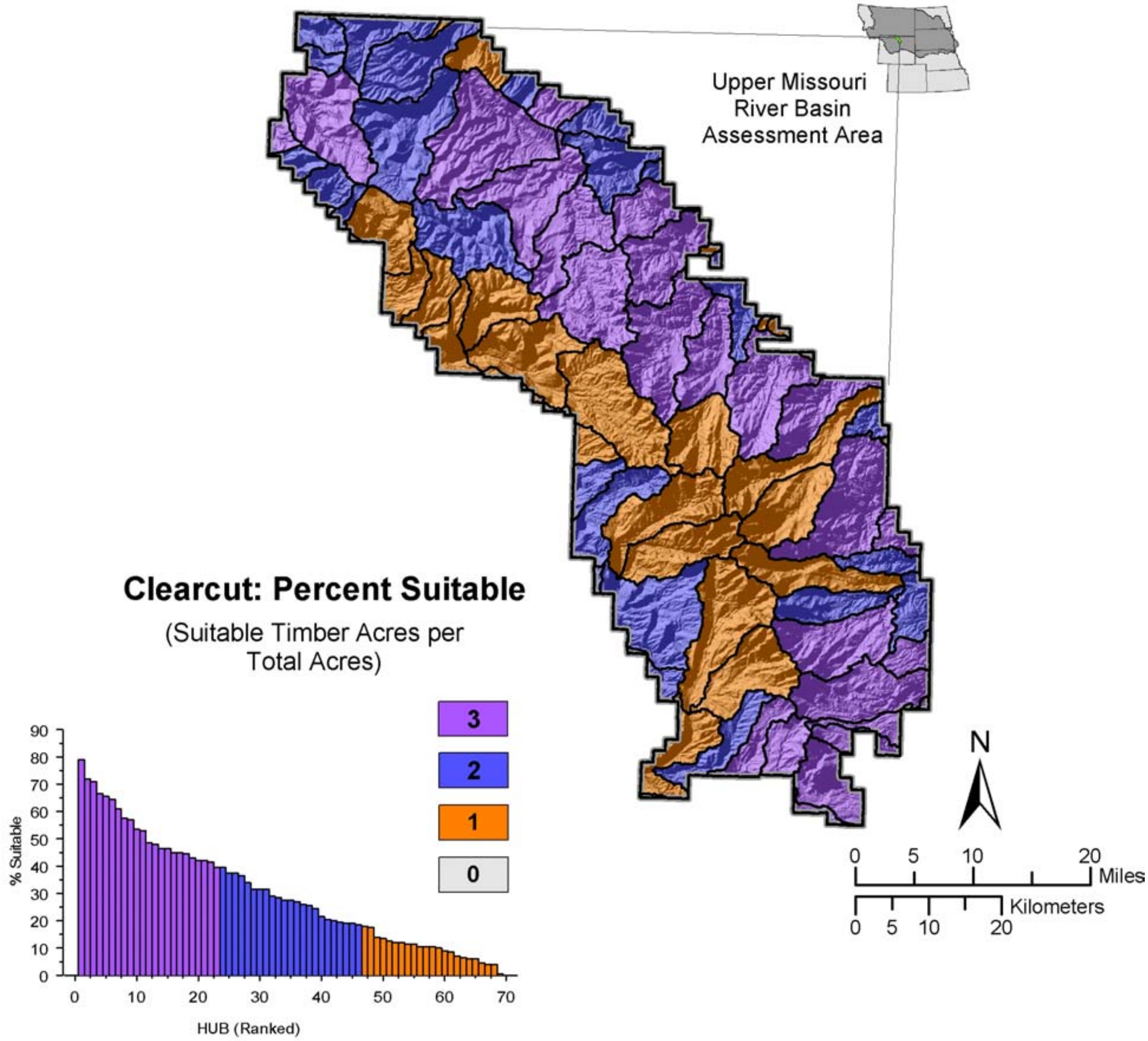

Figure 7.9. Percentage of commercially suitable timber per area of 6th level HUBs inside or intersecting Bighorn National Forest.

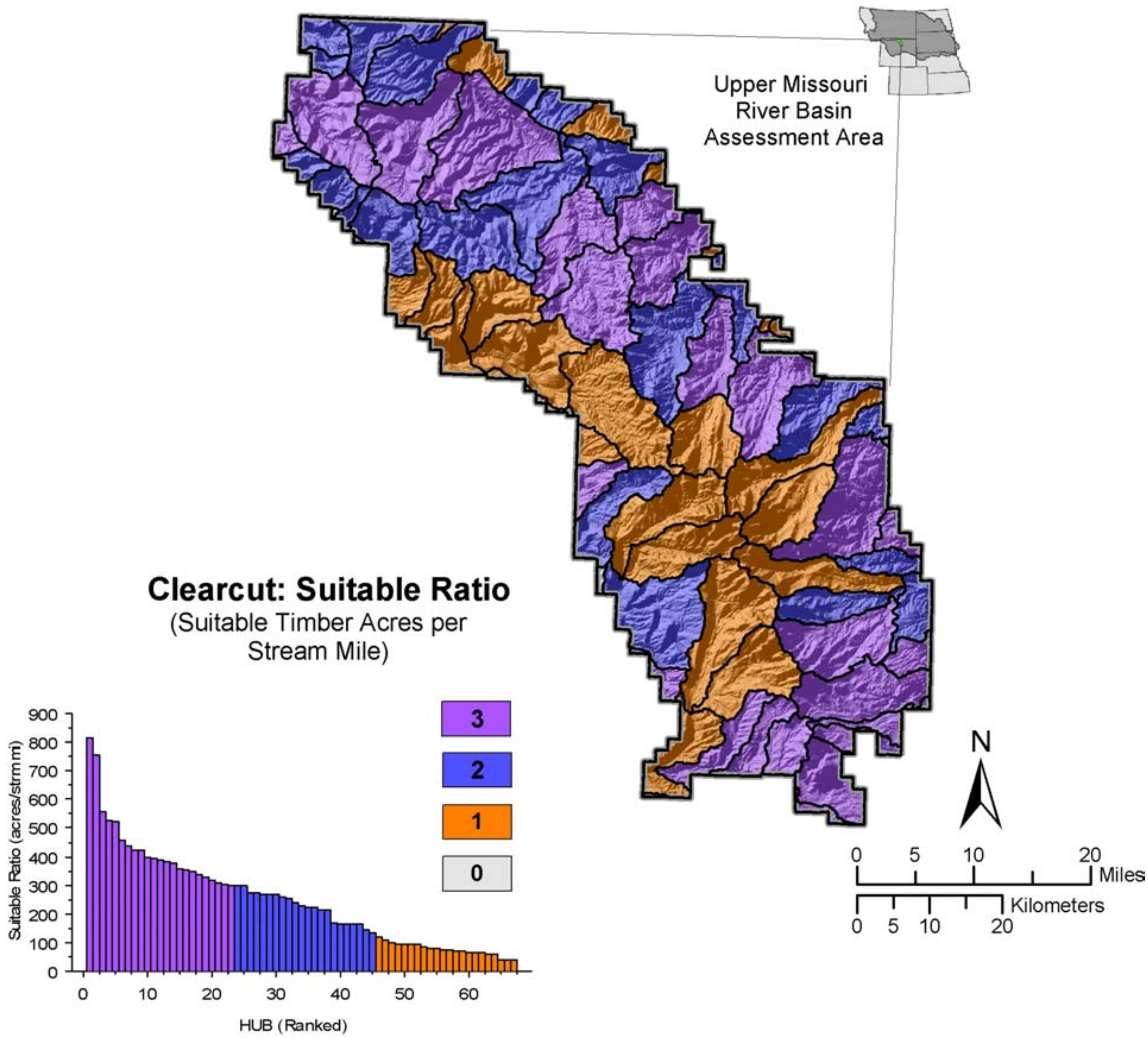

Figure 7.10. Area of commercially suitable timber per stream length in 6th level HUBs in Bighorn National Forest.

To address the potential influence of historic clearcutting on wetland resources, we compared the relative proportion of wetland acres within the clear cut boundaries to the total wetland acres for each 6th level HUB within the Forest boundary (fig. 7.11). Values ranged from Over 30% to 0, with only 33 of the 74 HUBs having any identified wetlands located within them. Most of the HUBs with the highest wetland area within clearcuts were located in the southern portion of the Forest, with only one located in the northern portion. Several HUBs with less than 5% of the wetlands within clearcut boundaries were located in the northern portion. Comparison of these results with Clusters 1w, 2w, and 5w, which showed a relatively high abundance of wetland habitat, provided little noticeable trends. The southern area which showed a relatively high amount of wetlands within the clear cut boundary also were in Cluster 5w which had the highest proportion of groundwater fed wetlands, including springs and seeps. The relatively high percentage of wetlands and the high percentage of wetlands in the clear cut boundaries in this southern most areas could be considered important from a wetland perspective. Cooper (Chapter 2 in Report 1) indicates that changes in groundwater flow in Cluster 2w of the 6th level HUBs could have dramatic effects on the wetlands identified there. The one 6th level HUB in Cluster 5w in the northern portion of the Forest that is in the upper one-third of wetland area within clearcut boundaries is located in the far northern portion of the Forest and could be an important area for wetland influence from historic clearcutting activities.

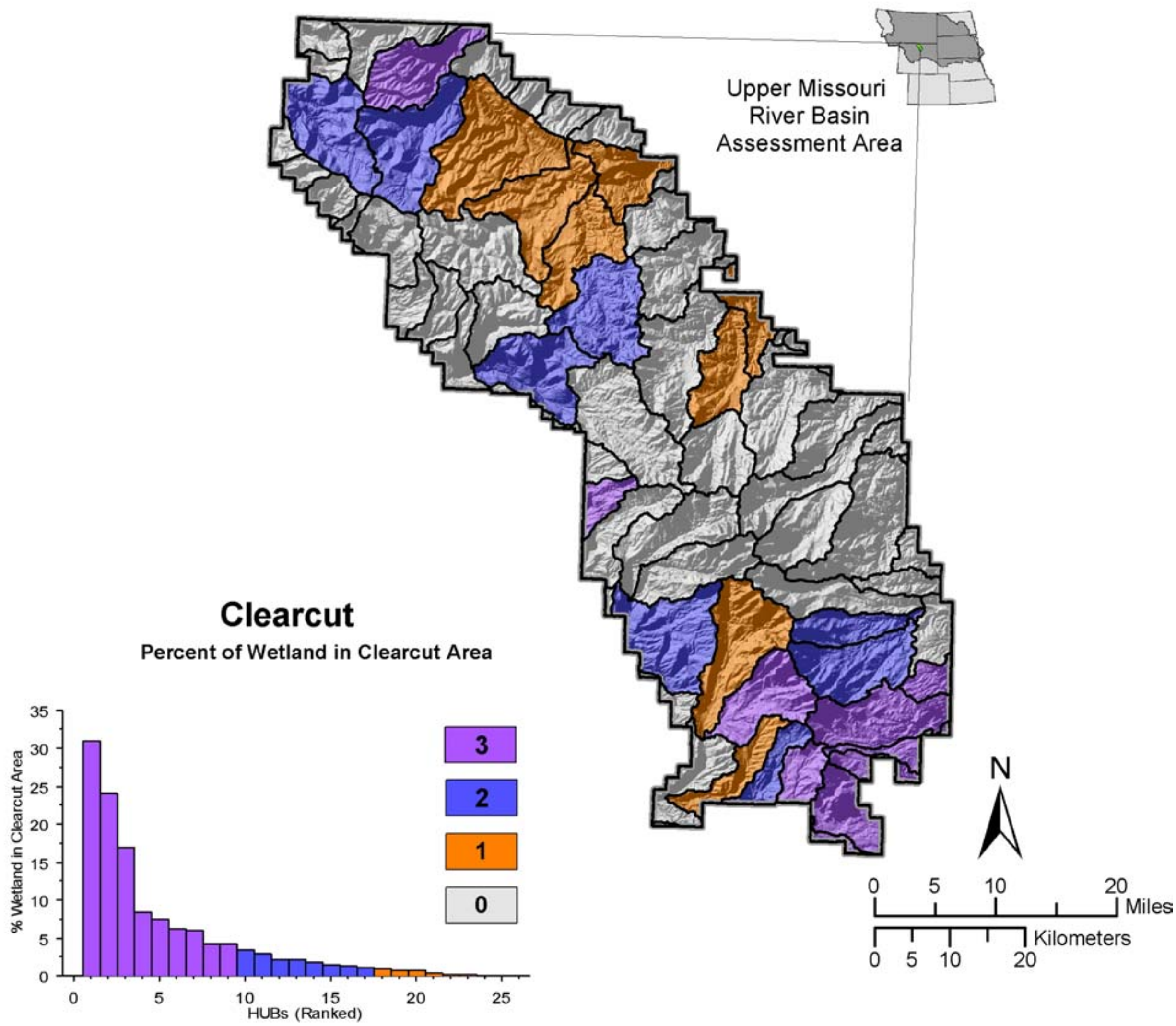

Figure 7.11. Relationship between percentages of wetland acres within historic clearcut boundaries for each 6th level HUB within the Bighorn National Forest. HUB numbers 100902050107, 100902050102 and 100902050101 had the three highest percentages respectively.

Reach/Site Scale

A host of issues and questions should be addressed at the reach/site level in order to determine the influence of timber harvest practices in the Bighorn National Forest, so that project level analyses are in accordance with Federal Land Policy and Management Act (FLPMA) directives concerning species viability and ecological sustainability. Changes in water quality, stream channel maintenance and sediment input, requirements and sensitivity of terrestrial, riparian, and aquatic vegetation, and the potential for direct and indirect effects on aquatic biota are aquatic, riparian, and wetland values that must be addressed at the reach/site scale to evaluate potential impacts of logging in the Forest. In addition, managers must still consider influences of previous logging. That is, the legacy of past timber harvest still influences the structure and function of aquatic, riparian, and wetland systems, so managers must deal with the cumulative effects of the past as well dealing with current and future needs (Beschta et al. 1995; McIntosh et al. 2000)

Specific questions related to resource values include, but are not limited to:

1. Are effects of past timber harvest still influencing resources via:
    a. Altered hydrology (e.g., frequency, distribution, timing, and magnitude of high flow events)?
    b. Changes in water quality (e.g., suspended fine particles, nutrient input, temperature regime)?
    c. Increased sediment yield (e.g., deposition of fines, mass wasting)?
    d. Channel alteration (e.g., degrading stream banks)?
    e. Degradation of riparian habitat (e.g., direct removal of vegetation, skidding, yarding)?
    f. Stream habitat simplification (e.g., loss of woody debris or overhead cover)?
2. Will future timber harvest cause similar changes listed above in number 1 (a-f) above?
3. Will future timber harvest occur in watersheds containing particularly significant plant or animal populations, such as sensitive Yellowstone cutthroat trout?
4. What is the cumulative influence of past clearcutting and currently used timber harvest techniques on aquatic, riparian, and wetland resources?

Information Needs

Streams within watersheds that have high amounts of timber harvest should be evaluated at the reach/site level to fully understand the influence that they have had on aquatic, riparian, and wetland resources. Some streams in these areas can be expected to have higher than average sediment loads and channel modifications due to accelerated runoff. The following variables can be used to assess the conditions of streams that: a) have been influenced by past timber harvest (e.g., by comparing logged streams to similar unlogged streams); or b) may be in watersheds subjected to future logging (e.g., compare variables pre- and post-logging within a reach).

1. Timing and magnitude of high-flow events or debris torrents
2. V*
3. D_{50} particle size or other measures to determine changes in stream sediment composition (e.g., siltation)
4. Distribution, frequency, and volume of large woody debris (LWD)
5. Percent cover
6. Stream width and depth
7. Pool/Riffle ratio
8. Changes in pool frequency and volume
9. Annual temperature regime/solar radiation
10. Primary production (chlorophyll *a* standing stock)
11. Diversity of aquatic invertebrates sensitive to environmental stressors (e.g., Ephemeroptera-Plecoptera-Trichoptera or EPT)
12. Diversity and biomass of resident fishes
13. Comparative abundance and diversity of wetland fauna in clearcut versus unlogged watersheds

Management Implications and Relationship to Ecological Drivers

Current logging practices have improved considerably since earlier clear cutting practices. Managers better understand the values of other resources and the influences that inappropriate timber harvest and related activities can have on them. However, like tie drives historic timber harvesting activities may have had an effect on aquatic, riparian, and wetland resources that are still being realized. It is important to understand where these activities occurred and what the current or future management activities will have on them.

Clusters with relatively high percentages of wetlands and riparian areas could have been influenced considerably by past logging practices, especially if these resources were not addressed in past decades. Table 7.3 illustrates the overall potential for historic clear cuts to influence wetlands and riparian areas based on the results of Cooper (see Chapter 2 in Report 1). In order to understand what potential effect historic clear cutting possibly had, it is important to compare the density of clear cuts in a particular 6th level HUB for wetlands (fig. 7.5) and for riparian areas (fig. 7.9), and the overall potential influence they could have had (table 7.3) on them. Reach/site analysis can further define historic influences once watersheds can be prioritized.

Table 7.3. Relationship between cluster number and potential influence of historic clearcutting on aquatic, riparian, and wetland resources.

Wetland Cluster Number*	Potential Influence on Wetlands**	Riparian Cluster Number*	Potential Influence on Riparian Areas*
1w	High	**1r**	High
2w	High	**2r**	High
3w	Low	**3r**	Moderate
4w	Low	**4r**	Low
5w	High	**5r**	Low
6w	Moderate	**6r**	Low
7w	Low		NA

** - Cluster numbers represent different groupings for wetlands and riparian areas. They cannot be used simultaneously with each other.*
*** - Based on the percentage of current and potential habitat described by Cooper (see Chapter 2 in Report 1 of this assessment).*

Influence of Fire

Overall, the effects of wildfire and prescribed fires on aquatic, riparian, and wetland ecosystems are poorly understood compared to those in terrestrial systems. Moreover, animal responses to fire are variable and complex. Although prescribed burns are a primary method of fuels reduction practiced in western U.S. forests, their effects are even less understood in comparison to wildfires (Pilliod et al. *in press*). However, it is generally assumed that impacts from prescribed burns will be less severe because they are set when conditions are such that effects on water resources can be somewhat controlled. At certain fire intensity, effects of wildfire and prescribed burns might be similar. Existing data do not permit an analysis stratified by fire type (e.g., wildfire versus prescribed burns) for the Bighorn National Forest, so this assessment will hereafter refer to ‘fires’ with the understanding that the majority of the data represent wildfires.

Basin Scale

Fire is a predominant natural disturbance structuring Rocky Mountain landscapes, and regional fire regimes are driven by weather conditions and fuel distribution (Meyer and Knight 2003; Bisson et al. 2003). In the Rocky Mountains, analysis of fire occurrence must be stratified by elevation because there are distinct trends whereby fire occurs less frequently in high elevation forests that receive more precipitation than low elevation forests (Meyer and Knight 2003). Moreover, the composition of these forests affects fire frequency and intensity.

High elevation forests in the region typically consist of stands of lodgepole pine, Englemann spruce, and subalpine fir. Fires in these forests are typically infrequent (fire-free intervals on the order of centuries), high-intensity stand-replacing crown fires. Weather conditions (e.g., drought or high temperatures) often determine the occurrence of large, stand-replacing fires in high elevation forests, but the abundance and distribution of fuels is also an important factor (Meyer and Knight 2003). Lower-intensity surface fires do occur in high elevation forests, but less frequently than stand-replacing fires.

Low elevation forests in the region generally contain ponderosa pine, Douglas fir, and limber pine. Fires in these forests are more frequent (fire-free intervals on the order of decades), low-intensity surface fires that kill some trees. These low-intensity surface fires typically kill young trees with thin bark, but not older trees with thicker bark, which produced and maintained comparatively low tree density in low elevation forests. Fire size and intensity in low elevation forests is positively related to the intervening period without fire (e.g., fire-free interval). Large severe fires are more likely to occur when the fire free interval increases and fuels have time to accumulate (Meyer and Knight 2003). There is some evidence to suggest that fire suppression, because lower-intensity surface fires are easier to control, may be affecting the fire regimes in low elevation forests. For example, current ponderosa pine stands in the Bighorn National Forest are denser than presumed historical stands because of fire suppression (Meyer and Knight 2003), thus increasing the potential for more intense fires.

The affect of fires on aquatic, riparian, and wetland resources is likely a function of habitat context (e.g., whether habitat is a low or high elevation forest), climate, and human activity (e.g., fire suppression and land use) (Bisson et al. 2003). Wildfires are a natural ecological element in the region and the regional fauna presumably evolved under the historical fire regime, so wildfires probably had positive effects, as well as some short-term negative effects, on aquatic, riparian, and wetland habitats and organisms.

Landscape Scale

At the landscape scale, two of seven 4th level HUBs have had at least 3% of their total area burned since 1910 (e.g., Little Big Horn River – 10080016 and Clear Creek – 10090206), but only one HUB has had more than 1% of its area burned in the last 40 years (e.g., 1.9% of Clear Creek; table 7.4 Spatial distribution of fires with respect to stream, riparian, and wetland habitat shows similar trends. For example, the same two HUBs (e.g., Little Big Horn River and Clear Creek) had at least 3% of their total valley bottom area burned by historical fires, but the remaining had 1% or less (table 7.5). Only Clear Creek had more than 1% of its valley bottom area burned by fires during the past 40 years. Thus, historical and recent fires do not represent significant disturbances to aquatic, riparian, and wetland resources at the landscape scale. However, though these fires did not cover a large area, their management and reach/site scale impacts may still be significant.

Table 7.4. Total and recent area burned by fires at the landscape scale for the Bighorn assessment area.

		Total Area Burned Since 1910		Total Area Burned in Last 40 years	
4th Level HUB Name	4th Level HUB Code	Acres	Percent of Total HUB Area	Acres	Percent of Total HUB Area
Nowood River	10080008	7,139.6	0.6%	4,384.9	0.3%
Big Horn Reservoir	10080010	4,949.8	0.4%	1,209.8	0.1%
Little Big Horn River	10080016	25,078.1	3.0%	6,775.5	0.8%
Upper Tongue River	10090101	14,523.3	0.9%	2,383.5	0.1%
Middle Fork Powder River	10090201	154.8	0.0%	154.8	0.0%
Crazy Woman Creek	10090205	443.2	0.1%	237.6	0.0%
Clear Creek	10090206	24,846.7	3.4%	13,816.5	1.9%
	Total	77,135.6	-	28,962.7	-
	Mean (per HUB)	*11,019.4*	*1.2%*	*4,137.5*	*0.5%*

Table 7.5. Total and recent valley bottom area burned by fires at the landscape scale for the Bighorn assessment area.

		Total Valley Bottom Area Burned Since 1910		Total Valley Bottom Area Burned in Last 40 years	
4th Level HUB Name	4th Level HUB Code	Acres	Percent of Total Valley Bottom Area in HUB	Acres	Percent of Total Valley Bottom Area in HUB
Nowood River	10080008	1,769.6	0.7%	1,029.2	0.4%
Big Horn Reservoir	10080010	1,137.6	0.4%	301.7	0.1%
Little Big Horn River	10080016	5,327.3	3.0%	1,489.2	0.8%
Upper Tongue River	10090101	3,172.4	1.0%	492.0	0.2%
Middle Fork Powder River	10090201	29.5	<0.1 %	29.5	<0.1 %
Crazy Woman Creek	10090205	67.8	<0.1 %	37.5	<0.1 %
Clear Creek	10090206	7,369.0	4.9%	4,206.5	2.8%
	Total	18,873.3	-	7,585.6	-
	Mean *(per HUB)*	*2,696.2*	*1.4%*	*1,083.7*	*0.6%*

The probability, extent, and intensity of future fires at the landscape scale of the Bighorn assessment area will be a function of elevation, climatic conditions, and the history of fire suppression and management. In high elevation forests, fire frequency at any point on the landscape may have been lowered because of fire suppression (Bornong 1996), but fire intensity likely falls within the historic range of variability because most past and present fires were stand replacing (Meyer and Knight 2003). High elevation forests, however, comprise a relatively small percentage of the total landscape area of 4th level HUBs. Lower elevation ponderosa pine forests are more common outside the Forest boundary than inside, and these forest stands are denser than under historical conditions because of fire suppression (Meyer and Knight 2003).

Management Scale

A total of 61 fires have been recorded in Bighorn National Forest since 1910, and these fires tended to be in the northern or eastern margins of the mountains (fig. 7.12 Particularly large fire years occurred in 1921, 1943, and 1988 (fig. 7.12a), but very little of the Forest burned between 1944-1966. Fires were more frequent in the early part of the record, and the average number of fires per decade has declined from nine from 1910-1959 to four from 1960-1999 (fig. 7.12b).

At the management scale, forty of 74 6th level HUBs intersecting the Bighorn National Forest have had forest fires since 1910, but both the total acreage and the percentage of a HUB burned were quite variable (fig. 7.13-7.14). Seventeen HUBs had greater than 100 acres burned, and HUBs 100800160301 and 100902060101 had greater than 9,500 acres burned. The eight most-burned HUBs, in terms of acreage, also had the greatest percentage of their total areas burned (range 12.1-42.4%; fig. 7.15). HUBs 100800160301 and 100902060102 had greater than 40% of their total area burned since 1910.

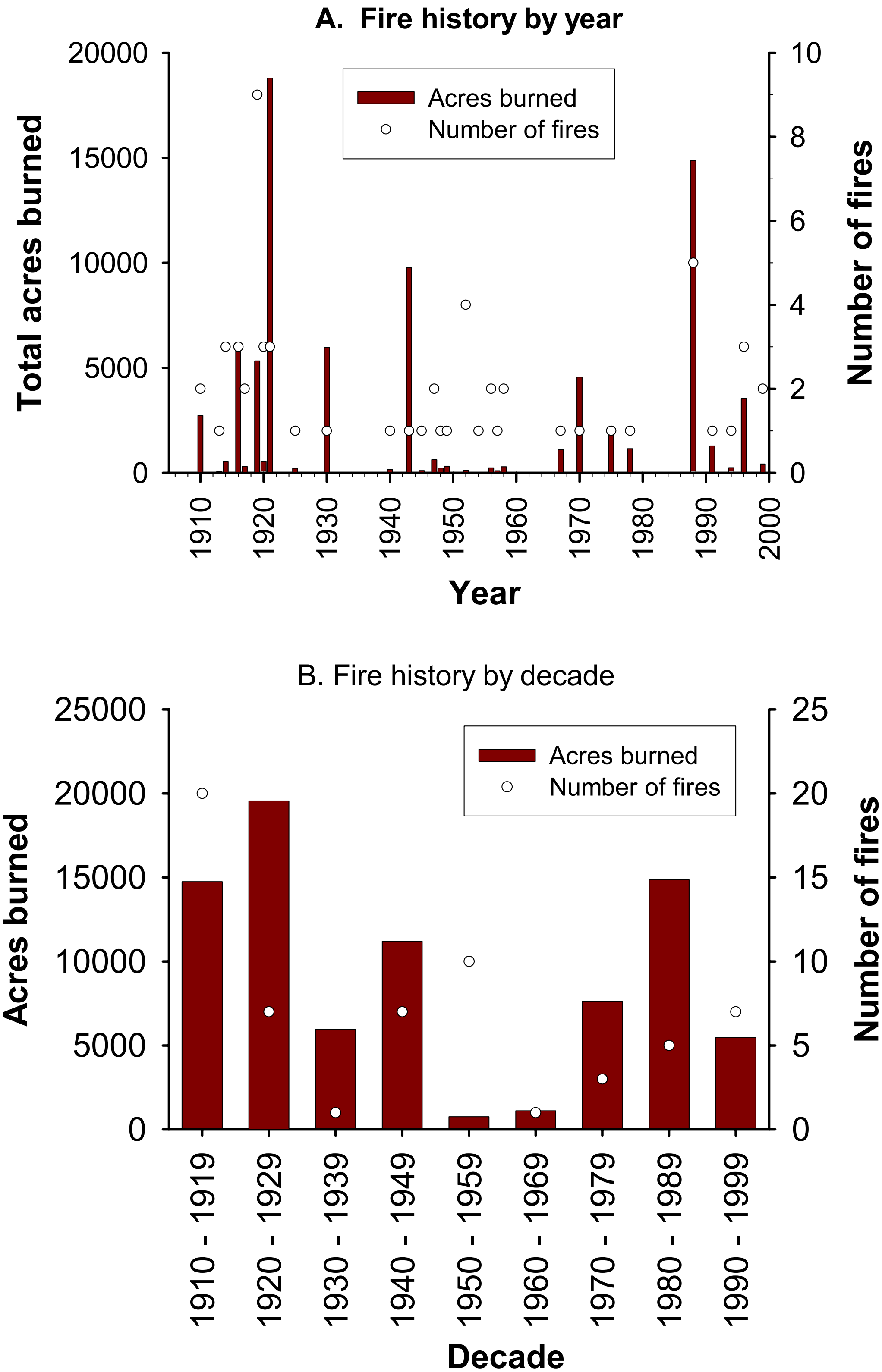

Figure 7.12. Fire history in the Bighorn National Forest since 1910 by year (A) and decade (B).

