STEPPE VEGETATION OF WASHINGTON

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KEY TO MAJOR STEPPE HABITAT TYPES IN EASTERN WASHINGTON AND NORTHERN IDAHO

The following key is applicable to stands that have not been greatly modified by grazing or fire. To identify others, the broad geographic position, the position in the local vegetation mosaic, the character of the soil, and the types of plants that have invaded disturbed soil are additional criteria that are highly useful.

1. *Agropyron spicatum* well represented; *Stipa comata* absent; woody plants not forming a closed canopy
  2. *Festuca idahoensis* occurring with the *Agropyron*
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        12. Soil deeper, with at least the upper 30cm relatively free of stones .... AGROPYRON SPICATUM-POA SECUNDA H.T. p. 18

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  13. Woody plants, if present, well spaced
    14. *Distinchlis stricta* very abundant; soils saline alkali
      15. Taller plants virtually absent .... DISTICHLIS STRICTA H.T. p. 50
      15. Taller plants conspicuous
        16. *Elymus cinereus* abundant; *Sarcobatus* absent .... ELYMUS CINERUS-DISTICHLIS STRICTA H.T. p. 50
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STEPPE VEGETATION OF WASHINGTON

R. DAUBENMIRE[1]

SUMMARY

An attempt has been made to determine the character of the pre-Caucasian types of vegetation in the steppe region of Washington, and investigate their distribution and environmental controls. Detailed quantitative analyses are presented for most of the 262 stands of virgin or near-virgin vegetation that have been located. Although the primary emphasis is on describing vegetative components of the ecosystem types and their distribution, enough climatic and soil data have been assembled to suggest the major factors controlling much of the vegetation pattern.

Most of the pre-Caucasian vegetation that has not been destroyed by cultivation or water impoundment has been modified by fire or grazing. Therefore, emphasis is appropriately on "habitat types," each of which is composed of all those areas that could support (if they do not still support) the same kind of stable plant community. The potential vegetation, under both disturbed and undisturbed conditions, of each of 40 habitat types is characterized. In addition, all published information that can be related to specific habitat types is brought together, including references to the occurrence of the types outside of Washington. A key is provided to facilitate identification of areas as to habitat type in those places where the vegetation has not been extremely disturbed.

Broad generalizations that can be drawn from the study as a whole concern species diversity, successional convergence resulting from disturbance, the significance of coverage sums, and the relation between the vegetation pattern and climatic classifications or soil classifications.

INTRODUCTION

Objectives

More than 6,000,000 hectares (24,000 square miles) of land in the eastern half of the State of Washington are too arid to support natural forest on the uplands. When first seen by white man a century and a half ago, the region was a steppe. The study here reported attempts to determine the character of the vegetation mosaic as it was when white man appeared on the scene, to establish the broad relationships of the different community-types to climate and soil, and to determine how fire and grazing modify the types.

Owing to the pervasiveness of white man's influences, very few fragments of primeval vegetation are left upon which to base such a study. Nearly all the land has been either cultivated or grazed heavily by domestic livestock. Fortunately, an early period of unrestricted grazing did not significantly alter much of the vegetation before agriculture began to make heavy demands for space. Fencing then aggravated the natural scarcity of watering places for domestic animals so that the range of their activity was drastically reduced. In consequence, it has been possible through diligent search spanning three decades to find scraps of apparently virgin vegetation in fence-corners, road right-of-ways, old cemeteries, and in places simply too remote from water to be grazed.

Still another major change in land use now under way is taking a further toll of natural vegetation. New hydroelectric dams are bringing an ever-increasing amount of land under irrigated cropping and creating high water tables where none existed before. However, there will always be a residue of land unsuited to any form of agriculture now practiced, owing to steepness of the topography, frequent interruption of good soil by rock outcroppings, stoniness, or elevation above irrigation systems. Such land will be valuable chiefly for the forage it can produce. Therefore, a study of the vegetation is not only of value from an historical and academic standpoint, but it should find direct application in managing residual grazing lands so they will provide the maximum sustained yield of forage.

Range management in North America has been dominated by the narrow view that only the few plants of direct use or detriment are worth consideration. In central Europe, as here, only a few species provide the bulk of forage in pastures; but there it has been recognized that to manage the grasslands in even a limited area properly, the autecologies of some 400-500 species must be understood, for plants of low economic value can have very high indicator significance (73). In view of the recent trend in North America to adopt the broader view, the ecosystem details presented here may find increasing use in managing rangelands more efficiently in Washington.

The vegetation of nonarable lands also bears a potential economic relationship to that of interspersed cropland by way of animals, especially insects that may rest, feed and ovulate in different plant communities (4, 31, 39). In the *Artemisia tridentata* region of southern Idaho, for example, an insect vector of a sugar beet disease has close relationships with unmanaged vegetation near croplands (92).

In an age when soil profiles that have evolved over millennia are being modified by man with increasing rapidity, technical descriptions of this component of pristine ecosystems are also worth recording, especially when they can be directly related to detailed botanical analyses made at each site. The relationship between vegetation and soil classification is in dispute, and the data obtained in this study definitely contribute to clarifying the situation.

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[1]Former Professor of Botany, Washington State University. Work was conducted under agricultural experiment station project 1224 and regional project W 25.

Acknowledgments

In 1938, 1939, and 1940, the Northwest Scientific Association made grants in aid to me to continue my work mainly in the eastern part of the steppe region. Later R. M. Turner contributed extensive reconnaissance work in the western part of the steppe. Then for a short while, limited funds provided for Biological and Medical Research by the State of Washington Initiative 171 were available. In 1954, the first substantial support was obtained when the studies were accepted as part of a Western Region study, W-25, "Ecology and improvement of brush-infested rangelands," and the Washington Agricultural Experiment Station allocated money from its regional research funds for this work. The results of all these increments of study are combined here.

It is a pleasure also to acknowledge the excellent cooperation of W. A. Starr, R. A. Gilkeson and S. H. Krashevski of the Washington State Soil Survey, who prepared detailed descriptions of the soil profiles at most of the sites where vegetation has been studied quantitatively. Jared Davis, Wayne Hanson, R. C. Pendleton, and W. H. Rickard of Biological Operations, General Electric Corporation, or of Battelle Northwest, at Richland, Washington, have been most helpful in facilitating studies on the Hanford Atomic Energy Reservation. Al Dick, Curtis Brooks, and Bill Larson donated land and labor for establishing exclosures which have been and will continue to be of great use in experimentation and in studying the life histories of plants in natural communities. Marvin D. Magnuson of the U.S. Weather Bureau supplied evapotranspiration calculations helpful in evaluating the climatic relationships of the vegetation. Harry Wegeleben generously shared his intimate knowldege of relic areas in the Goldendale region. Species of *Allium* and *Castilleja* have been identified by M. Ownbey. Jean B. Daubenmire contributed much valuable assistance in the field. Other assistance will be indicated at appropriate places.

Simultaneous studies concerning similar vegetation in adjacent areas, carried on by C. E. Poulton (Oregon), by E. W. Tisdale (Idaho) and A. McLean (British Columbia), have provided a unique opportunity for correlating work. Visiting each other's study areas and discussing them in the field has promoted more uniform synecologic treatment of the association concept and the naming of classification units. The advantages of such correlation are obvious when one considers their importance for the extrapolation of experimental studies in vegetation management from one region to another, and for the ultimate synthesis of the work into one coherent treatment of the regional vegetation patterns. These colleagues have, in addition, offered helpful criticisms of this manuscript.

Methods

If a serious attempt is to be made to correlate quantitative characters of a unit of vegetation (i.e., a "stand") with a particular soil (i.e., a "pedon") and a particular microclimate, then the vegetation unit must have maximum homogeneity, with the soil sampled near the center of the unit. A stand was considered homogeneous if on inspection the direction and percent slope were uniform, and variation in the community seemed more a result of chance rather than a result of soil heterogeneity, or variation in the time since the last fire or other disturbance. But homogeneity is always relative, and certainly the larger the sample the greater the probability of including significant variation in vegetation owing to hidden soil features, microrelief, unequal age, etc. It was therefore considered desirable to use the smallest sample that can be considered adequate. Previous study has shown that a sample of 4 m^2 provides closely reproduceable statistics for most species of herbs and shrubs in the community under study (24).

To sample a stand, a series of 40 plots 20 x 50 cm each were arranged along a line that followed a contour in an effort to remain within one phase of the soil catena. Any plots falling on paths, boulders, etc., were viewed as fragments of different minuscule ecosystems other than the matrix under study and objectively located substitutions were made by adding plots at the end of the line. Where necessary to maintain homogeneity throughout the series, the 40 plots were contiguous; but usually were spaced at half meter marks on the tape.

Canopy coverage. Coverage constitutes a simple but useful criterion of the relative importance of plants in a community and their impact on the remainder of the ecosystem. It has the tremendous advantage of allowing direct comparison of green macrophytes of all sizes on a common basis. It is more closely related to the amount of forage available than is any other readily determined parameter of a community (1).

Canopy coverage is defined as the percentage of ground surface incuded in the vertical projection of a polygon drawn about the extremities of the undisturbed foliage of a plant. Discontinuities within the canopy of one plant are ignored, as the aim is to evaluate each species with respect to the horizontal extent of its influence on soil, microclimate, animals and other kinds of plants. Each species is evaluated independently, and because the canopies of tall and low plants are superimposed, total canopy coverage for an area can far exceed 100%. In fact, the extent to which it exceeds this value measures the interlocking and overlapping of spheres of influence of the species, hence has been a useful criterion of the complexity of plant cover.

Two applications of the canopy coverage technique have been made. At the reconnaissance level, a complete taxonomic list was made for the vascular plants of an arbitrarily delimited stand approximately 5 x 5 m. Then estimates of coverage were recorded for each taxon by six coverage classes: 1 (0-5% coverage), 2 (5-25%), 3 (25-50%), 4 (50-75%), 5 (75-95%), and 6 (95-100%).

At a more intensive level of study, a coverage estimate was made for each species in each of 40 plots, 20 x 50 cm, using the coverage classes listed above. Midpoints of the percentage range for each coverage class recorded in the field were later averaged to obtain an estimate of the coverage of each species encountered in the 40 plots. The added labor required by this variant of the method is justified when an attempt is to be made to correlate quantitatively vegetation composition with environmental measurements, or where later reexamination of the plots is contemplated to document successional changes. With large plants that are erratically scattered, such as *Artemisia* or *Purshia*, this intensity of sampling does not yield coverage values of high accuracy. However, as I have shown previously, a line of plots usually shows canopy coverage with an error seldom rising to 5% for these large plants. Even this can be reduced considerably simply by doubling the number of plots for just these larger plants. For most small shrubs and herbs, the method gives highly reproduceable coverage estimates.

The number of species having any coverage in the 40 plots in a stand has been used as a criterion of species diversity, with aliens ignored. The populations of such species, mostly very small annuals, are so sparse in the virgin and near-virgin stands that have been selected for study that it is highly doubtful if they have displaced any indigenes, yet the number of aliens is considerable. If included in a study where quantities were not taken into account, they would bias any statistic used to express the character of pre-Caucasian vegetation in eastern Washington.

In addition to the quantitatively analysed flora that occurred in the plots (4 m^2 total), a supplemental list was made of any other species observed elsewhere in the same stand.

Frequency. The percentage of the 40 plots containing any coverage of a species is recorded in appendix B as frequency.

The relative magnitude of a frequency rating, when compared with the relative magnitude of the corresponding coverage value, provides an index of the uniformity of distribution of influence exerted by that species in the stand. For example, a plant with high frequency and low coverage must be contributing small amounts of cover rather uniformly over the stand. Among annuals, most of which have small coverage, frequency seems a more sensitive measure of their relative importance to each other than does coverage. On the other hand, some of these annuals indicate past disturbance in proportion to their coverage.

Appendix B includes the complete species lists, along with coverage and frequency values, and data on location, soils, etc. In this tabulation the county is indicated by the first five letters of its name. An entry of 10·50 signifies a mean canopy coverage between 9.6 and 10.5% and a frequency of 50%. An entry of +·2 indicates a mean coverage less than 0.6% and an occurrence in only one of the plots. Occurrence in the stand but not in any of the plots is shown by a +.

The segregation of woody taxa in the appendix into height classes called low shrubs, medium shrubs, tall shrubs and low trees corresponds with Raunkiaer's life-form classes: chamaephytes, nanophanerophytes, microphanerophytes and mesophanerophytes.

Considerable space has been saved in tabulation by entering the figure 99 wherever the actual frequency was 100%. These substitutions can be recognized since a real value of 99% is an impossibility when 40 plots are tallied.

Phenologic data have been obtained at only two stations, but these represent most of the ranges of moisture and temperature of the zonal climaxes in the Washington steppe. At each visit, notes were made as to whether each species was photosynthetically active or pollinating. In the communities studied all the species flowered during the period of their photosynthetic activity. All vasculares encountered in the 40 sample plots which had been studied in these two stands were included in the phenologic study, except that aliens were ignored. The aliens were nearly all winter annuals present only in traces, and would have biased data for the stand as a whole in favor of their distinctive type of phenology. Observations were more frequent during spring and early summer than in seasons of lesser activity. If any two individuals exhibited activity, the population of the species as a whole was recorded as active. Since such observations were scattered over several years with varying weather, the diagrams portray extreme dates of activity, and the data must be considered as approximating the maximal duration of activity rather than the mean range.

Productivity. To determine productivity by clipping takes so long that this type of evaluation was made at only a few representative sites. Usually four to ten plots, each 1 x 1 or 0.5 x 2 m in dimensions, were clipped at a time in April or May when the leaves of *Poa secunda* were fully developed yet green, and then in May or June when the fruits of the taller perennial grasses were almost mature. Other species were clipped at whichever of these dates came closest to their maximum seasonal development. A few early spring annuals had to be clipped in April. All herbs were clipped within 5 mm of the ground surface, air-dried, desiccated in a ventilated oven at 70 C for 24 hours, then weighed.

As with most productivity studies in vegetation having a dormant season, the aim has been to evaluate the terminal standing crop of shoot material. In addition to the usual sources of error, note that the new leaves put forth by many of our plants with the return of the rains in autumn may senesce well before the date in spring when the shoot as a whole has reached its maximum size.

An attempt was made to get a crude estimate of productivity of *Artemisia tridentata* by calibrating canopy coverage against dry matter. A few shrubs representing the principal range in size were selected. Then, all the current season's foliage was removed, along with the twigs to which it was attached. The canopy coverage of each of these plants was determined from measurements of eight equally spaced radii so that the oven-dry weight of new growth could be expressed per unit of canopy coverage. This value was then applied to the numerous data obtained in the 20 x 50 cm plots to estimate the productivity of this shrub.

Four plants were so analysed in an *Artemisia tridentata-Agropyron* stand, and four in an *Artemisia tridentata-Stipa* stand. The values obtained were 170.2 ± 16.8 (S.E.) g/m^2 and 187.7 ± 3.3 g/m^2, respectively, and these have been applied according to whether the *Agropyron* or the *Stipa* was the principal grass.

Soil sampling. A single pit for describing the soil profile was dug near the center of the line along which the 20 x 50 cm plots were arranged. These descriptions are too voluminous to publish in their entirety, but two of them suggesting the range of soils in most habitat types are given. Others that are available in the main file of ecosystem data can be recognized in appendix B as those for which the color of the darkest horizon is given.

A special series of soil samples for laboratory analysis was collected at most of the study sites, segmenting the profiles by decimeter horizons. This practice is fairly satisfactory in our steppe soils, since the horizons for the most part are poorly differentiated. These samples were analysed for pH, electrical conductivity, and moisture equivalent, since reaction, salinity and effective texture are generally important in differentiating vegetation in arid regions.

Another series of soil samples was obtained at representative sites for analysis in the Soil Testing Laboratory at Washington State University. These samples represented the upper 20 cm of the profiles. As in the series of samples mentioned above, particles exceeding 2 mm were discarded. The remainder were analysed for organic matter, base exchange capacity, percent base saturation, extractable P and K, and exchangeable Ca, Mg, Na, and K.

For a few of the study sites, glasshouse tests of the growth of native dominants were made in fertilized and unfertilized soils with the water content held rather constantly at either the moisture equivalent or field capacity by weighing the cultures. Since early seedling growth was to be evaluated, it seemed appropriate to use only the upper 20 cm of the profile for these tests. Chemical amendments were made according to the methods of Kitchen, et al. (72), Hoagland and Arnon (54), or Jenny, et al. (63). Each culture consisted of 4-9 plants growing in about 1300 g air-dry soil in metal cans that were well coated inside with asphaltum or polyethylene films, and shaded from direct insolation outside. Three or four cultures replicated each treatment.

Soil depth over bedrock has an obvious bearing on the distribution of communities and their productivity. An attempt was made to evaluate soil depth plus stoniness by Viro's method (122), although Viro devised the technique for estimating floating stones alone. At a season when the profile was moist, a sharpened steel rod ⅜″ in diameter with a cross-bar at the top for a handle was pushed into the soil at right angles to the surface. When the point was stopped by a stone or bedrock, the depth was recorded in centimeters. Fifty to 100 systematically spaced measurements were averaged as a sample.

Taxonomic considerations

An effort was made to identify and list all species of vascular plants in all the stands, regardless of any assumptions as to their relative importance. No attempt has been made to collect every species from every stand, but representative specimens of nearly all taxa have been filed in the herbarium at Washington State University. Identification was carried to the subspecific level where feasible, but where such distinctions rest on very ephemeral characters this was not practical. Furthermore, under the intense competition in climax vegetation, many species flower very sparingly and so cannot always be determined with certainty. Nomenclature for dicots follows Hitchcock, et al. (53), and nomenclature for monocots follows Davis (32), with two exceptions. *Agropyron spicatum* includes what has passed as *A. inerme,* this procedure being based on cytogenetic evidence of Stebbins and Pun (110) and progeny tests of Daubenmire (25). *Stipa williamsii* has likewise been treated as a pubescent form of *S. columbiana* undeserving of nomenclature or ecologic recognition.

Species and subspecies distinguished on the basis of morphology by at least some taxonomists have been found growing intermingled in the same population and pollinating at the same time,—a circumstance which casts doubt on the biologic merits of the separation. For such a reason, *Polygonum majus* has been included under *P. douglasii,* and subspecific categories in *Erigeron poliospermus, Dodecatheon pauciflorus, Lomatium triternatum,* and *Phlox longifolia* have been lumped. Varieties of *Chrysothamnus viscidiflorus* have not been recognized, for in the keys considerable emphasis is laid on plant height, and individuals in climax stands are always shorter than those growing at the margins of the stand on disturbed ground. Plants in the climax stands flower so weakly that this source of material is probably without representation in herbaria. It is felt that the var. *pubescens* corresponds closely with the plants in climax vegetation, yet rare individuals are glabrous.

A contrasted type of problem is presented by *Poa secunda,* which in the same habitat is commonly represented by two or more populations distinct as to morphology and often phenology as well (see Daubenmire 5340, 5517 and 5525 in Washington State Univ. Herb.). While it is not practical to recognize these variants, at least their existence should be recorded. I agree with Marsh (82) that *P. secunda* and *P. ampla* intergrade completely in many places, and in some stands (e.g., 77 and 123) my segregation was highly arbitrary.

Synecologic perspective and terminology

The philosophy has been accepted that any basic study of a vegetation mosaic must begin with emphasis on the relatively stable (i.e., climax) communities. After their structure and ecology have been worked out, it is not difficult to infer which climax disturbed vegetation has been derived from.

Since so much emphasis was accorded the climax status, it is appropriate to indicate the criteria used in its recognition. A stand of vegetation was considered climax if:

1. all young perennials that appeared successful in the community are represented by old individuals in the same stand,

2. alien species were absent, or if present were represented by few individuals of low vigor,

3. fire-sensitive species native to the area were not conspicuously absent.

Association tables (appendix B) show that stands meeting these requirements are remarkably similar over wide area, in contrast with the endless variety exhibited by stands that have been disturbed to varying degrees by fire or grazing. Such results lend confidence to a belief that essentially pristine remnants still exist and that these criteria have permitted their recognition.

Each type of climax, distinguished by close similarity in the dominants of all layers of vascular plants, is called an *association,* and every effort was made to include stands representing each association over as wide a range of environment as possible. The vegetation has been rather finely subdivided to bring to light as much detail as possible, for indiscriminate lumping can obscure much that is ecologically significant. As the steppe vegetation of the intermountain area becomes better known, it may be desirable to lump some of the types that are here separated, especially to meet practical need in range management. On the other hand, if it should prove desirable to split some of my groupings, the availability of the data for each stand makes this an easy task. It should be noted that the diagnostic characters listed first in the treatment of each association are the minimum needed for distinguishing the type only as it occurs in Washington. Emendations will undoubtedly be necessary as other tracts of closely related vegetation in surrounding areas are studied in detail.

The aggregate of all areas that support, or can support, the same primary climax is a *habitat type,* usually abbreviated as h.t. By emphasizing habitat types (h.ts.) the treatment of the region's ecosystems is simplified, for each kind of environment has distinctive potentialities as to pristine and derived types of communities.

Wherever large and ecologically heterogeneous vegetation categories have been considered adequate for some special purpose, these have been defined easily on the basis of dominants alone. But major dominants are usually species of wide distribution occurring in a variety of contrasted habitats, as indicated by wide differences in associated species. Therefore, discriminative study leads to dependence on minor species as indicators of smaller units of greater ecologic homogeneity, and such minor species are appropriately brought into the names of the associations. However, it is important for the reader to understand that the names given the associations cannot always indicate the most abundant or conspicuous plants.

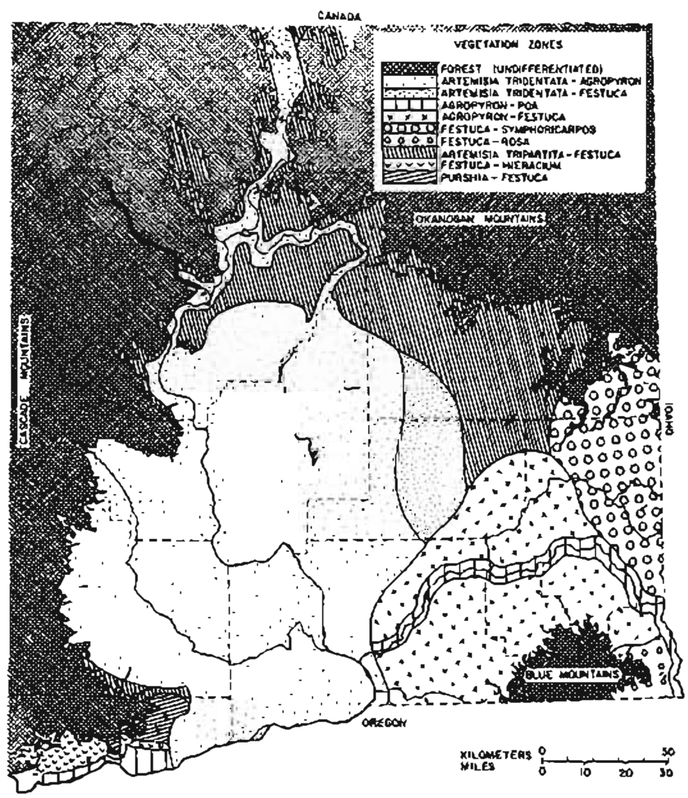
Another caution is needed. Any one ecosystem has a list of characters, biotic and abiotic, that collectively distinguish it. Single examples of an ecosystem-type often lack one or more of the characters that usually distinguish it, but the example can still be placed in its proper category by noting the remainder of the defining characters. Therefore, it should be kept in mind that an occasional stand named after a combination of species that is usually highly distinctive for the ecosystem may lack one of the characteristic species owing to accidents of dispersal.

In several situations, two or more associations showed complete intergradation with each other over a long series of intermediates. One has the alternative of referring to such a group collectively as a single variable association sometimes represented by simplified segregates, or recognizing the extremes as associations that are connected by a complete series of intergrades. The latter is certainly the more convenient from the standpoint of nomenclature. What is more important, it tends to stimulate search for the environmental conditions controlling variation within the series.

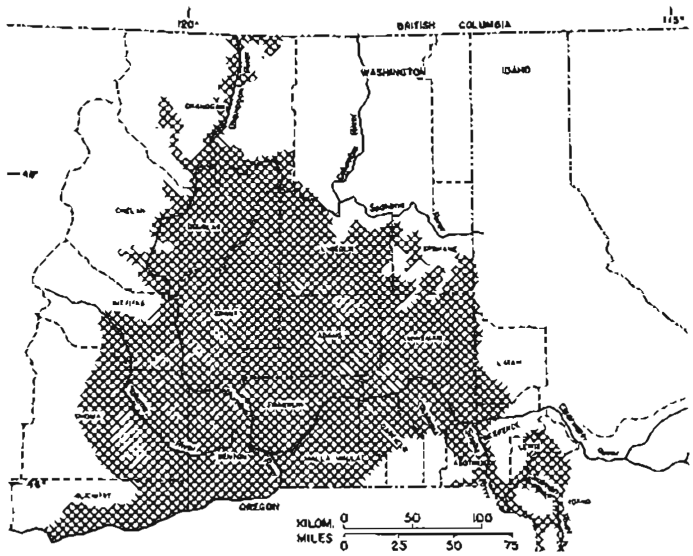
The amount of information available for vegetation, animal life, soils, climate and total geographic ranges of the 40 habitat types treated in this report is very unequal. It has been impossible to get much biotic information on some of them because they have been so disturbed that the opportunity seems to have been lost. For other groups of h.ts., it has been feasible only to characterize the group as a whole then indicate features that distinguish its members.

The stable communities of deep, nonstony loams that have gentle slope, are moderately drained, and have somewhat average chemical characteristics are referred to as *climatic climaxes.* Wherever soil becomes sufficiently shallow, stony, poorly drained, or chemically abnormal to produce a significantly different climax, this is called an *edaphic climax.* The term *topographic climax* refers to well-differentiated climaxes that are restricted to special microclimates such as those of slopes that face steeply to the south or the north, or the microclimates of frost-pockets. *Zootic climaxes* can be derived from any of the above primary climaxes and maintained by recurrent grazing and trampling.

Although all plant associations have climatic limits, only climatic climaxes show a pattern of mutually exclusive areas that fit together as a mosaic of *zones* (fig. 1). Only the climates of the zones have been studied directly. Data from weather stations in the zones have been used



1. Vegetation zones that comprise the steppe region of Washington, and the adjacent mountain systems. See figure 2 also.



2. Counties mentioned in the text, and major rivers.

to characterize their climates according to several proposed systems of climatic classification (appendix A). Zonal climates have also been compared from tabulation of calculated potential and actual evapotranspiration, De Martonne's monthly indices of water balance (precipitation in mm/temperature C+10), and mean monthly temperatures and median monthly precipitation using the period 1931-1952. In calculating water balance, abbreviated as P/T, mean monthly precipitation values have been used in the appendix classifications (as their authors intended); but in describing ecotones, median monthly values are employed.

These data have made it possible to express quantitatively certain differences in climates among the zones, and the nature of the differences suggests promising directions of research into the autecologies of the species whose distributions determine zone boundaries.

From appendix A it may be seen that except for the *Artemisia tridentata-Agropyron* zone (which has more weather stations than have been used at this time) relatively few stations have complete enough records to use in this study. In a direct assault on the climatic problems, the incomplete data for other stations might be adjusted and the results found useful.

The climatic ranges of associations other than the climatic climaxes have been indicated by listing the steppe zones in which they have been observed.

The physical setting

The steppe region of Washington occupies a basin, the Columbia Basin, that is encircled by forest-covered mountains (fig. 1). The floor of this basin was built up of numerous large flows of lava, mainly during Miocene time (13) that became downwarped so that the lava in the southwest corner now lies only 250 m above sea level, with the northerly and eastern margins remaining some 500 m higher.

The climate of this basin is characterized by moderately cold winters and warm to hot summers. The mean of the coldest month is between about -5.5 and 1.5 C; and the mean of the warmest month is between 18.5 and 24.5 C. Effective precipitation is mainly in the cold season, with the rains starting at about the time frost becomes frequent in autumn. While the wet winters are mild enough for intermittent photosynthesis and slow growth of many plants during warm weather, the great surge of growth and flowering is delayed until May and June. By this time, rainfall has diminished considerably and temperature is rising rapidly, so the ability of a soil to store water in winter and then support vigorous plant activity at the onset of summer becomes ecologically critical. The foliage of most upland herbs dies gradually as aridity intensifies during summer.

Air masses following the track of the westerlies cross the Cascade Mountains, which bound the steppe region on the west, then descend and become dry. This causes a strong rain shadow, which is why the Columbia Basin is too arid to support forest except along streambanks. At the leeward base of the Cascades where elevation is lowest, the median annual precipitation falls as low as 150 mm. As the air masses continue northeasterly up the gently rising floor of the basin, precipitation slowly increases until the annual total reaches as much as 550 mm just before steppe gives way to forest.

During Wisconsin glaciation, ice-caps barely extended onto the northern rim of the basin (95), but the location of this ice terminus was peculiarly critical, because the Columbia River flows westward along this margin of the steppe before it turns south at the base of the Cascades. From time to time, the Columbia flowing along the northern edge of the steppe was dammed by ice lobes, and large impoundments formed temporarily. At least once, an ice dam also blocked the Clark Fork River where it cuts through the Bitterroot Mountains and created a vast impoundment in Montana to the east of this bottleneck.Then the ice dam was breached rather suddenly when another ice lobe downstream was blocking the Columbia River where the Okanogan River empties into it. The water storage capacity of the Columbia Valley above the lower ice dam was vastly exceeded. The flood waters sought new routes in a southwesterly direction, reaching the Columbia Valley again at the southwest corner of the basin. Flooding of this type is believed to have occurred perhaps seven or more times (11).

Prior to the last glaciation, the basaltic floor of the basin had become rather thickly mantled with loess. During the glacial floods, a braided system of temporary streams quickly cut through the soft material to the basalt, leaving fusiform islands of loess enmeshed in a system of basalt-floored drainageways, some of which are quite wide. Locally, these nearly bare tracts of basalt are known as "scablands" and the equally dry canyons and deeply scoured valleys that were excavated in some of them are "coulees." Similar strips of basalt outcroppings have also been formed by other erosional processes on canyon rims well above the level of glacio-fluvial scouring.

A curious feature common to both flooded and unflooded scablands are small biscuit-like mounds of loess, commonly 1 m thick by 5 m in diameter, that are regularly dispersed over the otherwise bare surface of scabland outcroppings. This is the "biscuit and swale" topography of local usage. Differential erosion (124) and congeliturbation during glacial times (68) have been proposed as processes accounting for biscuit and swale topography.

Thin patches of alluvial material of wide variety were left on the floors of the scabland tracts that were scoured by melt-waters, but deep and extensive sheets of sandy outwash were deposited in the west-central part of the basin where water emerging from scabland tracts and coulees spread out before reentering the Columbia River.

Another substratal feature important in vegetation differentiation was caused by showers of volcanic ash drifting eastward from volcanoes in the Cascades. In places, this ash was blown or washed into hollows; elsewhere it was fixed in place by vegetation. The greatest ash shower was from the Mt. Mazama eruption in about 6600 B.P. (before present) and the next most important was an earlier one from the Glacier Peak eruption in about 12,000 B.P. (43). The ash from the newer eruption is relatively unweathered and fertile, but the older material from Glacier Peak is quite well weathered and infertile.

Because of aridity, saline-alkali conditions have developed locally in undrained depressions, especially on low stream terraces in the driest part of the basin.

Aborigines, grazing and fire

Archaeological investigations have shown that man has inhabited the steppe region of Washington for at least the last 12,000 years. Early man was a successful hunter, as fossils of large grazing mammals occur about the remains of his campfires (30). But the large mammals associated with the Ice Ages became extinct as climate warmed, and more modern forms, especially of ***Bison*** and ***Antelocapra*** invaded the steppe region from the south as the ice front receded. This newer fauna seems never to have spread much beyond the warmest and driest parts of the basin, and in post-hypsithermal time they dwindled steadily. In consequence, the aborigines came to depend more and more on fishing, so their villages became concentrated along streams where salmon and lampreys could be obtained readily.

Bison became extinct about 2,000 years ago (87). By the time the first white men came to eastern Washington, any antelope that might still have been present were very few and confined to the driest part of the steppe. The few deer and wapiti remained close to the forest border or to riparian thickets, and a few bighorn sheep lived on the basaltic ledges of the Columbia Valley from Grand Coulee southward. Thus the niche for grazing ungulates seems to have been fairly well occupied in late glacial time, but then became abandoned progressively.

About 1730 A.D., the aborigines acquired horses. This made a small change in their pattern of living, for it became practical to make brief excursions eastward across the Bitterroot Mountains into Montana to obtain bison meat, which was dried and packed home on animals.

There must undoubtedly have been excessive grazing pressure on the vegetation adjacent to the villages that were strung out along the rivers. Since the horses had to be herded closely against theft, vegetation damage was probably quite localized.

The first cattle were brought into the steppe region of Washington in 1834. It was estimated that the numbers had increased to about 200,000 by 1855 (19). Sheep raising developed principally in the 1880s, along with the rapid spread of agriculture at that time. It was during this period that wild horse herds became common in the steppe. The last of these were eliminated only during the course of the present investigation.

It should be apparent from the above that for many centuries before the arrival of white man, ungulate pressure played no significant part in the evolution of ecotypes of the steppe plants of Washington. East of the Rockies, where large herds of native ungulates have roamed uninterruptedly from Oligocene time to the present, rangelands recover quite rapidly when given respite from excessive animal use, but in no part of the Washington steppe has a restoration of density been documented. Each period of overuse by domestic animals simply reduces the density of the large perennial grasses to a lower level than the preceding, and highly adapted alien species claim the relinquished territory.

The striking inability of these native species to endure heavy use, or to regain population densities later, must reflect their long history of freedom from grazing pressure, at least in part. The aggressiveness of the aliens, notably ***Bromus tectorum*** and ***Poa pratensis,*** certainly contributes to the difficulty, for where these can be eradicated by cultivation, climate and soil permit the artificial establishment of good stands of the native grasses.

Cholis (14) opined that the vegetation of Washington rangelands was in better condition in 1950 than when Cotton (20) and Griffiths (46) surveyed and described them half a century earlier. After having examined many photographs made by H. L. Shantz in Washington in 1916 I am inclined to agree, for these photographs show extremely little grass associated with ***Artemisia tridentata,*** despite the fact that they were taken by a man primarily interested in characterizing the natural vegetation. However, the grasses must have been only grazed down severely, not killed, for a plant that has been depauperized by excessive grazing can respond very quickly to release from such pressure.

Sauer (106) wrote: "suppression of fire results in gradual recolonization by woody species in every grassland known to me." Sauer was suspicious of the fact that grassland herbs occur in the margins of contiguous forests, but floristic mixture is characteristic of nearly all ecotones, even those that occur under water! Sauer further contends that grassland climates are not consistently different from forest climates, but in Washington quantitative differences have been documented (23). The accounts of early white explorers tell of as much ***Artemisia*** spp. and ***Purshia*** in the Washington steppe as today. Inasmuch as fire readily kills both ***Artemisia tridentata*** and ***Purshia tridentata,*** their early widespread distribution disproves any opinion as to the omnipresence of fire. Since there were no game animals to be harvested by the use of fire, and fire is of little use in warfare when villages are along rivers, the aborigines had little incentive to burn steppe.

