COMMUNITY COMPOSITION ANALYSIS OF ALTERED VEGETATION COMMUNITIES FOLLOWING THE RELEASE OF GRAZING PRESSURE

by

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ABSTRACT

Determining community composition and recognizing successional gradients of community recovery following release from disturbance is vital in determining proper land management techniques. Successful native plant recovery depends on biotic and abiotic factors and the type and degree of anthropogenic disturbance. Degraded vegetation communities need initial survey efforts to determine the extent of degradation followed by consistent standardized monitoring to determine transition along successional gradients. The aim of this study was to determine community composition and successional gradients following release from livestock grazing. To this end, initial surveys were completed at the Lost Trail National Wildlife Refuge during the summers of 2013 and 2014, with the aim of evaluating the composition of each previously mapped community type and making recommendations for future management practices.

Prior to any fieldwork, various vegetation sampling methods were compared including, Daubenmire percent canopy cover (DPCC), point-intercept and modified Whittaker plots. The DPCC method was determined to be the most efficient for current and future sampling efforts, balancing the quality of data and the time needed for collection. Using this method, a minimum of 60 Daubenmire frames were sampled from 16 vegetation communities. The USFWS project objectives were to (1) determine if each of the premapped community types were named correctly, and (2) collect enough vegetation data to determine a 20% change in the five most common species with an accuracy of 80%. Species area curves were plotted, and sample adequacy calculated to determine if each community was adequately sampled. It was found that a minimum of 24 to 180 sample frames are necessary to sufficiently describe all communities. However, this number may increase as the communities transition to native-dominated stands. Litter depth was found to be the only statistically significant abiotic factor related to community composition ($P = 0.03$): litter depth is highly correlated with non-native species ($r = 0.904$), and the lack of litter is correlated with the presence of three climax species ($r = 0.736$). The intermontane grasslands in this refuge were found to be part of the Northern Fescue Grasslands rather than part of the Palouse Prairie.

INTRODUCTION

Quantification of plant diversity is an ever-growing concern for ecologists because of the encroachment of non-native species into native habitats. The loss of native plant populations caused by the invasion of non-native species affects the ecological function of native habitats, potentially leading to areas of local extinction (Schmitz and Simberloff, 1997; Wilcove et al. 1998). Some ecologists argue that the introduction of non-native species reduces habitat value and productivity for wildlife (e.g., Germano et al. 2012), while others argue that non-native species can have positive as well as negative effects (e.g., Hayes and Holzmueller, 2012). Brooks et al. (2004) have shown that the introduction of non-native species into undisturbed habitats degrades community structure, and resilience to fire.

Replacement of native vegetation by planted non-natives has been an intentional management practice in the past, and continues today. Beginning in the late 1800s in the western United States, non-native pasture grasses were planted on farms and ranches to control erosion and increase the availability and amount of forage for livestock (Heath et al. 1985). Planting non-native species, especially non-native grasses that produce thick litter beds, can limit the recovery of native species following the removal of grazing pressure.

The introduction of non-native species is second only to habitat destruction in causing the endangerment and decline of native species worldwide (Schmitz and Simberloff, 1997). The conservation and restoration of habitats, especially those that support essential target species' life cycles, are vitally important when developing ecosystem conservation plans. In recent decades, federal and state agencies have become increasingly interested in conserving and restoring habitats to their native conditions. This goal is reflected in the U.S. Fish and Wildlife Service (USFWS) mission statement.

> "The mission of the USFWS is working with others to conserve, protect, and enhance fish, wildlife, plants, and their habitats for the continuing benefit of the American people."

The need to control non-native grass species becomes important when the goal of local land management changes from livestock production to restoration of native vegetation communities. Descriptions of plant community composition is necessary because the release of grazing pressure allows some of these introduced species to form monotypic stands (Pellant et al. 2005), effectively eliminating re-colonization by native species (Holechek et al. 2011). Reduced or limited diversity and productivity of invaded habitat types can be detrimental to wildlife through the loss of features used for nesting, feeding or rearing offspring. This loss of features places additional stress on animal species already experiencing population declines. Additionally, some non-native plant species are less palatable than native species, effectively increasing grazing pressure on the remaining native species.

Efforts at the Lost Trail National Wildlife Refuge (LT-NWR), located approximately 20 miles northwest of Marion, MT. (Figure 1) reflect this situation.

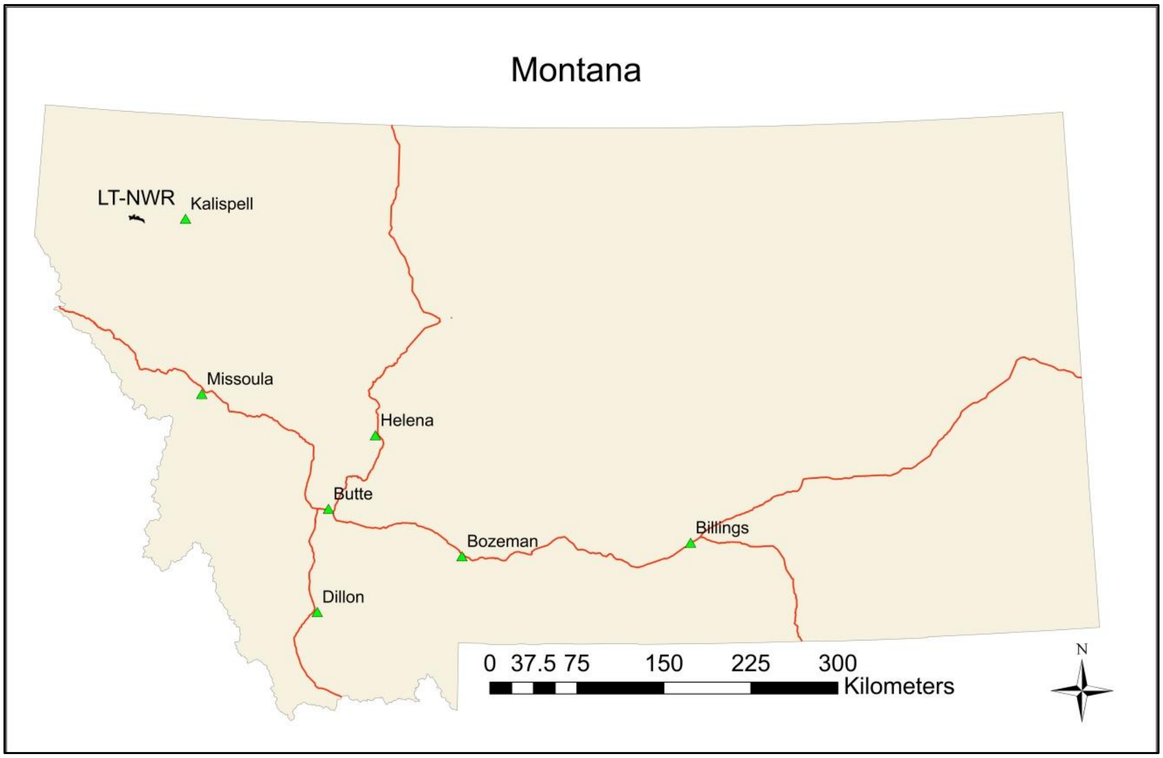

Figure 1. Location of Lost Trail National Wildlife Refuge

Refuge Background

Lost Trail National Wildlife Refuge was established in 1999, as part of a mitigative settlement under the Federal Energy Regulatory Committee's "no net wetlands loss" policy. This settlement, between the Montana Power Company, the Confederated Salish and Kootenai Tribes, and the USFWS established the 3,733-ha refuge, to mitigate the loss of wetlands (1,259-ha) submerged by the Kerr Hydroelectric generating facility (USFWS, 2005). Additionally, more than 1500 ha of degraded grassland habitat were protected. The USFWS considered that the open grasslands within the LT-NWR are one of the few locations in Montana where the Palouse Prairie ecosystem exists, even in a degraded state. Palouse Prairie, which is endemic to the northwestern United States and far southwestern Canada, has become extremely rare because of agricultural conversion, and currently exists intact in < 0.1% of its former range (Noss et al. 1995).

Prior to acquisition by the USFWS, the LT-NWR was a working cattle ranch, seasonally sustaining 700 to 800 head of cattle (Wiley, personal communication). Most of the ranch's wetland and riparian areas had been drained or impounded, and the converted areas planted to non-native pasture grasses to increase the amount of forage available to grazing livestock, through direct feeding or as supplemental hay. In the years leading up to acquisition by the USFWS, the ranch was overgrazed (USFWS, 2005), leading to conditions that favored expansion of non-native forbs and grasses. When the USFWS acquired the refuge, grazing livestock were removed, and the constructed drainage canal from Dahl Lake (the largest lake on the refuge) was filled to recharge the lake basin. Sporadic application of herbicide remains the only land management changes implemented by the USFWS since closure of the drainage canal and elimination of livestock grazing. Prior to implementing additional management actions to recover the native plant communities, the USFWS needed to know the current composition of the vegetation community types and adopt standard sampling protocols to obtain repeatable community-composition measurements.

Two descriptive vegetation units (*habitat type* and *community type*) are used in this thesis: (1) *habitat type* includes all parts of the landscape that support, or can support the same kind of relatively stable climax species in the absence of disturbance (Daubenmire, 1970);(2) *community type* includes individuals of each species distributed over the landscape based on the ecological amplitude of those species and the heterogeneity of the environment (Daubenmire, 1968). Using these definitions a single habitat type on LT-NWR could contain several community types.

Located in the intermontane grasslands of northwestern Montana, this refuge contains many different vegetation habitat types [described by dominant climax species (Daubenmire, 1970)], representing four major vegetation types (forested uplands, grasslands, riparian, and wetlands). Elevations across the refuge range from 1,060 to 1,353 meters; mean annual precipitation is 40.5 cm and mean annual temperature is 5.5°C.

Once the refuge was established, a comprehensive conservation plan (CCP) was developed to aid refuge managers in restoration and protection efforts. One of the most ambitious goals established in the CCP was to map and evaluate the condition of riparian, wetland, and grassland vegetation community types (USFWS, 2005), because these community types are more prone to invasion by non-native forage species than the adjacent forested uplands.

An initial USFWS mapping effort was undertaken to delineate the vegetation community types and describe the vegetation composition. This was done using the dominant species present and NRCS soil type to evaluate the potential climax vegetation. Identification of the ecological site potential would then guide restoration efforts that focused on increasing habitat value for nesting waterfowl and upland bird species, as well as improving native forage quality for deer, elk and moose.

The next step was to establish the vegetation baseline to facilitate future monitoring efforts. To fulfill this requirement, the Montana State University (MSU)

Department of Animal and Range Science was contracted to complete soil/vegetation ecological surveys in the previously mapped grassland vegetation community types. The primary provision of the contract was to establish a baseline community analysis of potential Palouse Prairie communities. The survey outcome would be used by refuge managers to monitor areas for potential degradation, and to provide a record of native vegetation recovery.

The purpose of this thesis is to synthesize the results of soil/vegetation surveys conducted during the summers of 2013 and 2014. Survey data were specifically collected to help determine:

- whether the previously mapped community types were named correctly;
- what number of samples per community type would be needed to detect a ≥ 20% change in the five most frequently occurring species in that community with an accuracy of 80%; and
- a set of standard sampling protocols for the USFWS.

A secondary objective of this study was to provide a new refuge map, accurately representing the existing vegetation community types and identification of community types that may represent stages in the recovery of the native grassland habitat types.

LITERATURE REVIEW

Named after the Palouse region in Washington, the Palouse Prairie is endemic to the northwestern United States and far southwestern Canada. In the U.S., it extends from Washington into Oregon, Idaho, Montana and Utah (Caldwell, 1961; Humphrey, 1945; Stoddart, 1941). This area is described as receiving 20 to 64-cm of precipitation annually (Stoddart, 1941) and contains two major climatic zones, a mesic zone, dominated by *Festuca idahoensis* and *Pseudoroegneria spicata*, and a xeric zone, dominated by *P. spicata* and *Poa secunda* (Tisdale, 1961). In both habitat types wildflowers, shrubs, mosses and lichens have been described as minor components (Weaver, 1917; Stoddart, 1941; Humphrey, 1945; Leopold and Denton, 1987; USFWS, 2001). Conservation of the Palouse Prairie is challenging because it is very susceptible to overgrazing by livestock and subsequent invasion by non-native species (Young, 1943).

Non-native species have the potential to become the dominant or codominant species in a disturbed community unless controlled (Pellant et al. 2005), however some non-native species can invade and become dominant in undisturbed communities, e.g., spotted knapweed (*Centaurea maculosa*) (Stohlgren et al. 1999; Zouhar, 2001). Most efforts to limit non-native plant invasion of threatened native community types rest on the reversal of the processes that open the community to invasion.

Wilcove et al. (1998) determined that the five most eminent threats to imperiled plant habitat loss are: 1) land development (36%), 2) conversion to agricultural lands (33%), 3) livestock grazing (33%), 4) outdoor recreation (33%), and 5) disruption of fire regime (20%); these categories are nonexclusive, therefore they do not sum to 100. These forms of disturbance increase the chance of invasion by non-native species. Because of the rich fertile soils and pattern of precipitation in the Palouse Prairie region, non-native species are able to outcompete many of the native species in disturbed locations (Vitousek, 1990). This likelihood emphasizes the need for long-term vegetation monitoring in any grassland conservation effort.

