Ungulate Baseline Inventory of the Gardiner Basin

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Part I.

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The availability of ecological baseline information is fundamental to successful conservation and restoration efforts. Commonly, such records provide a reference point for investigating the stability of vegetation, soil and wildlife communities when long term monitoring data is unavailable or incomplete. For example, Ecological Site Descriptions (ESDs) developed and archived by the USDA Natural Resource Conservation Service provide a well-documented platform for determining if local soil and vegetation conditions represent a departure from reference conditions. Unfortunately, these descriptions are largely unavailable for portions of National Forest, Bureau of Land Management, US Fish and Wildlife Service and National Park Service lands leaving ecologists and land managers with little information for determining the current status or condition of vegetation/soil complexes on public lands. The Custer-Gallatin National Forest faces this challenge when trying to quantify the long term effect of elk and bison grazing on public lands north of Yellowstone National Park. Where ESDs are outdated or unavailable an alternative approach would be to use earlier vegetation community descriptions generated by forest service personnel and university researchers e.g. Daubenmire (1942), Daubenmire and Daubenmire (1968), Hansen et al. (1995), Pfister et al (1977) and Mueggler and Stewart (1980). These rangeland, forest and riparian vegetation community type descriptions have sufficient species level detail to provide a comparison with current conditions. Resulting departures from these published references could be considered a measure of the effect of climate change, fire suppression or large ungulate grazing on the sustainability of vegetation communities on Forest Service lands within the northern winter range of the Gardiner Basin, Gardiner, Montana.

Critics could question the strength of the comparison between conditions in the basin and published vegetation community descriptions because none or few of the inventoried sites contributing to the published descriptions were likely to have occurred within the Gardiner Basin. Realistically, observed differences between published references and information collected in target areas could be reflective of dissimilarities among sampling protocols and local soil and weather conditions as much as changes due to long term grazing pressure or global warming. To overcome this limitation the Custer-Gallatin National Forest entered into a contract with the Animal and Range Sciences Department, Montana State University to develop an ecological baseline for grassland and shrub dominated communities within the northern winter range portion of the Gardiner Basin. Information on soils and vegetation community composition were gathered from 2015 through 2017 and then summarized into community associations. The goal of this effort has been to provide Forest Service ecologists and technicians with an ecological baseline description that can be used to evaluate future vegetation status for possible departure from the 2015-2017 reference conditions.

METHODS

Study Area Description

The Gardiner Basin is the rugged landscape immediately north of the Yellowstone volcanic plateau near the town of Gardiner in southwestern Montana (Fig.1). Formed from a complex geology the 47,937ha basin shares basement rocks with the continental interior, Paleozoic lithologies with the western interior, compressive tectonics with the Fold and Thrust Belt to its west, an extension of the Basin and Range province to the southwest and Cenozoic volcanism (Locke et al. 1995). Landscape and soil complexity is heightened further by landslides and the advance and retreat of glaciers from the Yellowstone ice cap during the Pleistocene. Resulting soil formations can be categorized into 3 broad groups, low elevation mountain slopes, those underlain by interbedded sandstone and shale and those underlain by granitic or volcanic rock (Davis and Shovic 1996). Soils of non-forested landforms overlying coarse-grained metamorphic rocks range form shallow to deep sandy loams and loams with 5 to 25% angular, coarse fragments in the upper 0.5m of the profile (Veseth and Montagne 1980). Where soils overlay limestone and hard, green-gray shales the lower horizons are reactive, the clay fraction increases with profile depth and may contain 50% or more angular limestone cobble (Veseth and Montagne 1980). Skeletal and mixed loamy to fine loamy soils have developed over volcanic flows from the Gallatin-Absaroka volcanoes (Veseth and Montagne 1980). In this last soil group clay content increases with depth making up 28% + of the lower horizons. The higher clay content gives these soils lower permeability and higher runoff than soils developed on the other geologic units.

The sagebrush (*Artemisia* ssp) and mixed sagebrush-grasslands of the basin serve as important winter range for bison, bighorn sheep, elk, mule deer and pronghorn antelope because the area remains relatively open (shallow snow depths) during winter months. At this point it is instructive to inform readers that there are no active domestic livestock grazing allotments remaining in the basin. Yearly average maximum – minimum temperatures are 14^{o} C and 0^{O} C respectively with average annual precipitation of 247mm at lower elevations and 432mm at higher elevations (WRCC 2017).

Most of the 8,094ha of private land within the Gardiner Basin occurs along the narrow, Yellowstone River corridor with 39,843ha of state and US Forest Service lands making up in the remainder of the basin landscape.

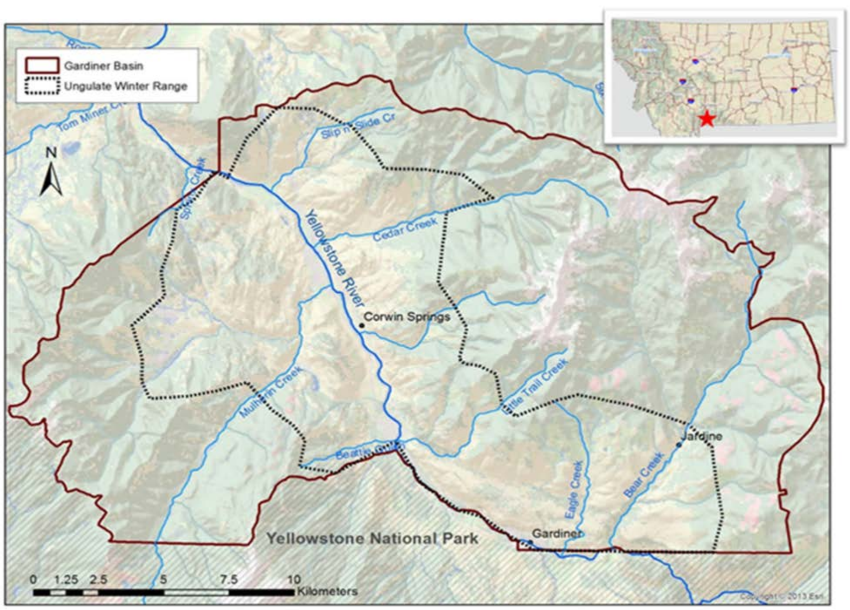

Fig. 1. The Gardiner Basin lies on the northern border of Yellowstone National Park and extends further north to meet the southwestern end of the Paradise Valley.

Study Approach

The goals and design of this study was a cooperative effort between scientists, biologists and managers of the Custer-Gallatin Forest staff, the Hebgen and Gardiner Ranger Districts and the Animal and Range Sciences Department, Montana State University. Management goals of both the federal and state agency coalesced around the shared but unverified assumption that historical wildlife population trends have been within the basin's ecological carrying capacity. However, assessment of this assumption is challenging because existing ecological condition platforms, e.g. *Soil Survey of the Gallatin National Forest* (Davis and Shovic 1996) and *Grassland and Shrubland Habitat Types of Western Montana* (Mueggler and Stewart 1980) do not contain local data or only describe the state of native vegetation communities in the broadest terms. Furthermore, there are no livestock/wildlife grazing exclosures outside Yellowstone National Park that could be used as a vegetation community reference. Realizing that assessing the influence of wildlife population fluctuations on ecological sustainability would be less rigorous than needed the following study objectives were developed; 1) assess the current state and condition of the Gardiner Basin winter range, specifically the sagebrush and sagebrush mixed grasslands; 2) use this assessment to develop a basin specific ecological baseline for future monitoring efforts; and 3) to evaluate the potential for the Gardiner Basin range to accommodate increasing levels of ungulate use associated with potential bison expansion from Yellowstone National Park. This report describes the outcome of objectives 1 and 2.

Vegetation cover, species frequency, shrub canopy cover, biomass production, soil texture, soil coarse fragments and soil depth were measured at 63 separate locations in the Gardiner Basin (Fig. 2). This information was summarized statistically to delineate vegetation community types (Appendix A).

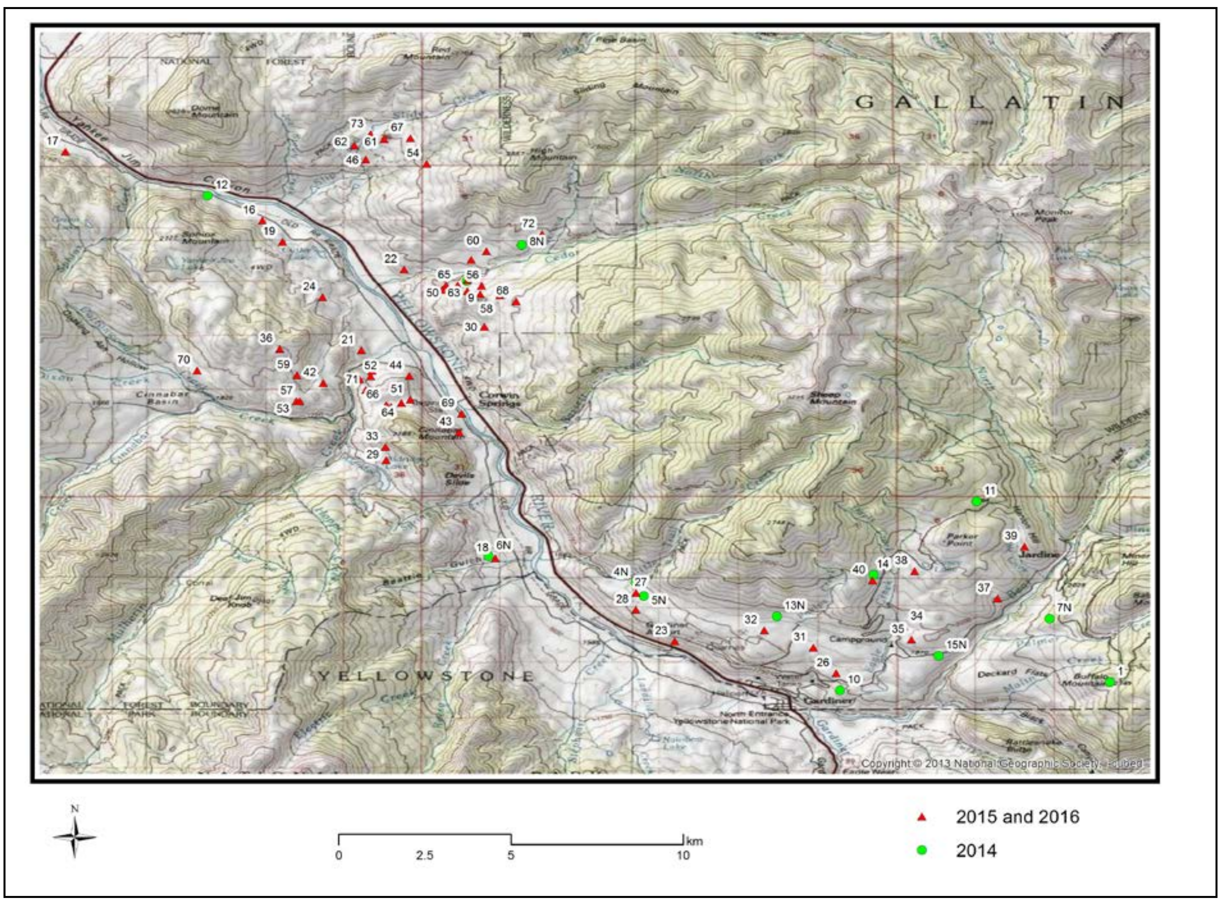

Fig. 2. Location of soil/vegetation sampling sites in the Gardiner Basin, Gardiner, MT. Site numbers correspond to numbers found in the respective vegetation community description.