Stewart (111) shared Sauer's opinion: "It is my present considered opinion that all grasslands occurring on deep fertile soil are man-made, by peoples who periodically set fire to the grass and kept woody vegetation from growing . . . ." Then later Stewart (112) added that this opinion was "substantiated by a careful analysis of the natural vegetation on the Palouse prairie of interior Washington . . . . A modern scientific study of the region reveals that sagebrush will invade the grass if it is not periodically burned."

I have been unable to confirm any part of this commentary or to find any other reference to such a study. As will be detailed later in this report, the sagebrush *Artemisia tridentata* is an integral part of the natural vegetation in a well-defined sector of the steppe region of Washington and here it will reinvade after each fire, but soil and climate (not fire!) prevent it from invading any of the other types of steppe communities.

Thus, there is no evidence that the distribution of vegetation types or species in eastern Washington is related to the past use of fire. The types of stable vegetation that characterize the landscape mosaic can be quantitatively related to climate and soil in a way that provides an ecologically rational interpretation of the pattern.

THE ZONAL SERIES

If one confines attention to the stable vegetation of deep loams in gentle upland slopes, this component of the steppe can easily be divided into nine associations. Each of the latter, as a climatic climax, is confined to a particular sector of the steppe region. These sectors, which will be referred to as zones, all fit together as a mosaic (fig. 1). Zonal boundaries are interpreted as reflecting climatic limits critical in the determination of competitive balances among community dominants.

All soils that the pedologist would classify as "zonal" are (or were) fully occupied by these nine plant associations. However, from a vegetation standpoint, the pedologist has defined zonal soils so narrowly that each climatic climax spreads from zonal onto certain regosols that appear to provide essentially equivalent conditions for plant growth.

The nine vegetation zones can be segregated into two groups on the basis of climate, vegetation structure and floristics. One group comprising five zones is peripheral, forming a linear but interrupted series in the slightly arid climates found just below lower timberline, and encircling the other four. The peripheral five tend to be lush, meadow-like communities (the "meadow-steppe" of some European ecologists) that cover the ground densely and have a conspicuous amount of large perennial forbs mingled with the dominant grasses (fig. 3, bottom diagram). Zonal soils in this series are mainly in the Prairie (Brunizem) and Chernozem Great Soil Groups. Differences among the plant associations in the group are related more to differences in the seasonal distribution of precipitation than to the total annual amount. The latter is not quite adequate for forest to maintain itself on loamy uplands.

The remaining four vegetation zones that are encircled by the above group are more arid, differing among themselves either as to the intensity of aridity or the seasonal distribution of precipitation. The vegetation is more open, and forbs are less conspicuous (fig. 3, uppermost and middle diagrams).

In fig. 1, the line separating forest from steppe has been photographically reduced from a map of forest types (117) that is biased in that it includes with "forest" most of the belt in which forest and steppe interdigitate. Thus, steppe occupies considerably more area than is shown, and a number of my meadow-steppe study sites fall within the area that appears on the map as "forest."

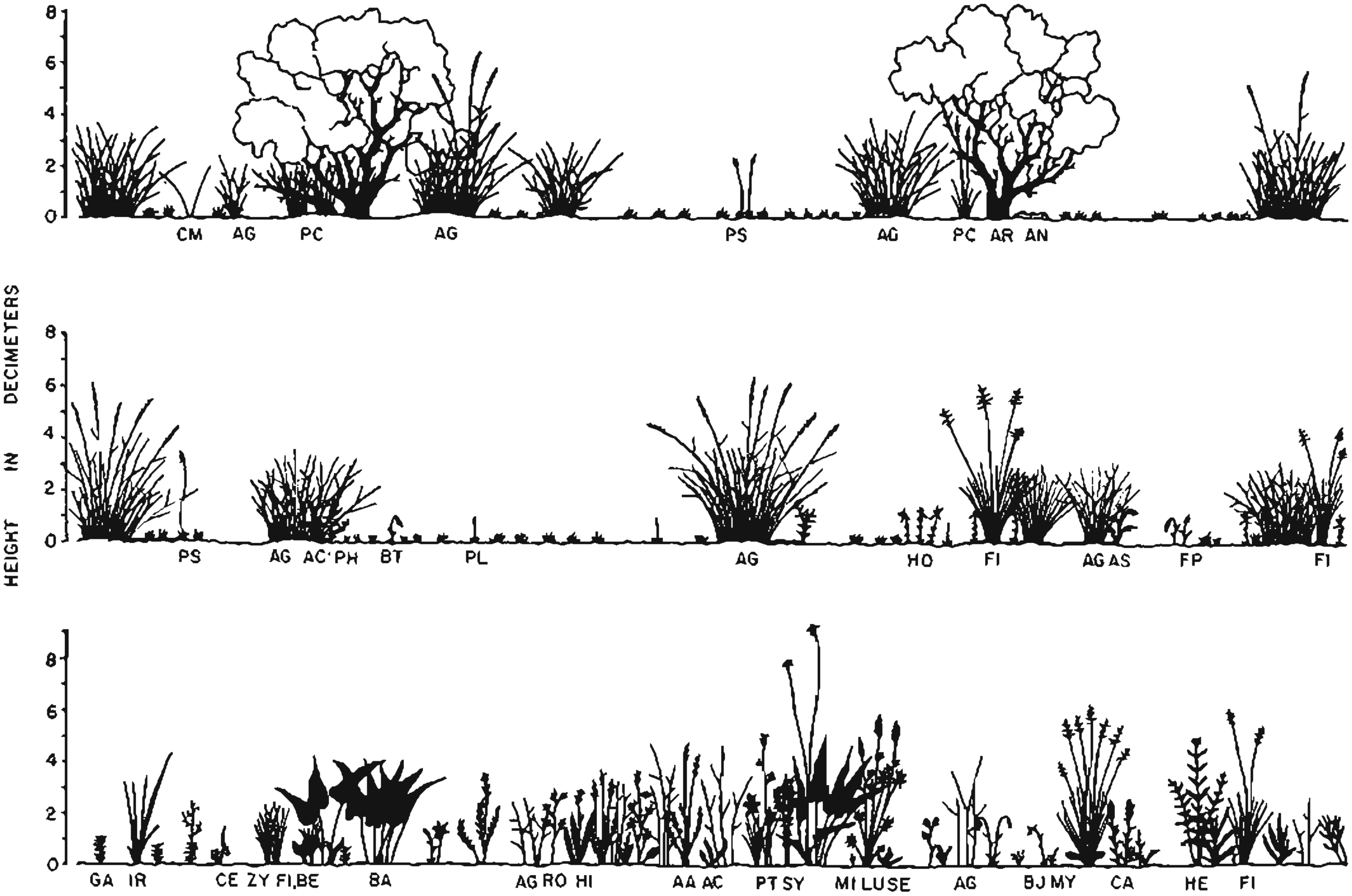
Boundaries of the steppe zones have been determined by plotting the distribution of relics on a map then drawing lines midway between the outposts representing contiguous types. Despite widespread destruction of the natural vegetation by agriculture, grazing, and fire, the map is believed to be accurate for the most part within 5 km of the original boundaries. Once the significant distinguishing characters of the vegetation types have been ascertained from well-preserved relics scattered within a zone, even tiny fragments of vegetation along fence lines can be highly useful in mapping.

Artemisia tridentata-Agropyron spicatum h.t.

Undisturbed vegetation in the *Artemisia tridentata-Agropyron* h.t. is distinguished by *Artemisia tridentata* ssp. *tridentata* as the principal shrub, and by *Agropyron spicatum* as the principal grass. Variable amounts of *Stipa comata, S. thurberiana, Poa cusickii* or *Sitanion hystrix* may be present, but even collectively their coverage never equals that of the *Agropyron*. *Festuca idahoensis* and *Purshia* are absent. The soils are mostly loams or stony loams.

The *Artemisia tridentata-Agropyron* association consists of four well-defined layers (fig. 3, uppermost diagram). The tallest is an irregular scattering of shrubs (fig. 4), among which the evergreen, gray-pubescent *Artemisia* is by far the best represented (appendix B-1). The density of this shrub was approximately 33 individuals per 100 m^2 at both stands 12 and 19. Very small amounts of one or more of *Chrysothamnus viscidiflorus, Tetradymia canescens, Chrysothamnus nauseosus* var. *albicaulis, Artemisia tripartita,* or *Grayia spinosa* may occur; these are listed somewhat in order of decreasing presence. *Artemisia tridentata* averages about 1 m high; associated are shrubs shorter, but on occasion (especially on moist sandy loams) the height of this *Artemisia* may exceed 2 m and the diameter 2 dm.

The second tallest layer consists chiefly of caespitose perennial grasses among which *Agropyron spicatum* is always the major species (appendix B-1). On a local scale, *Poa cusickii* is often restricted to north-facing slopes, this suggesting that it indicates a relatively moist facies of the association. However, when the stands in appendix B-1 are arranged according to the amount of *P. cusickii* they contain, none of the other data bear out such a hypothesis.



3. Representative physiognomic types in the zonal vegetation of the Washington steppe, as illustrated by profile drawings, to scale, of all vascular plants with any basal area impinging on a transect 2cm wide by 400cm long. Above: shrub steppe represented by *Artemisia tridentata-Agropyron* stand 27. Middle: true steppe represented by *Agropyron-Festuca* stand 60. Below: meadow steppe represented by *Festuca-Symphoricarpos* stand 155.

Key to species symbols:

Ac *Achillea lanulosa*
Ag *Agropyron spicatum*
An *Antennaria dimorpha*
Ar *Artemisia tridentata*
Aa *Astragalus palousensis*
As *Astragalus spaldingii*
Ba *Balsamorrhiza sagittata*
Be *Besseya rubra*
Bj *Bromus japonicus*
Bt *Bromus tectorum*
Ce *Calochortus elegans*
Cm *Calochortus macrocarpus*
Ca *Castilleja lutescens*
Fi *Festuca idahoensis*
Fp *Festuca pacifica*
Ga *Galium boreale*
He *Helianthella uniflora douglasii*
Hi *Hieraceum albertinum*
Ho *Holosteum umbellatum*
Ir *Iris missouriensis*
Lu *Lupinus sericeus*
Mi *Microsteris gracilis*
My *Myosotis micrantha*
Ph *Phlox longifolia*
Pl *Plantago patagonica*
Pc *Poa cusickii*
Ps *Poa secunda*
Pt *Potentilla gracilis*
Ro *Rosa spaldingii* or *R. nutkana*
Se *Senecio integerrimus exaltatus*
Zy *Zygadenus venenosus gramineus*

Neither does the distribution of *Stipa thurberiana* seem to reflect significant environmental variation when the data are arranged according to its representation.

For lack of any apparently better basis, the stands in the appendix are arranged according to Great Soil Groups. Even with this climatic implication, variation among the stands seems random rather than clinal. On the basis of coverage, even in the aggregate, perennial forbs are a minor constituent of this second layer. Owing to the openness of both the *Artemisia* and *Agropyron* layers, enough light penetrates for two other vegetation layers of lower stature to be well developed.

4. Stand 12, showing physiognomy characteristic of the *Artemisia tridentata-Agropyron spicatum* association in pristine condition.

Vasculares of a variety of life forms make up a third layer in which most of the vegetative shoots are well within 1 dm of the soil surface. Here the major species is clearly *Poa secunda*, a tiny, perennial, caespitose grass with coverage that varies from 13-75% in the stands studied. Most annuals in the association fit best into this stratum. The species that occur most regularly are, in order, *Bromus tectorum* (alien), *Festuca pacifica, Lappula redowskii, Descurainia pinnata* and *Gilia minutiflora*.

Owing to alternate freezing and thawing or wetting and drying, the surface of the soil is normally broken into a system of hexagonal areas about 1 dm across, separated by cracks 1-2 cm deep. Annuals often tend to be confined to such cracks. However, there is virtually no bare ground in the undisturbed climax, even in the driest part of the Washington steppe. Areas not occupied by the bases of vascular plants support a continuous but very thin and fragile crust of mainly crustose lichens, tiny acrocarpous mosses that rarely fruit (table 1) and occasionally, liverworts. This bottom layer is conspicuous only during the rainy season, since just a thin layer of dust settling on the fine-textured surface at the start of the dry season nearly obscures it.

A similar cryptogamic crust is characteristic of all but the saline-alkali soils in the Washington steppe. It is hard to imagine how dust storms such as we endure at present could have occurred before the advent of domestic animals. Measurements made half a century ago showed that the eastern (leeward) margin of the steppe was receiving about 1 cm of dust each decade through deflation of drier parts of the Columbia Basin (91).

An interesting feature of vegetation structure in some stands is the strong confinement of *Poa cusickii* to areas immediately beneath the canopies of *Artemisia* or *Grayia*, but not other shrubs. This shrub-dependence is conspicuous in some areas where *Poa* occurs (stands 20, 26, 27, 28 and 42 in appendix B-1) but unrecognizable in others.

Another dependency is conspicuous in that *Tortula* characteristically occurs in patches related to shrub canopies. In some stands it is also well represented beneath the overarching foliage of the tall grasses.

Epiphytic lichens (occasionally epiphytic mosses too)

Table 1. Representative mosses and lichens of the *Artemisia tridentata-Agropyron* association[a]

MOSSES

On soil:

Aloina rigida pilifera G	*Polytrichum piliferum* G
Bryum argenteum lanatum C	*Tortula brevipes* G
B. caespiticium C	*T. ruralis* C
Ceratodon purpureus C	

On stems of Artemisia:

Tortula ruralis C

LICHENS

On soil:

Acarospora	*Lecidea globifera* H
Candelaria vitellina H	*L.* (*icterica?*) H
Cladonia sp. H, W	*L. luridella* H, W
Collema (*tenax?*) W	*Leptogium pilosellum* H
Dermatocarpon hepaticum H	*Rannaria pezizoides* H
Diploschistes scruposus H, W	*Rinodina nimbosa* W
Lecanora gibbosa H	

On basalt stones:

Lecanora calcarea W	*Lecidea parasema* H
L. muralis W	

On stems of *Artemisia*:

Candelaria concolor H, W	*Physcia grisea* W
C. vitellina H	*P. pulverulenta argyphaea* H
Lecanora hageni W	*Rinodina sophoides*
Letharia vulpina W	*Xanthoria fallax* H, W
Parmelia esasperata H	*X. polycarpa* W
P. cf. *fuliginosa* W	

[a] Specialists who identified specimens submitted and have them as vouchers in their collections are indicated as:

C—Henry S. Conard	K—Wm. Bridge Cooke
G—Betty W. Higginbotham	W—William A. Weber
H—Albert W. Herre	

are abundant on the stems of shrubs. Long sequences of winter days with overcast skies, fog, or drizzling rain, with temperatures mostly above freezing, permit these plants to be intermittently active during the cool season.

As the dry season progresses, nearly all plants go into aestivation, one by one, except the larger shrubs. Mosses and the diminutive *Myosurus* and *Draba verna* (alien) complete their growth cycle and dry up late in April. *Poa* spp. remain active a few weeks longer. The largest grasses and forbs flower mostly in June; then their aerial parts start to desiccate.

The larger shrubs obviously depend on permanent supplies of moisture deep in the subsoil, for except for *Grayia*, their foliage remains active throughout summer. The leaves of *Artemisia tridentata* are produced early in summer then persist until well after a new crop of leaves appears next summer. Nearly all the other shrubs are leafless in winter. Flowering among these taller shrubs is spread over summer and autumn, beginning with *Tetradymia* in late June, and ending with *Artemisia tridentata* in October.

With the return of the rains in autumn, new leaves appear on the perennial grasses, and some of the annuals germinate. These plants then grow slowly and sporadically through winter, as above-freezing periods of weather permit. Most forbs, low shrubs and a few annuals remain dormant during the winter, confining their season of activity to spring and early summer.

Sociologic data for annuals are least informative of all the ecologic groups represented in the association tables, because not all species appear every year. Table 2 shows that the entire complement of annuals known to be present at these two sites has never shown up during the same year. Only three have appeared every year. Comparison of frequencies shows that *Festuca pacifica, F. octoflora* and *Bromus* tend to vary synchronously in degree of representation from year to year.

Net primary production for the *Artemisia tridentata-Agropyron* association varies from 72-115 $g/m^2/yr$, based on shoot material alone (appendix C). The yield of large perennial grasses, which comprise nearly all the useful forage, ranges from 35-57 $g/m^2/yr$ when not grazed. Stand 40, with the highest production, is nearest the moist eastern boundary of the *Artemisia tridentata-Agropyron* zone. Aside from this one record, most of the variation in values bears no apparent relation to position within the zone, altitude, or aspect. Since the determinations were made in different years, weather differences undoubtedly account for some of the variability.

Native mammals in the *Artemisia tridentata-Agropyron* h.t. today include coyote, badger, rabbits (black-tailed jackrabbit, white-tailed jackrabbit, cottontails and pigmy rabbit), chipmunk (where rock rubble is nearby), and mice. Most of these are common to most of the zones.

When stand 20 was analysed, the few *Stipa comata* plants were being rather heavily used by rabbits, whereas the *Agropyron* had not been eaten. Rabbits commonly keep *Phlox longifolia* grazed to a compact hemispheric cushion wherever these plants get established in openings, but individuals germinating under bunches of *Agropyron* and growing up through them expand to approximate the spread of the grass canopy before rabbits start to nibble the tips. Those directly underneath a large *Artemisia* often climb well over a meter, their flowers spreading over the top of the canopy to give the startling appearance of belonging to the *Artemisia*.

Rickard (96), analysing the small mammal populations of stable vegetation types in eastern Washington,

Table 2. Year to year variation in the frequency of annuals in permanent plots in *Artemisia tridentata-Agropyron* stands 42 and 43 (appendix B-1) which are located about 0.5 mile apart.

Species	Stand	% Frequency 1958	1959	1960	1961	1962	1963	1964
Festuca pacifica	42	92	100	32	88	58	90	80
	43	85	95	55	95	48	98	65
Festuca octoflora	42	92	85	40	88	30	98	47
	43	95	90	50	98	28	100	45
Bromus tectorum	42	45	90	55	62	18	50	52
	43	50	80	72	60	52	50	62
Lagophylla ramosissima	42	4						
	43	2	5	4	10			
Descurainia pinnata	42	18	20		25		18	2
	43	20		2	28	2	5	
Lappula redowskii	42	8	12		12			
	43	22	2		8			2
Draba verna	42	2		+			12	
	43		5		10		8	5
Cryptantha flaccida	42	12	10	4				
	43	2					2	
Linanthus pharnaceoides	42		2					
	43				2			
Gilia minutiflora	42		2					
	43		5					

had one station in the *Artemisia tridentata-Agropyron* association as defined in this publication. For a summary of his data, see appendix E.

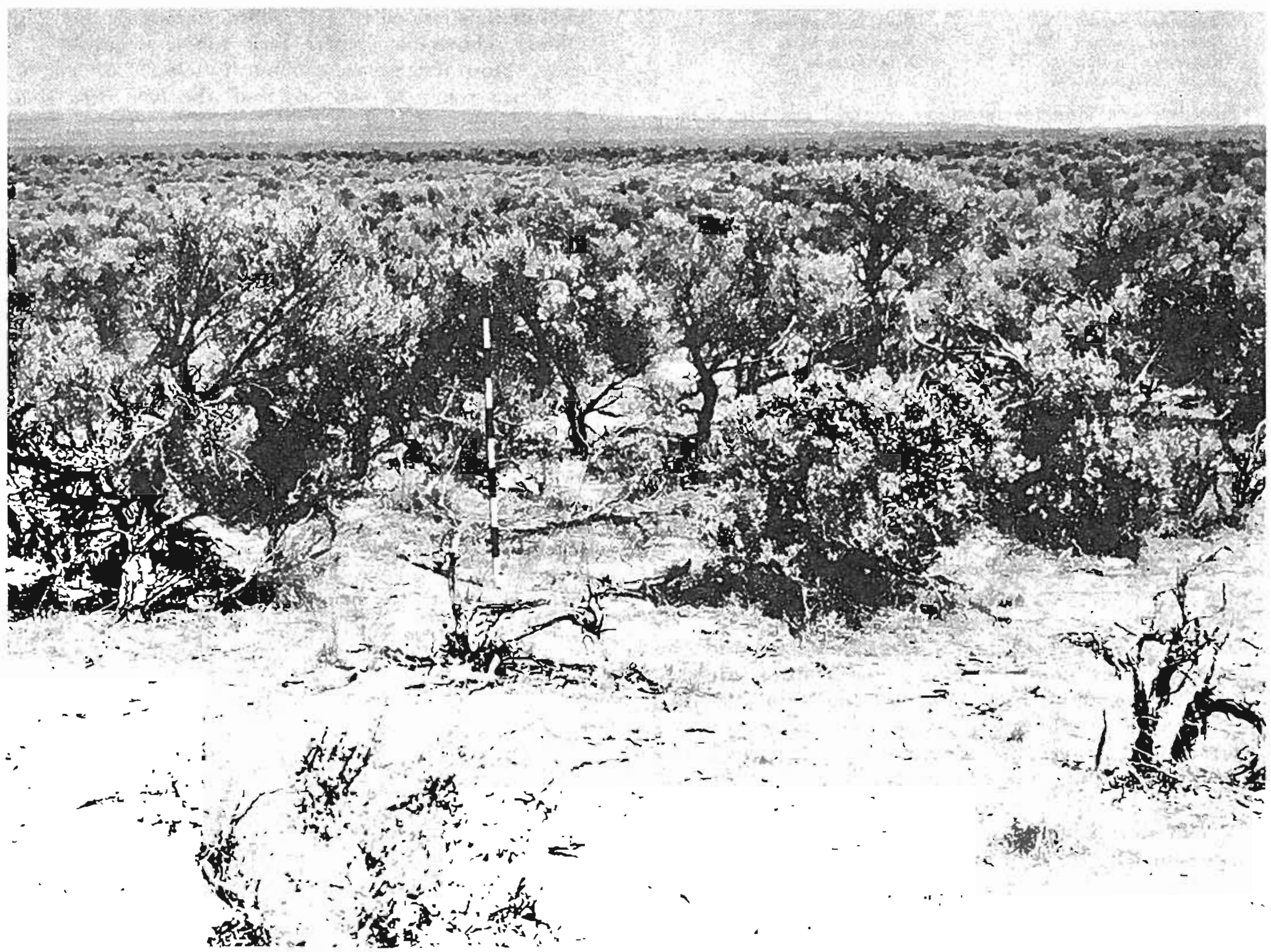
Dense, even-aged and short-lived tufts of seedlings, about 2 cm in diameter, which are occasionally observed in spring, are presumed to be mouse caches. Species stored in this way include *Bromus tectorum, Festuca octoflora, F. pacifica, Helianthella uniflora, Salsola kali* and *Triticum sativum.* The last was up to 200 m from the edge of the nearest field that could have served as a source of supply!

There is a marked tendency for near-virgin stands of *Artemisia tridentata-Agropyron* (and other types of shrub steppe) to have dense circular patches of *Bromus tectorum* that are confined to the area directly beneath the canopy of the shrubs. In some situations, this phenomenon may be related to burrowing activity by mice, but it seems much more likely to be due to the litter accumulation favoring *Bromus* establishment.

The character of the avifauna has been indicated by Booth (10). His study included a small portion of the *Artemisia-Agropyron* zone about Pasco, but a comparison of his figure 1 with figure 1 in this bulletin shows that his "Sagebrush Formation" was defined more broadly than I have defined the *Artemisia-Agropyron* zone. Also, the *Artemisia tridentata-Agropyron* h.t. was not distinguished from other h.ts. that are included in the zone.

Aroga websteri, a moth that locally devastates *Artemisia tridentata* by defoliation in southern Oregon and Idaho, is unknown from Washington. Likewise, the harvester ant, whose circular clearings take up so much of the land area in *Artemisia*-dominated vegetation of southeastern Oregon and southern Idaho, seems to be unrepresented in Washington. However, the dome-shaped litter nests of *Formica obscuripes* occur in the *Artemisia tridentata-Agropyron* association and in most other steppe types of Washington where the soil is deep and well-drained. Cicadas, including at least *Okanagana utahensis,* appear in great numbers locally in some years.

Observations on vegetation currently being grazed show that cattle and horses confine their attention to *Poa cusickii* exclusively as long as the supply lasts. *Agropyron*



5. Severe grazing in an *Artemisia tridentata-Agropyron spicatum* stand has eliminated nearly all herbaceous vegetation, leaving the *Artemisia* probably taller and denser than before grazing began.

and *Poa secunda* share second choice, but neither is relished when dry. As the large perennial grasses decline, *Bromus tectorum, Festuca pacifica, F. octoflora,* and *Plantago patagonica* increase, the first usually assuming dominance. If the concentration of animals is high, *Artemisia* suffers heavily from breakage; otherwise, the shrub increases in density and coverage (fig. 5). Moomaw's (84) study of six fencelines indicated that *Poa secunda,* presumably owing to its very low stature, showed no consistent downward trend under grazing heavy enough to reduce *Agropyron* and allow *Artemisia* to increase.

Sheep also prefer *Poa cusickii* to its associates. *Agropyron* is second choice, but under certain types of management, these animals take very little of *Poa secunda,* and they cause no breakage of the *Artemisia*. Under sheep use as well as cattle use, *Bromus* tends to take advantage of decreases in the larger perennial grasses. However, sheep relish this annual while it is green, so a fairly stable equilibrium is commonly attained in which *Bromus* and *Poa secunda* become the principal plants beneath an essentially normal *Artemisia* layer. *Plantago* and the annual species of *Festuca* also prosper as a result of heavy sheep grazing.

Appendix B-1 shows that the coverage of *Artemisia tridentata* in the *Artemisia tridentata-Agropyron* association ranges from 5-26%, yet all stands are interpreted as climax, or at most but slightly disturbed. One might question whether the stands with more *Artemisia* also have less of the perennial forage grasses and more of the annuals favored by grazing, with these reciprocal relations indicating varying degrees of grazing degradation. But when the stands are listed in order of the coverage of *Artemisia* (table 3), there is neither positive correlation with the grazing increasers, nor negative correlation with the preferred forage species. Thus the quantitative data for 14 excellent stands reveal wide variation in *Artemisia* coverage, which appears rather definitely not to reflect varying amounts of past grazing. Neither does *Artemisia* coverage correlate with any other variable in the data. It is suspected that its variation, which is often conspicuous when an extensive slope can be viewed from a distance, may reflect subsoil variations to which this deep-rooted shrub may be sensitive, whereas the shallow-rooted grasses are not directly affected by subsoil.

Ellison (38) has reviewed studies showing that the proportion of *Artemisia tridentata* in grazed vegetation declined, but that of the perennials increased after livestock were removed. He cautioned against an unwarranted extrapolation in assuming that this trend would lead ultimately to a complete elimination of the *Artemisia*. The considerable amounts of *Artemisia* in the excellent relic stands that have been analysed in Washington give much support to Ellison's warning.

Ellison (38) also stated that the "dominance of *Artemisia tridentata* and *Bromus tectorum*" results from "grazing pressure and *fire*" (italics mine). This is not true for Washington, for vegetation fires are usually hot enough to kill every plant of *Artemisia tridentata* (fig. 6). The green leaves and stem are consumed, and the fire commonly burns down through the root system enough to leave a gaping hole the diameter of the taproot. In the immediate vicinity of a shrub so completely consumed, *Descurainia pinnata,* which was previously sparse and scarcely more than 10 cm tall, usually appears in considerable numbers as robust individuals growing five times as tall.

Table 3. Relationship of variation in coverage of *Artemisia tridentata* to the coverage of the main forage grasses and to annuals that prosper with excessive grazing. All stands are in the *Artemisia tridentata-Agropyron* h.t., and show no evidence of modification by livestock.

% Canopy coverage			
Artemisia tridentata	*Agropyron*+ *Poa cus.*+ *Stipa thur.*	*Bromus tectorum*	*Bromus tec.*+ *Festuca spp.*+ *Plantago pat.*
26	56	1	1
20	58	1	5
19	45	+	+
18	72	+	+
16	48	1	1
16	41	+	1
12	75	+	4
11	36	1	5
10	33	0	0
9	76	0	+
9	49	+	14
9	35	+	9
8	70	0	+
6	49	1	6
5	60	+	+

Except for this *Artemisia,* all species of shrubs that occur in the h.t., as well as the perennial herbs, regenerate from subterranean organs after a fire. Damage to the grasses varies from none to heavy, presumably in accord with variations in the timing and intensity of burning. Productivity is considerably increased starting the first post-burn season.

Scattered *Artemisia* seedlings may be found the first spring after burning, since fires usually occur in summer and dissemination from contiguous unburned areas is in autumn. Thus, the oldest individuals to be found are reasonably reliable indicators of the time elapsing since the last fire. The new population builds up slowly until a coincidence of favorable circumstances allows many plants to get established, so that the stands tend to be even-aged. With excessive grazing causing a replacement of most perennial herbs by *Bromus tectorum* and other annuals, and with fire eliminating *Artemisia,* the percentage of rangeland dominated entirely by annuals (fig. 7) has been increasing progressively.

In the *Artemisia tridentata-Agropyron* h.t., cropping without irrigation is limited to cereal grains and the margin of profit is small in comparison with most other steppe zones. Land that has been cropped and then allowed to revegetate naturally comes under the control of *Bromus tectorum* within a few years. Clean cultivation so reduces the supply of *Bromus* seeds that at first the species is poorly represented in an abandoned field. The highly mobile tumbleweeds *Salsola kali* and *Sisymbrium altissimum* (both aliens) dominate for a year or two until the less-mobile *Bromus* can build up its population and virtually eliminate these pioneers.

In homologous habitats in southern Idaho, *Sitanion hystrix* is conspicuous on artificially bared surfaces along roads, in abandoned fields, and in areas recovering from overgrazing (52). In eastern Washington, it is seldom abundant except along roadsides where the topsoil has been scraped away.

6. Fire has eliminated *Artemisia tridentata* in the foreground, leaving *Chrysothamnus viscidiflorus* and the herbaceous components of the association essentially unaltered. Stand 28 is the unburned area in the background.

The recent expansion of irrigation in central Washington is creating water tables so close to the surface that in many places, the residual range vegetation is markedly affected. It is not uncommon to see *Typha latifolia* stands developing in swales among the skeletons of *Artemisia* bushes that have been killed by waterlogging of the soil.

The *Artemisia tridentata-Agropyron* zone abuts directly against forest along the Cascade foothills (fig. 1). Elsewhere, it is surrounded by less xerophytic steppe zones. Although none of the climatic classifications proposed for universal use serves to distinguish the climate of this zone from those which surround it (appendix A), each ecotone can be defined on the basis of consistent differences in climate as well as by consistent differences in vegetation.

The *Purshia-Festuca* zone to the southwest is cooler in spring and summer (March through September), with P higher in winter (November through March) and P/T higher in November, December, and March.

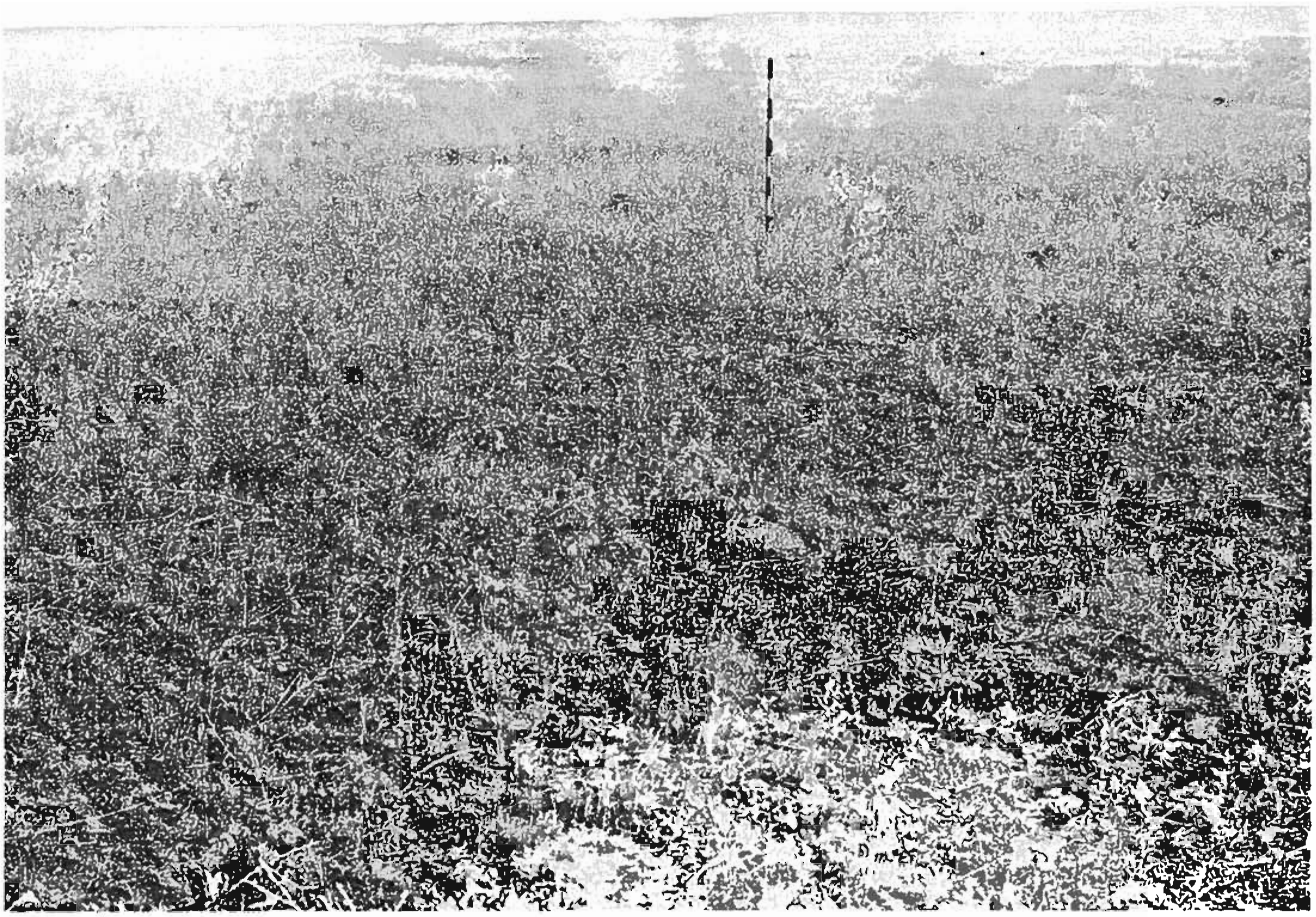
The *Artemisia tripartita-Festuca* zone on the west and north is cooler from later fall to early spring (October through April) with P and P/T higher for five months (September, November, December, January and March).

The *Artemisia tridentata-Festuca* zone to the east is cooler in late spring (May and June), with P and P/T also consistently higher in March.

The *Agropyron-Poa* zone is warmer in January, with higher P in March through June, September and October. The P/T is higher in March through June and in September.

The *Artemisia tridentata-Agropyron* h.t. reaches its highest altitude, at least 820 m, on the summits of the great basaltic ridges that rise above the floor of the Columbia Basin. This is considerably higher than the zone rises in the Cascade foothills to the west, or on the gently rising floor of the basin to the east. Judging from this vegetation pattern, the summits of these isolated ridges must be surprisingly dry for their elevation.