Vegetation surveys are used by land managers to provide early warning of potential problem areas (Pellant et al. 2005). Following this recommendation, the LT-NWR staff has chosen measures of community richness and diversity within grasslands on the refuge to determine the effects of non-native species on the refuge's remnant Palouse Prairie community types. To achieve this goal, baseline field data needed to be collected and standard monitoring protocols established. Some authors (Jennings et al. 2003; Liu et al., 2008) emphasize using remote sensing techniques to monitor changes in vegetation communities. However, remote sensing is not adequate for detailed analysis of vegetation communities because of the complexity of these communities (Hostert et al. 2003) and the expense of high-level resolution imagery necessary to segregate this complexity into map polygons. Furthermore, remote-sensing techniques are unable to delineate changes in soil type or depth to a restrictive layer, controlling factors in climax community composition.

To determine the potential climax plant community it is necessary to complete soil and vegetation surveys. MacDougall et al. (2006) and Baer et al. (2005) reported that soil characteristics alone have little capacity for predicting community type or potential invasion by non-native plant species, while Hanson et al. (2008) found that depth to restrictive layer plays a significant role. Therefore, it is necessary to determine soil type at each site to aid in predicting the potential of that area to be invaded by non-native species. The use of the NRCS Ecological Site Key and the appropriate NRCS Ecological Site Description can be the basis for identifying the potential climax vegetation species for a particular site. This information enables managers to determine the extent of degradation caused by overgrazing and/or site alteration based on the current community composition.

Many federal agencies (USDA Forest Service, U.S. Bureau of Land Management, U.S. Fish and Wildlife Service), and non-governmental organizations (NGOs) recognize and use various methods to determine vegetation community composition. Some of these methods include: photographic interpretation, pace, quadrat and nested frequency measures, cover class (Daubenmire method), line-intercept method, step-point method, point-intercept method, modified Whittaker plots, cover board method, density method, double-weight sampling, harvest method, comparative yield method, and visual obstruction method (Robel pole) (Coulloudon et al. 1999; Elzinga et al. 1998; Leis et al. 2003). To determine the current composition of the vegetation community types at LT-NWR, several of these sampling methods were reviewed, including the line point-intercept method, Daubenmire percent canopy cover (DPCC) and the modified Whittaker plot, because they are the methods most often used for vegetation community evaluation. Most importantly, the selected sampling technique had to provide the best compromise between highly accurate data and least possible time investment (and subsequent cost) for refuge personnel.

The line point-intercept method requires about half the time that other sample methods require but was rejected because it captures less than half of the diversity of a community, and the high degree of linearity in data collection misses many of the less common plants (Stohlgren et al. 1998). This is illustrated by results from Johnson (1957), which indicate that in relatively homogenous plant communities, the accuracy of vegetative sampling provided by 40 to 80 Daubenmire sample frames would require 1,200 to 38,940 line-intercept points to achieve the same level of accuracy. In contrast, Cain (1943) found that twenty $1/10^{th}$ m^2 rectangular sample frames were adequate for sampling alpine vegetation; Higinbotham and Higinbotham (1964) determined that fifteen $1/10^{th}$ m^2 sample frames were adequate for sampling a wide variety of other vegetation types, and that only a single species was added by collecting an additional 35 sample frames.

The modified Whittaker plot method requires substantial time to set up and sample accurately and needs to be replicated multiple times to detect uncommon species at a rate of 50% (Abrahamson et al. 2011). Rectangular plots often include more species than square or round plots of equal area because plants naturally grow in groups; this is especially true if the long leg of the rectangle is placed parallel to environmental gradients (Fidelibus and MacAller, 1993), thus the rectangular Daubenmire frame is better suited to capture uncommon species. For this reason, and because the DPCC method provided the best compromise between the length of time spent collecting and accuracy of the data collected, it was chosen as the sampling method for the LT-NWR.

Regardless of the survey method used, it is necessary for survey personnel to have good plant identification skills for an accurate description of the community composition.

Identification skills gained through taxonomy, botany, and range science classes are necessary to properly identify vegetation species found within survey quadrats (Daniels et al. 1994). If necessary, field training should be undertaken to guarantee that all technicians have the same level of expertise regarding plant identification and collection (Coulloudon et al. 1999). For these reasons, the use of student interns and seasonal technicians can be problematic in vegetation surveys, as these individuals may not be adequately trained in the identification of seedlings or rare species (Elzinga et al. 1998). It is also necessary to be able to distinguish between native and non-native species, especially when the goal is to restore previously altered communities. Additionally, field personnel should be trained in the use of the NRCS ecological site descriptions, as these references enable the user to identify the respective successional pathways for the community and therefore determine if additional management action is necessary.

The NRCS describes an ecological site potential as:

> "a distinctive kind of land with specific soil and physical characteristics that differ from other kinds of land in its ability to produce a distinctive kind and amount of vegetation and its ability to respond similarly to management actions and natural disturbances." (NRCS, n.d.).

Therefore, in addition to vegetation metrics, other site characteristics including slope, aspect, elevation and litter depth are used to refine the ecological site identification. For example, litter depth has been successfully used to determine changes in community type (Galvánek and Lepš, 2012; Pellant et al. 2005). Increases in non-native species, especially non-native grasses, increase litter depth and have been reported to decrease the recruitment of native seedlings (Foster and Gross, 1998; Xiong et al. 2003), subsequently reducing the richness and diversity of the overall community (Galvánek and Lepš, 2012; Xiong et al. 2003).

Not only does the higher level of litter produced by non-native grasses alter the recruitment of native seedlings(Pellant et al. 2005), it also changes the resilience and resistance to fire (Brooks et al. 2004; Vitousek, 1990). The increase in fine fuels produced by non-native grasses are highly effected by atmospheric moisture, promoting fire earlier in the spring and later into the fall (Brooks et al. 2004). The timing of fire effects community composition.

In the Northern Mixed Grass Prairie, spring (April 19-26) and fall (October 5-17) burns have been shown to increase forb density (Biondini et al.1989), while mid-summer fires favor C_3 grasses and decrease C_4 grasses (Howe, 2000). Native species have evolved with fire and the current policy of fire suppression favors non-native species (Ewing, 2002). Non-native grasses that alter fire regimes are recognized as some of the most damaging system-altering species, especially in the Great Basin (D'Antonio and Vitousek, 1992; Vitousek, 1990). Non-native annual grasses are generally fast growing and will overtake a community, creating an abundance of fine fuels that dry out quickly in fall, creating a higher potential for damaging fires. Regardless of method of introduction early detection of annual grasses can allow managers to take action to reduce the spread of these potentially harmful non-native annual grasses, which will subsequently reduce litter depth and potentially increase the cover of native species. To achieve this end, species area curves plotted using vegetation composition data can be used to determine if enough locations have been sampled to adequately describe the amount of non-native grasses in target communities that contain non-native grasses.

Species area curves (plotted as cumulative number of species vs. number of locations sampled) are used to describe communities (Cain, 1938) and to evaluate sample adequacy of a community type (Braun-Blanquet et al. 1932; Daubenmire, 1959; Fidelibus and MacAller, 1993). Sample adequacy is reached when additional sampling does not add more species. A standard number of plots necessary to accurately describe a community is unlikely because sample adequacy varies with heterogeneity of the vegetation rather than the size of the community (Canfield, 1941). As more plots are sampled, the area under study becomes more homogeneous and fewer additional species are encountered (Scheiner, 2003). As long as sampling remains within the bounds of the same general community, the species area curve will flatten as the number of new species found declines. The inflection point (where the species area curve flattens) is considered to be the minimum number of sample plots necessary to describe that community (Cain, 1938; Mosley et al. 1989). The increase in species with area sampled is considered one of the few laws of ecology, making species area curves a key measure of ecological patterns (Scheiner, 2003). The initial rise of the species area curve is caused by capture of the more dominant species, and the less dominant species are represented in the flatter portion of the line (Cain, 1938). The more homogeneous a community is the quicker the species area curve will flatten; this is caused by fewer species occurring at higher frequencies (Cain, 1938). Based on my review of the literature I would expect the communities dominated by non-native grasses to require the fewest number of samples to achieve sample adequacy.

Study Objectives

For the purpose of ecological restoration, existing plant communities need to be compared to a reference climax plant community. In this case, the existing plant community types will be compared to the Palouse Prairie, because it is expected that the grasslands within the refuge are degraded remnants of the Palouse Prairie.

The objectives of this study include:

1. determining if the grassland communities at the LT-NWR fit the Palouse Prairie description;

2. determining if certain abiotic data can be used to anticipate community composition.

3. developing a spatially accurate Geographic Information System (GIS) map of existing vegetation community types and;

4. developing a set of sampling protocols for the collection of vegetation data.

The baseline survey will provide a point of reference for determining future management strategies to reduce the extent of non-native and invasive species found in the grasslands within the refuge. The GIS map will provide a spatially accurate reference of existing community boundaries so future management actions can assess community expansion or decline.

METHODS

Field Methods

Several sampling strategies that can be used to collect baseline vegetation information were evaluated during this study, including the line point-intercept method, the modified Whittaker plot, the diagnostic plant indicator species, and Daubenmire percent canopy cover (DPCC). The protocols were evaluated to identify a method that would provide the best accuracy with the shortest possible time investment. Initially, a combination of two sampling methods were chosen, the line point-intercept method, and the Daubenmire percent canopy coverage method (DPCC). After initial sampling and data analysis, the line point-intercept method was dropped because it could require far too many sample points to describe the more diverse community types.

Initial efforts by USFWS managers to describe refuge grasslands consisted of mapping vegetation community types on a hardcopy, 20-year-old, black-and-white aerial photograph (Verlanic, personal communication). That photograph was georeferenced and digitized as an ArcMap shapefile for this study. The original ArcMap file contained over 200 individual community-type polygons, with many of the same type occurring in multiple locations. After merging the polygons containing the same community type, 32 different community types remained. Sixteen of the 32 vegetation community types are considered Palouse Prairie remnants by the USFWS. These 16 community types were evaluated in this investigation (Table 1).

Table 1. The 16 vegetation community types considered to be Palouse Prairie remnants in the original vegetation map for the LT-NWR, Marion, MT.

USFWS Vegetation Community type name	**Size (ha)**	**Abbreviation**
Artemisia frigida	9.9	Af
Bromus tectorum	14.8	Bt
Leymus cinereus	27.7	Ec
Festuca idahoensis	671.4	Fi
Festuca campestris	112.7	Fc
Koeleria pyramidata	17.6	Kp
Overgrazed (based on location)	1.3	O
Pascopyrum smithii	254.6	Ps
Pentaphylloides floribunda	6.3	Pf
Phleum pratense	360.9	Pp
Poa pratensis	25.1	Ppr
Pseudoroegneria spicata	40.9	Pss
Stipa richardsonii	2.6	Sr
Stipa spp.	5.3	Ssp
Symphoricarpos albus	6.8	Sal
Unknown (based on location)	23.1	U

Once the 16 Palouse Prairie community types were identified, ArcMap (version 10.1, ESRI, 2013) was used to randomly locate five sample locations in each vegetation community (Appendix A, Figure 10). Coordinates for each location were determined and loaded on a handheld GPS unit. Upon arrival at a sample location, a permanent fiberglass “center” pin was driven into the ground and four 50-m permanent transects were established in each cardinal direction.

Data were collected using a 20 x 50 cm sample frame placed at pre-determined intervals along each transect. Once a species was identified, the cover class (%) was determined and a midpoint value recorded (Table 2). If species could not be identified in the field, they were pressed and labeled with sample location and percent of frame, and brought back to the laboratory for identification. Some annual forb species were too immature to identify, therefore they were listed as unidentified annual forb (UAF).

Table 2. Daubenmire percent range and midpoint values (Daubenmire, 1959).

Percent Range	Midpoint value
0-5	2.5
5-25	15
25-50	37.5
50-75	62.5
75-95	85
95-100	97.5

Baseline information collected during this effort was used to evaluate the existing community composition and determine if the community types were representative of remnant Palouse Prairie grasslands. At each sample location, five categories of data were collected:

1) Soil type:
   Following NRCS recommendations, a soil pit was dug to a minimum depth of 50-cm, 1-m southwest of the center pin at each sample location, to avoid disturbing vegetation directly at the sample location. The soil type in each pit was identified using the NRCS ecological site key (NRCS, 2013).

2) Litter depth:
   Litter depth within each sample frame was measured at three points and the average recorded.

3) DPCC sample approach:
   At three locations along each transect, three sample frames were systematically established (totaling 12 sample frames per sample location, and 60 per community type, with the exception of the community types identified in Table 3). Foliar ground cover was estimated following the DPCC method. The DPCC sample frames were collected at 0-m, 25-m, and 50-m distances on the north and east transects and at 3-m, 25-m, and 50-m distances on the south and west transects.

The measurements collected on the south and west transects were offset to 3-m to avoid overlapping the north and east transect 0-m samples. The frames were placed such that the 20-cm end was against the transect tape at each location, on alternating sides of the transect line (Figure 2).

Table 3. Locations not fully sampled because of roads, creeks, or lakes.