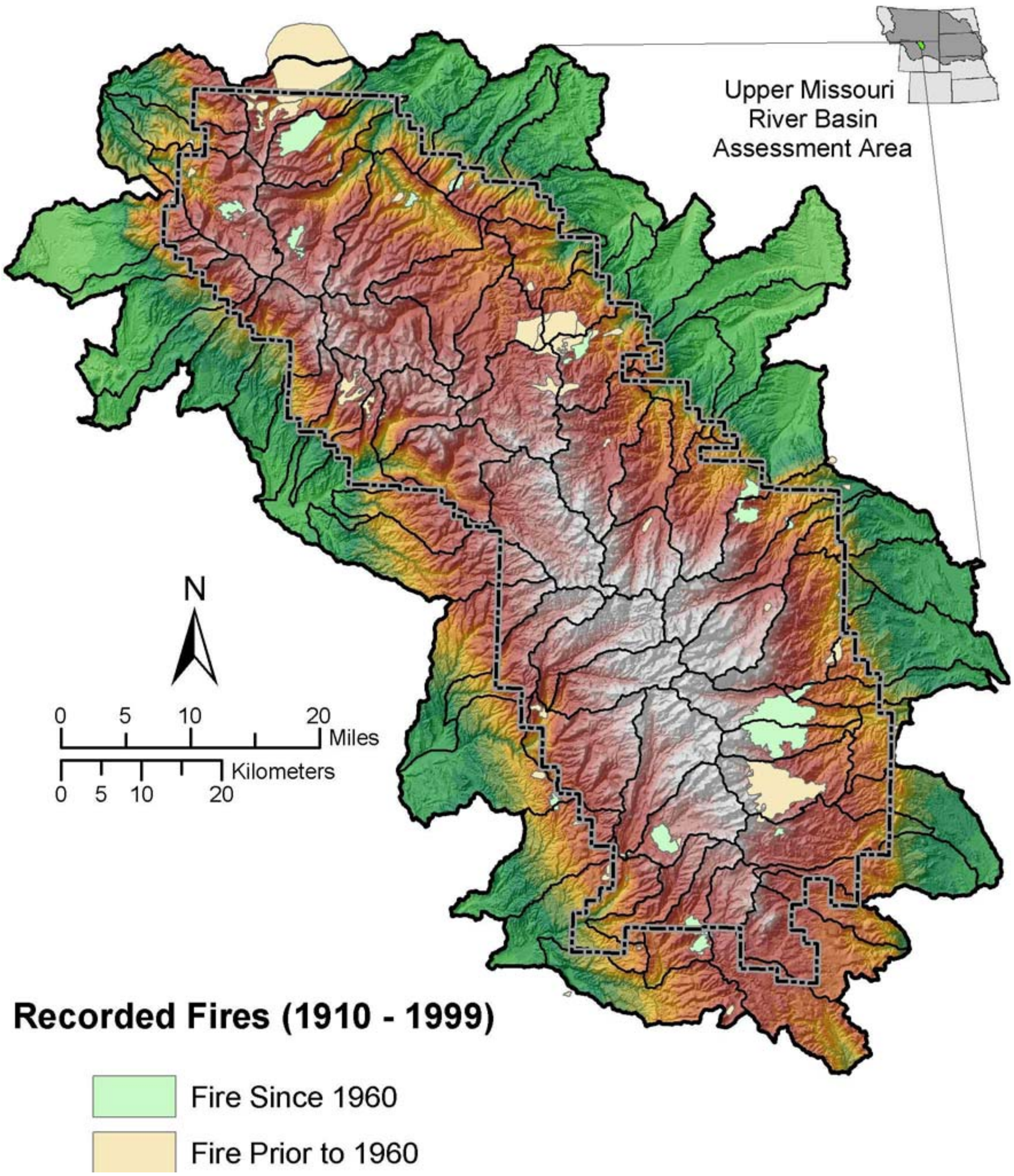

Figure 7.13. Distribution of fires within the 74 6th level HUBs intersecting the Bighorn National Forest.

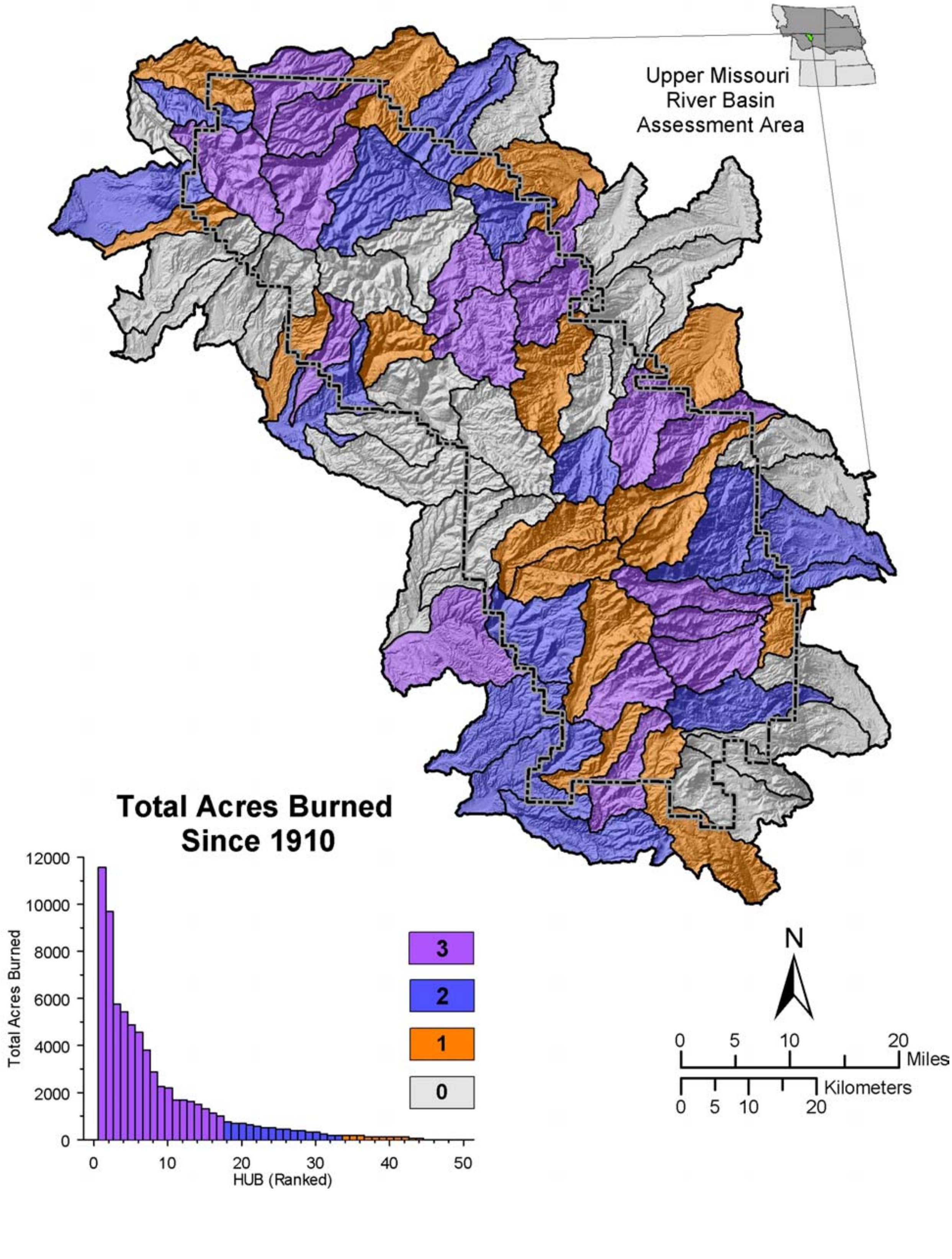

Figure 7.14. Total acres burned since 1910 for 74 6th level HUBs intersecting the Bighorn National Forest.

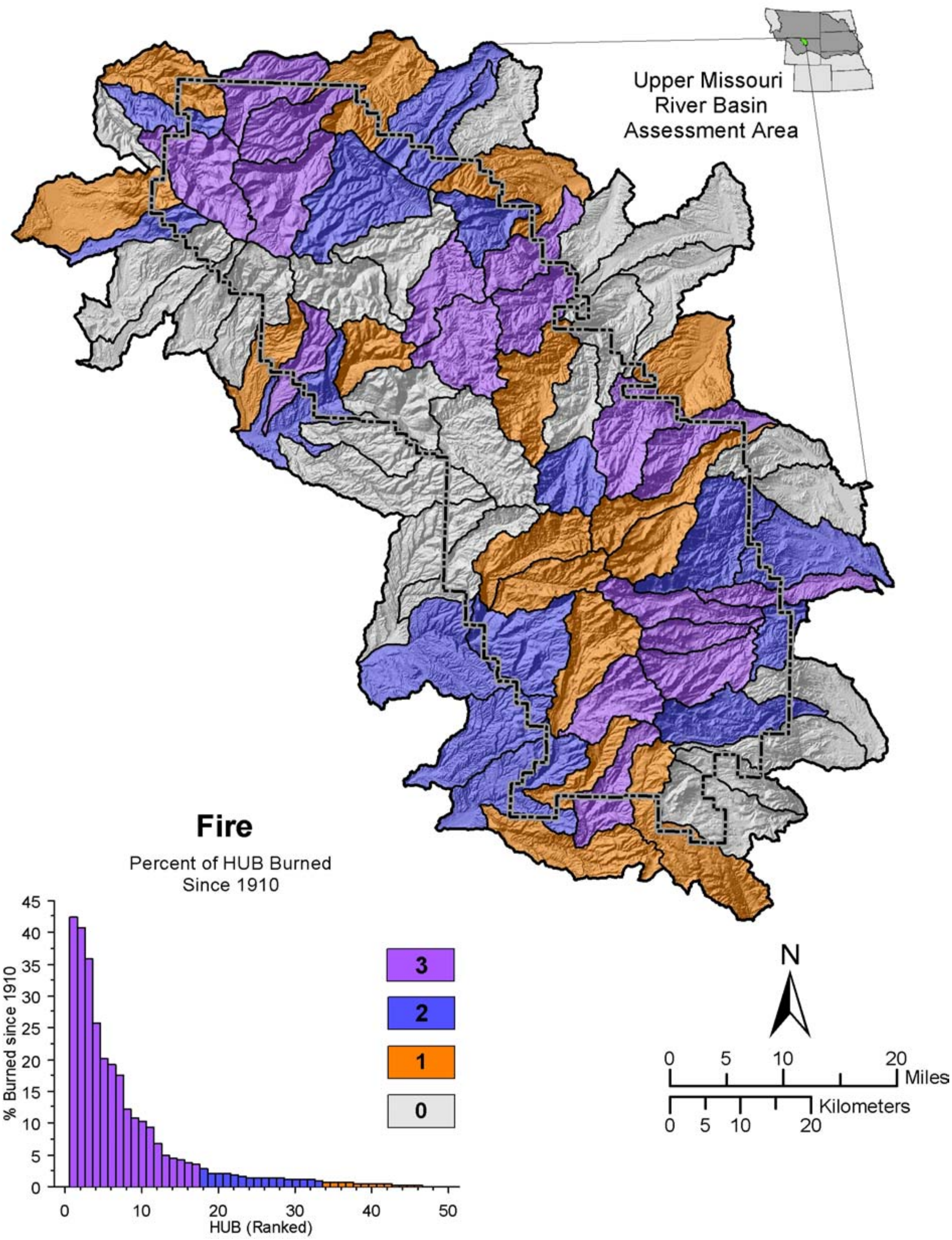

Figure 7.15. Percent of total HUB area burned since 1910 for 74 6th level HUBs intersecting the Bighorn National Forest.

For more recent fires, twenty-three of 74 6th level HUBs intersecting the Forest have had fires in the past 40 years (fig. 7.16). Three of these HUBs had greater than 4,500 acres burned (100902060102, 100902060103, and 100800160104), and were also the HUBs with the greatest percentage of their area burned (e.g., range 18.7- 40.8%; fig. 7.17). These three comparatively highly affected HUBs might be locations where indirect effects of fire (e.g., debris flows, sedimentation, etc.) might affect aquatic, riparian, and wetland resources.

The size of recent fires (e.g., those in the past 40 years) was positively correlated with the historical fire size since 1910 (Pearson's correlation on log [x+1] transformed area: $r = 0.51$, $n = 49$, $p = 0.0002$; PROC CORR, SAS Version 8.0). This implies that the recent large fires are also historically large fires.

The probability, extent, and intensity of future fires in Bighorn National Forest will be a function of elevation, climatic conditions, and the history of fire suppression and management. High elevation forests make up more than 80% of the forested area within Bighorn National Forest, and drought and high winds are more likely to affect fires in high elevation forests than fuels (Meyer and Knight 2003). In low elevation forests in the Bighorn National Forest, fire frequency has likely been reduced by fire suppression; so more intense stand-replacing fires should be more frequent that under historical conditions (Meyer and Knight 2003). Low elevation forests in the Bighorn National Forest are primarily Douglas fir (9% forested area) with some ponderosa pine (1%), and only about 3.7% low elevation forest (2,000 of 53,676 ha) in Bighorn National Forest has been burned between 1970 and 1996 (Meyer and Knight 2003).

Future effects of fire on aquatic, riparian, and wetland resources will depend on the location, extent, and intensity of the fires. For example, fishes inhabiting headwater stream reaches may be very susceptible to fire-related impacts because of the close connection between forest and stream habitat (Dunham et al. *in press*). In the Bighorn National Forest, native Yellowstone cutthroat trout are often restricted to these headwater habitats; so catastrophic wildfires have the potential to affect their populations. Total valley bottom acres burned and the percent valley bottom acres burned since 1960 are shown on Figures 7.18 – 7.19.

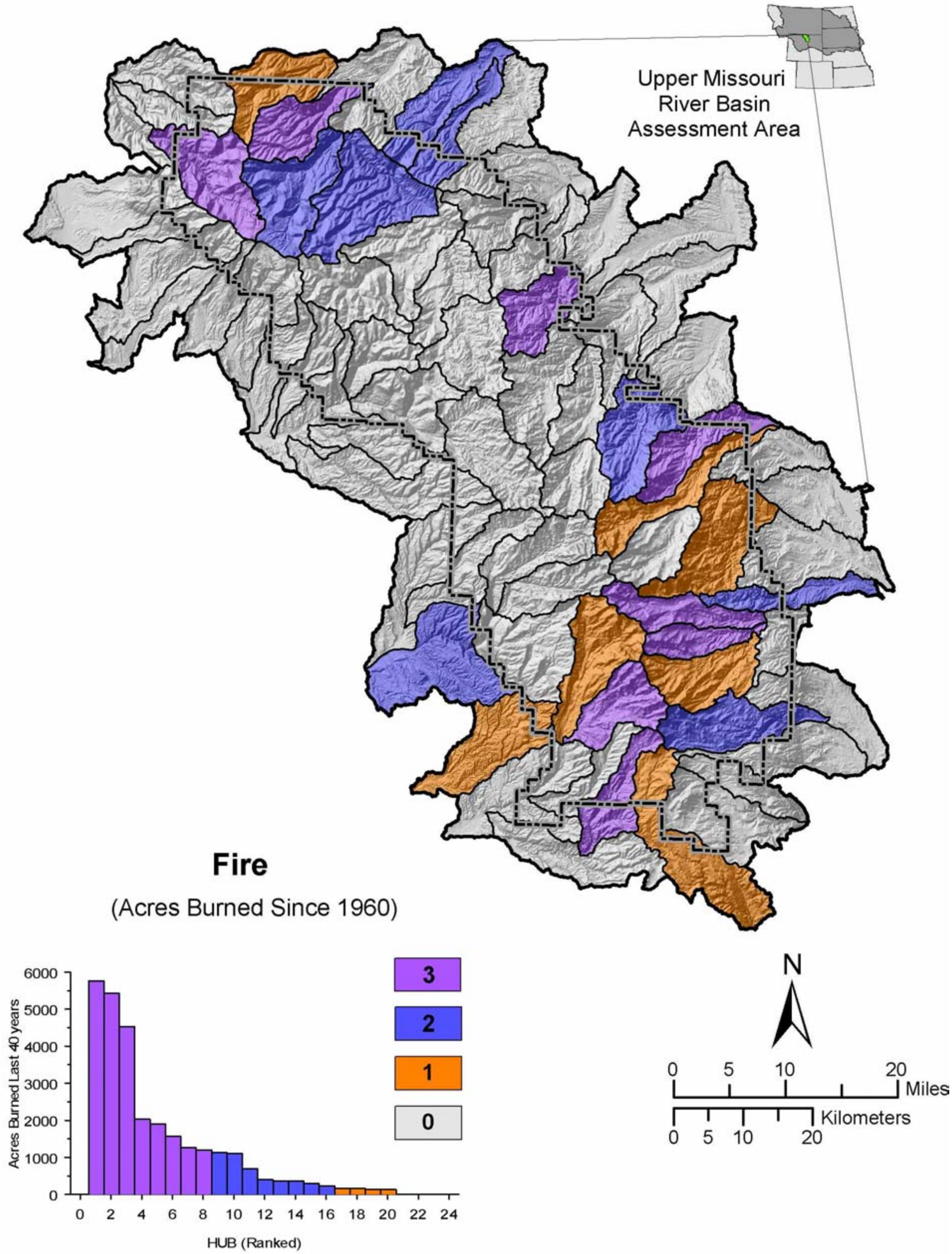

Figure 7.16. Acres burned during last 40 years for 74 6th level HUBs intersecting the Bighorn National Forest.

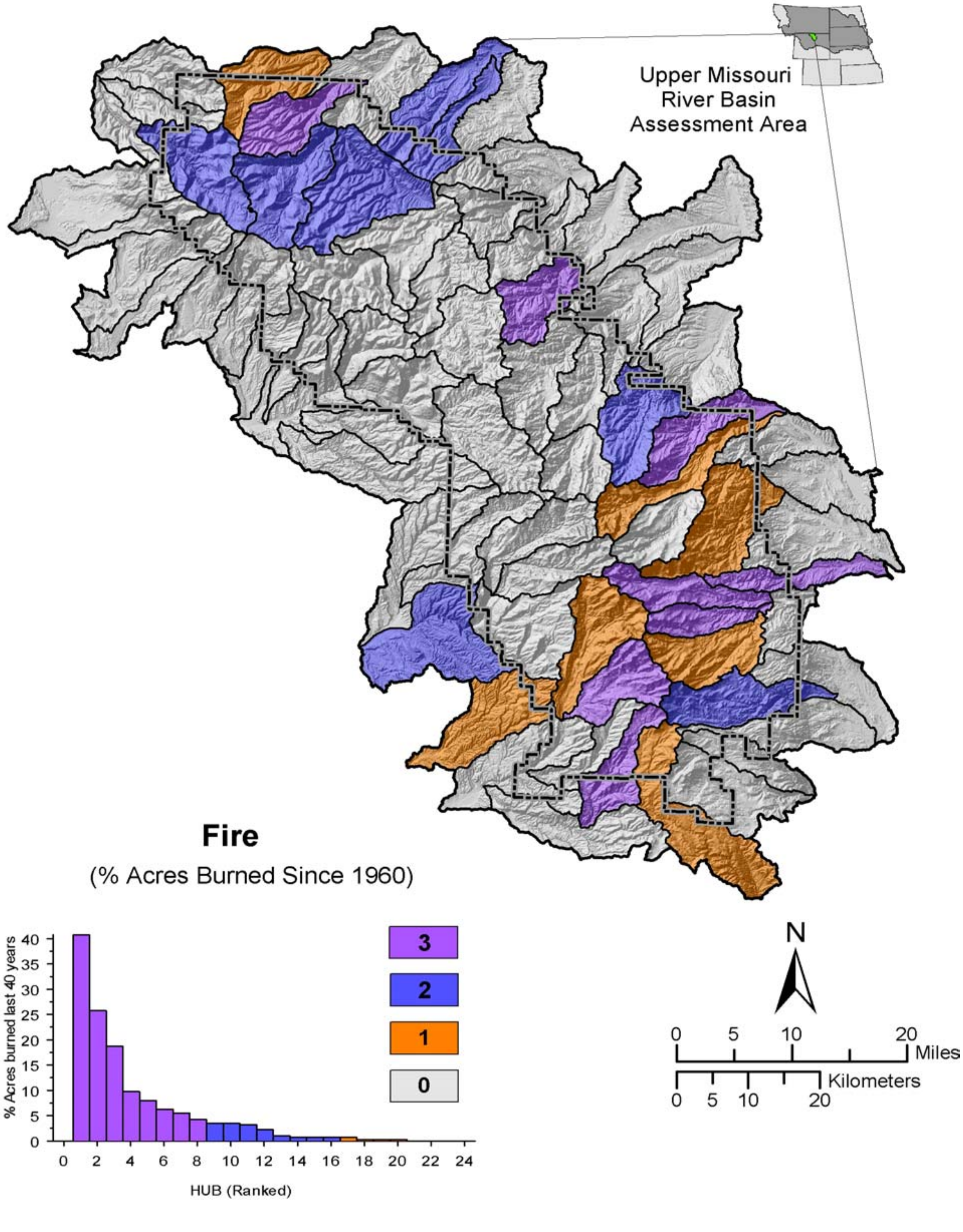

Figure 7.17. Percent of HUB area burned during last 40 years for 74 6th level HUBs intersecting the Bighorn National Forest.

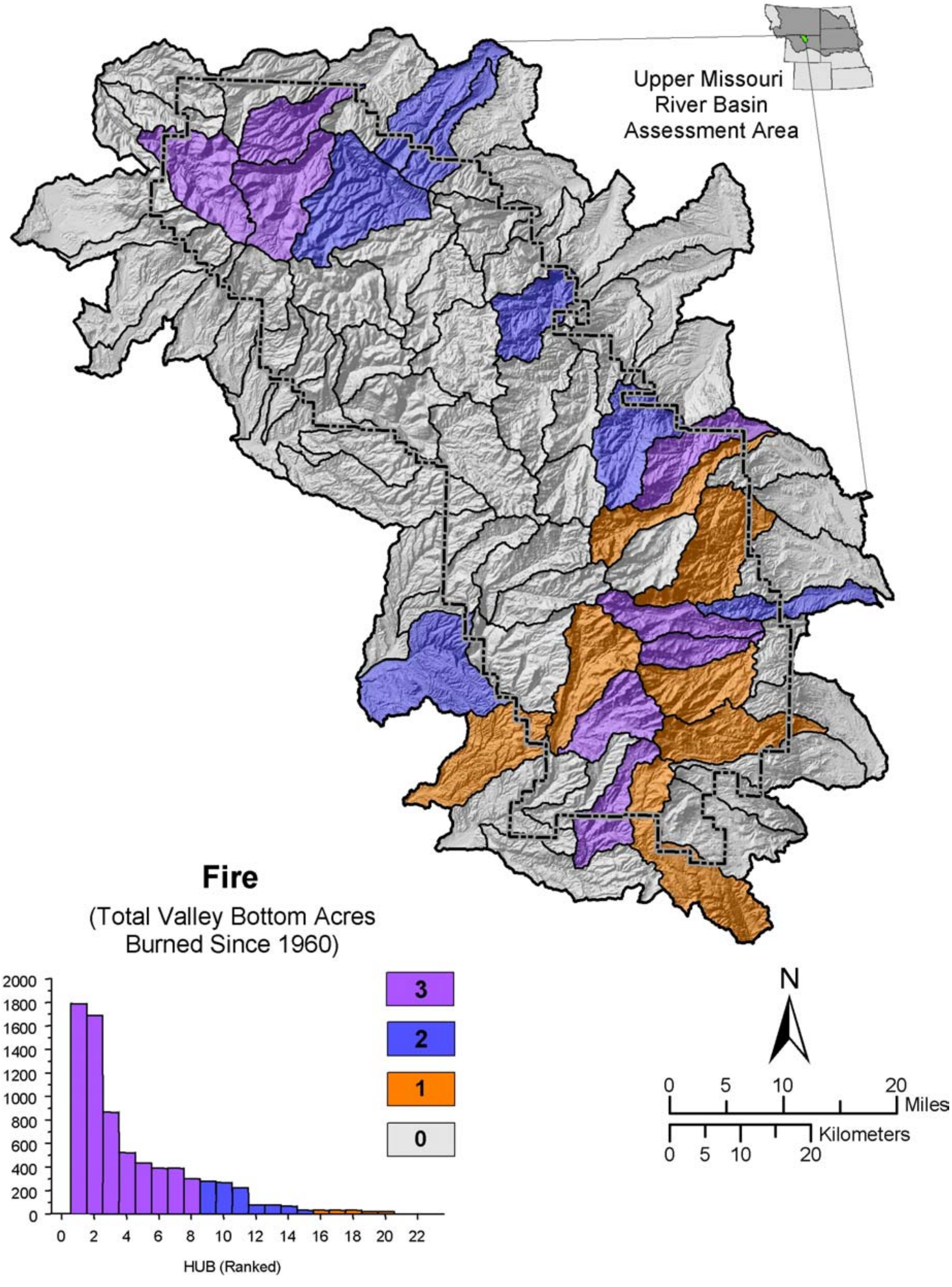

Figure 7.18. Total valley bottom acres burned since 1960 for 74 6th level HUBs intersecting the Bighorn National Forest.

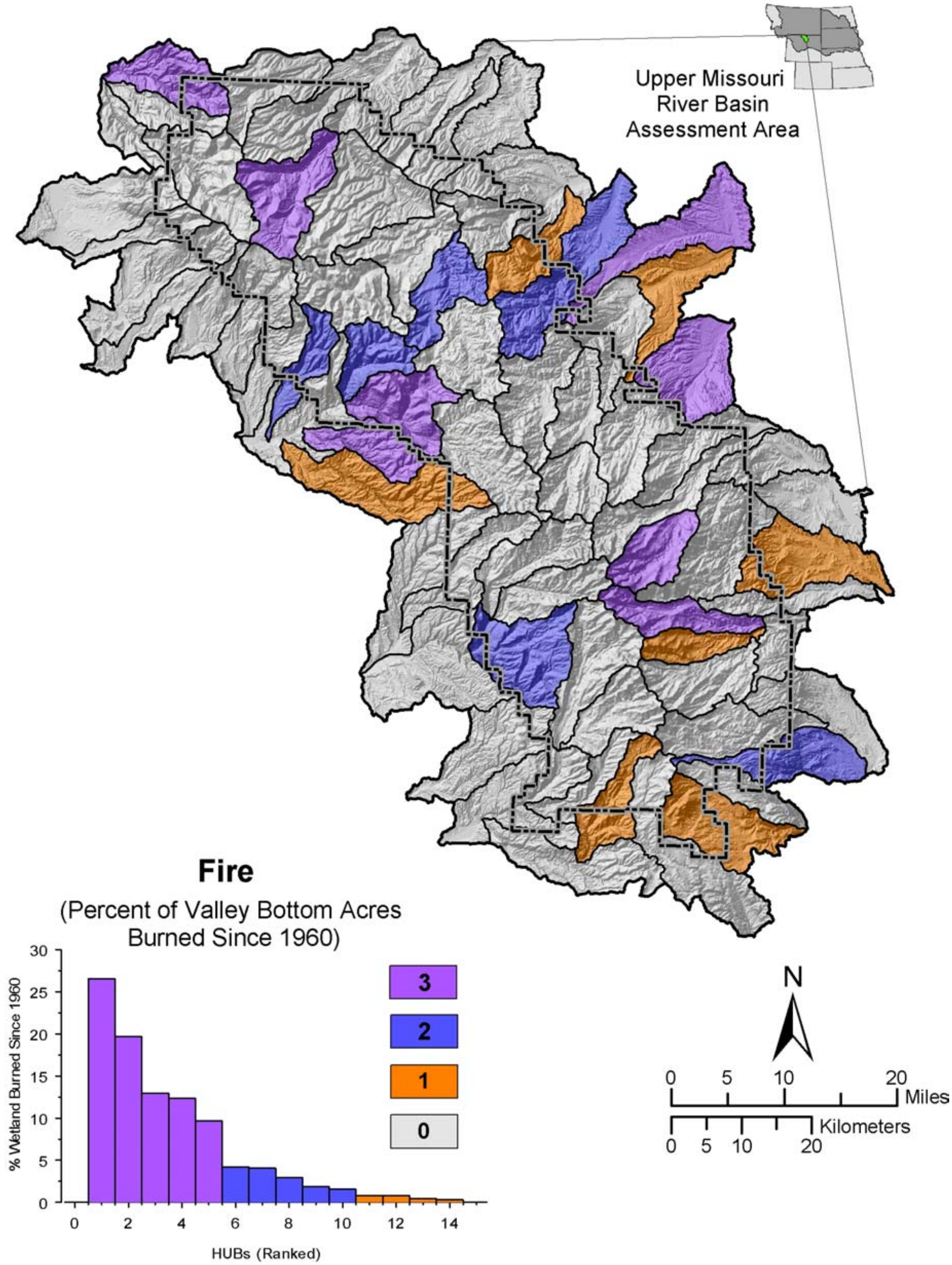

Figure 7.19. Percent of valley bottom acres burned since 1960 for 74 6th level HUBs intersecting the Bighorn National Forest.