Within the *Artemisia-Agropyron* zone, steep north-facing slopes support as topographic climaxes three associations that occur as climatic climaxes in contiguous but wetter zones: ***Purshia-Festuca, Artemisia tridentata-Festuca*** and ***Artemisia tripartita-Festuca.***



7. ***Poa secunda*** and ***Bromus tectorum*** dominant on an area from which *Artemisia tridentata* has been eliminated by fire, and *Agropyron spicatum* eliminated by overgrazing. South of Ephrata, Grant County, Washington.

For 14 years, determinations of the available water in the soil were made at stand 14 at one date between May 16-23. The depth of moisture penetration at this time of year should be a fair index of the water available to support the main period of growth in spring, since few effective showers fall later. Over the 14 years, the depth of moisture penetration (to be reported in detail in another publication varied from 5 to over 15 dm. Since the large perennial grasses there (*Agropyron spicatum, Stipa thurberiana* and *S. comata*) grew well and flowered even in the year of least moisture accumulation, it may be inferred that these grasses must depend primarily on roots in the upper half meter of the soil profile. The shrubs, which alone retain active foliage throughout summer after the upper soil horizons dry, must depend on moisture reserves below the surface of the lime-cemented layer that lies at about 15 dm. These reserves are replenished by above-average precipitation at intervals of a few years.

Details of one annual cycle of soil moisture use and recharge have also been followed (27) in another part of stand 14 about 100 m from where the annual samplings described above were made. In 1963 the rains began early in October, but succeeding showers yielded so little water that the moistened layer of soil extended downward at the rate of only 17 cm/month until about April 10. About May 1, the profile began to dry, starting at the surface. The thickness of the soil dried to the wilting point extended downward at the rate of about 50 cm/month. By the end of June, the profile was dry at least a meter deep.

Late in the dry season, *Artemisia* bushes well within the margins of a climax stand have slightly curled leaves, duller gray color, and flower less abundantly in comparison with bushes along roadsides where the soil moisture is undoubtedly higher. Further evidence that the supply of subsoil moisture upon which the plant depends in summer and fall is rather tenuous is the fact that *Artemisia* population density becomes static after the plant achieves only 5-25% coverage where the land supports a good cover of perennial grass, then increases when these grasses are removed. Apparently, in the absence of much grass, more water percolates to the subsoil, permitting additional plants to become established. The ability of *Artemisia* to reinvade after a fire which but increases the vigor of the grass layer proves the existence of moisture resources untapped by the grass. Thus the ecologies of the two plant types are in large part complementary.

In the *Artemisia tridentata-Agropyron* h.t., moisture equivalents of the soils (means of upper 5 dm) ranged from 24.5 to 7.1%; the latter extreme was in stand no. 193, on a steep north-facing slope. Depth to bedrock (mean of penetrometer readings) becomes critical when it decreases to about 35 cm. Soil is characteristically very slightly acid in the surface dm (pH 6.1-7.1); the values increase with depth to pH 6.9-8.0 in the fifth dm. These soils are well supplied with Ca and have negligible Na. Free lime, as indicated by effervescence with HCl, begins at depths varying from 7.5 cm (stand 13) to 94 cm (stand 34). Conductivity of the saturation extract is generally 0.1-0.2 mmho/cm, at least within the upper 5 dm of the profiles. The properties mentioned in this paragraph are rather representative of most of the steppe habitat types unless divergences are indicated.

Soil profiles in the *Artemisia tridentata-Agropyron* h.t. range from Sierozem through Brown Great Soil Groups, with considerable representation of Brown-Chestnut intergrades. The stands in appendix B-1 are grouped in order of increasing moisture status as judged from their Great Soil Group positions. There are no evident trends among species, or for the community as a whole, through this series. In the current soil classification, the profiles fall into two categories: Mollic Camborthid and Calcic Haploxeroll. The profile at stand 42, a Shano silt loam, represents a Sierozem and a Mollic Camborthid:

A1 0-4" Dark brown (10YR 3/3m) or brown (10YR 5/3d) silt loam with occasional basalt fragments on the surface; weak fine platy with a slight vesicular crust about 0.5" thick; very friable and soft; abundant roots; gradual smooth boundary

C 4-48" Brown (10YR 4/3m) or pale brown (10YR 6/3d) silt loam; massive; very friable, soft; roots plentiful; gradual smooth boundary

Cca 48-54" Pale brown (10YR 6/3m) or very pale brown (10YR 7/3d) silt loam; massive; very friable and soft; few roots; strongly effervescent (by R. A. Gilkeson).

Stand 10 represents the relatively wet end of the range of soil profile development. It is a Renslow silt loam, a Chestnut-Brown intergrade, and a Calcic Haploxeroll:

Stand 10 is on Renslow silt loam, representing a Chestnut-Brown intergrade and a Calcic Haploxeroll:

A11 0-5 cm Brown (10YR 4/3m) or pale brown (10YR 6/3d) silt loam with occasional basalt fragments; highly vesicular with a tendency to crust and crack on the surface; reducing to mixed fine rounded block and single grains; moderate to high root content.

A12 5-8 cm Dark brown (10YR 3/3m) silt loam with occasional basalt fragments; fine to medium platy with distinct silt coatings on horizontal faces of plates; dark lateral staining on inside of peds; roots spreading horizontally between cleavages

A3 8-17.5 cm Brown (10YR 4/3m) silt loam with numerous small basalt fragments and water-worn gravel; weak medium to large angular blocky; moderate roots

B1 17.5-42.5 cm Dark yellowish brown (10YR 4.5/3m) coarse silt loam with occasional small stones; coarse angular blocky

B21 42.5-57.5 cm Brown (10YR 4.5/3m) coarse silt loam with occasional basalt fragments and some fine-sand size pumice; moderate coarse prismatic to angular blocky; slightly hard when dry

B22 57.5-75 cm Brown (10YR 4.5/3m) with occasional sand-size pumice; massive to coarse prismatic, reducing to medium and coarse subangular blocky; hard when dry; slight gray color on surfaces of peds; few roots

B23 75-90 cm Brown (10YR 4/3m) with frequent basalt fragments, small to medium stones and occasional sand-size pumice; moderate small to medium massive to prismatic, with gray coatings on surfaces of peds and frequent organic accumulations along fine root channels

Bca 90 cm+ Matrix dark brown (10YR 3/3m) with white (10YR 8/2m) lime streaks and occasional fine water-worn pebbles and small to medium stones; strong massive, reducing to fine subangular blocky with tendency to medium to coarse platy; hard when dry; intensely patterned with lime streaks; peds with heavy lime coatings and darker staining than above horizons (by S. H. Krashevsky).

The *Artemisia tridentata-Agropyron* h.t. is probably the most extensive element in the steppe mosaic of Washington (fig. 1) and it has wide distribution outside the state. It has been documented in the Kamloops area of British Columbia (80, 115) and continues northward to Williams Lake (78). Eckert (37) lists an *Artemisia tridentata-Agropyron* association for central Oregon. The writer has seen stands in southern Idaho (e.g., in Kettle Butte Kipouka, 17 miles west of Idaho Falls, in northern Lemhi County, and in Ada County); in the northern edge of the Great Basin in Utah (e.g., 6 miles south of Howell); and in Montana (5 miles west of Missoula and 7 miles north of Clyde Park). There are small differences in the minor species among the remote stands, and only detailed study will tell whether there is anything to be gained by recognizing different phases of this widespread unit in different areas.

Artemisia tridentata-Festuca idahoensis h.t.

Relatively undisturbed vegetation in the *Artemisia tridentata-Festuca* h.t. has *Artemisia tridentata* var. *tridentata* as the principal shrub, and includes *Festuca idahoensis* among the grasses. Perennial forbs are usually well represented (sums of percentages usually between 12 and 88). The *Artemisia* occurs without relation to disturbed microsites. *Purshia* is absent.

Physiognomically, this association is identical with the *Artemisia tridentata-Agropyron* association.

Observations on both a local and a broad geographic scale abundantly demonstrate that *Festuca* is not as tolerant of dryness or heat as *Agropyron*. Therefore, its entry into zonal vegetation along what has been mapped as the eastern edge of the *Artemisia-Agropyron* zone (fig. 1) seems a clear reflection of a critical point on the scale of gradually increasing moisture and/or decreasing temperature on the gentle slope of the Columbia Basin. To lump this with the *Artemisia tridentata-Agropyron* association would create a large and ecologically more heterogeneous unit. Supporting this ecologic interpretation, the sums of coverages of the larger perennial grasses in the *Artemisia tridentata-Agropyron* stands studied ranged from 38-87. The corresponding sums for the *Artemisia tridentata-Festuca* stands ranged from 63-110. *Artemisia* shows no corresponding increase in dominance, so the heavier grass cover seems to make greater demands on environmental resources, using up all the additional moisture.

The pattern of interfingering at the zonal ecotone also reflects moisture or temperature limitations. The *Artemisia tridentata-Agropyron* association reaches its eastern limits as a topographic climax on south-facing slopes (e.g., stand 13), and the *Artemisia tridentata-Festuca* association extends farthest west on north-facing slopes. The latter association can be followed deeply into the *Artemisia-Agropyron* zone, but it rises to higher and higher altitudes on the mountainous ridges.

Along the northern border, at the contact with the *Artemisia tripartita-Festuca* association, the latter extends southward farthest on north-facing slopes and the *Artemisia tridentata-Festuca* extends farthest north on south-facing slopes. The eastern ecotone where the *Artemisia tridentata-Festuca* and *Agropyron-Festuca* zones make contact lies in a region of intense cultivation (almost entirely winter wheat grown on an alternate-year-fallow system). No opportunity has been found to observe the nature of the ecotone. However, this ecotone falls in a relatively narrow belt, and Ellison's (38) comment that the "Palouse grassland . . . association merges imperceptibly into the sagebrush association" certainly does not apply to Washington.

Artemisia tridentata-Festuca stands reappear unexpectedly in a disjunct situation as edaphic climaxes in that part of the *Agropyron-Festuca* zone at the northeast flank of the Blue Mountains, where the stands are associated with a complex of solodized solonetz soils. The altitude here is much higher than any part of the *Artemisia tridentata-Festuca* zone, and the zonal soils are in the Prairie Great Soil Group. A precipitation storage gage was maintained in an exclosure in one of these disjunct stands (stand 39) for most of 4 years. The data, adjusted to the long-term mean for Lewiston, Idaho, indicate a mean annual precipitation of 338 mm at the exclosure. Since the mean annual precipitation in the *Artemisia tridentata-Festuca* zone is only 252-274 mm, soil conditions in the disjunct area must greatly reduce the effectivity of the combination of high precipitation with low temperature. Owing to the special combination of conditions that favor *Artemisia tridentata-Festuca* stands there, nearly a fourth of the total species listed for the association (appendix B-2) were included in consequence of including this outpost. *Artemisia tridentata* var. *tridentata* to the northeast of the Blue Mountains must represent a population that reached the area in hypsithermal time then became disjunct because the climate changed.

Responses of this association to grazing and burning and the nature of secondary succession following fire are not significantly different from those of the *Artemisia tridentata-Agropyron* association. Stand 30, with its high coverage of *Plantago and Draba*, appears to be the one most likely to have been grazed heavily in the past; yet this disturbance could not have been prolonged, for *Festuca idahoensis* had the highest coverage here of any of the stands studied.

The *Artemisia tridentata-Festuca* zone is bounded on the west by the slightly warmer and drier *Artemisia tridentata-Agropyron* zone (fig. 1).

On the east it forms an ecotone with the *Agropyron-Festuca* zone, which is warmer in winter (November through March), has higher P in nine months (September through April, and June), and higher P/T in eight months (January through April, June, July, October and November).

To the north, the *Artemisia tripartita-Festuca* zone is consistently cooler except in November and December, has higher P in five months (September, and November through February), and higher P/T in the same five months.

Soil profiles in the *Artemisia tridentata-Festuca* h.t. fall into the Brown or Solonetz Great Soil Groups. Thus they are included within the range found in the drier *Artemisia tridentata-Agropyron* h.t. According to the newest classification, they represent mainly Calcic Haploxerolls or Lithic Mollic Camborthids, with one Typic Natrixeroll.

The profile at stand 15, a Ritzville silt loam and a Calcic Haploxeroll, represents a somewhat modal condition of a Brown zonal soil developed from loess in the *Artemisia tridentata-Festuca* zone. It was plowed after the vegetation was analysed but before the profile was described:

Ap 0-15 cm Brown (10YR 4/3m) silt loam, with the same texture in the following horizons:

A12 6-40 cm Brown (10YR 4/3m); weak medium to coarse subangular blocky

A3 40-70 cm Same color; weak medium to coarse subangular blocky

B1 70-95 cm Same color; weak coarse subangular to prismatic blocky

B2 95-120 cm Dark yellowish brown (10YR 4.5m); same structure as above

Bca 120 cm+ Effervescent; first difference in consistency (by R. A. Gilkeson).

The profile at stand 39, a Wiesenfels silt loam, represents a solodized solonetz in the climate of the *Agropyron-Festuca* zone, which is distinctly wetter than that of the *Artemisia tridentata-Festuca* zone where the *Artemisia tridentata-Festuca* association occupies zonal soils. In the most recent classification, this is a Typic Natrixeroll:

A11 0-2" Black (10YR 2/1m) silt loam; weak fine platy and subangular blocky; friable, loose; pH 7.6; slightly sticky, nonplastic; profuse roots; abrupt smooth boundary

A12 2-6.5" Black (10YR 2/1m) silt loam; weak medium and fine subangular blocky; friable, loose; slightly sticky, nonplastic; pH 7.6; abundant roots; clear wavy boundary

A13 6.5-11" Grayish brown (10YR 5/2d) or very dark brown (10YR 2/2) silt loam; weak medium and fine subangular blocky; friable, soft; slightly sticky, nonplastic; pH 7.8; weakly calcareous; abundant roots; abrupt smooth boundary

B2ca 11-16" Pale brown (10YR 6/3d) or dark brown (10YR 4/3m) silty clay loam; moderate medium and coarse prismatic, reducing to moderate medium subangular blocky; firm, slightly hard; sticky, moderately plastic; pH 8.3; conductivity 0.47 mmho/cm; highly calcareous; numerous roots; clear wavy boundary

B3ca 16-24" Light gray (10YR 7/2d) or light brownish gray (10YR 6/2m) silt loam; moderate medium and fine subangular blocky; firm, soft, slightly sticky, nonplastic; pH 8.5; conductivity 0.73 mmho/cm; numerous roots; abrupt smooth boundary

Dca 24"+ Very pale brown (10YR 8/3d) or very pale brown (10YR 7/3m) lime and silica cemented gravel and stones; pH 9.1; conductivity 1.45 mmho/cm; mat of roots at surface with very occasional penetration (by W. A. Starr).

The *Artemisia tridentata-Festuca* association occurs near Penticton, B.C. (78). It has been seen by the writer a few miles south of Virginia City, Montana, and in the western end of the Snake River Plain in southern Idaho. Farther east in Idaho, Tisdale et al. (116) have described an excellent virgin stand of the association. It has also been reported from central (37) and northern Oregon (94).

Agropyron spicatum-Poa secunda h.t.

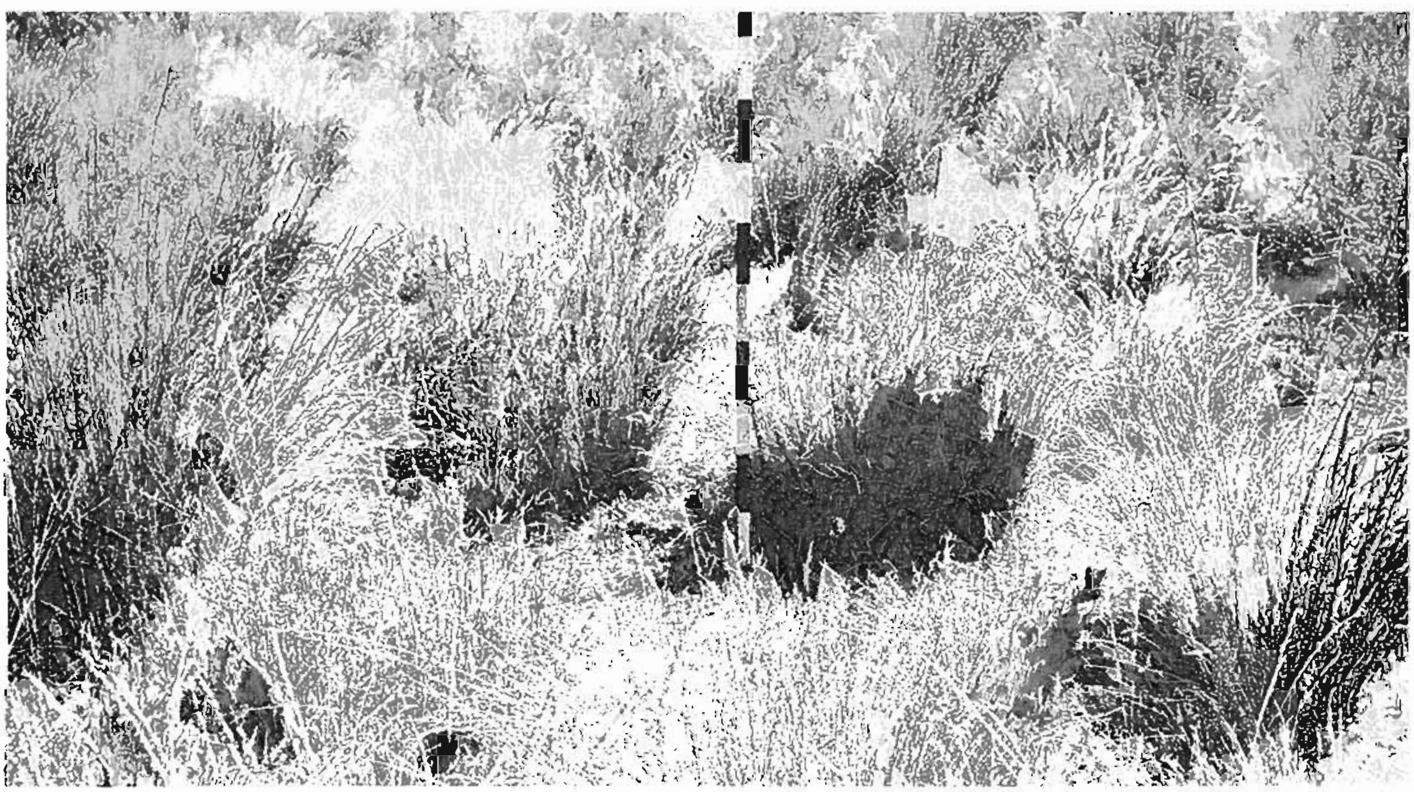
Undisturbed vegetation in the *Agropyron spicatum-Poa secunda* h.t. consists of these two caespitose grasses and very little else, although widely scattered individuals of *Chrysothamnus nauseosus* are characteristic. *Festuca idahoensis* and *Artemisia* are unrepresented. The soils are deeper than 20 cm by the penetrometer method of measurement.

The *Agropyron-Poa* h.t. occurs in two highly disjunct areas in Washington (fig. 1). The larger of these, which lies in the Snake River drainage, will be considered first.

Climax vegetation in the h.t. may be most simply characterized as nearly identical with the *Artemisia tridentata-Agropyron* association except for the absence of an *Artemisia* layer (fig. 8). Another difference that is notable, even if not so regularly diagnostic, is that *Chrysothamnus* is here usually represented by *C. nauseosus,* whereas in the *Artemisia tridentata-Agropyron* association it is usually represented by only *C. viscidiflorus.*

Productivity determinations in appendix C show that about 85% of the dry matter production is attributable to the *Agropyron.*

Phenologic observations for a stand of this association (stand 56, in the Larson exclosure) may be considered fairly representative of the hot-dry extreme of climatic variation in the Washington steppe (fig. 9). About half of the species of perennial herbs put forth new foliage at the start of the rainy season. They remain green during even the coldest part of winter, cold season dormancy being less pronounced than dry-season aestivation. (The



8. *Agropyron spicatum-Poa secunda* stand in pristine condition. This stand was used by Daubenmire and Colwell (28) in studies of grazing influence on soils. Franklin County, Washington.

reverse is true in the cool-wet extreme of our steppe climates.)

One of the annuals, *Montia perfoliata*, germinated in midwinter, but the other four were essentially spring annuals. Peak photosynthetic activity for the annuals as a group is in late April, but none of the annuals continued activity into the dry late-summer.

Shrubs are completely dormant in winter. They put forth leaves later in the wet season than do the other two life forms distinguished. The shrubs as a group flower definitely later in the season than the herbaceous perennials. Owing to the widely separated flowering periods of *Phlox longifolia* (in spring) and *Chrysothamnus nauseosus* (autumn), the flowering season of the shrubs extends over a longer season than for the other two life form groups.

All perennials and shrubs sprout readily from underground organs after a fire. Thus, the main floristic effect of burning is to alter species proportions among the annuals temporarily. Usually, the flowering of grasses is stimulated too, but occasionally fires are hot enough to cause considerable damage. For example, the edge of a steppe fire near, and comparable to, stand 159 in appendix B-3 was examined in detail the following summer. About half of the *Agropyron* plants were killed and only a small part of the basal area of the rest of the plants survived. Annuals had invaded abundantly (*Amsinckia, Helianthus, Lactuca, Leptilon* and *Sisymbrium*). The density of *Plantago* was halved, but the remaining individuals were twice normal size. Other species were not greatly altered in density or condition.

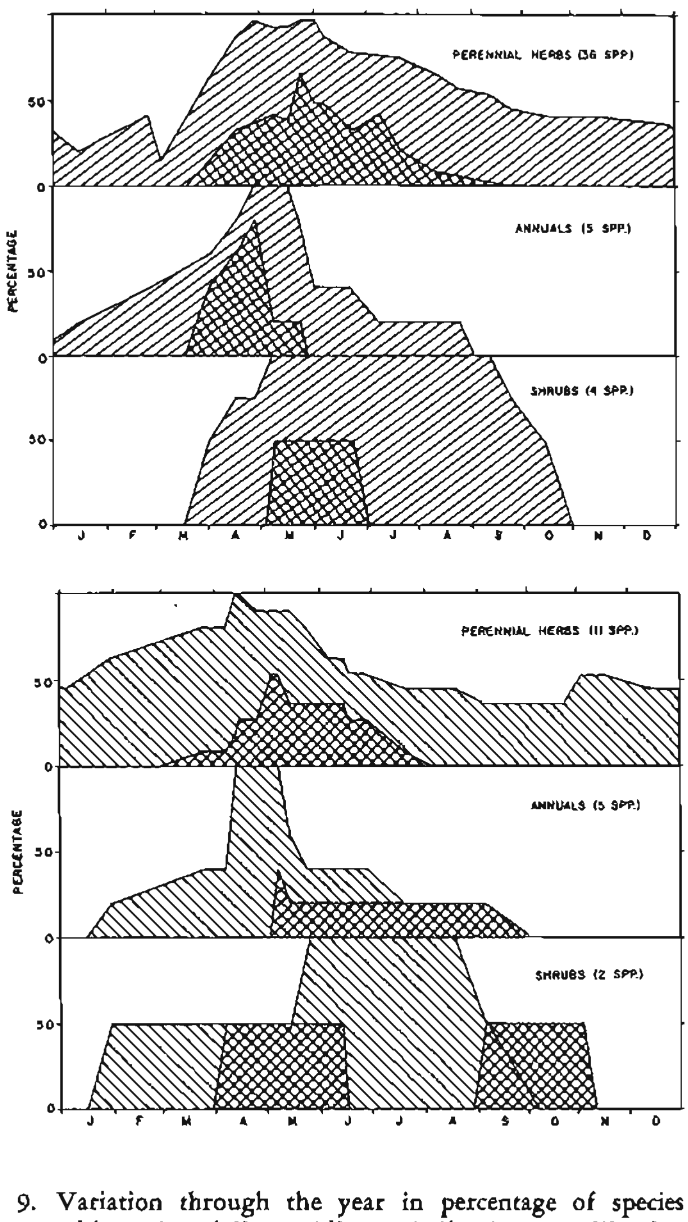
Excessive grazing by cattle or horses eliminates *Agropyron*, and reduces the amount of *Poa; Bromus tectorum* is the chief annual taking their places. *Chrysothamnus nauseosus* coverage often rises from less than 1% to 30% or more, but this happens chiefly where, as on steep slopes, hooves churn up the soil surface. Along the southern border of Washington, *Gutierrezia sarothrae* invades heavily grazed areas.

Heavy grazing by sheep differs in that it usually results in a more even balance between *Poa* and *Bromus*. However, sheep use can be so heavy as to completely eliminate the *Bromus*, which the animals relish, allowing *Poa secunda* to assume a high degree of dominance along with small annuals, especially members of the *Boraginaceae*.

For example, Daubenmire (21) analysed four stands of vegetation including a near-virgin stand of the *Agropyron-Poa association*, a zootic climax that had been produced by close sheep grazing, and two stands representing intermediate stages of retrogression. *Bromus tectorum* was barely represented, and it was prevented from setting seed, in the most intensively grazed area where *Poa secunda* was the outstanding dominant. Some years later, the sheep on this range were replaced by cattle. Poa then declined to a minor role with *Bromus* quickly assuming dominance in a new zootic climax. The effectiveness of sheep in eliminating *Bromus tectorum* from stands of mixed species has been reported elsewhere (70, 83).

Daubenmire and Colwell (28) followed up the study of vegetation change outlined above with an analysis of the effects of the change on soil conditions. They compared soils along a fenceline with a near-virgin stand of *Agropyron-Poa* on one side and a severely grazed tract on the other. Overgrazing was associated with an increase in the winter accumulation of soil moisture; decreased infiltration, aggregation and available phosphorus; increased humus in the upper decimeter of the profile, presumably because of the rapid turnover of annual root systems; higher fungal and bacterial populations; more active nitrification; and higher soil temperature during the season of most active growth.

Abandoned fields in the *Agropyron-Poa* h.t. develop a heavy stand of *Bromus tectorum* quickly. This grass may still dominate, with *Chrysothamnus nauseosus* present



9. Variation through the year in percentage of species with active foliage (diagonal lines) or pollinating (cross hatching) based on native species in stand 73 of the *Festuca-Symphoricarpos* association (above) and stand 56 of the *Agropyron-Poa* association (below).

in considerable amounts, more than 40 years after the abandonment.

Rickard (96) included one stand in the *Agropyron-Poa* association in his survey of small mammal populations (appendix D).

Booth's (10) observations on the avifauna of what he termed the "bunchgrass formation" are relevant to my *Festuca-Agropyron* and *Agropyron-Poa* zones combined. Again his units are much more heterogeneous than mine and the area he discussed lies in Oregon rather than in Washington.

Grasshopper outbreaks are common in the *Agropyron-Poa* zone. However, by the time these insects are large enough to consume much foliage daily, the grasses tend to be so dry that attention is concentrated on other plants, such as *Chrysothamnus, Artemisia tridentata* and *Salsola*. The *Artemisia* would be available in edaphic climaxes (*Artemisia tridentata-Agropyron* stands on stony soil, or *Artemisia tridentata-Stipa* stands on sandy soil), and the *Salsola* would be available only on disturbed soils.

In the drier area immediately west of the *Agropyron-Poa* zone, moisture percolates below the reach of grass roots often enough to maintain supplies of subsoil moisture that will carry *Artemisia tridentata* through the long dry summer and early autumn. With a better moisture balance in the *Agropyron-Poa* h.t., one might expect an even better supply of subsoil moisture that would support even more tap-rooted shrubs, but only scattered *Chrysothamnus* occurs here. This suggests the existence of an unused niche in the *Agropyron-Poa* ecosystem that results from a slightly different climate that makes the h.t. unsuitable for the establishment of most shrubs that could avail themselves of it.

Previously it was indicated that the *Agropyron-Poa* zone is slightly wetter (for 6 months) and warmer (January) than the *Artemisia-Agropyron* zone.

Moisture relations seem no different between the *Agropyron-Poa* and *Agropyron-Festuca* zones, but the latter, by virtue of its position on the plateau above the Snake River canyon, is consistently cooler for four months in winter (November, December, February and March).

Compared with the *Festuca-Symphoricarpos* zone, the *Agropyron-Poa* zone is warmer every month, has a lower P/T for eight months (September, November through March, July and August), with lower P in August.

There are no weather stations in the disjunct western segment of the *Agropyron-Poa* zone which abuts the *Festuca-Hieraceum* zone. But if comparisons based on weather data for the eastern segment are valid, the *Festuca-Hieraceum* zone is colder every month, with higher P/T from November through March, but with lower P/T in April, May and June. P is higher in the *Festuca-Hieraceum* zone in July, August and September.

Soil profiles in the *Agropyron-Poa* stands studied were divided among Sierozem, Brown, and Chestnut Great Soil Groups. In the alternative classification, they range from a Mollic Camborthid to Calcic Haploxeroll, Calcic Entic Haploxeroll, and Typic Haploxeroll. Stand 88 represents the *Agropyron-Poa* association as a topographic climax on a south-facing slope in the *Agropyron-Festuca* zone. Its profile, a Shano silt loam (Sierozem) and a Mollic Camborthid, is:

A11 0-5 cm Dark brown (10YR 3/3m) or brown (10YR 3/3d) silt loam; weak medium platy; very friable when moist, soft when dry; abrupt smooth boundary

A12 5-10 cm Dark brown to brown (10YR 4/3m) or pale brown (10YR 6/3d) silt loam; weak coarse platy; very friable when moist, soft when dry; clear smooth boundary

AC 10-35 cm Brown (10YR 5/3m) silt loam; very weak coarse subangular blocky; very friable when moist, soft when dry; gradual smooth boundary

C1 35-113 cm Similar to above horizon except for massive structure

Cca 113 cm+ Dark grayish brown (10YR 4/2m) or light gray (10YR 7/2d) silt loam; massive; very friable when moist, soft when dry; very calcareous (by R. A. Gilkeson).

Stand 159 represents the *Agropyron-Poa* association as a climatic climax. Although vegetation analyses at this site reveal close similarity to the above site (appendix B-3), the profile classifications are quite different. Stand 159 is on a Ritzville very fine sandy loam (Brown), which is a Calcic Haploxeroll:

A11 0-3″ Very dark grayish brown (10YR 3/2m) of light grayish brown (10YR 6/2d) very fine sandy loam; moderate coarse fine platy; nonsticky, nonplastic; soft, friable; numerous roots; abrupt smooth boundary

A12 3-9″ Dark brown (10YR 3/3m) or pale brown (10YR 6/3d) very fine sandy loam; weak medium fine angular blocky; nonsticky, nonplastic, friable, soft; numerous roots; clear wavy boundary

A13 9-15″ Dark brown (10YR 3/3m) or pale brown (10YR 6/3d) very fine sandy loam; weak medium subangular blocky; nonsticky, nonplastic, friable, soft; numerous roots; clear wavy boundary

AC 15-27″ Brown (10YR 4/3m) or pale brown (10YR 6/3d) very fine sandy loam; weak coarse prismatic; nonsticky, nonplastic, slightly firm, slightly hard; frequent roots; clear wavy boundary

C1 27-53″ Dark brown (10YR 3/3m) very fine sandy loam; massive; nonsticky, nonplastic; slightly firm, slightly hard; occasional roots; clear wavy boundary

Cca 53″+ Dark grayish brown (10YR 4/2m) very fine sandy loam; massive, compact to weak medium platy; nonsticky, nonplastic, slightly firm, slightly hard; no roots (by W. A. Starr).

Fig. 1 shows that the *Agropyron-Poa* zone occurs in two areas separated by the *Artemisia tridentata-Agropyron* zone; the area next to the Cascades is much the smaller. Here in the west, the zone extends from the Columbia River approximately 2/3 of the distance to the top of the gorge, before giving way to the *Festuca-Hieraceum* zone that characterizes the relatively flat bench above. In this area, when the *Agropyron-Poa* h.t. is depleted by overgrazing, it becomes dominated by ***Bromus tectorum, Chrysothamnus nauseosus, Gutierrezia sarothrae*** **or** ***Lupinus.***

Agropyron spicatum-Festuca idahoensis h.t.

In its relatively undisturbed condition, vegetation in the *Agropyron-Festuca* h.t. is dominated by *Agropyron spicatum* and *Festuca idahoensis; Poa secunda* is the third most productive grass. Shrubs are inconspicuous except for widely scattered individuals of *Chrysothamnus nauseosus*, and perennial herbs are likewise inconspicuous.

The *Agropyron-Festuca* association is physiognomically identical with the *Agropyron-Poa* association, differing only in the addition of the relatively mesophytic *Festuca idahoensis.* It differs from the *Artemisia tridentata-Festuca association* only through the absence of the *Artemisia.* Where the *Agropyron-Festuca* association meets meadow-steppe communities, the fewness of forbs and the absence of *Symphoricarpos, Rosa* and *Artemisia tripartita* distinguishes it. At ecotones with meadow-steppe, the *Agropyron-Festuca* association occupies relatively dry slopes as it interfingers with the others.

Several of the above moisture relationships are very well illustrated by stands 117, 118 and 119, all of which are within an area about 100 m across in the *Agropyron-Festuca* zone. Stand 118 is on the broad summit of a ridge (slope 1% NNE) and exemplifies the climatic climax of the area. Stand 119, on a steep (51%) SSE slope, is a relatively xerophytic topographic climax belonging to the *Agropyron-Poa* association. Stand 117, representing the *Artemisia tripartita-Festuca* association, occupies the opposite slope (51% N) in the role of a relatively mesophytic topographic climax. Thus relatively xerophytic vegetation penetrates the *Agropyron-Festuca* zone from one direction as far as relatively mesophytic vegetation penetrates from the opposite direction. This is a common pattern in vegetation mosaics throughout the region.

The *Agropyron-Festuca* zone is split into northern and southern segments by the Snake River valley, which contains part of the *Agropyron-Poa* zone. The segment lying south of the Snake River has several distinctive features. Here in the rain shadow of the Blue Mountains the zone rises to an elevation of 900 m. *Opuntia polyacantha* and *Artemisia tridentata* var. *tridentata* likewise rise to unusual elevations here. The *Opuntia* is locally a very minor member of the climatic climax (e.g., stand 41), increasing with overgrazing, although *Bromus tectorum* is still the major dominant of excessively grazed parts of the h.t. Much of the distinctiveness of the vegetation of this southerly sector of the zone is attributable to the soils which are an intricate mosaic with spots of solodized solonetz abundant (90).

On Wiessenfels Ridge (Asotin Co., S 24, T9N, R 47E) where detailed soil analyses were made by Peterson (90) a vegetation pattern has been well correlated with soil variation. On near-zonal soils, or where the prismatic B21 of the solodized solonetz lies deep, the *Agropyron-Festuca* association appears to be typically developed, but on eroded spots the perennial grasses become attenuated. Here the *Agropyron* and *Festuca* are typically lacking and the puddled surface of the depressions that retain water over long periods in the rainy season is covered with a blackish film of algae (chiefly *Tolypothrix* and *Microcoleus*), with scattered lichens (chiefly *Cladonia pyxidata, Caloplaca cirrichroa, Diploschistes scruposes*), and sterile mosses. Among the few vascular plants, *Lepidium perfoliatum* is outstandingly abundant but dwarfed to 1-3 cm tall. *Poa secunda* occurs here sparingly, and the diminutive *Myosurus aristatus* is well represented. The most unusual biologic feature of these shallow depressions is that here may be found an outpost of the subarctic snail *Succinea strigata* Pfeiffer (#214107 in U.S.Nat.Mus.), which appears in numbers during the wet season.