Sample location name	**Community type**	**Reason for not sampling**	**Number of DPCC frames not sampled**
Af-5-W	*Artemisia frigida*	Road in plots 2 & 3 W	2
O-2-E	Overgrazed	Road in plot 2 E	1
O-2-S	Overgrazed	Road in plots 2 & 3 S	2
O-3-S	Overgrazed	Road in plots 2 & 3 S	2
Pp-5-N	*Phleum pratense*	Creek at 3 N and 3 W	2
Ps-1-W	*Pascopyrum smithii*	Lake at plot 3 W	1
U-3-W	Unknown	Road in plot 1 W	1

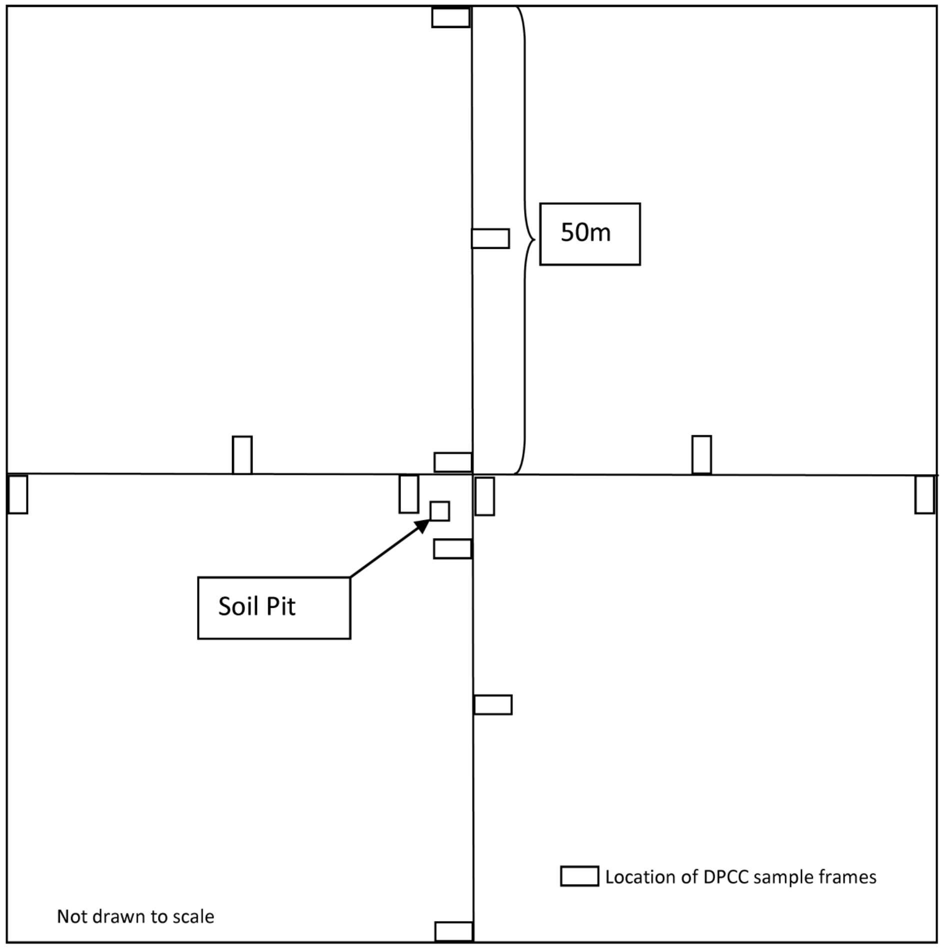

Figure 2. Position of DPCC sample frames and soil pit at each of the sample locations

Daubenmire midpoint values were recorded for each species based on the percent foliar canopy cover (Table **2**). For example, if *P. pratensis* was present in a sample frame at a percentage value of 35% a midpoint value of 37.5% would be assigned to this record. The midpoint values for all species and abiotic data in all 12 sample frames at a single sample location were averaged, providing the sample location values. This approach reduces the impact of human error in assigning actual percent cover values, subsequently increasing the ability to precisely measure successional change (Daubenmire, 1959).

However, the larger the midpoint value is, the larger the change needs to be before a change can be detected in monitoring records.

All field data were recorded directly into an Excel spreadsheet (Microsoft, 2007), further reducing the possibility of human error when transcribing data.

Data Analysis Methods

Biotic data consisted of the midpoint percent value for each species identified at each sampling point. While the abiotic data consisted of the average litter depth, recorded at three locations within each sample frame, the midpoint value for the percent litter, rock, bare ground and water. Additionally, elevation, slope, aspect, MAP and MAT were analyzed for each site. The Bray-Curtis dissimilarity index was used for analysis.

Data was recorded in a matrix of 1057 rows (sample frames) by 187 columns (species and abiotic data). Percent cover was recorded for each species, litter, rock, bare ground and water; depth (cm) was recorded for average litter depth and a 1 or 0 was recorded for soil type depending on presence. Species-area curves (SACs) were plotted using Microsoft Excel (Microsoft, 2007) and sample adequacy calculations were completed for each community type to determine if each community type had been adequately sampled. Hierarchical clustering using complete linkage was used to group sample location based on the biotic data; non-metric multidimensional scaling (NMDS) using Bray-Curtis distance measures utilizing 200,000 random start iterations analysis were computed using the statistical program R (RStudio, 2013). The NMDS analysis was used to determine the influence of the abiotic data on the “new” community types.

RESULTS

The line point-intercept method requires about half the time that other sample methods require (Stohlgren et al. 1998), but it was rejected because it is reported to capture less than half of the community diversity. The modified Whittaker plot method was rejected because of the length of time required for field set up and sampling. The DPCC method was selected as it was found to be the best compromise between time spent collecting and the accuracy of data collected. Site soil/vegetation surveys collected using the DPCC method can be used to determine if, and to what extent, native plant communities have been invaded by non-native species and the recovery of these community types following grazing.

Species area curves were plotted for each of the original community types to determine if additional sampling was necessary (Figure 3). Fourteen of the original community types were adequately described by fewer than the 60 sample frames in communities with >25% non-native species cover. None of these community types exceeded a species richness of 54 and most were below 50. Additional sampling was performed at three community types, one (*Leymus cinereus*) was sampled to ensure that no additional species would be added with additional sampling. The other two community types, *F. campestris* and *F. idahoensis* required additional sampling to ensure an adequate number of samples were collected for the species accumulation curve to plateau. Both had high species richness (61 and 70 respectively) and additional species were still being documented beyond the 60 sample frames necessary to describe the other communities.

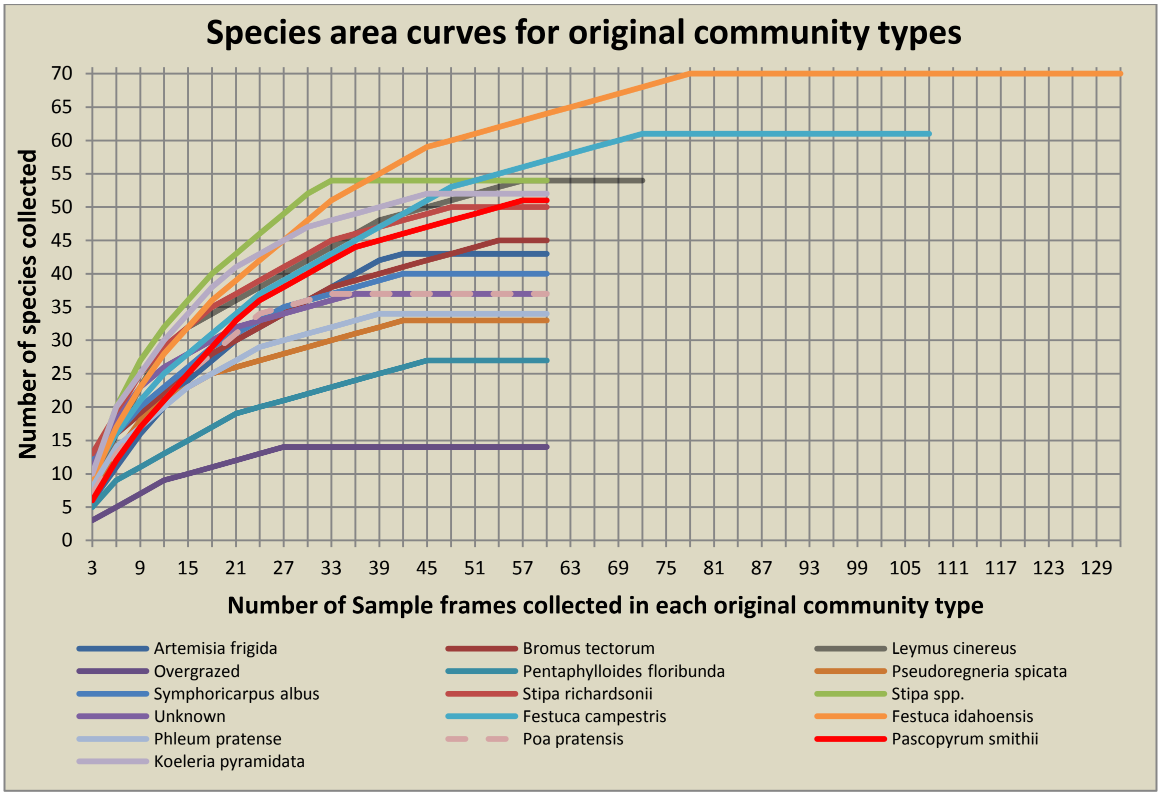

Figure 3. Species area curves for all sampled community types at the LT-NWR, Marion, MT.

In addition to the species area curves, a sample adequacy analysis (aka power analysis) was run for each of the community types (Table 4). This analysis shows that additional sampling was needed in nine of the sixteen original community types.

Table 4. Sample adequacy analysis for the 16 original vegetation community types at LT-NWR.

Name	**Number of frames sampled**	**Number of frames necessary for sample adequacy (p= 0.2)**	**Standard deviation**
Af	60*	36	2.6
Bt	60*	12	1.7
Ec	72	108	5.2
Fc	96	120	5.2
Fi	132*	36	3.1
Kp	60*	12	2.2
O	60*	12	1.9
Pf	60*	48	2.3
Pp.	60	120	3.2
Ppr	60	156	5.3
Ps	60	228	5.2
Pss	60	168	4.1
Sal	60*	36	2.6
Sr	60	252	7.7
Ssp	60	84	5.9
U	60	444	6.8
* met sample adequacy (P = 0.2), set by USFWS			

A total of 161 species were identified over the two years of sampling (Appendix A, Table 14), 131 native, 26 non-native and one listed as both native and non-native in the USDA plants database (USDA, 2014). An additional four unknown species were recorded in the survey. In all sampled community types, the total cover for native, non-native and unknown species was 51.4%, 47.0% and 1.6% respectively. Uncommon species have been found to have an unusually high influence (Oksanen, 2007), which skew statistical results (Brazner and Beals, 1997). Therefore, all species occurring in less than 5% of all sample locations were removed from further analysis (McCune and Grace, 2002). Once the uncommon species (<5%) were removed 17 species remained. Of these remaining species, ten were native, six were non-native and one was of unknown origins.

These remaining species were used to determine if the sample locations belong in the original community type or if they represent a new community type.

The statistical program R was used to create a dendrogram based on the biotic data collected (Figure 4). Prior to plotting this dendrogram, each of the sample locations were renamed using the dominant species at each location. The dendrogram grouped individual sample locations with other sample locations that had similar biotic values and produced seven “new” groups (A, B, C, D, E, F, G), for the grassland areas of the refuge. The dendrogram was pruned where stable groupings were evident and the 33.5% information remains allowed for practical interpretation. To verify that these newly identified community types were in fact different, five dissimilarity indices, using the biotic data collected, were compared to determine which index shows the largest amount of difference between the community types (Table 5); the larger the value the more dissimilar the communities. Based on these results the Bray-Curtis dissimilarity index was selected for this analysis. The values provided by the Bray-Curtis dissimilarity index shows that three of the community types are highly dissimilar to a single community (Table 6).

Table 5. Dissimilarity indices used for community comparison.

Euclidean	Manhattan	Bray-Curtis	Jaccard	Kulkczynski
0.07403	0.23896	0.34805	0.34805	0.33246

Table 6. Bray-Curtis dissimilarity values for biotic data collected at LT-NWR.

Group number and new name in ()	Group 5	Group 1	Group 4	Group2	Group 7	Group 6
Group1 (Fes.ida)	0.47					
Group 4 (Car.fil)	0.73	0.61				
Group 2 (Moss)	0.60	0.56	0.66			
Group 7 (Poa.com/Fes.cam)	0.60	0.56	0.58	0.46		
Group 6 (Poa.com/Thi.int)	0.74	0.71	0.76	0.61	0.39	
Group 3 (Thi.int)	0.62	0.57	0.58	0.40	0.40	0.52

These new community types were classified by habitat type using Mueggler and Stewart's "*Grassland and shrubland habitat types of Western Montana" (1980)* as a reference (Appendix Table 15). All of the new community types met the necessary criteria to fit into one of two Mueggler and Stewart (M&S) habitat types (Table 7). Groups 1, 2, 5, 6 and 7 fit the criteria for the M&S *F. campestris / F. idahoensis* habitat type, while groups 3 and 4 fit the criteria for the M&S *F. idahoensis / Carex filifolia* habitat type. Although each of these community types fit the M&S habitat type description, they were named for the current dominant species, so that identification of additional degraded community types would be more intuitive for refuge personnel. If more than one community type was dominated by the same species then the new community types were named using the two dominant species (Table 7).