RESULTS

This is the first section of a two part series; the second section covers similar material for the Hebgen Basin, West Yellowstone, MT. The various physical and biological measures made during field surveys in both areas have been summarized into individual chapters that cover specific bodies of information.

Chapter 1

The Physical Setting

Because of the complex geologic history of the Gardiner Basin landforms and soils are diverse over relatively small areas within the basin. Unlike the Yellowstone Valley and mountain ranges to the north and east of the Yellowstone Plateau the complexity of the Gardiner Basin sets challenging sideboards for defining the relationship between soils and vegetation communities. In an effort to account for the broad geologic influence within the basin Dr. Tom Keck, Custer-Gallatin National Forest soils specialist, codified the various formations into two broad categories, unconsolidated and bedrock. Unconsolidated landforms have been created by mass wasting, landslides and glacial advances ultimately producing highly variable and poorly developed soils. Because of long term stability the bedrock landforms, on the other hand, would be expected to produce more uniform, better developed soils. The first effort to identify patterns that could give rise to an ecological site was to compare soil depth, soil organic matter content, coarse fragment content and slope by geologic base setting (Table 1.1). Soil organic matter was

Table 1.1. Average values for various physical parameters measured at vegetation inventory sites during 2016 and 2017 in the Gardiner Basin, Gardiner Montana. Slope values represent the midpoint range of slope classes, 0 – 4%, 4 – 15%, 15 – 35%, 35 – 60%. Column values with different superscripts are different (p < 0.10).

geologic base	soil depth	soil OM	coarse fragment	slope
unconsolidated	50cm	6%[a]	1	26%
bedrock	43cm	3%[b]	1.2	30%

the only physical site attribute that differed by geologic base. This suggests that sites occurring on landforms derived from unconsolidated materials may be more productive than those occupying bedrock landforms. To check this idea we first compared soil texture classes between the geologic base conditions and then used REAP, Relative Effective Annual Precipitation, (Garcia 2011) to compare potential growing conditions among inventoried sites.

Based on the consistently higher soil organic matter in soils developed from unconsolidated geologic materials loamy textured soils were expected to occur more frequently. However, both landforms had loamy textured soils, varying from sandy loams to silt loams (Table 1.2). Surprisingly, the bedrock derived soils were more diverse than those developed on the more organic rich unconsolidated landforms.

Table 1.2. Soil texture classes recorded on inventoried sites in the Gardiner Basin, Gardiner, MT. Percentage values represent the proportion of inventoried sites that had each textural class.

Geologic base	Soil texture Classes
unconsolidated	sandy clay loams (50%); sandy loams (30%); clay loams (20%)
bedrock	sandy clay loams (20%); sandy loam (30%); clay loams (20%); loamy (20%); silt loam (10%)

The REAP model combines soil texture, slope, aspect and elevation with local annual precipitation values to predict plant available water. Higher values, e.g. 54, represent much better growing conditions than sites with lower values, e.g. 17. There was, however, no significant difference ($p > 0.10$) between the mean REAP value for unconsolidated sites, 39 and those for the bedrock derived sites, 37, indicating similar growing conditions on both landforms. The high spatial variability across the Gardiner Basin is reflected in the overall lack of differences in the various physical measures between unconsolidated landforms and those occurring on bedrock.

Chapter 2

Reference Communities – The Vegetation Baseline

Initial Categorization

The first approximation using vegetation canopy cover as an index identified 8 clusters with 6 that had 95% + similarity (Fig. 2.1). These clusters were further examined through MANOV testing to identify the possibility of more tightly clustered associations. The outcome of this effort (Fig. 2.2) indicated that identified clusters grouped around differing levels of sagebrush cover (*Artemisia tridentata* and *Artemisia nova*) in the sampled communities. Even though the clusters were statistically different ($p < 0.01$) in terms of sagebrush canopy cover the same associations did not appear to differentiate by geology or soil metrics. However, patterned differences did re-appear ($p < 0.01$) when aspect (NE vs SW) was compared among the groups (Fig 2.3). With sufficient evidence that the initial clusters were different a second similarity analysis was performed omitting geology and soil parameters.

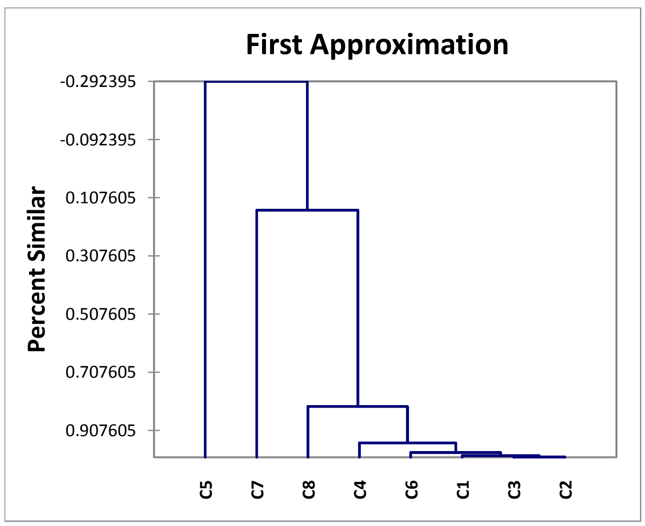

Fig. 2.1. Eight similar vegetation clusters drawn from Gardiner Basin field data collected during 2016 and 2017.

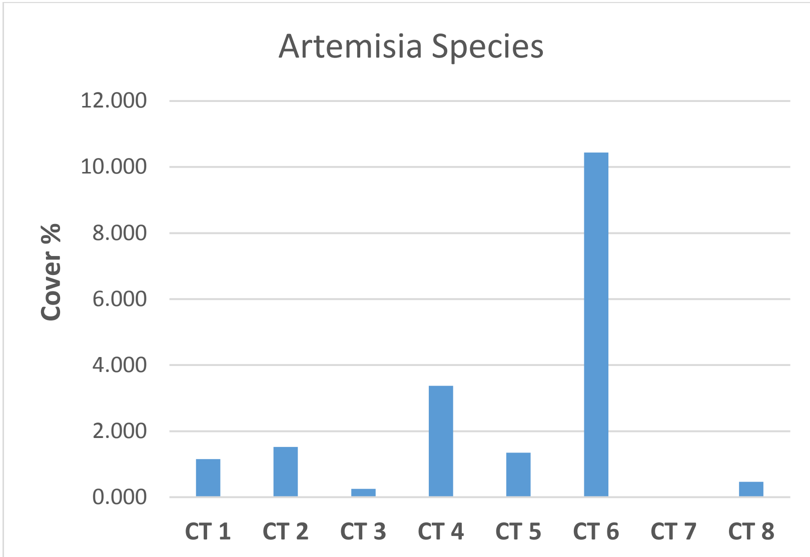

Fig. 2.2. Evidence that initial clusters were driven by the amount of sagebrush cover recorded at the various sites in the Gardiner field surveys.

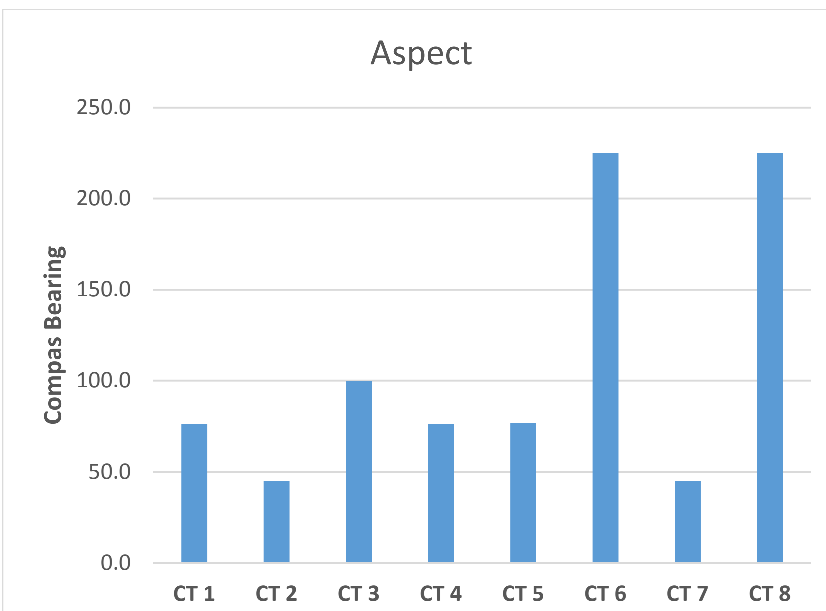

Fig. 2.3. Differences among the initial clusters due to aspect. Bearing values represent average of aspects NE (45°) and SW (225°) contained in each cluster.

Second Categorization

Re-analysis of the vegetation cover data accompanied by slope and aspect measures expanded the original 8 clusters to 12 with 94% similarity (Fig. 2.4). Within cluster variation was then tested with ANOV and paired T analyses. The expectation that similar variation among sites within a cluster would produce a non-significant p value ($p > 0.10$) was used to identify the most homogeneous clusters. Homogeneous clusters were classified as community types.

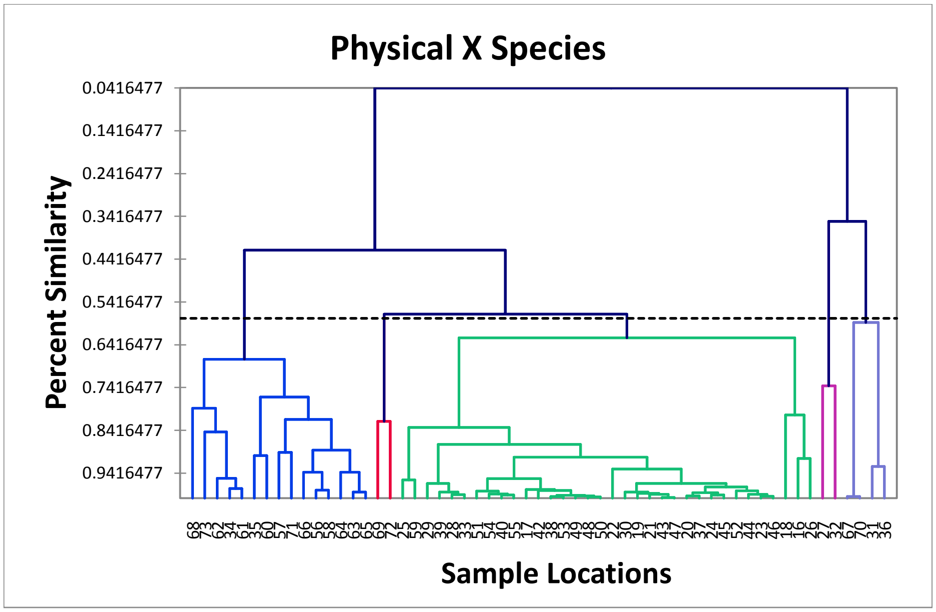

Fig. 2.4. Re-analysis of the original clusters identified in Fig. 2.3 combining vegetation cover, slope and aspect.

