CLASSIFICATION OF THE PLANT COMMUNITIES OF BEAVERHEAD, SILVER BOW, AND MADISON COUNTIES, MONTANA

VOLUME I (text)

Robert L. DeVelice
Montana Natural Heritage Program
1515 East 6th Ave., Helena, MT 59620

for

Bureau of Land Management
State Office
Billings, Montana

Assistance Agreement No. E950-A1-0006
Task Order No. 4

This document should be cited as follows:

DeVelice, R.L. 1992. Classification of the plant communities of Beaverhead, Silver Bow, and Madison counties, Montana. Volume I (text). Montana Natural Heritage Program, Helena, MT. 35 pp.

3/27/92

MISSION STATEMENT

This study on Bureau of Land Management (BLM) lands is a working component of the Montana Natural Heritage Program's (MTNHP) grasslands/shrublands ecological classification project (GSCP) and The Nature Conservancy's ecology program in the western United States. The Nature Conservancy program provides key information on plant communities to be used for conservation planning, management, research, and monitoring. Although grasslands and shrublands cover about 65% of the Montana landscape, an exhaustive review of existing information (MTNHP 1990) revealed them to be the least documented vegetation types of the state. Therefore, the GSCP is designed to complete the classification over the full range of ecological conditions and to conduct regional correlations of existing classifications. The information provided by the project will be the basis for programs to model the effects of management, global changes, and other variables on the vegetation types and diversity patterns, and their implications for further management and conservation planning. The project will continue to focus on strong collaborative work with the various state and federal agencies (BLM, USFS, DSL, BIA, DOD) and other institutions (e.g. Montana universities) in order to contribute to the development of a tightly integrated state-wide classification system.

ABSTRACT

Interrelationships between vegetation composition and environment were studied using 52 vegetation plots sampled in southwestern Montana. Using a combination of two-way indicator species analysis (TWINSPAN) and detrended correspondence analysis (DCA) 21 community types were identified. Of these types, three have not previously been described in the western United States and five have not previously been reported in Montana. All eight of these types appear to be rare in Montana. Additionally, eight TES plant species were observed within the set of sample plots. A total of 140 community types have now been documented from southwestern Montana, 54 of which are rare.

CONTENTS

INTRODUCTION

This study provides a classification of plant communities in southwestern Montana. The emphasis was on locating and describing rare or previously undescribed communities and common communities in good to excellent ecological condition on selected BLM lands in the Headwaters and Dillon Resource Areas. The comprehensive classification was based on the integration and synthesis of both existing data and newly sampled plots. This classification will be useful in identifying sensitive communities and natural areas where management activities may need to be adjusted to maintain habitat values. Additionally, the classification provides a reference system for baseline monitoring of environmental impacts and vegetation recovery and provides an ecological basis for categorizing environmental variation.

This work represents a step towards developing a comprehensive classification of Montana plant communities that will provide land managers and scientists a state-wide perspective of community variation (nation-wide when correlated with other state classifications). Such a perspective is invaluable towards making sound management prescriptions and predictions, designing and interpreting experiments, and identifying areas of critical importance for conservation.

This document is divided into three volumes: Volume I provides text describing previous research, the study area, the methods used, and results of this study. Volume II provides appendices containing detailed plant community and site data recorded during this study. Volume III provides close-up and aspect photographs from each site, referenced by plot numbers.

ACKNOWLEDGEMENTS

The author gratefully acknowledges the financial assistance provided by the USDI Bureau of Land Management and the Montana Natural Heritage Program. Additionally, Bureau of Land Management assistance in locating and assessing some of the field sites was greatly appreciated.

The author appreciated the assistance provided by Peter Achuff and Alistair McAlpine during the initial stages of fieldwork. Peter Achuff and Lisa Roe provided invaluable assistance in voucher specimen identification. Finally, appreciation is extended to Margaret Beer, Cedron Jones, and Diana Schwab for their conscientious assistance in data entry and data quality control.

PREVIOUS RESEARCH

Grasslands and shrublands cover about 65 percent of the Montana landscape yet are the most poorly described vegetation types of the state. In contrast, the classification of the forest types of Montana is largely complete. Filling the gap in grassland/shrubland community type characterization constitutes a primary goal of the Montana Natural Heritage Program's grasslands/shrublands ecological classification project of which this study is a component. This study constitutes a major and necessary step towards developing a comprehensive classification of all Montana plant communities.

To date, studies characterizing grassland and shrubland communities of Montana have been of limited geographical and ecological scope. The most extensive existing studies include Mueggler and Stewart's (1980) in western Montana, Jorgensen's (1979) and Harvey's (1982) studies in central Montana, the DeVelice et al. (1991) study in northeastern Montana, and Hansen (1985) and Hansen and Hoffman's (1985) work in southeastern Montana.

The classification of Montana's upland forest plant associations provided by Pfister et al. (1977) has been refined and extended by the work of Cooper and Pfister (1981; 1985), Hansen and Hoffman (1985), Hoffman and Hansen (1981), and Roberts (1980). A comprehensive classifications of Montana riparian sites (including forested, shrub dominated, and herb dominated communities) is nearing completion (Hansen et al. 1991).

Prior to initiating field sampling, literature review and data from previous research were used to develop a preliminary classification of southwestern Montana's plant communities. Forested communities in the study area have been largely described by Pfister et al. (1977) and riparian community types have been defined by Hansen et al. (1989). Mueggler and Stewart (1980) provide a relevant classification for the area but emphasized more common communities and predominantly sampled USDA Forest Service lands in their study. The present study is largely an expansion of Mueggler and Stewart's work to include descriptions of rare communities and also extends sampling onto selected BLM lands.

STUDY AREA

The study area basically includes the southern portion of Silver Bow County, the western portion of Madison County, and the eastern portion of Beaverhead County.

Physiography

The study area encompasses approximately 2.5 million acres and ranges in elevation from about 4,500 feet on the Beaverhead River

at Silver Star to 11,150 feet at the summit of Torrey Mountain in the Pioneer Mountains. The diverse topography of the area is matched by a diversity of soil parent materials including hard coarse-grained metamorphic rocks, limestone, shale, sandstone, intrusive and extrusive igneous rocks, and valley fill sediments (Veseth and Montagne 1980). The Pioneer Mountains and the Beaverhead, Gravelly, Snowcrest, and Centennial ranges all featured alpine glaciation during the Pleistocene (Montagne 1972).

Climate

Most of the study area experiences a continental climate. Average annual precipitation varies from over 50 inches at the crest of the Pioneer Mountains to between 8 and 16 inches throughout the bulk of the study area (see sheets 3 and 4 in Ross and Hunter 1976). The average length of the freeze-free season varies from less than 30 days to more than 70 days at high and low elevations, respectively (see Figure 13 in Montagne et al. 1982).

METHODS

Data Collection

Most field sampling was restricted to ten areas specifically selected by the USDI Bureau of Land Management. The ten areas examined and the survey acreages specified in the assistance agreement were as follows:

1. Centennial Sandhills (2400 acres)
2. Lime Gulch - Moose Creek (1000 acres)
3. Sheep Creek - Cabin Creek Slide (1000 acres)
4. Block Mountain - Hogback (500 acres)
5. Hahnkamp Island (50 acres)
6. Nemesis Mountain (100 acres)
7. Big Hole - Charcoal Gulch (350 acres)
8. Scudder Creek Exclosure (200 acres)
9. Johnson Creek Exclosure (200 acres)
10. Maiden Rock Exclosure (200 acres)

General descriptions of each of these sites, including assessments of their biodiversity significance, current and past landuse, and suggested conservation management needs, appear in Volume II, Appendix A. In addition to the 10 sites listed above, the site basic records provided in Volume II, Appendix A include eight additional sites not specified in the assistance agreement.

Within each of these areas, sampling focused on rare or previously undescribed communities and on common communities in particularly good condition. To minimize the confounding nature of heavy disturbance on vegetation occurrence, areas severely overgrazed, herbicide treated, mechanically disturbed, artificially

seeded, or irrigated were not sampled. Plots were established within portions of stands that appeared to be relatively uniform in topography and vegetation structure. Within an area, one to five plots were chosen from different topographic positions and where judgement indicated a marked change in vegetation composition.

Plot selection focused on contemporary stands of vegetation without reference to successional relationships among stands. No attempt was made to solely sample remnants of presettlement vegetation.

The data were recorded on Natural Heritage Program Community Survey (Figure 1) and Reconnaissance Soil Characterization (Figure 2) forms for each plot, and Site Survey Forms (Figure 3) for each site. Instructions for completing these three forms are provided in DeVelice (1991). The Community Survey Forms are basically the same as the general plot data and ocular plant species data forms used by the USDA Forest Service (USDA 1987). Complete lists and canopy cover estimates of vascular plant species were recorded within each 375 m^2 circular study plot. Site information such as altitude, slope, aspect, parent material, landform, and erosion characteristics were also recorded for each plot. A 20-inch deep reconnaissance soil pit was excavated at each site and information was collected to determine soil subgroup and available water holding capacity.