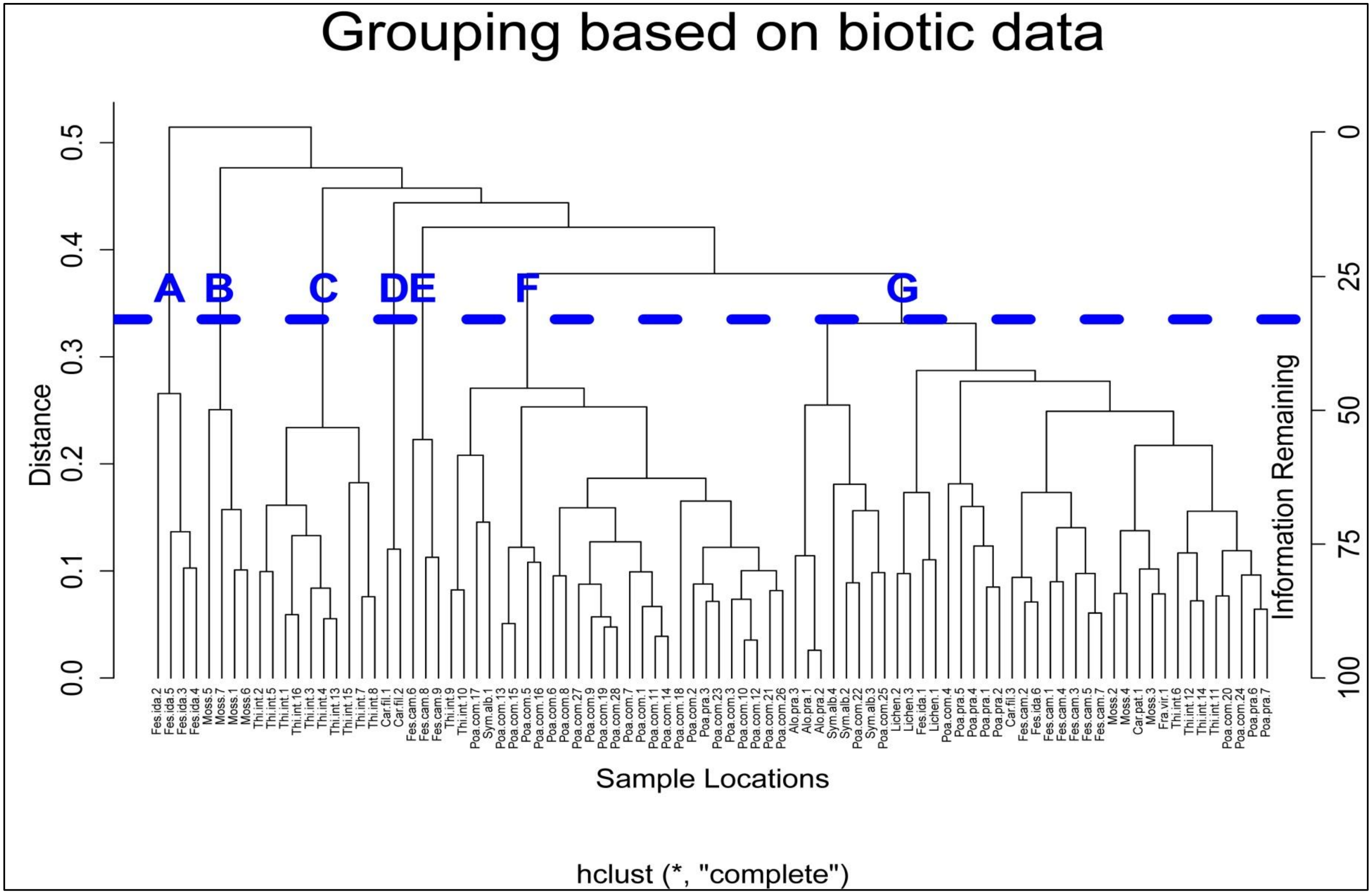

Figure 4. Dendrogram of sample locations at the LT-NWR grouped using biotic factors.
Dashed line identifies the pruning location and letters represent newly identified groups.

Table 7. New community types identified from dendrogram grouping of 2013 and 2014 field data. Dendrogram group number, M & S habitat type, and dominant vegetation are listed.

New community name	**M & S habitat type**	**Two dominant species**
Fes.ida	*F. campestris / F. idahoensis*	*F. idahoensis; F. campestris*
Moss	*F. campestris / F. idahoensis*	*Moss; F. idahoensis*
Thi.int	*F. idahoensis / C. filifolia*	*T. intermedium; F. idahoensis*
Car.fil	*F. idahoensis / C. filifolia*	*C. filifolia; F. idahoensis*
Fes.cam	*F. campestris / F. idahoensis*	*F. campestris; F idahoensis*
Poa.com/Thi.int	*F. campestris / F. idahoensis*	*P. compressa; T. intermedium*
Poa.com/Fes.cam	*F. campestris / F. idahoensis*	*P. compressa; F. campestris*

Soil Analysis

To determine if any of the vegetation community types (original and new) had an affinity for a specific soil, the NRCS soil type identified at each sample location was compared to the other sample locations in that community type. Over half of the sample locations in the original community types were found on the Loamy soil type (Table 10). However, the "Overgrazed" and "*Pentaphylloides floribunda*" community types were the only original community types where all five sample locations were found on the same soil type.

Comparisons of the new community types to the soil type was not possible as group 5, *F. campestris,* was the only new community type where the soil type was the same at all sample locations; however, it only consists of three sample locations (Table 10). Notably though, all seven of the new community types had at least one sample location that occurred on this same loamy soil. Each of the other six community types contained sample locations on various other soil types so the new community types could not be associated with a single soil type.

Once the new community types were identified, an NMDS ordination was plotted with the new community types as points and the abiotic variables plotted as vectors (arrows) in this same space. The arrows point in the direction of the increasing gradient change and the length is proportional to the strength of the gradient (Oksanen, 2007).

The abiotic environmental factors used to create the vectors in the NMDS ordination plot (Figure 5) were elevation, litter depth, % litter and % bare ground (Table 8). The position of the new communities in relation to the abiotic vectors indicates the relationship between these factors and the community composition. Litter depth is the only abiotic variable that had a statistically significant influence on the occurrence of community types in the NMDS ordination (p = 0.03) (Table 9). Furthermore, litter depth accounted for over 80% of the community type existence.

Table 8. Abiotic factors used in NMDS ordination plot to test for community type association

New Community Type Name	**Percent litter cover**	**Percent bare ground**	**Litter depth (cm)**	**Average elevation (m)**
F. idahoensis	40%	2%	3.6	1,131
Moss	33%	1%	3.7	1,084
T. intermedium	42%	1%	4.9	1,076
C. filifolia	36%	4%	3.6	1,086
F. campestris	39%	5%	2.5	1,101
P. compressa / T. intermedium	52%	2%	4.9	1,083
P. compressa / F. campestris	44%	6%	4.1	1,087

Table 9. Statistical results for NMDS ordination

	NMDS1	NMDS2	R^2	P value
Litter	0.99	0.15	0.37	0.39
Bare Ground	-0.95	-0.32	0.30	0.47
Litter Depth	0.97	-0.25	0.86	0.03
Elevation	-0.99	0.094	0.50	0.26

Table 10. Relationships of soil types and plant community types found during field sampling at LT-NRW Marion, MT.

NRCS soil type	Number of locations for each soil type	Original community types found in that soil type; see table 1 for names	New community types found in that soil type
Droughty	3	Bt.3; Ppr.2	Poa.com/Thi.int; Poa.com/Fes.cam
Droughty Steep	1	Af.1	Thi.int;
Gravelly	5	O.1; O.2; O.3; O.4; O.5	Thi.int; Poa.com/Thi.int;
Limy	3	Ec.1; Ec.2; Pss.2	Poa.com/Thi.int;
Loamy	46	Ec.3; Ec.4; Ec.6; Fc.1; Fc.2; Fc.3; Fc.5; Fc.7; Fc.8; Fi.1; Fi.2; Fi.2.1; Fi.2.2; Fi.3; Fi.4; Fi.4.3; Fi.4.4; Fi.5; Kp.1; Kp.2; Kp.3; Kp.4; Kp.5; Pp.4; Ppr.4; Ppr.5; Pss.1; Pss.4; Pss.5; Sal.1; Sal.2; Sal.3; Sal.4; Sal.5; Sr.1; Sr.2; Sr.3; Sr.4; Sr.5;Ssp.2; Ssp.5; U.1; U.2; U.3; U.4; U.5	Fes.ida; Moss; Thi.int; Car.fil; Fes.cam; Poa.com/Thi.int; Poa.com/Fes.cam
Loamy Argillic	3	Pss.3; Ssp.3; Ps.1;	Thi.int; Poa.com/Fes.cam
Overflow	6	Pf.1; Pf.2; Pf.3; Pf.4; Pf.5; Pp.2	Poa.com/Thi.int; Poa.com/Fes.cam
Rubbly	1	Fc.4	Poa.com/Fes.cam
Shallow Droughty	9	Af.2; Af.3; Af.4; Af.5; Bt.2; Bt.4; Fi.4.1; Fi.6; Ps.4	Fes.ida; Moss; Car.fil Poa.com/Fes.cam
Subirrigated	1	Ssp.4	Poa.com/Fes.cam
Thin Loamy	3	Ppr.1; Ps.2; Ps.3	Poa.com/Thi.int; Poa.com/Fes.cam
Thin Sandy	1	Ec.5	Poa.com/Fes.cam
Very Shallow	3	Bt.1; Bt.5; Ppr.3	Thi.int; Poa.com/Thi.int; Poa.com/Fes.cam
Wet Meadow	3	Fc.6; Pp.1; Pp.5	Poa.com/Thi.int; Poa.com/Fes.cam

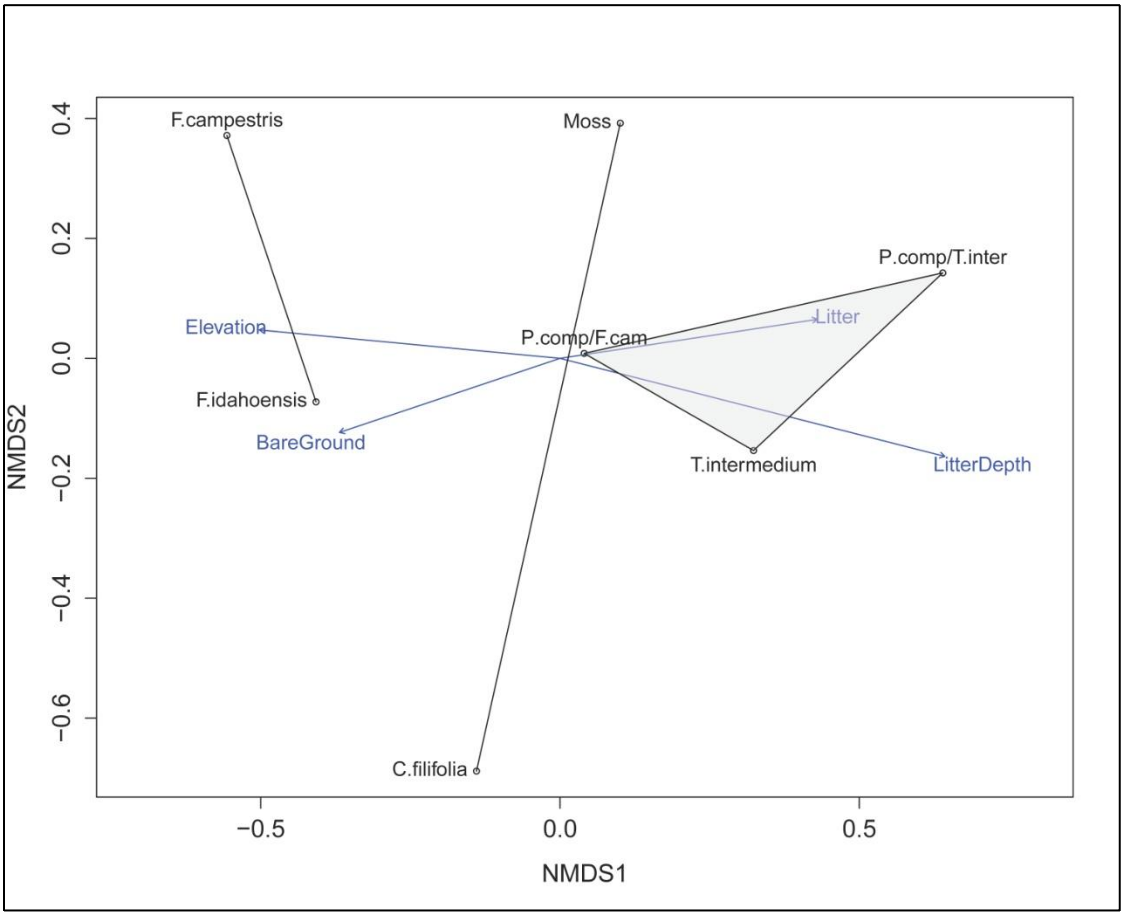

Figure 5. NMDS ordination plot showing relation of new community types to litter, litter depth, bare ground and elevation at the LT-NWR.

The NMDS ordination plot indicates that the *F. campestris* community type becomes more common with an increase in elevation, while the *F. idahoensis* community type develops at similar elevations but with an increase in bare ground. The *T. intermedium* community type is encountered more frequently as litter depth increases and the *P. compressa/T. intermedium* community type occurs as % litter and litter depth increase.

The NMDS analysis of the biotic data at each sample location has a stress level of 0.0795 and an R^2 value of 0.994 (Appendix A, Table 19). This stress level is considered to be a "great" representation of the data in reduced dimensions (i.e. a two-dimensional plot) (Oksanen, 2007) (Figure 5), and is a reliable estimate of the interaction between the abiotic and biotic factors.

The Bray-Curtis dissimilarity values for the biotic data show that the most degraded sites are at least 70% dissimilar from the climax dominated community types, while the three most degraded community types are more similar to each other (Table 11). Species area curves were plotted for each of the new community types based on the dissimilarity outcomes.

Table 11. Bray-Curtis dissimilarity values for the new vegetation community types at LT-NWR.

	F. campestris	*F. idahoensis*	*C. filifolia*	Moss	*P. com / F.cam*	*P. com / T. int*
F. idahoensis	0.47					
C. filifolia	0.73	0.61				
Moss	0.60	0.56	0.66			
P. com / F. cam	0.60	0.56	0.58	0.46		
P. com / T. int	0.74	0.71	0.76	0.61	0.39	
T. intermedium	0.62	0.57	0.58	0.40	0.40	0.52

The SACs show that three of the new community types were sampled adequately during the 2013/2014 surveys (Figure 6). As with the SACs for the original community types, a sample adequacy analysis was run on these new community types (Table 12). This analysis shows that five of the seven new community types were adequately sampled, with the remaining two community types needing only a single additional sample point to detect changes in the five most common species.