Rickard (96) included a stand of the *Agropyron-Festuca* association in his survey of small mammal populations (appendix D).

Quantitative studies of a fire that stopped within stand 41 showed that in the first post-burn season, *Descurainia pinnata, Sisymbrium altissimum* and *Opuntia polyacantha* were considerably reduced by the fire, and *Lactuca* seedlings were much fewer. On the other hand *Lithophragma bulbifera, Plantago patagonica* and *Bromus japonicus* were better represented on the burn. *Agropyron* produced 15 inflorescences/4m^2 on the burned area while remaining sterile in the unburned climax. *Festuca idahoensis* was essentially unchanged in flowering activity (10 inflorescences/4m^2 in unburned; 13/4m^2 in burned). The coverage of neither of the dominants was significantly altered by the fire.

It has been pointed out that the *Agropyron-Festuca* zone is cooler in winter than the *Agropyron-Poa* zone below it in the canyon. It is both wetter and warmer than the *Artemisia tridentata-Festuca* zone to the west, and so may be considered a homolog of that zone in a slightly wetter and warmer climate where *Artemisia tridentata* cannot grow on zonal soils.

Every month except July is warmer in the *Agropyron-Festuca* zone than in the *Artemisia tripartita-Festuca* zone on the north, and the P/T is lower from November through January.

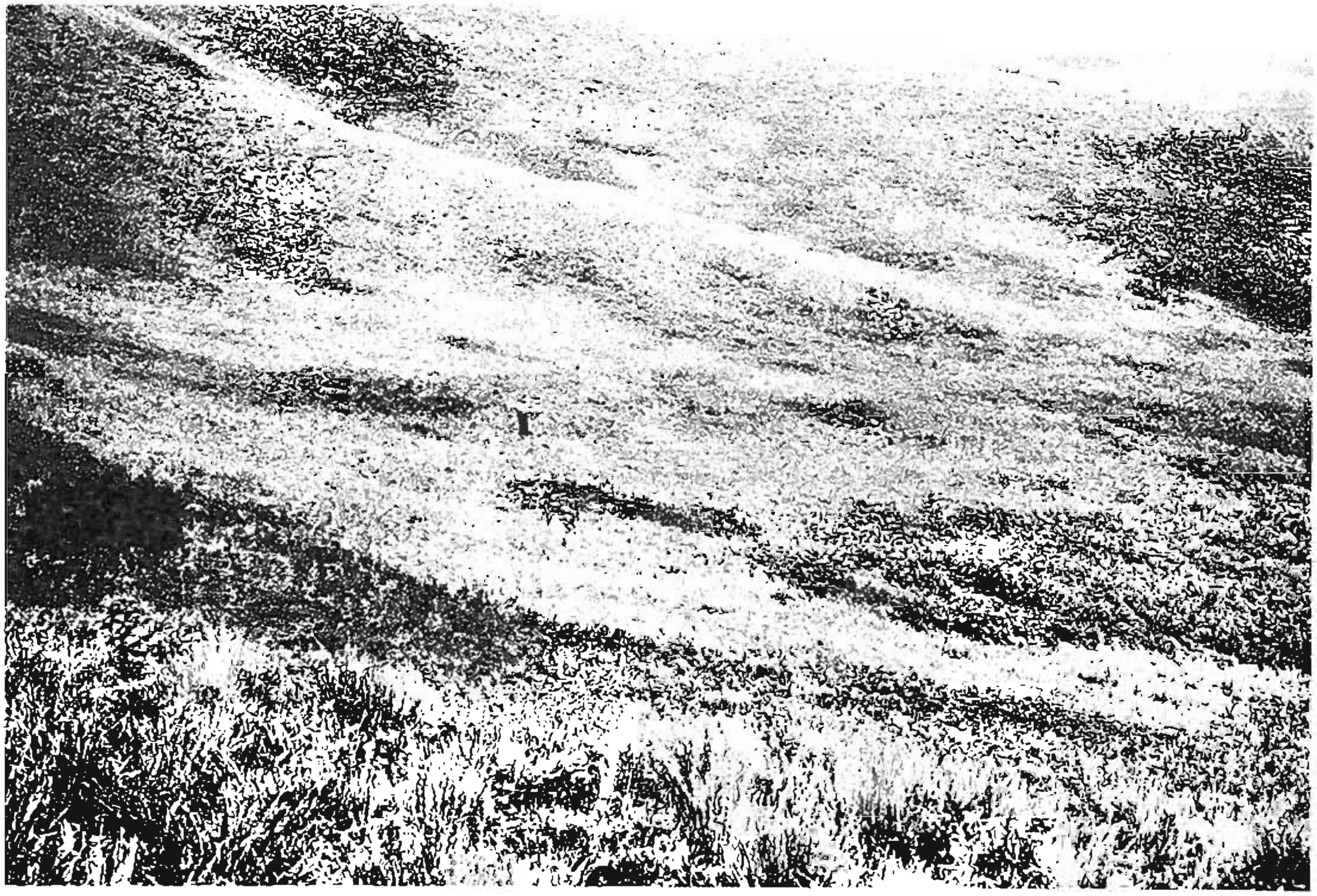
Every month in the *Agropyron-Festuca* zone is warmer than in the *Festuca-Symphoricarpos* and *Festuca-Rosa* zones, and the P/T is lower for at least nine months.

Soil profiles in the *Agropyron-Festuca* h.t. belong to a wide range of Great Soil Groups: Brown, Chestnut, Chernozem, Planosol, Solodized Solonetz, and Prairie-Grumusol intergrade. It is especially noteworthy that stand 148 had the highest coverage (91%) of the relatively mesophytic *Festuca idahoensis,* but represents a relatively aridic (Brown) soil profile. The lowest *Festuca* coverage (3%) was associated with a Chernozem profile (appendix B-4).

In the newer classification, the h.ts. are distributed among Calcic Haploxeroll, Calcic Entic Haploxeroll, Typic Haploxeroll, Natric Calcic Haploxeroll, Typic Natrixeroll, Typic Palexeroll and Vertic Argixeroll.

The soil profile in stand 148, a Ritzville loam (Brown) and a Calcic Haploxeroll, is:

A11 0-3" Light brownish gray (10YR 6/2d) or very dark grayish brown (10YR 3/2m) loam; moderate medium and fine platy; slightly sticky, nonplastic, friable, soft; pH 7.0; abundant roots; clear wavy boundary



10. Pristine landscape on a north-facing slope about 5 miles west of Colton, Whitman County, Washington. Patches of *Symphoricarpos-Festuca* scrub are dispersed over a matrix in which herbs dominate over these same shrubs. Stand 71 is in the area just downslope of the person. Stand 73 is on top of the low ridge at the upper right of the picture (with plowed hills beyond). This tract has been preserved through the efforts of the Department of Forestry and Range Management at Washington State University.

A12 3-9″ Grayish brown (10YR 5/2d) or very dark grayish brown (10YR 3/2m) silt loam; moderate medium and coarse subangular blocky; slightly sticky, nonplastic, firm, slightly hard; pH 7.1; numerous roots; clear wavy boundary

A13 9-20″ Grayish brown (10YR 5/2d) or very dark grayish brown (10YR 3/2m) silt loam; weak medium and coarse angular blocky; slightly sticky, nonplastic, friable, soft; pH 7.1; numerous roots; clear wavy boundary

AC 20-34″ Brown (10YR 5/2d) or dark brown (10YR 3/3m) silt loam; weak medium and fine subangular blocky; slightly sticky, nonplastic, friable, soft; pH 7.4; numerous roots; clear irregular boundary

C1 34-47″ Brown (10YR 5/3m or 10YR 4/3m) very fine sandy loam; single grain; nonsticky, nonplastic; friable, soft; pH 7.6; occasional roots; irregular boundary

C2ca 47″+ Dark grayish brown (10YR 4/2m) very fine sandy loam; single grain; nonsticky, nonplastic, friable, soft; pH 8.2; calcareous; occasional roots (by W. A. Starr)

At stand 152 the profile, a Brevier silt loam (Planosol) and a Typic Palexeroll, is:

A11 0-1.5″ Grayish brown (10YR 5/2d) or black (10YR 5/2m) silt loam; mixed weak fine granular and single grain; slightly sticky, nonplastic, friable, soft; pH 6.8; profuse roots; clear smooth boundary

A12 1.2-4.5″ Similar to above horizon, but with fewer roots; boundary clear and smooth

A2 4.5-8″ Dark gray (10YR 4/1m) or black (10YR 2/1m) silt loam; moderate medium and fine platy; slightly sticky, slightly plastic, firm, slightly hard; pH 6.7; abundant roots; abrupt wavy boundary

II B27 8-12″ Very dark brown (10YR 2/2m) clay; strong medium prismatic; very plastic, very sticky, very firm, very hard; pH 6.9; frequent roots; clear wavy boundary

II B22 12-16″ Very dark grayish brown (10YR 3/2m) clay; strong coarse prismatic; very sticky, very plastic, very firm, very hard; pH 7.9; very occasional roots;

clear wavy boundary

II B23ca 16-21" Dark brown (7.5YR 4/2m) clay; strong coarse prismatic; very sticky, very plastic, very firm, very hard; pH 8.2; seams and streaks of lime occupy about 15% of the mass; very occasional roots; abrupt wavy boundary

III Dr 21"+ Fractured basalt rock and stones, coated with lime (by W. A. Starr).

Festuca idahoensis-Symphoricarpos albus h.t.

The *Festuca idahoensis-Symphoricarpos albus* association is distinguished by the occurrence of *Festuca idahoensis* in a dense herb layer that also includes dwarf, mainly sterile plants of the shrub *Symphoricarpos albus. Artemisia, Eriogonum, Chrysothamnus* and *Purshia* are unrepresented. *Poa pratensis,* rather than *Bromus tectorum,* is the leading increaser under heavy grazing pressure. This essentially herbaceous type of community is always liberally sprinkled with enclaves of deciduous shrubbery that is considerably taller, and will be treated as a special phase of the association.

The dwarf shrub element of the predominately herbaceous community includes not only *Symphoricarpos,* but commonly *Rosa nutkana* or *R. woodsii,* which are its ecologic equivalents in this h.t. None of these is evident until the stand is inspected closely, for the stems are solitary, sparingly branched and do not project above the herbs (figs. 3, 10, 11). While the stems are well spaced, it is difficult to find a square meter that does not include one.

The herbaceous component of the *Festuca-Symphoricarpos* association includes the same two grasses, *Festuca idahoensis* and *Agropyron spicatum,* that are characteristic of more xerophytic associations to the west. Here in the wetter climate they are joined by *Koeleria cristata* and a great variety of perennial forbs, mostly species with conspicuous flowers. Essentially, this same assemblage of grasses and forbs is common to all members of the meadow-steppe associations that form a chain about the periphery of the steppe region of Washington. It is the shrubby component that differs so strikingly from one member of the chain to the next.

Species diversity, defined as the numbers of species found in areas of a constant size in a series of communities, generally increases from the driest steppe ecosystem to the wettest. Diversity is maximum in the peripheral belt of meadow-steppe of which the *Festuca-Symphoricarpos* h.t. is a segment (appendix E). Also, the increasing percentage of forbs with increasing moisture culminates in the meadow-steppe belt (appendix E).

Although the association is uniformly rich in perennial forbs, a number of which have high constancy, there is considerable variation in their species composition from stand to stand (appendix B-5). A good illustration of the mosaic (rather than clinal) character of this variation can easily be had by comparing the four analyses listed as stand 71, 72, 73 and 74. All represent different topographic positions in the same tract of virgin steppe, with the most remote members of the series only about 300 m apart.

In contrast with the steppe communities described previously, the ecotype of *Agropyron spicatum* represented in the *Festuca-Symphoricarpos* association is strongly rhizomatous. This ecotype seems to be selected out of a

11. Detail of *Festuca idahoensis-Symphoricarpos albus* stand 72 on July 2, just after the flowering season.

gene pool that includes genetic determiners for either the caespitose or rhizomatous habit. Most seeds have the potentiality for the caespitose form regardless of the type of parent (25), and this is the prevailing form that becomes established on newly bared areas. After a dense plant cover develops a selection during population turnover eliminates caespitose forms in favor of rhizomatous.

The rhizomatous ecotype produces very few inflorescences. When all tillers were clipped from an area in a *Festuca-Symphoricarpos* stand and weighed, the spike-bearing tillers made up only 3% of the dry weight. When this exercise was repeated in a nearby lithosolic *Agropyron-Poa* stand where all plants were strongly caespitose, the spike-bearing tillers comprised 40.4% of the total production.

Although all the other perennial grasses are caespitose, the rhizomatous habit of *Agropyron* in this association, combined with the profusion of large perennial forbs mingled with the grasses, gives the stands a uniform physiognomy. This contrasts markedly with the pronounced bunchiness of the herbaceous component of more xerophytic associations (see fig. 3, and compare figs. 4, 5, 6 and 8 with fig. 10).

Approximately one third of the perennial herbs remain photosynthetically active through the winter. Low temperature at this season is more of a limiting factor than drouth in late summer (fig. 9). As noted previously, the reverse is true in more arid parts of the steppe. The winter leaves are much smaller than those which expand in spring, and the extent to which these persist or are replaced in summer is not known. The peak of vegetative activity among the perennials as a group comes several weeks later than in the *Agropyron-Poa* association (fig. 9).

Among the annuals, flowering is concentrated earlier in the season than that of perennials—again a reversal of the relation in drier parts of the steppe (fig. 9). Two of the annuals, *Collinsia parviflora* and *Montia perfoliata*, germinated in midwinter; the other three are spring annuals. After reaching a peak of photosynthetic activity in early May, this function of the annuals as a group declined more sharply than in perennials.

Leafiness among the shrubs is more nearly centered on the warm season than is true of the other two life-form groups. Except for their complete inactivity in winter, the phenology of the shrubs is similar to that of the perennials in this association.

Productivity has been evaluated in three widely scattered stands (appendix C).

Except where the overhead shade is very dense or the litter very deep, the ground is covered by lichens and pleurocarpus mosses that are evidently coarser in texture than those forming the epigeous crust in more arid parts of this steppe (table 4). Cooke (18) included two stands of the *Festuca-Symphoricarpos* association (his stands "FN" and "FC", but not his "FS") in his survey of cryptogamic vegetation in eastern Washington and northern Idaho.

A tractor turning a single furrow was used to stop the spread of a fire just about to cross stand 71. In June of the following year it was difficult to see any difference

Table 4. Representative mosses and lichens of the *Festuca-Symphoricarpos* association. See table 1 for key to location of specimens.

MOSSES	
On soil:	
Barbula cylindrica C	*Eurhynchium strigosum* S
B. vinealis S	*E. substrigosum* K
Brachythecium albicans K, C	*Funaria hygrometrica* K
B. albicans occidentale H	*Leptobryum pyriforme* K
B. lutescens K	*Orthotrichium macounii* S
Bryum argenteum H	*Phascum cuspidatum*. S, H
Camptothecium (aenium?) H	*Pohlia cruda* K, C
Ceratodon purpureus K, H	*Polytrichum juniperinum* S
Didymodon recurvirostris K, C	*Pterigoneuron subsessile* S
Encalypta rhabdocarpa K	*Tortula princeps* K
E. vulgaris apiculata H	*T. ruraliformis* S, C
Eurhynchium diversifolium C, S, K	*T. ruralis* C, H, K
E. fallax C, S	*Weissia* sp. H
On basalt stones:	
Ceratodon purpureus C	*G. trichophylla* C
Grimmia apocarpa C	*Homalothecium nevadense* S
G. montana C	*Tortula ruraliformis* C, S
LICHENS	
On soil:	
Cladonia chlorophaea simplex K	*Peltigera canina rufescens* K, W
C. fimbriata K	*P. canina spongiosa* K
C. pyxidata K, W	*P. membranacea* K
Diploschistes actinostromus K	*P. scutata* K
	Physcia grisea K

in the vegetation on the two sides of that fire barrier, although *Sisymbrium altissimum* was conspicuous on the ridge of overturned sod.

Rickard (96) analyzed the small mammal component of two *Festuca-Symphoricarpos* stands (appendix D). Grazing of *Poa* spp. is quite evident along rodent runways through the community. The only mouse cache observed consisted of *Erythronium* seeds.

Johnsgard and Rickard (65) analyzed the breeding bird population in what appears to be the largest remaining tract representing this association. Early in this century, the sharp-tailed grouse was abundant in the *Festuca-Symphoricarpos* zone. With the passing of the natural plant cover this grouse disappeared completely from the zone. The alien ringnecked pheasant, which prospers in an artificial vegetation composed mainly of wheat and peas grown alternately, is the modern equivalent of the grouse that has disappeared.

The Columbian ground squirrel, badger, and white-tailed deer are well represented in the *Festuca-Symphoricarpos* zone, the last using the interspersed thickets of shrubs for cover. The tree frog *Hyla regilla* and salamander *Amblystoma macrodactylum* are surprisingly common; both wander far from the wet places they depend on for breeding.

Unlike the shrubs in most of the other steppe associations, the dwarfed *Symphoricarpos* and *Rosa* plants are highly palatable, so they decline simultaneously with the herbs under cattle grazing. A fenceline at stand 76 permitted comparison of lightly grazed (mainly by sheep) and ungrazed vegetation with the following responses evident in the quantitative analyses (see box).

All of the invaders and more than half the increasers are annuals. The other two groups are entirely perennials or shrubs. These data do not bear out Young's (130)

UNAFFECTED (THUS FAR)	DECREASERS	INCREASERS
Antennaria luzuloides	*Astragalus spaldingii*	*Achillea millefolium*
Castilleja cusickii	*Balsamorhiza sagittata*	*Agropyron spicatum*
Fritillaria pudica	*Brodiaea douglasii*	*Bromus japonicus*
Gaillardia aristata	*Calochortus elegans*	*Bromus mollis*
Haplopappus liatriformis	*Carex geyeri*	*Collinsia parviflora*
Iris missouriensis	*Festuca idahoensis*	*Draba verna*
Lithophragma parviflora	*Geranium viscosissimum*	*Epilobium paniculatum*
Lomatium triternatum	*Geum triflorum*	*Erigeron corymbosus*
Lupinus sericeus	*Helianthella uniflora*	*Koeleria cristata*
Lithospermum ruderale	*Hieraceum albertinum*	*Lithophragma bulbifera*
Rosa spp.	*Potentilla gracilis*	*Microsteris gracilis*
Senecio integerrimus		*Montia linearis*
Symphoricarpos albus	INVADERS	*Montia perfoliata*
Zygadenus gramineus	*Lagophylla ramosissima*	*Stellaria nitens*
	Myosurus aristatus	*Sisyrinchium inflatum*
	Sanguisorba occidentalis	
	Veronica arvensis	

statement that *Astragalus, Bromus tectorum, Lupinus* and *Potentilla* increase in this h.t. as grazing eliminates *Festuca* and *Agropyron,* but his observations may refer to areas altered by cattle rather than sheep.

As grazing progressively thins the native perennials in the *Festuca-Symphoricarpos* h.t., the alien *Poa pratensis* invades and takes their places, finally becoming the dominant of a zootic climax. A few of the native species, chiefly *Iris* and *Clematis,* are avoided by grazers, even when all others have been eliminated. Thus, scattered individuals in a virgin stand often become large populations in a heavily grazed area. While the native flora undoubtedly has much more to offer in the way of diversified foods and nutrients, as a whole the plants are less palatable as they mature and are much less tolerant of heavy grazing than is the *Poa.* From this standpoint the grazing value of the vegetation would seem to be enhanced by heavy use. Once retrogression has allowed a given degree of replacement of natives by the *Poa,* there seems to be no reversal of trend when grazing pressure is reduced or eliminated. Thus the amount of *Poa* in the stands is probably a good measure of the most extreme reduction a stand has ever been subjected to. In comparison with more xerophytic associations, *Bromus tectorum* is poorly represented in grazed parts of this h.t. In lightly grazed stands, *Bromus brizaeformis, B. mollis,* and, especially, *B. japonicus* are often abundant.

The point that the *Festuca-Symphoricarpos* zone is cooler and wetter than the *Agropyron-Festuca* and *Agropyron-Poa* zones has been made.

To the north and west where the *Festuca-Symphoricarpos* zone form an ecotone with the *Artemisia tripartita-Festuca* zone, the former has the higher annual rainfall, 561-435 mm as against 425-396 mm. Also, the former has higher P in September, October, November, February, March and May, and higher P/T in September, October, April and May. It is not only wetter but also warmer than the *Artemisia tripartita-Festuca* zone in December and January. The additional rainfall in autumn in the *Festuca-Symphoricarpos* zone is probably the most critical aspect of these differences. It would alleviate the drouth that intensifies progressively throughout summer, and thus prevent the vegetation from going into the winter with a great soil moisture deficit. These climatic differences affect climax structure chiefly in the shrubby elements. *Artemisia tripartita* and *Eriogonum heracleoides* are associated with dry autumn climate, and *Symphoricarpos* and *Rosa* with wet autumns. The grasses and forbs are very much the same in both climaxes.

In the *Festuca-Rosa* zone south of the Clearwater Canyon, the climate is colder except in February and August. P and P/T are lower in winter (November through February) but higher during most of the summer (April through September). Here again the climatic differences between zonal climaxes are reflected mainly in the shrubs. The abundant *Symphoricarpos* of the northern unit disappears completely from the climatic climax, and the *Rosa* becomes highly restricted.

The annual march of soil moisture accumulation and use was followed in part of stand 155. At this site, the data for 1962-63 indicated that the soil never dried to the wilting point deeper than 6 dm. In all other steppe associations studied concurrently, soil drouth extended well below a meter. An earlier study in part of stand 76 showed that the entire upper meter can desiccate in this association (27).

Kardos (69) reported the results of lysimeter studies made very near stand 92 as having been made in a "virgin bunchgrass area." The site of the lysimeter installation was virgin in the sense that it had never been plowed, but the vegetation had been disturbed and therefore was not strictly comparable to that part of the stand used in the present study.

Soil profiles in the *Festuca-Symphoricarpos* h.t. range from Chernozem to Prairie to Planosol. In contrast with the zonal associations described previously, pH decreases from the 1st to the 5th decimeter. This reflects the absence or at least deep placement of a layer of lime accumulation in this relatively wet climate. The black color of the A1 horizon is also a consistent character.

In the alternative classification, the profiles include Typic Argixeroll, Vertic Argixeroll, Glossoboralfic Argindoll, Typic Palexeroll, Abruptic Palexeroll and Calcic Haploxeroll.

Stand 163 represents the *Festuca-Symphoricarpos* association on a Prairie soil (Palouse silt loam), a Typic Argixeroll:

A11 0-3″ Black (10YR 2/1m) silt loam; moderate medium and fine granular; slightly sticky, nonplastic, friable, slight hard; abundant roots; clear wavy boundary

A12 3-5.5″ Black (10YR 2/1m) silt loam; weak coarse platy, reducing to moderate fine subangular blocky and coarse granular; slightly sticky, nonplastic, friable, slightly hard; abundant roots; clear wavy boundary

A13 5.5-13″ Very dark grayish brown (10YR 3/2d), or very dark brown (10YR 2/2m) silt loam; moderate coarse platy, reducing to medium subangular blocky; slightly sticky, nonplastic, friable, slightly hard; numerous roots; clear wavy boundary

A3 13-21″ Dark brown (10YR 3/3m) silt loam; moderate medium and fine angular and subangular blocky; slightly sticky, nonplastic, slightly firm, slightly hard; clear wavy boundary

B11 21-28″ Dark brown (7.5YR 3/2m) silt loam; moderate medium and fine angular blocky; sticky, slightly plastic, slightly firm, slightly hard; numerous worm casts and channels; frequent roots; streaks and splotches of dark organic matter staining; clear wavy boundary

B12 28-37″ Brown (7.5YR 4/2m) silty clay loam; moderate medium and fine angular and subangular blocky, with frequent siliceous coatings on ped faces; sticky, slightly plastic, firm, hard; occasional roots; clear wavy boundary

B21 37″+ Brown (7.5YR 4/2m) silty clay loam; moderate medium prismatic, reducing to strong medium and fine subangular blocky, with intense siliceous coatings on pores and ped faces; occasional roots (by W. A. Starr).

Stand 106 is on a Planosol (Thatuna silt loam), a Glossoboralfic Argindoll:

A11 0-9″ Black (10YR 2/1m) silt loam; weak fine granular; slightly sticky, slightly plastic, friable, soft; abundant roots; clear wavy boundary

A12 9-19″ Very dark brown (10YR 2/2m) silt loam; weak medium granular; slightly sticky, slightly plastic, friable, soft; numerous roots; clear wavy boundary

A13 19-33″ Dark brown (10YR 3/3m) silt loam; moderate medium and fine subangular blocky, reducing to medium granular; slightly sticky, slightly plastic, slightly firm, slightly hard; numerous roots; clear wavy boundary

A3 33-44″ Dark grayish brown (10YR 4/2m) silt loam; moderate medium and fine subangular blocky; slightly sticky, slightly plastic, slightly firm, slightly hard; numerous roots; clear wavy boundary

A2 44-50″ Grayish brown (10YR 5/2m) silt loam; moderate fine angular blocky, with conspicuous gray siliceous coatings on ped faces and in pores; slightly sticky, slightly plastic, firm, slightly hard; frequent roots; clear wavy boundary

B21 50-55″ Brown (10YR 4/3m) silty clay loam; moderate medium and fine subangular blocky, with conspicuous gray siliceous coatings on ped faces; sticky, plastic, firm, hard; occasional roots; clear wavy boundary

B22 55″+ Dark yellowish brown (10YR 4/4m) silty clay loam; moderate medium and fine prismatic, reducing to fine prismatic and medium angular blocky; sticky, plastic, firm, hard; occasional roots (by W. A. Starr).

The main body of the *Festuca-Symphoricarpos* zone occupies a central position on the eastern margin of the Columbia Basin (fig. 1). In addition, a narrow fringe occurs along the northern base of the Blue Mountains, reaching its western extremity in Walla Walla County. This western extension is both narrow and discontinuous, occurring mainly on north-facing slopes. Stand 136 exemplifies such a situation.

A vegetation mosaic closely similar to the *Festuca-Symphoricarpos* association with its accompanying *Symphoricarpos* phase has been observed about 14 miles west of Bozeman, Montana. McLean and Holland (79) have also described a closely similar community in the valley of the Columbia River near its head in British Columbia.

Symphoricarpos phase

Shrub thickets, mostly between 0.5-3 m tall that contain *Symphoricarpos albus* and occur in a matrix of the *Festuca-Symphoricarpos* association, are considered a phase of that association.

In size and complexity the thickets are quite variable. Small thickets may be only a few meters in diameter and consist mainly of *Symphoricarpos*. Other, usually larger thickets usually have a relatively low marginal zone of *Symphoricarpos* about 0.5 m tall surrounding a central core of *Rosa woodsii* + *R. nutkana* which is about 1 m tall. At a still more complex level, *Prunus virginiana* growing 2-3 m tall dominates a central core that may be surrounded in turn by successive belts of *Rosa* and *Symphoricarpos*.

In three areas, reconnaissance surveys were made of the shrub thickets in a landscape mosaic. The data (appendix B-6) show that the thickets ranged from 4-25m in diameter, and from 0.5-3.0 m tall. They are exposure-independent, and occur on slopes of variable steepness. An appreciable percentage of the land surface is occupied by these thickets (fig. 10).

In appendix B-6, the thickets in each area are arranged from left to right from the lowest to the tallest, based on maximum height in the center. The tallest thickets are dominated by *Prunus* and are predominately on northerly slopes. Although *Symphoricarpos* and *Rosa* dominate in the marginal parts of the streamlined thickets, they also continue beneath the *Prunus* as an understory. Most of the large perennial herbs found in the thickets are in the marginal parts where the shrubbery is low and thin. Most of the annuals grow where the soil has been disturbed by rodents or badgers.

The herbaceous components of the thickets are in the main the same species that occur in the *Festuca-Symphori-*

carpos association, but here there are few openings between shrubs that favor heliophytes of their stature, so they are not abundant. Thus, the thicket represents a reversal of dominance between the herbaceous and woody components of the *Festuca-Symphoricarpos* association. *Agastache urticifolia* was the only species of native vascular plant found in the thickets that was not in the herbaceous matrix surrounding the thickets. When *Prunus, Crataegus, Amelanchier* and *Populus tremuloides* occur as accidentals in *Festuca-Symphoricarpos* stands, they are all dwarfed in proportion to the dwarfing of the *Symphoricarpos* and *Rosa* there, even though in a nearby thicket they are much larger and more vigorous.

Although no *Vaccinium caespitosum, Calamagrostis rubescens* or *Epilobium angustfolium* were encountered in the *Symphoricarpus* thickets sampled, these typically "forest species" reach the dry extreme of their ecologic amplitude in association with *Symphoricarpos* thickets. The occurrence of a *Vaccinium* in steppe is especially notable. *Epilobium* is not a fire-induced species in this vegetation matrix.

An explanation of the positions and sizes of the thickets in the vegetation mosaic is obscure. The margins of *Crataegus* stands, which occupy areas of above-average moisture, are always separated from grassland by a fringe of *Symphoricarpos* thicket. Also, at the dry edge of the *Festuca-Symphoricarpos* association's range (e.g., west of Prescott) the thickets tend to be restricted to ravines or other depressions. Thus, in places the pattern suggests slightly more moisture in the thicket areas than in the surrounding matrix, but such a hypothesis falls short elsewhere. Over most of the range of the mosaic, thickets are common on dry southwesterly exposures, and the bottoms of swales are as often herbaceous as shrubby (fig. 10).

Soil characters throw no light on the problem. Presumably owing to the superior protection afforded against predators, rodents have been very active in the thickets for perhaps centuries. Any slight difference in the soil profiles can be attributed to animal influences if not to the shrub patch itself.

There is no evidence that the thickets are spreading. Even if they had spread slowly, they occupy so much of the mosaic that they would long ago have eliminated the intervening herbaceous component. Rather well-used old squirrel burrows in the grassland have shown no tendency to release the adjacent dwarfed shrubs from suppression.

These shrub thickets are considered but a phase of the *Festuca-Symphoricarpos* association for three reasons:

1. There are no consistent differences in their floras; only the relative dominance of herbs and shrubs is reversed.

2. The two vegetation types occur in intimate mixture, and have the same geographic distribution.

3. There is no apparent difference in the intrinsic environmental characteristics.

A curious phenomenon is the readiness with which *Malus sylvestris* and occasionally *Pyrus communis* or *Prunus avium* become established in *Symphoricarpos* thickets from fruit residues discarded by man. In places along old railways, almost continuous strips of seedling apple trees show that former railway passengers frequently ate fruit as the trains wound their way through the loessal hills with their windows open.

Cook (18) included two stands (his "SN" and "SC," but not his "SS") of the *Symphoricarpos* phase in his survey of fungi, lichens and mosses.

All shrubs of the thickets sprout readily from just below the soil surface following a fire, and within about 3 years, evidence of a fire has been effaced. No known seral species are involved in the regeneration.

Rickard's (96) analysis of small mammals showed the shrub thickets to be faunistically richer than the intervening grassland, with a remarkable segregation of species of *Microtus* despite the fine texture of the vegetation mosaic. *Microtus longicaudis* is essentially confined to the thickets, where *M. montanus* was captured only in the herbaceous matrix (appendix D).

Deer are more abundant in the *Festuca-Symphoricarpos* zone now than when the area was controlled by Indians, owing to the greater hunting pressure then. *Prunus*-dominated thickets are especially useful as cover for deer. They have often been seen in the area shown in fig. 10, and coyote preying on *Microtus montanus* have also been observed there.

The twigs and leaves of the dominant shrubs are quite palatable to livestock. All shrubs subjected to heavy grazing are replaced by a *Poa pratensis* community, which is undoubtedly more productive of usable forage that is the primary climax.

Johnsgard and Rickard (65) analyzed the spring and early summer bird population of a steppe mosaic a few miles west of Colton, which is now owned and protected by Washington State University. The thicket component of the mosaic proved to be about 20 times as useful to birds as either the herbaceous matrix (*Festuca-Symphoricarpus* association), or the stand of *Agropyron-Poa* grassland on the contiguous south-facing slope. Brewers sparrow, one of four species that nested only in the thickets, has become one of the "rarest" native birds in eastern Washington (55). The bird is still abundant in remaining fragments of this steppe moisaic, but seems unable to adapt to changing conditions as the natural vegetation disappears.

Festuca idahoensis-Rosa nutkana h.t.

The *Festuca idahoensis-Rosa nutkana* h.t. is recognized by its supporting a meadow-like community of which *Festuca idahoensis* is a constituent. Shrubs within the community, if any, are very dwarfed *Rosa nutkana* or *R. woodsii. Symphoricarpos, Artemisia, Eriogonum, Chrysothamnus* and *Purshia* are unrepresented.

The *Festuca-Symphoricarpos* and *Festuca-Rosa* ecosystems are closely similar. They are known to differ only in:

1. the absence of *Symphoricarpos* from the latter, accompanied by an attenuation of *Rosa*

2. association with thickets in which *Symphoricarpos* is lacking

3. a restriction of geographic range to the rainshadow of the Blue Mountains

4. a distinctive climate.

The presence of *Symphoricarpos* in stand 154 (appendix

B-5) is interpreted as an accident consequent on its location just a few meters from the edge of a stand of *Pinus ponderosa-Symphoricarpos* forest in which this shrub is an undergrowth dominant.

Cooke (18) included one stand of the *Festuca-Rosa* association (his "FS") in his survey of fungi, lichens and bryophytes.

The *Festuca-Symphoricarpos* zone is at about the same altitude as the *Festuca-Rosa* zone, but lies to the north of the Clearwater and Snake Rivers, and is wetter in winter but drier most of the other seasons, as indicated earlier. The *Agropyron-Poa* zone, which follows the Snake and Salmon River Valleys, has a drier climate than the *Festuca-Rosa* zone on the contiguous plateau above.

Rosa nutkana phase

The *Rosa* phase of the *Festuca-Rosa* association consists almost entirely of *Rosa nutkana* and/or *R. woodsii*, lacks *Symphoricarpos*, and is confined to the *Festuca-Rosa* zone.

In this zone, the shrub patches are more definitely related to swales in the topography than are shrub patches in the *Festuca-Symphoricarpos* mosaic.