Data Analysis

Analysis focused on using a combination of classification, to determine community types, and ordination (gradient analyses), to describe general patterns of communities in relation to environmental factors. Classification was accomplished using two-way indicator species analysis (TWINSPAN; Hill 1979a) in the CEP MS-DOS computer package (Mohler 1987). Ordination was achieved using the detrended correspondence analysis (DCA) algorithm in the CANOCO computer package (Ter Braak 1988). The input data were species cover variables recorded in each plot. Both TWINSPAN and DCA are based on the same mathematical strategy (i.e., reciprocal averaging; Hill 1979a,b) and thus offer direct comparisons between the results of ordination and classification.

All default options in the TWINSPAN algorithm were used except that pseudospecies cut levels were set at 0, 5, and 20 percent cover. Also, all default options were used in running the ordinations except that rare species were downweighted. First, the entire data matrix of 52 stands and 268 species were analyzed. Second, to reduce the amount of variation being considered, which is substantial in the whole matrix, the species list was thinned to the 55 most characteristic species.

COMMUNITY SURVEY FORM

MTNHP
5/27/91

GENERAL PLOT DATA

IDENTIFICATION AND LOCATION

MANUAL_____ UNITS __ft __m
PLOT NO._____ MO____ DAY___ YEAR____ EOCODE_____*___
EXAMINER(s) _____
PNC_____ CT_____
SITE_____ STATE_____ COUNTY_____
PURP___ PREC___ QUADNAME_____ QUADCODE_____
____T/____R/___S/___4S/___4/4 COMMUNITY SIZE (acres)_____
PLOT TYPES_____ PLTRL_____ PLOT W_____ SURVEY_____
PHOTOS_____
DIRECTIONS -->_____
_____
_____
_____

CONSERVATION RANKING

COND ___ Com: _____
VIAB ___ Com: _____
DEFN ___ Com: _____
RANK ___ Com: _____
_____
MGMT: _____
PROT: _____

ENVIRONMENTAL FEATURES

DL_____. SOIL RPT_____
SOIL UNIT_____ SOIL TAXON_____
PM_____ LANDFORM_____ PLOT POS_____ SLP SHAPE_____ ASP_____
SLOPE % _____ ELEVATION _____ EROS POTENT_____ EROS TYPE_____
HORIZON ANGLE (%): N____E____S____W____ IFSLP_____ IFVAL___.___
SPFE_____
GROUND COVER: ___S+___G+___R+___L+___W+___M+___BV+___O = 100%
DISTURBANCE HISTORY (type, intensity, frequency, season)--> ____
_____
_____
_____

RIPARIAN FEATURES: Channel Width_____Channel Entrench_____
Surface Water_____Ht.Abv.H20_____Dist. from H20_____

GENERAL SITE DESCRIPTION (landscape features and adjacent ct's)

_____
_____
_____
_____
_____

Figure 1. Example of community survey form used.

OCULAR PLANT SPECIES DATA

PltIDL____

PLOT NO. _____ NO. SPECIES ____ PNC _____

TREES Tot Cv___ MHt___
Tal Cv___ Med Cv___
Low Cv___ Grd Cv___

		CC
T 1		
T 2		
T 3		
T 4		
T 5		

SHRBS Tot Cv___ MHt___
Tal Cv___ Med Cv___
Low Cv___ Grd Cv___

		CC
S 1		
S 2		
S 3		
S 4		
S 5		
S 6		
S 7		
S 8		
S 9		
S10		
S11		
S12		

GRAM Tot Cv___ MHt___
Med Cv___ Low Cv___
Grd Cv___

		CC
G 1		
G 2		
G 3		
G 4		
G 5		
G 6		
G 7		
G 8		
G 9		
G10		
G11		
G12		

FRBS Tot Cv___ MHt___
Med Cv___ Low Cv___
Grd Cv___

		CC
F 1		
F 2		
F 3		
F 4		
F 5		
F 6		
F 7		
F 8		
F 9		
F10		
F11		
F12		
F13		
F14		
F15		

FERN Tot Cv___ MHt___ Med Cv___
Low Cv___ Grd Cv___
BRYO/LICH Tot Cv___

COMMENTS (EODATA) --> _____

Figure 1. (continued)

RECONNAISSANCE SOIL CHARACTERIZATION FORM

MTNHP 5/29/91

IDENTIFICATION

PLOT NO._____ MO____ DAY___ YEAR___ EST SOIL DEPTH_____
EXAMINER(s)_____
SOIL SUBGROUP_____

SOIL DESCRIPTION

HORZ 1 _____ DEPTH (cm) _____ to _____ TEXTURE_____
STRUC_____ COLOR_____ FRAGS_____ EFFER_____
NOTES_____

HORZ 2 _____ DEPTH (cm) _____ to _____ TEXTURE_____
STRUC_____ COLOR_____ FRAGS_____ EFFER_____
NOTES_____

HORZ 3 _____ DEPTH (cm) _____ to _____ TEXTURE_____
STRUC_____ COLOR_____ FRAGS_____ EFFER_____
NOTES_____

HORZ 4 _____ DEPTH (cm) _____ to _____ TEXTURE_____
STRUC_____ COLOR_____ FRAGS_____ EFFER_____
NOTES_____

HORZ 5 _____ DEPTH (cm) _____ to _____ TEXTURE_____
STRUC_____ COLOR_____ FRAGS_____ EFFER_____
NOTES_____

Figure 2. Example of reconnaissance soil characterization form used.

SITE SURVEY FORM

MTNHP
5/27/91

IDENTIFICATION AND LOCATION

MANUAL _____
SITENAME_____ STATE _____
MO DAY YEAR EXAMINERS
____-____-____ _____
____-____-____ _____
____-____-____ _____
COUNTY:_____ QUADNAME: _____ QUADCODE: _____
_____ _____ _____
_____ _____ _____
____T/____R/_____SECTION(s)
____T/____R/_____SECTION(s)
DIRECTIONS --> _____

ELEMENT OCCURRENCES

Date: _____

Element Name	Occ. No.	Plot No.	Found?	Found?	Found?

REVISIT NEEDS--> _____

SITE DESCRIPTION/DESIGN

SITE DESCRIPTION--> _____

TOPOGRAPHIC BASE MAP:
___yes___no 1. element locations and/or boundaries?
___yes___no 2. both primary and secondary boundaries?

Figure 3. Example of site survey form used.

BOUNDARY JUSTIFICATION-->_____

PROTECTION URGENCY
U1 immediate threat
U2 threat w/i 5 yrs
U3 threat but not w/i 5 yrs
U4 no threats
U5 land protected
PU COMMENTS:

MANAGEMENT URGENCY
M1 needed this year
M2 needed w/i 5 yrs (or loss)
M3 needed w/i 5 yrs (or degrade)
M4 may be needed in future
M5 none needed
MU COMMENTS:

STEWARDSHIP

LAND USE COMMENTS -->_____

POTENTIAL HAZARDS -->_____

EXOTIC FLORA/FAUNA COMMENTS-->_____

OFF-SITE CONSIDERATIONS-->_____

SITE AND ELEMENT MANAGEMENT NEEDS -->_____

SKETCH MAP (e.g., show: (1) EO locations, (2) study plots, (3) natural landmarks, (4) disturbance features, such as structures, trails, logging areas, etc... Include cross section if possible. Include scale and indicate north.)

Figure 3. (continued)

In some instances, a particular TWINSPAN class included a plot or plots that, based on field experience and ordination patterns, appeared to be better placed in a different existing TWINSPAN class. These plots were repositioned in the classification as appropriate.

In addition to helping refine the classification, ordination assisted in describing and interpreting general patterns of vegetation communities and environment. For example, DCA extracts the dominant compositional gradients from the species data matrix. The environmental controls of these compositional gradients are then interpreted based on comparisons with the site data.

Taxonomic Considerations

Nomenclature follows Hitchcock and Cronquist (1973) except for Arabis fecunda and Lesquerella paysonii which follows Rollins (1984) and Rollins and Shaw (1973), respectively, and Mertensia lanceolata which follows Dorn (1984). Scientific names of all species observed in this study and their code names are listed in Volume II, Appendix B.

RESULTS AND DISCUSSION

Community Type Classification

Classification of the 52 study plots resulted in the definition of 21 community types. These and 119 additional community types documented in southwestern Montana (but not sampled in this study) are listed in Volume II, Appendix C.

A table of average species cover and constancy within each of the 21 sampled community types is provided in Volume II, Appendix D. Vegetation and site characteristics of each sample plot are given in Volume II, Appendix E and F, respectively.