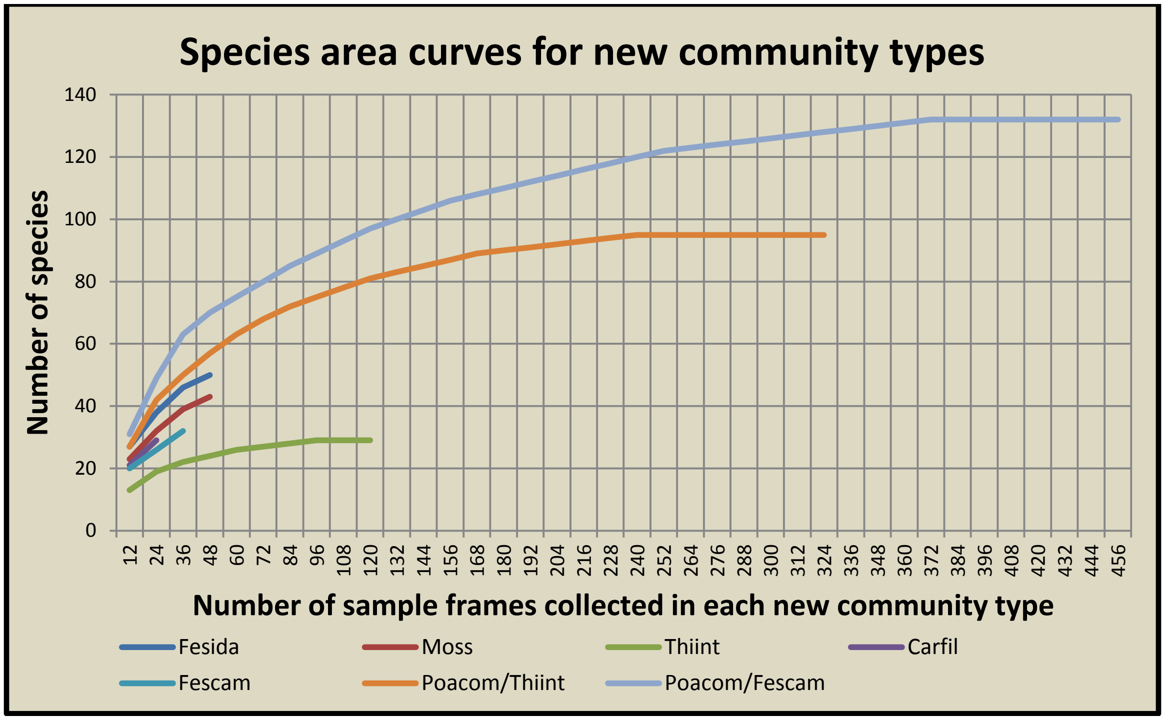

Figure 6. Species accumulation curves re-plotted for new community types identified in the 2013/2014 grassland survey at the LT-NWR.

Table 12. Sample adequacy analysis for the seven new LT-NWR community types using a 20% confidence interval.

Name	Number of frames sampled	Number of frames necessary for sample adequacy (p=0.2)	Standard deviation
Fes.cam	36	48	3.21
Fes.ida	48*	48	3.86
Car.fil	24*	24	2.83
Moss	48*	36	2.99
Thi.int	120	132	2.75
Poa.com/Fes.cam	324*	108	5.70
Poa.com/Thi.int	444*	180	6.45
* met USFWS standard of 20% change with 80% accuracy (P = 0.2).			

Successional Gradients

Successional gradients were derived by ranking (lowest to highest) litter depth, percent cover of *F. idahoensis, C. filifolia* and *F. campestris* (climax species) and the percent cover of non-native species present in each community type (Figure 7). Information gained from the NMDS and community composition analysis elevates confidence in the accuracy of these comparisons. These successional gradients were determined using the correlation and R^2 values.

Soil moisture increase (Daubenmire and M&S) →

Fes.ida **(22%)**	
F. idahoensis	22%
F. campestris	4%
C. filifolia	4%
Litter depth	1.4-cm

Fes.cam **(25%)**	
F. idahoensis	11%
F. campestris	25%
C. filifolia	4%
Litter depth	0.9-cm

Car.fil **(27%)**	
F. idahoensis	4%
F. campestris	2%
C. filifolia	27%
Litter depth	1.4-cm

Moss (23%)	
F. idahoensis	7%
F. campestris	3%
C. filifolia	1%
Litter depth	1.5-cm

Thi.int **(13%)**	
F. idahoensis	7%
F. campestris	2%
C. filifolia	1%
Litter depth	1.9-cm

Poa.com **(5%) /** ***Fes.cam*** **(4%)**	
F. idahoensis	2%
F. campestris	4%
C. filifolia	2%
Litter depth	1.6-cm

Poa.com **(16%) /** ***Thi.int*** **(3%)**	
F. idahoensis	2%
F. campestris	1%
C. filifolia	1%
Litter depth	1.9-cm

Note: percent value following community name is percent of that (those) species the community is named for

Figure 7. Successional gradient analysis from the most degraded community type to climax community types, based on a decrease in litter depth and an increase in climax species; gradients split using soil moisture.

Further support for this proposed gradient was generated from a correlation analysis using the total percent of climax species present and the litter depth (Figure 8), This calculation yielded an r = – 0.763 with an associated R^2 value of 0.58. As litter depth increases the cover of climax species declines (Figure 7). Equally important, another correlation analysis comparing the total percent of non-native species cover and litter depth in each community type produced an r of 0.904, the associated R^2 value is 0.82. The use of litter depth to order community types into an apparent successional pathway is justified by the high level of composition variance (82%) this measure explains.

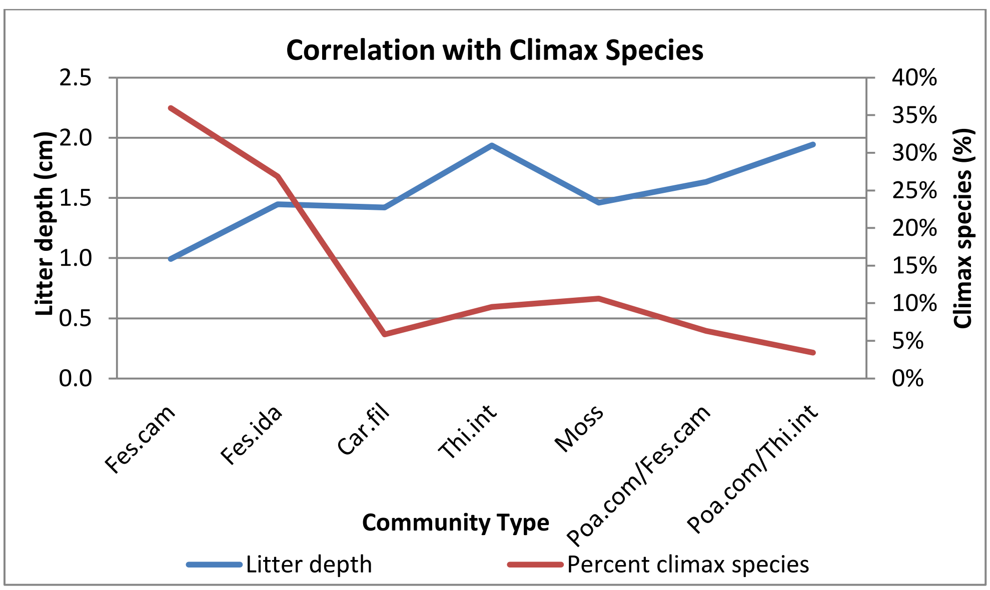

Figure 8.Correlation with grassland climax species at LT-NWR; correlation value (r = –0.763).

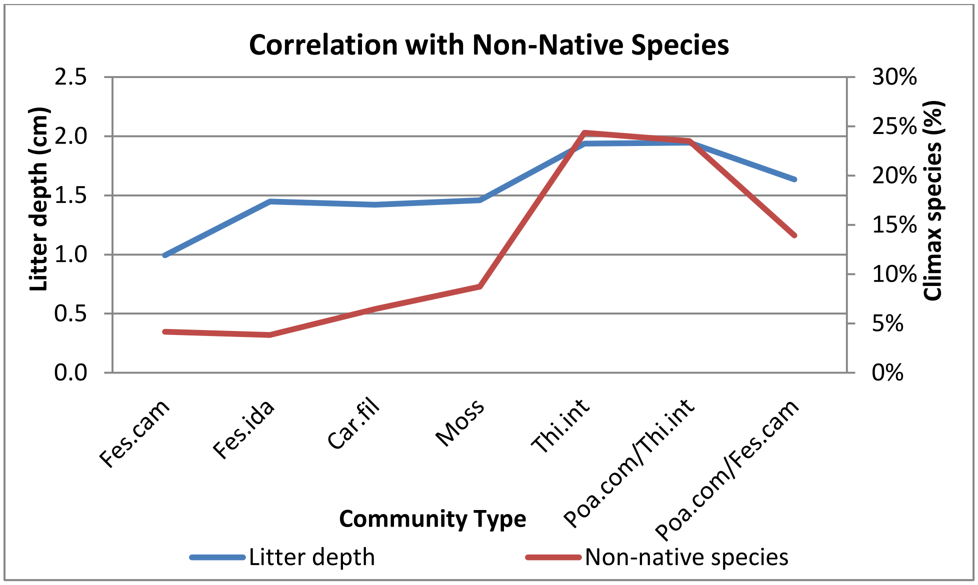

Figure 9. Correlation with non-native grassland species at LT-NWR; correlation value (r = 0.904).

Finally, species composition of each of the new community types was compared to the NRCS ecological site description for this Northwestern Montana [missing text?]. The *F. campestris* and *F. idahoensis* community types compare well to the NRCS described potential climax communities for loamy soils (Table 13). The percent cover values for the *F. campestris* and *F. idahoensis* community types was determined by dividing the summed percent cover of cool season bunchgrasses and rhizomatous grass / grasslike by the total percent cover, rather than adding the percent cover for each species as was the case in Figure 7 above.

Table 13. NRCS ESD identified climax composition on loamy soils and composition of *F. campestris* and *F. idahoensis* community types at LT-NWR.

	C_3 bunchgrass	Rhizomatous grass /grasslike	Forbs	Shrubs
NRCS climax communities	75%	10%	10%	5%
F. campestris	75%	10%	10%	5%
F. idahoensis	27%	4%	0.01%	0%

DISCUSSION

As part of their Palouse Prairie recovery effort, USFWS managers want to be able to predict vegetational changes following the release of grazing pressure in the LT-NWR. To quantify the level of departure from the potential historic reference condition, the vegetation communities were sampled and compared to the accepted Daubenmire (1970) description of the various Palouse Prairie habitat types. Daubenmire (1970) described three climax vegetation habitat types within the Palouse Prairie:

1. The bluebunch wheatgrass / Idaho fescue (*P. spicata / F. idahoensis*) habitat type is dominated by these grasses, with *P. secunda* being the third most common grass. This habitat type contains few shrubs and perennial forbs.
2. The Idaho fescue / common snowberry (*F. idahoensis / S. albus*) habitat type forms a dense herbaceous layer containing *F. idahoensis* with dwarf specimens of *S. albus, Artemesia, Eriogonum, Chrysothamnus* and *Purshia. P. pratensis* increases in this habitat type with heavy grazing pressure. In moist areas, *Koeleria pyramidata* occurs with a variety of perennial forbs.
3. The Idaho fescue / Nootka rose (*F. idahoensis / R. nutkana*) habitat type is a meadow-like community differing from the *F. idahoensis / S. albus* habitat type by the lack of *S. albus*, due to lower levels of moisture.

Generally, the same assemblage of grasses and forbs is common to all Palouse Prairie; instead it is the shrub component that varies enough to separate the habitat types (Daubenmire, 1970).

Given the historic use of the refuge, followed by 15 years of no livestock grazing, the current composition of some of the sampled vegetation communities should have met the criteria for Palouse Prairie. Enough representative vegetation samples were collected from some of the identified community types to determine whether, with proper land management, the degraded community types had made the transition back to a species composition similar to those described for any of the three Palouse Prairie habitat types. However, with the conspicuous lack of *P. spicata* and the abundance of *F. campestris,* the community types found at LT-NWR appear to fit Moss' (1943) description of Fescue Grasslands, rather than Daubenmire's Palouse Prairie description.

Original Community Types

The use of SACs to determine sample adequacy seems to provide more reliable results than the use of sample adequacy calculations, even though both were derived using presence-absence data. Sample adequacy calculations are subjected to a high degree of variation in the standard deviation, which is caused by a large difference in the number of species detected in each of the sample frames. For example, the original *F. campestris* community type was sampled adequately according to the SAC, however sample adequacy analysis indicated it needed to be sampled at two more locations to achieve sample adequacy. This is because the SAC is based on the presence of additional species collected with each additional sample frame collected, while the sample adequacy analysis uses the standard deviation of the differences in number of species collected in each frame to determine the minimum number of frames necessary to achieve a predetermined accuracy. *F. campestris* had a maximum of 15 species detected and a minimum of 2 species detected in the 32 frames collected. The reverse is also true; the new *C. filifolia* community type had a low standard deviation, therefore the sample adequacy analysis showed that it had been sampled adequately, however the SAC indicated that two sample locations were not sufficient for adequate sampling.