Within cluster statistical evaluations produced 11 clusters with similarities of 90+%. Based on the high degree of similarity the clusters are considered to represent community types (Table 2.1). Once these

Table 2.1. Vegetation community types identified within the Gardiner Basin, Gardiner Montana.

Non-forested Community Types Gardiner Basin, Montana
Abandoned Agricultural Lands
Basin Big Sagebrush
Black Sagebrush Level
Black Sagebrush Steep
Idaho Fescue, loamy grasslands
Idaho Fescue/bluebunch grasslands
Mountain Big Sagebrush Steep
Mountain Big Sagebrush Forb
Mountain Big Sagebrush Sandy Loam
Mountain Big Sagebrush Deep loamy
Mountain Big Sagebrush Degraded

community types had been identified a third level of statistical analyses revealed a more detailed view of the interaction between vegetation cover, soil, geology and slope. For example, community types dominated by black sagebrush (*Artemisia nova)* could be segregated into two distinct subtypes or phases. The level phase occurs on an average slope of 11%, has fewer coarse fragments within the soil column and less surface rock than sites occupying steeper sites. Grassland and mountain big sagebrush community types could also segregated into subtypes or phases.

Third Categorization

Finally, the physical and vegetation attributes for sites within each community type or community type phase were pooled to create a unique description for each type (Appendix B). These descriptions can be used as the baseline for determining ecological condition. Summary community type descriptions are included below. Note! Site numbers associated with each community type can be found on the map in Fig. 2 of the introduction.

Abandoned Agricultural Fields Community Type Description:

Sites - 40, 41, 60, 67, 69, 72

This community type is identified by the high cover of introduced forage grasses, minimal shrub cover and low amounts of native grasses and forbs. Most of the abandoned sites are on level landforms but those occupying steeper sites have a SW aspect. There are relatively few surface rocks and the upper portions of the soil profile have little to no coarse fragment (> 2mm dia.). Soils are loamy textured, non-reactive (low calcium carbonate) and are similar to those observed in the grassland community types.

Because of historic use for hay production and livestock grazing this community type has both more bare ground and introduced grass cover than similar sites found in the basin big sagebrush and grassland community types. In abandoned fields where native shrubs are present basin big sagebrush (*Artemisia tridentata tridentata*) is more common than mountain big sagebrush (*A. tridentata vaseyana)* suggesting that these sites were probably basin big sagebrush before agricultural conversion. Importantly, black sagebrush (*Artemisia nova*) was not identified in any of the abandoned fields. This is the second most productive community in terms of biomass production.

Basin Big Sagebrush (Artemisia tridentata tridentata) Community Type Description

Sites – 18, 27, 31, 51

This shrub dominated community is found on gentle to moderately steep slopes (4 – 15%). Seventy five percent of the inventoried sites had a NE aspect. While soil depth, coarse fragments and surface rock are similar to the abandoned agricultural fields and grassland community types, this community type differs in terms of soil organic matter content and soil texture. The basin big sagebrush community type has much less soil organic matter than the abandoned agricultural fields and 80% of the basin big sagebrush sites have a sandy loam soil texture.

Basin big sagebrush has nearly 10X the canopy cover of other native shrubs in this community type. While perennial bunchgrasses (bluebunch wheatgrass and Idaho fescue) are present their cover amounts do not differ from that recorded in the abandoned agricultural fields and SW phase grassland community types. However, needleandthread grass (*Hesperostipa comata)* has greater cover in the basin big sagebrush community type than recorded in either the abandoned agricultural fields or grassland community types. The higher presence of the mid seral needleandthread in this community type coupled with levels of the early seral or disturbance species, Sandberg bluegrass (*Poa secunda*) and Prairie junegrass (*Koeleria macrantha*), similar to those found in the abandoned agricultural fields and NE grassland community types suggests a lower ecological condition for this community type. However, needleandthread occurs more frequently on coarse textured soils so its high cover level in this community type is more reflective of the sandy loam soil texture than ecological condition.

Black Sagebrush (*Artemisia nova)* Community Type Description:

Steep Sites – 25, 28, 29, 30, 33

Level Sites – 53, 57, 59, 66, 71

This community type is identified by black sagebrush canopy cover exceeding 14%. There are two distinct phases dictated by slope, level (11.5%) and steep (35+ %). The steep phase has a higher ratio of coarse sized fragments (gravel and cobble) in the upper soil column and more surface rock than found in level areas dominated by black sagebrush. While soil depth is comparatively similar (level = 0.28m; steep = 0.39m) the steep site soils are more reactive to acid suggesting higher calcium carbonate. The steep phase is most often found on slopes with a NE aspect.

Shrub cover in both phases is similar but the cover of the two dominate perennial bunchgrasses in this community type differs between the phases. Idaho fescue (*Festuca idahoensis)* is more abundant in the level phase while bluebunch wheatgrass (*Pseudoroegneria spicata)* has greater cover in stands representing the steep phase. The greater abundance of bluebunch wheatgrass in the steep phase is expected because of the higher amounts of coarse fragments in the soil and more surface rock.

Grassland Community Type Description:

Idaho Fescue/bluebunch Sites – 17, 23, 43, 44, 46, 47, 52, 58

Idaho Fescue, loamy sites – 48, 49, 50, 56, 63, 64, 65, 68

This community type can be identified by the dominance of grasses and relatively low shrub cover (< 3%). Gardiner Basin grasslands occur in two distinct phases but unlike the conditions observed in the black sagebrush community types these associations are differentiated by the aspect rather than slope. When the 16 sites are grouped by slope two distinct phases appear, steep sites, those over 35% slope and those level to moderately sloping, less than 35%. This difference carried over into higher amounts of bare ground, more surface rocks and higher amounts of coarse fragments within the soil column on the steep sites when compared to the level and moderately steep sites. However, these differences were not reflected in the vegetation associations.

Rearranging the sites by aspect (SW and NE) muted differences in slope and coarse fragments but revealed differences in soil organic matter, surface rocks, bare ground and foundational geology. Grasslands occurring on SW facing slopes had more bare ground and surface rocks than similar communities occupying NE slopes. Conversely, all NE grassland sites occurred on unconsolidated geologic materials and had higher levels of soil organic matter than the SW phase.

Higher nutrient levels and water holding capacity associated with greater amounts of soil organic matter in the Idaho Fescue, loamy phase support greater amounts of Idaho fescue and forbs than found in similar communities occurring on SW facing slopes.

Mountain Big Sagebrush Community Type Description:

This association is the most physically diverse of the five general community types identified in the Gardiner Basin. Plant communities dominated by mountain big sagebrush (*Artemisia tridentata vaseyana*) were found on all slope classes and aspects and could not be differentiated in terms of coarse fragments within the soil column, amount of bare ground or soil organic matter content. However, there were significant differences in terms of soil depth, surface rock and soil calcium carbonate. Along with these physical differences there were differences in sagebrush cover, Idaho fescue cover, needleandthread grass and forb cover. Similarity analysis using these parameters indicated five phases within the mountain big sagebrush community type; steep, silty, sandy loam, deep loamy and degraded.

Steep Sites – 20, 37, 45

Forb Sites – 54, 61, 62, 73

Sandy Loam Sites – 34, 35, 36, 38, 42

Deep Loamy Sites – 16, 24, 26, 39

Degraded Sites – 19, 21, 22, 32, 51, 70

Slope, coarse materials within the soil column and the amount of bare ground did not differ among the five identified phases. However, soils within the deep loamy (56cm deep) and degraded (48cm deep) phases are much deeper than those found in the other phases. Sandy loam soils (47cm deep) are equivalent in depth to the degraded phase but much deeper than soils in the forb (29cm deep) and steep (22cm deep) phases. There is more surface rock in the steep and degraded phases than the other 3 phases. The amount of surface rock doesn't differ between the deep loamy, forb and sandy phases. Finally, soils in the degraded phase are more reactive to acid (higher calcium carbonate) than soils in the other phases.

Mountain big sagebrush cover (6 – 7%) is equivalent in the steep, deep loamy, sandy loam and forb phases. Sites within the degraded phase have much less mountain big sagebrush cover (2%). The greatest coverage of Idaho fescue (17%) is found in the sandy loam phase. This is followed by the forb phase with 14% cover. Idaho fescue cover is equivalent in the steep, deep loamy and degraded phases. Coverage of the mid seral, grazing tolerant needleandthread grass is equivalent in steep, deep loamy, sandy loam and silty phases but all are much lower than levels recorded in the degraded phase. Forb cover, especially that of tailcup lupine (*Lupinus caudatus),* is greatest in the forb phase with the next highest cover in the sandy phase and the least amount in the steep, deep loamy and degraded phases.

It is important to note that the deep loamy, sandy loam and degraded phases exist on the deepest soils recorded in the non-forested Gardiner basin environments so these phases should have the greatest coverage of sagebrush, grasses and forbs. However, the high amount of surface rock, significantly lower sagebrush cover and higher amounts of needleandthread grass in the degraded phase are indicative of historic, heavy winter use that has led to low ecological condition. Even though mountain big sagebrush cover in the deep loamy sites remains comparable to that in the other phases the low amount of Idaho fescue and appearance of the invasive annual grass, cheatgrass brome (*Bromus tectorum*), in the understory indicates these sites have also experienced prolonged heavy use. Management will be more effective over time if the deep loamy and degraded phases are treated with the same outcomes in mind.

With long term management in mind and the historic heavy reliance on big sagebrush communities by wintering populations of deer and elk it appeared useful to include additional measures of shrub canopy cover and density in this ecological baseline effort.

Chapter 3

Shrub Intercept Cover and Density Baseline

The community types identified through summarization of the canopy cover data remained unchanged even when shrub cover was re-calculated using canopy interception. This is likely due to the fact that sagebrush cover was the primary determinate of community types in the earlier canopy cover analyses. Based on the level of sagebrush canopy intercepted by transect lines at each site abandoned agricultural fields, the grassland phases and the mountain big sagebrush steep phase had the lowest sagebrush (*Artemisia nova, Artemisia tridentata)* cover. The black sagebrush and mountain sagebrush silty phase community types had the greatest sagebrush cover of all the community types (Table 3.1).

Table 3.1. Sagebrush cover determined through canopy intercept measurements in the various vegetation community types inventoried in the Gardiner Basin, MT. Values with different superscripts are significantly different (p < 0.10).

Community Type	Sagebrush Canopy
Abandoned Agricultural Fields	2.7^{a}
Basin Big Sagebrush	7.8
Black Sage, level phase	6.6
Black Sage, steep phase	8.3^{b}
Grassland, Idaho Fescue, loamy	4^{a}
Grassland, Idaho Fescue/bluebunch	2^{a}
Mountain, deep loamy phase	6.9
Mountain, degraded phase	5.4
Mountain, sandy loam phase	6
Mountain, forb phase	8.9^{b}
Mountain, steep phase	4.2^{a}

Values from Table 3.1 can be used as a reference in future monitoring efforts to determine the impact of browsing on the woody component of each community type.