To address the potential influence of natural fires on wetland resources, we identified the percentage of wetlands within a fire boundary for each 6th level HUB (fig. 7.20). Only fifteen of the 74 6th level HUBs have had any identifiable wetlands burned since 1960. Of those HUBs were wetlands were identified in the burn area, only five had 10% or more in the burn boundary, and only two had 20% or more. These results indicate that while natural fires have relatively rare in the Bighorn National Forest, relatively little wetland area has been within their boundary. The areas where the percentage is relatively high could be considered areas where further monitoring should be conducted to determine the extent of influence, and whether it is recovering in light of other management activities.

Reach/Site Scale

Although the area burned by fires at the landscape and management scales may be comparatively small, site impacts from fires can be considerable. Specific questions to consider at the reach/site scale include:

1. Do past fires result in:
   a. Altered hydrology (e.g., increased frequency and magnitude of high flow events)?
   b. Changes in water quality (e.g., increased nutrient input and solar radiation)?
   c. Increased sediment yield (e.g., increased sedimentation and debris flows)?
   d. Channel alteration (e.g., degrading stream banks)?
   e. Loss of riparian and wetland habitat (e.g., direct removal of vegetation)?
2. Will future fires cause similar changes listed above in number 1 (a-e) above?
3. Will future fires occur in watersheds containing particularly significant plant or animal populations, such as sensitive Yellowstone cutthroat trout or native amphibians?

Information Needs

HUBs with recent fire activity should be monitored for changes in the following:

1. Area of riparian and wetland habitat burned
2. Timing and magnitude of high-flow events or debris torrents
3. D_{50} particle size or other measures to determine changes in stream sediment composition (e.g., siltation)
4. Abundance and distribution of coarse woody debris (CWD)
5. Percent cover of riparian vegetation
6. Stream width and depth
7. Pool/riffle ratio
8. Annual temperature regime/solar radiation
9. Primary production in streams (chlorophyll *a* standing stock)
10. Diversity and biomass of resident amphibians & fishes; short- and long-term trends in their populations

Actively monitoring the ecological effects of wildfires will provide the opportunity to learn how a significant natural disturbance influences the flora and fauna of aquatic, riparian, and wetland habitats. Fires will continue to occur on the Forest; so post-fire sampling will be an integral part of the learning and assessment process.

Management Implications and Relationship to Ecological Drivers

Naturally occurring fires are an important process for aquatic, riparian, and wetland resources (Bisson et al. 2003). While aquatic, riparian, and wetland ecosystems maybe resilient to the effects of fire, we have created "unnatural" fuel and aquatic, riparian, and wetland conditions in many areas. Road crossings and culverts, water diversions and reservoirs, grazing activities, and a variety of other activities have created artificial conditions where the ability to respond to the effects of natural fires (resiliency) has been compromised. In order to respond to natural (and prescribed fire) in a way that is ultimately beneficial to aquatic, riparian, and wetland resources, management of other

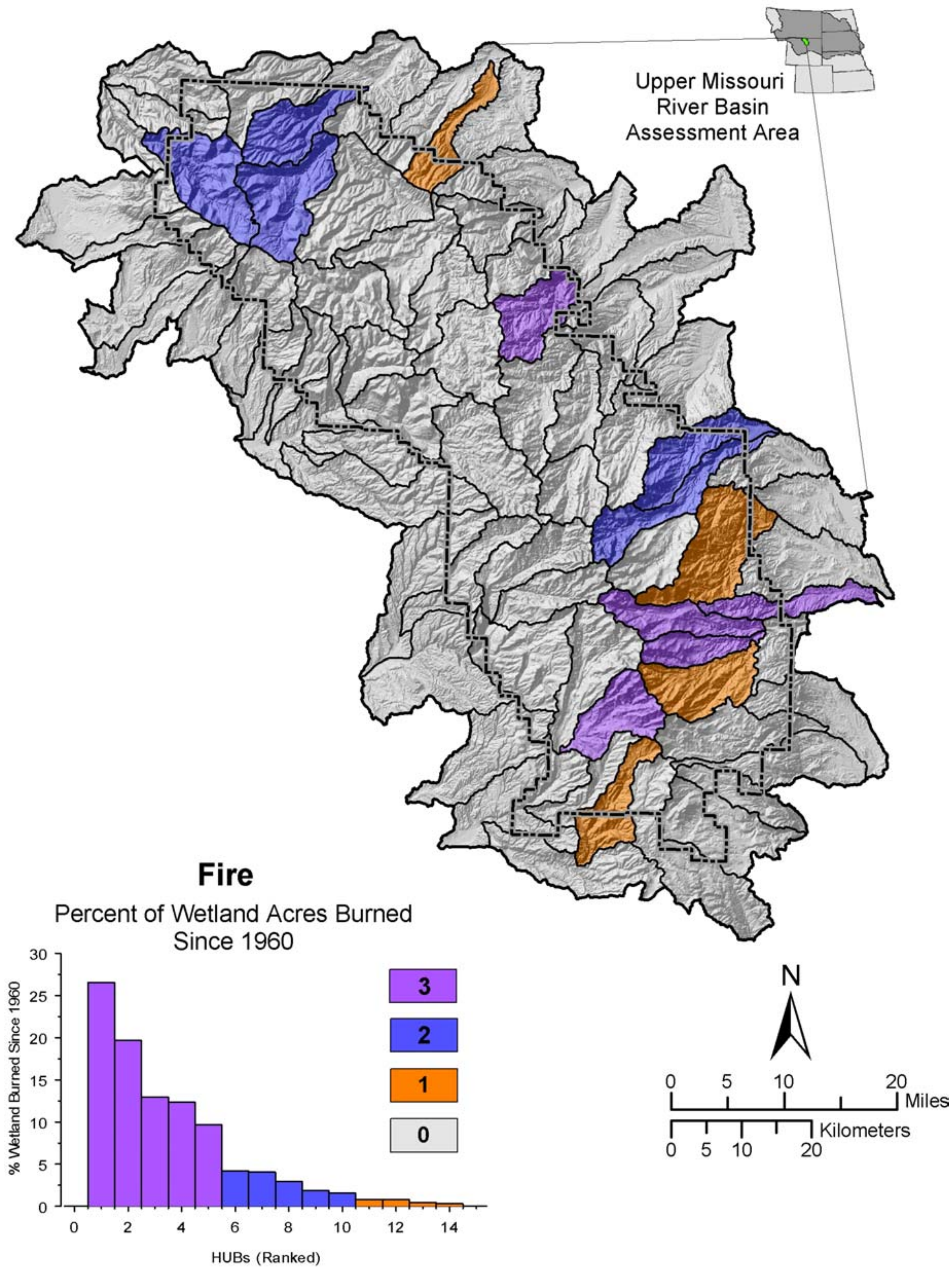

Figure 7.20. Percentage of wetland burned within the fire boundaries for 6th level HUBs since 1960. The two highest percentages are for HUBs 100902060102 and 100902060107.

activities should be considered. Activities that fragment stream and riparian species such as roads, culverts, reservoirs etc. should be considered when addressing the ability of aquatic, riparian, and wetland resources to recover within a normal time period following natural fire. The ability of fish to move back into watersheds, which were severely burned, is in large part a result of their ability to migrate into the area without barriers.

While prescribed fire is meant to minimize the potential effects of larger natural fires, the resiliency of aquatic, riparian, and wetland resources should also be addressed. If cumulative influences within a watershed have already significantly been compromised, the aquatic, riparian, and wetland resources in that watershed may be further impacted by prescribed fire, and not be able to respond in a positive fashion. The result is aquatic, riparian, and wetland resources that are constantly in a "poor condition", with little resiliency left and little habitat for those species that rely on them.

Sediment production is a common result of fires, both natural and prescribed. The intensity of the fires, steepness of hill slopes, local climatic conditions and local geology all influence the amount sediment that is transported to aquatic, riparian, and wetland ecosystems. Wohl (Chapter 2 in Report 1) describes that sensitivity to changes in sediment supply increases at lower stream gradients where pool-riffle channel morphology is more likely to be present. While sediment may be "produced" from areas with steeper topography and stream channels, they are less sensitive to changes. Rahel (Chapter 2 in Report 1) also identifies these low gradient stream channels as being the most "productive" for fish. Table 2.8 in Report 1 of this assessment identifies the relative sensitivity of stream channels to increases in sediment production. Sixth level HUBs within Clusters 2r and 3r as being "moderately" sensitive to increased sediment supply because of their relatively abundant low gradient reaches. Clusters 1r, 4r, and 5r would be less sensitive, while Cluster 6r is highly sensitive but with very limited area within the Bighorn National Forest boundary.

Influence of Tie Drives

<u>Basin Scale</u>

The Upper Missouri River Basin was one of the last areas in the region to be settled, lagging approximately 40 years behind Colorado and southern Wyoming (Wohl 2001). Thus, the demand for wood for building materials from the Basin did not increase until the early 1900s, which was relatively late in the overall development of the West.

Railroad ties were a key forest product from the Basin, competing with other uses such as construction lumber and timber for mining operations. Demand for ties and other wood products led to widespread and largely unregulated logging led to near deforestation in parts of Wyoming. Tie hacks, loggers who specialized in cutting and hewing railroad ties, tended to cut selectively, but affected forest structure and tree composition. They chose the highest-quality trees, leaving the remaining 'undesirable' trees to reproduce. After felling the trees and hewing them into the proper dimensions, the ties would then be transported out of the forest to mills or rail yards by floating them down streams (fig. 7.21). These 'tie drives' were very destructive to stream morphology because they scoured streambeds and destroyed banks (fig. 7.22), and their effects are still evident in many locations in Wyoming that had historical tie drives (Knight 1994).

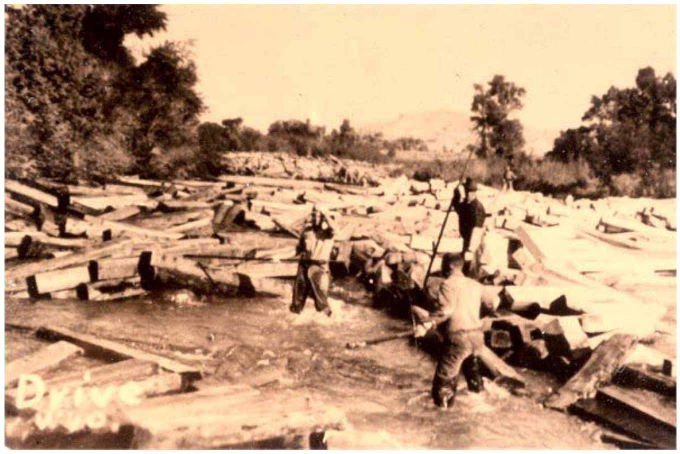

Figure 7.21. Tie hacks floating ties in preparation for a tie drive in a Wyoming stream (photo credit: Wind River Historical Center, Dubois, WY).

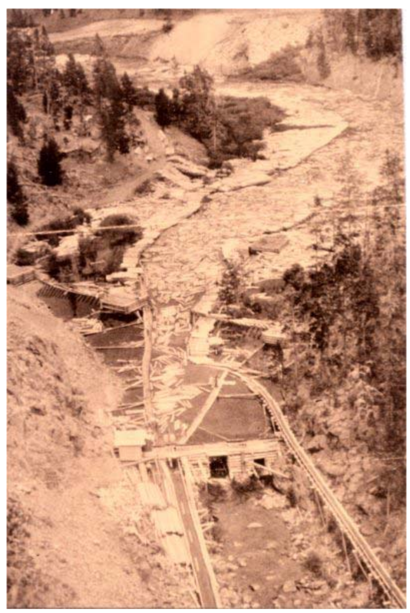

Figure 7.22. Tie jam at Warm Springs, Wyoming (photo credit: Wind River Historical Center, Dubois, WY).

Landscape Scale

Euro-American settlement of the Big Horn Mountains began in the 1880s, coinciding with expansion of railroad lines, and increased the demand for processed timber products. The first mill in Sheridan County, Wyoming, was built at the mouth of Little Goose Creek in 1881, and seven years later a total of six sawmills were operating in the foothills of the Big Horn Mountains (Granum 1990).

Although demand for lumber increased, bringing the product to market was difficult. The timbered area in the Big Horn Mountains was limited, and difficult to access. At the landscape level, effects of past tie drives in the Bighorn National Forest are primarily evident in the Upper Tongue River 4th level HUB (10090101) (fig. 7.23). The prime timber formed a narrow tract only 6 by 15 miles, located between the South Fork Tongue River and Wolf Creek, and extending from the valley of Sheep Creek in the north, to the head of Big Goose Creek in the south (Granum 1990) The location of the town of Sheridan was a convenient place to process and ship wood products to different areas. The Tongue River and Goose Creek are located relatively close to Sheridan, making the operation from cutting to processing a relatively efficient process.

Steep and rocky terrain made even the most easily reached timber extremely difficult to access, and transport of logs to valley mills by wagon or sleigh was generally untenable. One commonly employed alternative was to build a V-shaped trough with a steady downhill grade, fill the trough with water from an adjacent stream, and float the logs to the valley bottoms (Granum 1990). Ties and timbers were also floated downstream in the natural channel (often in conjunction with flumes, fig 7.24), and tie hacks capitalized on high discharge during snowmelt runoff or often built splash dams that when opened sent a surge of water downstream capable of moving entrained timbers. The stream channels often being greatly modified to transport large numbers of logs.

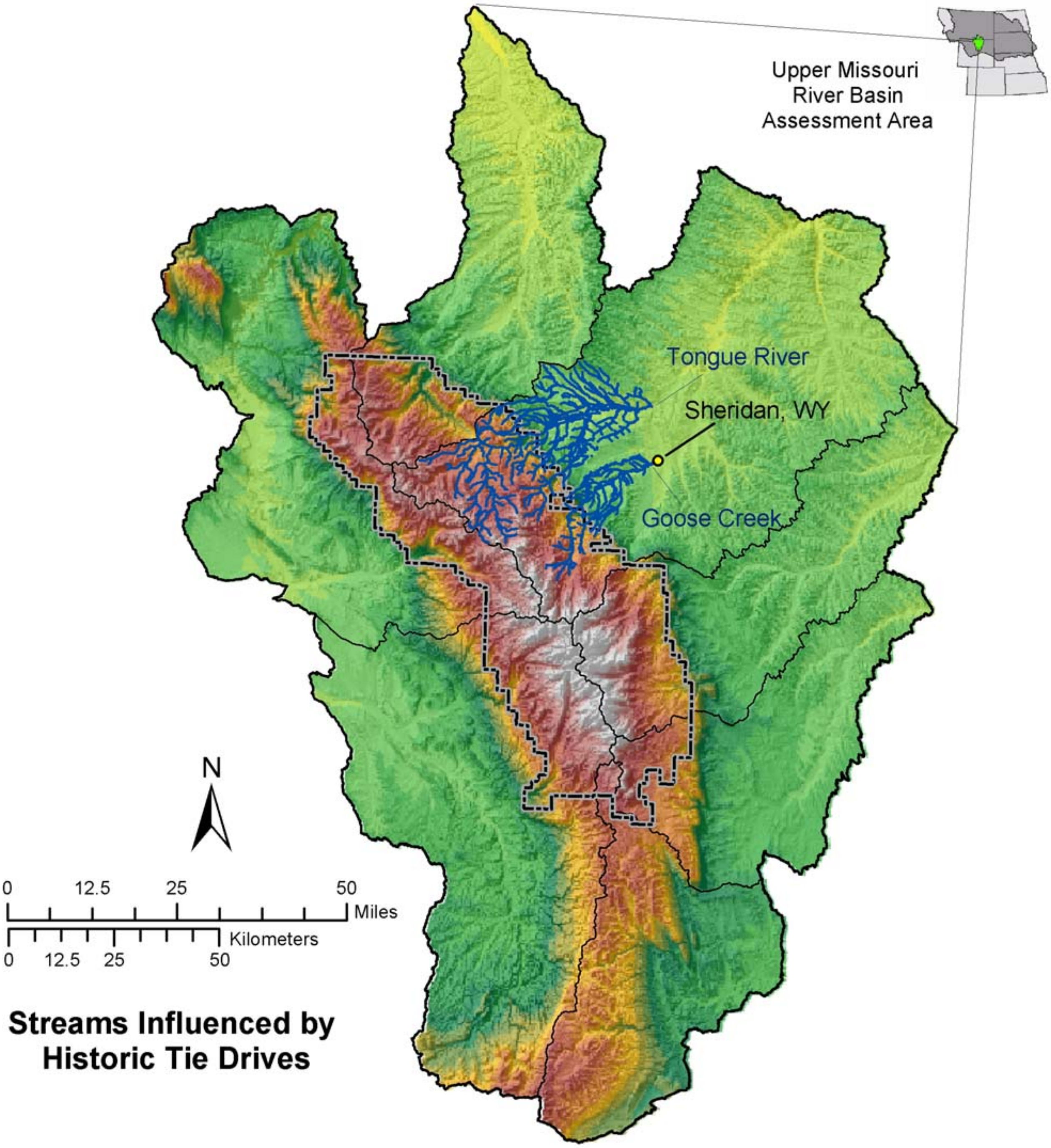

Figure 7.23. Landscape scale of the Bighorn ecosystem showing the two major stream network where tie drives occurred, the Tongue River and Goose Creek. The town of Sheridan was located nearby, where lumber was used for construction and a place to ship wood products to different areas.

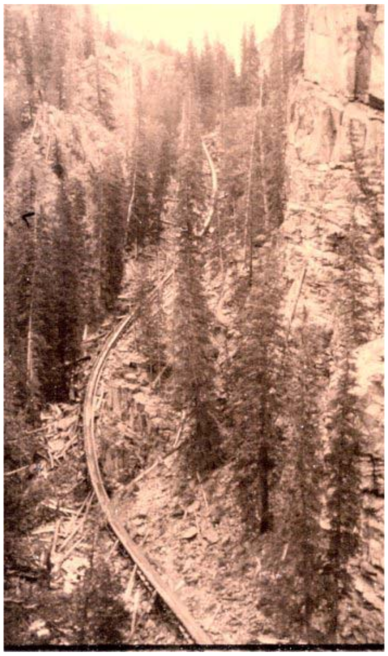

Figure 7.24. Flume used to transport timber from forest headwaters to valley bottoms (photo credit: Wind River Historical Center, Dubois, WY).

Management Scale

Only a qualitative analysis on the effects of tie drives on aquatic, riparian, and wetland resources is possible at the management level because of a basic lack of quantitative information on the extent of habitat influenced by past tie drives. While we can identify 6th level HUBs and stream names where tie drive activities occurred, we do not know the exact length of the influenced streams. Analysis at the site/reach level could identify tie-drived reaches. Changes in channel morphology and riparian plant species could be dramatically different in these areas.

In 1893, a mill was constructed on Sheep Creek in an area with lodgepole pine suitable for railroad ties, and a flume connected the mill to the Tongue River downstream. In addition, blasting and vegetation removal to facilitate spring tie drives modified the Tongue River.

Timber harvest moved deeper into the South Tongue watershed in the early 1900s, and tie hacks constructed splash dams on the East and West Forks of the South Tongue River (fig. 7.25). A total of eight HUBs along the eastern face of the Bighorn National Forest were influenced by tie drives within the Bighorn National Forest boundary.

After 1912 use of flumes and tie drives decreased, because high-quality lumber cut elsewhere was brought to the region via railroad and sawmills located in the foothills of the Big Horn Mountains provided lower-quality timber for general construction and mining. Tie drives probably had acute effects on aquatic, riparian, and wetland flora and fauna, but their influences on habitat structure and function have persisted for decades after the final drives. Direct contact with passing timber during tie drives or mobilization of stream sediments likely caused the direct mortality of fishes, amphibians, aquatic invertebrates and plants, and riparian vegetation. Lingering influences on aquatic, riparian, and wetland resources still evident today because streams subjected to tie drives tend to be wider and shallower, have higher water velocities and increased bed mobility, and less coarse woody debris to form pool habitats compared to unaffected streams. The net result of this habitat degradation and simplification is probably population level declines for aquatic, riparian, and wetland flora and fauna compared to pre-tie drive conditions.

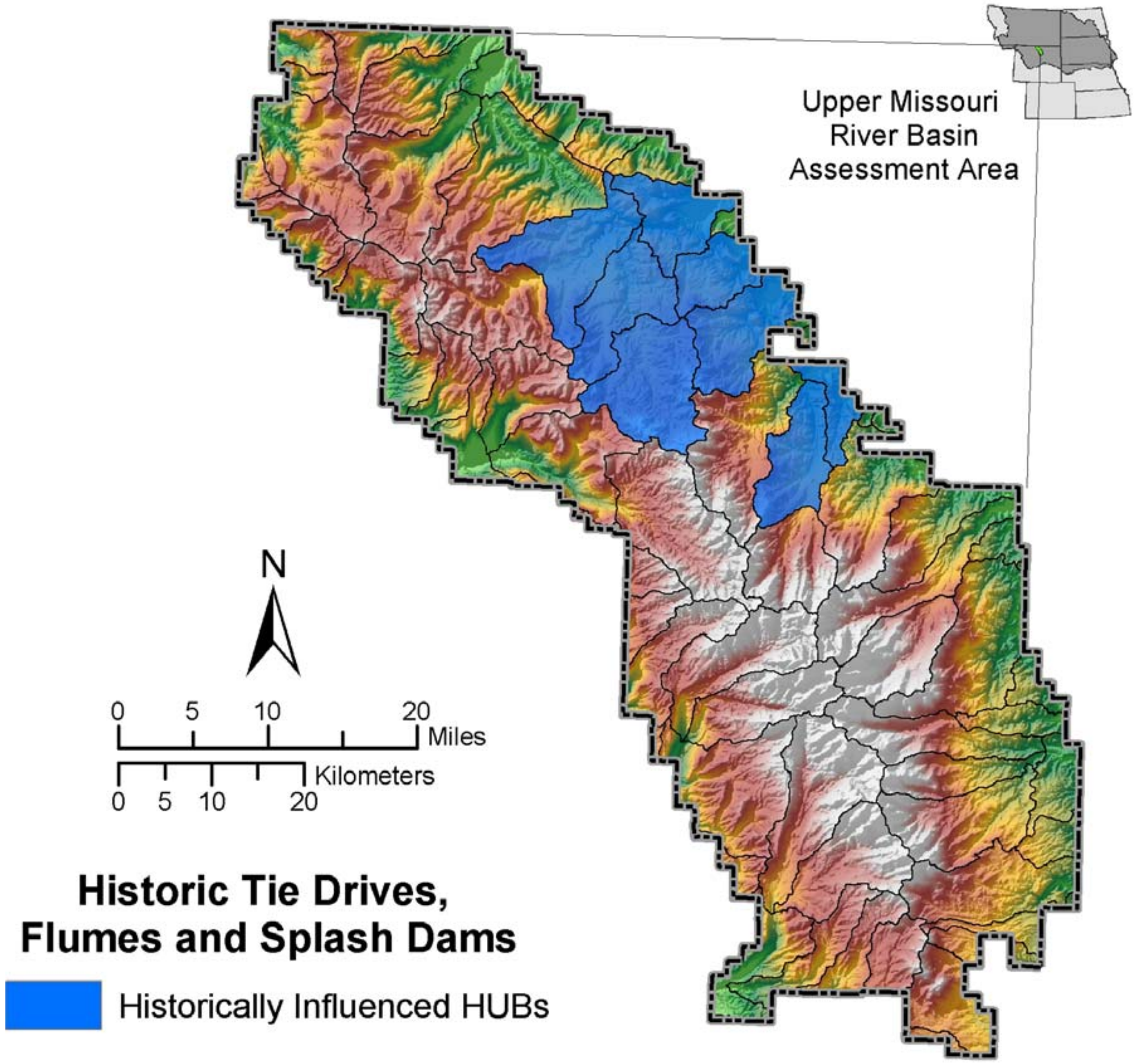

Figure 7.25. 6th level HUBs with reaches of streams and riparian areas influenced by tie drives.

Reach/Site Scale

Inventory and monitoring at the reach/site scale will help determine the extent to which tie drives have affected aquatic, riparian, and wetland resources in the Forest. Specific questions related to effects of historical tie drives are, but are not limited to:

1. How have tie drives:
   a. Altered hydrology (e.g., faster water delivery due to channel simplification and loss of riparian vegetation)?
   b. Caused changes in sediment yield (e.g., increased bedload mobility)?
   c. Caused channel alteration (e.g., changes in channel profile, direct channel modifications)?
   d. Caused direct changes to aquatic, riparian, and wetlands habitat (e.g., habitat simplification, removal of riparian vegetation or coarse woody debris)?
   e. Caused changes in aquatic and riparian diversity, biology, etc.?

Information Needs

In addition to explicitly measuring the extent of stream affected by tie drives, specific measurements to take at the reach/site level in streams affected by tie drives (for potential comparison to unaffected reaches/streams) include:

1. Location of former flumes, mills, and splash dams
2. Channel sinuosity
3. Stream substrate composition
4. Pool/riffle ratios
5. Number of pieces of coarse wood debris
6. Number of trees >20 cm dbh within 50 m from stream banks
7. Abundance and diversity of aquatic, riparian, and wetland flora and fauna (e.g., fishes, invertebrates, amphibians, riparian vegetation).

Management Implications and Relationship to Ecological Drivers

The effect of tie drives on aquatic, riparian, and wetland resources is still being realized today. The best management consideration for these stream systems and associated riparian areas is to work towards increasing the complexity of habitats and diversity and abundance of riparian and aquatic species. Consideration of this management goal should be considered when working in 6th level HUBs with tie drive effects. Active management to increase habitat complexity and resiliency could also be considered. Incorporation of large woody debris, and boulders into the riparian and stream channel could increase the restoration process. Planting of appropriate woody riparian species could also ensure the long-term incorporation of large woody debris into the system.

While the effect of timber harvest could influence wetland ecosystems in the area of tie drives, the primary influence would be to riparian and aquatic ecosystems. The highest influence to these resources would be expected to be associated with high percentages of low gradient stream channels (associated with large riparian areas and increased fish habitat, high productivity (high percentage of calcareous geology), and warmer climatic conditions (rain-and-snow hydrology). Sixth level HUBs within Clusters 2 and 5 would compromise the areas with the potential for the highest productivity, Table 7.6 illustrates the number of HUBs associated with tie drives, and those most likely to effect instream and riparian production.

Based on these results, it may be valuable to initially prioritize stream and riparian areas within 6th level HUBs by the cluster they are in. In addition, presence or reintroduction potential of rare species, and cumulative effects of management would be important.

Table 7.6. Clusters containing historic tie drives and relationship to the "potential" for restoration from an aquatic and riparian production standpoint.

Clusters Containing Tie Drives	Number of 6th Level HUBs	Potential for Instream Restoration*	Potential for Riparian Restoration**
1r	3	Low	High
2r	2	High	High
3r	2	Low	Low
6r	2	Low	Low

**- Based on potential to increase habitat and populations of coldwater fish and general aquatic productivity, from Rahel and Poff (see Chapter 2 in Report 1).*
*** - Based on potential to improve/increase riparian communities and function, from Cooper (see Chapter 2 in Report 1).*

Influence of Livestock Grazing

This section provides an evaluation of the influence of domestic livestock management activities on the Bighorn National Forest and associated aquatic, riparian, and wetland ecosystems.

Livestock grazing has the potential to have a significant influence on riparian, wetland, and aquatic resources if it is not managed properly (Binkley and Brown, 1993). There are numerous references to document these potential influences although most references discuss impacts from improperly managed livestock grazing rather than from proper management (Kauffman and Krueger 1984; Buckhouse 1981; Meehan and Platts 1978; Binkley and Brown, 1993; Larson et. al. 1998).

Livestock grazing may also be used to positive effect when managed properly and when focused on meeting well defined interdisciplinary objectives. Grazing can: stimulate new growth of both herbaceous and woody species; increase total production; provide increased palatability and nutrient quality to other animal grazers; increase herbaceous plant density, and alter habitat structure and composition to meet specific species objectives (such as managing for specific threatened or endangered species habitats or alteration of habitat relationships to favor certain species) (Krueger and Anderson, 1985).