Using the SACs the *F. campestris* and *F. idahoensis* communities required four and six additional locations respectively, as both continued to acquire additional species as more frames were sampled. Both of these communities have (1) litter depths at least 0.6-cm less than the average of the other community types (4.1-cm and 3.8-cm respectively vs. average of 4.7-cm); (2) nearly twice the average percent cover of native species (41% and 43% respectively vs. 25% average) and (3) about half the average percent cover of non-native species (14% and 12% respectively vs. 25% average). This may be partly due to the physical location of these communities, as both are at higher elevations and on steeper slopes than the other communities. The elevation at sample locations ranged from 1,066 to 1,219, with the overall elevation difference between all points of 153-m. The *F. campestris* and *F. idahoensis* communities were located on slopes varying from 10° to 20°, making them impractical to convert to improved pastures. Therefore, it is likely that these two communities are more representative of undisturbed states than the other community types that were either heavily grazed or re-seeded for higher forage production. Using these analyses, new mapping needs to be developed to provide a more accurate representation of the existing community types.

The community types identified in the original mapping are not be sufficient to guide recovery because these map units show that native bunchgrasses dominate much of the refuge. Updated GIS mapping using the information gleaned from the collected data will provide the USFWS with a better representation of the existing altered Northern Fescue Grasslands. This map will also show where the most degraded community types exist, and will provide information about where initial restoration efforts need to be focused.

New Community Types

Using the NRCS ecological site descriptions for loamy soil type, I identified several community types that may represent the potential climax grassland vegetation at most locations within the LT-NWR. Compositional data from the existing *F. campestris* and *F. idahoensis* community types are similar to the NRCS described potential climax community found on loamy soils. However, no relationship was found between the soil type and its respective vegetation community, because six of the seven new community types had points that were found on different soil types, suggesting that historic pasture improvement projects play a larger role in current vegetation composition than does soil type. This led to renaming the new community types for the current dominant vegetation species rather than the potential climax species, which will aid efforts to monitor future successional change in each community type.

Many of the abiotic variables collected were not used in the analysis of community composition for two reasons. First, two of the variables, bare ground and rock, were not recorded at more than 5% of the sample locations, and second, the resolution of the GIS data, e.g., the MAP and MAT, was not at a fine enough scale to indicate differences at the various sample locations. Slope and aspect were also removed from the analysis because random selection of survey locations produced a very small number of points that were located on steep slopes or north-facing aspects; only five sites occurred at locations with >5% slope and only a single point occurred on a north-facing slope.

Dissimilarity analysis showed that the *Poa.com/Thi.int* community type was the most different from the *F. campestris, F. idahoensis*, and *C. filifolia* community types. Correlation further indicates that the composition of each community type is strongly associated with the depth of the litter. Community types with a higher percent cover of non-native species have a higher litter depth and community types with a lower percent cover of non-native species have a lower litter depth. Eighty-one percent of the variation in community composition is explained by litter depth. In combination, the outcomes justify arrangement of the new communities in successional gradients from the most altered to representative grassland (Figure 7). This graphic is split into two “arms” based on soil moisture. The climax species, *F. idahoensis* and *C. filifolia,* prefer drier sites than *F. campestris.* This is consistent with both Moss’ (1943) and Coupland and Brayshaw’s(1953) description of the Northern Fescue Grasslands.

Northern Fescue Grasslands

The composition of the new community types at LT-NWR were compared to the description of the Palouse Prairie. The *F. idahoensis* and *C. filifolia* community types are the only community types that fit the description of Palouse Prairie. However, all seven of the new community types fit into two M&S habitat type descriptions and both of these M&S habitat types resemble the narrative for the larger Northern Fescue Grasslands.

The Northern Fescue Grassland community is composed of two dominant species, *F. campestris* and *F. idahoensis*, which are allied with subdominant grass and grass-like species including: *Agropyron subsecundum, A. trachycaulum, Danthonia intermedia, F. idahoensis, Helictotrichon hookeri, K. pyramidata, Muhlenbergia richardsonis, Stipa spartea* and *Carex* spp. The forb component includes: *Cerastium arvense, Achillea millefolium, Galium boreale*, and *Anemone patens,* while the shrub, *Pentaphylloides floribunda*, is characteristic of moister sites (Coupland and Brayshaw, 1953). *Festuca campestris* is the more common of the two dominant species in three of the seven new community types at LT-NWR, and one of the top five dominants in the other four community types. *Festuca idahoensis* was one of the top two dominant species in five of the seven community types and in the top five dominant species in the other two community types. *Danthonia intermedia, F. idahoensis, K. pyramidata, Carex spp., A. millefolium, G. boreale* and *P. floribunda* were all recorded in the community types at LT-NWR and are identified as subdominant components of the Northern Fescue Grassland community types. The Northern Fescue Grassland shares species, *F. idahoensis, S. columbiana, A. spicatum, Geranium viscosissimum, Lithospermum ruderale*, and *Balsamorrhiza sagittata* with the Palouse Prairie (Moss, 1943). The dominance of *F. campestris* and lack of *P. spicata* distinguish the Northern Fescue Grasslands from the Palouse Prairie.

In addition to looking at native status, an attempt was made to classify the species present in each of the community types by their seral status (climax, late-seral, mid-seral, early-seral or pioneer) to further refine the successional gradients model. However, after a thorough search, successional status on seven of the sixteen identified species (44%) was unavailable (four natives and three non-natives). An expanded effort was made to gather this same information for all 161 species identified at LT-NWR, but was only available for 57 (35%) of the 161 species (Table 14). It should be noted that, in spite of the limited information, the climax communities contained a higher percent of listed late-seral and climax species than the more altered sites.

Recovery of Degraded and Altered Community Types

Sheley et al. (2006) described three requirements for successional change: site availability (caused by disturbance), species availability (from seedbank or re-seeding) and species performance. To facilitate recovery of the altered community types at the LT-NWR, two important successional steps must occur. First, site availability is limited in the grassland community types because of the thick litter layer. The second successional step is species availability. The present level of native climax species in the altered community types on the refuge may not provide enough seed to allow the native grasses to recover in a reasonable time frame. The length of time since disturbance has probably reduced the vitality of any native bunchgrass seeds that had existed in the soil seed bank. Furthermore, *F. campestris* germination drops to <50% after approximately 30 months (Romo, 1996); *F. idahoensis* germination drops from >80% at 3 months to <60% after 12 months (Goodwin et al. 1995). The initial germination rate of *C. filifolia* is low (33%) and scarification appears to lower the rate of germination; seedling survival after two years is very low (0.94%) (Hauser, 2006). The depth of the existing litter bed and lack of existing viable seed will inhibit natural recovery.

Native bunchgrasses do not produce a large quantity of easily distributed viable seed, which limits their ability to quickly occupy newly disturbed sites, or successfully compete with many of the introduced rhizomatous grasses. Without additional land management actions, the introduced grasses, especially *T. intermedium, P. compressa* and *P. pratensis* may be able to invade the unaltered sites because of the thick layer of litter produced each year by these three species. The buildup of litter will inhibit the growth of annual forbs, decreasing diversity, as well as allowing the introduced grasses to outcompete the native bunchgrasses by utilizing resources made available through the elimination of the native forbs.

SUMMARY

Both biotic and abiotic data were collected from 88 sample locations in 16 previously identified community types to provide baseline data for current community composition. There are several findings available from this effort.

- Nine of the 88 sample locations were named correctly (Appendix, Table 16), all of which were in the original *F. campestris* and *F. idahoensis* community types. This means that the USFWS will not need to recover these locations. However, they will need consistent monitoring to ensure that any nearby stands of introduced grasses do not begin to overtake these communities.
- A minimum of 2 to 15 sample locations (24 to 180 sample frames) should be monitored in representative stands of each new community type to detect a ≥20% change in the five most common species with at accuracy of at least 80%. This number will likely change as the communities transition to native dominated communities.
- To facilitate direct comparison with this baseline survey a set of monitoring protocols is outlined in Table 20 (Appendix A).
- Litter depth is the only significant abiotic variable ($p = 0.03$) effecting community composition. It is strongly correlated with the presence of non-native species ($r = 0.904$) and negatively correlated with the presence of three climax species ($r = 0.763$).
- The same community type occurred on many different soil types, because both the soils and the community types were anthropogenically disturbed. Historic use and

disturbance regimes play a significant role in the dominance of non-native species (Hanson et al. 2008).

- The study also provides a baseline measure of the current community composition, which will allow for accurate monitoring and assessment of any additional land-management decisions. Site names and GPS locations of surveyed points can be found in Appendix A, Table 21.
- The vegetation communities at LT-NWR better fit the description for Northern Fescue Grassland communities (Appendix, Table 18) than Palouse Prairie, due to the amount of *F. campestris* and the noticeable lack of *P. spicata*. Table 15 describes the reference community for recovery efforts.
- Potential successional gradients, following the release of grazing pressure, were determined, starting from the most disturbed to the most likely climax vegetation communities. These potential pathways can be used to determine progress towards the reference community types.
- The presence of non-native species in all community types needs to be regularly monitored to evaluate changes that result from implemented recovery actions. The *Poa. com / Fes. cam, Poa. com / Thi. int* and *Thi. int* community types should be sampled every three years; the Moss community type should be sampled every four years, and the *Car. fil, Fes. ida.* and *Fes. cam* community types should be sampled every five years. This sampling time-frame will allow enough time for the community types to change, but will still be a short enough interval to allow the managers to correct any counterproductive land management actions.

SUGGESTIONS FOR FUTURE MANAGEMENT

The overriding long-term goal of the USFWS comprehensive conservation plan is to restore native ecosystems. In order for the USFWS to accomplish this goal on the altered grasslands at the LT-NWR, additional land management decisions need to be put into action. Many of these communities are currently dominated by introduced pasture grasses, which have developed into monotypic stands that will remain unchanged without control by fire, grazing or mechanical interventions (e.g., mowing and raking or selective weeding). The persistence of the mm stands is due, in part, to litter accumulation.

The thick layer of non-native grass litter in many of the community types is inhibiting the recovery of native species by shading the soil, which reduces soil temperature, subsequently reducing native seed germination. MacDougall and Turkington (2007) found that the present-day dominance by non-native grasses is more a function of the long-term absence of burning than the uniqueness of their traits or competitive ability. Therefore, to reduce the amount of non-native grasses and subsequent litter layer, two well-understood “disturbance” techniques can be used. Managers may want to use a combination of adaptive management and small-scale trials to evaluate how the vegetation communities at LT-NWR will respond to each of these disturbance techniques. It is likely that there are few viable seeds remaining in the seedbank, and very few of the disturbed community types have an adequate density of native bunchgrasses to provide seed for reestablishment, so treated areas will have to be re-seeded to accelerate recovery.

Short-term grazing (targeted impact, low risk); Livestock, particularly cattle, brought in from the neighboring ranches and allowed to graze in high numbers (1 to 2 head / acre) for a short duration (8 to 10 days) in temporary pastures will aid in the breakdown and subsequent decomposition of the litter layer. A combination of cattle, goats and sheep should be used in locations where shrubs and trees have began to encroach on the grasslands, as the goats and sheep will effectively browse these species, while the cattle will provide the area with heavier hoof action to break up the litter. Cattle will need to be grazed twice prior to reseeding. Prior to the third grazing, the treatment area should be broadcast seeded with *F. campestris, F. idahoensis*, and *Stipa columbiana* at a rate of 10-12 lbs of live seed per acre.

Prescribed fire (broad impact, moderate risk); An increase in the natural disturbance regime (fire) will promote the growth of native species, and, depending on timing of disturbance, the reduction of non-native grasses. Burning small patches (100 to 200 acres/year) effectively reduces the amount of non-native grasses, especially if they are burned in mid-summer prior to seed set (MacDougall and Turkington, 2007). Decreasing the depth of the existing litter bed through the use of fire could help the transition from non-native- to native-dominated communities. Burning the litter during mid-summer prior to seed-set of introduced grass will allow the native species to have a competitive advantage over the non-native species. Native grazers generally tend to graze closer to field edges and in transition areas rather than in the center of open fields, so burning patches of 100 to 200 acres will reduce the impact that these native grazers have on a recovering burned area. Burn treatments >20 acres provide the native plant species a greater chance of survival, thereby increasing the habitat value to both the native grazers and upland nesting bird species. Burned areas should be broadcast seeded with *F. campestris, F. idahoensis*, and *Stipa columbiana* at a rate of 10-12 lbs of live seed per acre within two weeks of the burn.

Several authors found that mowing and raking and selective weeding was as effective as burning in reducing the amount of non-native grasses, indicating that biomass removal is an important factor for restoring degraded grasslands (Galvánek and Lepš, 2012; MacDougall and Turkington, 2007). Mowing and raking or selective weeding are **not recommended** for this location due to the size of the area and the fact that many of the community types have soils that are saturated until August (Wiley, personal communication). Regardless of method used or level of reseeding needed, the reduction of litter will allow native forbs and grasses to grow, increasing the habitat availability for native wildlife species.