Summarization of shrub counts within the 2m belt overlying each transect (Table 3.2) indicates the Idaho fescue/bluebunch phase and abandoned agricultural fields had fewer shrubs ($p < 0.10$) than the other community types. On the other hand, the steep black sagebrush phase has the highest shrub density. Closer review of shrub density within the mountain big sagebrush phases (Fig. 3.1) indicates that the deep loamy, sandy loam and forb phases had more shrubs than the other two phases. The shrub density reference values shown in Table 3.2 can be used separately or combined with shrub canopy cover (Table 3.1) to gain a second objective measure of shrub sustainability in the Gardiner Basin.

Table 2. Shrub density for each of the identified community types in the Gardiner Basin. Values with different superscripts are different ($p < 0.10$).

Community Type	Sagebrush Density (m^2)
Abandoned Agricultural Fields	0.2[a]
Basin Big Sagebrush	0.4
Black Sage, level phase	0.9[b]
Black Sage, steep phase	0.7
Grassland, Idaho Fescue, loamy	0.5
Grassland, Idaho fescue/bluebunch	0.2[a]
Mountain, deep loamy phase	0.4
Mountain, degraded phase	0.6
Mountain, sandy loam phase	0.6
Mountain, forb phase	0.6
Mountain, steep phase	0.4

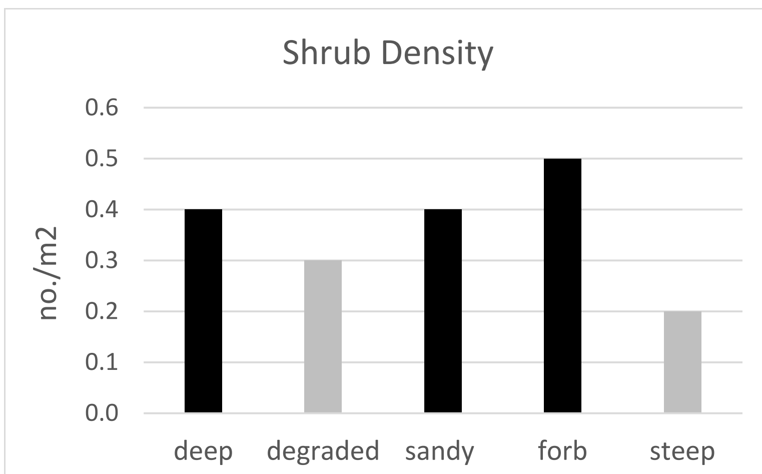

Fig. 3.1. Comparison of shrub density (no./m^2) within the five mountain big sagebrush phases identified in the Gardiner Basin. Dark bars are significantly different ($p < 0.10$) from the lighter bars.

Chapter 4

APPLICATION OF REFERENCE BASELINE

Community Type Identification Key

Even though this report contains vegetation composition and physical descriptions for each of the sites inventoried in this process, managers may have a need to evaluate the ecological condition of a non-inventoried site. The first step would be to determine which community type the newly inventoried area matches. Inventory results can then be compared to the respective community reference to determine ecological condition. A decision matrix or site key was developed from the community type descriptions to help biologists and managers determine the community type they are working in. Having decided which community type the inventoried area matches the manager can then use the appropriate reference community type from Appendix B to determine if the newly inventoried site composition meets (static ecological condition), exceeds (improving ecological condition) or falls below (declining ecological condition) the baseline conditions listed for the chosen community type. To provide guidance in this effort an example exercise follows.

Determining the Community Type

The lack of objective ecological references was the primary challenge this project was designed to overcome. Without grazing exclosures or ecological site descriptions (USDA Natural Resource Conservation Service, *www.nrcs.usda.gov*) managers have little objective guidance to evaluate ecological status or condition. A second tier of criteria available for the manager when these first resources are unavailable is previously published plant community descriptions. A reasonable resource is a 1980 USDA Forest Service publication, *Grassland and shrubland habitat types of western Montana,* General Technical Report INT-66 which continues information from at least 3 locations within the Gardiner Basin. Information from this report will be used to 1) demonstrate how to use community type reference descriptions to determine ecological status and 2) determine the ecological condition of all the inventoried Gardiner Basin shrub and grassland communities.

While community type descriptions have been tied to the respective sites in Appendix D, there may be times when range conservationists or biologists may find it necessary to inventory different areas within the basin. To evaluate ecological status of previously non-inventoried sites it will be necessary to first determine which reference community type best describes the new site. Figure 4.1 can be used with cover data from a newly inventoried range or shrubland site to determine the relevant community type. For example, canopy cover data from a site not included in this inventory has 2% bluebunch wheatgrass (*Pseudoroegneria spicata),* 29% Idaho fescue (*Festuca idahoensis),* 14% hoods phlox (*Phlox hoodii*) and 1% twisted leaf rabbitbrush (*Chrysothamnus viscidiflorus)*. With less than 5% shrub cover (only 1% rabbitbrush) the shrub dominated community types can be bypassed leaving the choice between communities with high percentages of non-native grasses and those with high percentages of Idaho fescue and bluebunch wheatgrass. On the new site there are no introduced grasses, the combined cover of Idaho fescue and bluebunch wheatgrass is greater than 5% and forb cover exceeds 5% so the new site is native grassland. Finally, the high cover of Idaho fescue (29%) and hoods phlox (14%) meet or exceed the levels necessary for the newly inventoried site to fall into the Idaho Fescue Loamy phase community type.

Using the Gardiner Community Type Reference Tables to Determine Current Ecological Condition

In the example below (Table 4.1) a community type description from Mueggler and Stewart 1980 is compared to the Gardiner Basin grassland community type reference communities to arrive at an estimate of ecological status.

Table 4.1. Comparison of Gardiner Basin grassland community composition to the Idaho fescue/bluebunch wheatgrass community type, Mueggler and Stewart (1980) Grassland Guide. BELOW = less than ecological potential, EXPECT = within expected range of potential ecological potential; ABOVE = above ecological potential; NR = not recorded.

Fesida/Psespi (Mueggler and Stewart 1980)		Grassland Idaho Fescue loamy	Grassland Idaho fescue bluebunch	Ecological Status
Artemisia frigida	2	NR	0.1	BELOW
Festuca idahoensis	37	13	4	BELOW
Pseudoroegneria spicata	18	3.7	3.6	BELOW
Koeleria macrantha	4	2.4	1.2	BELOW
Poa secunda	3	0.8	0.3	BELOW
Heterostipa comata	3	NR	0.8	BELOW
Poa cusickii	1	1.3	0.8	EXPECT
Carex spp	1	0.2	0.2	BELOW
Astragalus spp	1	1.6	0.2	EXPECT
Agoseris glauca	2	NR	NR	BELOW
Antennaria rosa	2	1.4	0.1	BELOW
Achillea millefolium	1	1	NR	EXPECT
Arenaria congesta	1	0.3	0.1	BELOW

Species cover for the two grassland phases, Tables 5 and 6, Appendix B, are added to a table containing measures for the same species listed for the appropriate community type, Idaho fescue/bluebunch wheatgrass, described in Mueggler and Stewart. Cover values can then be directly compared to learn how close or distant the Gardiner sites are from the published expectation for western Montana grasslands. The values for climax and mid seral grasses (*Festuca idahoensis* and *Koeleria macrantha*) in the Gardiner grasslands are dramatically lower ($p < 0.05$) than those listed for the same high condition community types described by Mueggler and Stewart. Lower values indicate a low ecological status. After completing this exercise for all the community types in Appendix C it is apparent that none of the inventoried community types in the Gardiner Basin are close to the ecological potential described in the Mueggler and Stewart (1980) guide. This suggests that years of heavy use by elk and bison has reduced the ecological status of the non-forested ecological community types in the basin. It will be necessary to revisit the inventory sites using information from Appendix D to determine whether ecological trend is on the upswing or if the vegetation communities continue to decline.

Fig 1. Key to the Identification of Non-forested Vegetation Community Types in the Gardiner Basin

1. Sagebrush canopy cover > 5% ……… 2.
    - 2. *Artemisia tridentata* cover < 1%, *Artemisia nova* canopy cover > 10 % ………………………… 3.
        - 3. Climax grass cover > 10%, forb cover > 5%, surface rock < 3%, slopes 4 – 15% ………. **Level Black sagebrush**
        - 3. Climax grass cover < 2%, forb cover < 2%, surface rock > 10%, slopes 35 – 60% …….. **Steep Black sagebrush**
    - 2. *Artemisia tridentata vaseyana* or *tridentata* cover > 5%, *Artemisia nova* cover 2% or less. 4.
        - 4. *A. tri. vaseyana* cover > 5%, *A. tri. tridentata cover* < 5% …………. **Mountain big sagebrush** 5.
        - 4. *A. tri. tridentata* cover > 5%, *A. tri. vaseyana* cover < 5% …………. **Basin big sagebrush**
            - 5. *Artemisia tridentata vaseyana* cover > 5%, *Festuca idahoensis* cover > 10% ……….. 6.
                - 6. Climax grass cover > 20%; forb cover < 10%; soil depth > 30cm……………… **Sandy Loam Phase**
                - 6. Climax grass cover 10 - 17%; forb cover > 10%; soil depth < 30cm ………………. **Forb Phase**
            - 5. *Artemisia tridentata vaseyana* cover 7% or less; *Festuca idahoensis* cover < 5% 7.
                - 7. Climax grasses < 10%, forb cover < 3%, soil depth > 50cm ……………………………. 8.
                    - 8. *Artemisia tridentata vaseyana* cover < 3%, spike clubmoss …….. **Degraded Phase**
                - 7. Climax grasses < 10%, forb cover at least 3%, soil depth < 30cm …………………. 9.
                    - 9. *Artemisia tridentata vaseyana* cover > 5%, no spike clubmoss …………. **Steep Phase**

1. Sagebrush canopy cover < 5% ……… 10.
    - 10. *Artemisia nova* cover ≤ 3%, Artemisia tridentata cover ≤ 1%, combined cover of *Festuca idahoensis* and *Pseudoroegnaria spicata* > 5%, other perennial grass cover > 5%, forb cover at least 5%, introduced or non-native grass cover < 1% ……………………………………………………. **Grasslands. 11**
        - 11. Southwest aspect, *Festuca idahoensis cover* < 10%, forb cover < 3%.............**Idaho Fescue/Bluebunch Phase**
        - 11. Northeast aspect, *Festuca idahoensis cover* > 10%, forb cover > 3% ………………… **Idaho Fescue, loamy Phase**
    - 10. *Artemisia tridentata tridentata* cover < 5%, *Artemisia tridentata vaseyana* cover < 2%, non-native or introduced grass cover > 10%, forb cover < 4% ………………………………………. **Abandoned Agriculture Lands**

To add breadth to evaluation of ecological condition in the Gardiner Basin three other useful indices have been included in Appendix B. Each indicator can be used alone or in combination with the other two for determining changes in the sustainability of the respective community type or phase. The disturbance species measure is the combined total of early, mid-seral and non-native species within the vegetation community. This represents the vegetation cover most likely to decrease as the community moves on an upward recovery trend or will exhibit an increase should the community begin to unravel ecologically.