Basin and Landscape Scales

The lands within the Bighorn National Forest and the surrounding watersheds have been grazed by wild ungulates for thousands of years (Knight 1994). As a result, the native plants and plant communities have evolved to tolerate some level of intensity, timing, frequency, and duration of grazing and browsing. Throughout time, deer and elk would have moved up and down elevational gradients in seasonal migration patterns attuned to the weather and the growth or dormancy of preferred plant species. Buffalo occupied the plains and lower slopes and even moved into the higher open valleys. Large wild ungulate populations have fluctuated over the past century with some species being eliminated (bison) or drastically reduced only to recover to historically high levels (elk), and others establishing resident populations where there likely were none historically (e.g., moose) (Murray 1980). Livestock grazing probably began with the Native Americans. Once Native Americans acquired the horse, they would have grazed their livestock across this landscape with winter encampments in the lower valleys, summer camps occurring in the high mountains, and frequent nomadic movements of bands or tribes in response to resource (food and shelter) availability, and tribal tradition. Effects of the horse use on the natural resources would likely have been localized and, across the landscape, would have been a relatively minor landscape level impact. Euro-American settlers brought livestock with them as they settled in the valleys and plains surrounding the Big Horn

Mountains (Knight 1994). At first, livestock numbers would have been limited primarily to pack and saddle stock and a few animals needed for subsistence. However, by the late 1800s (circa 1890) (Meyer and Knight 2003) large herds of livestock were brought into and through the Big Horn Mountains. From this time on into the early 1900s heavy and improperly managed livestock grazing became the norm. Livestock, especially sheep, were allowed to graze up-slope as the snow receded, following the green-up of the forage species. They then frequently remained on the mountains until snow drove them down. At times significant numbers of cattle and horses moved off of the Crow Reservation in Montana and onto the Forest (Meyer and Knight 2003).

At their peak, livestock numbers were extremely high on the Bighorn National Forest (e.g., approximately 3,000 cattle and 450,000 sheep in 1898; Meyer and Knight 2003). Livestock operator management consisted primarily of trying to get to the forage before other livestock owners could do so. Obviously the resources were not adapted to support this intensity, timing, duration, and frequency of grazing effects, and severe damage was experienced and documented in many of the more accessible areas (Walcott 1899; Meyer and Knight 2003). Often these impacts took the form of changes in plant species composition, accelerated erosion, down cutting of streams, lowered water tables, and declines in production. These impacts were compounded by earlier removal of beaver and extended drought cycles that hit much of the western U.S. during this period. With the extremely heavy stocking, many areas that are not today considered as suitable and capable rangeland, and therefore are not grazed by livestock to any appreciable extent, would have experienced impacts. However, the areas most heavily impacted would have been the more accessible areas, e.g., the riparian valley bottoms and wetland areas, flatter slopes, and the open grasslands, shrub lands, or forested lands with easy access and available water.

With the advent of the Forest Service and the establishment of the Bighorn Reserve in 1897, improved livestock management slowly came to the Bighorns. At first, control was very limited and livestock numbers may have actually increased to over 30,000 cattle and 374,734 sheep by 1904 even while grazing seasons remained quite long, limited primarily by snow (Meyer and Knight 2003). Actual use was probably even greater as trespass was a significant problem.

Over time, improvements in management have focused on bringing permitted numbers and seasons in line with grazing capacity, development of improvements such as fencing and water sources to better control livestock, and implementation of the latest, albeit frequently evolving, science. By 1931 actual cattle use was reported at 32,352 head for approximately a 3.5-month season and sheep use at 126,765 head for approximately a 2.5-month season. Note that over time cattle were replacing sheep as the preferred permitted livestock while the total animal unit months under permit (AUMs) declined. Permitted livestock grazing has continued to decline during the past 4 to 5 decades, due significantly to reductions in sheep grazing, primarily associated with operator economics. More recently, implementation of Land and Resource Management Plan (LRMP) standards focused on meeting desired conditions has resulted in reductions in authorized and actual use. Currently (as of 2001) there are 21,187 head of sheep (14,349 AUMs) permitted for about a 2.5-month grazing season and 29,229 head of cattle (119,359 AUMs) permitted for about a 3 to 3.5 month grazing season. There are also 353 head of horses permitted for 1,335 AUMs (Forest Service data, Bighorn National Forest).

Table 7.7 and Figure 7.26 show approximate and very general information regarding livestock numbers. It should be noted that in the early years of grazing permit administration, trespass could have added greatly to the estimated numbers. In addition, it took many years for the actual grazing seasons to get shortened from the situation where the livestock ran from snowmelt to snowfall, to where they are today at 2.5 to 3.5 months on average. Changes in permitted numbers cannot tell the entire story as the change in season was equally, or more probably of somewhat greater importance in terms of livestock influences on aquatic, riparian, and wetland resources. In interpreting the table below, note that in terms of forage use, one mature cow is generally considered to be equivalent to five sheep.

Table 7.7. Approximation of livestock trends. Note that numbers represent rough estimates, and should be used to define trends rather than indicating exact stocking rates. (Data from Meyer and Knight 2003 and various other U.S. Forest Service sources).

Year	Cattle (head)	Sheep (head)
1870s	Minor	Minor
1898	3,000	450,000
1904	30,000+	374,734
1912	34,000	105,000
1916	36,000	108,000
1918	43,000	113,000
1919	48,500	117,000
1924	29,000	94,000
1931	32,352 (Season reduced to 3.5 mo.)	126,765 (Season reduced to 2.5 mo.)
1980's	33,000	58,000
1985	33,000	58,000
2001	29,229	21,187

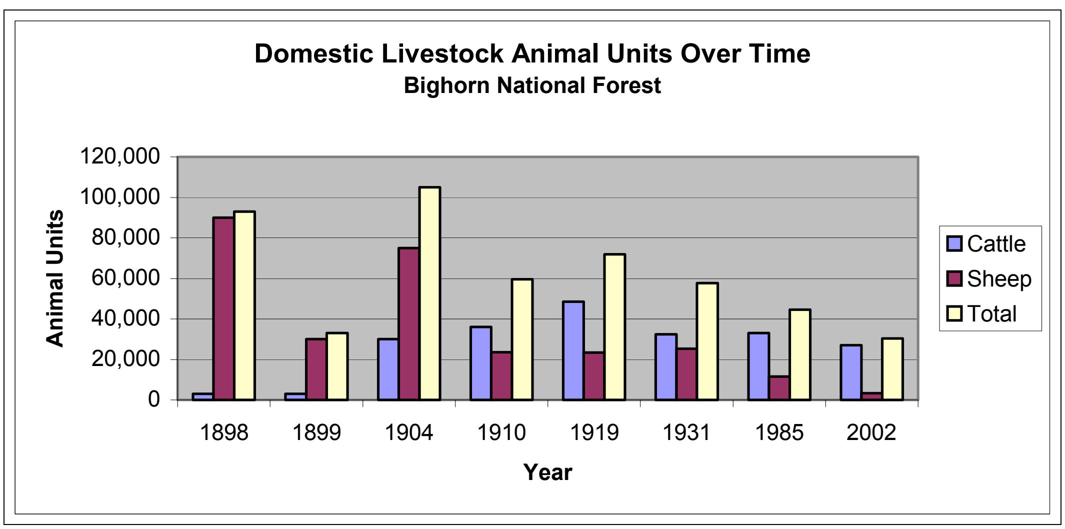

Figure 7.26. Domestic livestock animal units for cattle, sheep, and total (cattle and sheep combined) on the Bighorn National Forest over time (Meyer and Knight 2003; Murray 1980).

Landscape and Management Scales

Portions of the Bighorn National Forest and the surrounding watersheds are stocked by livestock today at rates that are considered to be relatively high (USFS data for Rocky Mountain Region). For reference, locations of livestock grazing allotments as used throughout this assessment are presented in Figure 7.27. Approximately 83% of the area within the Bighorn National Forest is in active allotments (e.g., there is a term grazing permit in effect which authorizes livestock use of the specified allotment), with the area associated with the Cloud Peaks Wilderness having the largest extent of area with no current active allotments.

Management has intensified over the past few decades on the Bighorn National Forest, although not uniformly across the landscape. The result being that some allotments are well and intensively managed and others continue to need improvement. There are a few active sheep allotments still remaining although much of the area suited to sheep grazing has been vacated and the allotments closed. Most of these vacant (e.g., there is no permit currently in effect but the allotment remains available for grazing upon appropriate decision) and closed allotments (the allotment is no longer available for permitting of livestock use) came into that status for economic reasons when the livestock operators determined that it simply was not economically feasible to continue to operate on those lands and waived (relinquished) their permits back to the Forest Service. Today, most of the Bighorn National Forest permitted use is by cattle.

Forest reports indicate that of the 333,020 acres currently identified with rangeland management objectives (out of a total of approximately 917,970 acres in allotment status), 128,965 acres (39%) are meeting or moving toward LRMP objectives, 37,969 acres (11%) are not meeting or moving toward objectives and 166,086 acres (50%) are of undermined status (USFS Allotment Status data). This by no means represents the total allotment acres but is presented as an indication of current management status. Note that a significant portion of the landscape does not have current data to indicate status.

In terms of riparian conditions, the latest Forest reports indicate that there is a total of 57,572 riparian acres identified to date. Of this, 12,865 acres (22%) are shown as meeting or moving toward LRMP objectives, 11,561 acres (20%) are not meeting or moving toward objectives and 33,146 acres (58%) are of undetermined status. This information for 'percent meeting' is likely to be low, as many of the riparian areas that are less accessible to livestock, have not yet been evaluated and many of these would likely be found to be meeting or moving toward objectives. These figures are very difficult to evaluate because riparian areas are subject to a wide variety of influences. This means that in most instances, a less than satisfactory condition is the result of a number of past and present activities. Livestock grazing may be one factor but it is seldom the sole factor. Often roads are major impacts and in some areas, recreational activities, large wild ungulates, and past activities such as tie drives may be the major continuing influence.

Livestock Preference Model

Domestic livestock are not randomly distributed across the landscape. In order to assess the possible distribution of permitted livestock across the landscape, and to allow for an assessment of areas most likely to experience livestock grazing influences, a model was developed to assess livestock preference. The parameters of this model may be modified to reflect changed or different scenarios. The model first uses the LRMP suitability and capability process to identify areas across the landscape where livestock grazing may be appropriate (e.g., the land is determined to be both suitable and capable for livestock grazing). This suitability and capability process includes elements, which account for the long-term health and sustainability of the ecosystems, and discounts any areas where livestock grazing has been determined to be inappropriate for any of a variety of reasons.

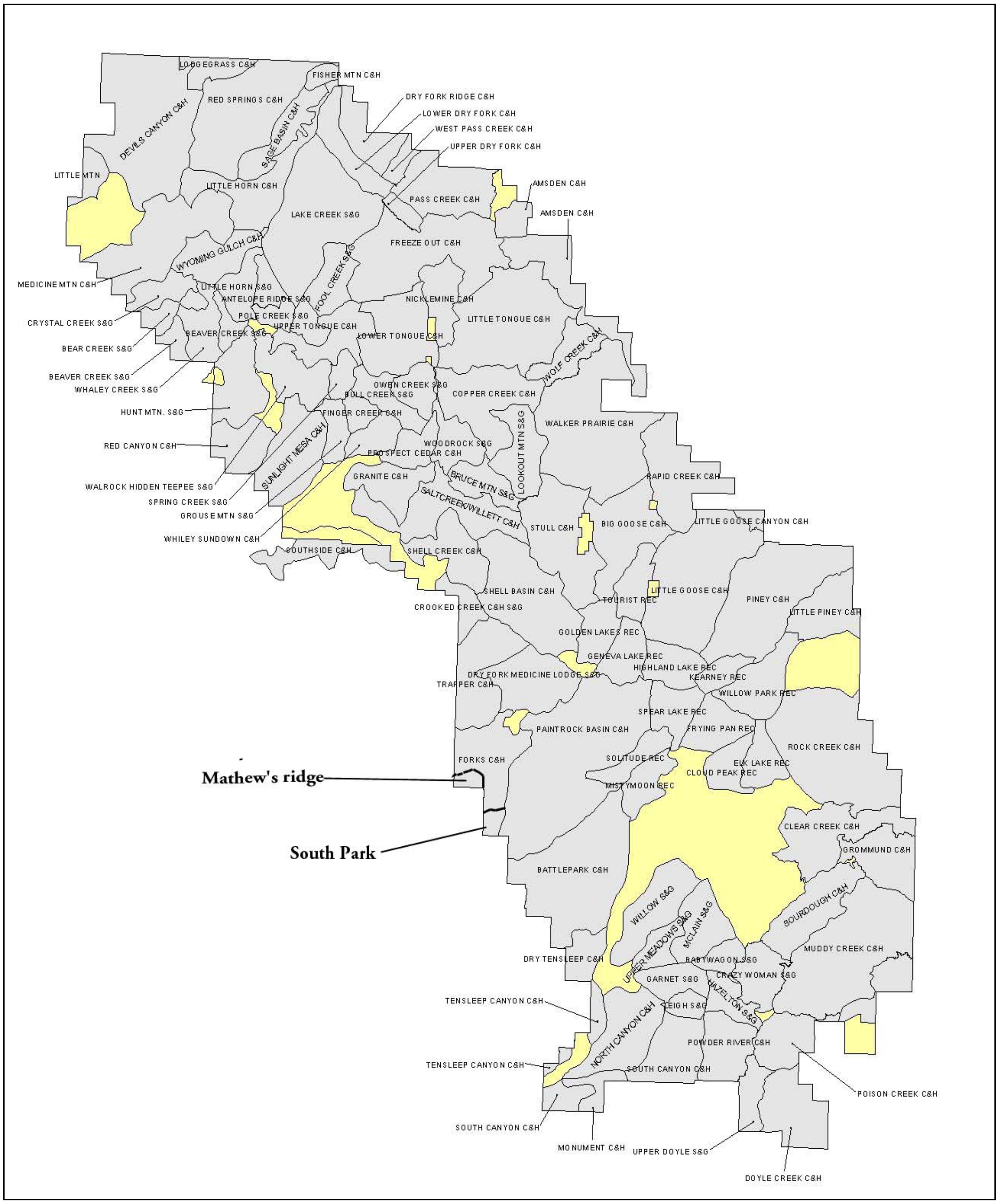

Figure 7.27. Current livestock allotments, both active and vacant for cattle and sheep on the Bighorn National Forest. Yellow blocks are not in allotment status.

The model then takes this suitability determination and overlays it with allotment status, as active, vacant, or non-allotment, permitted livestock kind, as cattle or sheep, and assesses livestock preference in terms of three factors that are key indicators of livestock preference (slope, distance to water, and canopy cover). Although other factors could be locally important, the model was run using these three components as a reasonable means of arriving at a general assessment across the entire landscape. The end result is a set of maps, with associated data tables, showing where livestock use could be expected, expressed in terms of: High Preference, Moderate Preference, Low Preference, None (no preference), and Non-allotment status. Where actual use mapping is available, this would be a preferable alternative to the preference model; however, this information is not generally available for most areas.

The findings of this modeling exercise across the landscape of the Bighorn National Forest indicate that a large part of the landscape is in the "Non-Allotment", and preference-rating category of "None." This means that of the total 1,107,670 acres of the Forest (1985 LRMP, Bighorn National Forest), approximately 185,848 acres are in non-allotment status. Of the active and vacant cattle and sheep allotments, approximately 798,319 acres (87%) would be expected to show little to no influence by current livestock activities (e.g., they are non-suitable and/or show a preference of "none").

Only 11 percent of the landscape of the Bighorn National Forest would be expected to have current livestock influences to any appreciable degree (e.g., a modeled preference rating of moderate or high). This is significant in that it puts livestock grazing into a landscape perspective. While livestock grazing allotments cover large extents of the landscape on a map-area basis, the on-the-ground area actually affected by livestock grazing to any significant extent is much lower.

As we lack information for the private lands within the basin area, it was not possible to assess potentials for effects to those areas. Private lands tend to be managed more intensively for specific uses. It would be expected that private lands managed for livestock production, or for rural home sites with associated livestock use, would show greater potential for effects than would be expected on the National Forest.

On the approximately 718,284 acres within active cattle allotments, 24,143 acres (3% of the active cattle allotment acres) model as a high preference; 50,363 acres (7%) a moderate preference; and, 12,195 acres (2%) a low preference (fig. 7.28). In other words, only 12% of the acres within active cattle allotments would be expected to show effects of livestock management to a high, medium, or even a low extent. In general the low preference acres would be expected to have only minimal livestock activity and therefore limited potential for influences. The areas identified as high or moderate are where livestock activity is most likely to occur based on the model, and where the potential for livestock influences is the greatest. In general, livestock prefer the lower gradient areas near water. Frequently these conditions are coincident with riparian and wetland areas. This would tend to indicate a strong correlation between livestock preference and certain riparian or wetland areas with habitat characteristics preferred by livestock. This is especially true for the low gradient, open canopy, minimal rock/deep fine textured soil sites, and would be significantly less true for the steeper gradient rocky and/or dense canopy cover sites.

Note that there is variability inherent in this model that is going to be magnified at the site scale. Additional validation will need to occur in order to determine its utility at localized scales.

On the 26,542 acres in vacant cattle allotments, only a total of 569 acres (2%) of the total would be considered to have a potential for high, moderate, or low livestock effects if the area is ever permitted.

On the 150,267 acres within active sheep allotments, 25,703 acres (17%) model as high preference; 5,918 (4%) a moderate preference; and, 621 (trace) low preference (fig. 7.29).

Within the 26,729 acres of vacant sheep allotments, 3,203 acres (12% have a high preference; 734 acres (3%) a moderate preference; and, 54 acres (trace) a low preference indicating that only about 15% of the total acres within vacant sheep allotments would be modeled as having a potential for livestock effects if the area is ever permitted.

This modeling indicates that livestock effects are relatively localized and that much of the landscape is not likely to be significantly affected by current management. This is not to say that historical activities did not affect some of these areas, as it is highly likely that impacts did occur during the era of heavy stocking and limited management, and many of these affects may still be carrying foreword. Nor is it an indication of the degree of actual effects in specific areas (specifically high and moderate preference areas and areas too small or unique to be picked up by the model). Site-specific inventory, analysis, and planning will need to focus on localized

Table 7.8a. Cattle Active Allotment Preference Rating.

	Non-suitable	None	Low	Moderate	High	Total
Acres	588,533	43,050	12,195	50,363	24,143	718,284
Percent	82	6	2	7	3	100

Table 7.8b. Sheep Active Allotment Preference Rating.

	Non-suitable	None	Low	Moderate	High	Total
Acres	115,558	2,467	621	5,918	25,703	150,267
Percent	77	2	T	4	17	100

Table 7.8c. Cattle Vacant Allotment Preference Rating.

	Non-suitable	None	Low	Moderate	High	Total
Acres	25,646	327	36	418	115	26,542
Percent	97	1	T	2	T	100

Table 7.8d. Sheep Vacant Allotment Preference Rating.

	Non-suitable	None	Low	Moderate	High	Total
Acres	22,573	165	54	734	3,203	26,729
Percent	85	T	T	3	12	100

influences and on validation of the model

Tables 7.8a-d show acres and percent of active allotments by predicted preference for cattle and for sheep. Obviously preference ratings are not evenly distributed across the landscape. Some areas, particularly those open low gradient riparian areas and meadows, aspen types, and grasslands on shallow slopes near water tend to be high preference while steeper areas and areas with dense conifer canopy rate out as low to none. The maps (figs. 7.28 and 7.29 and associated tables 7.8a-d, and 7.9) provide useful tools in assessing the potential for effects across the landscape and provide information for more intensive investigation into specific areas, with a likely focus on the high or moderate preference areas.

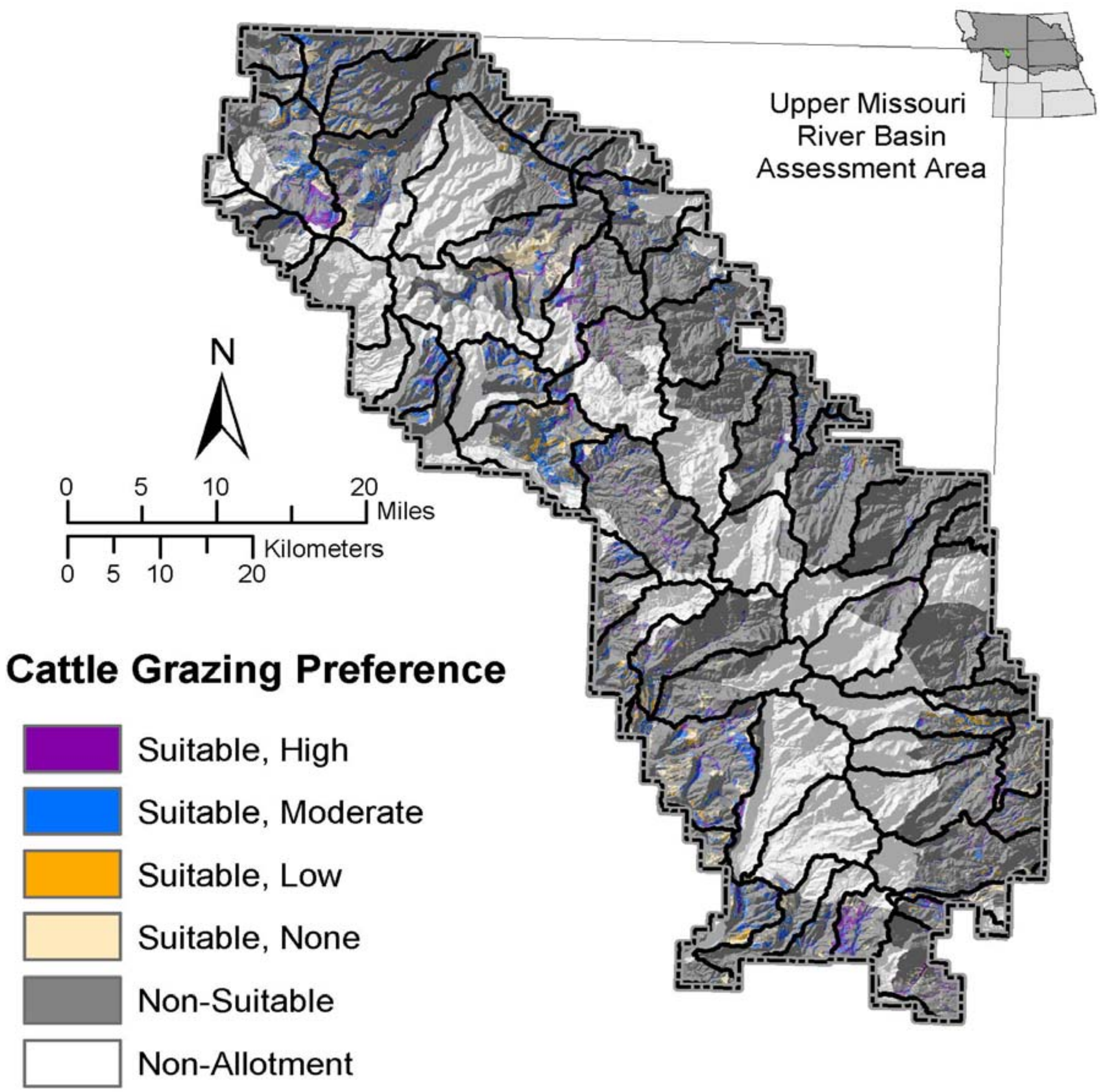

Figure 7.28. Predicted Cattle Preference Model, which portrays suitable rangeland with varying degrees of modeled livestock preference.

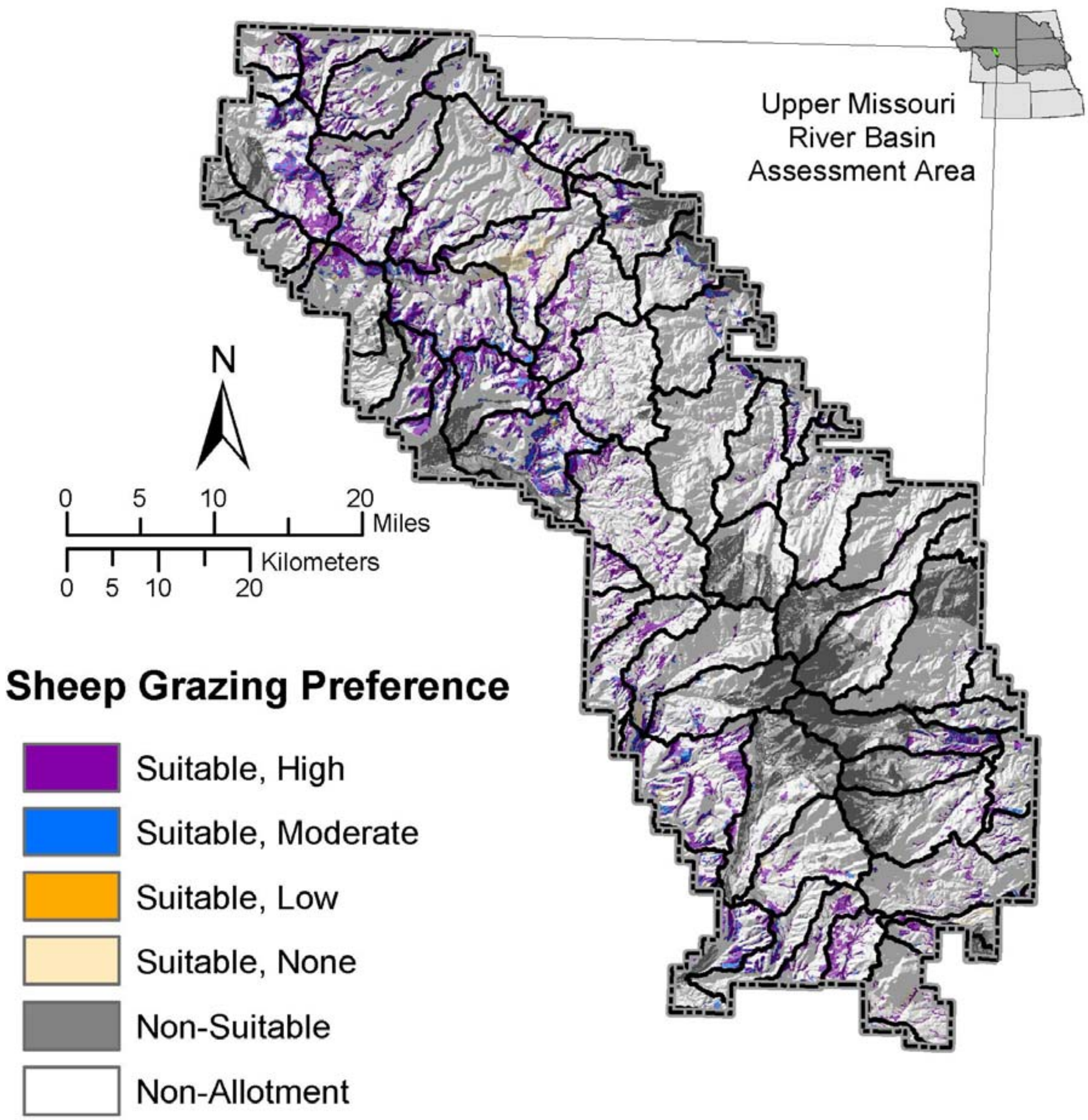

Figure 7.29. Predicted Sheep Preference Model, which portrays suitable rangeland with varying degrees of modeled livestock preference.

Stocking Density

The next step in this modeling process is to model permitted AUMs on active allotments (separately for cattle and for sheep), and then on 6th level HUBs (separately by valley bottom acres and by suitable wetland acres). This part of the assessment focuses on the potential influences of permitted livestock stocking density on aquatic, riparian, and wetland resources. Allotments or 6th level HUBs with greater stocking densities (expressed as a low number of suitable acres per AUM) would be areas where management would want to carefully assess whether or not the current stocking density was appropriate when considering the current or potential intensity of management. Highly productive meadows or parks would be expected to be capable of supporting a relatively high stocking density while maintaining long-term health and sustainability under proper management. On the other hand, low productivity grasslands on shallow soils or low productivity conifer types, would be expected to be capable of maintaining only a relatively low stocking density (e.g., a larger number of acres per AUM) under proper management if they are to be able to maintain their long term health and sustainability.

In addition to stocking density expressed against suitable acres on an allotment basis, the assessment also evaluates stocking density against suitable valley bottom acres and wetlands as a measure of the potential for livestock influences to the aquatic, riparian, and wetland resources.

Table 3.45 displays stocking densities by HUB for cattle and for sheep. The table also shows stocking densities for suitable acres and for suitable valley bottom acres separately. In those HUBs containing both National Forest Service lands and outside lands, the figures should be used with caution because we lack information regarding stocking densities on the non-National Forest Service lands. Omitted from the table are HUBs that are entirely outside of National Forest Service lands because of the lack of stocking information for those lands.