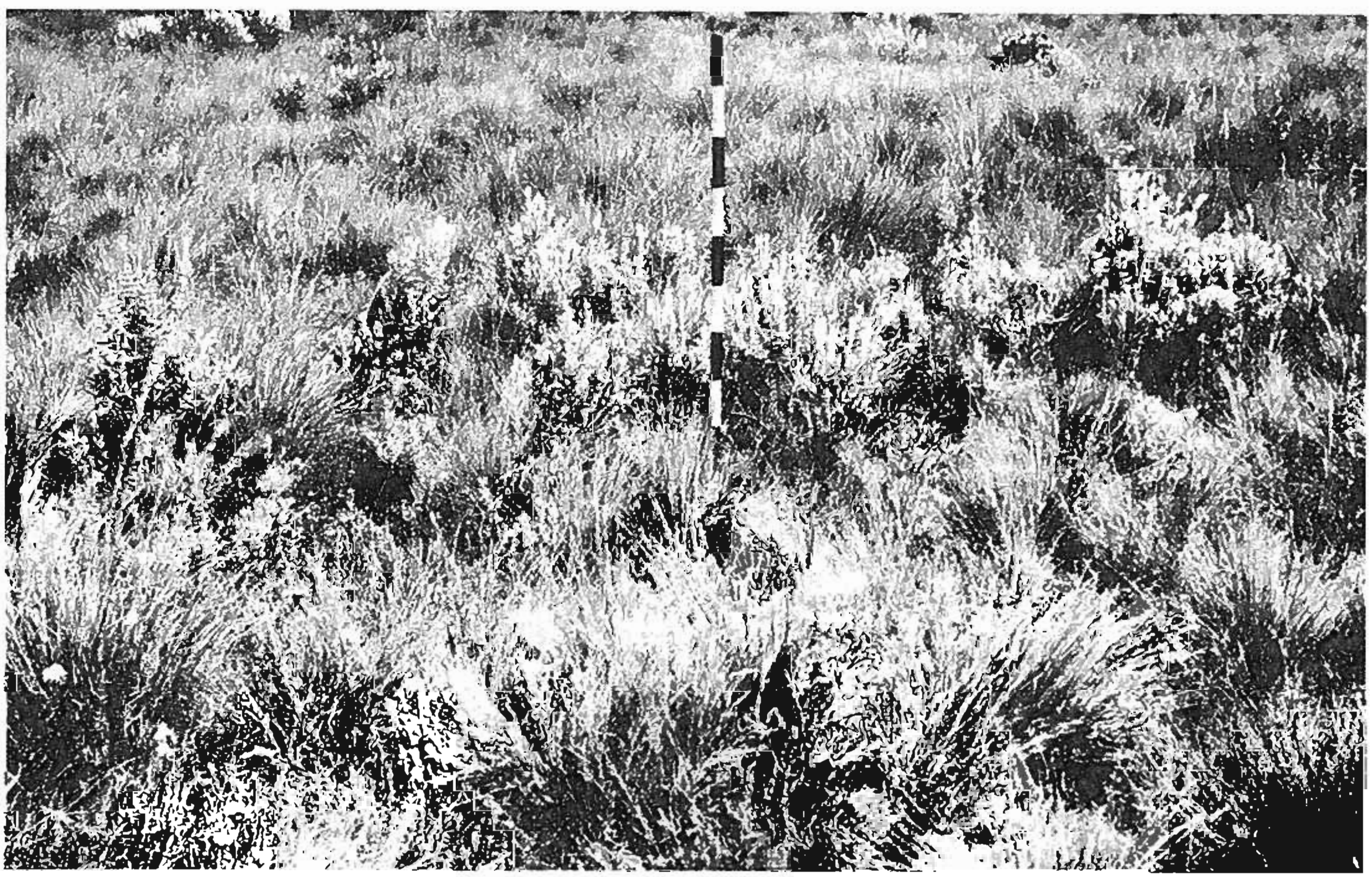
Cook (18) included one stand (his stand "SS") of the *Rosa* phase in his study of cryptogamic plants.

Artemisia tripartita-Festuca idahoensis h.t.

Stable vegetation in the *Artemisia tripartita-Festuca* h.t. is distinguished by a discontinuous layer of *Artemisia tripartita* that rises but slightly above a continuous herb layer (fig. 12) of which *Festuca idahoensis* is a member. If *Artemisia tridentata* is present, it is confined to disturbed places. *Symphoricarpos* and *Purshia* are absent.

Artemisia tripartita is scarcely half as tall as *A. tridentata* on the average. Since it reproduces freely by sprouts from shallow lateral roots, small individuals are a more evident component of the populations, and the physiognomy of the community is relatively uniform. At stand 4, for example, 317 stems of *Artemisia tripartita* arose independently (i.e., not clustered) in 10 m^2 area. These ranged in height up to 5 dm, with 1-2 dm the modal size class. Griffiths' (46) statement that "sagebrush was not prominent on the high elevations" between Grand Coulee and the Columbia River (i.e., Douglas County, see fig. 2) must refer to the small stature of *Artemisia tripartita* in comparison with *A. tridentata*. The two species were not generally distinguished taxonomically at that time.

The rather lush herbaceous component of this association usually includes many perennial forbs, most of which are shared with the other meadow steppe associations. In appendix B-7 the 19 stands analyzed are arranged according to the highly variable amounts of *Festuca idahoensis* they contained, since this species is especially sensistive to moisture, in order to show the degree to which clinal variation in other species correlates. Certain species tend to



12. *Artemisia tripartita-Festuca idahoensis* stand 62.

be chiefly in the wet end of the assumed moisture gradient (*Agrostis interrupta, Bromus commutatus, Arnica sororia, Carex filifolia, Hesperochiron pumilus*, and *Sisyrinchium inflatum*). Others are better represented toward the dry end (*Agropyron spicatum, Arenaria congesta, Crepis atribarba, Collomia linearis*, and *Lappula redowskii*). In this association, and often within a single stand, the growth form of *Agropyron* varies from caespitose to rhizomatous.

The *Artemisia tripartita-Festuca* and *Festuca-Symphoricarpos* ecosystems are sharply contrasted in a number of ways despite their juxtaposition in the meadow steppe belt just below lower timberline (fig. 1). *Artemisia tripartita, Eriogonum heracleoides, Chrysothamnus* and *Tetradymia* are common throughout the former but lacking in the latter. *Symphoricarpos* and *Rosa*, which give the *Festuca-Symphoricarpos* association its character, are all but unknown in the *Artemisia tripartita* association.

Artemisia tridentata can invade the *Artemisia tripartita-Festuca* h.t. only on the disturbed soils of road cuts or animal burrows. In the latter microsite, *Elymus cinereus* is an even more conspicuous invader. This grass is especially conspicuous on the loessal mounds scattered over scablands in the *Artemisia tripartita-Festuca* zone. These mounds, fragments of the *Artemisia tripartita-Festuca* h.t., provide the only stone-free substrate for rodents to burrow into, and it then proves equally easy for badgers to dig them out. Thus the soil of these mounds is invariably much churned, and this favors *Elymus* invasion. Rodents such as *Microtus* and *Citellus* appear to be especially fond of grazing *Carex filifolia* in this vegetation.

When the association is grazed by cattle *Festuca idahoensis* and *Agropyron* decrease. *Stipa columbiana* and *Poa secunda* commonly increase at first, then annuals such as *Bromus tectorum, Festuca pacifica* and *Plantago* replace the perennials. *Chrysothamnus nauseosus* also increases. *Poa ampla*, although very poorly represented in climax stands, locally becomes very abundant in vegetation that has been disturbed in the past. *Artemisia tripartita* seems little affected by grazing, even when this is severe enough to cause annuals to replace most perennials.

The coverage of annuals that increase with grazing pressure shows no inverse correlation with the coverage of *Festuca idahoensis* across the association table (appendix B-7). Therefore, it is reasonably certain that the wide range in its coverage does not reflect unsuspected differences in past grazing use, and in the main, the stands selected represent pristine conditions rather faithfully.

The sharp-tailed grouse, formerly widespread in meadow-steppe zones in Washington, has become largely restricted to the *Artemisia tripartita-Festuca* zone (129).

Detailed studies were made at the edge of a fire that stopped before completely crossing stand 160. In the first post-burn season, the sum of coverages was reduced from 153 to 105. Although it was obvious that litter destruction left much bare soil exposed, no erosion could be seen on this 31% slope. Burning stimulated many new sprouts to rise from the lateral roots of the *Artemisia*, and the old shoots regenerated from adventitious buds on the lower 2 cm of their stems. Some bunches of *Festuca* were killed and others damaged, yet the total coverage was scarcely reduced, presumably owing to increased vigor of the residual plants. Inflorescences were shorter but more numerous in *Festuca* and *Koeleria*, but taller and fewer in *Agropyron*. Apparently, no major species was killed or none invaded because of the fire. Some were reduced significantly in coverage (*Erigeron corymbosus, Eriogonum heracleoides, Madia exigua*). Others benefitted from the burning (*Arenaria congesta, Frasera albicaulis, Phlox longifolia*). *Agropyron* coverage was reduced chiefly because the post burn tillers stood more stiffly erect.

Earlier it was pointed out that climatic differences are correlated with ecotones which the *Artemisia tripartita-Festuca zone* makes with the *Artemisia tridentata-Agropyron, Artemisia tridentata-Festuca, Agropyron-Festuca* and *Festuca-Symphoricarpos* zones. In the southwest part of the steppe region, a disjunct segment of the *Artemisia tripartita* zone makes contact with the *Purshia-Festuca* zone (fig. 1). The climate of the former is colder in winter (October, December, January and February), and consistently wetter in several months (more P in January, July and August; higher P/T in August, September, November and January).

In the central part of the steppe region, the *Artemisia tripartita-Festuca* h.t. penetrates drier zones to the south in all cases as a topographic climax restricted to northerly slopes and loessal soils. The inclusion of *Balsamorhiza sagittata* (rather than *B. careyana*), *Koeleria* and *Stipa columbianum* are floristic differences that further distinguish the *Artemisia tripartita-Festuca* association from these more xerophytic communities to the south. However, the dominance of the *Artemisia tripartita* among shrubs is the most obvious character.

Stand 117 (appendix B-7) is remarkable for its low species diversity and sparsity of perennial forbs. It represents a topographic climax deep within the *Agropyron-Festuca zone*. Other north-facing slopes in this area also support this attenuated form of the association, but most of them have more coverage of the *Artemisia*.

The limited penetration of the *Artemisia tripartita-Festuca* association into the *Festuca-Symphoricarpos* zone involves sites with shallow stony soil where the water-storage capacity is limited. This habitat of compensation is thus stringly different from the preferred habitats where contact is made with drier zones.

Soil moisture has been studied through an annual cycle of use and recharge in one stand of the *Artemisia tripartita-Festuca* association (27). Although the upper three decimeters of the profile were dry by mid-June, the remainder of the upper meter was not exhausted of its growth water until very late in the dry season. On the whole, available soil moisture was more limited here than in the *Festuca-Symphoricarpos* stand studied concurrently.

Soil pH nearly always increases with depth in the *Artemisia tripartita-Festuca* h.t., which is a result of rainfall hardly adequate to prevent lime accumulation. In contrast, the pH of soils in the contiguous *Festuca- Symphoricarpos* h.t. nearly always decreases at least to a depth of half a meter.

A wide range of Great Soil Groups is represented by vested in a thin fleshy pericarp that soon dries. Chipmunks, Brewers blackbirds and starlings have been seen feeding heavily on these fruits during their brief fleshy stage, despite their extremely bitter taste to humans. Then mice apparently use the dried fruits extensively after they drop from the bushes, for most seedlings found while examining hundreds of sample plots have occurred in dense tufts about 2 cm in diameter, such as result from the germination of seeds in forgotten mouse caches. When fire eliminates Purshia from an area, mouse distribution of the achenes must play an important role in its reinvasion.

Purshia is important as winter browse for deer and wapiti. Snows in winter force these animals down from the mountain forests to low altitude where they often damage orchards, which are extensive in the foothills from the Yakima Valley northward. The native plant most useful in attracting these animals away from cultivated areas at this season is *Purshia*. This shrub is not only abundant in the steppe just below lower timberline, but also dominates undergrowth in the contiguous *Pinus-Purshia* forests. Maintenance of *Purshia* populations, if not their artificial increase, is therefore a major objective of game management along the eastern edge of the Cascades. Although livestock readily eat *Purshia* in winter when snow covers the ground, animals are seldom turned out on native range at this season; thus, its major economic value in the Cascade foothills is related to winter browse for deer and wapiti.

When the *Purshia-Festuca* association is grazed excessively, *Stipa columbianum* and *Poa secunda* tend to increase during the early stages of retrogression, but *Bromus tectorum* eventually becomes the major species with continued heavy grazing.

In discussing climates of the contiguous zones, it was pointed out that the *Purshia-Festuca* zone is cooler and wetter than the *Artemisia tridentata-Agropyron* and *Artemisia tripartita-Festuca* zones, but is drier and cooler than the *Festuca-Hieraceum* zone.

All three soil profiles examined in the level loessal area in the southerly region where the Purshia-Festuca association is climatic climax belong to the Chestnut Great Soil Group and Typic Haploxeroll category. Stand 125 represents this group:

A1 0-5″ Dark grayish brown (10YR 4/2d) or very dark brown (10YR 2/2m) silt loam; mixed weak medium and fine subangular blocky and weak medium and fine granular; slightly sticky, slightly plastic; friable, soft; pH 6.4; abundant roots; clear smooth boundary

B11 5-9″ Dark grayish brown (10YR 4/2d) or very dark brown (10YR 2/2m) clay loam; moderate medium and fine angular blocky; moderately sticky, moderately plastic; firm, slightly hard; pH 6.5; numerous roots; clear wavy boundary

B12 9-13″ Dark brown (10YR 3/3m) clay loam; moderate medium subangular blocky; stick, plastic; firm, slightly hard; pH 6.5; numerous roots; clear wavy boundary

B21 13-20″ Very dark brown (10YR 2/2m) silty clay loam; moderate medium and fine angular blocky; sticky, plastic; firm, slightly hard; pH 6.4; occasional roots; clear wavy boundary

B22 20-30″ Very dark grayish brown (10YR 3/2m) silty clay; moderate medium and coarse angular blocky; sticky, plastic; firm, slightly hard; pH 6.5; occasional roots; clear wavy boundary

B3 30-36″ Yellowish brown (10YR 5/4m) silty clay; weak medium and fine angular blocky; sticky, plastic; firm, slightly hard; pH 6.4; occasional roots; abrupt wavy boundary

II Dr 36″+ Fractured basalt bedrock. (by W. A. Starr).

The two profiles examined northward in the Cascade foothills were a Chernozem-Regosol intergrade (stand 78) and a Regosol, or a Typic Haploxeroll and a Typic Vitrandept, respectively. At stand 78 the profile was:

A11 0-3″ Very dark brown (10YR 2/2m) coarse sandy loam; weak fine granular; friable; roots abundant; abrupt smooth boundary

A12 3-8″ Very dark brown (10YR 2/2m) coarse sandy loam; weak fine subangular blocky; friable; roots fewer; gradual smooth boundary

AC 8-18″ Dark brown (10YR 3/3m) sandy loam with few fine gravels; very weak medium subangular blocky; friable; roots plentiful; diffuse smooth boundary

C1 18-39″ Brown (10YR 4/3m) gravelly sandy loam; massive; friable; roots plentiful; clear smooth boundary

D 39″+ Basic igneous and acid igneous cobble of glacial origin, with some soil material between cobbles; lime accumulation on lower surfaces; few roots. (by R. A. Gilkeson).

THE EDAPHIC SERIES: Habitats with soils that are shallow or abnormal in physical or chemical properties

Nearly all of the ecosystem types grouped here extend across a much wider spectrum of climates than any climatic climax, and their macroclimates are far from being mutually exclusive as those of the climatic climaxes are. While their ecology cannot be narrowly related to climate, there is usually a highly predictable relationship to some soil abnormality. This is the basis for distinguishing the stable vegetation of nonzonal soils as edaphic climaxes.

Deep soils dominated by gravel, sand or strongly weathered volcanic ash

Deep soils that are dominated by gravel, sand or strongly weathered volcanic ash share important and distinctive ecologic characteristics as shown by their close relation to the dominance of *Stipa comata* in the herb layer. *Agropyron spicatum*, often accompanied by *Festuca idahoensis*, characterizes most other deep but nonsaline soils.

Where gravel and sand dominate the mineral framework, the moisture-holding capacity of the soil is low. Where weathered volcanic ash dominates, the moisture-holding capacity can be high. For example, the lacustrine accumulation of ash at stand 80 (appendix B-9) has a moisture equivalent of 20.8%. The vescicular character of the ash particles, rather than a high colloid content, gives such soil its high water-retention.

Since sand and volcanic ash differ so much in their water relations, their apparent ecologic equivalence obviously does not reside simply in their water-holding capacities, even though the average *Stipa* soil is definitely coarser-textured than the average *Agropyron* soil. A clue to the problem is provided by the observation that *Agropyron spicatum* can grow luxuriously on almost pure volcanic ash of recent (Hypsithermal) origin. This circumstance suggests that the low fertility of *Stipa* soils derived from older and more strongly weathered ash or sand and gravel is probably the key to their ecology.

All available chemical analyses for soil (upper 20 cm) and all available moisture equivalent (upper 50 cm) were grouped according to whether *Stipa comata* or *Agropyron spicatum* was the dominant grass. One group consisted of 14 sets of data divided among *Artemisia tridentata-Stipa*, *Purshia-Stipa* and *Stipa-Poa* h.ts. The other consisted of 20 sets of data representing *Artemisia tridentata-Agropyron*, *Artemisia tridentata-Festuca* and *Agropyron-Festuca* h.t.s. Although data were available for more soils in wetter zones, those were not considered as rigorously comparable to the *Stipa* soils, all of which were from the drier zones.

In this comparison, the least overlap in values was between moisture equivalents, cation exchange capacities, and Mg contents (table 5). In these respects, the groups of soils differed at the 95% confidence level; differences in phosphorus content did not quite reach that level. In all those stands where the moisture equivalents of *Stipa*-dominated soils were relatively high, the exchange capacity or Mg content was well below normal. Thus it is concluded that *Stipa* soils are either drier or less fertile, if not both, than *Agropyron* (and *Festuca*) soils.

Despite the good differentiation between *Stipa* and *Agropyron* soils in the upper 20 to 50 cm of their profiles as shown above, the same data give no clue to why *Purshia*, *Artemisia tridentata*, and *Artemisia tripartita* characterize the shrub layer at different places where the soils are dominated by *Stipa comata*, then show the same segregation in *Agropyron* soils. Perhaps the ecology of these shrubs, which must maintain contact with permanent moisture supplies in the subsoil, must be explained on the basis of characters of the deeper horizons that have not yet been studied.

It is interesting that the median coverage of *Artemisia tridentata* is essentially identical in stands of *Artemisia tridentata-Agropyron* and *Artemisia tridentata-Stipe*. Evidently, the soil factor that so strongly governs the composition of the grass layer has negligible influence on the population density of this shrub. Although there are fewer data for comparison, *Purshia* likewise seems no different in its coverage on *Stipa* and *Agropyron* soils.

Table 5. Means and fiducial limits for certain characters of soils from stands dominated by *Stipa comata* and other stands dominated by *Agropyron spicatum* (sometimes accompanied by *Festuca idahoensis*).

Dominant Grass	No. of Stands	Moisture Equivalent (%)	Exchange Capacity (meq/100g)	Exchangeable Mg (meq/100g)
Stipa comata	14	11.1±3.2	6.3±1.4	1.16±0.20
Agropyron spicatum	20	21.0±3.3	15.2±2.6	3.06±0.67

The oft-repeated statement that stands of *Artemisia tridentata* indicate good agricultural land is not true for the extensive areas of *A. tridentata-Stipa* h.t. in Washington, unless one can fertilize and irrigate economically.

The soil differences distinguishing *Stipa* and *Agropyron*(*-Festuca*) soils tend to be reflected in other elements of the vascular flora, if not in the dominant shrubs. *Plantago patagonica* is far more regularly associated with *Stipa* habitats, and *Leptodactylon* is closely confined to the group. In the *Artemisia tridentata-Agropyron* zone, *Balsamorhiza careyana* is the characteristic representative of *Stipa* sites. The coverage of Poa secunda is lower in *Stipa* habitats. It is notable, however, that species diversity is not conspicuously different between *Agropyron* and *Stipa* h.ts. (appendix E).

Starting with Cotton's comment based on his observations during travels in Washington (19), *Stipa comata* has often been considered an increaser if not an invader of grazed areas formerly dominated by other perennial grasses. However, Griffiths (46), who drew his conclusions from similar observations, pointed out the soil correlation. The present study indicates that soil is the more important differentiating factor in Washington. Fencelines would constitute the most solid evidence in favor of Cotton's hypothesis. But no fenceline that has *Stipa comata* dominant on one side with a more palatable grass dominant on the other has been found in Washington.

It must be admitted that negative evidence is not definitive, and that *Stipa comata* may well be an invader or increaser in other geographic regions, e.g. British Columbia (115). The clear preference of livestock for *Agropyron* and *Festuca idahoensis* when these grow mixed with *Stipa* suggests that intergrades at least can be converted to pure *Stipa* stands through differential grazing pressure. However, jackrabbits have been observed to graze *Stipa* and avoid *Agropyron* in a mixed stand, thus tending to have the reverse effect.

As a dominant grass, *Stipa comata* is well represented only in the drier zones in the interior of the steppe region. It plays this role in the meadow steppe types only along the western flank of the Okanogan Mountains where it grows on sands in the lower margin of the *Artemisia tripartita-Festuca* zone.

Artemisia tridentata-Stipa comata h.t.

The *Artemisia tridentata-Stipa comata* h.t. is recognized by the superposition of a layer of *Artemisia tridentata* over a grass layer that is outstandingly dominated by *Stipa comata.*

Except for the substitution of *Stipa comata* for *Agropyron,* the *Artemisia tridentata-Stipa comata* association closely resembles the *Artemisia tridentata-Agropyron* association on both a physiognomic and floristic basis (fig. 14, appendix B-9). *Stipa* is less palatable to livestock than *Agropyron,* but when there is no superior forage available, *Stipa* is the main forage species. If heavily used, it is replaced by annuals such as *Bromus tectorum* and *Plantago patagonica.* In the Okanogan Valley, *Sporobolus, Gypsophila paniculata,* and *Artemisia frigida* become conspicuous as disturbance opens up a *Stipa* stand. *Purshia tridentata* readily invades the habitat where the surface soil has been removed, as along roadsides.

Soil profiles in the *Artemisia tridentata-Stipa* stands studied included Sierozem, Regosol, and intergrades between Brown and Regosol and between Chestnut and Regosol. They included Typic Haploxeroll, Calcic Haploxeroll, Typic Xeropsamment, Typic Xerorthent, Mollic Camborthid and Typic Vitrandept.

The profile at stand 129, a Royal loamy fine sand (Sierozem) and a Mollic Camborthid, is:

A11 0-2" Dark brown (10YR 3/3m) or light brownish gray (10YR 6/2d) loamy fine sand; single grain; nonsticky nonplastic; friable, loos; pH 7.1; abundant roots beneath grass bunches; clear wavy boundary

AC 2-10" Brown (10YR 4/3m) or light brownish gray (10YR 6/3d) loamy fine sand; massive; slightly compact; pH 7.4; many roots beneath grass bunches; clear wavy boundary

C1 10-20" Brown (10YR 5/3m) or light brownish gray (10YR 6/2d) loamy fine sand; massive; slightly compact; pH 7.6; occasional roots; clear wavy boundary

C2 20-30" Brown (10YR 5/3m) or light brownish gray (10YR 6/2d) loamy very fine sand; massive; slightly compact; pH 8.1; numerous roots; clear wavy boundary

CSca 30"+ Light brownish gray (10YR 6/2m) or light gray (10YR 7/2d) fine sand; single grain; friable, loose; pH 8.8; calcareous; occasional roots. (by W. A. Starr).

At stand 36 the soil profile, an Ellisforde very fine sandy loam (Chestnut-Regosol intergrade) and a Calcic Haploxeroll, is:

A11 0-5cm Very dark grayish brown to dark brown (10YR 3/2.5m) or light brownish gray to pale brown (10YR

14. *Artemisia tridentata-Stipa comata* stand 36.

15. *Purshia tridentata-Stipa comata* stand 137.

6/2.5d) very fine sandy loam; very weak coarse and medium granular; soft, friable; pH 6.8; many roots

A12 5-15cm Very dark grayish brown to dark brown (10YR 3/2.5m) or light brownish gray to pale brown (10YR 6/2.5d); weak medium subangular blocky; pH 6.7; frequent roots

C1 15-33cm Dark grayish brown (10YR 4/2m) or pale brown (10YR 6/3d) very fine sandy loam; weak moderate to coarse angular blocky; more compact than C2; pH 6.5

C2 33-58cm Brown (10YR 5/3m) or pale brown (10YR 6/3d) very fine sandy loam; very weak medium angular blocky; pH 6.8

C3ca 58-74cm Light gray (10YR 7/1m) or white (10YR 8/1d) silt loam; moderate medium angular blocky; tongued with extensions of horizon above; pH 8.0; highly calcareous; roots frequent

C4ca 74-100cm Grayish brown (10YR 5/2m) or white to very pale brown (10YR 7.5/3d) very fine sandy loam; loose, single-grained; calcareous with frequent nodules that are strongly calcareous; pH 7.6

D1ca 100-122cm Light brownish gray (2.5Y 6/2m) or light gray (2.5Y 7/2d) fine silt; brittle, laminated, compact; pH 8.1

D2ca 122-168cm Grayish brown (2.5Y 5/2m) or light brownish gray (10YR 6/2d) succession of strata of fine silt with loose single grain structure and silt in thin brittle layers; all mildly effervescent; pH 8.2

The *Artemisia tridentata-Stipa* h.t. occurs throughout the *Artemisia tridentata-Agropyron* zone and the *Artemisia tridentata-Festuca* zone. It has been reported from British Columbia (80), northern Oregon (94), and eastern Idaho (88). A similar community dominated by *Artemisia tridentata* var. *vaseyana* occurs in west central Wyoming (109).

Purshia tridentata-Stipa comata h.t.

The *Purshia tridentata-Stipa comata* h.t. is recognized by the combination of a shrub layer dominated by *Purshia tridentata* in combination with an herb layer dominated by *Stipa comata* (fig. 15).

In Washington *Purshia* reaches its lowest altitude in the *Artemisia tridentata-Agropyron* zone where it occurs almost entirely on sands with *Stipa comata*. This *Purshia-Stipa* association differs from the *Artemisia-Stipa* association only in the substitution of one dominant for the other, and they intergrade over a long series of intermediates. Only the relatively pure types were selected for detailed study, since this procedure was likely to provide the most information about differences in environment favoring one shrub against the other.

Although many *Purshia-Stipa* stands seem fully as stable as any of the *Artemisia-Stipa* stands, there can be no doubt but that the *Purshia-Stipa* community can be seral to *Artemisia tridentata-Stipa* in places. Bare road cuts running through *Artemisia-Stipa* stands 24 and 130 have been invaded by *Purshia*, although the latter has obviously been unable to invade well-vegetated surfaces in the h.t. Across the dirt road from *Artemisia-Stipa* stand 170 was an apricot orchard that had been established under irrigation, then abandoned at least 24 years before it was studied. During this period a normally dense stand of *Stipa comata* (coverage 80%, frequency 100%) had reinvaded, with *Purshia* forming a vigorous shrub layer among the decadent apricot trees. Occasional plants of *Artemisia tridentata* had entered from time to time since cultivation ceased, but no *Poa secunda* had appeared as yet. With the *Artemisia-Stipa* association prevalent in the landscape and coming up to the opposite side of the road from the orchard, there is little doubt that the orchard represents an *Artemisia-Stipa* habitat.

Bromus tectorum is again the major increaser in Purshia-Stipa stands that are overgrazed. Where the surface soil is removed, *Eriogonum niveum* invades the raw gravel and sand readily.

Soil profiles in the *Purshia-Stipa* h.t. vary from Sierozem to Brown-Regosol intergrades, to Regosol, and from Mollic Camborthid to Typic Xeropsamment and Typic Vitrandept.

In stand 137, the soil is a Royal fine sand (Sierozem) and a Mollic Camborthid:

A11 0-2″ Dark brown (10YR 3/3m) or pale brown (10YR 6/3d) fine sand; single grain; friable, loose, nonsticky, nonplastic; pH 7.2; dense mat of fine roots; abrupt smooth boundary

A12 2-9″ Dark brown (10YR 3/3m) or pale brown (10YR 6/3d) fine sand; massive, slightly compact, nonsticky, nonplastic; friable, slightly hard; pH 7.9; abundant roots; clear wavy boundary

C1 9-38″ Brown (10YR 5/3m) or very pale brown (10YR 7/3d) fine sand; massive, slightly compact; nonsticky, nonplastic, friable, slightly hard; pH 7.7; roots plentiful but decreasing with depth; clear wavy boundary

C2ca 38″+ Brown (10YR 5/3m) or light gray (10YR 7/2d) fine sand; single grain; nonsticky, nonplastic, friable, loose; calcareous; pH 7.9; occasional roots (by W. A. Starr).

Stand 21 illustrates a *Purshia-Stipa* stand on Skaha fine sandy loam, a Brown-Regosol intergrade and a Typic Xeropsamment:

A1 0-7.5cm Very dark grayish brown (10YR 3/2m) fine sandy loam with 5-10% gravel; occasional granulation where roots are dense

A3 7.5-17.5cm Dark brown (10YR 3/3m) sandy loam with 10-15% gravel; mixed massive to single grain with occasional fine to medium blocks

C1 17.5-30cm Dark yellowish brown (10YR 4/4m) sandy loam; similar to above horizon but with about 25% gravel

C2 30-77.5cm Coarse sand with 25-30% gravel with same color as above; loose and single-grained

D 77.5cm+ River-washed sand and fine gravel composed of mixed quartzitic, granitic and basaltic particles; salt-and-pepper colored; single-grained; loose (by W. A. Starr).

In Washington, the *Purshia-Stipa* h.t. seems restricted to the *Artemisia tridentata-Agropyron* zone, but extends southward in that zone into Oregon (94). East of Drummond, Montana, 2½ miles, a stand of this association has been noted on gravelly sandy loam.

Stipa comata-Poa secunda h.t.

In stands of the *Stipa comata-Poa secunda* association that are well preserved, *Stipa comata* and *Poa secunda* are the two major herbaceous species. Widely scattered bushes of *Chrysothamnus nauseosus* are the only evident shrubs.

Physiognomically, the *Stipa-Poa* association is indistinguishable from the *Agropyron-Poa* and *Agropyron-Festuca* associations of contiguous heavier-textured soils.

In following sandy soils eastward from the driest part of the Columbia Basin, a point is reached where *Artemisia tridentata-Stipa* stands are no longer to be found only because the dominant shrub extends no farther along the climatic gradient. Beyond this point, which lies well within the *Agropyron-Poa* and *Agropyron-Festuca* zones, the *Stipa-Poa* association characterizes soils homologous with those of the *Artemisia tridentata-Stipa* h.t.

In overgrazed areas, *Bromus tectorum* assumes dominance, and *Chrysothamnus nauseosus* increases. At stand 168 (appendix B-10) *Artemisia tridentata* has invaded mounds resulting from rodent excavations.

Soil properties that distinguish the *Stipa-Poa* h.t. from those of the adjacent climatic climaxes have been included in table 5. This h.t. differs from the *Artemisia-Stipa* and *Purshia-Stipa* h.ts. primarily in climate.

Soil profiles in the four stands analysed were divided among Sierozem and Brown Great Soil Groups, and among Mollic Camborthid, Calcic Haploxeroll and Typic Torriorthent.

Stand 168 is on Wacota loamy fine sand (Brown), a Typic Torriorthent:

A1 0-4″ Dark grayish brown (10YR 4/2m) or pale brown (10YR 6/3d) loamy fine sand; single grain and fine granular; nonsticky, nonplastic; friable, soft; numerous roots; abrupt smooth boundary

AC 4-16″ Dark grayish brown (10YR 4/2m) or pale brown (10YR 6/3d) loamy fine sand; single grain nonsticky, nonplastic; friable, soft; frequent roots; clear wavy boundary

C 16-38″ Brown (10YR 5/3m) or very pale brown (10YR 7/3d) fine sand; single grain; nonsticky, nonplastic; friable, soft; occasional roots; abrupt wavy boundary

Dva 38″+ Grayish brown (10YR 5/2m) or white (10YR 8/2d) medium sand (volcanic ash); single grain; nonsticky, nonplastic; friable, soft; no roots. (by W. A. Starr).

At stand 86 the profile is a Shano very fine sandy loam, volcanic ash variant, (Sierozem) and a Mollic Camborthid:

A1 0-5cm Dark brown (10YR 3/3m) very fine sandy loam; very weak medium platy; very friable when moist, soft when dry; abrupt smooth boundary

AC 5-60cm Dark brown to brown (10YR 4/3m) fine sandy loam; very weak coarse subangular blocky; very friable when moist, soft when dry; gradual smooth boundary

C1 60-135cm Similar to above, except massive and contains appreciable amounts of caliche fragments

Cca 135cm+ Grayish brown (10YR 5/2m) or light gray (10YR 7/2d) loamy fine sand size ash; very calcareous; firm in place, noncoherent when disturbed. (by R. A. Gilkeson).

The *Stipa-Poa* h.t. occurs in the both segments of the *Agropyron-Poa* zone, but in the eastern segment it extends no farther east than about Central Ferry. It occurs in the *Agropyron-Festuca* zones wherever there is sandy soil. It is well represented in western Montana although the *Stipa* there is only about half as tall as in Washington. In the Ruby Valley east of Dillon, Montana, *Bromus tectorum* grows thickly on gravel overturned at the edges of roadways, but seems unable to invade the *Stipa-Poa* h.t. without equivalent disturbance, as it can in Washington. Van Ryswyk, et al., (121) have documented the *Stipa comata-Poa* association near Kamloops, B.C.

Eriogonum niveum phase

An *Eriogonum niveum* phase of the *Stipa-Poa* association can be recognized by the relatively large amount of *Eriogonum niveum*: 6-10% coverage in comparison with 0-1% in the *Stipa-Poa* association.

Other conspicuous differences can be added (appendix B-10). In the phase, *Stipa comata* has relatively low coverage (1-10% versus 50-95%); the soil is gravelly or stony (rather than deep sand or volcanic ash); and the summed coverage percentages for the stands are only 44-56% (rather than 137-181%). Finally, there is an important geographic distinction—the phase occurs in the *Artemisia tridentata-Agropyron* and *Artemisia tripartita-Festuca* zones, whereas the *Stipa-Poa* association appears confined to the *Agropyron-Poa* and *Agropyron-Festuca* zones.

Poulton (94) has recognized this vegetation type in northern Oregon.

Artemisia tripartita-Stipa comata h.t.

The *Artemisia tripartita-Stipa comata* h.t. is distinguished by having *Artemisia tripartita* as the principal shrub and *Stipa comata* as the principal perennial grass (appendix B-10).

Physiognomically, *Artemisia tripartita-Stipa comata* stands are indistinguishable from *Artemisia tripartita-Festuca* stands.

In the stands sampled, the moisture equivalents of the soils ranged from 9.9-12.3%, in comparison with a range of 14.2-31.6% for *Artemisia tripartita-Festuca* soils. These *Stipa*-dominated soils tend to differ from those of lower zones in their lower pH (6.3-6.9 in the 5th dm, as compared with 6.6-8.2), reflecting the higher moisture balance and deeper deposition of lime.

Soils shallow to bedrock (lithosols)

The lithosols considered here generally consist of a thin layer of frost-jumbled basalt blocks resting on the jointed bedrock from which they were weathered. Typically, there is a wide hiatus in the size-class distribution of particles in the rooting medium. For the most part, a large proportion is stones, few pebbles, almost no gravel or coarse sand; most of the interstitial material is sandy loam or loam. Except for one h.t. this fine material is closely similar to the nearby aeolian material of the zonal soils. Morphologically, the soils vary from those that completely lack visible horizon differentiation to those that are aptly called pigmy profiles, with thin but well developed horizons.