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APPENDIX A

SUPPLEMENTAL DATA

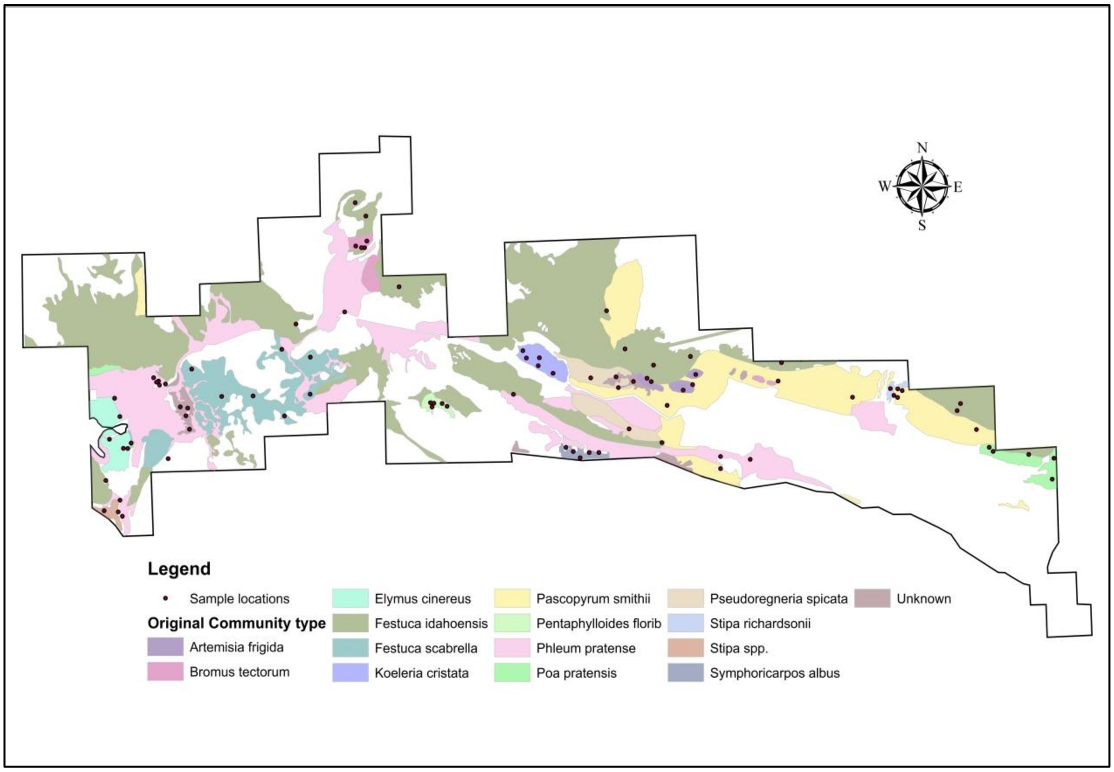

Figure 10. Random sample locations in original vegetation community types at LT-NWR.

Table 14. Scientific and Common name and Lifeform of species identified at LT-NWR

Scientific Name	Common Name	Native (N) / Non-native species (NNS)	Successional status (Pioneer, early, mid, late, climax)
Achillea millefolium	Common Yarrow	N	Pioneer
Agrostis gigantea	Redtop	NNS	Pioneer
Agoseris glauca	False dandelion	N	Unknown
Agropyron cristatum	Crested wheatgrass	NNS	Unknown
Agropyron dasystachyum	Thickspike wheatgrass	N	All
Agropyron elongatum	Tall Wheatgrass	NNS	Unknown
Agropyron repens	Quackgrass	NNS	Early
Agropyron spp.	--	N	Unknown
Agropyron trachycaulum	Slender wheatgrass	N	Pioneer
Agrostis scabra	Rough bentgrass	N	Pioneer
Agrostis stolonifera	Creeping bentgrass	NNS	Pioneer
Allium spp.	--	N	Pioneer
Alopercurus pratensis	Meadow foxtail	NNS	Unknown
Alnus incana	Gray alder	N	Unknown
Amelanchier alnifolia	Saskatoon serviceberry	N	Unknown
Anemone multifida	Pacific anemone	N	Unknown
Annual brome	--	NNS	Unknown
Antennaria rosea	Rosy pussytoes	N	All
Arctostaphyllis uva-ursi	Bearberry	N	Unknown
Arenaria congesta	Ballhead Sandwort	N	Unknown
Artemisia frigida	Prairie sagewort	N	Unknown
Artemisia tridentata	Big sagebrush	N	Climax
Aster ericoides	Heath aster	N	Unknown
Aster spp.	--	N	Unknown
Astragalus alpinus	Alpine milkvetch	N	Pioneer/Early
Astragalus spp.	--	N	Unknown
Hackelia floribunda	Manyflower stickseed	N	Unknown
Bouteloua gracilis	Blue grama	N	Late - Climax
Bromus carinatus	Mountain brome	N	Pioneer/Late
Bromus inermis	Smooth brome	NNS	Pioneer
Bromus tectorum	Cheatgrass	NNS	Pioneer/Climax
Calamagrostis rubescens	Pinegrass	N	All
Calamovilfa longifolia	Prairie sandreed	N	All
Camassia quamash	Camas	N	Pioneer/Early
Carex douglasii	Douglas' sedge	N	Unknown
Carex filifolia	Threadleaf sedge	N	Late
Carex multicostata	Manyrib sedge	N	Unknown
Carex praticola	Meadow sedge	N	Unknown
Carex scirpoidea	Northern singlespike sedge	N	Unknown
Carex ulticulata	Beaked sedge	N	Pioneer
Centaurea maculosa	Spotted Knapweed	NNS	Pioneer
Chamerion angustifolium	Fireweed	N	Pioneer

Table 14.(Continued) Scientific and Common name and Lifeform of species identified at LT-NWR

Scientific Name	**Common Name**	**Native (N) / Non-native species (NNS)**	**Successional status (Pioneer, early, mid, late, climax)**
Chrysothamnus viscidiflourus	Rabbitbrush	N	Unknown
Cirsium arvense	Canada thistle	NNS	Early
Cirsium undulatum	Wavyleaf thistle	N	Unknown
Collomia linearis	Tiny trumpet	N	Unknown
Comandra pallida	Bastard toadflax	N	Unknown
Crepis capillaris	Smooth hawksbeard	N	Unknown
Crepis spp.	--	N	Unknown
Cryptantha spp.	--	N	Unknown
Cynoglossum officinale	Gypsyflower	NNS	Unknown
Danthonia unispicatum	Onespike danthonia	N	Unknown
Delphinium bicolor	Little Larkspur	N	Unknown
Distichlis spicata	Inland saltgrass	N	Early-Climax
Dodecatheon pulchellum	Darkthroat shootingstar	N	Unknown
Draba spp.	--	N	Unknown
Eleocharis spp.	--	N	Unknown
Elymus glaucus	Blue wildrye	N	Early
Equisetum arvense	Field horsetail	N	All
Equiseitum hymale	Scouringrush horsetail	N	Unknown
Erigeron glabellus	Streamside fleabane	N	Unknown
Erigeron spp.	--	N	Unknown
Eriogonum umbellatum	Sulphurflower buckwheat	N	Unknown
Festuca campestris	Rough Fescue	N	Early-Climax
Festuca idahoensis	Idaho Fescue	N	Climax
Fragaria spp.	--	N	Unknown
Fragaria virginiana	Virginia strawberry	N	Unknown
Fritillaria pudica	Yellow fritillary	N	Unknown
Galium boreale	Northern Bedstraw	N	Early-Late
Galium spp.	--	N	Unknown
Gaura coccinea	Scarlet beeblossom	N	Unknown
Geranium richardsonii	Richards crane's-bill	N	Unknown
Geum triflorum	Prairie-smoke	N	Early
Machaeranthera pinnatifida	Lacy tansyaster	N	Unknown
Hedysarum occidentale	Western sweetvetch	N	Unknown
Hesperostipa comata	Needle-and-thread	N	Early
Heterotheca villosa	Hairy false goldenaster	N	Unknown
Hordeum brachyantherum	Meadow barley	N	Unknown
Hordeum jubatum	Foxtail barley	N	Pioneer
Juncus balticus	Baltic Rush	N	All
Juncus spp.	--	N	Unknown
Koeleria pyramidata	Prairie June Grass	N	Mid-Climax
Lathyrus latifolius	Perennial pea	N	Unknown
Lepidium densiflorum	Common pepperweed	BOTH (USDA)	Unknown

Table 14. (Continued) Scientific and Common name and Lifeform of species identified at LT-NWR

Scientific Name	**Common Name**	**Native (N) / Non-native species (NNS)**	**Successional status (Pioneer, early, mid, late, climax)**
Lepidium perfoliatum	Clasping pepperweed	NNS	Unknown
Lemna minor	Common duckweed	N	Unknown
Leymus cinereus	Basin wildrye	N	Early/Climax
Lichen spp.	Lichen	N	Unknown
Lithospermum ruderale	Western stoneweed	N	Unknown
Lomatium macrocarpum	Bigseed biscuitroot	N	Unknown
Lomatium spp.	--	N	Unknown
Lomatium triternatum	Nineleaf biscuitroot	N	Unknown
Lupinus caudatus	Tailcup lupine	N	Early-Climax
Mahonia repens	Creeping barberry	N	Unknown
Maianthemum stellatum	Starry false lily of the valley	N	Mid
Medicago hispida	Burclover	NNS	Unknown
Mentha arvensis	Wild mint	N	Unknown
Moss	Moss	N	Unknown
Muhlenbergia cuspidata	Plains Muhly	N	Unknown
Nassella viridula	Green needlegrass	N	Unknown
Orthocarpus luteus	Yellow owl's clover	N	Unknown
Pachistima myrsinites	Myrtle boxwood	N	Climax
Pascopyrum smithii	Western wheatgrass	N	All
Penstemon procerus	littleflower penstemon	N	Unknown
Pentaphylloides floribunda	Shrubby cinquefoil	N	Unknown
Petasites frigidus	Arctic sweet coltsfoot	N	Unknown
Phacelia linearis	Threadleaf phacelia	N	Unknown
Phalaris arundinacea	Reed canary grass	NNS	Early-Late
Phleum pratense	Timothy hay	NNS	Early/Mid
Pinus contorta	Lodgepole pine	N	Pioneer
Pinus ponderosa	Ponderosa pine	N	Pioneer
Poa ampla	Big bluegrass	N	Unknown
Poa Compressa	Canada bluegrass	NNS	Early
Poa nevadensis	Nevada bluegrass	N	Unknown
Poa palustris	Fowl bluegrass	NNS	Unknown
Poa pratensis	Kentucky bluegrass	NNS	Climax
Poa secunda	Sandberg bluegrass	N	Unknown
Populus tremuloides	Quaking aspen	N	Pioneer/Early
Potentilla anserina	Silver cinquefoil	N	Unknown
Potentilla gracilis	Northwest cinquefoil	N	Unknown
Potentilla recta	Sulphur cinquefoil	NNS	Early
Pseudotsuga menziesii	Douglas-fir	N	Climax
Pseudoroegneria spicata	Bluebunch wheatgrass	N	Pioneer/Climax
Puccinellia nuttalliana	Nuttall's alkali-grass	N	Unknown
Ranunculus spp.	--	N	Unknown
Rhamnus spp.	--	N	Unknown

Table 14. (Continued) Scientific and Common name and Lifeform of species identified at LT-NWR

Scientific Name	**Common Name**	**Native (N) / Non-native species (NNS)**	**Successional status (Pioneer, early, mid, late, climax)**
Ribes cereum	Wax currant	N	Early/Mid
Ribes spp.	--	N	Unknown
Rosa woodsii	Wood's rose	N	All
Rudbeckia triloba	Browneyed susan	N	Unknown
Salix brachycarpa	Shortfruit willow	N	Pioneer/Early
Scirpus acutus	Hard-stem Bulrush	N	Unknown
Scirpus spp.	--	N	Unknown
Selaginella densa	Lesser Spikemoss	N	Climax
Senecio spp.	--	N	Unknown
Silene spp.	--	N	Unknown
Solidago missouriensis	Missouri goldenrod	N	Pioneer-Mid
Spartina gracilis	Alkali cordgrass	N	Unknown
Sporobolus airoides	Alkali sacaton	N	Pioneer/Early
Stellaria longipes	Longstalk Starwort	N	Unknown
Stipa coloumbiana	Columbia needlegrass	N	Unknown
Stipa occidentalis	Western needlegrass	N	Climax
Stipa richardsonii	Richardson's needlegrass	N	Unknown
Suaeda intermedia	Mojave seablite	N	Unknown
Symphoricarpos albus	Common Snowberry	N	Early-Climax
Taraxacum officinale	Common dandelion	NNS	Unknown
Thalictrum occidentale	Western Meadowrue	N	Unknown
Thinopyrum intermedium	Intermediate wheatgrass	NNS	Unknown
Tofieldia glutinosa	sticky tofieldia	N	Unknown
Tradescantia spp.	--	N	Unknown
Tragopogon dubius	Yellow salsify	NNS	Unknown
Trifolium pratense	Red clover	NNS	Unknown
Trifolium repens	White clover	NNS	Unknown
Unknown annual forb	--	--	Unknown
Unknown perennial forb	--	N	Unknown
Unknown annual grass	--	NNS	Unknown
Viola spp.	--	N	Unknown
Vicia americana	American vetch	N	Unknown
Vulpia octifloria	Sixweeks fescue	N	All
Zigadenus venenosus	Meadow death-camas	N	Unknown

Table 15. Mueggler and Stewart habitat type descriptions*

M&S habitat type*	**Vegetative composition**
F. Idaho/C. filifolia	The absence of *Agropyron* and the constant association and abundance of *Carex filifolia*, *Danthonia intermedia, Geum triflorum* and *Gentiana affines* with *Festuca idahoensis* delineate this type from others within the *Festuca idahoensis* series. *Agropyron caninum* and *Carex petasata* are other constant graminoids; *Carex rupestris* occasionally forms a substantial part of the community. Other constant forbs include *Achillea millefolium, Agoseris glauca, Antennaria rosea, Arenaria congesta, Cerasitum arvense, Polygonum bistortoides,* and *Potentilla* spp. Shrubs are virtually nonexistent in this type.
F. campestris/F. idahoensis	Despite the great mixture of species within the FESC/FEID h.t., the vegetation is usually dominated by the two fescues, *Festuca scabrella* and *Festuca idahoensis*. In contrast to the FESC/AGSP h.t., *Agropyron spicatum* and shrubs are less conspicuous and may be absent; canopy cover of *Festuca scabrella* tends to be greater; and *Danthonia intermedia, Stipa occidentalis*, and *Carex* spp. are more prevalent. Species diversity is also greater with a generally higher proportion of such forbs as *Geum triflorum, Galium boreale, and Campanula rotundifolia*. *Koeleria cristata* is a consistently occurring grass. *Lupinus sericeus* can be a dominant forb in this type, though it does not occur in all stands.