Additional general information describing each sample plot is provided as element occurrence records in Volume II, Appendix G. Finally, Volume II, Appendix H provides a comprehensive listing of condensed plant and community element occurrence records (from the MTNHP database) on BLM lands within Beaverhead, Silver Bow, and Madison counties.

Vegetation-Environmental Relationships

The DCA ordinations based on the 55 most characteristic species in the data set are presented in Figures 4 through 7.

Ordination of all 52 plots indicates that 45 plots lie near the origin of the first and second axes and that the six riparian community types occur as outliers (Figure 4). When the first and

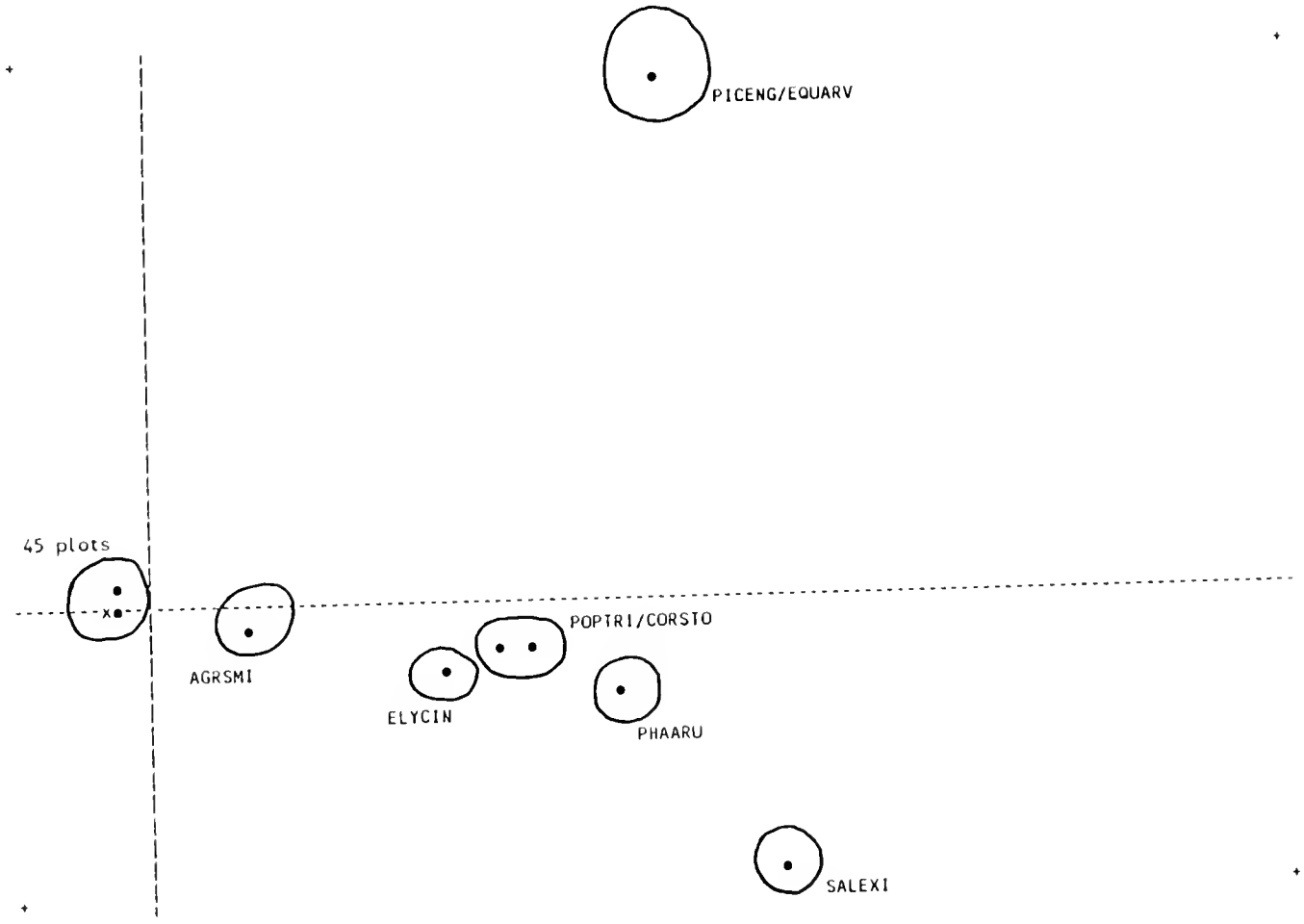

Figure 4. Distribution of all 52 sample plots along the first and second DCA axes. x indicates more than one plot at that ordination position. See the community type descriptions for definitions of the codes used.

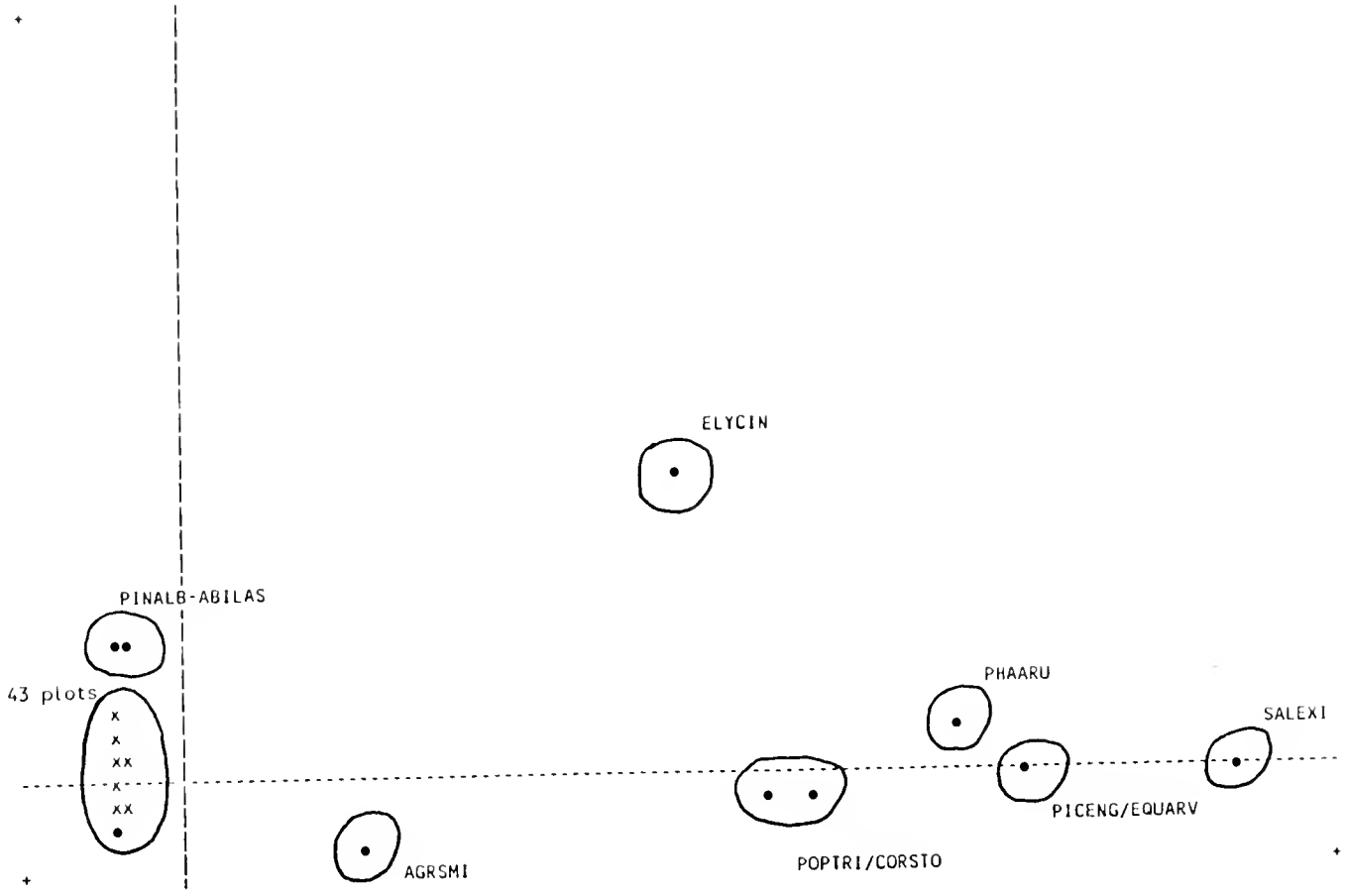

Figure 5. Distribution of all 52 sample plots along the first and third DCA axes. x indicates more than one plot at that ordination position. See the community type descriptions for definitions of the codes used.