At the juncture of a residual body of loess and an area where the loess has been eroded until a lithosol remains, there is usually an abrupt vegetation discontinuity. Taller vegetation with a much greater biomass usually gives way to a moderately dense carpet of *Poa secunda* with foliage only about 5cm tall, over which low shrubs or plants of similar stature form a highly discontinuous second layer. Usually, the ground surface is conspicuously interrupted by angular fragments of basalt. Like the loessal filling between them, these fragments support a well-developed lichen-bryophyte crust (table 6).

The major characteristics of the substrate and the carpet of *Poa* are remarkably uniform throughout most of the considerable area of such lithosols. However, the species forming the taller layer differ from place to place. They occur together in certain combinations, or segregate as relatively pure stands. This tendency for segregation of the overstory species provides the most obvious basis for dividing the lithosols into h.ts.

At a number of places where shallow-soil and deep-soil communities form a narrow ecotone, a flexible tape was carefully laid along what was judged to be the center

Table 6. Representative mosses and lichens of the *Artemisia rigida-Poa* association. See table 1 for key to location of specimens.

MOSSES	
On soil:	
Bryum argenteum lanatum C	*G. montana* C
Ceratodon purpureus C	*Tortula ruralis* C
Grimmia alpestris C	
On basalt stones:	
Grimmia alpestris C	*G. decipiens* C
On stems of Artemisia:	
Grimmia alpestris C	*Tortula ruralis* C
Orthotrichium affine C	
LICHENS	
On soil:	
Acarospora schleicheri W	*Diploschistes scruposus* H
Candelaria vitellina H	*Lecanora cinerea* H
Catillaria melaena washingtoniana H	*Lecidea globifera* H
Cladonia pyxidata H	*L. luridella* W
Dermatocarpon acarosporoides H	*L. russellii* W
D. hepaticum H	*Leptogium lichenoides pulvinatum* H
D. rufescens H	*L. pilosellum* H
	Peltigera canina H
On basalt stones:	
Caloplaca cf. *atroalba* W	*L. cyanea* H
Candelaria vitellina H	*L.* (*pavimentans* ?) W
Lecanora calcarea W	*Parmelia conspersa* H
L. gibbosa H	*Rhizocarpon bolanderi* W
L. muralis H	*Verrucaria* sp.
Lecidea atrobrunnea W	
On stems of Artemisia:	
Buellia lauri-cassiae H	*Physcia ascendens* H
Candelaria vitellina W	*P. pulverulenta* H, W
Lecanora hageni W	*Rinodina sophodes* H
Parmelia exasperata H	*Xanthoria polycarpa* H, W
On moss:	
Cladonia cariosa H	

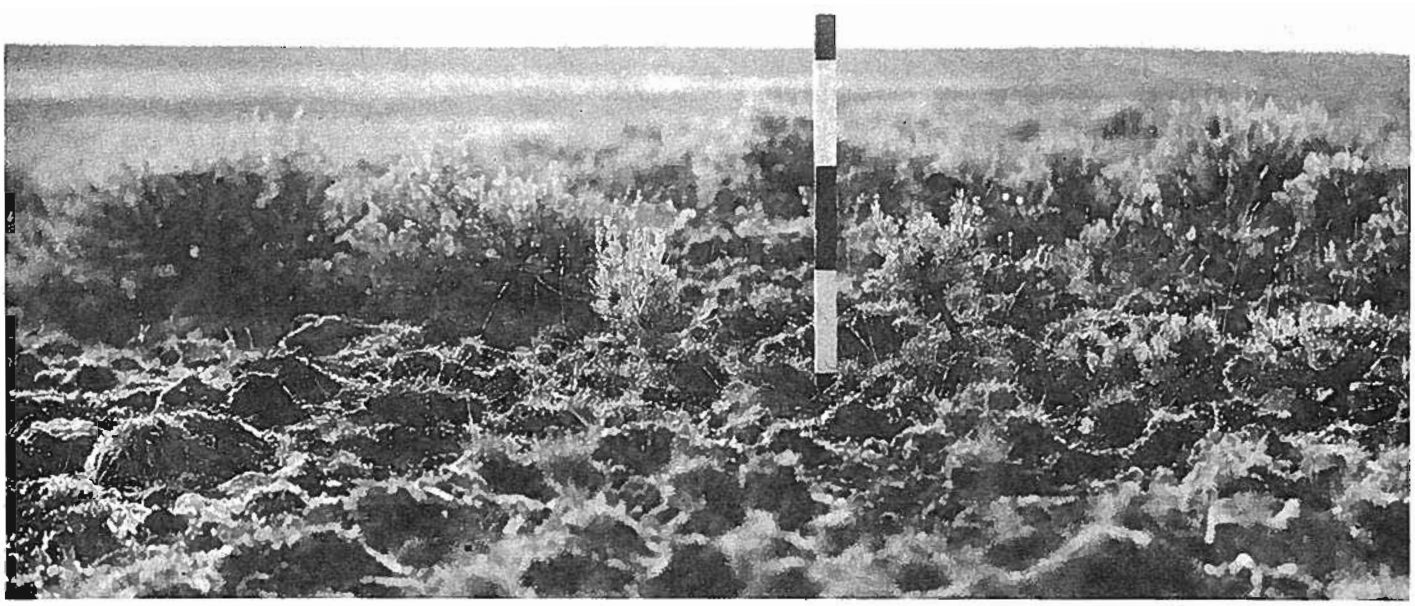
of the ecotone, and soil depth was determined at 100 equally spaced points along the tape. The purpose was to determine the extent to which it might be possible to obtain a quantitative expression of the point along a gradient where soil depth becomes ecologically critical,—i.e., to define "deep" soil and "shallow" soil in terms significant for this vegetation mosaic.

The mean value for soil depth in the middle of the ecotones varied from 9.8 to 30.2 cm. Variation within this range was not related to annual precipitation over the range of 230-480 mm, nor altitude over the range of 210-700 m, nor to direction or degree of slope from 0-26%. Correlations were in no way improved by calculating averages after reducing the occasional large depth measurements to 25, or 30 or 35 cm. The generalization is thus warranted that soil depth does not become critical until the mean decreases to 10-30 cm, and microclimate and macroclimate have no predictable influence on variations in this critical depth. In other words, 30 cm of loam, and sometimes less, are adequate to support a climatic climax in this vegetation mosaic.

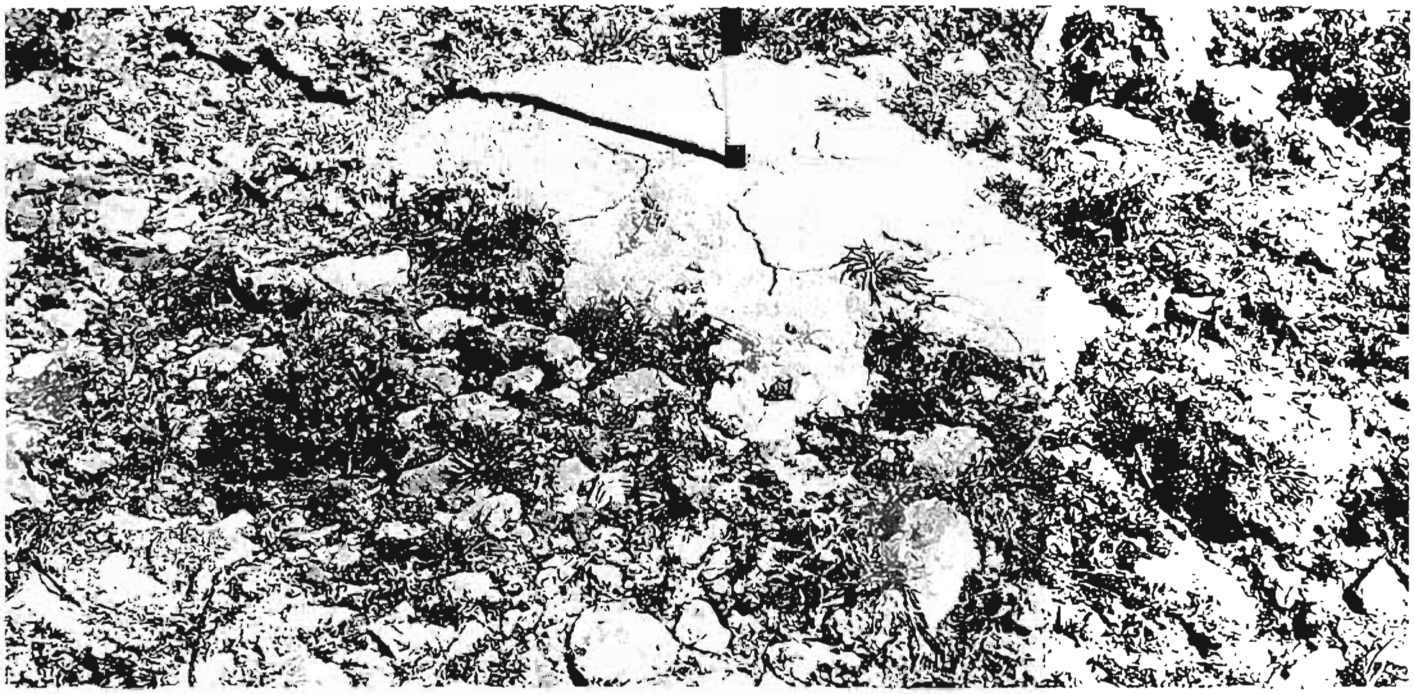
Other depth measurements were usually made along the line of coverage plots which were always well within each of the stands studied. Variations in soil depth at these places likewise showed no consistent differences among the h.ts. Neither was any other character of the soil (pH, moisture equivalent, chemical analyses, morphology of the profile) correlated with h.ts., despite the fact that a person can often stand on a lithosol with one foot in the margin of one association and the other in a different association! Factors not included among those measured must obviously determine which shrub dominates. The factor most strongly suspected is variation in the nature of the fracture-system of the subtending basalt. Geographic limitations to the areas over which the various h.ts. are found suggest that macroclimate accounts for some of the h.t. distinctions, but neither macroclimate nor microclimate explains the juxtaposition of segregates that are frequently in proximity.

As a class, the shallow-soil communities are less subject to modification by livestock than any other series. Except for lithosols in the rather moist eastern margin of the steppe, *Poa secunda* is subject to so much sun and wind influence, and frequent soil drouth, that its foliage is too stunted to be attractive to the animals except when feed is extremely short. Furthermore, in winter when this plant is green, the filling between the stones is usually so saturated and soft that hooves might as well be striking directly against the bare edges of the angular fragments. Livestock will develop trails across lithosols to get from one area of deep soil to another, but seldom do they graze a lithosol significantly until they have badly depleted all other available forage. As might be inferred from some of the foregoing remarks, these h.ts. usually have very low forage potential.

Lithosolic h.ts. occur in part on slopes, and in part on flat areas that appear to have neither horizontal nor vertical drainage. The flat areas commonly have water standing on their surfaces during periods of thaw in winter, but since the vegetation there is no different from that of nearby areas with sloping surfaces, it may be assumed that the fracture systems of the subtending basalt are generally characterized by water saturation during the rainy season. This excessive wetness is conducive to congeliturbation and to the heaving of certain species. Individual plants of *Poa secunda* are commonly lifted until they are perched on mounds approximately 5cm wide by 5cm tall (fig. 16).



16. Frost-heaved *Poa secunda* (hemispheric mounds about 4 cm high) and a young plant of *Artemisia rigida* (to right of stake) that has been frost-lifted with about 10 cm of its tap root exposed. Land surface in this *Artemisia rigida-Poa secunda* stand 62 is level.



17. "Frost boil" as it appeared on April 9 in an *Eriogonum thymoides-Poa secunda* stand. Two rosettes of the perennial *Lewisia rediviva* to the right of the stake have reestablished normal relations with the new surface.

Until *Artemisia rigida* is several years old it too is subject to frost-lifting, and many young plants do not develop resistance to this force until about 15cm of their tap root has been exposed by one or more episodes of frost-lifting, which makes the bush appear much like a miniature apple tree (fig. 16). The subtending basalt must play much the same role here as does permafrost in arctic regions. "Frost boils" commonly form where interstitial loam is suddenly extruded through a weak place in the freezing crust (fig. 17). The centrifugal thrust sometimes turns pedestalled plants of *Poa secunda* on their sides with the roots exposed. Pebble nets are often discernible (fig. 18). Near the southern edge of continental glaciation, huge inactive stone nets formed during glacial times are common in lithosolic h.ts. in Washington.

The combination of summer drouth and heat, alternating with winter wetness and frost action, would seem to make the lithosolic sites especially rigorous for vascular plants, yet species diversity is often as great as on some of the deep-soil h.ts. (appendix E).

In spring, the dark green of the lichen-bryophyte crust turns still darker as the vegetation desiccates. This, together with the black of any exposed basalt, makes the lithosolic components of a landscape mosaic stand out as conspicuously dark patches, despite the brown tufts of the tiny *Poa*. All of the shrubs, however, retain active leaves during summer, showing clearly the vital importance of moisture stored in the narrow confines of the fracture system of the basalt.

There appears to be no regular difference in either soils or vegetation between lithosols produced by glaciofluvial erosion, and those on ridges where only wind and rain could have kept the basalt exposed.

Segregation of stands into associations is less satisfactory in the lithosols than in any other series. Whereas many stands are outstandingly dominated by single species (*Artemisia rigida, Eriogonum niveum, E. microthecum, E. sphaerocephalum, E. douglasii,* and *Agropyron spicatum*), in a sizeable residue, dominance is variously divided among a broad spectrum of species. Most of those in the last group have been named after *Eriogonum thymoides*. The segregation indicated in table 7 is not so artificial as it seems, for study sites (appendix B-11 and B-12) were selected to demonstrate variety rather than to show that many hundreds of stands are clearly dominated by the single species after which the types are named.

As a group, the shallow soils support the maximum diversity of species in *Allium, Eriogonum, Lomatium, Cruciferae* and suffrutescent plants (lumped with other chamaephytes as low shrubs in the tables). At the same time with a single exception, they produce less grass per m^2 per year than any other group of h.ts. in the steppe. They may be species-poor, presenting a drab and monotonous appearance, or they may have high diversity and at the peak of flowering provide a handsome display of color.

The thick farinaceous roots of several species of *Lomatium* which grow abundantly on lithosols (especially *L. macrocarpum, L. gormani,* and *L. canbyi* were gathered by the aborigines, dried, pounded into flour, moistened and baked to make a hard biscuit. As this was one of their main items of plant food, the food-gathering activities of early man could have influenced the amount of *Lomatium* found in lithosolic vegetation today. *Lewisia rediviva* is another plant common to lithosols that was extensively dug (and still is to some extent) for its roots.

Rodents with burrows in adjoining habitats where the soil is deep evidently forage widely over lithosols, for there is frequent evidence of digging for subterranean plant organs, presumably the roots of ***Lomatium***. The seeds of ***Lewisia*** are so attractive to mice that the maturing ovaries are often destroyed.

Artemisia rigida-Poa secunda h.t.

The *Artemisia rigida-Poa secunda* h.t. is recognized by its supporting a community consisting of a *Poa secunda* layer that is overtopped by well-spaced bushes of the low *Artemisia rigida* (fig. 19). In its typical form, other shrubs are rare. The soils are always thin and stony, with basaltic bedrock immediately below.

As a rule, the *Artemisia rigida-Poa* association looks monotonous and impoverished, for although the species diversity may be high, it results from the inclusion of a few individuals of many kinds of small plants. Shantz (107) recognized this extensive association as "scabland sage," but made no mention of the *Poa* layer (appendix B-11).

Beneath the canopy of each *Artemisia* plant, the more vigorous growth of *Tortula* and other mosses (table 6), combined with the litter of the deciduous shrub, tends to build up a hemispheric mound that in wetter zones may

18. Violence of frost action in lithosols attested by pebble nets in *Artemisia rigida-Poa secunda* stand 50. Decimeter segment of stake in upper right corner, with portion of *Artemisia rigida* in lower right corner and *Poa secunda* scattered about.

Table 7. Percentage canopy cover of the principal low shrubs and *Agropyron spicatum* in the lithosolic habitats sampled. Data extracted from appendix B-11 and B-12. Stands interpreted as intergrades are not named.

Association	Stand	*Artem. rigida*	*Eriog. thymo.*	*Haplo. steno.*	*Phlox hoodii*	*Eriog. sphaer.*	*Eriog. dougl.*	*Eriog. niveu*	*Eriog. micro*	*Agrop. spica.*
	50	29								
	49	27								
	51	25								
Artemisia rigida-Poa	52	14		+						
	114	10								
	236	34						+		
	140	10			+		+			
	112	12	5							
	111	19	4			+		+		
	110	13	+	1	2					
	89	6	2	+	1		+			
	238	17	1	6	+	3				
	113	9	+	9	2	+				
	108		4	4	+					
	141		3	3	+	3				
Eriogonum thymoides-Poa	84		14	4			6	1		
	46		1	1						
	45		3	8						
	47			+	6					
	116			6	2	8				
Eriogonum spaeroce-Poa	44			2		4				
	176		+			13				
Eriogonum doug.-Poa	90						6			
	142				10		23			
	115							+		
	85							2		
Eriogonum niveum-Poa	173							7		+
	174							5		+
	175							1		+
	182							14		
	177							+	17	2
	178							+	14	+
Eriogonum microthec-Physaria	179							+	15	
	180							12	12	
	44			2		4				11
	143							+		70
Agropyron-Poa (lith.)	97									47
	109									69
	181									39

become 2 dm thick. *Poa secunda* and *Lithophragma bulbifera* become especially abundant on such mounds. When the *Artemisia* reaches the end of its life span, these hummocks slowly disintegrate.

The absolute restriction of this community to basalt is notable. The Upper Grand Coulee that marks part of the eastern boundary of Douglas County is a gorge formed by glacial floods that cut down through all the basalt strata and well into Colville granite below. At the north end of the Coulee, thin soils on granite support *Eriogonum niveum* rather than *Artemisia*. But on travelling southward down the floor of the Coulee, one sees the line of contact between the overlying basalt and the subtending granite descend, and with it the lower limit of *Artemisia rigida*, until even the floor of the Coulee becomes basaltic and this *Artemisia* is everywhere the dominant shrub of lithosols.

In the southeastern quarter of the Washington steppe region, it is common to find the *Artemisia rigida-Poa* and *Eriogonum niveum-Poa* associations alternating with remarkably sharp ecotones separating the stands on the same basaltic outcrop. Where they occur on the same slope, either may lie above the other. On Badger Mountain in western Douglas County, lithosols are occupied by the *Artemisia rigida-Poa* association on the south slope, but by the *Eriogonum thymoides-Poa* association on the summit and north slope. These sharp segregations contrast with the tendency for the *Artemisia rigida-Poa* association to intergrade with several other lithosolic associations (table 7).

Artemisia rigida is preferred browse for wapiti, but these animals do not range far enough into the steppe to get into the area where the most extensive stands of this shrub occur. Domestic livestock also consume the *Artemisia* readily when grass forage is not plentiful, and stands of severely hedged plants are not difficult to find. *Bromus tectorum* is the most ubiquitous increaser.

Rickard (96) captured only one species of mouse in the *Artemisia rigida* stand that he studied (appendix D).

Soils identified in the *Artemisia rigida-Poa* h.t. were divided between Lithic Argixeroll and Lithic Haploxeroll.

Stand 49, a Lithic Argixeroll, is in the *Festuca-Symphoricarpos* zone at about the cool-moist limits of the association. The profile is a Gwin fine sandy loam:

A1 0-1″ Very dark grayish brown (10YR 3/2m) or dark grayish brown (10YR 4/2m) fine sandy loam; massive, vesicular, with common very fine and medium pores; nonsticky, nonplastic, firm, slightly hard; pH 6.4; abrupt smooth boundary

B1 1-2.5″ Dark brown (10YR 3/3m) or brown (10YR 5/3d) loam; massive, slight vesicular, with few fine and medium pores; pH 6.4; nonsticky, nonplastic, firm, slightly hard; numerous stones; abrupt smooth boundary

B2 2.5-7″ Dark brown (7.5YR 3/2m) or brown (7.5YR 5/3d) loam with frequent rock fragments and stones; moderate medium and fine subangular blocky; slightly sticky, nonplastic, firm, slightly hard; pH 6.4; clear wavy boundary

D 7″+ Fractured basalt bedrock (by W. A. Starr).

Stand 114 is in the driest part of the *Artemisia tridentata-Agropyron* zone. The profile, a Lickskillet very fine sandy loam, is classed as a Lithic Haploxeroll:

A 0-4″ Brown (10YR 4.3m or 10YR 5/3d) very fine sandy loam with 70% angular basalt stones; single grain; nonsticky, nonplastic, friable, soft, pH 7.2; abundant roots; clear irregular boundary

B 4-8″ Brown (10YR 4/3m or 10YR 5/3d) silt loam with 40% angular basalt stones; moderate medium and fine angular blocky; slightly sticky, nonplastic, firm, hard; pH 7.2; numerous roots; abrupt wavy boundary

II Dr 8″+ Fractured basalt bedrock (by W. A. Starr).

The *Artemisia rigida-Poa* h.t. is the most widespread member of the lithosolic series in the Washington steppe; it occurs from the *Artemisia tridentata-Agropyron* zone up into the forested slopes of the Cascades and Blue Mountains as far as the *Pseudotsuga* zone. In the Bitterroot foothills, however, it barely gains representation in the *Festuca-Symphoricarpos* and *Festuca-Rosa* zones. It also occurs in central (94) and southeastern (46) Oregon, and in Adams and Washington Counties in Idaho.

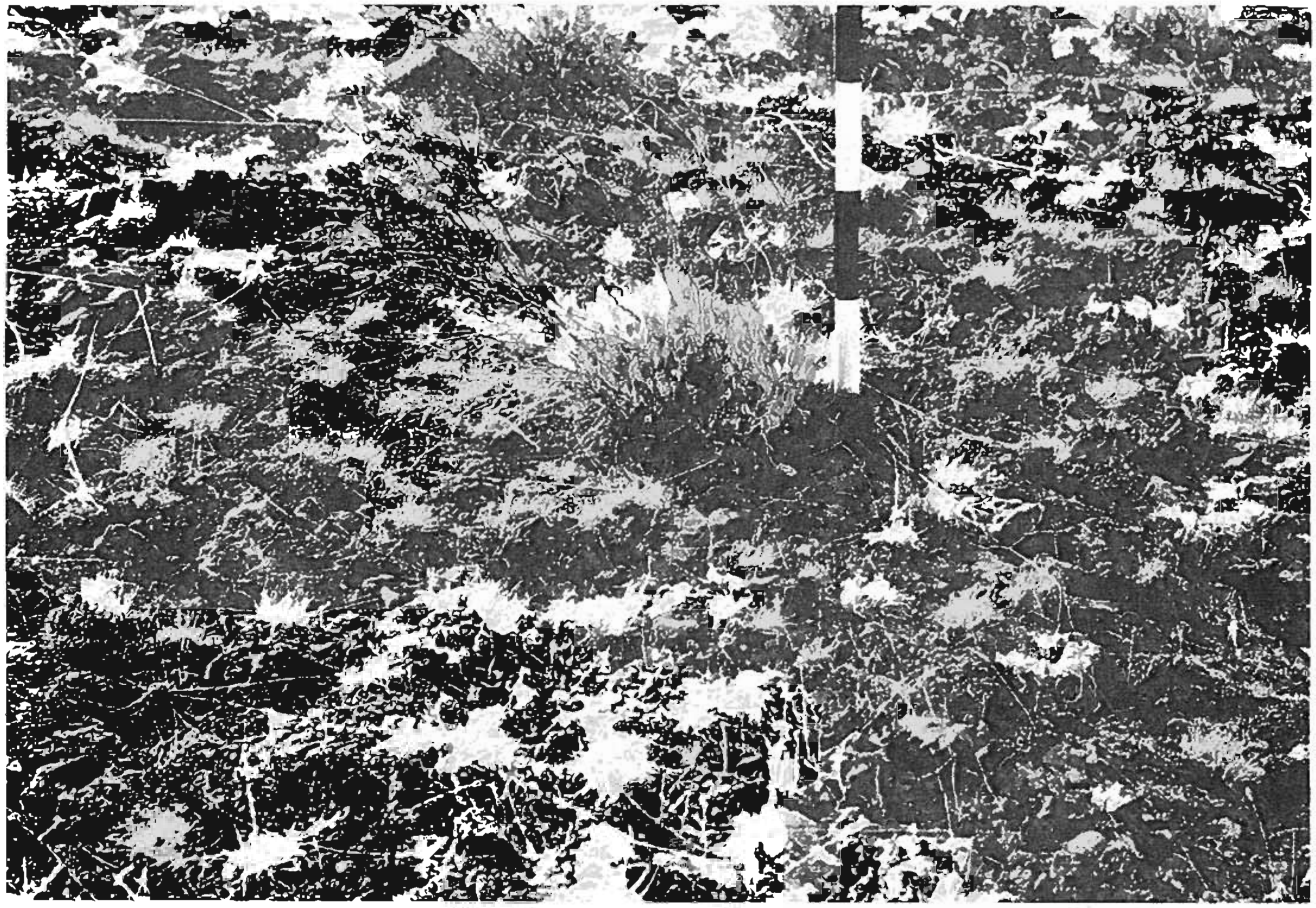
Eriogonum niveum-Poa secunda h.t

The *Eriogonum niveum-Poa* association consists of a sward of *Poa secunda* associated with few to many individuals of the dwarf, white-leaved shrub *Eriogonum niveum* (fig. 20). The shallow stony soil can be derived from a variety of types of parent rock.

The sharp ecotones between *Eriogonum niveum-Poa* and *Artemisia rigida-Poa* stands have been mentioned. In an experiment, the *Artemisia* and *Eriogonum* were grown from seed, separately and in mixture, in soil from an *Artemisia* habitat and in soil from an *Eriogonum* habitat. The cultures were started in midwinter in a glasshouse and moved out-of-doors near Pullman in spring.

Throughout the experiment, soil moisture was brought up to the field capacity often and both species developed rapidly. Some of the *Eriogonum* plants flowered at the end of summer. The shrubs developed equally on both soils, and as satisfactory in mixed cultures as in pure.

19. *Artemisia rigida-Poa secunda* stand 49.



20. *Eriogonum niveum-Poa secunda* stand 175.

Thus the factor which determines the sharp ecotones in the field appears to be connected with the environment of the roots that penetrate the weathered fracture planes of the parent rock, and has nothing to do with the character of the solum or biotic interference of one species with the other. Unlike any other species among the dwarf shrubs of lithosols, *Eriogonum niveum* rarely appears in mixture with others.

Eriogonum niveum is also unique in its vigorous invasion of recently bared gravelly soils. Its success here suggests the possibility of planting the species as an aid in artificially stabilizing sandy or gravelly soils, despite the limitations of its rosette-like form and tap root.

Eriogonum appears to recover well from cattle use, even when the shoots are taken to the ground surface. Grazing at this intensity results in the replacement of *Poa secunda* by such annuals as *Bromus tectorum, Festuca pacifica* and *Erodium cicutarium.*

The soil at stand 85 (appendix B-12) is a gravelly silt loam lacking evident profile development:

0-10 cm Very dark grayish brown (10YR 3/2m) or grayish brown (10YR 5/2d) stony and gravelly silt loam; vesicular; very friable when moist, soft to slightly hard when dry; pressure faces between stones and soil common; abrupt irregular contact with bedrock

10 cm+ Somewhat fractured, vesicular basalt, relatively unweathered; root mats extending into rock cracks by R. A. Gilkeson).

At stand 175 the soil profile is a Bakeoven silt loam, a Lithic Haploxeroll:

A 0-1" Very dark brown (10YR 2/2m) or grayish brown (10YR 4/2d) silt loam; weak medium subangular blocky and coarse granular; numerous roots; abrupt smooth boundary

AC 1-3" Very dark grayish brown (10YR 3/2m) or grayish brown (10YR 5/2d) loam; weak medium angular blocky; slightly sticky, nonplastic; friable, slightly hard; frequent roots; abrupt smooth boundary

Dr Highly vesicular platy basalt with very little interstitial material (by W. A. Starr).

The *Eriogonum niveum-Poa* h.t. occurs mainly in the eastern half of the Washington steppe. There, it alternates with the *Artimisia rigida-Poa,* lithosolic *Agropyron-Poa,* or *Eriogonum microthecum-Physaria* h.ts. Westward, it extends into the *Agropyron-Poa* and *Agropyron-Festuca* zones and from there southward along the western base of the Blue Mountains into Oregon (94).

Eriogonum sphaerocephalum-Poa secunda h.t.

The *Eriogonum sphaerocephalum-Poa* h.t. is recognized as a lithosol supporting a *Poa secunda* layer, with *Eriogonum sphaerocephalum* the principal member of the low shrub layer (appendix B-12).

The soil profile at stand 44 is a Lickskillet silt loam, a Lithic Haploxeroll:

A 0-3" Light brownish gray (10YR 6/2d) or very dark brown (10YR 2/2m) silt loam with considerable grit and fine rock fragments; moderate medium to coarse subangular blocky, tending toward medium platy and vesicular in the upper part: firm, slightly hard, slightly sticky, nonplastic; numerous roots

B 3-7" Brown (7.5YR 4/2d) or dark brown (7.5YR 3/2m) silt loam; weak medium and fine subangular blocky; sticky, slightly plastic; numerous roots

Dr 7" Fragmented basalt (by W. A. Starr).

Stand 116 was on a Bakeoven loam, a Lithic Haploxeroll:

A11 0-2" Reddish yellow (7.5YR 6.6d) or dark brown (7.5YR 3/4m) loam; moderate coarse platy; slightly firm, hard, nonsticky, nonplastic; pH 7.0; numerous roots

A12 2.5-4.5" Strong brown (7.5YR 5/6d) or dark brown (7.5YR 3/4m) loam; moderate medium and fine subangular blocky; slightly sticky, nonplastic; pH 6.9; occasional roots

B1 4.5-7.5" Strong brown (7.5YR 5/6d) or dark brown 7.5YR 3/3m) clay loam; weak medium and fine subangular blocky; moderately sticky, moderately plastic; pH 6.9; numerous roots

B2 7.5-8.5" Yellowish red (5YR 5/8d) or dark reddish brown (5YR 3/4m) clay loam; weak fine subangular blocky; sticky, plastic; pH 6.9; occasional roots (by W. A. Starr).

The *Eriogonum sphaerocephalum-Poa* h.t. occurs in the *Artemisia tridentata-Agropyron, Artemisia tridentata-Festuca* and *Artemisia tripartita-Festuca* zones.

Eriogonum douglasii-Poa secunda h.t.

The *Eriogonum douglasii-Poa secunda* h.t. is recognized as a lithosol supporting a *Poa* layer. *Eriogonum douglasii* is the principal member of the low shrub layer. See appendix B-12 and fig. 21.

21. *Eriogonum douglasii-Poa secunda* stand near Satus Peak, Klickitat County, Washington. The side of a road cut blasted into the basalt shows the shallowness of the soil and pattern of jointing in the bedrock to good advantage.

The soil profile at stand 47 is an unnamed loam classified as a Typic Argixeroll:

A1 0-4" Light gray (10YR 7/2d) or very dark grayish brown (10YR 3/2m) loam; with 15% rounded quartzitic gravel; mixed weak, fine granular, fine subangular blocky, and single grain; slightly sticky, nonplastic; friable, soft; pH 6.4; abundant roots; clear wavy boundary

A12 4-8" Light gray (10YR 7/2d) or very dark grayish brown (10YR 3/2m) silt loam, with 10% rounded quartzitic gravel; mixed weak, medium and fine subangular blocky and weak medium and fine granular; slightly sticky, slightly plastic, friable, soft; pH 6.3; numerous roots; abrupt smooth boundary

B1 & A2 8-14" Dark brown (7.5YR 3/2m) clay loam with 10% rounded quartzitic gravel; moderate, medium subangular blocky with many conspicuous gray coatings on peds and some peds vesicular; slightly sticky, moderately plastic, firm, slightly hard; pH 6.3; frequent roots; abrupt wavy boundary

B2 14-23" Dark brown (10YR 3/3m) clay with 10% rounded quartzitic gravel; massive; very sticky, very plastic, very firm, very hard; pH 5.6; occasional roots; abrupt irregular boundary

Dr 23"+ Fractured basalt (by W. A. Starr).

The *Eriogonum douglasii-Poa* h.t. is found mainly along the flank of the Cascades from Ft. Simcoe southward, in the *Artemisia tridentata-Agropyron* and *Purshia* zones.

Eriogonum compositum-Poa secunda h.t.

The association distinguished by joint dominance of *Eriogonum compositum* and *Poa secunda* appears restricted to the *Festuca-Hieraceum* zone. Many stands have been seen there, but none has been studied.

Eriogonum thymoides-Poa secunda h.t.

In the *Eriogonum thymoides-Poa* h.t., there is a relatively rich mixture of low shrub among which *Eriogonum thymoides* and *Haplopappus stenophyllus* are commonly codominant (appendix B-11). *Poa secunda* is again the chief grass present.

Table 4 shows that this association intergrades freely with the *Artemisia rigida-Poa* association, so that by inference the environment must be very similar. However, here there occur a number of species with showy flowers, especially *E. thymoides*, with some plants having sulfur-yellow capitula and others in the same stand having dark red, *Haplopappus*, *Viola* and *Phlox*, so that the stand provides a magnificent floral display early in June. Typical *Artemisia rigida-Poa* stands, of which there are many hundreds, are in contrast very drab at all seasons.

Stand 46 is on a Gwin stony loam, which is a Lithic Argixeroll:

A1 0-3cm Light brownish gray (10YR 6/2d) or dark brown (10YR 3/3m) loam; weak fine granular to single grain; pH 6.5; numerous roots

A3 3-11cm Light brownish gray (10YR 6/2d) or dark yellowish brown (10YR 3/4m) loam; weak to moderate medium subangular blocky, reducing to fine subangular blocky to medium granular; pH 6.8; roots numerous

B1 11-17cm Pale brown (10YR 6/3d) or dark brown (10YR 3/3m) clay loam; moderate medium to fine angular blocky; with frequent basalt pebbles and fragments and numerous basalt stones pH 6.5; frequent roots

B21 17-25cm Dark yellowish brown (10YR 3/4d) or dark brown (10YR 3/3m) clay loam, mixed with basalt that is fractured in vertical planes and beginning to weather; B1 above is tongued down into fracture planes of basalt; pH 6.6

B22 25-29cm Dark brown (10YR 3/4d) or very dark grayish brown (10YR 3/2m) clay loam developed principally as facings on fractured basalt blocks and tongued down into D; pH 6.3

B23 29-32cm Fractured basalt with clay loam facings as above; pH 6.4

B24 (D) 32cm+ Fractured basalt with clay loam or silty clay loam facings as above; pH 6.4

D Partially fractured basalt. (by W. A. Starr)

Stand 141 is on Bakeoven loam, a Lithosolic Chestnut and a Lithic Haploxeroll:

A1 0-5" Light brownish gray (10YR 6/2d) or very dark grayish brown (10YR 3/2m) silt loam with 10% angular basal pebbles; mixed weak coarse platy, weak medium subangular blocky, and weak fine granular; slightly sticky, slightly plastic, friable, slightly hard; vesicular; pH 6.8; roots abundant in surface inch, numerous below; abrupt smooth boundary

B1 & A2 5-8" Brown (10YR 5/3d or 10YR 4/3m) silt loam with 30% stones; weak medium subangular blocky, ped surfaces with distinct gray silica coatings; slightly sticky, slightly plastic, firm, slightly hard; pH 6.4; roots frequent; clear wavy boundary

B2 8-12" Brown (10YR 5/3d or 10YR 4.3m) clay loam with 60% stones; moderate medium and fine angular blocky; moderately sticky, moderately plastic, firm, hard; vesicular; pH 6.5; occasional roots; abrupt irregular boundary

Dr 1"+Fractured platy basalt. (by W. A. Starr)

The *Eriogonum thymoides-Poa* h.t. tends to be centered on the driest part of the Columbia Basin, but in this area it ascends to the *Pseudotsuga* zone in both the Cascade foothills and on Badger Mountain in Douglas County.