*(Mueggler and Stewart, 1980)

Table 16. Original and new community names (highlighted names remained the same)

Original Name	New Name	Original Name	New Name
Af.1	T.intermedium.1	Pf.1	P.Compressa.10
Af.2	F.campestris.1	Pf.2	P.Compressa.11
Af.3	Moss.1	Pf.3	P.Compressa.12
Af.4	F.campestris.2	Pf.4	P.Compressa.13
Af.5	Moss.2	Pf.5	P.Compressa.14
Bt.1	Moss.3	Pp.1	P.Compressa.15
Bt.2	C.filifolia.1	Pp.2	A.pratensis.1
Bt.3	P.pratensis.1	Pp.4	P.pratensis.4
Bt.4	P.pratensis.2	Pp.5	A.pratensis.2
Bt.5	P.Compressa.1	Ppr.1	T.intermedium.6
Ec.1	P.Compressa.2	Ppr.2	P.Compressa.16
Ec.2	P.pratensis.3	Ppr.3	T.intermedium.7
Ec.3	Moss.4	Ppr.4	P.Compressa.17
Ec.4	F.campestris.3	Ppr.5	P.Compressa.18
Ec.5	F.campestris.4	Ps.1	T.intermedium.8
Ec.6	Moss.5	Ps.2	F.virginiana.1
Fc.1	F.campestris.5	Ps.3	T.intermedium.9
Fc.2	F.campestris.6	Ps.4	P.pratensis.5
Fc.3	F.campestris.7	Ps.5	T.intermedium.10
Fc.4	F.idahoensis.1	Pss.1	T.intermedium.11
Fc.5	P.Compressa.3	Pss.2	P.Compressa.19
Fc.6	P.Compressa.4	Pss.3	P.Compressa.20
Fc.7	F.campestris.8	Pss.4	T.intermedium.12
Fc.8	Lichen.spp.1	Pss.5	P.Compressa.21
Fi.1	C.patricola.1	Sal.1	S.albus.1
Fi.2	F.idahoensis.2	Sal.2	S.albus.2
Fi.2.1	Moss.6	Sal.3	P.Compressa.22
Fi.2.2	C.filifolia.2	Sal.4	S.albus.3
Fi.3	F.idahoensis.3	Sal.5	P.Compressa.23
Fi.4	P.Compressa.5	Sr.1	P.pratensis.6
Fi.4.1	F.idahoensis.4	Sr.2	P.Compressa.24
Fi.4.3	F.campestris.9	Sr.3	T.intermedium.13
Fi.4.4	P.Compressa.6	Sr.4	T.intermedium.14
Fi.5	F.idahoensis.5	Sr.5	P.pratensis.7
Fi.6	F.idahoensis.6	Ssp.2	P.Compressa.25
Kp.1	Lichen.spp.2	Ssp.3	S.albus.4
Kp.2	P.Compressa.7	Ssp.4	A.pratensis.3
Kp.3	Lichen.spp.3	Ssp.5	P.Compressa.26
Kp.4	P.Compressa.8	U.1	P.Compressa.27
Kp.5	Moss.7	U.2	T.intermedium.15
O.1	T.intermedium.2	U.3	C.filifolia.3
O.2	T.intermedium.3	U.4	T.intermedium.16
O.3	T.intermedium.4	U.5	P.Compressa.28
O.4	T.intermedium.5		
O.5	P.Compressa.9		

Table 17. Litter depth, percent native and percent non-native composition in new community types.

New community name	**Litter depth (cm)**	**Percent native species**	**Percent non-native species**
F. idahoensis	1.45	34.32%	3.85%
Moss	1.46	40.47%	8.75%
T. intermedium	1.94	19.63%	24.36%
C. filifolia	1.42	39.58%	6.46%
F. campestris	0.99	41.94%	4.17%
P. compressa / T. intermedium	1.94	9.23%	23.50%
P. compressa / F. campestris	1.63	18.40%	13.94%
Average	1.55	29.08%	12.15%

Table 18. Vegetation description of Northern Fescue Grasslands*

E.H. Moss habitat type*	**Vegetative composition**
Festuca / Danthonia association	The dominant grasses are *F. campestris, F .idahoensis, Danthonia intermedia*, of which the *Danthonia* species are localized in their dominance. Moreover, *Danthonia Parryi* appears to be largely restricted to the western part of the region, but might conceivably extend throughout the association in the course of time. Characteristic associated grasses are *Koeleria gracilis, Agropyron grifithsii, A. dasystachyum, A. trachycaulum, Stipa spartea, S. columbiana, Poa cusickii,* and *Avena hookeri*. Grasses of less common occurrence are *Agropyron spicatum, A. smithii, Stipa richardsonii, S. viridula, Poa interior, P. canbyi, P. juncifolia, Calamagrostis montanensis, Bromus marginatus, Elymus condensatus*, and *Muhlenbergia* spp. The chief sedge is *Carex eleocharis,* while *C. heliophila* occurs frequently, *C. obtusata, C. siccata, C. xerantica*, and *C. scirpiformis*, occasionally. Shrubs are important elements in the association. *Rosa* spp. and *Pentaphylloides floribunda* are scattered in the grassland, while *Symphoricarpos occidentalis, Elaeagnus argentea, Amelanchier alnifolia, Prunus melanocarpa, and Salix bebbiana* are generally localized and tend to form societies within the association. In the more sheltered and mesic areas, distinct willow thickets are formed, with *Salix bebbiana* as the dominant species. The association is characterized by a large number of herbaceous forbs, some of them showing a high degree of fidelity, others tending to occur locally in considerable abundance. Leading species include *Geranium viscosissimum, Pulsatilla ludoviciana, Lithospermum ruderale, Liatris punctata, Lupinus leucopsis, Allium cernnuum, Thermopsis rhombifolia, Achillea millefolium, Galium boreale, Aster Geyeri, Erigeron conspicuus, E. caespitosus, Potentilla spp., Antennaria spp., Artemisia gnaphalodes, A. pacifca, Balsamorrhiza sagittata, Solidago glaberrima, S. decumbens, S. missouriensis, Comandra pallida, Cerastium. arvense, Hedysarum alpinum, H. sulphuresence, Thalictrum venulosum, Oxytropis gracilis, O. splendens, Vicia sparsifolia, Anemone cylindrica, A. globosa, Gaillardia aristata, Androsace puberulenta, Sieversia ciliata, Agoseris glauca, Viola adunca, Zygadenus gramineus, Fragaria spp., Lychnis Drummondii, Delphinium bicolor, Cheirinia inconspicua,* and *Artemisia frigida*. Species of only occasional or rare occurrence include *Ranunculus* cardiophyllus, R. affinis, Paronychia sessiliflora, Astragalus striatus, A. goniatus, A. flexuosus, Zizia cordata, Penstemon nitidus, P. confertus, P. procerus, Dodecatheon Cusickii, D. pauciflorum, Solidago mollis, Vicia americana, Besseya wyomingensis, Castilleja spp., Hieracium canadense, Plantago septata, Heuchera flabellifolia, Senecio canus, S. hydrophilus, Erigeron glabellus, Gentiana plebeja, G. affinis, Bupleurum americanum, Lomatium simplex, Astragalus bisulcatus, and *Polytrichum piliferum*.

*(Moss, 1943)

Table 19. R output for NMDS analysis using biotic data in the Bray-Curtis dissimilarity index in two-dimensions

Data:	biotic
Distance	bray
Dimensions	2
Stress	0.0795915
Stress type 1	weak ties
Two convergent solutions found after 26 tries; Scaling: centering, PC rotation, half-change scaling; species: expanded scores based on 'biotic'	
Stressplot R^2 Value	0.994
Note: 'biotic' is name of species database	

Table 20. Recommended sampling protocols for future USFWS surveys at the LT-NWR, Marion, MT.

Recommended sampling procedures (This approach will allow direct comparison to data from the 2013/2014 baseline inventory**).**
1. Relocate identified sample point (see Table 21) • Refer to Figure 6 and Table 12 for number of samples necessary in each community type.
2. String 50 m tape between center pin and permanently marked end pin (marked with survey stake)
3. Collect Daubenmire percent canopy cover class data at 0 m, 25 m and 50 m distances on the North and East transects, and at 3 m, 25 m and 50 m distance on the South and West transects.
4. Record all biotic and abiotic variables originally collected. • Percent cover for each species present, litter, rock, bare ground and water • Litter depth at three random points within each frame • Slope • Aspect • Elevation
5. Enter this information into an excel spreadsheet
6. Determine the average percent cover for each of these variables.
7. If any of the variables occurs in <5% of the sample locations, remove it from further analysis
8. The species average percent and compare with the baseline for that species
9. Determine if community composition is continuing to transition into a native dominated community type.
10. If the community type has not changed or is becoming more dominated by non-native species consider new management strategies.

Table 21. New community type name and lat/long for each point sampled during 2013/2014 inventories at LT-NWR.

New community type name	Latitude	Longitude	New community type name	Latitude	Longitude
T.intermedium.1	48.177750	-114.85805	P.Compressa.9	48.179114	-114.95375
F.campestris.1	48.175980	-114.86033	P.Compressa.10	48.175280	-114.90441
Moss.1	48.177477	-114.86665	P.Compressa.11	48.174850	-114.90474
F.campestris.2	48.176590	-114.85864	P.Compressa.12	48.175220	-114.90294
Moss.2	48.177070	-114.86593	P.Compressa.13	48.174880	-114.90209
Moss.3	48.176710	-114.84353	P.Compressa.14	48.175350	-114.90500
C.filifolia.1	48.193480	-114.91590	P.Compressa.15	48.167750	-114.84883
P.pratensis.1	48.194250	-114.91547	A.pratensis.1	48.186120	-114.91972
P.pratensis.2	48.193500	-114.91645	P.pratensis.4	48.176050	-114.89031
P.Compressa.1	48.193710	-114.91746	A.pratensis.2	48.168180	-114.85406
P.Compressa.2	48.174730	-114.95990	T.intermedium.6	48.167390	-114.79965
P.pratensis.3	48.176870	-114.96074	P.Compressa.16	48.168350	-114.80659
Moss.4	48.171630	-114.95803	T.intermedium.7	48.164450	-114.79563
F.campestris.3	48.172140	-114.96184	P.Compressa.17	48.166868	-114.79523
F.campestris.4	48.171050	-114.95942	P.Compressa.18	48.166668	-114.80022
Moss.5	48.171360	-114.95796	T.intermedium.8	48.166780	-114.85411
F.campestris.5	48.169713	-114.95157	F.virginiana.1	48.170450	-114.80876
F.campestris.6	48.176700	-114.93628	T.intermedium.9	48.185407	-114.87347
F.campestris.7	48.176740	-114.94183	P.pratensis.5	48.174600	-114.83047
F.idahoensis.1	48.176720	-114.92620	T.intermedium.10	48.174228	-114.85959
P.Compressa.3	48.174284	-114.93082	T.intermedium.11	48.171675	-114.87006
P.Compressa.4	48.182000	-114.93100	P.Compressa.19	48.177699	-114.87659
F.campestris.8	48.181000	-114.92600	P.Compressa.20	48.177740	-114.87212
Lichen.spp.1	48.180000	-114.94700	T.intermedium.12	48.169988	-114.86433
C.patricola.1	48.167390	-114.96266	P.Compressa.21	48.171888	-114.87153
F.idahoensis.2	48.179850	-114.85888	S.albus.1	48.169070	-114.87723
Moss.6	48.198720	-114.91734	S.albus.2	48.169740	-114.88129
C.filifolia.2	48.197140	-114.91553	P.Compressa.22	48.169240	-114.88002
F.idahoensis.3	48.180940	-114.87040	S.albus.3	48.169040	-114.87552
P.Compressa.5	48.184880	-114.92838	P.Compressa.23	48.169805	-114.88212
F.idahoensis.4	48.172700	-114.81207	P.pratensis.6	48.175201	-114.82166
F.campestris.9	48.173500	-114.81145	P.Compressa.24	48.174680	-114.82316
P.Compressa.6	48.178840	-114.84284	T.intermedium.13	48.175473	-114.82374
F.idahoensis.5	48.178970	-114.86544	T.intermedium.14	48.174420	-114.82251
F.idahoensis.6	48.188850	-114.91000	P.pratensis.7	48.175770	-114.82320
Lichen.spp.2	48.179280	-114.88580	P.Compressa.25	48.163710	-114.96063
P.Compressa.7	48.178350	-114.88322	S.albus.4	48.163190	-114.95991
Lichen.spp.3	48.180210	-114.88786	A.pratensis.3	48.165060	-114.96026
P.Compressa.8	48.181070	-114.88843	P.Compressa.26	48.164312	-114.96304
Moss.7	48.180190	-114.88556	P.Compressa.27	48.177670	-114.86785
T.intermedium.2	48.178719	-114.95290	T.intermedium.15	48.173130	-114.95678
T.intermedium.3	48.178346	-114.95170	C.filifolia.3	48.175340	-114.94627
T.intermedium.4	48.178248	-114.95275	T.intermedium.16	48.174730	-114.94673
T.intermedium.5	48.178588	-114.95326	P.Compressa.28	48.167449	-114.86145