Biomass production (kg/ha) is important along two avenues of thought. First, higher levels of production are generally associated with communities in stable or improving ecological condition. The mountain big sagebrush sandy loam phase is a reasonable example of the relationship between ecological condition and biomass production. However, the abandoned agricultural fields are an exception to this broad axiom. The presence of a non-native monoculture makes this community type the second most productive in the Gardiner Basin so collection of biomass information (clipping studies) must be accompanied by detailed species composition inventories to avoid misinterpretation of community condition. The greatest utility of the biomass reference production is for calculating ungulate carrying capacity.

The percent grass value is included with the biomass production to avoid over calculation of how many grazers can be supported within the Gardiner Basin over a given period of time. An example follows.

1. Carrying capacity model = $\dfrac{\text{Kg/ha x ha x FA}}{\text{Intake (kg/animal/month)}}$

2. Where kg/ha is biomass from Appendix B, ha is the size of the area under consideration and FA is the proportion of the forage base to be allocated to the target grazer. Intake is derived from animal weight (kg) x 0.025/day x 30 days

3. The initial estimate of bison carrying capacity using an average bison weight of 408kg, biomass production of 1,000ha for the NE grassland community type (Appendix B) and 25% forage allocation would work out as follows.

$$\dfrac{\text{199kg/ha x 1,000ha x 0.25}}{\text{10kg/day x 30 days}}$$ = 166 animals for 1 month, 55 for 3 months or 28 for 6 months

4. However, this is an over estimate because bison forage primarily on grasses and sedges and the 199kg includes all herbaceous material. Accordingly, management based on this initial calculation would lead to heavy overuse of basin grasslands. A more sustainable carrying capacity can be derived by correcting the initial calculation with the 46% grass composition occurring within the NE grassland community type.

5. The available forage generated in the initial calculation (model numerator) is 49,750kg so this value is multiplied by 0.46 to yield the actual amount of grass-based forage available to bison. When divided by the 300kg monthly intake the resulting value is 22,885 kg or 76 animals for 1

month. A short hand approach would be to multiple the initial carrying capacity of 166 animals for 1 month by 0.46. This produces the same value, 76 bison for 1 month, as does recalculating the model numerator.

There are three important rules to keep in mind when calculating carrying capacity from this model and information supplied in Appendix B. First, FA or forage allocation provides a mathematical approach for dividing the forage resource among the various grazing classes while safeguarding forage plant health and vigor. In this example bison, the target species, are allocated 25% of the available forage base, leaving 15% for elk and 10% for mule deer or bighorn sheep. To maintain overall ecological condition the sum of allocations to all grazers should not exceed 50%. Second, care should be exercised in choosing the amount of area thought to be used by the grazers. Slope, distance to water, private land and road density must be taken into account to avoid over estimating the amount of forage available to the anticipated population. Finally, estimation of animal intake in this model is based on the weight of the most common age and gender in the targeted population. Using the body weight of mature bull elk and bison to estimate monthly intake will under estimate the number of individuals the area can support.

Ecological Status and Condition

The information contained in this report has been organized to help managers objectively determine the ecological condition of non-forested vegetation communities in the Gardiner Basin. Historically, ecological condition has determined from measures of ecological status. It is important to understand that the inventoried data reported from surveys in the Gardiner Basin represent the vegetation community at a point in time, in this case the period 2015 – 2017. Consequently, the information in Appendix B represents the ecological status of the community types not ecological condition. Determination of ecological condition necessitates access to a vegetation and soils reference metric so departure from the expected norm (reference data) can be measured. The example discussed earlier in this chapter is such an action. Judgement about the ecological condition of the Gardiner Basin communities can only be made by comparing the respective ecological status (point-in-time measure) to a known reference. To illustrate this process we used the 1980 Mueggler and Stewart grassland guide as the known reference. Differences between values from this survey and those in the published guide provide a baseline view of the ecological condition of Gardiner Basin shrub and grassland communities. Information from future inventories can now be compared to the Gardiner Basin reference values described in chapters 2 and 3 and Appendix B.

Concerns about the validity of the current low ecological condition rating can only be addressed through repeated measures of soil and vegetation attributes at the locations described in Appendix D. The field sampling protocol described in Appendix A was designed to facilitate repeat sampling of the same location over multiple years. The number and length of transect lines coupled with multiple vegetation measures will compensate for the likely “3m miss” of the original center point described by the GPS coordinates. Repeat sampling of the original sites in future years will also provide Forest Service managers with an objective measure of how management actions are affecting the long term sustainability of the basin’s non-forested communities.

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APPENDIX A.

Study Methods and Statistical Analysis

Study Design – Jodi Canfield, Custer-Gallatin wildlife biologist, Thomas Keck, Custer-Gallatin soils specialists and Montana Fish, Wildlife and Parks biologists provided the first layer for study site selection by outlining the primary wildlife wintering area within the basin (Fig.1). Then the ARCINFO GIS based mapping tool was used to categorize the winter range into a series of sampling polygons based on the criteria or layers shown in Table 1.1. Soil development, landform stability, vegetation productivity potential and wildlife landform preference were bracketed by five primary selection criteria; geologic control, aspect, elevation, conifer cover and slope. Geologic control was used as a predicator of soil texture and depth; elevation, conifer cover and slope as predicators of wildlife use and aspect plus geology as predicators of potential vegetation productivity. For example, a vegetation/soil complex occurring on a steep (35 – 60%), SW facing, bedrock controlled landscape could be expected to have less vegetation cover, lower vegetation biomass and more grazing pressure than a similar community on a steep, NE facing, unconsolidated landform. Having used ARCMAP the resulting 16 possible combinations (classes) of geology, aspect and slope could then be georeferenced to randomly locate sampling locations. Identified locations that fell within 600m of an established road or another sampling location were eliminated from the selection list. By the end of the 2016 field season 4 sites (replicates) had been sampled within each polygon establishing a pool of 64 inventoried classes for describing the shrub and grassland communities within the Gardiner Basin winter range (see Fig. 2 in the Introduction).

Data Collection – Each sampling locality was accessed by locating the respective GPS coordinate generated during the site selection process described above. To fully describe the vegetation complex at the site species frequency, canopy cover and biomass production measurements were made along 4 – 50m transects originating from the GPS point (Fig. D.1). Transects were laid out from the referenced point in each of the four cardinal directions. This approach was designed for ease of re-sampling during future monitoring efforts because wildlife pressure and high recreational traffic limit the utility of permanent markers. Using 4 transects elevates the likelihood of re-capturing some if not all of the plant species and soil surface conditions at later dates.

Measurement of species frequency of occurrence was made at 1m intervals along each 50m transect (Fig. D.1). Frequency measures were totaled and divided by 200 to provide an average for each species at the site. Vegetation canopy cover was estimated from 0.2m x 0.5m microplots (Daubenmire 1968) systematically placed at 10m intervals along each 50m transect (Fig. D.1). Cover values from all 20 micro-plots were averaged to produce the canopy cover estimate for the site. Herbaceous biomass was measured by clipping all standing material to 2 – 3cm height in a 0.25m2 frame systematically located at the 20 and 40m point along each transect. Harvested material was bagged by species in an individually identified and returned to the MSU campus to determine dry weight. The dried weights were pooled to arrive at grams/m2. This made conversion to kg/ha straightforward.

Because several of the wildlife species (mule and pronghorn) using the Gardiner basin winter range are browsers and two other species (elk and bighorn sheep) rely on shrubs during heavy snow periods two additional vegetation measures were made at each site. Shrub density was estimated by counting all shrubs falling within a 2m x 50m belt overlying each transect (Fig. D.1). The counts were pooled and divided by 200m2 to arrive at shrubs per m2. The size and extent of shrub canopy at each site was determined by measuring the portion of each shrub intercepted by the transect line. For ease of reporting these measures were converted to percent by totaling all measures and dividing by 200m. These metrics will provide range and wildlife biologists more precision when estimating browsing use on the winter range.

A soil pit was excavated near the center point after the vegetation information was collected. Soil characteristics recorded at each site were profile depth, coarse fragment content (by weight) and calcic status (reaction to dilute HCL). A 100g sample of material was removed from each horizon, sealed in individually identified plastic bags and returned to the MSU campus for texture (Gee and Bauder 1986) and total organic matter content analyses (Ball 1964).

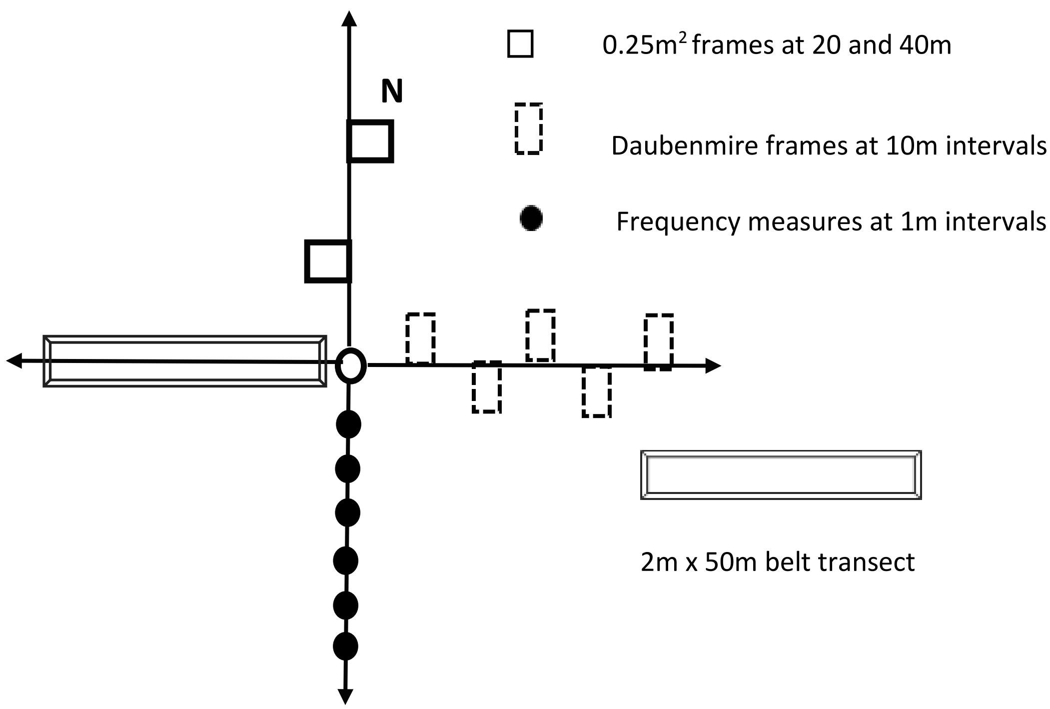

Fig. 1. Sampling design used to collect vegetation and soil data in the Gardiner Basin. The circle at the center represents the location of the soil collection pit.

To facilitate comparison of vegetation community characteristics to the physical conditions of the Gardiner Basin we used a plant growth potential model developed by the Montana Natural Resource Conservation Service (NRCS 2012) to estimate soil moisture at a site by using annual precipitation, slope, aspect and soil properties. We chose to use this model because it was used successfully to predict the occurrence of fescue (Festuca campestris + Festuca idahoensis) and bluebunch wheatgrass (Pseudoroegneria spicata) dominated communities on the National Bison Range in western Montana (Neto 2014).