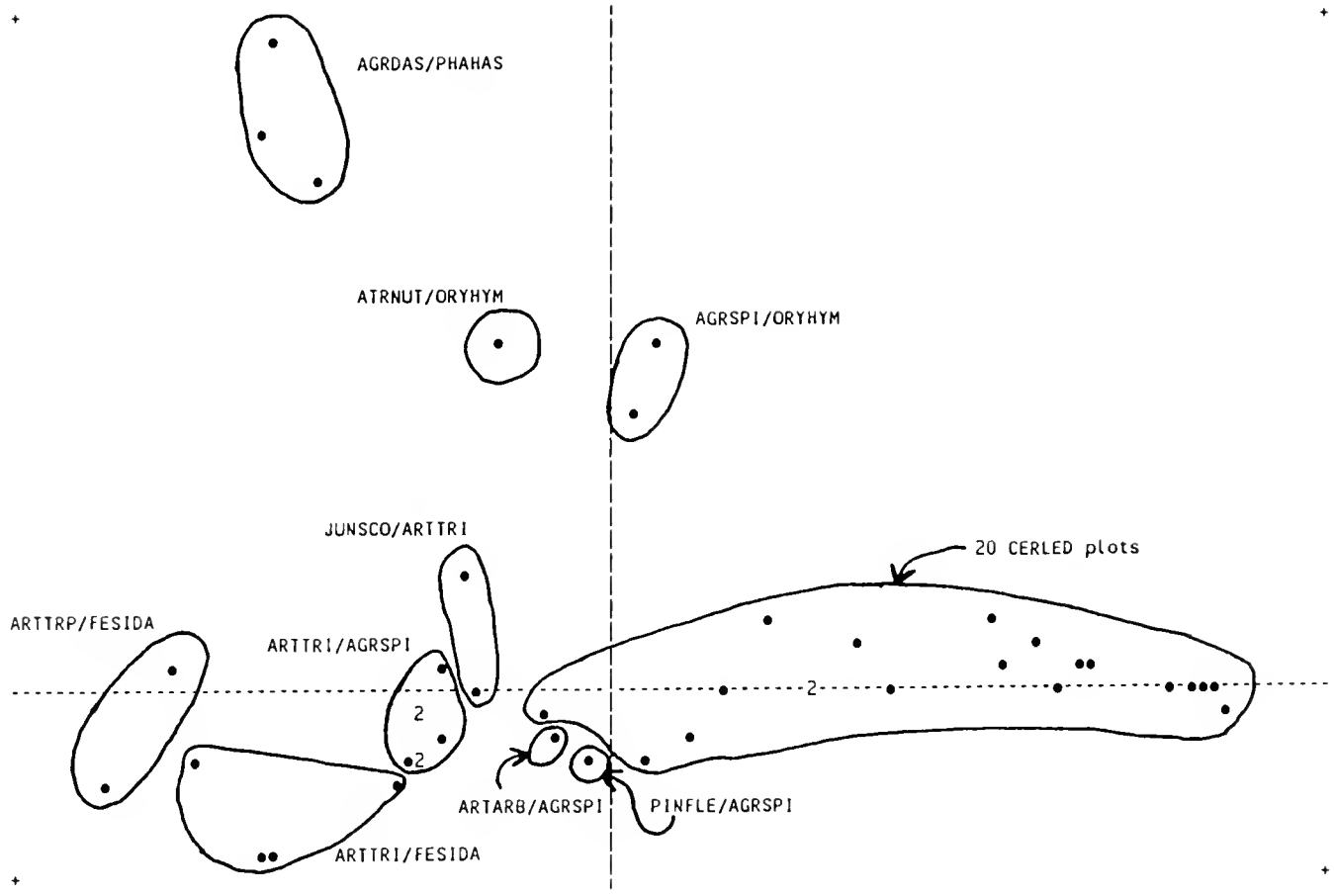

Figure 6. Distribution of the 43 non-riparian and non Pinus albicaulis-Abies lasiocarpa sample plots along the first and second DCA axes. 2 indicates two plots at that ordination position. See the community type descriptions for definitions of the codes used.

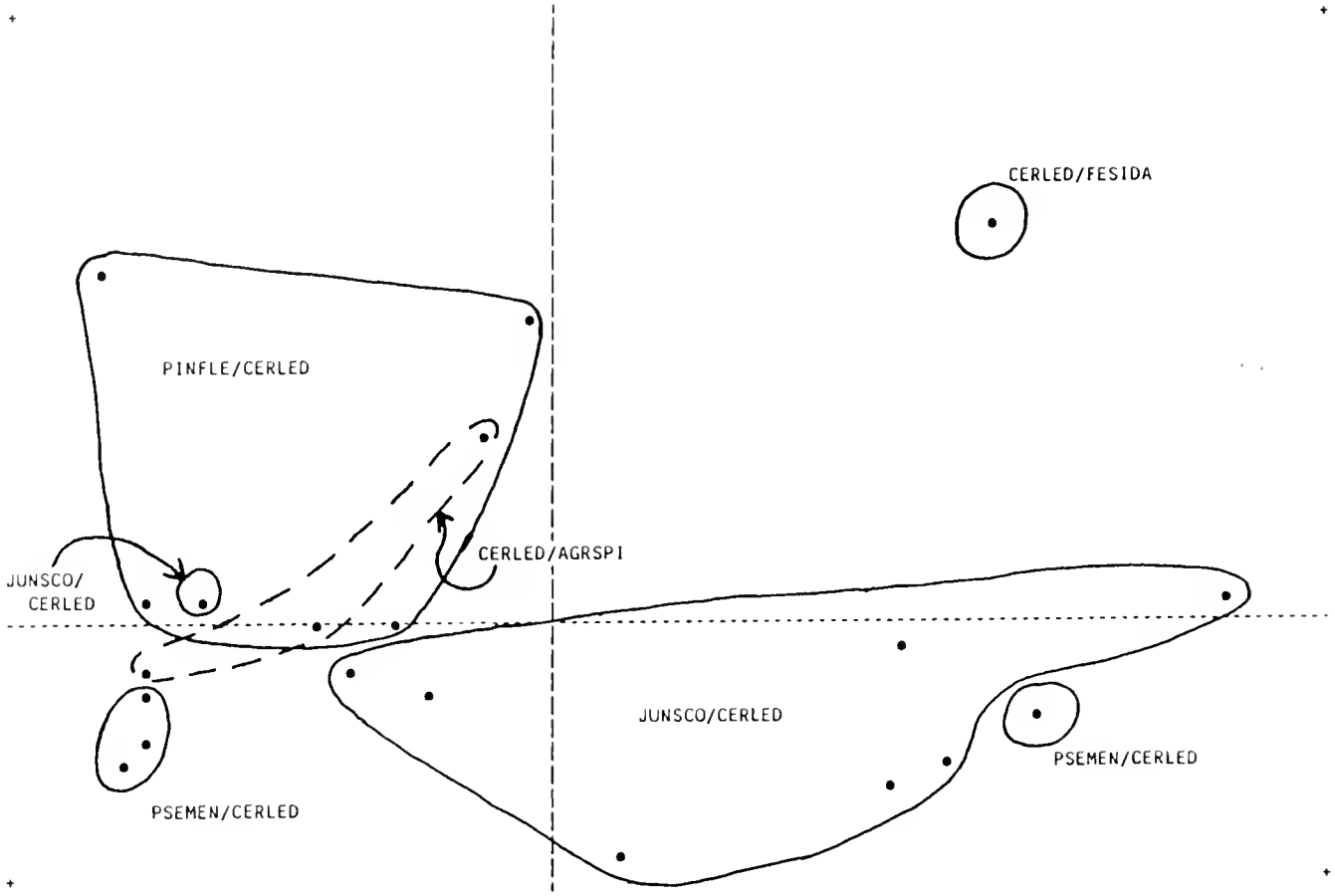

Figure 7. Distribution of the 20 Cercocarpus ledifolius dominated or co-dominated sample plots along the first and second DCA axes. See the community type descriptions for definitions of the codes used.

third axes are shown (Figure 5), the high elevation Pinus albicaulis-Abies lasiocarpa community type joins the riparian types as an outlier. The Picea engelmannii/Equisetum arvense, the Salix exigua, the Phalaris arundinacea, the Populus trichocarpa/Cornus stolonifera, and the Elymus cinereus community types are the most extreme outliers, highlighting their unique vegetation composition among the community types sampled.

Ordination of the 43 non-riparian and non Pinus albicaulis-Abies lasiocarpa sample plots along the first and second axes is shown in Figure 6. The vertical axis appears to follow a soil disturbance gradient with the Agropyron dasystachyum/Phacelia hastata sand dune type and the Agropyron spicatum and Atriplex nuttallii/Oryzopsis hymenoides badlands types on one end of the axis relative to sites on less erosive substrates. The horizontal axis basically follows a gradient of increasing slope steepness, soil coarse fragment content, and probability of limestone occurrence from left to right. The five Cercocarpus ledifolius dominated or co-dominated types (20 plots) are clustered together in the right half of the second axis.