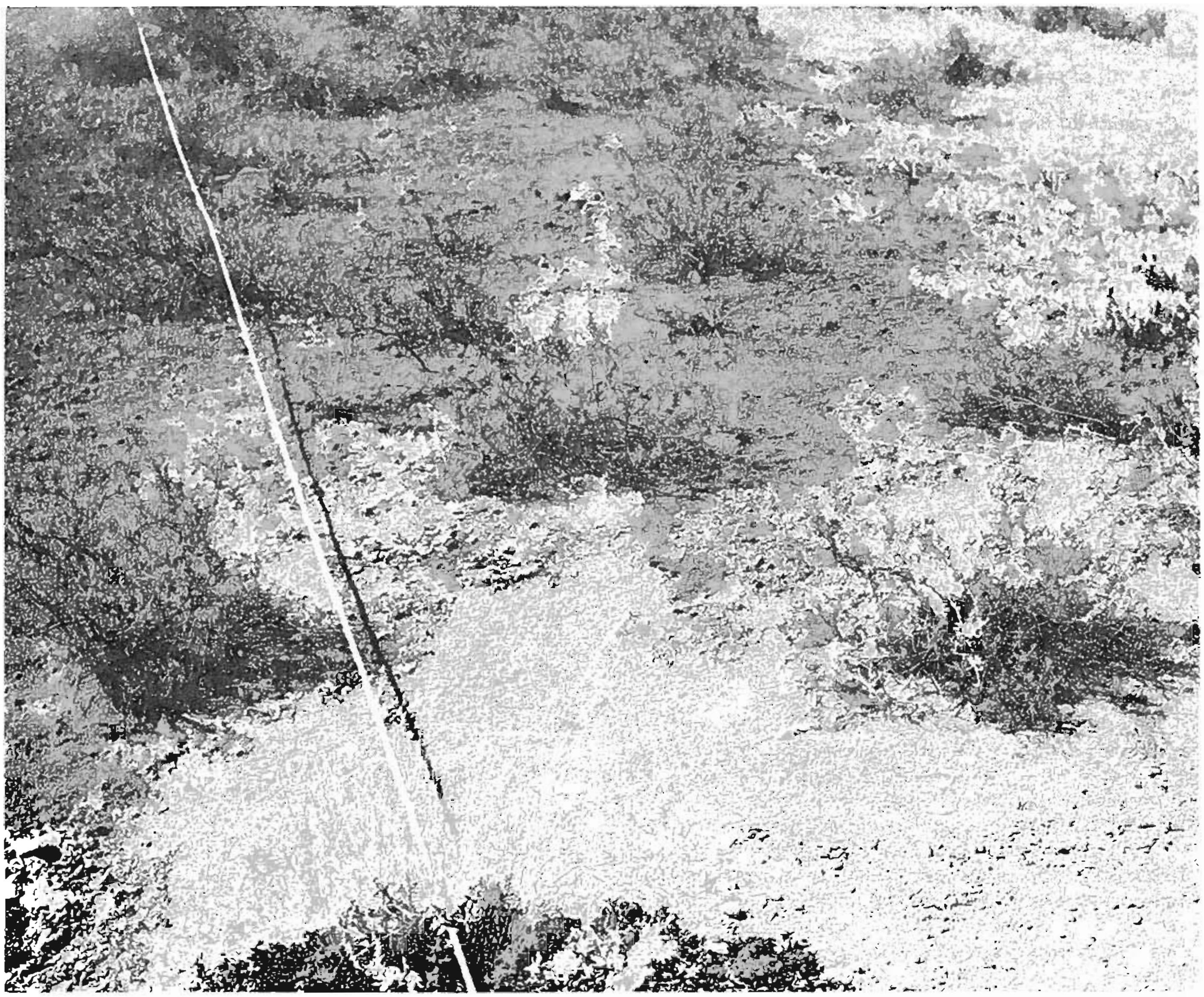
Eriogonum microthecum-Physaria oregana h.t.

The *Eriogonum microthecum-Physaria oregana* h.t. is distinguished by having *E. microthecum* as the only conspicuous shrub, by the high constancy of *Physaria oregana*, and by a coarse and manifestly unstable rooting medium that has been derived from hydrothermally altered basalt.

Eriogonum microthecum laxiflorum, *Physaria oregana* and ***Mentzelia laevicaulis acuminata*** form a distinctive group of characteristic species for this h.t., and provide nearly all the biomass as well. The near absence of both a *Poa secunda* (appendix B-12) and a moss-lichen crust, which are conspicuous on all other lithosolic h.ts., must be related to substrate instability in large measure, for the few representatives of these elements are nearly all clustered about *Eriogonum* bushes that tend to create small enclaves of relatively stable surface. *Eriogonum microthecum* is easily the tallest of the shrubs found on lithosols in the Washington steppe, commonly rising to a height exceeding half a meter (fig. 22).

Nearly all the basalt that is exposed over the Columbia Basin is hard and brittle; the fracture systems resemble those in Figs. 21 and 23. However, intercalated layers of basalt with markedly different properties occur in a few places along the south-facing slope of the Snake River Valley east of the mouth of Steptoe Canyon in southern Whitman County, Washington. This material is hydrothermally altered and intricately fractured. Despite the fracturing, the rock is so firm that it can be broken apart only with blows from a metal pick; yet the roots of *Eriogonum* have been followed 8 dm into the rock where they had made their way following the larger pores, and possibly enlarged the passageway through pressure and/or solution. Weathering of this material yields particles mainly of coarse sand to gravel size. About 30-40% of the particles won't pass a 2 mm screen. Such material forms a very thin and unstable veneer over the outcropping.

The peculiarities of this substrate extend to its chemical composition. Analyses of bulk samples obtained from two of the study sites showed that the <2 mm fraction, in



22. *Eriogonum microthecum-Physaria oregana* stand 179 with the tape along which sample plots were distributed. Upper right corner is in a *Sporobolus-Poa* habitat with *Bromus tectorum* and *Chrysothamnus nauseosus* conspicuous at this season.

comparison with a nearby stand of *Agropyron-Poa*, has high pH (7.6-7.9), low organic matter (0.2-0.3%), high cation exchange capacity (28-31 meq/100g soil), very high Ca (9,000-11,000 lb/acre, and 22-23 meq extractable Ca/100g soil), high soluble Na (0.22-0.29 meq/100g), and low P (2.5 lb/acre).

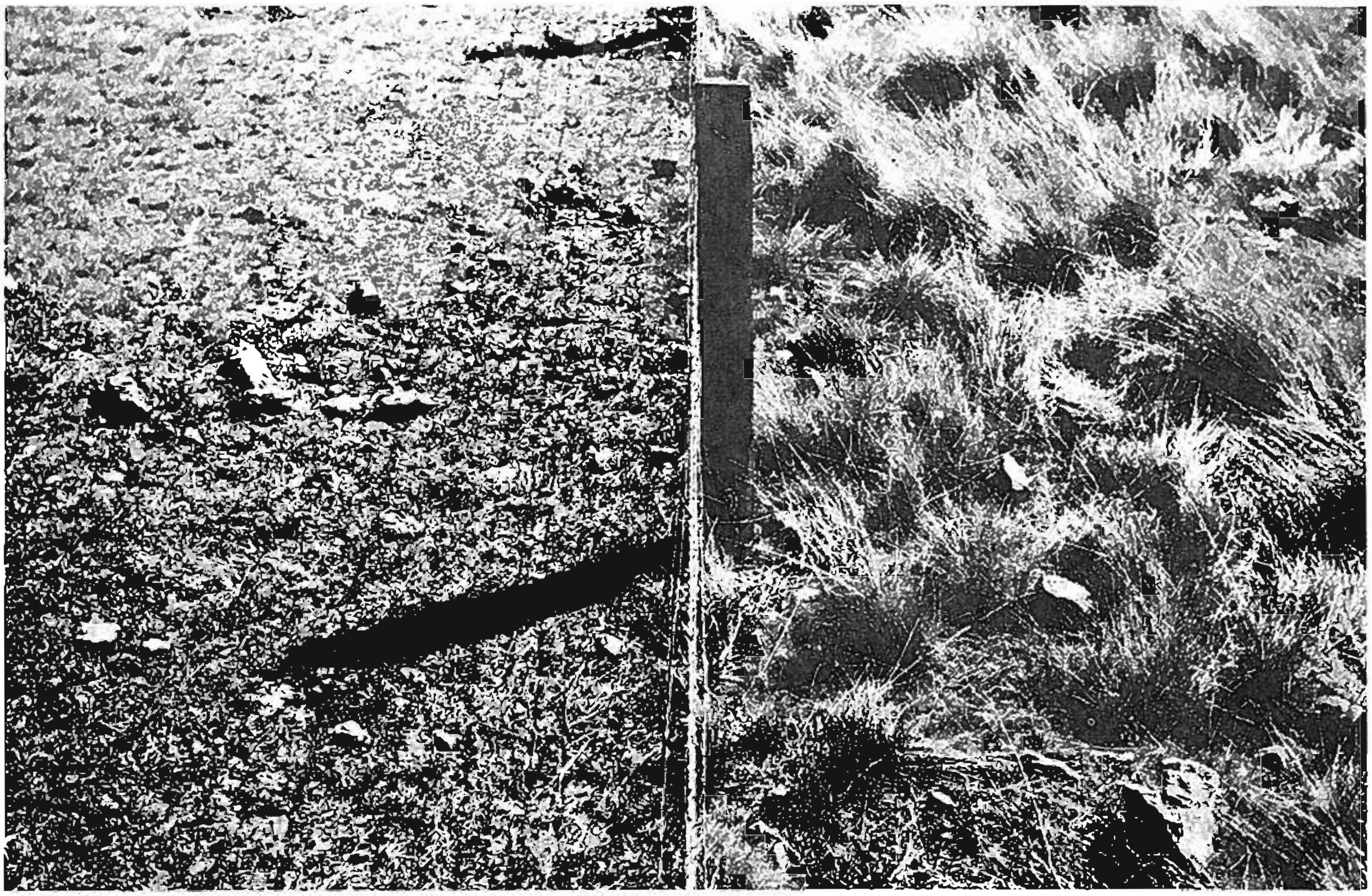
The extremely limited occurrences of this h.t. in the *Agropyron-Poa* zone of southeastern Washington seem to represent the northern terminus of its range. It has been observed in abundance on the east side of the Snake River northward from Pittsburgh Landing, Idaho. Undoubtedly, many such sites occur over the rather inaccessible slopes of canyons here and in contiguous Oregon. The "Picture Gorge basalt" described by Waters (123) appears at least similar to the Snake River outcrops that support the *Eriogonum microthecum-Physaria* stands the writer has seen, and may provide clues as to the locations of additional stands in Oregon.

Agropyron spicatum-Poa secunda h.t., lithosolic phase

The lithosolic phase of the *Agropyron-Poa* h.t. is distinguished by having *Agropyron spicatum* and *Poa secunda* as the two major dominants, this phase occurs on very shallow soil (usually much less than 35cm deep) over bedrock (fig. 23).

The *Agropyron-Poa* association and its lithosolic phase differ chiefly as to their subordinates (appendix B-3). In the latter, *Chrysothamnus* is rare and *Plantago* was not encountered; whereas in the former, both were regularly present. *Allium*, *Eriogonum* and species of *Lomatium* other than *L. macrocarpum* and *L. triternatum* are also common on lithosols but rare on deep soils. The ecotypes of *Poa secunda* in the lithosolic *Agropyron-Poa* h.t. are distinctly taller and more robust than those of most other lithosols, thus approaching *P. canbyi* or *P. ampla* as-tra-

23. Profile of a stand of *Agropyron-Poa*, lithosolic phase, showing the fractured basalt beneath the thin layer of stony soil. Stand 143 is on the slope above this point.



24. Late winter picture showing completeness of use of *Agropyron spicatum* to the left of the fence in this lithosolic *Agropyron-Poa* habitat. Surface stones were thrown here by blasting nearby.

ditionally recognized in taxonomic manuals. Perennial forbs provide about seven times as much coverage in the lithosolic member of the pair under comparison (appendix B-3). However, these forbs are mainly small species with finely divided leaves, so the forb difference is not apparent in the field.

There is a tendency toward lower coverage of both *Agropyron* and *Poa* on the shallow soils, and productivity there may be slightly less. However, in the whole spectrum of shallow-soil communities, the lithosolic *Agropyron-Poa* h.t. is by far the most productive, mainly by virtue of the well-developed overstory of *Agropyron* that occurs in place of a sparse overstory of low shrubs. Since soil depth and quality are comparable with other lithosolic h.ts., higher productivity is a consequence of climate that permits *Agropyron* to dominate.

Although after the grass has matured the caespitose ecotype of *Agropyron* can be grazed down to the soil surface without significant damage to the ecosystem (figs. 24, 25), grazing while the plant is flowering or forming fruits is always injurious and allows *Bromus tectorum* to increase in the habitat. Young (130) erroneously assumed that before the era of livestock, *Festuca idahoensis* was present in lithosolic *Agropyron-Poa* stands which occur in the *Festuca-Symphoricarpos* zone. This grass is universally absent from the h.t.

The soil profile at stand 97, in the *Agropyron-Festuca* zone, is a Bakeoven silt loam and a Lithic Argixeroll:

A1 0-2″ Dark brown (7.5YR 3/2m) or brown (7.5YR 4/2d) silt loam, layered within a stone pavement in places; moderate medium and fine graunlar, vesicular, cloddy; some tendency to weak medium platy; slightly sticky, nonplastic, friable, slightly hard; pH 7.4; very few roots; abrupt smooth boundary

B1 2-4″ Dark brown (7.5YR 3/2m) or brown (7.5YR 5/2d) clay loam with frequent stones; moderate fine and medium angular blocky; sticky, plastic, firm, hard; pH 6.9; numerous roots; abrupt smooth boundary

B2 4-6″ Dark brown (7.5YR 3/2m or d) silty clay loam with frequent stones; moderate medium and coarse angular blocky; very sticky, very plastic, firm, hard; pH 7.0; frequent roots; abrupt smooth boundary

D 6″+ Fractured, sharply angular basalt rock (by W. A. Starr).

The soil profile at stand 143, in the *Festuca-Symphoricarpos* zone, is also a Bakeoven silt loam, but a Lithic Haploxeroll:

A1 0-3″ Brown (10YR 5/3d) or dark brown (10YR

3/3m) silt loam with 10% basaltic pebbles; mixed moderate medium platy and medium and fine subangular blocky; slightly sticky, slightly plastic, firm, slightly hard; pH 6.8; profuse roots; abrupt smooth boundary

B1 3-6″ Brown (7.5YR 4/4d) or dark brown (7.5YR 3/2m) silt loam with 40% stones; moderate medium and fine subangular blocky; slightly sticky, nonplastic, firm, slightly hard; pH 6.6; numerous roots; clear wavy boundary

B2 6-11″ Brown (7.5YR 4/2d) or dark brown (10YR 3/2m) clay loam with 70% stone; moderate fine subangular blocky; moderately sticky, moderately plastic; firm, slightly hard; pH 6.4; occasional roots; abrupt irregular boundary

II Dr 11″+ Fractured basalt bedrock (by W. A. Starr).

The lithosolic *Agropyron-Poa* h.t. occurs in the *Festuca-Symphoricarpos*, *Festuca-Rosa* and *Agropyron-Festuca* zones. Its best representation is in that part of the last zone south of the Snake River. There it occupies extensive south-facing slopes, with the *Agropyron-Festuca* association on deep soils of gentle slopes or north exposures. It will be recalled that the *Agropyron-Poa* association also extends into the *Agropyron-Festuca* zone, chiefly on deep soils of south-facing slopes in the dry edge of the zone.

Saline-alkali soils

All parts of the Washington steppe except the moist margins have local areas, mainly on poorly-drained valley fill, where salt accumulated as inflowering subsurface water evaporated. Not only does salinity exceed the tolerance limits of the average land plant, but the Na ion is so abundant that these saline soils seem always to have detrimentally high pH as well. Texturally, they run the gamut from sands to very heavy loams.

Saline-alkali soils in Washington are linked by a common carpet of *Distichlis stricta*, a perennial, strongly rhizomatous grass that forms a dense sward with practically all the herbage below 20cm. Ecotones where this *Distichlis* sward meets upland types of vegetation are usually very sharp. Unlike most of our dominant grasses, *Distichlis* remains dormant all winter. New tillers appear only after the return of warmth in late April; but once the shoots appear, they remain green in summer when the upland grasses go into aestivation.

Another outstanding even if less conspicuous character of all the h.ts. in this series is the apparent bareness of the fine-textured soils between the vascular plants. In all other h.ts. of the steppe save the *Eriogonum microthecum-*

25. Later picture of the same area shown in figure 24. Close use of *Agropyron* during the dormant season has had no significant effect on productivity. In the ungrazed area to the right, the grass bunches are lighter in color owing to the presence of old bleached shoots. *Sisymbrium altissimum*, a tall annual forb that is favored by disturbance, is conspicuous in the grazed area.

Physaria h.t., the soil is covered by an essentially continuous crust of fine-textured mosses and lichens.

Superimposed over the *Distichlis* sward, one usually finds an open stand of either the deciduous, succulent-leaved shrub *Sarcobatus vermiculatus*, or the large, coarse bunchgrass *Elymus cinereus.* Often the *Sarcobatus-Distichlis* and *Elymus-Distichlis* associations are distinct, even when contiguous, but intergrades are common. The floras of all three of the halophytic h.ts. recognized are typically rather improverished.

Except where artificial drainage has been installed, almost the only use of saline-alkali areas has been grazing, because they furnish green forage all summer while upland grasses desiccate, it seems impossible to find areas where one can be confident that the vegetation has not been somewhat altered by domestic animals. For this reason, vegetation analyses have been made only at the reconnaissance level.

The heavy grazing to which most saline-alkali areas have been subjected leads ultimately to dominance by annuals such as *Bromus tectorum*, *Lepidium perfoliatum* and *Bassia hyssopifolia*, but the *Distichlis* itself is highly tolerant of grazing. Only severe use, involving some use also of the less palatable associates *Elymus* and *Sarcobatus*, will bring about its displacement. The introduced *Lepidium*, a very common plant on severely disturbed upland soils, is most successful in competition with native vegetation in the saline-alkali h.ts. There is some evidence of ecotypic differentiation of this species into halophytic and glykophytic races (15).

At each ecotone between the *Elymus-Distichlis* association and an upland community, the *Elymus* extends beyond the apparent limits of salinity. *Sarcobatus*, and especially *Distichlis*, are more closely confined to saline-alkali soils.

Upland grasses are markedly intolerant of saline-alkali soils, but *Chrysothamnus* spp. and *Artemisia tridentata* have a degree of tolerance. As an example, the following data represent analyses from a rare stand of *Artemisia tridentata-Distichlis* in the *Artemisia tripartita-Festuca* zone. (Another stand of this character has been noted about 1 mile north of Broadview, Montana.)

Soil depth dm	Moisture equiv.	pH (paste)	pH after dilution*	Conduct. (mmho/cm^2)
1	23.8	9.5	9.7	1.5
2	23.6	8.9	9.2	0.9
3	23.0	9.6	9.7	1.4
4		9.9	9.9	3.4
5	21.3	9.9	9.9	4.6

* 1:50 with water

These data show that Dayton's statement that *Artemisia tridentata* is "markedly intolerant of alkalinity, both in soil and subsoil" needs qualification.

All three of the h.ts. recognized have similar zonal distribution. They occur in the *Artemisia tridentata-Agropyron, Artemisia tridentata-Festuca, Agropyron-Poa, Agropyron-Festuca* and *Artemisia tripartita-Festuca* zones.

Distichlis stricta h.t.

An apparently pure sward of *Distichlis stricta* characterizes this h.t. Only a small fraction of the saline-alkali areas in Washington fits this category (fig. 26), and no stands have been analysed in the present study.

Despite the fact that highway maintenance in this area does not involve salting, *Distichlis* commonly invades the shoulders of roadways immediately adjacent to the pavement where one would not suspect natural salinity.

McLean (78) reports this h.t. as far north as Kamloops, B.C.

Fairchild and Willson (41) analysed the soil algae in a Washington stand clearly identified with the *Distichlis stricta* association. They found 13 spp. of *Cyanophyta*, 4 of *Chlorophyta*, and 2 of *Chrysophyta.*

Elymus cinereus-Distichlis stricta h.t

The *Elymus-Distichlis* h.t. is recognized by its supporting a two-layered association consisting of a continuous phase of the short *Distichlis stricta*, with well spaced bunches of *Elymus cinereus* superimposed. The latter commonly exceed 2m in height when the inflorescences have matured (fig. 27).

The ecotype(s) of *Elymus cinereus* in Washington have decidedly more coarse textured and harsh foliage than those the writer has observed in the Great Basin. Undoubtedly, for this reason the grass is little used by livestock except in spring when the leaves first expand. The associated *Distichlis* is preferred most of the year. Under continued heavy use, however, the bunches dwindle in size progressively. According to Cotton (19) *Elymus* was second in importance to *Agropyron* as a native forage grass in the Yakima Valley, and was extensively cut for hay there in the early days of settlement.

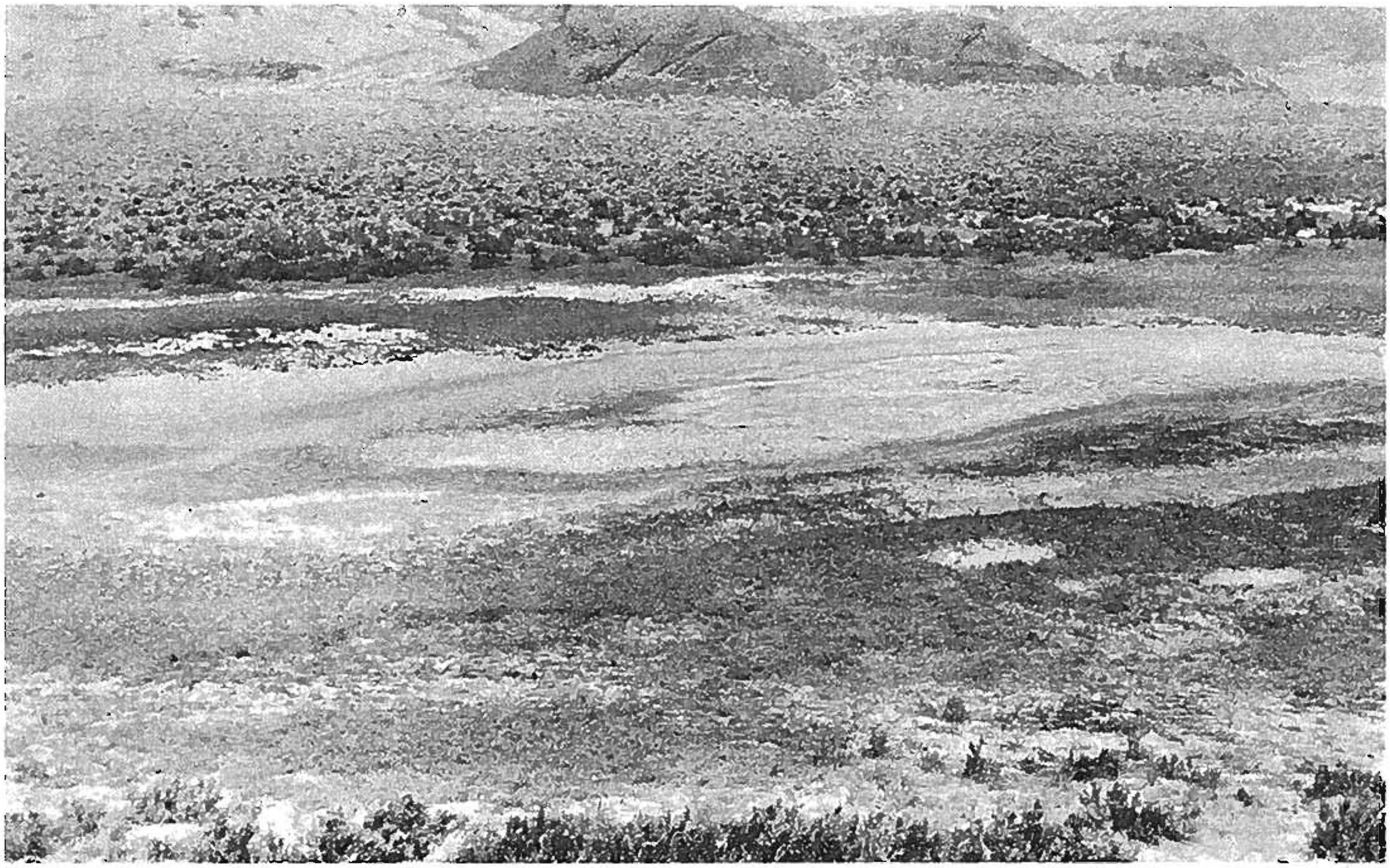
An *Elymus-Distichlis* stand along the highway just east of Dusty has been burned annually for many years by highway "clean-up" crews, but the plants continue to show high vigor and vitality.

A description of the profile (Pedigo silt loam, saline variant) in a very typical *Elymus-Distichlis* stand (SE 14, SW ¼, Sec.3, T15N, R45E), but one not included in the reconnaissance analyses, has been provided through the courtesy of R. Chapin of the Soil Conservation Service:

A11 0-6" Dark grayish brown (10YR 4/2d) or very dark brown (10YR 2/2m) silt loam; weak fine platy; slightly hard, friable, slightly sticky, nonplastic; pH 9.4; slightly effervescent; clear smooth boundary

A12 6-20" Dark grayish brown (10YR 4/2d) or very dark brown (10YR 2/2m) silt loam; moderate granular to weak platy; slightly hard, friable, slightly sticky; nonplastic; pH 8.9-9.2; strongly effervescent; clear smooth boundary

A13 20-26" Dark gray (10YR 4.5/1d) or very dark gray (10YR 3/1m) silt loam; moderate medium granular; slightly hard, friable, slightly sticky, nonplastic; pH 8.9; strongly effervescent; roots abundant in this and above horizons, few below; clear wavy boundary.



26. Zonation of vegetation around a saline playa. Surrounding the barren center is a broad belt of *Distichlis stricta,* then a narrow belt of *Sarcobatus-Distichlis,* with *Artemisia tridentata-Agropyron* steppe on still higher ground in the distance. Grand Coulee.

C1 26-35″ Light gray (10YR 7/1d) or dark grayish brown (10YR 4/2m) silt loam; moderate subangular blocky; hard, firm, slightly sticky, nonplastic; pH 8.9; strongly effervescent; clear wavy boundary

C2 35-44″ Light gray (10YR 7/1d) or dark grayish brown (10YR 4.5/2m) very fine sandy loam; massive; soft, very friable, nonsticky, nonplastic; abrupt smooth boundary

IIC3 44-78″ Light gray (10YR 7/1d) or dark grayish brown (10YR 4/2m) silt loam; massive; hard, firm, nonsticky, slightly plastic; pH 9.0; strongly effervescent; water table at 52″ on July 15, 1968.

Poulton (1955) recognized the *Elymus-Distichlis* association in northern Oregon, and I have seen stands as far south as Nevada. McLean (78) reports their occurrence as far north as Kamloops, B.C.

Sarcobatus vermiculatus-Distichlis stricta h.t.

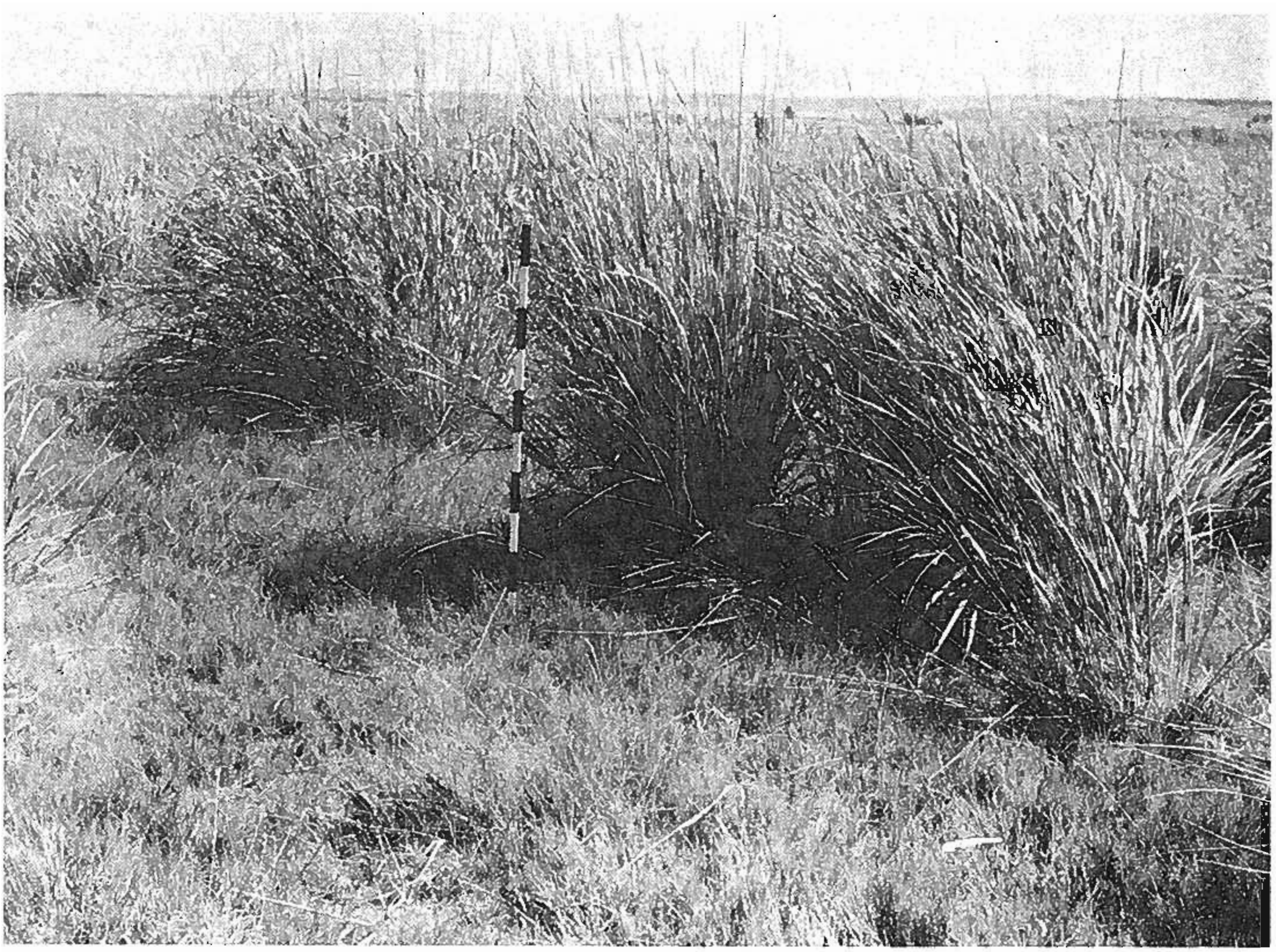
The *Sarcobatus-Distichlis* h.t. is recognized by a sward of *Distichlis* over which are scattered bushes of *Sarcobatus vermiculatus* growing 1-2m tall (fig. 28).

Ordinarily, *Sarcabatus* is little used by livestock, but under heavy grazing pressure the shrubs become smaller and develop a compact canopy of foliage, with *Bromus tectorum* replacing the *Distichlis.* Rickard (102) showed that in a *Sarcobatus* stand where *Distichlis* had presumably been replaced by *Bromus* because of past heavy grazing, winter rains moistened the soil profile no deeper than 6dm. However, the negligible transpiration of the leafless shrub in winter allowed so much water to be stored in the soil that the following spring *Bromus* was distinctly more productive here than in a nearby area where the only shrub was the evergreen, *Artemisia tridentata.*

Fire kills *Sarcobatus* back only to the ground surface, and sprouts from the root summit appear promptly afterward.

Preliminary tests of the upper 5cm of the soil at 10 locations in a *Sarcobatus-Distichlis* stand confirmed previous findings (42) that *Sarcobatus* raises soil pH directly beneath the canopy, but did not indicate higher salt accumulation as found in Utah:

pH (soil paste)		mmho/cm^2 (sat. extr.)	
between *Sarcobatus*	under *Sarcobatus*	between *Sarcobatus*	under *Sarcobatus*
9.4	10.0	3.4	5.0
9.4	10.0	4.0	5.5
9.4	10.0	4.5	5.5
9.7	10.0	6.0	5.7
9.9	10.1	7.0	12.0



27. Stand of *Elymus cinereus-Distichlis stricta* northwest of Ewan, Whitman County, Washington.

Because of these tests, soil sampling to compare pH and salinity among h.ts. (figs. 29, 30) was restricted to places in the *Distichlis* matrix remote from any of the scattered large plants, for that is where new seedlings get established.

As a general rule, conductivities less than 4 mmho/cm represent the glykophyte range; fewer and fewer species tolerate salinity as a conductivity increases from 4-16 mmho/cm. Only well-adapted halophytes tolerate still higher values. *Elymus* is on both nonsaline and saline soils, but was never found where the surface soils were as extremely saline as in some *Distichlis* and *Sarcobatus* stands. The species must be considered a facultative halophyte, and tests have shown that its broad ecologic amplitude is more likely due to genetic plasticity than to ecotypic differentiation (15).

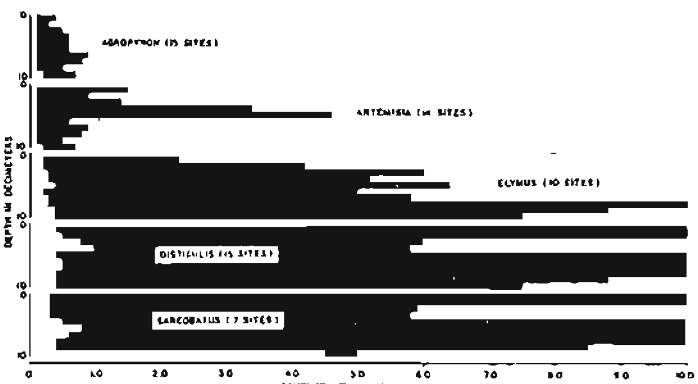
In view of the above, halophytic zonation with only the *Distichlis* sward nearest the center of a saline playa must therefore reflect mainly a superior endurance of poor aeration than the *Elymus* occurring on slightly higher ground. The tendency toward restriction of *Sarcobatus* to still higher ground may reflect either higher soil aeration requirements, or greater tolerance of salt, which may become more concentrated there as the dry season advances. As others have concluded from their observations, minimal salinity values do not seem critical; i.e., halophytes do not *require* high salinity.