Statistical Analysis

First Approximation – Throughout the data analysis site rather than microplot or frame was used as the replicate. A 68 (site) x 42 (measured parameters) matrix was constructed with all the information collected during the 2015 and 2016 field seasons. The potential for groupings based on parameter similarities was investigated with agglomerative hierarchical clustering (Addinsoft 2017). Sites identified as being at least 95% similar were considered a unique grouping.

Second Approximation – Multiple Analysis of Variance (Addinsoft 2017) was used to test for differences among the 42 measured parameters within the groups identified through cluster analysis. We chose an alpha level of 0.10 for significance in this study because of the high level of variation anticipated from the geologic setting, non-uniformity in wildfire history and wildlife grazing. Values were assigned for the non-measured parameters, geology, aspect, slope and soil reaction, to facilitate statistical analysis. Unconsolidated geologic sites were given a value of 1, bedrock sites 2, SW aspect 225o, NE aspect 45o and midpoint for slopes, e.g. 4 – 15% = 9.5. Sites within clusters that were significantly different (p = 0.10) in one or more of the physical parameters where removed from the group and assigned to another likely group. This approach continued until all groupings were similar.

Third Approximation – Analysis of Variance and T tests (Addinsoft 2017) were used where appropriate to further refine site groupings on the basis of vegetation and soil attributes. Again, using an alpha of 0.10, sites within groups that were significantly different from companion sites were either re-assigned to other groups or partitioned as a phase within the parent group. This level of analysis also provided the opportunity to formalize board interpretations of ecological condition within the Gardiner Basin.

APPENDIX B

Gardiner Basin Reference Community Types

1. Reference Composition for Abandoned Agricultural Fields Community Type, Gardiner Basin, Gardiner, Montana.

Geology	Aspect	Slope%	Species	% Cover	Disturbance Species (%)	Biomass (kg/ha)	Grass as % of Biomass
bedrock[a]	Flat	0 - 4	*Shrubs:*				
unconsolidated	SW[b]	4 - 35	Artemisia tridentata tridentata	2.8			
			Artemisia tridentata vaseyana	1.2			
			Ericameria nauseosa	0.3			
			Grasses and Grass-likes:				
			Bromus inermis	15			
			Poa pratensis	11			
			Festuca idahoensis	2.6	0.5	605	74
			Leymus cinereus	1.4			
			Pascopyrum smithii	1.1			
			Pseudoroegneria spicata	0.6			
			Koeleria macrantha	0.4			
			Poa secunda	0.1			
			Forbs:				
			Achillea millefolium	1.6			
			Geranium viscosissimum	1.8			
			Lupinus caudatus	1.1			
			Symphyotrichum ericoides	0.8			

2. Reference Composition for Basin Big Sagebrush Community Type, Gardiner Basin, Gardiner, Montana.

Geology	Aspect	Slope%	Species	% Cover	Disturbance Species (%)	Biomass (kg/ha)	Grass as % of Biomass
bedrock	SW	4 – 15	*Shrubs:*				
Unconsolidated	NE	4 - 15	Artemisia tridentata tridentata	10.3			
	NE	15 - 35	Artemisia tridentata vaseyana	1.5			
			Ericameria nauseosa	0.1			
			Grasses and Grass-likes				
			Festuca idahoensis	5.7			
			Hesperostipa comata	4			
			Pseudoroegneria spicata	3	2.9	266	31
			Poa secunda	2.1			
			Koeleria macrantha	0.8			
			Carex spp	0.6			
			Achnatherum nelsonii	0.1			
			Forbs:				
			Cymopterus spp	1.5			
			Gutierrezia sarothrae	0.8			
			Crepis acuminata	0.3			
			Phlox longifolia	0.3			
			Symphyotrichum ericoides	0.25			
			Antennaria microphylla	0.2			
			Arenaria congesta	0.1			

3. Reference Composition for Black Sagebrush Community Type, Steep Phase, Gardiner Basin, Gardiner, Montana.

Geology	Aspect	Slope%	Species	% Cover	Disturbance Species (%)	Biomass (kg/ha)	Grass as % of Biomass
bedrock	NE	35 - 60	*Shrubs:*				
	NE	15 - 35	Artemisia nova	17			
			Ericameria nauseosa	0.5			
			Artemisia tridentata vaseyana	<0.1			
			Grasses and Grass-likes:				
			Pseudoroegneria spicata	7.5			
			Koeleria macrantha	2.3			
			Festuca idahoensis	1	2.8	319	41
			Hesperostipa comata	0.9			
			Poa secunda	0.5			
			Leucopoa kingii	0.3			
			Carex spp	0.1			
			Forbs:				
			Phlox hoodii	0.4			
			Symphyotrichum ericoides	0.4			

4. Reference Composition for Black Sagebrush Community Type, Level Phase, Gardiner Basin, Gardiner, Montana

Geology	Aspect	Slope%	Species	% Cover	Disturbance Species (%)	Biomass (kg/ha)	Grass as % of Biomass
bedrock	SW	4 - 15	*Shrubs*:				
	SW	15 - 35	Artemisia nova	14.7			
	Flat	0 - 4	Ericameria nauseosa	0.7			
unconsolidated	NE	4 - 15	Artemisia tridentata vaseyana	0.3			
			Grasses and Grass-likes:				
			Festuca idahoensis	5.9			
			Pseudoroegneria spicata	4.5			
			Koeleria macrantha	3.5	5.4	156	40
			Poa secunda	1.9			
			Leucopoa kingii	1.1			
			Carex spp	0.7			
			Hesperostipa comata	0.2			
			Forbs:				
			Astragalus spp	2.3			
			Phlox hoodii	2.0			
			Antennaria microphylla	1.0			
			Lupinus caudatus	0.5			
			Phlox longifolia	0.4			
			Crepis acuminata	0.2			
			Achillea millefolium	0.1			

5. Reference Composition for the Grassland Community Type, Idaho fescue/bluebunch Phase, Gardiner Basin, Gardiner, Montana.

Geology	Aspect	Slope%	Species	% Cover	Disturbance Species (%)	Biomass (kg/ha)	Grass as % of Biomass
bedrock	SW	35 - 60	*Shrubs:*				
	SW	15 - 35	Artemisia nova	2			
Unconsolidated	SW	35 - 60	Artemisia tridentata tridentata	0.5			
			Juniperus scopulorum	0.2			
			Grasses and Grass-likes:				
			Festuca idahoensis	4			
			Pseudoroegneria spicata	3.6			
			Koeleria macrantha	1.2	1.5	175.5	53
			Hesperostipa comata	0.8			
			Poa fendleriana	0.8			
			Poa secunda	0.3			
			Carex spp	0.2			
			Forbs:				
			Gutierrezia sarothrae	0.8			
			Senecio spp	0.3			
			Silene acaulis	0.3			
			Symphyotrichum ericoides	0.3			
			Phlox hoodii	0.2			
			Astragalus spp	0.2			
			Artemisia frigida	0.1			
			Antennaria microphylla	0.1			

6. Reference Composition for Grassland Community Type, Idaho fescue, loamy Phase, Gardiner Basin, Gardiner, Montana.

Geology	Aspect	Slope%	Species	% Cover	Disturbance Species (%)	Biomass (kg/ha)	Grass as % of Biomass
unconsolidated	NE	4 - 15	*Shrubs*:				
	NE	15 – 35	Artemisia nova	3.3			
	NE	35 - 60	Artemisia tridentata vaseyana	0.9			
			Grasses and Grass-likes:				
			Festuca idahoensis	13			
			Pseudoroegneria spicata	3.7			
			Koeleria macrantha	2.4			
			Poa fendleriana	1.3			
			Poa pratensis	0.9	4.1	199	46
			Poa secunda	0.8			
			Leucopoa kingii	0.3			
			Carex spp	0.2			
			Forbs:				
			Symphyotrichum ericoides	2.4			
			Astragalus spp	1.6			
			Phlox hoodii	1.4			
			Antennaria microphylla	1.4			
			Achillea millefolium	1			
			Cymopterus spp	0.8			
			Phlox longifolia	0.8			
			Crepis acuminata	0.7			
			Arenaria congesta	0.3			
			Moss-like				
			Selaginella densa	1.8			

7. Reference Composition for Mountain Big Sagebrush Community Type, Steep Phase, Gardiner Basin, Gardiner, Montana.

Geology	**Aspect**	**Slope%**	**Species**	**% Cover**	**Disturbance Species (%)**	**Biomass (kg/ha)**	**Grass as % of Biomass**
Bedrock	SW	15 - 35	*Shrubs*:				
Unconsolidated	SW	35 - 60	Artemisia tridentata vaseyana	7.1			
			Grasses and Grass-likes:				
			Festuca idahoensis	4			
			Pseudoroegneria spicata	3.8			
			Koeleria macrantha	2.4			
			Poa secunda	1.1	3.1	208	40
			Hesperostipa comata	0.4			
			Forbs:				
			Phlox hoodii	1.5			
			Achillea millefolium	0.8			
			Antennaria microphylla	0.3			
			Lupinus spp	0.3			
			Symphyotrichum ericoides	0.3			

8. Reference Composition for the Mountain Big Sagebrush Community Type, Forb Phase, Gardiner Basin, Gardiner, Montana.

Geology	Aspect	Slope%	Species	% Cover	Disturbance Species (%)	Biomass (kg/ha)	Grass as % of Biomass
Bedrock	Flat	0 - 4	*Shrubs*:				
	NE	4 - 15	Artemisia tridentata vaseyana	7.1			
Unconsolidated	SW	4 - 15	Ericameria nauseosa	0.4			
	SW	15 - 35					
			Grasses and Grass-likes:				
			Festuca idahoensis	13.6			
			Poa pratensis	1.8			
			Pseudoroegneria spicata	1.7			
			Achnatherum nelsonii	0.9			
			Koeleria macrantha	0.8	1.2	174	33
			Hesperostipa comata	0.8			
			Poa secunda	0.4			
			Carex spp	0.3			
			Danthonia intermedia	0.2			
			Forbs:				
			Lupinus caudatus	3.6			
			Phlox longifolia	2.8			
			Symphyotrichum ericoides	2.6			
			Antennaria microphylla	1.8			
			Achillea millefolium	1.6			
			Arenaria congesta	1.6			
			Astragalus spp	0.6			
			Crepis acuminata	0.3			
			Taraxacum officinale	0.3			
			Geranium viscosissimum	0.2			
			Moss-like				
			Selaginella densa	0.8			