Ordination of the 20 Cercocarpus ledifolius dominated or co-dominated sample plots along the first and second axes is shown in Figure 7. Considerable similarity in vegetation composition occurs among the five community types identified as suggested by the single C. ledifolius cluster in Figure 6 and the overlap among four of the five types in Figure 7. Only the single C. ledifolius/Festuca idahoensis occurrence does not overlap with the other community types (Figure 7). The primary distinguishing feature in composition among the C. ledifolius types is the presence (often with less than 5% canopy cover) or absence of a coniferous tree species. Environmentally, occurrences in the upper left hand quarter of the ordination are predominantly found on limestone derived substrates. Other locations within the ordination space have a lower probability of limestone occurrence.

Community Type Descriptions

1. **Pinus albicaulis-Abies lasiocarpa Type (PINALB-ABILAS; whitebark pine-subalpine fir; G5 S5)**

Vegetation.--Pinus albicaulis, Abies lasiocarpa, Picea engelmannii, and occasionally Pseudotsuga menziesii occur in varying amounts in the often open, stunted, and wind-deformed tree layer. The undergrowth is highly variable in composition and few individual species ever exceed 5% cover.

Physical Setting.--The type occurs on glaciated mountain ridges and upper slopes at elevations above 8900 feet. The total cover of soil, gravel, and rock exceeds 50%. The soil surface is often unstable because of a lack of adequate vegetation cover.

Soils are typically gravelly to very gravelly, feature a cryic temperature regime, and may be strongly to violently effervescent. Textures are sandy loams to loams. Soil depth is shallow to moderately deep. Available water holding capacity varies from low to medium.

Adjacent Communities.--This type occurs at, or near, upper timberline. It is often bordered below by the Abies lasiocarpa-Pinus albicaulis/Vaccinium scoparium type and above by alpine scrub. Unvegetated talus slopes sometimes interfinger with this type.

Other Studies.--This type has been described in Montana by Pfister et al. (1977).

2. **Pinus flexilis/Agropyron spicatum Type (PINFLE/AGRSPI; limber pine/bluebunch wheatgrass; G5 S4)**

Vegetation.--Pinus flexilis characterizes the very open tree layer. Artemisia spp. are often present in the shrub layer. Agropyron spicatum is well represented to abundant and Hesperochloa kingii may be common.

Physical Setting.--This type occurs on steep, dry forested slopes at elevations around 7000 feet. The total cover of soil, gravel, and rock exceeds 50%. The soil surface is often unstable because of a lack of adequate vegetation cover.

Soils are generally Entisols derived from calcareous parent materials, are moderately deep, and are often violently effervescent and very gravelly. Textures range from loams to silts. Available water holding capacity varies from low to medium.

Adjacent Communities.--The type occurs adjacent to, or within, the grassland/shrubland zone and is often transitional to communities in the Agropyron spicatum, Artemisia tridentata, and Cercocarpus ledifolius series. Unvegetated talus slopes and limestone outcrops sometimes interfinger with this type.

Other Studies.--This type has been described in Montana by Pfister et al. (1977).

3. **Pinus flexilis/Cercocarpus ledifolius Type (PINFLE/CERLED; limber pine/mountain mahogany; G3? S3?)**

Vegetation.--Pinus flexilis and Juniperus scopulorum characterize the very open tree layer. Abundant Cercocarpus ledifolius characterizes the undergrowth. Other species that are generally present with cover exceeding 1% include Arcto-

staphylos uva-ursi, Haplopappus acaulis, Agropyron spicatum, Carex rossii, and Oryzopsis hymenoides.

Physical Setting.--The type occurs on steep dip slopes and residual mountain slopes at elevations between 6000 and 6800 feet. The total cover of soil, gravel, and rock exceeds 90% on some sites and is always higher than 30%. The soil surface is usually unstable because of the general lack of adequate vegetation cover.

Soils are derived from limestone parent materials and are Lithic Ustorthents and are often very gravelly. Textures vary from sands to loams. Strong effervescence characterizes the surface of most of the soils and violent effervescence is usually present within the profile. Available water holding capacity varies from low to high.

Adjacent Communities.--Adjacent communities on deeper, less rocky, and more stable soils include Pinus flexilis/Festuca idahoensis, Pseudotsuga menziesii/Agropyron spicatum, and Pseudotsuga menziesii/Festuca idahoensis.

Other Studies.--This type has not previously been reported in Montana but has been reported in Idaho, Utah, and Wyoming (Bourgeron and Engelking 1991).

4. **Pseudotsuga menziesii/Cercocarpus ledifolius Type (PSEMEN/CERLED; Douglas-fir/mountain mahogany; G3? S3?)**

Vegetation.--Pseudotsuga menziesii characterizes the open tree layer, sometimes in association with Juniperus scopulorum. Abundant Cercocarpus ledifolius characterizes the undergrowth. Other species that are generally present with cover exceeding 1% include Artemisia frigida, A. tridentata, and Agropyron spicatum.

Physical Setting.--The type occurs on generally steep residual mountain slopes and ridges at elevations between 5900 and 6600 feet. The total cover of soil, gravel, and rock ranges from 40 to 90%. The soil surface is usually unstable because of a general lack of adequate vegetation cover.

Soils are generally derived from igneous or metamorphic parent materials and are non-effervescent (not calcareous). Textures vary from sands to clay loams and are gravelly to very cobbly. Soil depth varies from shallow to moderately deep. Available water holding capacity varies from low to medium.

Adjacent Communities.--Forested communities on adjacent more mesic and less rocky sites include Pseudotsuga menziesii/

Festuca idahoensis and P. menziesii/Agropyron spicatum. Adjacent grasslands and shrublands include Agropyron spicatum/Poa sandbergii and Artemisia tridentata/Agropyron spicatum, respectively.

Other Studies.--This type has not previously been reported in Montana but has been reported in Idaho, Utah, and Wyoming (Bourgeron and Engelking 1991).

5. **Juniperus scopulorum/Artemisia tridentata Type (JUNSCO/ARTTRI; Rocky Mountain juniper/big sagebrush; G2? S2?)**

Vegetation.--Juniperus scopulorum is the only tree species present. Species exceeding 5% cover in the undergrowth include Artemisia tridentata, Opuntia polyacantha, Agropyron spicatum, Aristida longiseta, Bouteloua gracilis, Oryzopsis hymenoides, and Stipa comata.

Physical Setting.--The type occurs on plateaus and residual mountain slopes at elevations between 5500 and 6000 feet. The total cover of soil, gravel, and rock averages 70%. The soil surface is sometimes unstable because of a lack of adequate vegetation cover.

Soils are generally shallow or very shallow (i.e., lithic) and are derived from igneous or sedimentary parent materials and feature strong to violent effervescence. Textures vary from sandy loams to silt loams and are gravelly to very gravelly. Available water holding capacity varies from low to medium.

Adjacent Communities.--The Artemisia tridentata/Agropyron spicatum community type often occurs on adjacent less rocky sites with deeper soils. More mesic sites with similar soils feature the Juniperus scopulorum/Cercocarpus ledifolius community type.

Other Studies.--This type has not been previously described but has been reported as a possible type in Colorado and Wyoming (Bourgeron and Engelking 1991).

6. **Juniperus scopulorum/Cercocarpus ledifolius Type (JUNSCO/CERLED; Rocky Mountain juniper/mountain mahogany; G3 S3)**

Vegetation.--Juniperus scopulorum is the only tree species present. Abundant Cercocarpus ledifolius characterizes the undergrowth. Other species that are generally present with cover exceeding 1% include Artemisia frigida, Opuntia polyacantha, Agropyron spicatum, and Oryzopsis hymenoides.

Physical Setting.--The type predominantly occurs on steep dip slopes and residual mountain slopes at elevations between 5500 and 6500 feet. The total cover of soil, gravel, and rock usually exceeds 50% and the soil surface is often unstable because of a lack of adequate vegetation cover.

Parent materials are predominantly quartzite or limestone and soils are generally Orthents and are shallow (lithic) and gravelly to very stony. Textures vary from loamy sands to loams. Most of the soils exhibit strong and/or violent effervescence. Available water holding capacity is mostly low due to the coarse soil textures, abundant coarse fragments, and shallow depth.

Adjacent Communities.--The Juniperus scopulorum/Cercocarpus ledifolius and C. ledifolius/Agropyron spicatum types are ecologically similar and intergrade. Of the two types, J. scopulorum/C. ledifolius occurs in slightly more mesic situations. The J. scopulorum/Artemisia tridentata and A. tridentata/Agropyron spicatum types adjoin J. scopulorum/Cercocarpus ledifolius on drier sites. The Agropyron spicatum/Bouteloua gracilis type is often found on adjacent less rocky and less steep sites.

Other Studies.--This type has been described in Montana by Chaffee (1981).