In general, the stocking densities for specific allotments on the Bighorn National Forest appear to be relatively high, especially for select cattle allotments (fig. 7.30 and table 7.9). If this high stocking density is not mitigated by intensive management systems, this could be an indicator of potential problems. In addition, if the high stocking density is compounded by other factors such as high large wild ungulate use, or past impacts such as railroads, roads, or heavy logging these areas would likely be areas of concern. This may indicate a need to focus management attention on those high stocking density allotments to determine whether or not management intensity is sufficient to sustain the high stocking densities while providing for the long term health and sustainability of the resources.

A separate evaluation relates the stocking densities within a specific HUB based on: a) the percent of the valley bottom acres; and b) the percent of the wetland acres, as they are associated with high stocking density allotments. This assessment allows for a focus on those HUBs where the valley bottom or wetland areas may be subject to livestock influences relative to high stocking densities. This model is a landscape scale model and will not pick up site-specific variations. It is used only to portray landscapes where there may be concerns. Site-specific assessments will be needed to determine local conditions. This modeling assessment is shown in Figures 7.31 and 7.32 with associated data in the appendix.

The data shows that some HUBs (shown primarily in purple but also including a few of the higher value HUBs shown in blue, figs. 7.31 and 7.32) have a high percentage of their valley bottom and/or their wetland acres located within allotments identified as having high stocking densities. This does not indicate that any specific riparian or wetland is heavily stocked, especially where sheep allotments are concerned, but is simply a predictive model of areas that may be of concern. In general, any suitable acres per AUM values of less than 4.0 could be cause for concern. On most landscapes, stocking densities significantly greater than 4.0 acres per AUM should be expected under sound management and proper stocking (note: the lower the value shown as acres per AUM value, the higher the stocking density). On a site-specific basis, high stocking densities could be appropriate if there are substantial acres of highly productive rangeland in the area relative to the amount of authorized AUMs. This model is simply a means of displaying potential areas of concern.

Figure 7.30 portrays stocking densities by allotment. Showing stocking density by active allotment gives a current picture of potential concerns regarding the level of stocking on suitable rangelands. Figures 7.31 and 7.32 portray the percent of the valley bottom and percent of the wetland within the HUB that is located within allotments with high stocking densities. The color distinctions in Figures 7.31 and 7.32 simply divide the total number of HUBs into thirds and do not coincide with logical breaks for an evaluation of high, moderate, or low stocking densities. However, in most instances, all of the purple colored HUBs could be of concern, as could the upper tier of blue colored HUBs (see data in table 3.46 regarding specific details for each HUB). Note that frequently, allotment boundaries and HUB boundaries do not coincide. Therefore, a specific HUB can contain both areas that are stocked at a high density and areas that are stocked at a low to moderate density, and possibly even areas with no stocking.

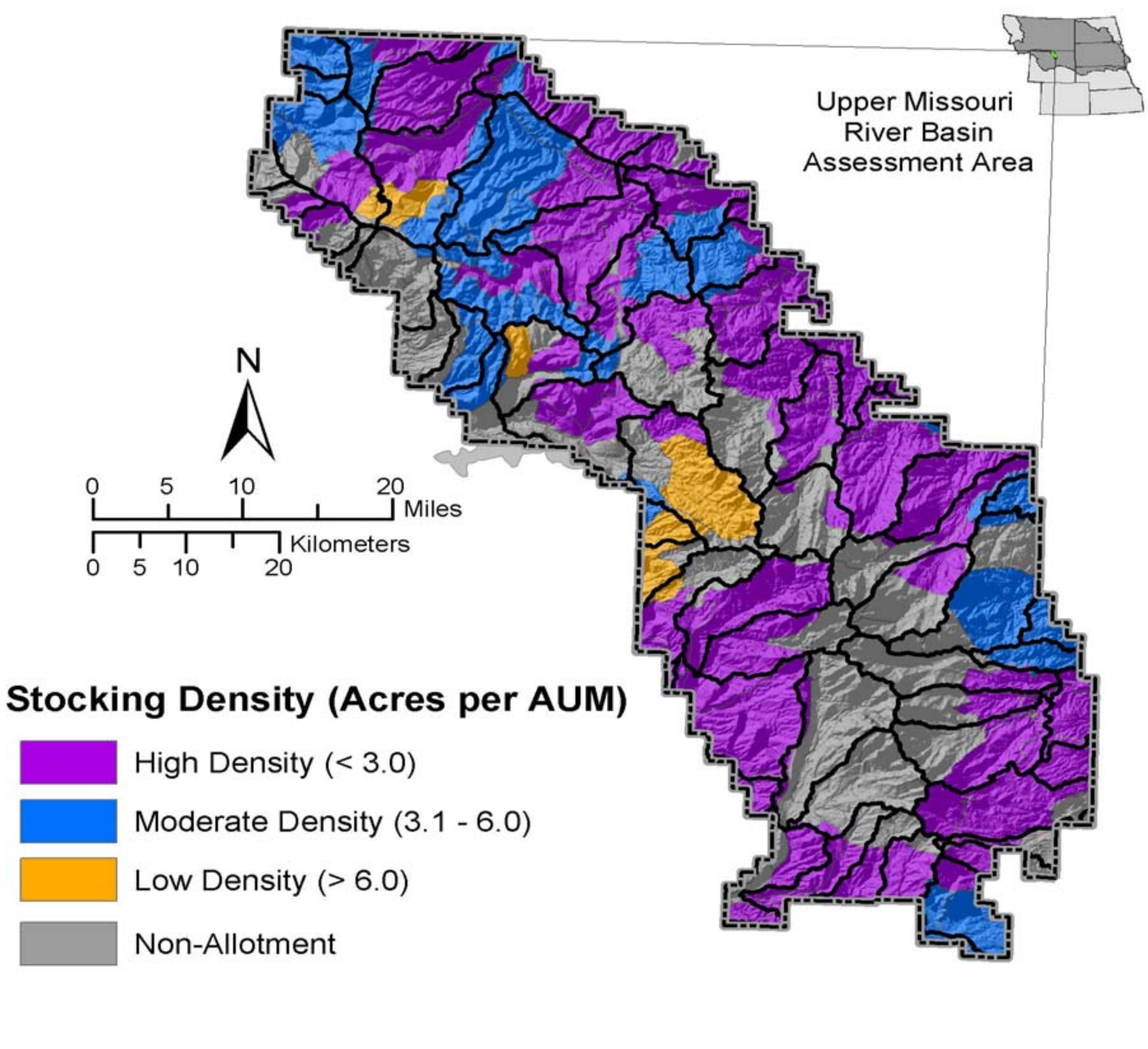

Figure 7.30. Cattle and sheep allotments and stocking density expressed as suitable acres per AUM.

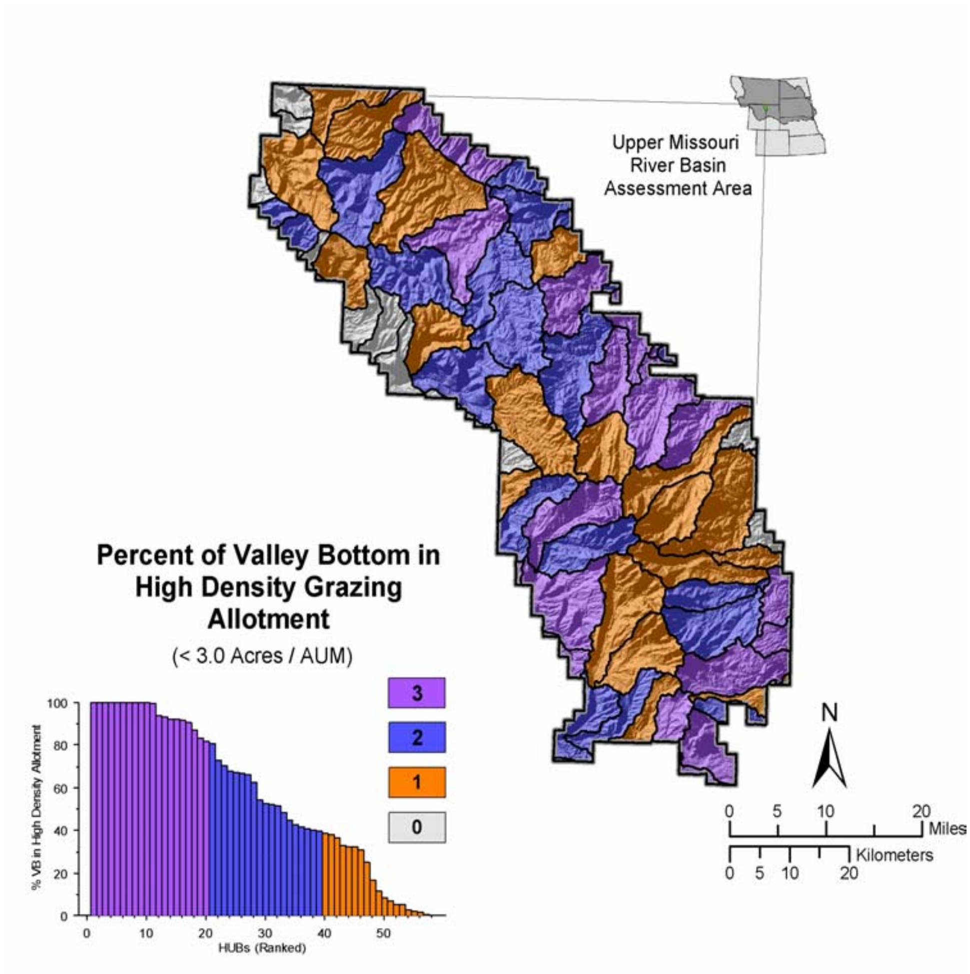

Figure 7.31. Percent of the valley bottom falling within high stocking density allotments (<3.0 Acres/AUM).

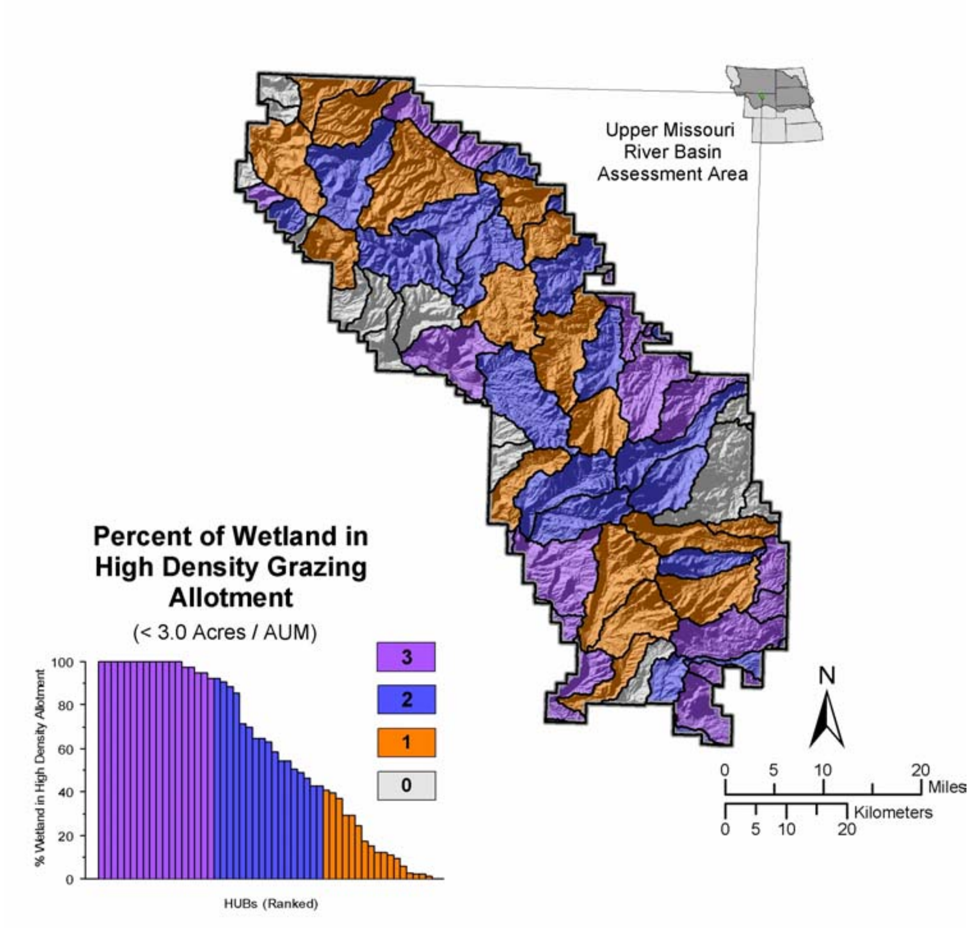

Figure 7.32. Percent of wetland falling within high stocking density allotments (<3.0 Acres /AUM).

Reach/Site Scale

When evaluating the influences of livestock grazing at the reach/site scale, the following data collection methods should be considered:

1. Residual stubble height over time.
2. Green-line cross-section and woody retention on selected reference areas of interest.
3. Invasive species inventory relative to livestock grazing influences.
4. EPA stream bank stability rating relative to livestock influences.
5. Proper functioning condition assessment as the findings relate to livestock management practices.
6. Channel morphology changes relative to livestock influences.
7. Water quality and/or macroinvertebrate indexes as the findings relate to livestock management practices.
8. Degree to which terms and conditions from the grazing permit (and associated plans or instructions - such as allowable use, pasture timing requirements, etc.) are met.

Management Implications and Relationship to Ecological Drivers

Historically, improperly managed livestock grazing impacted many landscapes. In some instances, these impacts carry foreword to today and can be seen in down cut stream channels and altered plant communities, especially on low gradient riparian hardwood communities. For the most part, current influences of livestock grazing are localized and are limited on a landscape basis. However, certain aquatic, riparian, and wetland areas continue to show impacts. Frequently these are the lower gradient areas both with historical carry-over effects and/or current influences from other anthropogenic activities (recreation, forest management, road management, big game, invasive species, and so forth).

In addition to livestock grazing, there are many other anthropogenic influences on the landscape that have occurred historically, and in some cases continue to occur today. These influences act cumulatively with livestock management in terms of effects on resource conditions and trends.

Livestock grazing (and in some instances, grazing by large wild ungulates) tends to have the greatest influence on riparian and wetland areas that are: low gradient; fine textured soils with a minimal amount of rock, cobble, or boulders; open canopy or low shrub vegetation types; and, have available water (although there may be some avoidance of standing water areas). These factors are dependent on the timing of the use, the kind of livestock (sheep vs. cattle), the intensity of grazing use, the duration and frequency of grazing; and, the associated management practices, including especially the level of permittee interest and involvement.

This potential for livestock influences correlates with certain riparian and wetland clusters (see the Ecological Driver Analysis Chapter in Report 1 for characteristics of specific clusters). Relative to livestock grazing, management scale riparian clusters with a high percentage of low gradient systems (Riparian Clusters 3r, 5r, 6r, and to a lesser extent 2r), and with non-calcareous geology (Riparian Clusters 1r, 3r, 6r, and portions of 2r) would be the most sensitive to grazing influences on hydrology and sediment. Of these clusters: Cluster 6r occurs predominantly off of the Forest or only along the very lower edges in the northwest and northeast with much of this area in non-allotment or vacant status; Cluster 2r occurs only along the very southern edge of the Forest and at one HUB on the west side with most of this area in active allotment status; Cluster 1r occupies a large part of the upper elevations with a significant part in non-allotment or vacant allotment status; Cluster 3r occupies mid elevations on the east slope with one HUB on the west side, most of which is in active allotment status; and, Cluster 5r occupies the lower Forest boundary along the west side and a significant acreage within the northern portion of the Forest where most of the area is in active allotment status. The information contained in the Ecological Driver Analysis Chapter (see Chapter 2 in Report 1) regarding the characteristics of each cluster can be used in conjunction with the preference model and the stocking density model to focus administrative attention on those areas most likely to experience livestock influences on clusters with the greatest potential for hydrological or sediment influences by livestock.

Of the seven management scale wetland clusters identified for the Bighorn assessment area, Cluster 7w is located predominately off of the Forest. Of the remaining six clusters, Cluster 1w dominates the high elevation, non-calcareous and un-glaciated ridges with glaciated valleys. This cluster contains significant riparian and wetland areas. This cluster is very sensitive to management activities that affect hydrologic or sediment regimes. Although livestock does not graze much of this cluster, the lower elevations are within active allotments. Cluster 2w occupies high elevation, non-calcareous areas without glacial history. Significant portions of this cluster are within active grazing allotments. This cluster supports large amounts of groundwater-fed wetlands. Although not highly sensitive to management effects on sediment or hydrology, it can be seriously affected by activities that alter groundwater flow. Cluster 3w occupies southeastern mid-slope sites with much of the cluster falling within active allotments. These areas are predominantly non-calcareous and un-glaciated with large percentages of the riparian areas being associated with stream systems. They are highly sensitive to changes in flow regime and can be affected by livestock influences to vegetation and stream banks. Cluster 4w is found on the southwestern side of the mountains in calcareous, un-glaciated areas along the Forest fringes. Although small in size within the Forest, much of the area is within active allotments. It has a low proportion of wetlands and meadows but a high proportion of stream related riparian systems, many with intermittent flow. These areas are very sensitive to changes in flow and can be influenced by livestock effects to vegetation and soils. Cluster 5w is found in the north-central Big Horn Mountains with mostly calcareous and un-glaciated characteristics. Portions of these areas are relatively low gradient with broad valleys and a high proportion of lakes and meadows (groundwater driven systems). These areas can be highly sensitive to management influences to vegetation, soils, water flow, and sedimentation. Most of this area is within active allotments, most of which is permitted for use by sheep. Sheep tend to be more effectively managed in these kinds of areas than do cattle, and are less likely to have significant influences under proper management. Cluster 6w is located around the lower mid slopes of the Forest, predominately in the northeast and west portions. These areas are non-calcareous and were not glaciated. They have a small proportion of riparian areas many of which may be wetlands (e.g., groundwater driven). They are sensitive to changes in flow as well as sediment. A portion of this cluster is located within active allotments.

From a fisheries management standpoint, livestock grazing primarily influences populations indirectly through habitat modification rather than directly such as through mortality. In evaluating the potential influence of livestock grazing on fisheries habitats, the management-scale riparian clusters are used. Clusters 1r and 4r are generally the high elevation, cold water systems, with the primary difference from the aquatic biota standpoint being the higher productivity of Cluster 4r due to the calcareous geology. For both clusters, the inclusions of relatively low gradient systems provide the greatest potential for biotic productivity and the greatest potential for influences by livestock. With most of the livestock use focused on the lower elevations of these clusters, there is a potential for influences. Cluster 2r is difficult to interpret on a landscape basis due to its heterogeneity. The most productive areas would be within calcareous geology with low gradients. It is in these areas that management concerns should be focused. Clusters 3r and 5r are mid elevation with a relatively high biotic productivity and diversity, with Cluster 5r having the greater productive potential due to its calcareous geology (see also riparian cluster discussion above). In both instances, the lower gradient systems are the most critical from a biotic productivity standpoint as well as from the potential influence by livestock grazing. Cluster 6r has a generally low gradient and would be sensitive to sediment and channel changes, which can greatly influence biotic productivity and composition. Livestock can potentially affect this cluster through vegetative and stream bank effects.

Management of livestock in the Bighorn assessment area needs to consider the type of riparian or wetland area, the relative susceptibility of that area to influences (specifically from livestock), and both the predicted preference (as refined by site specific monitoring of actual use by livestock) and stocking density (again, as refined by site specific data).

In those clusters with the greatest potential for livestock influences, management must carefully control the timing, intensity, duration, and frequency of the grazing to ensure that: soils are dry enough to withstand hoof effects; preferred forage species are able to provide for replenishment of root reserves and to complete life cycles including seed set or other reproduction. Timing involves not only ensuring that the turn out date considers forage species phenological stage and soil moisture but also that these same tenants are provided for throughout the grazing season. It also involves ensuring that plants have a periodic opportunity for re-growth and photosynthesis following defoliation by grazing. Intensity involves ensuring that the amount of plant material harvested or impacted is managed to levels that will ensure that the plant is able to meet its life cycle requirements with no long-term negative effects. Frequency involves ensuring that individual plants are not grazed repeatedly throughout the season in order to allow those specific plants the opportunity to recover from the influence of harvest of a portion of the leaf area. Duration is closely related to both intensity and frequency but is also focused on ensuring that the grazing animal is not allowed to remain on a given area for a period of time such that excessive compaction or disturbance of the soil occurs. Management must also take into account that grazing and browsing will occur by both livestock and big game and that the basic tenants of management apply to all species of grazers.

Overall, management must provide for long term monitoring as a means of ensuring that the influences of grazing are managed in such a manner that the long term health and sustainability of the plants or soil are not compromised.

Information Needs

An assessment of livestock effects is incomplete without data indicating long-term conditions and trends. Some of this data exists, much dating back for decades, but is not in a format (electronic) that allows for ready access or management. This data should be moved to Terra (the current corporate database) as soon as feasible. Data needs to be collected across the landscape in order to allow adequate assessment of trends and effects of livestock grazing. In addition, new data collections should utilize the information contained in this document as a tool to improve monitoring efforts. Over time, this data should be examined in the context of validating the models and in determining conditions and trends for specific benchmark areas. Allotment management planning on a landscape scale would be an appropriate time to manage this data to provide needed answers.

In order to conduct a detailed evaluation, it is necessary to have detailed plant community mapping and data. This is lacking for the non-conifer vegetative types. Future efforts need to focus on collection of site-specific plant community mapping and data for grasslands, shrublands, riparian areas, and wetlands.

It would be helpful to have a summary assessment of historical livestock grazing in terms of numbers (or AUMs) and the species of livestock grazing specific areas. This would allow for a better assessment of the historical context of livestock management.

Table 7.9. Stocking density for cattle and sheep by 6th Level HUB.

Cattle

6th Level HUB Code	NF	Area (Ac)	NF Area (Ac)	AUM	Suit./ Active Area (Acres)	AUM per Suitable Active Area (Acres)	Suitable Acres per AUM	Active/ Suitable Valley Bottom Area (Acres)	AUM per Active/ Suitable Valley Bottom Area (Acres)	Suitable Valley Bottom Acres per AUM
100800080401	NF	33069	33069	186	881	0.21	4.74	204	0.91	1.098
100800080402	NF	23623	23624	74	594	0.12	8.04	210	0.35	2.841
100800080601	NF	26503	26504	106	2278	0.05	21.49	893	0.12	8.424
100800080602	NF	22096	22094	5	1620	0.00	303.00	562	0.01	105.115
100800100103	NF	18343	18348	802	4361	0.18	5.44	926	0.87	1.155
100800160101	NF	35069	35072	1278	6759	0.19	5.29	2006	0.64	1.570
100901010101	NF	28718	28719	840	1944	0.43	2.31	824	1.02	0.981
100901010102	NF	29542	29538	1663	7439	0.22	4.47	2766	0.60	1.664
100901010103	NF	31051	31052	799	1765	0.45	2.21	704	1.13	0.881
100901010104	NF	23492	23491	561	3145	0.18	5.60	1138	0.49	2.027
100901010201	NF	20600	20602	46	24	1.93	0.52	19	2.44	0.410
100901010202	NF	19599	19602	243	770	0.32	3.17	251	0.97	1.034
100902060101	NF	27027	27026	491	1124	0.44	2.29	446	1.10	0.908
100902060102	NF	14151	14153	352	914	0.39	2.59	216	1.63	0.613
100902060103	NF	20998	20994	362	2971	0.12	8.20	775	0.47	2.140
100902060301	NF	21715	21716	71	300	0.24	4.25	227	0.31	3.214
100800080403	B	40770	15887	1258	4781	0.26	3.80	1163	1.08	0.925
100800080404	B	14959	13778	640	2108	0.30	3.29	535	1.20	0.836
100800080405	B	21164	10535	313	1530	0.20	4.88	476	0.66	1.519
100800080406	B	33531	357	54	212	0.25	3.94	50	1.08	0.930
100800080502	B	35372	3949	310	1666	0.19	5.38	393	0.79	1.268
100800080603	B	36426	33549	1329	10817	0.12	8.14	3420	0.39	2.573
100800080604	B	47342	1294	40	802	0.05	20.17	197	0.20	4.954
100800080605	B	24305	17762	302	1683	0.18	5.57	430	0.70	1.423
100800080606	B	36949	7583	188	811	0.23	4.32	227	0.83	1.208
100800100101	B	37696	37627	1059	5364	0.20	5.07	1774	0.60	1.675
100800100102	B	27427	27306	1180	8272	0.14	7.01	2373	0.50	2.012
100800100104	B	28117	10786	111	2413	0.05	21.77	465	0.24	4.195
100800100105	B	19929	1639	0	0	0.00	N/A	0	0.00	N/A
100800100106	B	42283	6076	145	1124	0.13	7.75	315	0.46	2.173
100800100107	B	15560	10980	113	2614	0.04	23.15	424	0.27	3.755
100800100203	B	32937	17364	0	0	0.00	N/A	0	0.00	N/A
100800100204	B	20477	9771	0	0	0.00	N/A	0	0.00	N/A
100800100305	B	20506	2821	0	0	0.00	N/A	0	0.00	N/A

6th Level HUB Code	NF	Area (Ac)	NF Area (Ac)	AUM	Suit./ Active Area (Acres)	AUM per Suitable Active Area (Acres)	Suitable Acres per AUM	Active/ Suitable Valley Bottom Area (Acres)	AUM per Active/ Suitable Valley Bottom Area (Acres)	Suitable Valley Bottom Acres per AUM
100800100307	B	17522	237	0	0	0.00	N/A	0	0.00	N/A
100800100309	B	37023	7270	204	467	0.44	2.29	167	1.22	0.817
100800100401	B	14520	4728	155	268	0.58	1.73	77	2.01	0.497
100800100402	B	43131	3835	192	6	32.05	0.03	2	96.14	0.010
100800100601	B	35142	31342	1641	8643	0.19	5.27	2405	0.68	1.465
100800100602	B	12392	8	3	0	0.00	N/A	0	0.00	N/A
100800100603	B	14280	3690	111	638	0.17	5.76	72	1.54	0.650
100800100604	B	25490	7535	226	1088	0.21	4.81	268	0.84	1.185
100800160102	B	46301	46302	1557	2308	0.67	1.48	648	2.40	0.416
100800160103	B	39006	10211	308	1185	0.26	3.84	179	1.72	0.580
100800160104	B	24306	23938	160	4396	0.04	27.46	687	0.23	4.291
100800160107	B	26855	4862	219	1005	0.22	4.58	339	0.65	1.546
100800160108	B	17296	7304	179	1044	0.17	5.85	150	1.19	0.840
100800160109	B	26401	42	1	0	0.00	N/A	0	0.00	N/A
100800160301	B	27300	14001	325	3907	0.08	12.03	886	0.37	2.729
100901010105	B	18911	17637	447	2184	0.20	4.89	542	0.82	1.213
100901010106	B	36226	10043	163	314	0.52	1.92	98	1.67	0.599
100901010107	B	21725	13858	209	1040	0.20	4.98	212	0.99	1.014
100901010109	B	23691	22661	486	1309	0.37	2.69	380	1.28	0.782
100901010110	B	22218	145	0	0	0.00	N/A	0	0.00	N/A
100901010203	B	33993	33232	168	949	0.18	5.65	326	0.52	1.939
100901010204	B	28855	9511	239	1320	0.18	5.52	346	0.69	1.446
100901010205	B	27141	659	21	109	0.19	5.30	30	0.69	1.459
100901010206	B	32329	29903	502	2292	0.22	4.56	388	1.30	0.772
100901010207	B	35753	1654	50	189	0.27	3.77	22	2.28	0.439
100901010209	B	39075	919	5	108	0.04	22.80	12	0.39	2.533
100902010301	B	44903	12533	331	2920	0.11	8.83	957	0.35	2.894
100902050101	B	29998	27464	451	1704	0.26	3.78	697	0.65	1.547
100902050102	B	29044	6594	166	863	0.19	5.20	231	0.72	1.391
100902050103	B	28000	6125	53	1488	0.04	28.04	349	0.15	6.577
100902050106	B	35183	16871	395	1448	0.27	3.66	864	0.46	2.186
100902050107	B	16707	5705	163	1274	0.13	7.84	399	0.41	2.455
100902060104	B	12920	10193	390	1865	0.21	4.78	619	0.63	1.586
100902060107	B	16906	7491	86	886	0.10	10.29	259	0.33	3.008
100902060201	B	40047	36055	194	358	0.54	1.84	167	1.16	0.860
100902060202	B	37836	5398	54	328	0.16	6.10	110	0.49	2.046