9. Reference Composition for Mountain Big Sagebrush Community Type, Sandy Loam Phase, Gardiner Basin, Gardiner, Montana

Geology	Aspect	Slope%	Species	% Cover	Disturbance Species (%)	Biomass (kg/ha)	Grass as % of Biomass
bedrock	NE	15 - 35	*Shrubs*:				
	SW	35 - 60	Artemisia tridentata vaseyana	6.1			
Unconsolidated	SW	4 - 15	Artemisia nova	1.5			
	SW	15 - 35	Artemisia tridentata wyomingensis	0.4			
			Ericameria nauseosa	0.2			
			Grasses and Grass-likes:				
			Festuca idahoensis	17.4			
			Pseudoroegneria spicata	4.7			
			Koeleria macrantha	2.3	4	677	63
			Poa secunda	1.8			
			Poa fendleriana	1.8			
			Danthonia intermedia	1.4			
			Leucopoa kingii	1.1			
			Poa pratensis	0.9			
			Achnatherum nelsonii	0.7			
			Forbs:				
			Lupinus caudatus	3.3			
			Astragalus spp	2.1			
			Symphyotrichum ericoides	1.3			
			Antennaria microphylla	0.5			
			Phlox hoodii	0.4			

10. Reference Composition for Mountain Sagebrush Community Type, Deep Loamy, Gardiner Basin, Gardiner, Montana

Geology	Aspect	Slope%	Species	% Cover	Disturbance Species (%)	Biomass (kg/ha)	Grass as % of Biomass
bedrock	NE	4 - 15	*Shrubs*:				
	NE	15 - 35	Artemisia tridentata vaseyana	7.1			
Unconsolidated	NE	35 -60	Artemisia tridentata tridentata	0.8			
	Flat	0 - 4	Ericameria nauseosa	0.5			
			Artemisia tridentata wyomingensis	0.2			
			Grasses and Grass-likes:				
			Pseudoroegneria spicata	5.4			
			Koeleria macrantha	2.4	4.6	287.6	34
			Poa secunda	2.1			
			Hesperostipa comata	1.3			
			Festuca idahoensis	0.9			
			Carex spp	0.2			
			Forbs:				
			No forbs recorded				
			Annual Bromes				
			Bromus tectorum	3.7			

11. Reference Composition for Mountain Sagebrush Community Type, Degraded, Gardiner Basin, Gardiner, Montana

Geology	Aspect	Slope%	Species	% Cover	Disturbance Species (%)	Biomass (kg/ha)	Grass as % of Biomass
bedrock	NE	35 - 60	*Shrubs*:				
	SW	15 - 35	Artemisia tridentata vaseyana	2.4			
	Flat	0 - 4	Ericameria nauseosa	1.6			
unconsolidated	NE	15 - 35	Artemisia tridentata wyomingensis	0.8			
	Flat	0 - 4	Artemisia nova	0.6			
			Grasses and Grass-likes:				
			Hesperostipa comata	5.2			
			Pseudoroegneria spicata	3.4			
			Koeleria macrantha	2.6	5.2	230.5	49.8
			Poa secunda	2.6			
			Festuca idahoensis	2.4			
			Pascopyrum smithii	1.6			
			Poa pratensis	0.4			
			Poa fendleriana	0.1			
			Carex spp	0.1			
			Forbs:				
			Gutierrezia sarothrae	1.1			
			Achillea millefolium	1			
			Antennaria microphylla	0.6			
			Phlox hoodii	0.4			
			Moss-like				
			Selaginella densa	7.5			

APPENDIX C

Ecological Condition of Non-forested Vegetation Communities in the Gardiner Basin, Gardiner, Montana

Ecological Condition of Basin Big Sagebrush (*Artemisia tridentata tridentata*) community types in the Gardiner Basin, Gardiner Montana. NR = not recorded in this inventory; INTRO = introduced, non-native species; RCR = recovery species; EXPECT = within expected potential range; ABOVE = greater than ecological potential; DOWN = less than ecological potential; NR = not recorded at site.

Artemisia tridentata/Festuca Idahoensis (Mueggler and Stewart 1980)		Abandoned Ag Fields	Status	Basin Sagebrush	Status
Artemisia tridentata tridentata	23	2.8	BELOW	10.3	BELOW
Artemisia tridentata vaseyana	NR	1.2	RCR	1.5	RCR
Ericameria nauseous	NR	0.3	RCR	0.1	RCR
Bromus inermis	NR	15	INTRO	NR	NR
Poa pratensis	NR	11	INTRO	NR	NR
Festuca idahoensis	36	2.6	BELOW	5.7	BELOW
Danthonia intermedia	16	NR	BELOW	NR	BELOW
Achnatherum nelsonii	14	NR	BELOW	0.1	BELOW
Bromus marginatus	13	NR	BELOW	NR	BELOW
Elymus trachycaulus	12	NR	BELOW	NR	BELOW
Carex spp	9	NR	BELOW	0.6	BELOW
Poa cusickii	6	NR	BELOW	NR	BELOW
Koeleria macrantha	3	0.4	BELOW	0.8	BELOW
Pseudoroegneria spicata	2	0.6	BELOW	3	EXPECT
Poa secunda	NR	0.1	EXPECT	2.1	DOWN
Leymus cinereus	NR	1.4	RCR	NR	NR
Pascopyrum smithii	NR	1.1	RCR	NR	NR
Heterostipa comata	2	NR	BELOW	4	BELOW
Calamagrostis montanensis	2	NR	BELOW	NR	BELOW
Geum trifolium	10	NR	BELOW	NR	BELOW
Eriogonum umbellatum	10	NR	BELOW	NR	BELOW
Achillea millefolium	8	1.6	BELOW	NR	BELOW
Helianthella spp	7	NR	BELOW	NR	BELOW
Geranium viscosissimum	5	1.8	BELOW	NR	BELOW
Phlox hoodii	3	NR	BELOW	NR	BELOW
Phlox longifolia	NR	NR	BELOW	0.3	BELOW
Arenaria congesta	3	NR	BELOW	0.1	BELOW
Astragalus spp	2	NR	BELOW	NR	BELOW
Symphyotrichum ericoides	2	NR	BELOW	0.2	BELOW
Cerastium arvense	2	NR	BELOW	NR	BELOW
Lupinus caudatus	NR	1.1	RCR	NR	BELOW
Agoseris glauca	1	NR	BELOW	NR	BELOW
Antennaria rosa	1	NR	BELOW	0.2	BELOW
Cymopterus spp	NR	NR	NR	1.5	RCR
Gutierrezia sarothrae	NR	NR	NR	0.8	RCR
Crepis acuminata	NR	NR	NR	0.3	RCR

Ecological Condition of Mountain Big Sagebrush (Artemisia tridentata vaseyana) community types in the Gardiner Basin, Gardiner Montana. NR = not recorded in this inventory; INTRO = introduced, non-native species; RCR = recovery species; EXPECT = within expected ecological potential range; ABOVE = greater than ecological potential; BELOW = less than ecological potential

Artemisia tridentata/Festuca Idahoensis (Mueggler and Stewart 1980)		Steep Phase	Status	Forb Phase	Status
Artemisia tridentata vaseyana	23	7.1	BELOW	7.1	BELOW
Ericameria nauseous	NR	NR	EXPECT	0.4	EXPECT
Festuca idahoensis	36	4	BELOW	13.6	BELOW
Danthonia intermedia	16	NR	BELOW	0.2	BELOW
Achnatherum nelsonii	14	NR	BELOW	0.9	BELOW
Carex spp	9	NR	BELOW	0.3	BELOW
Koeleria macrantha	3	2.4	EXPECT	0.8	BELOW
Pseudoroegneria spicata	2	3.8	ABOVE	1.7	EXPECT
Poa secunda	NR	1.1	ABOVE	0.4	ABOVE
Poa pratensis	NR	NR	NR	1.8	BELOW
Heterostipa comata	2	0.4	BELOW	0.8	BELOW
Achillea millefolium	8	0.8	BELOW	1.6	BELOW
Geranium viscosissimum	5	NR	BELOW	0.2	BELOW
Phlox hoodii	3	1.5	BELOW	NR	BELOW
Phlox longifolia	NR	NR	EXPECT	2.8	BELOW
Arenaria congesta	3	NR	EXPECT	1.6	BELOW
Astragalus spp	2	NR	EXPECT	0.6	BELOW
Symphyotrichum ericoides	2	0.3	BELOW	2.6	EXPECT
Lupinus caudatus	NR	0.3	ABOVE	3.6	ABOVE
Antennaria rosa	1	0.3	EXPECT	1.8	EXPECT
Crepis acuminata	NR	NR	EXPECT	0.3	EXPECT
Taraxacum officinale	NR	NR	EXPECT	0.3	BELOW
Selaginella densa	NR	NR	EXPECT	0.8	BELOW

Ecological Condition of Mountain Big Sagebrush (Artemisia tridentata vaseyana) community types in the Gardiner Basin, Gardiner Montana. NR = not recorded in this inventory; INTRO = introduced, non-native species; RCR = recovery species; EXPECT = within expected ecological potential range; ABOVE = greater than ecological potential; BELOW = less than ecological potential

Artemisia tridentata/Festuca Idahoensis (Mueggler and Stewart 1980)		Sandy Loam Phase	Status	Deep Loamy	Status
Artemisia tridentata vaseyana	23	6.1	BELOW	7.1	BELOW
Artemisia tridentata tridentata	NR	1.5	EXPECT	0.8	EXPECT
Artemisia tridentata wyomingensis	NR	0.4	EXPECT	0.2	EXPECT
Ericameria nauseous	NR	0.2	EXPECT	0.5	EXPECT
Festuca idahoensis	36	17.4	BELOW	0.9	BELOW
Danthonia intermedia	16	1.4	BELOW	NR	BELOW
Achnatherum nelsonii	14	0.7	BELOW	NR	BELOW
Carex spp	9	NR	BELOW	0.2	BELOW
Poa cusickii	6	1.8	BELOW	NR	BELOW
Koeleria macrantha	3	2.3	EXPECT	2.4	EXPECT
Pseudoroegneria spicata	2	4.7	ABOVE	5.4	ABOVE
Poa secunda	NR	1.8	BELOW	2.1	BELOW
Leucopoa kingii	NR	1.1	BELOW	NR	BELOW
Poa pratensis	NR	0.9	BELOW	NR	BELOW
Heterostipa comata	2	NR	BELOW	1.3	BELOW
Bromus tectorum	NR	NR	EXPECT	3.7	BELOW
Phlox hoodii	3	0.4	DOWN	NR	DOWN
Astragalus spp	2	2.1	Static	NR	DOWN
Symphyotrichum ericoides	2	1.3	Static	NR	DOWN
Lupinus caudatus	NR	3.3	IMPR	NR	DOWN
Antennaria rosa	1	0.5	Static	NR	DOWN

Ecological Condition of Mountain Big Sagebrush (Artemisia tridentata vaseyana) community types in the Gardiner Basin, Gardiner Montana. NR = not recorded in this inventory; INTRO = introduced, non-native species; RCR = recovery species; EXPECT = within expected ecological potential range; ABOVE = greater than ecological potential; BELOW = less than ecological potential.