7. **Artemisia arbuscula/Agropyron spicatum Type (ARTARB/AGRSPI; low sagebrush/bluebunch wheatgrass; G4G5 S3S4)**

Vegetation.--Artemisia arbuscula and Agropyron spicatum are abundant within this community type and dominate the shrub and herb layers, respectively. Other species that are generally present with cover exceeding 1% include Artemisia frigida and Chrysothamnus nauseosus.

Physical Setting.--The type predominantly occurs on steep, rocky slopes at elevations around 7000 feet. The total cover of soil, gravel, and rock usually exceeds 50% and the soil surface is often unstable because of a lack of adequate vegetation cover.

Soils are generally deep Orthents and are very gravelly and sometimes violently effervescent. Textures are mostly loams. Available water holding capacity is low to medium.

Adjacent Communities.--The Artemisia arbuscula/Agropyron spicatum and A. tridentata/Agropyron spicatum types are ecologically similar and often adjoin one another. Of the two

types, the A. tridentata type generally occurs on more mesic sites.

Other Studies.--This type has been described in Montana by Mueggler and Stewart (1980).

8. Artemisia tridentata/Agropyron spicatum Type (ARTTRI/AGRSPI; big sagebrush/bluebunch wheatgrass; G5 S5)

Vegetation.--Artemisia tridentata and Agropyron spicatum are abundant within this community type and dominate the shrub and herb layers, respectively. Other species that are generally present with cover exceeding 1% include Artemisia frigida, Opuntia polyacantha, Bouteloua gracilis, Poa sandbergii, and Stipa comata.

Physical Setting.--The type occurs on flat to steep, rocky plateaus, dip slopes, and residual mountain slopes at elevations between 5000 and 6000 feet. The total cover of soil, gravel, and rock ranges from 20 to 70% and the soil surface is stable with little or no evidence of accelerated erosion.

Parent materials include igneous and metamorphic rocks. Soils are generally Calciorthids or Argiborolls and are gravelly to very stony. The Calciorthid soils are violently effervescent in portions of the profile. Soil depth ranges from shallow to moderately deep. Textures are mostly loams to clay loams. Available water holding capacity ranges from low to high.

Adjacent Communities.--The Artemisia tridentata/Agropyron spicatum and A. arbuscula/Agropyron spicatum types are ecologically similar and often adjoin one another. Of the two types, the A. arbuscula type generally occurs on more xeric sites. The A. tridentata/Festuca idahoensis type occurs on more mesic and cooler sites. The Agropyron spicatum/Bouteloua gracilis type is often found on adjacent less rocky and less steep sites.

Other Studies.--This type has been described in Montana by Mueggler and Stewart (1980).

9. Artemisia tridentata/Festuca idahoensis Type (ARTTRI/FESIDA; big sagebrush/Idaho fescue; G5 S4)

Vegetation.--Artemisia tridentata and Festuca idahoensis are abundant within this community type and dominate the shrub and herb layers, respectively. Agropyron spicatum may also be well represented to abundant. Other species that are gener-

ally present with cover exceeding 1% include Koeleria cristata, Poa sandbergii, and Stipa comata.

Physical Setting.--The type occurs on flat to steep residual mountain slopes and rolling uplands at elevations between 6000 and 7600 feet. The total cover of soil, gravel, and rock ranges from 40 to 60% and the soil surface is usually stable with little or no evidence of accelerated erosion.

Parent materials include igneous and metamorphic rocks. Soils are generally Argiborolls and either lack coarse fragments or are gravelly to very gravelly. The soils are generally not calcareous and, thus, are not effervescent. Soil depth ranges from shallow to very deep. Textures are mostly loams to clay loams. Available water holding capacity ranges from low to high.

Adjacent Communities.--The Artemisia tridentata/Agropyron spicatum type occurs on more xeric and warmer sites.

Other Studies.--This type has been described in Montana by Mueggler and Stewart (1980).

10. Artemisia tripartita/Festuca idahoensis Type (ARTTRP/FESIDA; threetip sagebrush/Idaho fescue; G5 S3)

Vegetation.--Artemisia tripartita, Festuca idahoensis, and Stipa comata are abundant within this community type. Other species that are generally well represented include Artemisia frigida, Chrysothamnus viscidiflorus, Tetradymia canescens, Lupinus sericeus, Koeleria cristata, and Poa sandbergii.

Physical Setting.--The type occurs on gently rolling uplands at elevations between 6500 and 7000 feet. Bare soil cover ranges from 10 to 30% and coarse fragment cover is generally less than 20%. The soil surface is usually stable with little or no evidence of accelerated erosion.

Parent materials include eolian deposits and igneous rocks. Soils generally lack coarse fragments, are not calcareous, and are deep to very deep. Textures range from sands to sandy loams and available water holding capacity ranges from low to medium.

Adjacent Communities.--The Artemisia tripartita/Festuca idahoensis and A. tridentata/Festuca idahoensis types are ecologically similar. Of the two types, the A. tripartita type generally occurs on more xeric sites. In the Centennial Valley, the Agropyron dasystachyum/Phacelia hastata type is often found on adjacent sand dune and blow out sites.

Other Studies.--This type has been described in Montana by Mueggler and Stewart (1980).

11. *Atriplex nuttallii*/*Oryzopsis hymenoides* Type (ATRNUT/ORYHYM; Nuttall saltbush/Indian ricegrass; G3G4 S2?)

Vegetation.-- Total vegetation cover in this badlands type seldom exceeds 5%. Characteristic species include *Atriplex nuttallii*, *Chrysothamnus nauseosus*, and *Oryzopsis hymenoides*.

Physical Setting.--The type occurs on steep badland sites at elevations around 5000 feet. Bare soil cover totals at least 60% and most of the remaining ground cover is comprised of coarse fragments. The soil surface is unstable because of a lack of adequate vegetation cover and gully erosion is common.

Parent materials are sedimentary rocks and soils are very shallow and poorly developed. Soils range from not gravelly to very gravelly and are non-calcareous. Textures are generally very fine (e.g., silty clay loams) and available water holding capacity is low.

Adjacent Communities.--Vegetation on adjacent more stable soils include the *Artemisia tridentata*/*Agropyron spicatum* type on non-alkaline soils and the *Sarcobatus vermiculatus*/*Agropyron smithii* type on alkaline soils.

Other Studies.--This type has not previously been reported in Montana but has been reported in Colorado and is listed as questionably present in Oregon and Wyoming (Bourgeron and Engelking 1991).

12. *Cercocarpus ledifolius*/*Agropyron spicatum* Type (CERLED/AGRSPI; mountain mahogany/bluebunch wheatgrass; G5 S4)

Vegetation.--*Cercocarpus ledifolius* is abundant and the dominant vegetation feature of this community type. *Agropyron spicatum* is the only other species that is always well represented with cover exceeding 5%.

Physical Setting.--The type generally occurs on steep mass wasted slopes at elevations between 7000 and 8000 feet. The total cover of soil, gravel, and rock usually exceeds 50% and the soil surface is unstable because of a lack of adequate vegetation cover.

Parent materials are predominantly limestone and soils are generally Ustorthents and are shallow (lithic) and very gravelly to very cobbly. Textures are mostly loams. The soils exhibit violent effervescence. Available water holding

capacity is low due to the coarse soil textures, abundant coarse fragments, and shallow depth.

Adjacent Communities.--The Cercocarpus ledifolius/Agropyron spicatum and Juniperus scopulorum/C. ledifolius types are ecologically similar and intergrade. Of the two types, J. scopulorum/C. ledifolius occurs in slightly more mesic situations. The Artemisia arbuscula/Agropyron spicatum and Pinus flexilus/A. spicatum types are sometimes found on adjacent less rocky sites with deeper soils.

Other Studies.--This type has been described in Montana by Mueggler and Stewart (1980).

13. Cercocarpus ledifolius/Festuca idahoensis Type (CERLED/FESIDA; mountain mahogany/Idaho fescue; G2? S2?)

Vegetation.--Cercocarpus ledifolius and Agropyron spicatum are abundant. Festuca idahoensis cover generally exceeds 5%. Other species that are generally present with cover exceeding 1% include Artemisia frigida, A. tridentata, Opuntia polyacantha, and Poa sandbergii. Bromus tectorum may be abundant.

Physical Setting.--The type occurs on steep residual mountain slopes at elevations around 6000 feet. The total cover of soil, gravel, and rock usually exceeds 40% and the soil surface is stable with no evidence of accelerated erosion.

Parent materials are granitic and soils are Ustorthents and are moderately deep and very cobbly. Textures vary from loamy sands to sandy loams. The soils are non-calcareous and their available water holding capacities are low due to the coarse soil textures and abundant coarse fragments.

Adjacent Communities.--The Cercocarpus ledifolius/Festuca idahoensis and C. ledifolius/Agropyron spicatum types are ecologically similar and intergrade. Of the two types, C. ledifolius/A. spicatum occurs in slightly more xeric situations. The Pseudotsuga menziesii/F. idahoensis type may be found on adjacent more mesic sites that are less rocky and have deeper soils.