100902060302	B	24942	23756	109	360	0.30	3.30	114	0.96	1.045
100902060303	B	25198	18950	198	353	0.56	1.78	59	3.36	0.298
100902060304	B	20035	4879	36	50	0.72	1.38	13	2.78	0.360
100902060305	B	26263	232	2	0	0.00	N/A	0	0.00	N/A

Sheep

6th Level HUB Code	NF	Area (Ac)	NF Area (Ac)	AUM	Suit./ Active Area (Ac)	AUM per Suitable /Active Area (Acres)	Suitable Acres per AUM	Active/ Suitable Valley Bottom Area (Ac)	AUM per Active/ Suitable Valley Bottom Area (Ac)	Suitable Valley Bottom Acres per AUM
100800080401	NF	33069	33069	930	675	1.38	0.73	334	2.79	0.36
100800080402	NF	23623	23624	2652	1835	1.45	0.69	945	2.81	0.36
100800080601	NF	26503	26504	138	60	2.30	0.43	27	5.12	0.20
100800080602	NF	22096	22094	0	0	0.00	N/A	0	0.00	N/A
100800100103	NF	18343	18348	77	1623	0.05	20.97	351	0.22	4.53
100800160101	NF	35069	35072	1914	2524	0.76	1.32	703	2.72	0.37
100901010101	NF	28718	28719	6057	8205	0.74	1.35	1553	3.90	0.26
100901010102	NF	29542	29538	1169	985	1.19	0.84	267	4.38	0.23
100901010103	NF	31051	31052	0	1257	0.00	N/A	247	0.00	N/A
100901010104	NF	23492	23491	1874	1787	1.05	0.95	528	3.55	0.28
100901010201	NF	20600	20602	0	0	0.00	N/A	0	0.00	N/A
100901010202	NF	19599	19602	0	0	0.00	N/A	0	0.00	N/A
100902060101	NF	27027	27026	2	0	0.00	N/A	0	0.00	N/A
100902060102	NF	14151	14153	0	0	0.00	N/A	0	0.00	N/A
100902060103	NF	20998	20994	0	0	0.00	N/A	0	0.00	N/A
100902060301	NF	21715	21716	0	0	0.00	N/A	0	0.00	N/A
100800080403	B	40770	15887	0	0	0.00	N/A	0	0.00	N/A
100800080404	B	14959	13778	529	160	3.31	0.30	63	8.40	0.12
100800080405	B	21164	10535	658	1084	0.61	1.65	242	2.72	0.37
100800080406	B	33531	357	0	0	0.00	N/A	0	0.00	N/A
100800080502	B	35372	3949	0	0	0.00	N/A	0	0.00	N/A
100800080603	B	36426	33549	0	0	0.00	N/A	0	0.00	N/A
100800080604	B	47342	1294	0	0	0.00	N/A	0	0.00	N/A
100800080605	B	24305	17762	1615	1164	1.39	0.72	437	3.70	0.27
100800080606	B	36949	7583	436	279	1.56	0.64	111	3.93	0.25
100800100101	B	37696	37627	360	466	0.77	1.29	192	1.88	0.53
100800100102	B	27427	27306	8	74	0.11	9.20	5	1.61	0.62
100800100104	B	28117	10786	0	5	0.01	71.43	0	0.00	N/A
100800100105	B	19929	1639	0	0	0.00	N/A	0	0.00	N/A
100800100106	B	42283	6076	53	380	0.14	7.19	114	0.46	2.16
100800100107	B	15560	10980	224	969	0.23	4.32	148	1.52	0.66

6th Level HUB Code	NF	Area (Ac)	NF Area (Ac)	AUM	Suit./ Active Area (Ac)	AUM per Suitable /Active Area (Acres)	Suitable Acres per AUM	Active/ Suitable Valley Bottom Area (Ac)	AUM per Active/ Suitable Valley Bottom Area (Ac)	Suitable Valley Bottom Acres per AUM
100800100203	B	32937	17364	7159	4002	1.79	0.56	1022	7.01	0.14
100800100204	B	20477	9771	0	0	0.00	N/A	0	0.00	N/A
100800100305	B	20506	2821	2582	801	3.22	0.31	250	10.33	0.10
100800100307	B	17522	237	209	0	0.00	N/A	0	0.00	N/A
100800100309	B	37023	7270	2547	238	10.70	0.09	67	38.01	0.03
100800100401	B	14520	4728	0	0	0.00	N/A	0	0.00	N/A
100800100402	B	43131	3835	0	0	0.00	N/A	0	0.00	N/A
100800100601	B	35142	31342	403	326	1.24	0.81	110	3.67	0.27
100800100602	B	12392	8	0	0	0.00	N/A	0	0.00	N/A
100800100603	B	14280	3690	0	0	0.00	N/A	0	0.00	N/A
100800100604	B	25490	7535	0	0	0.00	N/A	0	0.00	N/A
100800160102	B	46301	46302	3684	4932	0.75	1.34	1243	2.96	0.34
100800160103	B	39006	10211	0	0	0.00	N/A	0	0.00	N/A
100800160104	B	24306	23938	0	0	0.00	N/A	0	0.00	N/A
100800160107	B	26855	4862	0	0	0.00	N/A	0	0.00	N/A
100800160108	B	17296	7304	0	0	0.00	N/A	0	0.00	N/A
100800160109	B	26401	42	0	0	0.00	N/A	0	0.00	N/A
100800160301	B	27300	14001	0	0	0.00	N/A	0	0.00	N/A
100901010105	B	18911	17637	0	0	0.00	N/A	0	0.00	N/A
100901010106	B	36226	10043	0	0	0.00	N/A	0	0.00	N/A
100901010107	B	21725	13858	0	0	0.00	N/A	0	0.00	N/A
100901010109	B	23691	22661	0	0	0.00	N/A	0	0.00	N/A
100901010110	B	22218	145	0	0	0.00	N/A	0	0.00	N/A
100901010203	B	33993	33232	0	0	0.00	N/A	0	0.00	N/A
100901010204	B	28855	9511	0	0	0.00	N/A	0	0.00	N/A
100901010205	B	27141	659	0	0	0.00	N/A	0	0.00	N/A
100901010206	B	32329	29903	0	0	0.00	N/A	0	0.00	N/A
100901010207	B	35753	1654	0	0	0.00	N/A	0	0.00	N/A
100901010209	B	39075	919	0	0	0.00	N/A	0	0.00	N/A
100902010301	B	44903	12533	460	475	0.97	1.03	208	2.21	0.45
100902050101	B	29998	27464	719	130	5.53	0.18	58	12.40	0.08
100902050102	B	29044	6594	0	0	0.00	N/A	0	0.00	N/A
100902050103	B	28000	6125	27	8	3.39	0.29	0	0.00	N/A
100902050106	B	35183	16871	198	265	0.75	1.34	105	1.88	0.53
100902050107	B	16707	5705	0	0	0.00	N/A	0	0.00	N/A
100902060104	B	12920	10193	0	0	0.00	N/A	0	0.00	N/A
100902060107	B	16906	7491	0	0	0.00	N/A	0	0.00	N/A
100902060201	B	40047	36055	0	0	0.00	N/A	0	0.00	N/A

6th Level HUB Code	NF	Area (Ac)	NF Area (Ac)	AUM	Suit./ Active Area (Ac)	AUM per Suitable /Active Area (Acres)	Suitable Acres per AUM	Active/ Suitable Valley Bottom Area (Ac)	AUM per Active/ Suitable Valley Bottom Area (Ac)	Suitable Valley Bottom Acres per AUM
100902060202	B	37836	5398	0	0	0.00	N/A	0	0.00	N/A
100902060302	B	24942	23756	0	0	0.00	N/A	0	0.00	N/A
100902060303	B	25198	18950	0	0	0.00	N/A	0	0.00	N/A
100902060304	B	20035	4879	0	0	0.00	N/A	0	0.00	N/A
100902060305	B	26263	232	0	0	0.00	N/A	0	0.00	N/A

Influence of Wild Ungulates

This section provides an assessment of the effects of large wild ungulates on the Bighorn National Forest and associated aquatic, riparian, and wetland habitats. The species of interest are elk, moose, bison, bighorn sheep, deer (both mule and white tailed), and pronghorn.

This section evaluates the likely influence of these species on habitats, and their relationship with other activities, most specifically livestock grazing. There is very little site-specific information regarding the effects of these wildlife species on aquatic, riparian, wetland, or terrestrial habitats in the Bighorn Assessment Area, therefore much of the assessment will rely on effects noted elsewhere and extrapolated to the Bighorn area. Other sources of information are personal observations from resource specialists and USFS information related to the Big Horn Mountains.

Basin and Landscape Scale

Wild ungulates have been present in the upper Missouri Basin for over 60 million years (Knight 1994). While the species of wild herbivores has changed over the millennia, their presence has been realized throughout the basin. Following the last glaciation period, the current species of herbivores were present. Other large herbivores like the wooly mammoth became extinct with the change in climate approximately 9,500 years ago. While large predators like the wolf and grizzly bear were present in the basin until shortly after the arrival of Euro-American settlers, it is doubtful that Native Americans had a significant influence on wild ungulate populations. The presence of a large population of bison also indicates that their populations were largely effected by other "natural" conditions.

The arrival of Euro-American settlers had a marked influence on native wildlife, including wild ungulates. Wolves and grizzly bears were largely eliminated from most areas by the turn of the century, and bison were basically extinct as a free roaming animal by 1890 (Knight 1994). In addition, other large ungulates were also reduced significantly.
Prior to the late 1800s wild ungulate populations were abundant and probably cyclic. It would be expected that large populations of large wild ungulates such as elk, deer (mule and white tailed), bighorn sheep, pronghorn, and bison would have resulted in influences to native vegetation in at varying temporal and spatial scales. Areas such as mountain meadows and riparian areas during the summer, and open grasslands in the spring or fall would have been preferred and would likely have experienced localized influences similar to what is currently experienced in Yellowstone and other National Parks (Kay 2001a; Kay 2001b; Singer et. al. 2000; Singer et al. 1998; Meadows, 2001)

On a landscape scale, bison were historically the dominant species on the short or mixed grass foothills and plains. Elk were common and were reported as being present in the plains but most common in the wooded draws, foothills and mountains. Deer were reported as being present and widespread, most commonly near some form of cover (vegetative or topographic). Bighorn sheep were present, but apparently were never observed in high numbers. Antelope were numerous and dispersed across the open grasslands. Moose were not believed to be present historically but may have been occasional visitors or migrants (Meyer and Knight 2003).

Early Native Americans would have hunted all of these species, but the extent to which they affected species populations is debatable. It is entirely possible that the early Snake Indians and their predecessors and successors were also capable of impacting populations to some degree, but little to no specific information is available to quantify this effect (Meyer and Knight 2003).

Pressure on big game populations increased significantly in and following the 1860s as the Native Americans and Euro-American settlers began to hunt for commercial purposes (primarily buffalo hides). In addition, the increase in Native American population density as a result of forced migration also increased subsistence-hunting pressure on all game animals in the federally reserved areas. Euro-American settlers were also hunting for subsistence, market, and hides with the impacts beginning to have major consequences (Murray 1980). By the 1890s, indications are that big game populations were greatly reduced and that hunting success in that time period was very limited. Predator control programs were in full operation at this time. The belief was that if hunting could be controlled and predators eliminated, large wildlife populations would recover. These predator control programs, along with a general dislike of all predators by livestock operators, eliminated the grizzly bear and the wolf from the assessment area.

From about 1890 to the early 1900s subsistence, market, and sport hunting greatly impacted native herbivore populations. Elk disappeared from the Big Horn Mountains and the last bison was seen in the early 1880s (Meyer and Knight 2003). Bighorn sheep and deer populations were reduced. This reduction in large wild ungulates would potentially have allowed for recovery of any associated impact areas. However, at this same general time, livestock numbers were increasing dramatically to the point where they greatly exceeded any reasonable grazing capacity. In many areas, this overpopulation negated any benefits accruing from reduced large wild ungulate populations.

Table 7.10 represents estimates of elk and deer numbers over time as taken from the Bighorn HRV Assessment (Meyer and Knight 2003). The numbers, though approximate, are presented to show general population trends.

In the more recent past, populations of some large wild ungulates have increased significantly. Elk were re-introduced to the area from 1909 to 1919, and moose were introduced in the 1950s (Meyer and Knight 2003). During the same time, deer populations have varied but are currently at or possibly below levels experienced in the mid to early parts of the last century (fig. 7.33). In part it is possible that elk, with their wider range of adaptability, are replacing deer in some parts of their overlapping territories. In addition, for both species, more notably for deer, alterations in critical winter range due to agriculture, and urbanization may be impacting these populations. On the other hand, moose populations have increased since reintroduction. Bighorn sheep populations appear to be very low and are probably well below historic levels. Bison continue to be absent as wild herbivores. Pronghorns are present but restricted to the open plains and foothills.

The effects of bison on the short grass or mid-grass plains and foothills are replicated only in part by the presence of livestock. However, the spatial and temporal distribution of domestic livestock does not fully replicate natural disturbance patterns. These disturbances would include seasonal migration patterns, heavy disturbance followed by periods of inactivity, and development of buffalo wallows, among others. Many of the plant and animal species of the landscape would have adapted to these patterns and intensities of effects. It is unclear how current plant communities are affected by the absence of bison, and how accurately the presence of livestock may replicate the native disturbance ecology. However, their behavioral patterns indicate that there are considerable differences in the way they distribute themselves on the landscape. Where native plant communities have not been disturbed by agriculture or urban development, most communities appear to be relatively intact. Bison as a wild, free-roaming species are not present in the assessment area. There are a few small herds maintained in the area as tourist attractions or commercial livestock but these are very limited in both numbers of animals and distribution.

At their present levels, elk, deer, and moose populations almost certainly have an effect on certain plant communities. The most noticeable effects occur on winter ranges (including fall and spring transition ranges) and in the higher elevations on the highly preferred plant communities such as aspen and willow. Plant reproduction and long-term health are influenced by these animal species

Table 7.10. Large wild ungulate population trends in the Bighorn National Forest. This information is taken from a variety of sources including Murray 1980, Meyer and Knight 2003, and Annual Fish and Game Reports for the Forest.

Year	Elk	Deer	Bighorn Sheep	Moose
1910	0	2,000		
1911		1,890	150	
1915	383	1,575	171	
1917+	Protections imposed-730	Projections imposed – 2,500	Projections imposed – 100-200	
Early 1920s	Recognition of need for winter range (State)			
1924	2,033			
1925	State acquires additional winter range	2,500		
1926	Limited hunting resumes			
1929	3,825	2,900-4,525 (depending on source)	Sheep begin to decline	
Mid 1930s	88,000 ac fenced to exclude livestock for elk			
1933	4,450	9,100 (resource problems noted)		
1950	4,500	12,000		Introduced in 1950s
1970	9,000	37,000		
1980	11,000	15,000		
1985	7,500	15,000		
1994				400
1999			20	
2001	7,100	15,000		

but information specific to the assessment area is limited in availability. D. Beard (oral commun., Bighorn National Forest, 2002) has documented utilization of willows (marked twigs) of up to 80% by large wild ungulates.

The data show a high degree of temporal and spatial variability. Prior to domestic livestock introduction by large wild ungulates alone can have a significant influence upon the environment. This is supported by information from the Yellowstone ecosystem showing impacts by large wild ungulates (Singer et al. 1998 and 2000; Kay 2001). Once livestock enter an area, the combined utilization of the two groups of grazing animals can continue to increase.

S. Gall and D. Morris (oral commun., 2002) also have photographs of exclosures showing the influences of wild and domestic grazing. Their information indicates that the exclusion of livestock alone may not be adequate to ensure recovery of riparian hardwood species if large wild ungulates continue to impact the system. In the Buckley Creek area, where livestock are excluded but elk retain access; height of the willow is unchanged when comparing plants inside the exclosure with those outside. S. Gall and D. Morris (oral commun., 2002) note that the area inside does appear to have a greater overall cover. Comparisons made of stream channel condition indicate that conditions were significantly less disturbed inside exclosures. They note that recovery of willow and bog birch to approximate potential height can occur within 3-5 years following exclusion, while aspen will take several times longer.

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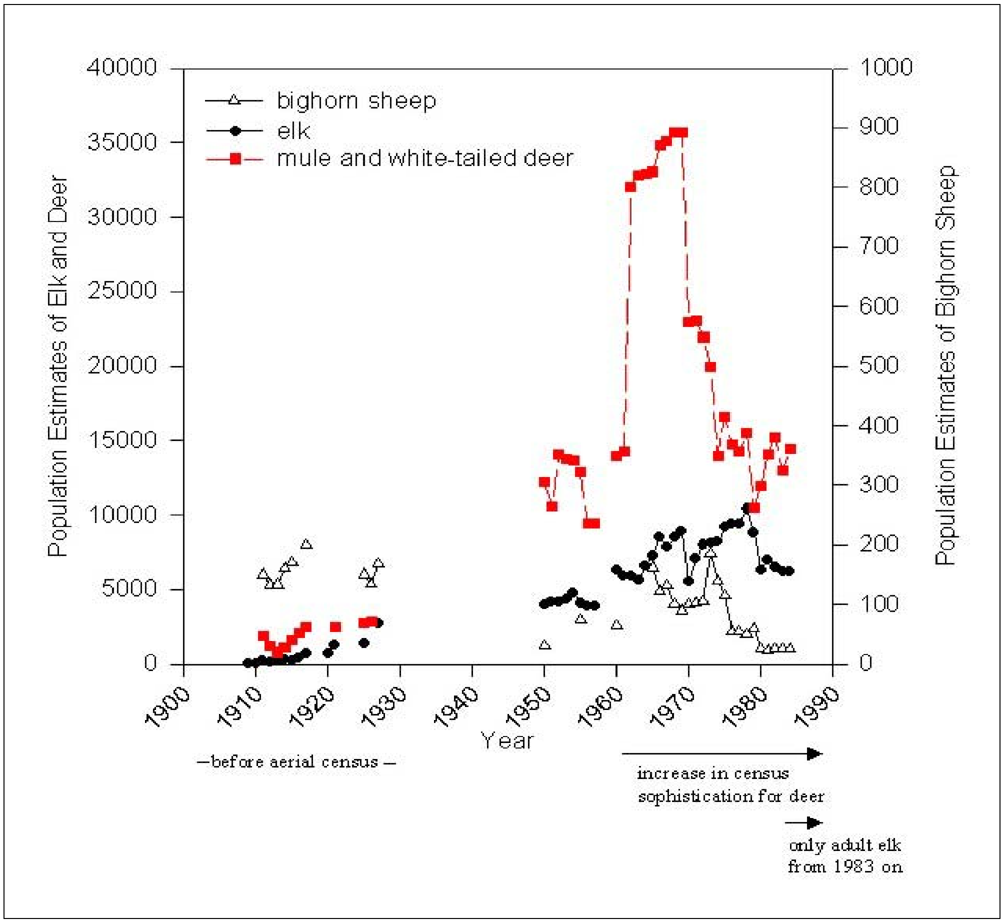

Figure 7.33. Population estimates for elk and deer (left axis), and Bighorn sheep (right axis) on the Bighorn National Forest (data from USDA Forest Service 1985, 1994, and from 1909-1929 Annual Fish and Game Reports for the Forest; from Meyer and Knight 2003)

Overall, the long term effects of large wild ungulates alone in some areas has the potential to influence growth, form, reproduction, and long-term health of riparian, wetland and aquatic species if their densities become high enough in a given location.

Management and Reach/Site Scales

The relatively high numbers of large wild ungulates now on the Bighorn National Forest would indicate that influences on aquatic, riparian, and wetland resources have increased since their populations began increasing in the 1950s. The observations with regard to aspen are supported by numerous studies throughout the west (Kay 2001; Rolf 2001; Kilpatrick and Abendroth 2001). However, without adequate study, it is very difficult to specify what part of the overall effects is attributable to large wildlife and what is specifically related to other impacts (livestock, timber harvest, etc.). In addition, there is no information identifying population size prior to Euro-American settlers.

Observations indicate that large wild ungulates are having localized effects on plant communities, particularly in riparian and wetland areas and in the spring and fall range (R. Stellingwerf and D. Beard Bighorn National Forest, oral. commun., 2002). Seasonal migration patterns generally follow the seasonal growth cycle of available forage. By grazing plants very early in their growth cycle, or by grazing or browsing them repeatedly, damage can occur. Where populations of the wild ungulates are high, this effect can be significant. In the fall and winter, these animals tend to browse on the palatable shrub species with the degree of impact corresponding to the population levels, in many instances being significant.

Elk on the Bighorn National Forest tend to utilize all available habitats across the landscape. They can be found on the foothills, in private lands such as agricultural farmland, on the steep slopes and within the upper elevation parks, meadows, and timbered areas. Elk are found throughout the Forest with the possible exception of some of the very highest elevations and steep rocky breaks. Their ability to make use of a wide range of habitats (habitat generalists) may qualify them as the dominant species. Although elk tend to be found in the dense conifer types, they also frequent open sagebrush or grasslands (usually not too far from some form of vegetative or topographic cover) and in riparian and wetland areas. Elk prefer grass and forbs for foraging but do browse on the more palatable shrub species, particularly aspen.

With the current population, elk have the potential to have an increased influence on vegetative resources in riparian areas and wetlands. Elk use can also impact willow or other palatable shrub species and are an indication of the cumulative effects of elk, moose, and domestic livestock (S. Gall, D. Morris and D. Beard, oral commun., 2002). Three way exclosures are used in various places across the National Forest System as an attempt to differentiate the effects of elk, deer, moose, and livestock grazing. In addition, some work has been done on the Bighorn National Forest focused on evaluating impacts by livestock vs. large wild ungulates on willow and other riparian hard wood shrubs. These results are not available yet.

Deer have long been recognized for the fact that population numbers have at times increased beyond the ability of the landscape to sustain them. Following the population trends in Table 7.10 and Figure 7.33, it is obvious that once the severe impacts of unregulated hunting pressure were removed (in part when areas of the Big Horn Mountains were set aside to protect big game populations), populations expanded dramatically. Increasing populations were observed until the 1960s and '70s when populations began to decline. The available data indicate that populations increased to the point where the deer were severely impacting forage and browsed resources on the Forest (Bighorn National Forest, non-published range reports). The effects on the fall, winter, and spring ranges were even more severe as palatable shrubs were heavily hedged and reproduction of the palatable species was retarded or even eliminated.

For deer, winter range is critical. Over time, much of their winter range has been altered by agriculture, livestock grazing, and more recently by urbanization sprawl and development. The State has responded in part by acquiring key winter range areas and setting them aside for use by large wild ungulates. However, deer populations continue to remain at relatively low levels. One possibility for their relatively low population is that the deer are being replaced in part by elk. Elk are believed to surpass the deer in terms of adaptability and being more of habitat generalists rather having the more constrained habitat needs of deer. Another proposed explanation is that winter range is even a more limiting factor than generally believed.

Bighorn sheep continue to be limited in numbers. Bighorn sheep today are generally restricted to the steep rocky breaks, as that is where they find habitat that provides the greatest protection and solitude. Although populations may impact small-localized areas, especially around water or within winter ranges, little is known of their overall effects on the landscape. It is generally believed that their effects are minimal and localized.

Bison continue to be absent from the Forest as a wild population. Some domestic herds are found in areas near the Forest and within the assessment area. For example, a small herd is maintained in Sheridan City Park, and one commercial herd was maintained east of Clairmont (current status unknown) (S. Gall, oral commun., 2002). To an unknown degree, the effects of bison (both positive and negative) have been assumed over much of the Bighorn Assessment Area. Bison are believed to have never been overly abundant in this area but were noted to have a population substantial enough to have influenced their environments (Meyer and Knight 2003).

Most of the effects of bison grazing and migration would have been found on the grasslands and short grass steppe of the plains and foothills. It is likely that some limited effects occurred in the mountains, especially on the meadows, riparian areas, and grasslands or shrub lands, but these were probably relatively minor and localized. Bison relationships with the environment however cannot be totally replicated by livestock. For example, bison would have migrated seasonally up and down the mountain, grazing progressively higher and lower as weather and growing conditions dictated. They also migrated north and south in response to seasonal changes. Also, bison were free ranging animals whereas livestock are confined within relatively small landscapes and are rotated between various areas. The net difference in effects on the plant communities between the two kinds of animals cannot be known for sure, but there are undoubtedly differences.

In terms of riparian and wetland habitats, it is likely that livestock have had a more significant influence than bison. This is a result of the much more dense populations and management practices of livestock during the past century. Today, the effects are likely to be similar although in areas livestock use will still be more intensive and of different timing and duration than would have been true of the bison.

Moose populations, since their introduction, have continued to grow. Moose prefer dense conifer and shrubby riparian and wetland areas. As their numbers have increased, it is probable that their effects on their environment have also increased. Moose will impact riparian areas and wetlands through trampling of wet soils and stream banks and browsing on palatable shrubs. In areas where moose concentrate, it is possible to observe heavily browsed willows and other shrubs but it is impossible to differentiate between the browsing by moose and that resulting from elk, deer, or livestock without intensive study.

Pronghorn populations are likely below historic levels but appear to be relatively stable at present. These animals are primarily grassland dwellers foraging on forbs, sagebrush and grasses. Impacts across the landscape are not believed to be significant. Localized conflicts do exist with regard to grazing of irrigated lands.

The effects of large wild ungulates on the landscape cannot be considered as an independent effect. All of the effects of these animals occur in conjunction with other activity effects in a cumulative nature. For this reason, this section will address what is known about large wild ungulate effects in the context of their cumulative nature occurring with the effects of other impacting activities.

The most recognized cumulative effects on the resources occur with the relationship between livestock and large wild ungulates. This is discussed in some detail in the Livestock Grazing section of this report.

The most commonly recognized effects of large wild ungulates include:

1. Impacts on fall, winter, and spring range as animals migrate seasonally across elevation zones. Large concentrations of animals on wet soils can cause trampling or displacement damage and uproot grass plants. Because of the nutritional needs of these animals, certain plant species are the focus of browsing and grazing. Often at this time of year these will be the palatable shrub and tree (aspen) species that provide the highest nutritional value. Effects can be severe locally in highly preferred areas and migration corridors or can be minimal in areas little used by the wildlife.
2. Impacts on summer ranges including especially grazing and browsing impacts on aspen and riparian and wetland vegetation. Effects can include trampling of wet soils and excessive browsing of hardwood species. Long-term effects can be reductions in vigor or reproductive ability of plants and changes in species composition and cover.

These effects can be compounded or even masked by similar effects of livestock grazing and browsing. When both classes of ungulates make use of the same plant species and habitats, the effects are often magnified. Implementation of a forest plan allowable-use-standards is designed to mitigate this dual effect situation and to maintain the long-term health of the plant communities. This is generally effective on a landscape but may not resolve localized situations where both groups graze palatable vegetation.

Information Needs

There is considerable controversy surrounding domestic and wildlife grazing. In terms of the effects of large wild ungulate populations on the resources of the Bighorn assessment area, there is far more that we do not know that there is that we do. Anecdotal evidence from Bighorn National Forest land managers, along with limited monitoring data, indicates that there are localized problems with excessive use of certain plant species and communities. However, there is limited data available to quantify these findings. Historically there is strong anecdotal evidence because deer, elk and moose populations have increased considerably in the last half-century, these impacts may have occurred for decades but again; there is limited empirical information.

The best information available at present appears to be a combination of the best available population estimates (population trend information) combined with anecdotal and monitoring evidence from resource professionals. This information can be evaluated against such research as does exist with regard to large wild ungulate effects. In some areas, such as within the Greater Yellowstone ecosystem, there are studies quantifying effects that can be extrapolated to the Bighorn assessment area.

It would therefore be beneficial if the existing anecdotal and data evidence could be gathered for the Bighorn National Forest, and then evaluated against research from other areas.

In addition, the following information gaps have been identified. These gaps are such that our current ability to conduct a realistic assessment of large wild ungulate effects is extremely limited.

1. Monitoring (3-way exclosures or other means) to determine actual use levels in key areas by large wild ungulates. There would need to be enough study sites to adequately address spatial differences in effects.
2. Monitoring of these study sites to determine long-term effects on plant composition, cover, and trends.

3. Evaluation of seasonal migration patterns and dispersal patterns across the landscape.
4. Evaluation of cumulative effects of browsing by large wild ungulates plus livestock on aspen and riparian hardwood plant communities.
5. Evaluation of effects of browsing on upland shrub communities such as mountain mahogany.
6. Evaluation of effects of seasonal migration patterns (e.g., utilization of forage species during the spring and fall) on herbaceous plant composition and cover.