Artemisia tridentata/Festuca Idahoensis (Mueggler and Stewart 1980)		Degraded Phase	Status
Artemisia tridentata vaseyana	23	2.4	BELOW
Artemisia tridentata wyomingensis	NR	0.8	EXPECT
Ericameria nauseous	NR	1.6	EXPECT
Artemisia nova	NR	0.6	EXPECT
Festuca idahoensis	36	2.4	BELOW
Danthonia intermedia	16	NR	BELOW
Achnatherum nelsonii	14	NR	BELOW
Bromus marginatus	13	NR	BELOW
Elymus trachycaulus	12	NR	BELOW
Carex spp	9	0.1	BELOW
Poa cusickii	6	0.1	BELOW
Koeleria macrantha	3	2.6	BELOW
Pseudoroegneria spicata	2	3.4	EXPECT
Poa secunda	NR	2.6	EXPECT
Pascopyrum smithii	NR	1.6	EXPECT
Heterostipa comata	2	5.2	BELOW
Poa pratensis	NR	0.4	INTRO
Geum trifolium	10	NR	BELOW
Eriogonum umbellatum	10	NR	BELOW
Achillea millefolium	8	1	BELOW
Helianthella spp	7	NR	BELOW
Geranium viscosissimum	5	NR	BELOW
Phlox hoodii	3	0.4	BELOW
Arenaria congesta	3	NR	BELOW
Astragalus spp	2	NR	BELOW
Symphyotrichum ericoides	2	NR	BELOW
Cerastium arvense	2	NR	BELOW
Agoseris glauca	1	NR	BELOW
Antennaria rosa	1	0.6	EXPECT
Gutierrezia sarothrae	NR	1.1	BELOW

Ecological Condition of Black Sagebrush (Artemisia nova) community types in the Gardiner Basin, Gardiner Montana. NR = not recorded in this inventory; INTRO = introduced, non-native species; RCR = recovery species; EXPECT = within expected potential range; ABOVE = greater than ecological potential; BELOW = less than ecological potential.

Artemisia tridentata/Festuca Idahoensis (Mueggler and Stewart 1980)		Steep Phase	Status	Level	Status
Artemisia nova	8	17	ABOVE	14.7	ABOVE
Chrysothamnus viscidiflorus	1	NR	EXPECT	NR	EXPECT
Tetradymia canescens	1	NR	EXPECT	NR	EXPECT
Artemisia tridentata wyomingensis	NR	0.1	EXPECT	0.3	EXPECT
Ericameria nauseosa	NR	0.5	EXPECT	0.7	EXPECT
Festuca idahoensis	31	1	BELOW	5.9	BELOW
Carex spp	NR	0.1	EXPECT	0.7	EXPECT
Poa cusickii	2	NR	BELOW	NR	BELOW
Koeleria macrantha	9	2.3	BELOW	3.5	BELOW
Pseudoroegneria spicata	24	7.5	BELOW	4.5	BELOW
Poa secunda	3	0.5	BELOW	1.9	BELOW
Leucopoa kingii	NR	0.3	BELOW	1.1	BELOW
Heterostipa comata	NR	NR	EXPECT	0.2	EXPECT
Geum trifolium	3	NR	BELOW	NR	BELOW
Achillea millefolium	2	NR	BELOW	0.1	BELOW
Astragalus spp	NR	NR	BELOW	2.3	BELOW
Phlox hoodii	4	0.4	BELOW	2	BELOW
Phlox longifolia	1	NR	BELOW	0.5	Static
Oxytropis spp	7	NR	BELOW	NR	BELOW
Symphyotrichum ericoides	3	0.4	BELOW	NR	BELOW
Agoseris glauca	1	NR	BELOW	NR	BELOW
Antennaria rosa	12	NR	BELOW	1	BELOW
Crepis acuminata	NR	NR	EXPECT	0.2	EXPECT

APPENDIX D

Gardiner Basin Sampling Locations, Geology, Aspect, Slope and Community Types

Site ID	Latitude	Longitude	elevation	geology	aspect	Slope Class	Community Type	location	Sample Year
16	45.16042	-110.843	1541	unconsolidated	flat	0-4%	Mountain big sagebrush, deep phase		2015
17	45.17882	-110.895	1602	bedrock controlled	sw	35-60%	Grassland, Idaho fescue/bluebunch		2015
18	45.07004	-110.782	1610	unconsolidated	ne	4 - 15%	Basin big sagebrush	beadie gulch	2015
19	45.15473	-110.838	1615	unconsolidated	ne	15-35%	Mountain big sagebrush, degraded phase		2015
20	45.12023	-110.815	1655	bedrock controlled	sw	15-35%	Mountain big sagebrush, steep phase	universal church	2015
21	45.12573	-110.817	1662	unconsolidated	ne	15-35%	Mountain big sagebrush, degraded phase	universal church	2015
22	45.14732	-110.806	1668	bedrock controlled	ne	35-60%	Mountain big sagebrush, degraded phase	oto ranch	2015
23	45.04797	-110.735	1690	unconsolidated	sw	35-60%	Grassland, Idaho fescue/bluebunch	travertine road	2015
24	45.13993	-110.827	1703	unconsolidated	ne	35-60%	Mountain big sagebrush, deep phase	universal church	2015
25	45.11792	-110.818	1739	bedrock controlled	ne	35-60%	Black sagebrush, steep phase	hideway road	2015
26	45.03937	-110.693	1779	bedrock controlled	ne	4-15%	Mountain big sagebrush, deep phase	travertine road	2015
27	45.06086	-110.746	1794	bedrock controlled	sw	4-15%	Basin big sagebrush	travertine road	2015
28	45.05637	-110.746	1794	bedrock controlled	ne	15-35%	Black sagebrush, steep phase	travertine road	2015
29	45.09635	-110.811	1819	bedrock controlled	ne	15-35%	Black sagebrush, steep phase		2015
30	45.1321	-110.785	1839	bedrock controlled	ne	35-60%	Black sagebrush, steep phase		2015
31	45.04624	-110.699	1845	bedrock controlled	ne	4-15%	Basin big sagebrush	travertine road	2015
32	45.05086	-110.712	1878	bedrock controlled	flat	0-4%	Mountain big sagebrush, degraded phase	travertine road	2015
33	45.0999	-110.811	1923	bedrock controlled	ne	35-60%	Black sagebrush, steep phase		2015
34	45.05184	-110.676	1938	unconsolidated	sw	4-15%	Mountain big sagebrush, sandy loam	eagle creek	2015
35	45.04833	-110.674	1955	unconsolidated	sw	15-35%	Mountain big sagebrush, sandy loam	eagle creek	2015
36	45.1261	-110.839	1983	bedrock controlled	ne	15-35%	Mountain big sagebrush, sandy loam	hideway road	2015
37	45.0593	-110.651	2057	bedrock controlled	sw	35-60%	Mountain big sagebrush, steep phase	bear creek	2015
38	45.06661	-110.673	2137	bedrock controlled	ne	15-35%	Mountain big sagebrush, sandy loam	eagle creek	2015
39	45.07324	-110.644	2153	bedrock controlled	ne	15-35%	Mountain big sagebrush, deep phase	eagle creek	2015
40	45.0642	-110.684	2144	bedrock controlled	sw	15-35%	Abandoned agricultural fields	eagle creek	2015
41	45.14991	-110.789	1768	unconsolidated	sw	15-35%	Abandoned agricultural fields	oto ranch	2015
42	45.117	-110.827	1811	bedrock controlled	sw	35-60%	Mountain big sagebrush, sandy loam	hideway road	2015
43	45.10375	-110.792	1632	bedrock controlled	sw	35-60%	Grassland, Idaho fescue/bluebunch	old Yellowstone trail	2016
44	45.11886	-110.805	1720	bedrock controlled	sw	35-60%	Grassland, Idaho fescue/bluebunch	cinabar mountain	2016
45	45.17848	-110.803	2057	unconsolidated	sw	35-60%	Mountain big sagebrush, steep phase	slip & slide	2016
46	45.17664	-110.816	1857	unconsolidated	sw	35-60%	Grassland, Idaho fescue./bluebunch	slip & slide	2016

Site ID	Latitude	Longitude	elevation	geology	aspect	Slope Class	Community Type	location	Sample Year
48	45.14077	-110.786	1869	unconsolidated	ne	35-60%	Grassland, Idaho fescue, loamy phase	oto ranch	2016
49	45.14152	-110.79	1835	unconsolidated	ne	35-60%	Grassland, Idaho fescue, loamy phase	oto ranch	2016
50	45.14304	-110.795	1768	unconsolidated	ne	35-60%	Grassland, Idaho fescue, loamy phase	oto ranch	2016
51	45.11255	-110.805	1753	bedrock controlled	sw	15-35%	Mountain big sagebrush, degraded phase	cinabar mountain	2016
52	45.11877	-110.815	1693	bedrock controlled	sw	15-35%	Grassland, Idaho fescue/bluebunch	cinabar mountain	2016
53	45.11206	-110.834	1894	bedrock controlled	sw	15-35%	Black sagebrush, level phase	hideway road	2016
54	45.17561	-110.8	2013	unconsolidated	sw	15-35%	Mountain big sagebrush, forb phase	slip & slide	2016
55	45.11059	-110.81	1800	unconsolidated	ne	15-35%	Basin big sagebrush	cinabar mountain	2016
56	45.14298	-110.786	1814	unconsolidated	ne	15-35%	Grassland, Idaho fescue, loamy phase	oto ranch	2016
57	45.11211	-110.833	1902	bedrock controlled	sw	4-15%	Black sagebrush, level phase	hideway road	2016
58	45.14043	-110.781	1928	bedrock controlled	sw	4-15%	Grassland, Idaho fescue, loamy	oto ranch	2016
59	45.11905	-110.834	1934	bedrock controlled	sw	4-15%	Black sagebrush, level phase	hideway road	2016
60	45.15217	-110.785	1804	unconsolidated	sw	4-15%	Abandoned agricultural fields	oto ranch	2016
61	45.18218	-110.811	1992	unconsolidated	sw	4-15%	Mountain big sagebrush, forb phase	slip & slide	2016
62	45.18044	-110.819	1921	bedrock controlled	ne	4-15%	Mountain big sagebrush, forb phase	slip & slide	2016
63	45.14453	-110.79	1782	unconsolidated	ne	4-15%	Grassland, Idaho fescue, loamy phase	oto ranch	2016
64	45.11167	-110.807	1782	unconsolidated	ne	4-15%	Grassland, Idaho fescue, loamy phase	cinabar mountain	2016
65	45.14304	-110.792	1785	unconsolidated	ne	4-15%	Grassland, Idaho fescue, loamy phase	oto ranch	2016
66	45.11111	-110.811	1799	unconsolidated	ne	4-15%	Black sagebrush, level phase	cinabar mountain	2016
67	45.18249	-110.805	2036	unconsolidated	flat	0-4%	Abandoned agricultural fields	slip & slide	2016
68	45.13885	-110.777	2013	unconsolidated	flat	0-4%	Grassland, Idaho fescue, loamy phase	oto ranch	2016
69	45.10874	-110.791	1554	unconsolidated	flat	0-4%	Abandoned agricultural fields	old Yellowstone trail	2016
70	45.12027	-110.86	1937	unconsolidated	flat	0-4%	Mountain big sagebrush, degraded phase	hideway road	2016
71	45.11509	-110.816	1765	bedrock controlled	flat	0-4%	Black sagebrush, level phase	cinabar mountain	2016
72	45.1568	-110.77	1960	bedrock controlled	flat	0-4%	Abandoned agricultural fields	oto ranch	2016
73	45.18345	-110.815	1959	bedrock controlled	flat	0-4%	Mountain big sagebrush, forb phase	slip & slide	2016

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