Other Studies.--This type has not been previously described.

14. Agropyron dasystachyum/Phacelia hastata Type (AGRDAS/PHAHAS; thickspike wheatgrass/silverleaf Phacelia; G2? S2?)

Vegetation.--Agropyron dasystachyum is well represented to abundant within this community type. Other species that are

generally present with cover ranging from 1 to 20% include Chrysothamnus nauseosus, Tetradymia canescens, Eriogonum ovalifolium v. celsum, Linum perenne, Phacelia hastata, Psoralea tenuifolia, Oryzopsis hymenoides, and Stipa comata.

Physical Setting.--This type has only been observed in the Centennial Valley. It occurs on sand dunes and blow outs at elevations around 6700 feet. Bare soil (sand) cover ranges from 60 to 90% and coarse fragments are absent. The soil surface is usually unstable because of a lack of adequate vegetation cover.

Parent materials are eolian sand deposits. Soils are very deep Ustic Torripsamments and lack coarse fragments and are not calcareous. Textures are sands and available water holding capacity is low due to the coarse texture.

Adjacent Communities.--The Artemisia tripartita/Festuca idahoensis and A. tridentata/Festuca idahoensis types are usually found on adjacent more stable soils and sites.

Other Studies.--This type has not been previously described.

15. Agropyron spicatum/Oryzopsis hymenoides Type (AGRSPI/ORYHYM; bluebunch wheatgrass/Indian ricegrass; G3? S2?)

Vegetation.-- Total vegetation cover in this badlands type seldom exceeds 15%. Characteristic species include Gutierrezia sarothrae, Agropyron spicatum, Aristida longiseta, and Oryzopsis hymenoides.

Physical Setting.--The type occurs on steep badland sites at elevations around 5500 feet. Bare soil cover totals 20 to 70% and most of the remaining ground cover is comprised of coarse fragments. The soil surface is unstable because of a lack of adequate vegetation cover and rill and sheet erosion is common.

Parent materials are sedimentary rocks and soils are shallow and poorly developed. Soils range from not gravelly to very gravelly and are strongly to violently effervescent. Textures are sands to loams and available water holding capacity is low.

Adjacent Communities.--Vegetation on adjacent more stable soils include the Artemisia tridentata/Agropyron spicatum and Agropyron spicatum/Bouteloua gracilis types.

Other Studies.--This type has not previously been reported in Montana but has been reported in Wyoming (Bourgeron and Engelking 1991).

16. *Picea engelmannii/Equisetum arvense* Type (PICENG/EQUARV; Engelmann spruce/field horsetail; G4 S3)

Vegetation.--*Picea engelmannii* dominates the overstory and *Equisetum arvense* is abundant in the undergrowth. The undergrowth is typically rich in species and high in total cover. Species that are typically well represented include *Linnaea borealis*, *Actaea rubra*, *Fragaria virginiana*, *Smilacina stellata*, *Thalictrum occidentale*, and *Calamagrostis canadensis*.

Physical Setting.--This type occurs on wet, flat sites in alluvial basins. Elevations are around 6500 feet. The total cover of litter, wood, and moss equals or exceeds 70% of the ground surface. The soil surface is generally stable with no evidence of accelerated erosion.

Soils are derived from mixed alluvial parent materials and are non-calcareous. These soils are wet throughout the year and are often richly organic, e.g., Histic Cryaquolls. Additionally, the soils are very deep, lack coarse fragments, are loamy in texture, and have a very high available water holding capacity.

Adjacent Communities.--A complex of riparian forest, shrub, and graminoid communities usually occur adjacent to the *Picea engelmannii/Equisetum arvense* type.

Other Studies.--This type has been described in Montana by Pfister et al. (1977).

17. *Populus trichocarpa/Cornus stolonifera* Type (POPTRI/CORSTO; black cottonwood/red-osier dogwood; G4 S4)

Vegetation.--*Populus trichocarpa* dominates the overstory and *Juniperus scopulorum* is common in the middle layer. The undergrowth is typically rich in species and high in total cover. The pattern of occurrence of undergrowth species is often highly variable spatially reflecting the pattern of fluvial disturbances active on most *Populus trichocarpa/Cornus stolonifera* sites. Species that are typically well represented include *Cornus stolonifera*, *Rosa acicularis*, *Symphoricarpos albus*, *Galium boreale*, *Smilacina stellata*, *Poa palustris*, and *Poa pratensis*.

Physical Setting.--This type occurs on gravelly alluvial parent materials on flat flood plains and terraces in wide valley bottoms. Elevations are between 5000 and 5500 feet. Litter plus wood cover equals or exceeds 60% of the ground surface. The soil surface is generally stable with no evidence of accelerated erosion.

Soils are often Typic Udifluvents, are very deep with textures varying from sandy to loamy, and are non-calcareous. Available water holding capacity varies from low (sandy soils high in coarse fragment content) to very high (loamy soils without coarse fragments).

Adjacent Communities.--The Phalaris arundinacea, Eleocharis spp., and Salix exigua types occur on wetter sites. More xeric sites often feature the Artemisia tridentata/Agropyron spicatum type. The Populus trichocarpa/ Cornus stolonifera type intergrades with the Juniperus scopulorum or the Pseudotsuga menziesii/Cornus stolonifera types under conditions of less fluvial disturbance (Hansen et al. 1991).

Other Studies.--This type has been described in Montana by Hansen et al. (1991).

18. Salix exigua Type (SALEXI; sandbar willow; G5 S4)

Vegetation.--Salix exigua dominates the overstory (often with a total canopy cover of 100%). The undergrowth is typically very depauperate due to the intense competition with S. exigua and seldom exceeds 5% total cover. Species that are often present in this sparse undergrowth include Cirsium arvense, Mentha arvensis, and Phalaris arundinacea.

Physical Setting.--This type occurs on gravelly alluvial parent materials on flat flood plains and terraces in wide valley bottoms. Elevations are between 5000 and 5500 feet. Litter plus wood cover equals or exceeds 60% of the ground surface and soil cover is typically around 20%. The soil surface is unstable because of a lack of adequate vegetation cover and the active fluvial disturbance regime present on S. exigua sites.

Soils are often Aquic Udifluvents, are very deep with sandy textures, have a low available water holding capacity, and are non-calcareous. Coarse fragment contents vary from gravelly to very cobbly.

Adjacent Communities.--Adjacent wetter sites are often open water. Adjacent drier riparian communities often feature the Populus trichocarpa/Cornus stolonifera type.

Other Studies.--This type has been described in Montana by Hansen et al. (1991).

19. Agropyron smithii Type (AGRSMI; western wheatgrass; G4 S3)

Vegetation.--Agropyron smithii forms abundant cover within this type. Other species that may be well represented with greater than 5% cover include Carex stenophylla, Koeleria cristata, Poa pratensis, and Equisetum hyemale.

Physical Setting.--This type occurs on alluvial parent materials on flat flood plains in wide valley bottoms at elevations around 5000 feet. Litter cover equals or exceeds 50% of the ground surface. The soil surface is generally stable with no evidence of accelerated erosion.

Soils are often very deep with sandy loam to clay textures, have a high available water holding capacity, and are non-calcareous. Many of the soils are alkaline. Coarse fragment contents are generally low.

Adjacent Communities.--Adjacent wetter communities are usually graminoid dominated, while adjacent drier sites often feature communities in the Artemisia tridentata series.

Other Studies.--This type has been described in Montana by Hansen et al. (1991).

20. Elymus cinereus Type (ELYCIN; basin wildrye; G4 S2?)

Vegetation.--Elymus cinereus dominates (often with a total canopy cover of 100%). Juncus balticus and Poa pratensis may be well represented. The total cover of additional species seldom exceeds 5%.

Physical Setting.--This type occurs on gravelly alluvial parent materials on flat terraces in wide valley bottoms at elevations around 5500 feet. Litter cover equals or exceeds 60% of the ground surface. The soil surface is generally stable with no evidence of accelerated erosion.

Soils are often Mollisols, are very deep with loamy textures, high available water holding capacity, and are non-calcareous. Coarse fragment are generally absent.

Adjacent Communities.--Adjacent wetter communities often feature the Salix exigua type while drier uplands are often

characterized by the Artemisia tridentata/Agropyron spicatum type.

Other Studies.--This type has not previously been reported in Montana but has been reported in Colorado, Idaho, Oregon, and Washington (Bourgeron and Engelking 1991).

21. Phalaris arundinacea Type (PHAARU; reed canarygrass; G4 S4)

Vegetation.--Phalaris arundinacea dominates (often with a total canopy cover of 100%). The undergrowth is typically very depauperate due to the intense competition with P. arundinacea. Poa palustris may be well represented and Cirsium arvense and Mentha arvensis are often common. The total cover of the few additional species seldom exceeds 1%.