Management Implications and Relationship to Ecological Drivers

The complexity and controversy involving domestic and wildlife grazing in the Bighorn National Forest indicates that the influences to aquatic, riparian, and wetland resources are real, but the mechanisms not yet thoroughly understood. Understanding of the relationship between the Ecological Driver analysis and aquatic, riparian, and wetland resources could help in addressing where the most influences might be. Table 7.11 illustrates the clusters that might be influenced most by domestic as well as wildlife grazing. These clusters contain the highest percentage of drivers that would predict abundance of wetlands and riparian areas. In addition, stream systems within low gradient portions of these HUBs would be sensitive to wild and domestic activity along stream banks. Reaches within "low and moderate" categories with low stream gradients would also be considered highly sensitive to grazing effects on aquatic, riparian, and wetland resources. Addressing the relationship between wild and domestic grazing could be conducted in these watersheds may provide insight into the relationship between the two activities.

Table 7.11. Relationship between cluster number and potential influence of wild ungulate grazing on aquatic, riparian, and wetland resources.

Wetland Cluster Numbers*	Potential Influence on Wetlands*	Riparian Cluster Numbers*	Potential Influence on Riparian Areas**
1w	High	**1r**	High
2w	High	**2r**	High
3w	Low	**3r**	Moderate
4w	Low	**4r**	Low
5w	High	**5r**	Low
6w	Moderate	**6r**	Low
7w	Low		NA

**Cluster numbers represent different groupings for wetlands and riparian areas at the management scale. They cannot be used simultaneously with each other.*
*** Based on the percentage of current and potential habitat described by Cooper (see Chapter 2 in Report 1 of this assessment).*

Vegetation Management Cluster Analysis

A cluster analysis of the three activities of the vegetation management category (excluding wild and domestic grazing) was performed to identify the additive effects of vegetation management activities on aquatic, riparian, and wetland resources. These three activities were analyzed separately from grazing because of the dissimilar influences of the activities. Five criteria were used in the cluster analysis, and are summarized in Table 7.12. This analysis was performed at the management scale, with data existing for all portions of the 74 HUBs within the Bighorn National Forest boundary. The clusters derived from the analysis of the vegetation management activities have been assigned the 'vm' suffix. HUBs where no vegetation management activities were present were removed from the dataset prior to the cluster analysis, and assigned as Cluster 0vm. The cluster analysis was performed in PC-ORD2, with four clusters identified at approximately 20% of the information remaining (fig.7.34. Each cluster has been labeled on the dendrogram. Table 7.13 summarizes the mean criteria values for each cluster.

A general conclusion from this analysis is that the only two clusters with historic tie drives and historic clear cutting (Clusters 2vm and 3vm) were the ones that exhibited the highest percentages of fire within valley bottoms and second highest of wetlands (fig. 7.35). The results are not easily explainable within the context of this assessment. They could be related to dense vegetation growth resulting from historic clearcuts and tie hacking operations resulting in increased fires, lightning strike intervals, or other factors. This phenomenon would be valuable to address further to identify the elements contributing to these results.

Cluster 3vm, the cluster with the highest potential for influence from fire, historic clearcutting and tie hacking, is prevalent on the eastern and southern flanks of the Big Horn Mountains. While fire and timber harvest are relatively high in this cluster, it also contains the most tie hacked stream segments. Those 6th level HUBs associated with the northeastern portion of the Bighorn National Forest represent the areas where all three activities occurred. The group of 6th level HUBs located in the southern portion of the Forest was not tie hacked but underwent recent fires and had historic clear cutting in them.

Cluster 2vm represents the group of 6th level HUBs with the second highest percentages of values. There are relatively few HUBs within this cluster, and the highest mean percentage of valley bottoms that were within fire boundaries were found in this cluster.

Cluster 0vm, the cluster with no identified activity occurring, coincides with the Cloud Peak Wilderness area, as well as the more remote portion of the forest on the western and northern flanks of the mountain range. Clusters 1vm and 4vm also exhibited relatively little additive effects of these activities.

An analysis of variance (ANOVA) statistical test was utilized to examine the clusters for significant differences in criteria values (table 7.14).

Table 7.12. Summary of criteria used in the vegetation management cluster analysis.

Criterion	Explanation
Percent of Valley Bottom in Historic Clearcut Area	Percent of Total Valley Floor Area inside a Historic Clearcut Area
Percent of Wetland in Historic Clearcut Area	Percent of Total Wetland Area inside a Historic Clearcut Area
Percent of Valley Bottom in Area Burned Since 1960	Percent of the Total Valley Floor Area inside a Fire Boundary that has Occurred since 1960
Percent of Wetland in Area Burned Since 1960	Percent of the Total Wetland Area inside a Fire Boundary that has Occurred since 1960
HUB Influenced by Historic Tie Drives	Presence/Absence of Historic Tie Drives

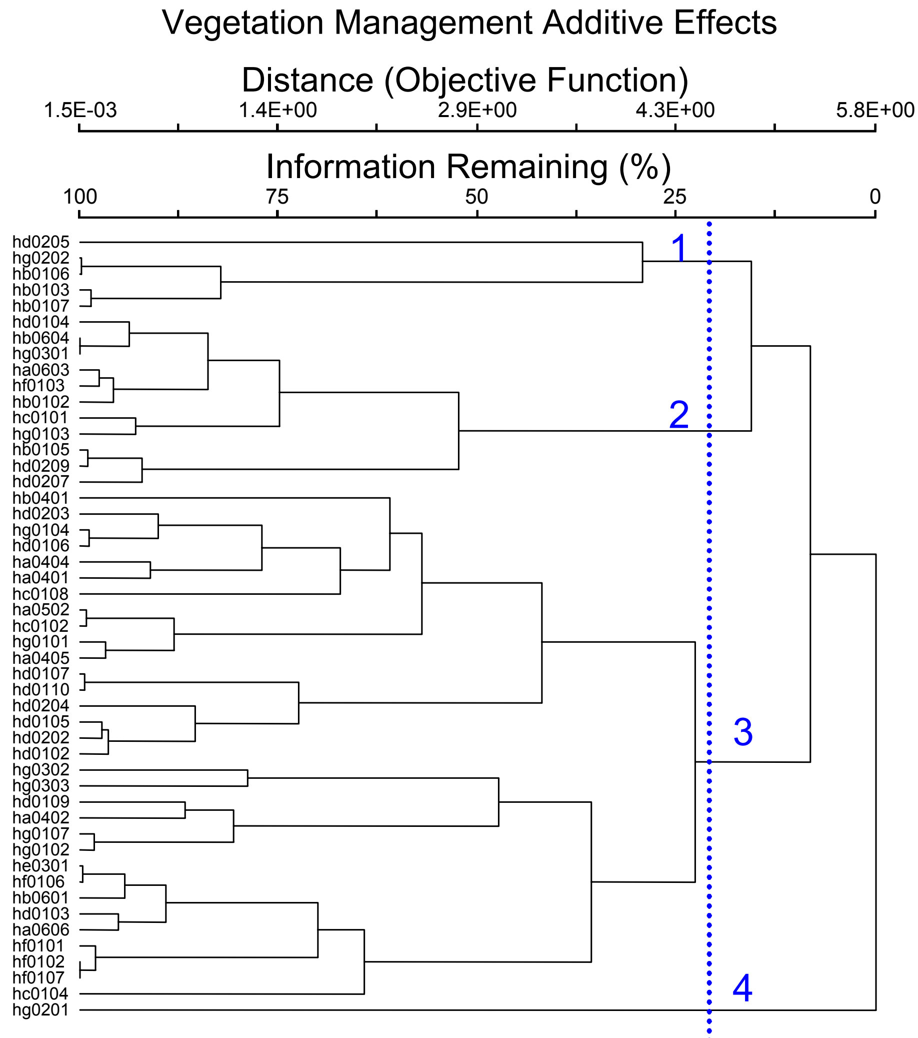

Figure 7.34. Dendrogram produced by cluster analysis of vegetation management criteria.

Table 7.13. Cluster analysis displaying mean values for each criterion.

	Population	Cluster 0vm	Cluster 1vm	Cluster 2vm	Cluster 3vm	Cluster 4vm
	n = 74	n = 25	n = 5	n = 11	n = 32	n = 1
Mean Percent Valley Bottom in Clearcut	1.82	0.00	0.00	1.89	3.56	0.00
Mean Percent Wetland in Clearcut	1.74	0.00	0.00	1.15	3.62	0.00
Mean Percent Valley Bottom in Burned Area	3.55	0.00	1.08	23.08	0.11	0.00
Mean Percent Wetland in Burned Area	1.33	0.00	0.00	1.54	2.53	0.25
Number of HUBs w/ Historic Tie Drives	9.00	0.00	0.00	1.00	8.00	0.00

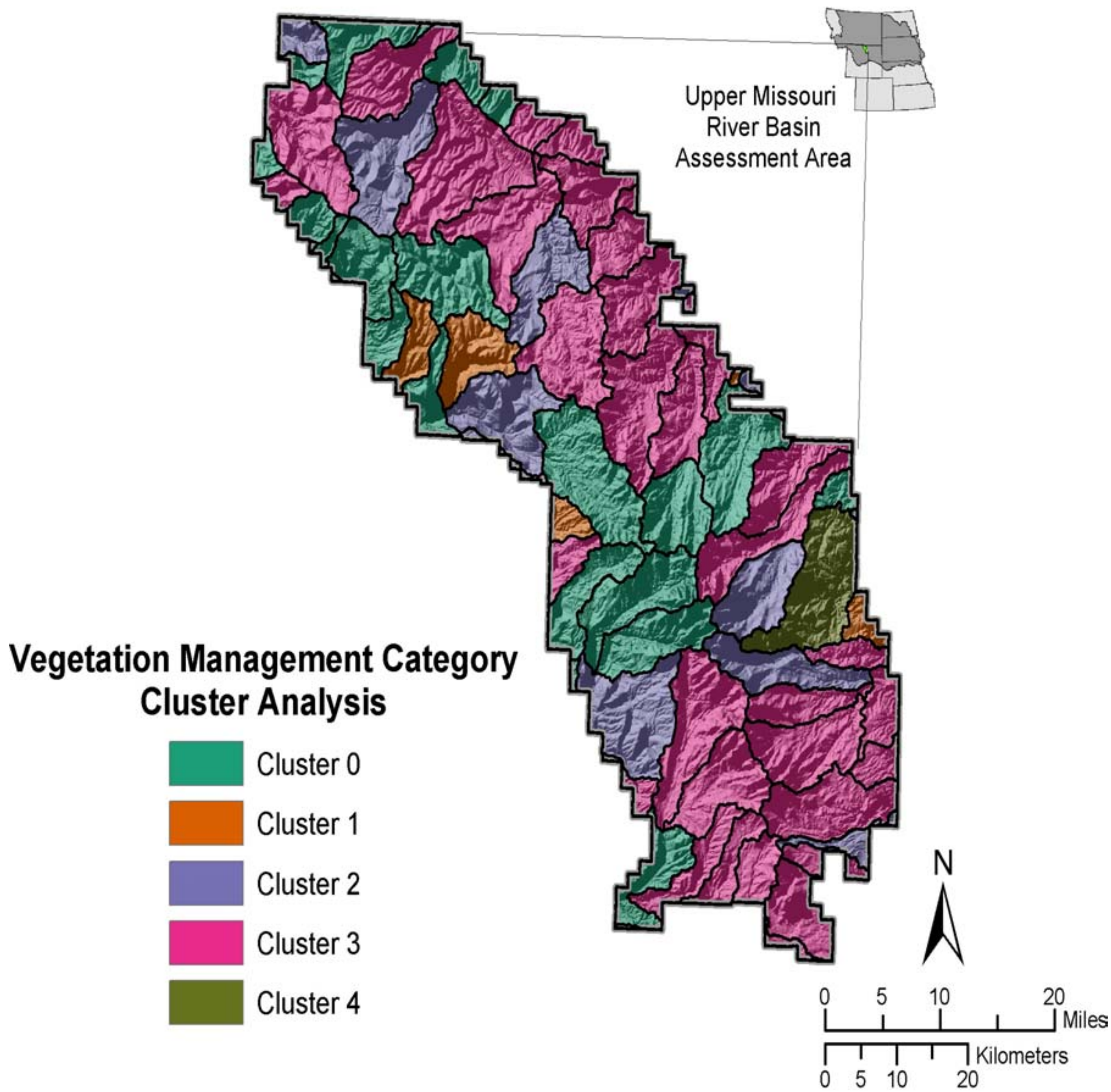

Figure 7.35. Cluster analysis results for the vegetation management category.

Table 7.14. ANOVA results summary: test for significant differences between clusters for each vegetation management criterion.

Criterion	F Value	Probability > F
Percent of Valley Bottom in Clearcut Area	4.5258	0.0026
Percent of Wetland in Clearcut Area	2.1666	0.0818
Percent of Valley Bottom in Area Burned Since 1960	13.3911	< .0001
Percent of Wetland in Area Burned Since 1960	1.3094	0.2751
HUB Influenced by Historic Tie Drives	n/a	n/a

Alpha = .05

Statistically Significant (purple)

Not Statistically Significant (orange)

Cumulative Percentile Ranking

When mapped (fig. 7.36), the distribution of clusters reflects a general spatial pattern. Those HUBs that have the highest potential for being influenced by vegetation management activities are dispersed along the eastern and southern flanks of the Big Horn Mountains. These HUBs are included in Clusters 2vm and 3vm. Cluster 0vm does not have any identified vegetation management activities. This cluster is generally located away from transportation corridors, in the more remote portions of the National Forest along the northern and western flanks of the mountain range.

The sum of the percentile ranks of the five criteria of the vegetation management category was calculated to identify the additive effects of vegetation management activity on aquatic, riparian, and wetland resources. The five criteria used in this analysis are summarized in Table 7.12. This analysis was performed at the management scale, with data existing for all portions of the 74 HUBs within the Bighorn National Forest boundary. Quartile values were then identified for the cumulative rankings. The quartiles were used as a means of grouping the cumulative ranks (fig. 7.36). Group 1 identifies those HUBs within the lowest quartile of cumulative rankings. Group 2 identifies those HUBs within the 25th – 49th percentiles of cumulative rankings. Group 3 identifies those HUBs within the 50th – 74th percentiles of cumulative rankings. Group 4 identifies those HUBs within the highest quartile of cumulative rankings.

HUBs 100901010104 and 100901010109 have the highest cumulative ranking value of 10 out of a possible 15-percentile sum. There were thirteen HUBs, which did not contain any of these three activities associated with aquatic, riparian, and wetland resources. While three of these HUBs were totally within the Bighorn National Forest boundary, there were several others that had most of their area within the boundary.

This analysis is relative only to the portion of the 6th level HUBs surface area within the Bighorn National Forest boundary, and is intended to provide the reader with the additive rankings at this scale. Unlike the previous methodology, the results are evenly distributed across the total number of HUBs at this scale. If conducted consistently across the region, this type of analysis can identify the location of a particular HUB within the context of other forests or throughout the region.

Groups 3 and 4, which have the higher cumulative percentile rankings, are dispersed throughout lower elevation portions of the National Forest that are not included in the wilderness. The HUBs including the Cloud Peak Wilderness are included in the lowest cumulative percentile ranking. The other groupings are dispersed in what seems to be a spatially random pattern.

This information should be valuable in identifying 6th level HUBs that could be used as “reference” watersheds for influences from historic clear cutting, wild fire and tie hacking activities on aquatic, riparian, and wetland resources. In addition, if consistent measurements are identified at the reach/site scale, the relative influence of these activities should illustrate their influence within a given cluster. Comparisons between different clusters may (and probably would) result in erroneous comparisons since ecological characteristics (drivers) are different.

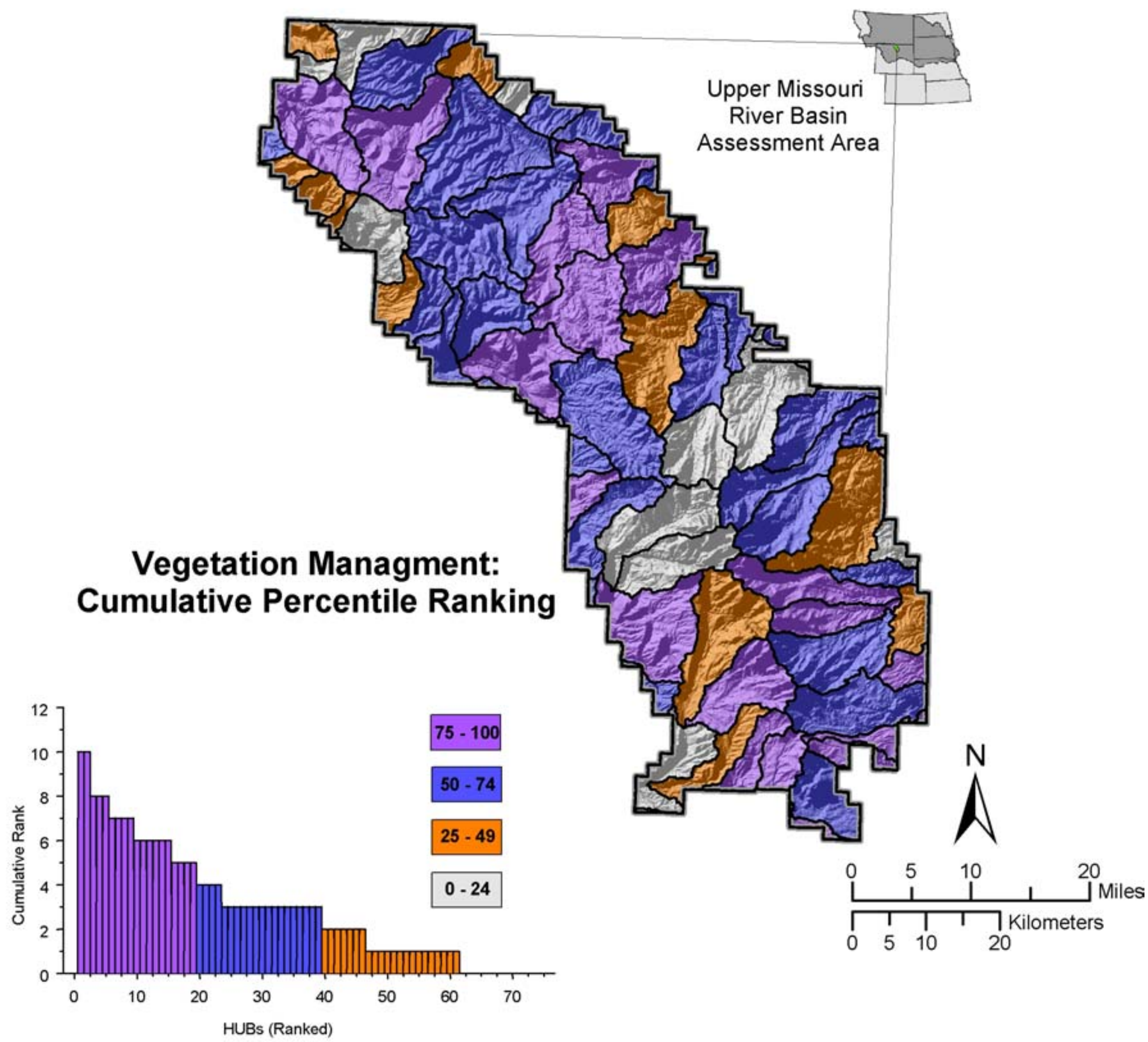

Figure 7.36. Vegetation management category: cumulative percentile rankings.

Chapter 8
Urbanization Category

Key Findings

1. Major oil and gas, and electrical lines are not located within the Bighorn National Forest (BNF).
2. Human populations have changed from less than one million in 1900, to slightly less than six million in 2000 with an estimated projection of over eight million for Colorado, Wyoming, and Montana. The potential influence on aquatic, riparian, and wetland resources from visitors to the BNF could increase as a result of this population change.
3. Population density estimates are given for the 4th level HUBs at the landscape scale, with the Upper Tongue watershed continuing to be the highest of any of the HUBs.
4. There are very limited private in-holdings that could influence aquatic, riparian, and wetland resources in the BNF. The USDA Forest Service manages approximately 99% of the land within the Forest boundary.
5. The highest potential for influences on aquatic, riparian, and wetland resources from the urbanization results may be from increased recreational use and increased demands for water as local communities grow.

Influence of Major Transmission Corridors

Transmission corridors support a variety of uses including communication, various energy supplies and electricity. In order to provide these important uses to the public, various "infrastructure" must be built including telephone lines, electrical power transmission lines, natural gas and oil pipes, telephone fiber optics lines, etc. Corridors consist of the clearing of vegetation, often with an associated system of access roads and trails. Transmission corridors can also be local in scope, providing access for a single small pipeline in an oilfield network. Or, a corridor might be a major arm in a regional network covering and ultimately disturbing large land areas. For this assessment the analysis of transmission corridors is confined to a discussion of linear features associated with these corridors.

Basin Scale

Geologic basins in Montana and Wyoming produce important amounts of oil and gas, serving regional markets. Large regional pipelines cross public and private lands and are owned and managed by various interests. In addition, Bureau of Reclamation Pick-Sloan project hydroelectric dams in the Upper Missouri River Basin generate electricity supplied to the national grid via the Western Area Power Administration Transmission Network.

Landscape Scale

The location of transmission corridors depends upon several factors including: product source location, destination location, topography, ownership pattern, and cultural pattern.

Transmission corridors include water delivery systems that include major dams to the north including delivery to a much larger market to the south along the Colorado Front Range. Oil and gas production fields exist in basins both east and west of the Big Horn Mountains. Topographic control is evident by the placement of lines outside of upland areas where corridor engineering and environmental costs can be much higher than in lowland terrains characterized by less dramatic relief, less resistant geology, and sometimes less diverse and fragile ecology. Moreover, ownership and cultural patterns can induce corridor placement by offering less resistant regulatory and administrative regimes.

Figure 8.1 shows the placement of major oil and gas, and electrical transmission lines at the landscape scale. These major lines illustrate the overall pattern of transmission corridors and show that disturbance and other influences from major corridors are confined to areas beyond the Big Horn Mountains and the National Forest boundary.

Even so, while the lines are outside of the Forest, important aquatic, riparian, and wetland systems downstream from these corridors may be influenced by disturbance and altered runoff from the installation and maintenance of these corridors.

In summary, the landscape assessment area includes nearly 750 total miles of transmission corridor (table 8.1). While corridor width figures were not available for this analysis we can develop a sense for the potential magnitude of surface disturbance by choosing a reasonable approximation for major corridor width and then calculating area. Choosing a width of 300 feet means the area of direct influence would be over 27,000 square feet or about 42 square miles. The indirect influences or risks to aquatic, riparian, and wetland resources would have to be evaluated at more localized scales. However, since all of these corridors are located downstream of the Bighorn National Forest, we would not expect any influences of these areas within the Forest boundary.

Management Scale

Major corridor placement and activity does not directly affect 6th level HUBs within the Bighorn National Forest boundary. Some adjacent watersheds are affected downstream beyond the mountain front. Furthermore, the cultural, ownership and topographic patterns in the larger aquatic, riparian, and wetland landscape suggest that major corridor development is unlikely to appear in the near future.

As a consequence, management decisions in consideration of major corridors could be aimed at maintaining superior upstream water quality and volumes in an effort to mitigate downstream impacts introduced by transmission corridors.

Table 8.1. Summary by 4th level HUB of major transmission lines at the landscape scale. The acres equivalent column illustrates the potential magnitude of disturbance from major corridors and assumes a 300 average corridor width.

4th Level HUB Code	Length in Miles Oil and Gas	Length in Miles Electricity	Total Miles	Acres Equivalent at 300 ft. Corridor
10080008	58.57	0.01	58.58	2,130.01
10080010	28.04	61.97	90.02	3,273.39
10080016	23.27	52.41	75.68	2,751.93
10090101	198.74	46.01	244.75	8,899.96
10090201	30.74	12.20	42.94	1,561.50
10090205	69.60	25.48	95.08	3,457.60
10090206	122.94	18.73	141.67	5,151.70
Total	531.91	216.81	748.72	27,226.08

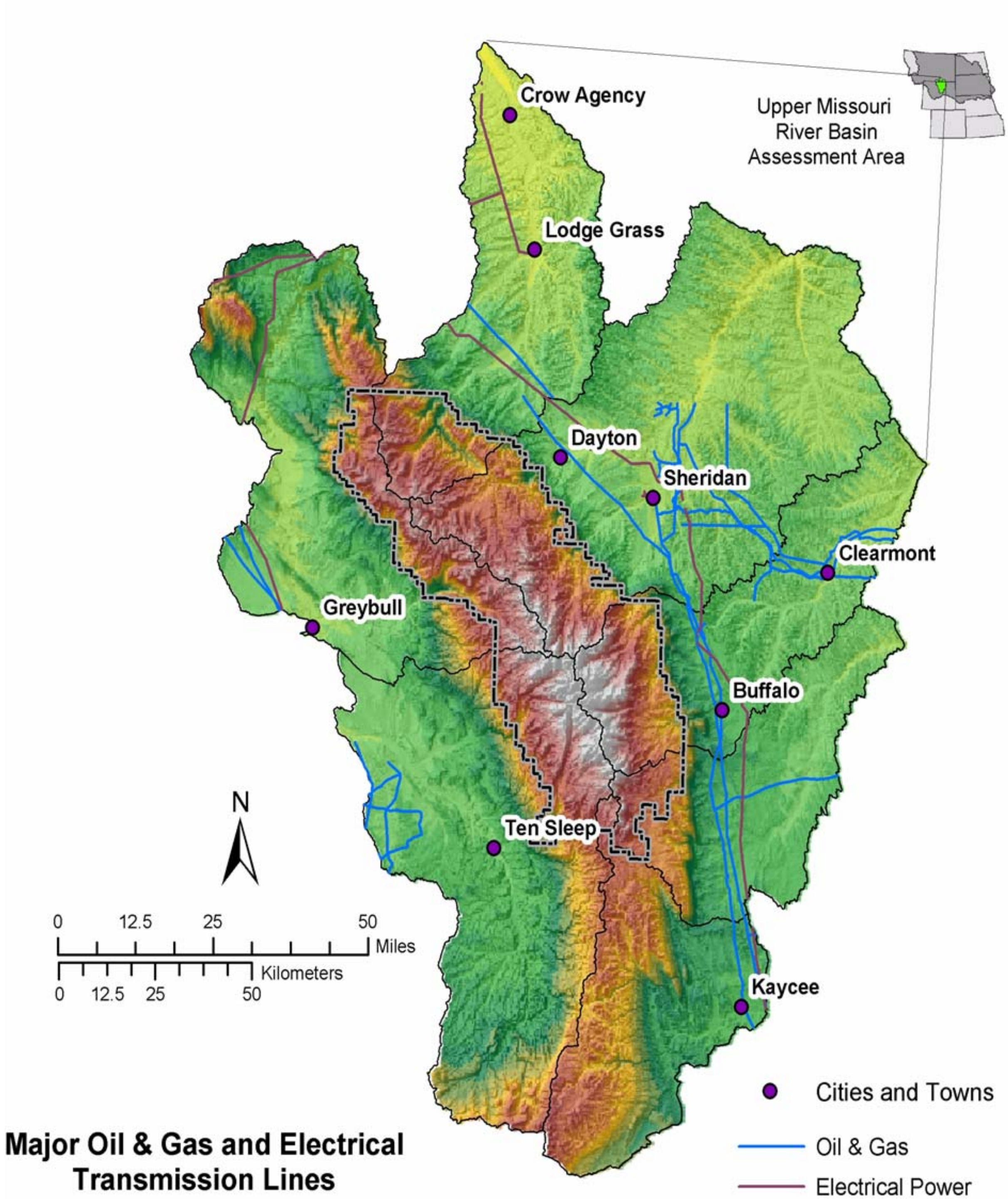

Figure 8.1. Major oil and gas, and electrical transmission lines at the landscape scale.

Influence of Urbanization

Basin Scale

The influence of urbanization upon aquatic, riparian, and wetland resources in the basin reflect both demography and geography in the basin and beyond. Population trends in this portion of Wyoming and Montana, over the past thirty years, have shown very little change (table 8.2) but in the coming years this situation may change. The western states comprise the fastest growing area in the United States, with an expected increase of almost 50 million people by the year 2050 (Center of the American West (CAW) 2003). While most of this growth is expected in three states; Colorado, Utah and Arizona, the states of Wyoming and Montana are also expected to grow as well (fig. 8.2).