Physical Setting.--This type occurs on gravelly alluvial parent materials on flat flood plains in wide valley bottoms at elevations around 5000 feet. Litter and soil cover equals or exceeds 30% and 20% of the ground surface, respectively. The soil surface is generally stable with no evidence of accelerated erosion.

Soils are often Fluvaquents or Fluvents, are very deep with loamy sand to loam textures, medium available water holding capacity, and are non-calcareous. Coarse fragment contents vary from none to gravelly.

Adjacent Communities.--Adjacent wetter sites often feature open water while adjacent drier riparian communities include the Populus trichocarpa/Cornus stolonifera type and a wide variety of other riparian types.

Other Studies.--This type has been described in Montana by Hansen et al. (1991).

Special Status Plant Observations

The eight TES plant species observed within the study plots, the plot numbers in which they were found, and the global and state rarity rankings for these species are presented in Table 1. Preliminary verification of the Lesquerella paysonii specimens by Dr. Reed Rollins of the Harvard University Herbaria suggests these specimens may be L. prostrata (also a S1 species). Dr. Rollins indicated in a December 11, 1991 letter that he will resolve this identification problem as soon as possible.

Table 1. TES plant species observations by plot number and global and state rarity rank.

SPECIES/RANK		PLOT NUMBERS
Agastache cusickii	G3G4 S1 3C	91RD 27
Arabis fecunda	G2 S2 C2	91RD 16; 91RD 17; 91RD 24
Arenaria kingii	G4 S1	91RD 29; 91RD 34; 91RD 31
Astragalus ceramicus v. apus	G4T3 S1 3C	91RD 37
Cryptantha fendleri	G4 S1	91RD 36; 91RD 38
Draba densifolia	G5 S2	91RD 14
Eriogonum ovalifolium v. celsum (nevadense)	G5T4 S2	91RD 35; 91RD 36; 91RD 37; 91RD 38; 91RD 39
Lesquerella (paysonii?)	G4 S1	91RD 26; 91RD 34; 91RD 41; 91RD 42

CONCLUSIONS

One function of the MTNHP is the development of a statewide database of plant community occurrences. A major limitation is the current lack of a comprehensive grassland/shrubland community classification. This study represents a step towards achieving such a comprehensive classification.

Another function of the MTNHP is to provide information regarding communities and sites for conservation. A classification such as this is necessary to define and identify key elements and sites in southwestern Montana for potential long-term preservation. Similarly, government agencies could use the classification for the identification and design of natural areas.

This classification can be usefully applied in stratifying vegetation/environmental variation to assess management options and results. The classification can also assist in minimizing impacts from intensive management by identifying sensitive plant communities (e.g., Agropyron dasystachyum/Phacelia hastata). The classification also provides a tool for baseline monitoring and predicting long-term vegetation responses to management activities. This capability would also assist agencies in meeting regulatory mandates (e.g., requirements of FLPMA).

Even following this study, existing classifications and data inadequately describe the grassland and shrubland communities of Montana. Major additional field sampling is necessary before a comprehensive grassland/shrubland community classification can be developed. Additional grassland/shrubland studies are planned in Montana over the next two years. This effort will provide additional knowledge regarding community patterns, processes, and physical environment relations. Such knowledge will be invaluable towards developing full capability to inventory Montana communities and to increase predictive capability (e.g., build vegetation and biodiversity models).

LITERATURE CITED

Bourgeron, P. and L. Engelking. 1991. Western regional community classification (Draft). The Nature Conservancy, Boulder, CO.

Chaffee, G.B. 1981. Vegetation report, Limestone Hills quarry area. Report prepared for Continental Lime, Inc. by ECON Inc., Helena, MT.

Cooper, S.V. and R.D. Pfister. 1981. Forest habitat types of the Blackfeet Indian Reservation. Review draft, 5/21/81, for Bureau of Indian Affairs, Wind River Agency, Fort Washakie, WY.

Cooper, S.V. and R.D. Pfister. 1985. Forest habitat types of the Crow and Northern Cheyenne Indian Reservations. Termination report to Bureau of Indian Affairs, Billings Area Office (draft). USDA Forest Service, Intermountain Forest and Range Experiment Station, Ogden, UT.

DeVelice, R.L. 1991. MTNHP site and community survey manual. Version 91B. Montana Natural Heritage Program, Helena, MT.

DeVelice, R.L., J. Lichthardt, and P.S. Bourgeron. 1991. A preliminary classification of the plant communities of northeastern Montana. Montana Natural Heritage Program, Helena, MT.

Dorn, R.D. 1984. Vascular plants of Montana. Mountain West Publishing, Cheyenne, WY.

Hansen, P.L. 1985. An ecological study of the vegetation of the Grand River/Cedar River, Sioux, and Ashland districts of the Custer National Forest. Unpublished dissertation. South Dakota State University, Brookings, SD.

Hansen, P.L. and G.R. Hoffman. 1985. An ecological study of the vegetation of the Grand River/Cedar River, Sioux, and Ashland districts of the Custer National Forest: a habitat type classification. USDA Forest Service Cooperative Agreement No. RM-80-131-CA.

Hansen, P., R. Pfister, J. Joy, D. Svoboda, K. Boggs, L. Myers, S. Chadde, and J. Pierce. 1989. Classification and management of riparian sites in southwestern Montana. Draft version 2. Montana Riparian Association, School of Forestry, University of Montana, Missoula, MT.

Hansen, P., K. Boggs, R. Pfister, and J. Joy. 1991. Classification and management of riparian and wetland sites in Montana. Draft version 1. Montana Riparian Association, School of Forestry, University of Montana, Missoula, MT.

Harvey, S.J. 1982. Vegetation of Musselshell and Petroleum counties, Montana. Unpublished report to the Soil Conservation Service, Roundup, MT.

Hill, M.O. 1979a. TWINSPAN: A FORTRAN program for arranging multivariate data in an ordered two-way table by classification of the individuals and attributes. Ecology and Systematics, Cornell University, Ithaca, NY.

Hill, M.O. 1979b. DECORANA: A FORTRAN program for detrended correspondence analysis and reciprocal averaging. Ecology and Systematics, Cornell University, Ithaca, NY.

Hitchcock, C.L. and A. Cronquist. 1973. Flora of the Pacific Northwest. University of Washington Press, Seattle, WA.

Hoffman, G.R. and P.L. Hansen. 1981. Habitat types of the Custer National Forest. USDA Forest Service Contract No. RM-RFP-80-131-CA.

Jorgensen, H.E. 1979. Vegetation of the Yellow Water Triangle, Montana. Montana Department of Fish and Game, in cooperation with the Bureau of Land Management. Helena, MT.

Mohler, C.L. 1987. Cornell ecology programs: MS-DOS microcomputer package. Microcomputer Power, Ithaca, NY.

Montagne, J.M. 1972. Quaternary system, Wisconsin glaciation. In W.M. Mallory, et al. (eds.). Geologic Atlas of the Rocky Mountain Region. Rocky Mountain Association of Geologists. Hershfield Press, Denver, CO.

Montagne, C., L.C. Munn, G.A. Nielsen, J.W. Rogers, and H.E. Hunter. 1982. Soils of Montana. Bulletin 744. Montana Agricultural Experiment Station, Montana State University, Bozeman, MT.

MTNHP. 1990. Guide to the natural vegetation of Montana (draft). Montana Natural Heritage Program, Helena, MT.

Mueggler, W.F. and W.L. Stewart. 1980. Grassland and shrubland habitat types of western Montana. USDA Forest Service General Technical Report INT-66.

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

Roberts, D.W. 1980. Forest habitat types of the Bear's Paw Mountains and Little Rocky Mountains, Montana. Unpublished M.S. thesis, University of Montana, Missoula, MT.

Rollins, R.C. 1984. Studies in the Cruciferae of western North America II. Contributions to the Gray Herbarium 214:1-18.

Rollins, R.C. and E.A. Shaw. 1973. The genus Lesquerella (Cruciferae) in North America. Harvard University Press, Cambridge, MA.

Ross, R.L. and H.E. Hunter. 1976. Climax vegetation of Montana based on soils and climate. USDA Soil Conservation Service, Bozeman, MT.

Ter Braak, C.J.F. 1988. CANOCO--A FORTRAN program for canonical community ordination by (partial) (detrended) (canonical) correspondence analysis, principal component analysis and redundancy analysis (Version 2.1). TNO Institute of Applied Computer Science, Wageningen, The Netherlands.

USDA (United States Department of Agriculture). 1987. Ecosystem classification handbook. FSH 12/87 R-1 SUPP 1. USDA Forest Service, Northern Region, Missoula, MT.

Veseth, R. and C. Montagne. 1980. Geologic parent materials of Montana soils. Bulletin 721. Montana Agricultural Experiment Station, Montana State University, Bozeman, MT.