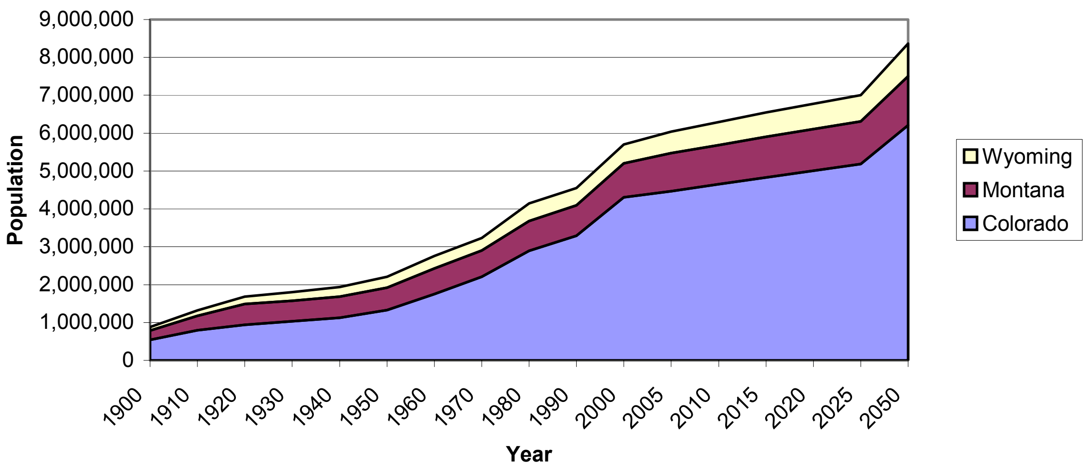

Figure 8.2. Actual and projected populations for Wyoming, Montana, and Colorado. Colorado is expected to absorb most of the population gain along the Rocky Mountain Front Range. Graph adapted after CAW 2003.

Table 8.2. Historic and projected populations for the U.S., the Western states along with Colorado, Montana and Wyoming. Table adapted after Center of the American West 2003.

Area	1900	1950	2000	2050	2000 to 2050	% 2000 to 2050
United States	76,212,168	151,325,798	285,230,516	395,461,000	110,230,484	38.65%
Western States	4,091,349	19,561,525	61,359,463	109,304,000	47,944,537	78.14%
Colorado	539,700	1,325,089	4,301,261	6,208,000	1,906,739	44.33%
Montana	243,329	591,024	902,195	1,292,000	389,805	43.21%
Wyoming	92,531	290,529	493,782	863,000	369,218	74.77%

Expanding populations along the Rocky Mountain Front Range are expected to be concentrated in existing cities and towns. Figure 8.3 illustrates this expectation for five western states including Wyoming and Montana over the next 50 years by showing expected change in land use categories (e.g., conversion from rural to suburban and urban) around principal towns and cities in those western states. It is evident that in the landscape area, growth by cities and towns such as Sheridan, Cody, and Casper will yield a corresponding growth in demands for resources in the assessment area. Increased population in these towns and cities would result in an increased in need for water. A consequent increase in water and wastewater facilities should be expected as well. These increases would place greater demands on upland watersheds in the Big Horn Mountains.

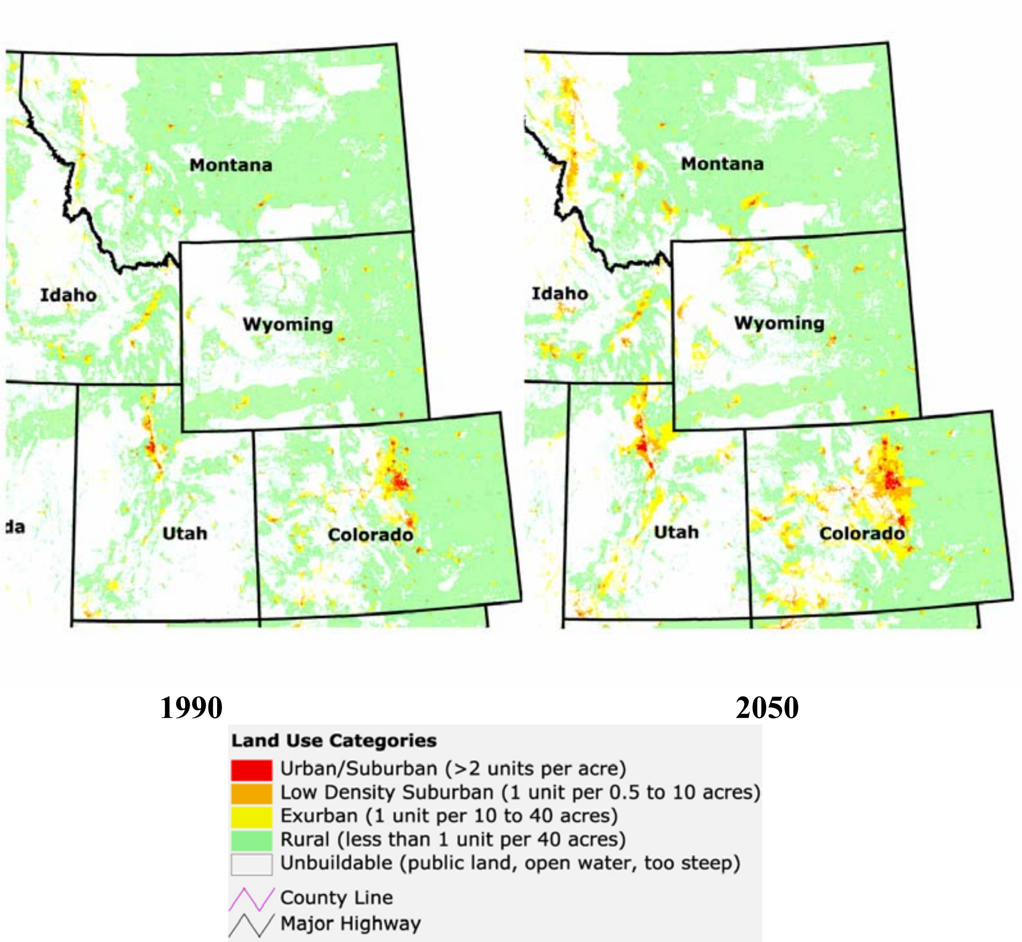

Figure 8.3. Change in land use categories from 1990 to projected 2050. Use categories are expected to change, especially in and around larger towns and cities. Maps adapted after Center of the American West 2003.

Both current and projected populations and population density vary widely between 4th level HUBs. The 4th level HUBs east of the Big Horn Mountains Divide carry the highest populations and population densities than those to the west, which are the lowest. Table 8.3 and Figure 8.4 show populations for principal cities and towns in the landscape. Table 8.4 and Figure 8.5 show population density by 4th level HUB.

Table 8.3. Current (2000) and projected (2050) population values for cities and towns in the assessment area. The projected values are calculated by simple application of the 74% percent growth rate from Table 3.51 to year 2000 population values. In 2000, Sheridan, Buffalo, and Greybull contain over 80% of the population of all cities and towns. City and town 2000 population values from ESRI 2000.

City/Town Name	Pop. 2000	Pop. 2050
Sheridan	13,000	24,186
Buffalo	3,302	5,745
Greybull	1,789	3,113
Crow Agency	1,446	2,516
Ranchester	676	1,176
Dayton	565	983
Lodge Grass	517	900
Ten Sleep	311	541
Kaycee	256	445
Clearmont	119	207
Total	22,881	39,812

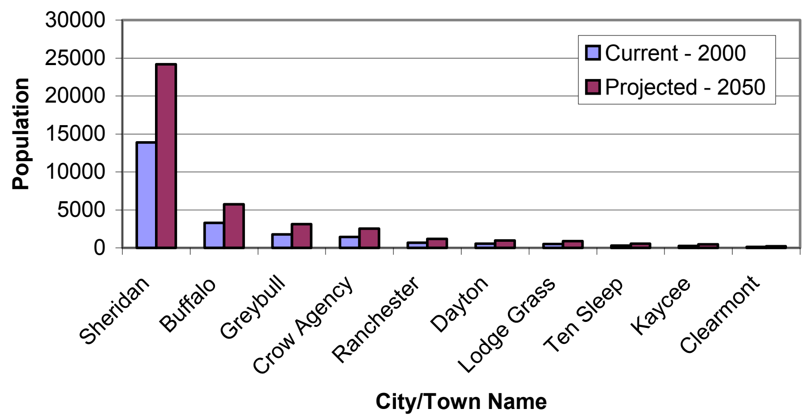

Figure 8.4. Graphical representation of current (2000) and projected (2050) population values for principal cities and towns in the assessment area. City and town 2000 population values from ESRI 2000.

Table 8.4. Current (2000) and projected (2050) population values for 4th level HUBs. These values are sums of city and town populations by HUB. Values obtained by integration of ESRI 2000 and CAW 2003 data.

4th Level HUB Code	4th Level HUB Name	Population 2000	Pop. Density 2000 Pop/Mile^2	Population 2050	Pop. Density 2050 Pop/Mile^2
10090101	Upper Tongue River	15,141	6.0	26,345	10.4
10090206	Clear Creek	3,421	3.0	5,952	5.2
10080016	Little Big Horn River	1,963	1.5	3,416	2.6
10080010	Big Horn Reservoir	1,789	1.0	3,113	1.7
10080008	Nowood River	311	0.2	541	0.3
10090201	Middle Fork Powder River	256	0.3	445	0.5

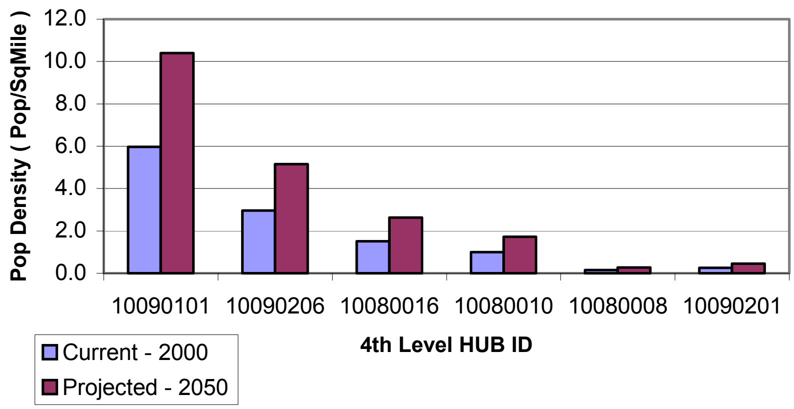

Figure 8.5. Graphical representation of population values by HUB for year 2000 and projected values for year 2050. The Upper Tongue River and Clear Creek watersheds, on the east flank of the Big Horn Mountains, contain over 80% percent of the city and town population. Values obtained by integration of ESRI 2000 and CAW 2003 data.

Land ownership pattern is an important geographic control on population distribution (fig 8.6 and table 8.5). The overall distribution of privately owned lands is key to the shape size and pace of growth of towns and cities. Private lands are the fodder for growth. Public lands provide resources and can enhance quality of life. In the aquatic, riparian, and wetland landscape, large contiguous blocks of private land, east of the mountains, place few limits on community and population growth. Isolated private tracts interspersed within public (e.g., BLM, U.S. Forest Service, and state) lands may show little growth over time. This is especially so for rural private lands beyond practical commuting distances of vibrant population centers.

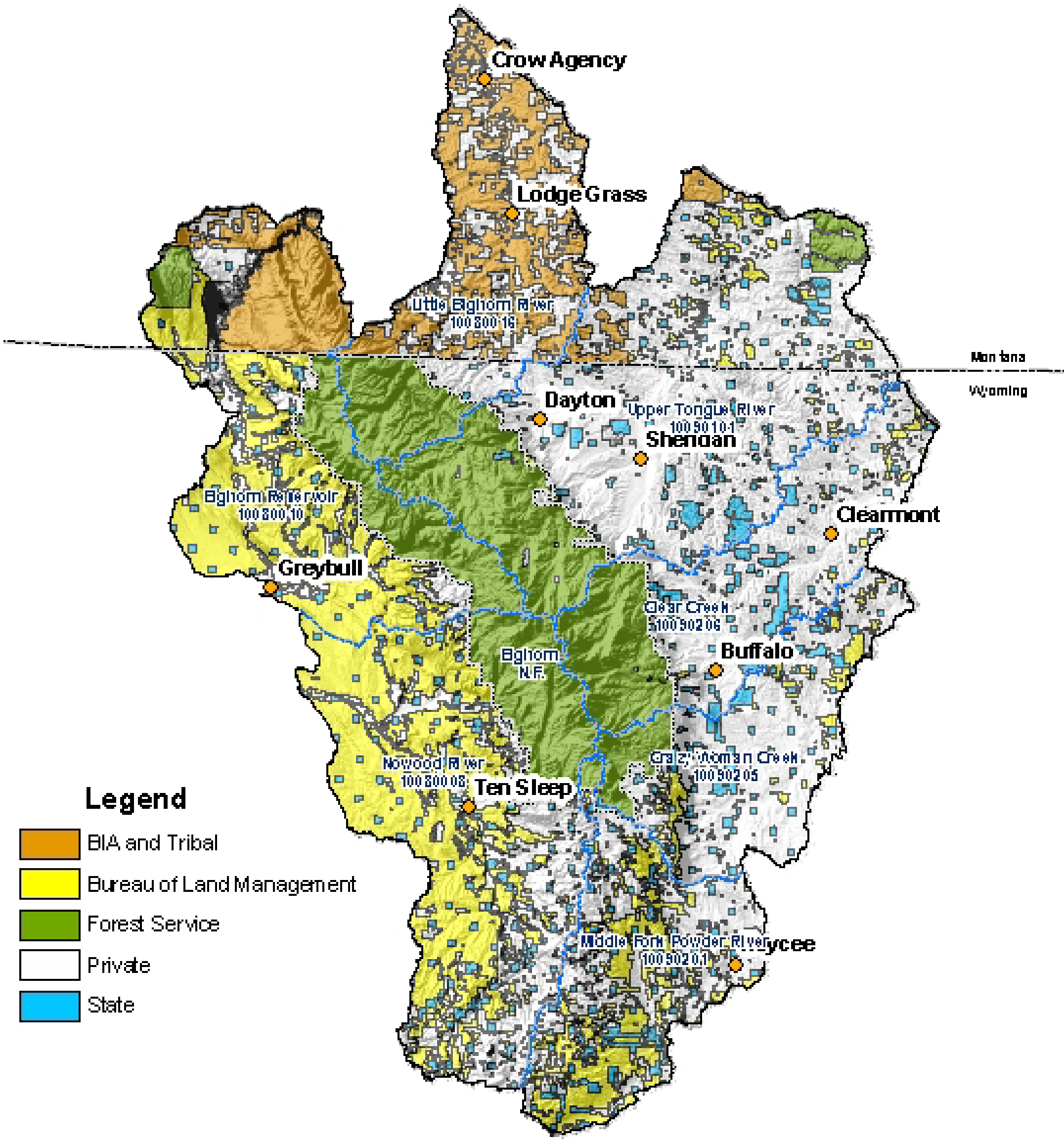

Figure 8.6. Land ownership at the landscape scale. Principal cities and towns are labeled. Private lands on the east and south flanks of the Big Horn Mountains correspond to higher populations and population densities. Large contiguous blocks of private lands to the east place few limits on growth. Adapted after BLM 2003 and Montana 2003.

Table 8.5. Land ownership in the assessment area. Nearly 50% of the landscape is privately controlled while the BLM and U.S. Forest Service manage almost 40% of the land. Forest Service ownership includes lands outside the Bighorn National Forest boundaries. Source BLM 2003 and Montana 2003.

Ownership	Acres	Percent of Landscape Area
Other	2,573	0.04%
Bureau of Indian Affairs	643,957	9.37%
Bureau of Land Management	1,459,833	21.25%
Bureau of Reclamation	88	0.00%
Department of Defense	4,541	0.07%
Forest Service	1,175,104	17.10%
National Park Service	42,659	0.62%
Private	3,082,355	44.86%
State	448,534	6.53%
Water	11,572	0.17%
Total	6,871,216	

Management Scale

There is little opportunity for community or domestic growth on private lands within the Bighorn National Forest. Within the Forest boundary ownership is nearly homogeneous. Forest Service lands comprise just over 99.3% percent of the total area. Lands held by state agencies account for about 0.3% percent leaving just under 0.5% of the remaining lands in the Forest privately held (table 8.6). These private lands are comprised of twenty parcels ranging in size from about 40 to 1,200 acres. The average size is about 228 acres. In addition, there are four state parcels ranging in size from about 300 to 1,500 acres – the average size of these state parcels is about 740 acres.

Table 8.6. Land ownership distribution in the Bighorn National Forest (BNF). Forest ownership is dominated by the U.S. Forest Service with over 99% being Forest Service jurisdiction or ownership. Source is modified after BLM 2003 and Montana 2003.

Ownership	Number of Parcels	Acres	Percent of BNF
Forest Service	1	1,104,933.0	99.326%
Private	20	4,545.6	0.409%
State	4	2,948.3	0.265%
Total	25	1,112,427.0	100.000%

Private and state in-holdings constitute a small percentage of the lands within the Bighorn National Forest (table 8.6). Privately owned lands become a dominant characteristic of the 6th level HUBs immediately outside of the Forest boundary; this is especially true on the eastern side of the mountains. These eastern watersheds with high percentages of private lands are evident in Figure 8.7, which shows 6th level HUBs ranked by percentage of watershed privately held for watersheds in and adjacent to the Bighorn National Forest. The eleven watersheds with no private in-holdings are listed in Table 8.7.

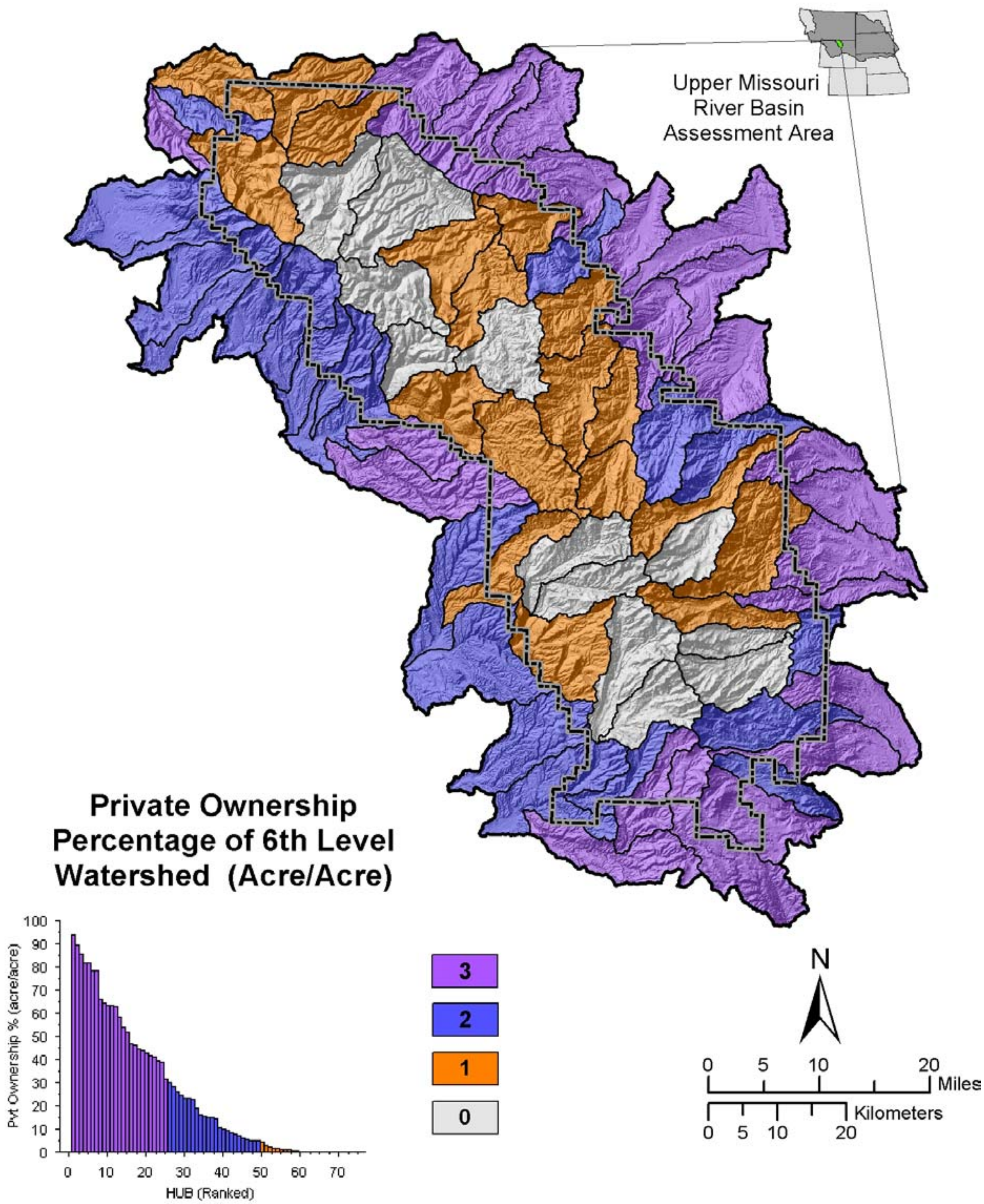

Figure 8.7. The percentage of 6th level HUBs in private ownership. The high ranking of watersheds to the east and south is indicative of overall ownership pattern outside of the Forest boundary. The twelve watersheds containing no private land in-holdings are listed in Table 8.5.

Table 8.7. 6th level HUBs inside the Bighorn National Forest with no private in-holdings.

6th Level HUB Code	6th Level HUB Name
100800080401	Upper Tensleep Creek
100800080402	East Tensleep Creek
100800080601	Paint Rock Creek-Trout Creek
100800080602	Long Park Creek
100800100103	Cedar Creek
100800160101	Little Big Horn River-Wagon Box Creek
100800160102	Dry Fork Little Big Horn River
100901010101	North Tongue River
100901010103	Upper Tongue River
100902060101	South Clear Creek
100902060102	Middle Clear Creek
100902060301	South Piney Creek

The twelve 6th level HUBs within the Bighorn National Forest that have no private in-holdings (fig. 8.6 and table 8.7) could be ideal watersheds for native species management due to the ability of state and federal agencies to implement necessary management actions throughout the HUBs. For example, native trout management in watersheds with no private in-holdings would allow managers to apply a "metapopulation" approach where intermixing populations could be established. At the same time managers could avoid jurisdictional problems that come about when management is made more cumbersome by mixed ownership. This is especially important with mobile populations, such as native trout, where population movements may cross ownership or jurisdictional bounds. Close examination of ecological driver characteristics would also be important, in order to prioritize HUBs for this purpose.

Disturbance (e.g., logging, mining, road building) on the twenty private parcels within the Bighorn National Forest could influence function of aquatic, riparian, and stream systems downstream. Within the boundaries of the National Forest there are about 76 miles of stream that are downstream from private parcels (fig. 8.8). There is an additional 165 miles of streams in those watersheds that lap over the Forest boundary and include lands outside the Forest. The total number of miles of all potentially affected downstream stream segments in the management scale area is 241.

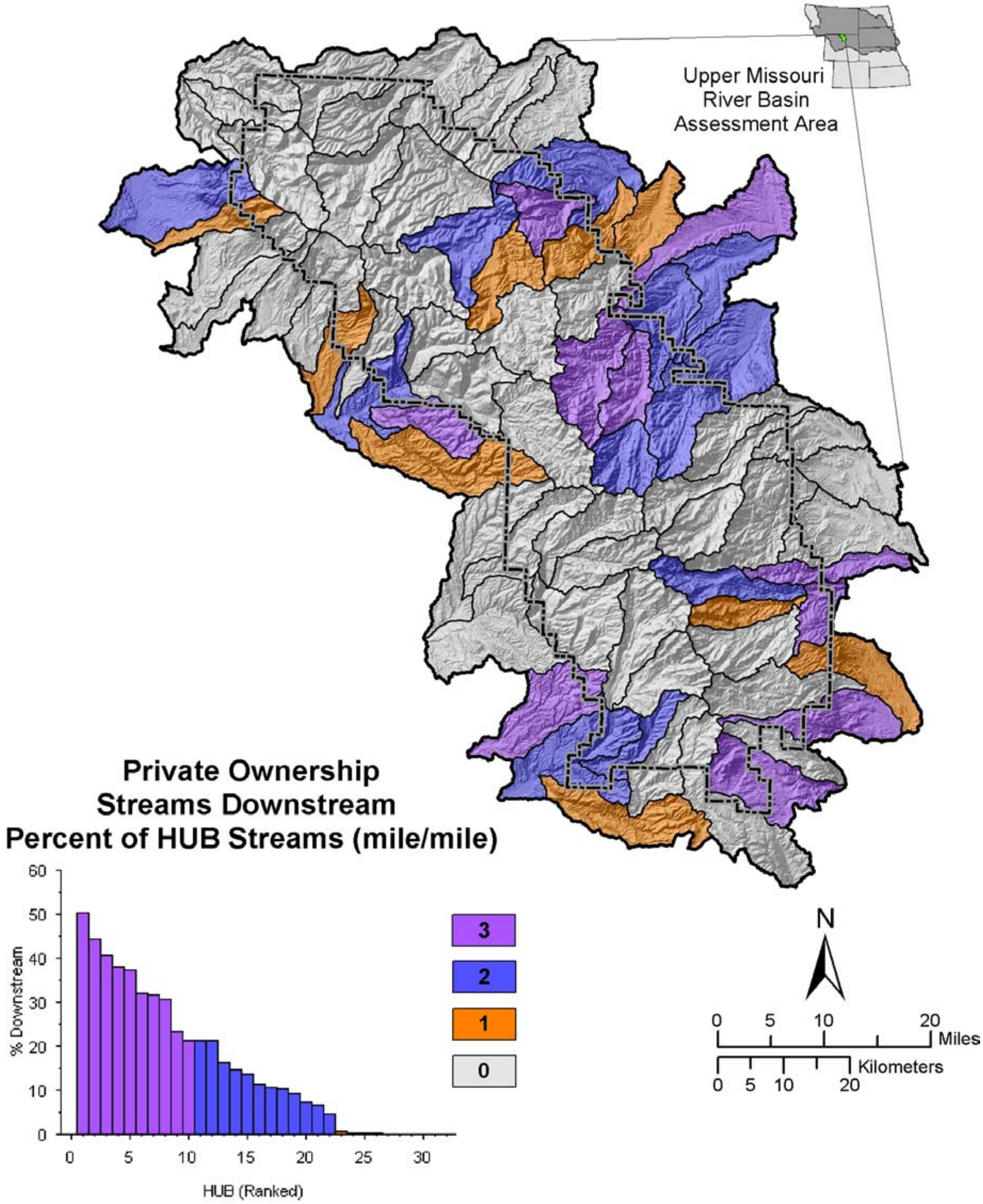

Figure 8.8. Percentage of 6th level HUB streams, total mileage, to mileage of streams downstream from private lands. Twenty privately held parcels averaging about 200 acres in size influence 241 miles of stream. The five HUBs with the highest ranking are listing in Table 8.8.

Table 8.8. 6th level HUBs with the highest percentage of stream mileage to mileage of streams downstream from private lands.

6th Level HUB Code	6th Level HUB Name	Downstream Mileage	HUB Total Stream Mileage	Percentage
100902060107	French Creek	17.0	33.9	50.25%
100902050106	Upper Middle Fork Crazy Women Creek	18.7	42.4	44.22%
100800100105	White Creek	14.1	34.8	40.59%
100800080502	Brokenback Creek	18.5	48.5	38.09%
100901010105	Tongue River-Sheep Creek	12.9	34.4	37.40%
	Total	81.2	193.9	

Reach/Site Scale

The influence of management activities on downstream aquatic, riparian, and wetland resources is best addressed at the reach/site scale. Many of the same influences of management activities found from Forest Service activities may be observed on private in-holdings. However, in some cases, there are fewer regulations on private lands, and influences may be even more pronounced. Some specific questions that should be asked when addressing the influences of management activities form private lands include:

1. What activities are most noticeably occurring or have occurred on the private land, which would potentially influence aquatic, riparian, and wetland resources on Forest Service property?
2. What role does the Forest Service have in working cooperatively with landowners to ensure that aquatic, riparian, and wetland resources downstream are treated appropriately?
3. If new actions are being considered on private lands, does the Forest Service have the necessary monitoring information to identify change as a result of the action?
4. Do special use permit authority apply to activities that could influence aquatic, riparian, and wetland resources on Forest Service lands, or are their connected actions?
5. What aquatic, riparian, and wetland resource values are located downstream of the private lands that are important or should be addressed as a result of activities upstream on private lands?

Information Needs and Management Implications

As mentioned previously, there are relatively few private in-holdings within the Bighorn National Forest boundary. However, some activities within these in-holdings, such as ski areas, reservoirs, and developments can have influences on aquatic, riparian, and wetland resources for considerable distances downstream. Monitoring information on these influences could be valuable for quantifying these influences. In addition, if a “change in management” were to be proposed on a particular property, information on the current condition of particular resource values would be valuable if the Forest were to be part of any licensing process. As the population increases, and more focus is given to these desirable in-holdings, we could see a pronounced increase in the influence of activities on private in-holdings on downstream aquatic, riparian, and wetland resources.

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