In general, species pH ratings parallel salinity ratings (fig. 29, 30). This shows that Na content and total electrolytes are positively correlated, but *Artemisia* appears more tolerant of relatively high alkalinity than of high salinity. Since *Artemisia* and *Sarcobatus* commonly occur mingled in intergrade stands, the pH data reflect this field relationship more closely than do the salinity data.

In summary, the sharp ecotones between uplands with such grasses as *Agropyron spicatum*, *Stipa comata*, and *Poa secunda*, and lowlands where these species are spatially replaced by *Distichlis*, are well correlated with mutually exclusive ranges of pH and salinity in the upper meter of the soil profiles. *Distichlis* and *Sarcobatus* closely resemble each other in tolerance of high salinity and pH. Both seem more tolerant than *Elymus*, which is only a facultative halophyte. The zonal relations within the halophyte series are determined by some factor or factors not here

28. Stand of *Sarcobatus vermiculatus-Distichlis stricta* east of Satus, Yakima County, Washington.

considered, possibly soil aeration, or salinity intensification during late summer. *Artemisia tridentata* is commonly associated with *Sarcobatus* in habitats that otherwise would pass as *Sarcobatus-Distichlis* h.t., but is not commonly associated with *Elymus* and *Distichlis*. This closer affininity



29. Total observed ranges of conductivity by decimeter horizons. For the soils supporting *Agropyron,* all soils were sampled to a meter depth; but in some of the other soil groups, high water tables interfered with getting as many samples of the lower horizons as are indicated. The high salinities for *Artemisia* were all obtained at a site that was not sampled below 5 dm, and it might be expected that the values continued to increase with depth.

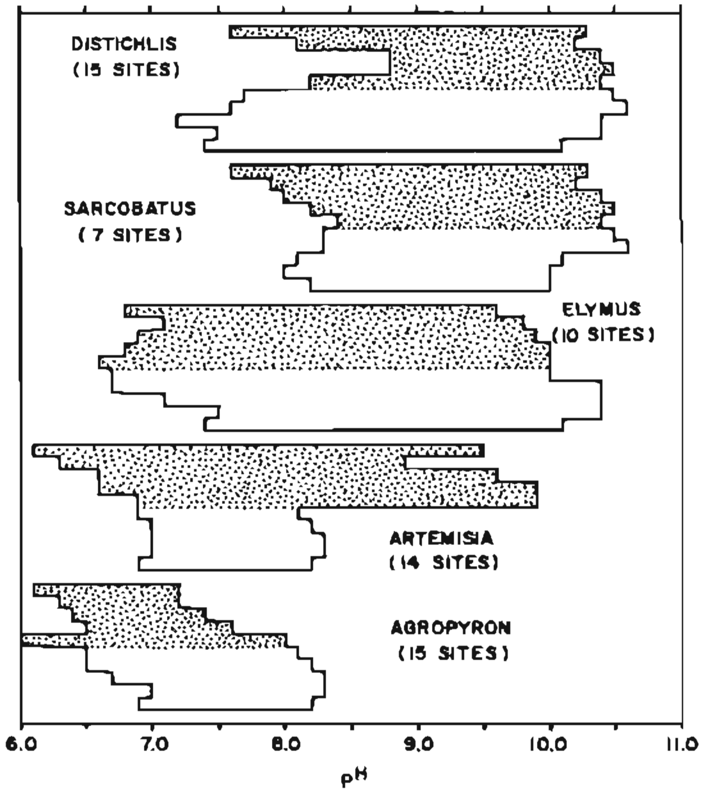
of *Artemisia* with *Sarcobatus,* considered in respect to its well-known sensitivity to poor soil aeration, strengthens the topographic inference as to a difference in aeration requirements of *Sarcobatus* and *Elymus.*

Rickard (99) has observed *Artemisia tridentata* dying in a stand where it is mixed with *Sarcobatus.* The soil here has been eroding because of excessive grazing in the past. Therefore, he interpreted the changing shrub ratio as the result of loss of a relatively nonsaline surface layer on which the *Artemisia* has been dependent, so that a greater proportion of the profile is now saline. Other relevant data on the ecology of *Sarcobatus* in Washington have been presented by Rickard and Cline (100, 101, 102, 103).

The *Sarcobatus-Distichlis* association has been reported for Oregon by Poulton (94), and I have seen stands in Wyoming, Utah and Nevada. In Washington it has not been seen except in the *Artemisia tridentata-Agropyron* and *Artemisia tripartita-Festuca* zones.

Nonsaline soils that are more moist than zonal soils

Here are included deciduous forest and woodland or tall scrub occurring within the general limits of the steppe region, and where the dominance of these life forms is obviously related to more abundant and dependable supplies of soil moisture than are provided by zonal soils.



30. Total ranges of observed soil pH by decimeter horizons. Limitations indicated in figure 29 also apply here. The area representing the upper 5 dm has been stippled to facilitate separate visual comparisons among upper and lower soil levels.

Only the best-defined types of riparian forest and woodland are treated, since there appears to be considerable variety to vegetation in this category, little total area is involved, and disturbance has been so widespread that much time would be required to define all the reasonably distinct habitat types. Extensions of coniferous forest into the steppe region, as on certain lithosols or the protected slopes of deep valleys, have been considered in a previous study (29).

Crataegus douglasii-Symphoricarpos albus h.t.

Distinguishing criteria of climax vegetation in the *Crataegus-Symphoricarpos* h.t. are the presence of an almost complete cover of woody plants about 5-7m tall, in which *Crataegus douglasii* is dominant, the presence in the undergrowth of *Symphoricarpos albus,* and often of *Spiraea betulifolia* as well. The sharing of herbs common to the *Festuca-Symphoricarpos* association is also highly diagnostic, especially *Achillea millefolium, Besseya rubra, Galium boreale, Geranium viscosissimum, Iris missouriensis, Lithophragma parviflora, Potentilla arguta,* and *P. gracilis. Heracleum, Hydrophyllum fendleri,* and *Populus* are unrepresented.

Crataegus stems are usually clustered from the base or from a point just a few dm above the soil surface. Since many of the thorny shade-killed lower branches persist indefinitely, the vegetation has much the character of a thicket, through which it is difficult for a person to make his way. *Amelanchier alnifolia* and *Prunus virginiana,* shorter in other steppe h.ts., commonly grow tall enough here to become minor constituents of the dominant canopy. *Crataegus columbianum* is occasionally represented in small amounts. Coverage of this tall shrub overstory usually varies between 65-100%.

Coverage of the medium shrub layer varies inversely with the denseness of the canopy overhead (appendix B-14). This layer is represented by the *Symphoricarpos* union (*Symphoricarpos albus, Rosa nutkana, R. woodsii,* and *Spiraea betulifolia*) that occurs also as an element of the herb layer in the *Festuca-Symphoricarpos* association, dominates the shrub phase of the latter, then forms the characteristic undergrowth of *Pinus ponderosa-Symphoricarpos* and *Pseudotsuga menziesii-Symphoricarpos* forests in the surrounding mountains (29).

In the herb stratum of the *Crataegus-Symphoricarpos* association, *Montia perfoliata* and *Galium aparine* are the most characteristic plants, even if they are not diagnostic.

Presumably because of the sudden and heavy leaf cast in autumn, epigeous cryptogams are lacking. However, mosses tend to cover all of about the lower 3dm of the *Crataegus* trunks, dwindling upward to a maximum elevation of about 3m. Fine textured lichens cover most of the remaining bark surface, but are not conspicuous.

Crataegus stands support a rich avifauna, relative to other components of the vegetation mosaic, even during the leafless period (45). The berries dry on the twigs and supply significant amounts of food for fructivorous birds, at least in autumn. The divaricately branched stems seem to have special attraction for cover and nesting. Black-billed magpie nests are built mainly in *Crataegus* crowns, and long-eared owls then find the tops of old magpie nests good foundations for nests of their own. Some of the smaller birds such as thrushes and vireos inhabit only the *Crataegus* of steppe vegetation and seem unable to accommodate themselves to city living. These are doomed to disappear as the *Crataegus* thickets are eliminated from the countryside, and this is being effected rapidly by the use of herbicides. Rickard (96) has provided data on small mammal population (appendix D).

Cattle readily eat all *Crataegus* foliage that is within reach, as well as the shrubs and herbs beneath. Grazing tends to replace the community with a sward of *Poa pratensis* (often with *P. compressa* also), in which alien forbs are represented especially by *Cirsium vulgare, Dipascus sylvestris,* and *Taraxacum. Arctium minus* is characteristic of disturbed places that are still shaded. The *Poa* sward that is favored both by heavy grazing and herbicide elimination of the *Crataegus* provides better grazing than the natural vegetation. For the most part, the slopes on which this vegetation occurs are too steep to be cultivated without inviting disastrous slumping of the upper soil horizons. The remaining fragments of *Crataegus*-dominated vegetation are all so modified by grazing that quantitative data have been taken at only the reconnaissance level.

Generalized descriptions of landscapes in the *Festuca-Symphoricarpos* zone prepared by surveyors in 1875 do not mention *Crataegus* vegetation. Had these thickets been well represented, it seems incredible that they would have failed to mention such a source of inconvenience to anyone who had to cross and recross major valleys. It seems reasonable to assume that the pattern of *Crataegus* stands in eastern Washington, as described in this report is natural, and hypothesize that fire at some period prior to the land survey had reduced the populations to coppice.

The alternative hypothesis of recent invasion is unlikely because:

1. The present stands are of similar age and development.

2. Everwhere the old trees are multiple-stemmed.

3. Recent invasion would undoubtedly involve severe disturbance, but the *Crataegus* habitats are not in vulnerable situations and for the most part are on soils that have never been cultivated.

There is no record of frequent firing of steppe or burning by aborigines, and no aspect of their economy would have benefitted therefrom. It seems much more likely that the hypothecated period of burning was coincident with the early period of white settlement.

The first wave of settlement followed the discovery of gold just east of the steppe in Idaho. When this mineral resource proved small, many of the disappointed fortune-hunters chose to remain in the area. Agricultural statistics for Whitman County from the 1870 census appear unavailable, but Walla Walla County at that time was producing 242,740 bushels of cereal grains per year (120). Production in Whitman County was not far behind (93). Considering the low yield per acre at that time, a fairly large amount of land with post-harvest stubble must have been burned each year to facilitate tillage. There was little incentive or technology for preventing the spread of these fires over the landscape.

Results of agronomic research and improved technology later discouraged farmers from stubble-burning after the wheat harvests. As the numbers and sizes of fires decreased, *Crataegus* thickets redeveloped from stump sprouts.

In addition to the absence of reference to *Crataegus* thickets in descriptions of the townships at the time they were surveyed, five other bits of evidence support the hypothesis of an interlude of burning.

1. The multiple-stemmed form of nearly all *Crataegus* plants suggests origin of the aerial parts from root systems that survived after the shoots were removed.

2. The dead but persistent lower branches of the present stands could be largely a consequence of their development when the stands were more open.

3. King (71) has commented that bird records made at the start of this century show that the black-billed magpie was a rare bird, and only a summer resident at that, in the *Festuca-Symphoricarpos* zone. Most of its population at that time was associated with woody vegetation (*Celtis douglasii, Populus trichocarpa, Alnus rhombifolia*, etc.) along the Snake River and tributary ravines. By contrast, at mid-century King (71) notes the bird as a common year-around resident of the *Festuca-Symphoricarpos* zone. There, it is characteristic of high thickets with by far most of its nests in *Crataegus*. If *Crataegus* had been reduced to stump sprouts by frequent fires at the start of the century, the elimination of its preferred nesting cover would have restricted the bird to the Snake River Canyon, with subsequent expansion out of the Canyon as fires diminished and the *Crataegus* plants grew to their maximum size.

4. A series of photographs of one landscape spanning the period 1916-1968 clearly documents the rapid development of a *Crataegus-Symphoricarpos* stand during a period when the hypothecated sequence would have been operating (figs. 31, 32, 33).

5. Finally, the abundance in *Crataegus* thickets of herbs that are much better represented in the *Festuca-Symphoricarpos* association, and are now in very poor vigor and vitality in the thickets, suggests their possible interpretation as relics from a period of less shade. As pointed out earlier, these herbs are highly tolerant of late summer fires.

McMinn (81) made comparative studies of soil temperature (at 20 cm) and soil moisture during one summer. He found that the soil in *Crataegus-Symphoricarpos* stands was consistently cooler than in stands of the *Festuca-Symphoricarpos* association and its shrub phase. The profile under *Crataegus* had dried to the wilting coefficient only to a depth of 5 dm by later summer. The other two steppe communities dried out dinstinctly faster.

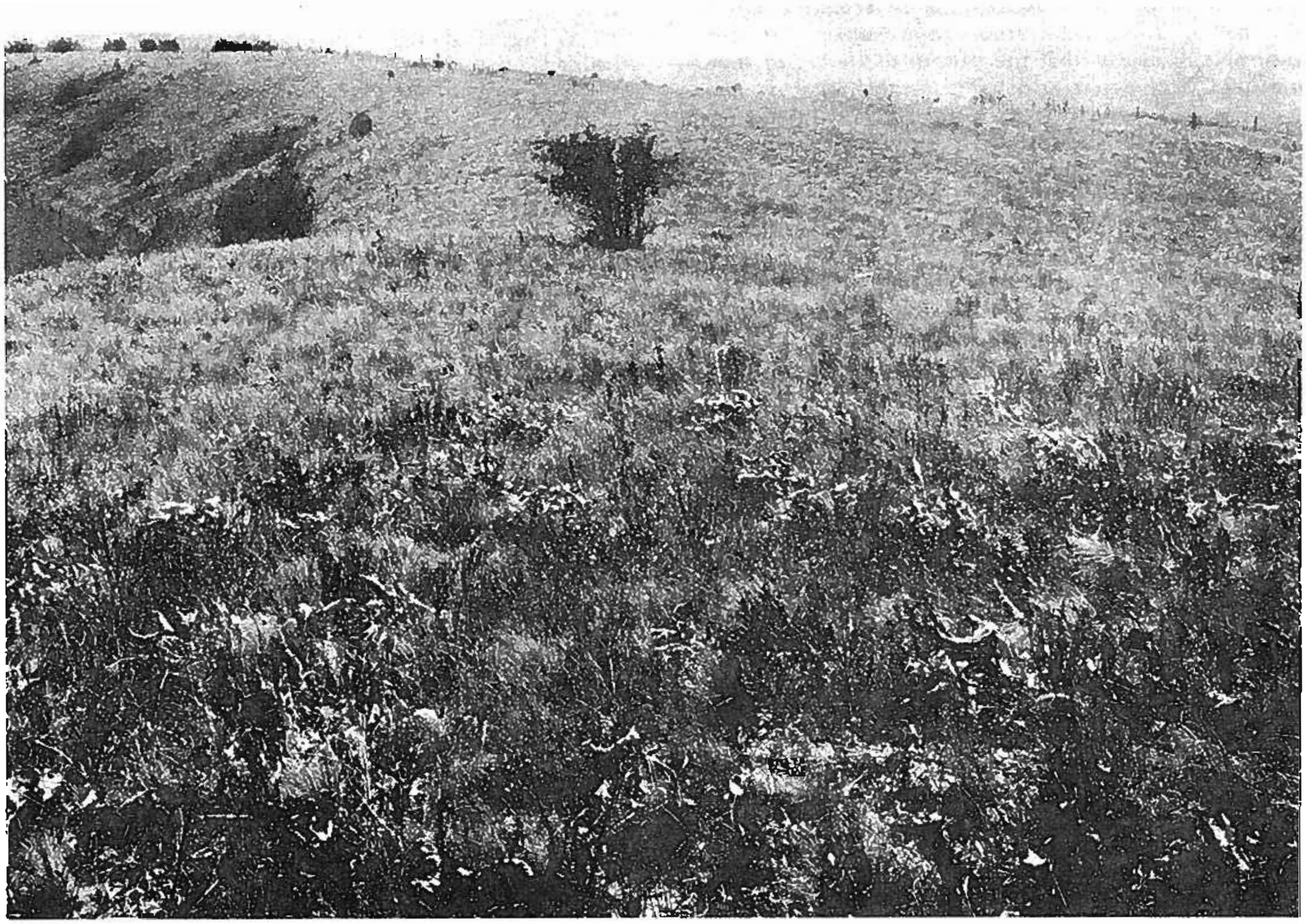
Crataegus-Symphoricarpos stands occur on all directions of exposure. On northerly slopes, the higher moisture status can be explained simply on the basis of reduced insolation, possibly aided by precipitation blown over the ridge summits. On southerly exposures, the high moisture demand may be satisfied by horizontal drainage over the surface of basalt strata that bring water near the surface along valley sides. On these slopes, the *Crataegus-Symphoricarpos* stands commonly form ecotones with stands of the very xerophytic lithosolic *Agropyron-Poa* association. The latter are apparently limited to places where basalt approaches the soil surface without bringing significant water with it, or with the shrub phase of the *Festuca-Symphoricarpos* association where moisture conditions are intermediate. Because the *Crataegus-Symphoricarpos* stands are independent of direction of slope and require only above-average soil moisture, the association is considered an edaphic climax.

Major valleys in the *Festuca-Symphoricarpos* zone commonly support *Pinus ponderosa-Symphoricarpos albus* forest on the sheltered slopes. Corresponding topography in ravines that branch off to the side support *Crataegus-Symphoricarpos* stands. McMinn's (81) study of soil moisture conditions in summer showed that the soils of the latter retain moisture better than soils under the pine.

The *Crataegus-Symphoricarpos* h.t. seems confined to the *Festuca-Symphoricarpos* and *Festuca-Rosa* zones.

Populus tremuloides phase

At frequent intervals over the range of the *Crataegus-Symphoricarpos* association there occur stands apparently normal for that association both as to biotic and physical features, except that *Populus tremuloides* is well represented (appendix B-14). An interesting microseral phenomenon seems to characterize these stands. *Populus* can grow up through a *Crataegus* canopy, ultimately reaching twice its height, and when overtopped the *Crataegus* starts to decline progressively. However, the *Populus* is subject



31. Remnant of virgin steppe still preserved on the campus of Washington State University, as photographed by H. L. Shantz, September 2, 1916. The isolated multiple-stemmed *Crataegus* on the ridge summit appears to have no living foliage below about 1.5 m. This is not likely a consequence of grazing, since the herbaceous cover in the foreground shows no use. It could well result from fire creeping across partially dried grassland in midsummer. A line of shrubs has developed along the fence in the distance.

to heart rot and therefore short-lived. The population as a whole dies back to the ground when the trees reach a diameter of about 2 dm at breast height and appear to be about 50 years old. The *Populus* collapse allows the regeneration of the enfeebled *Crataegus*, which then redevelops a nearly complete canopy before root sprouts of the *Populus* appear and start to grow up through it again.

This phase of the *Crataegus-Symphoricarpos* h.t. seems worthy of recognition because the distinction between *Crataegus* stands that are permanent and those in which dominance seems to alternate between *Crataegus* and *Populus* is sharp, and may well reflect some subtle ecologic difference.

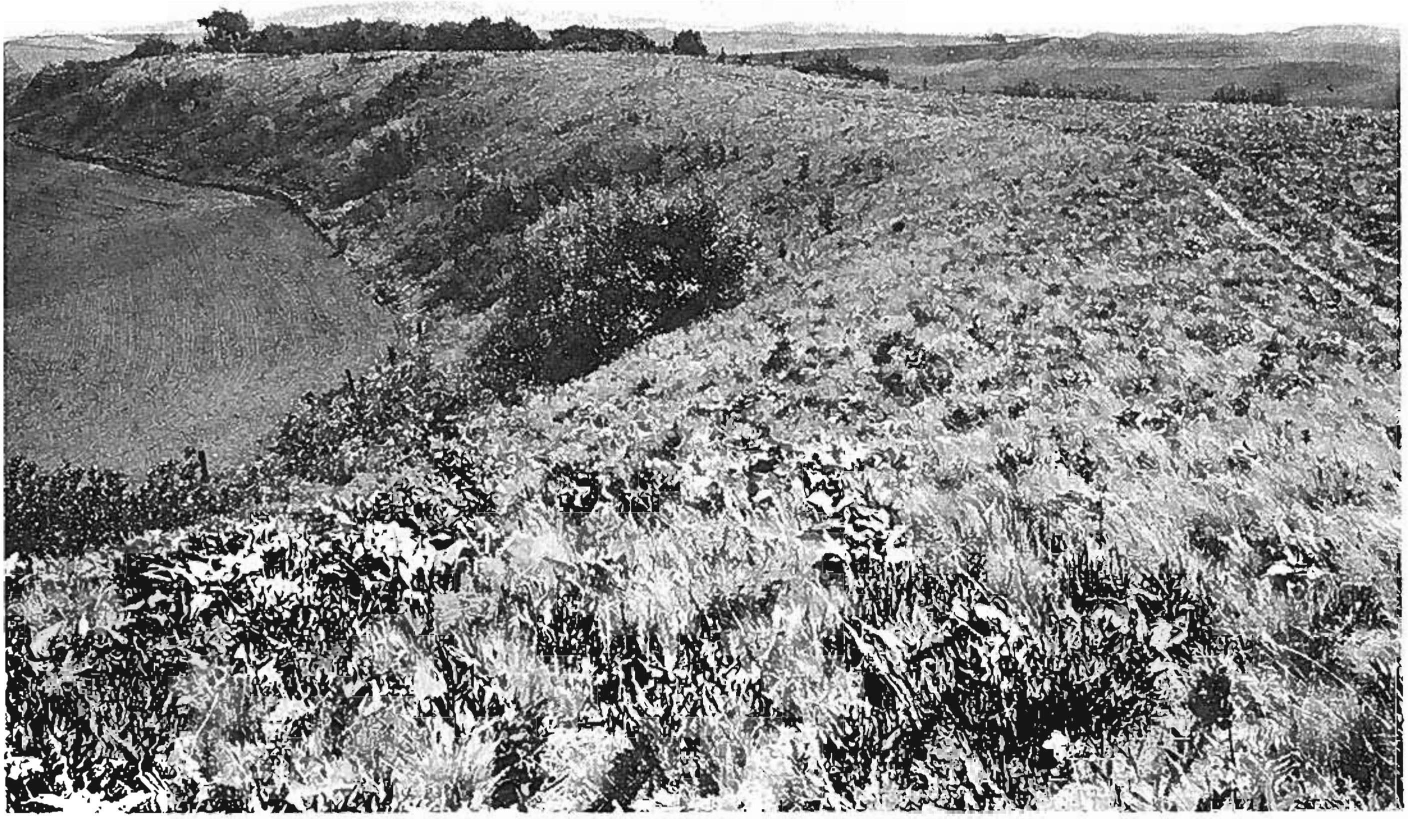
The unit recognized above is clearly distinguished from a closely related *Populus tremuloides-Symphoricarpos albus* association that is much more widespread in the northern Rockies (77) and on the east slope of the Cascade Mountains. But the unit lacks the *Crataegus* layer, and so far as is known is not subject to repeated episodes of simultaneous stem dieback.

Crataegus douglasii-Heracleum lanatum h.t.

Climax vegetation in the *Crataegus-Heracleum* h.t. consists of a nearly complete cover of woody plants growing about 5–7m tall, among which *Crataegus douglasii* is most dominant, combined with an undergrowth in which *Heracleum lanatum*, *Hydrophyllum fendleri* and *Urtica dioica* dominate, either singly or collectively. *Rosa* and *Symphoricarpos* are at most poorly represented in this h.t., but will invade disturbed areas readily.

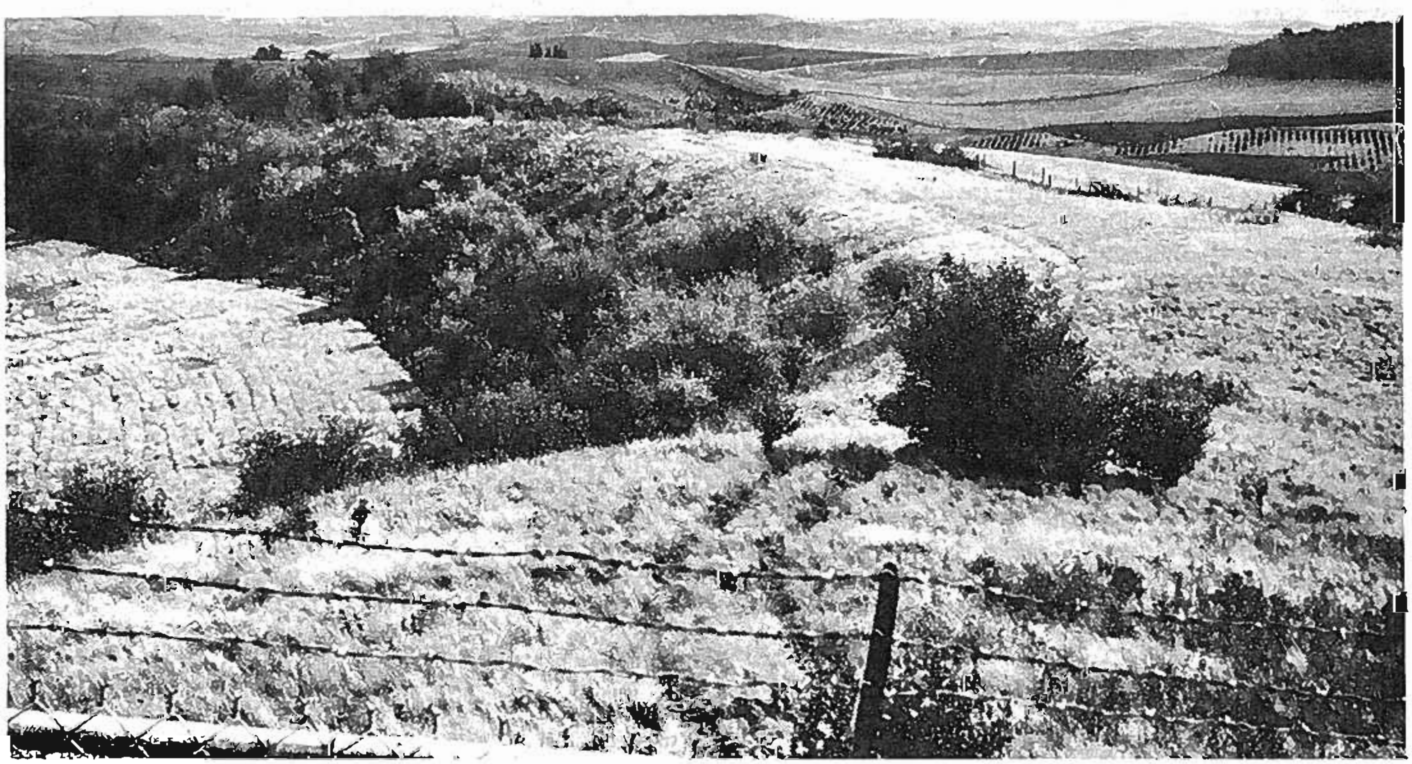
Except for *Lomatium dissectum*, the *Crataegus-Heracleum* association shares no significant floristic features with the *Festuca-Symphoricarpos* or *Festuca-Rosa* associations of adjacent uplands. This stands in sharp contrast with the *Crataegus-Symphoricarpos* association.

On the other hand, the *Crataegus-Heracleum* association frequently contains elements more common in forests of the adjacent mountains, such as *Circaea alpina*, *Cornus stolonifera*, *Elymus glauca*, *Geum macrophyllum*, *Osmorhiza chilense*, *Pteridium aquilinum*. This association fur-



32. View similar to figure 31, as photographed May 7, 1939. In this photo, the camera point was far forward of that in figure 31. The isolated, multiple-stemmed *Crataegus* on the ridgetop was present then, but outside the field of view. The coverage and height of the woody vegetation, including the *Prunus virginiana*-dominated strip along the fence, obviously increased in the 23 years after figure 31.

33. View similar to figure 31 as photographed in 1968. Twenty-nine more years have allowed still further expansion of the woody vegetation. The formerly isolated *Crataegus* is surrounded by what are probably clonal offspring.



ther differs from the *Crataegus-Symphoricarpos* association by being more susceptible to invasion by perennial herbaceous aliens.

The overstory of the *Crataegus-Heracleum* association is essentially like that of the *Crataegus-Symphoricarpos* association. Beneath the trees the *Heracleum*, a coarse herb, usually grows well over 2m tall (fig. 34) penetrating the lower part of the thorny tangle of persistent branches of the *Crataegus*. It produces many large leaves held horizontally, and these intercept nearly all the light filtering through the *Crataegus* canopy. This double screening of incident radiation must play a major role in reducing the numbers of shorter plants that can get established below the *Heracleum*, at least limiting those which cannot develop in spring before the *Heracleum* foliage expands. Even though the stand sizes were not closely standardized so that precise comparisons are justified, it is evident in comparing appendices B-14 and B-15 that a distinctly lower species diversity characterizes the *Crataegus-Heracleum* association.

Where a small disturbance allows *Rosa* to get established, it grows as least as tall as the *Heracleum* (which *Symphoricarpos* cannot do), presumably in response to the crowding and to favorable moisture and fertility. Mosses on the bark tend to be more conspicuous and to extend farther above the ground than they do in the *Crataegus-Symphoricarpos* association.

Cattle eat *Heracleum* readily; a colloquial name for the plant is "cow parsnip." But the plant withstands grazing poorly, and so is easily eliminated, with a *Poa pratensis* meadow taking its place. Alien weedy perennials accompanying the *Poa* include *Artemisia absinthinum*, *Cirsium vulgare*, *Dipsacus sylvestris*, *Marrubium vulgare*, *Tanacetum vulgare* and *Taraxacum*. *Arctium minus*, another alien favored by disturbance, is mainly confined to areas still well shaded by *Crataegus*. While *Heracleum* grows luxuriantly and fruits vigorously in the shade of a *Crataegus* canopy, it performs equally well, even if the stature is shorter, when the canopy is removed, providing the area is not grazed (fig. 35).

The *Crataegus-Heracleum* h.t. is primarily characteristic of aggraded valley floors (locally called "flats") which border intermittent or permanent creeks. These valleys were probably V-shaped during late glacial time, then accumulated fills of silt-plus-clay during the Hypsithermal interval. Today, vertical-walled trenches are being cut through those fine sediments. The *Crataegus-Heracleum* h.t. is, however, not confined to valley floors. It often extends up contiguous northerly slopes, sometimes to more than 15m above the valley floor where seepage water comes practically to the soil surface, and even higher along the bottoms of V-shaped ravines opening onto the major valleys.

Valley floors representing the *Crataegus-Heracleum* h.t. are typically bordered by the *Crataegus-Symphoricarpos* h.t. on the contiguous north-facing slope, and by the lithosolic *Agropyron-Poa* h.t. on the opposite slope. The h.t. is homologous with the *Populus trichocarpa-Cicuta* h.t. in a slightly drier climate, and with the *Elymus cinereus-Distichlis* h.t. in an environment still drier where salts

34. *Crataegus douglasii-Heracleum lanatum* stand on Union Flat Creek west of Pullman, Washington. *Heracleum* in essentially the same density as in this small opening extended back under the *Crataegus*.

can accumulate in the soil. Scattered individuals and clumps of *Elymus cinereus* are common in the ecotone between *Crataegus-Heracleum* and the lithosolic *Agropyron-Poa* associations. However, these spots have normal pH and solute content, and the soil profiles show no evidence of having been salinized during the Hypsithermal period.

Until a few years ago, a plantation of *Ulmus* growing a few miles northwest of Pullman, Washington, occupied parts of a slope and the contiguous "flat." Beneath the *Ulmus*, a typical stand of the *Symphoricarpos* union had redeveloped on the slope after the disturbance caused by cultivating and planting an exotic tree. At the foot of the slope, this gave way to a stand of the *Heracleum* union. Before the invasion of white man, both topographic positions undoubtedly supported a cover of *Crataegus*. This

35. This valley bottom near Pullman, Washington, once bore a nearly complete cover of *Crataegus douglasii* (deciduous low tree to right) with an understory of *Heracleum lanatum* (flowering herb to left of fence). To the left of the fence, crews maintaining the railway right-of-way removed the *Crataegus*, then continued to destroy new shoots as they appeared. To the right of the fence, cattle have brought about a complete replacement of the *Heracleum* by *Poa pratensis* without significant damage to the *Crataegus*. Two zootic climaxes have been derived from the same edaphic climax. Since this picture was taken, the *Crataegus* has been destroyed by herbicide applied aerially.

situation showed quite clearly the independent occupancy of sites by forest overstory and understory, which is equally conspicuous in coniferous forest in the nearby mountains (29).

The *Crataegus-Heracleum* h.t. is confined to the wetter parts of the *Festuca-Symphoricarpos* and *Festuca-Rosa* zones. In the aggregate, it includes considerable area. The flatness of the valley floors, combined with their deep soils and favorable moisture relations have resulted in nearly all of the h.t.'s being taken over for grain cropping or permanent pasture. One of the colloquial names for *Crataegus* is "thorn," and the village of Thornton, Washington, was probably so named because it was in a "flat" which, to judge from the topography, must certainly have been covered by *Crataegus* when white man settled the area.

Populus tremuloides phase

The *Crataegus-Heracleum* association is locally replaced by a variant that has an intermittent *Populus tremuloides* overstory. The *Crataegus* and *Populus* canopies here have apparently the same relationship to each other as in the *Crataegus-Symphoricarpos association* and its *Populus tremuloides* phase (fig. 36).

Two other minor variants of stream terraces supporting *Crataegus* deserve mention. In places, *Populus trichocarpa* borders the stream, rising high above the *Crataegus* canopy that covers the remainder of the terraces on either side. It is possible that this tree was much more abundant before the arrival of white man, and that early settlers made heavy use of the only fairly large tree present in the steppe. *Salix* spp. and *Alnus tenuifolia* are also occasionally encountered along waterways, but they are not so abundant as the *Populus trichocarpa.*

On a few stream terraces, *Pinus ponderosa* is superimposed over the *Crataegus* layer. Examples can be seen in the Lewis and Clark State Park, 2 miles east of Waitsburgh, in Columbia County, Washington, and in the valley of Paradise Creek a few miles east of Pullman, in Whitman County.

Populus trichocarpa-Cicuta douglasii h.t.

The *Crataegus-Heracleum* h.t., which characterizes valley floors in the wetter part of the *Festuca-Symphoricarpos* and *Festuca-Rosa* zones, is replaced geographically on approaching drier climates by a distinctly different homolog that is botanically distinct in both major layers. *Heracleum* is replaced by *Cicuta douglasii,* another tall herb in the *Umbelliferae. Crataegus* yields its overwhelming control of the overstory to *Populus trichocarpa* (fig. 37).

This h.t. extends well out into the contiguous *Agropyron-Festuca* zone. For example, it lines the Palouse River from a point about 5 miles ESE of Colfax on the South Fork, to where this river forms the boundary between Whitman and Adams Counties. It also lines Lapwai Creek between Spalding and Culdesac, Idaho. Everywhere the vegetation has been even more completely disturbed than the *Crataegus-Heracleum* association, and so has not been amenable to study. The best remaining fragments are along Lapwai Creek near Lapwai.

Alnus rhombifolia h.t.

Narrow valleys emptying into the Snake River in Whitman and Asotin Counties have a strip of *Alnus rhombifolia*-dominated forest along the waterway (fig. 38). This *Alnus* grows to about 13m tall and 6dm in diameter, which makes it second in size to only *Populus trichocarpa* among our deciduous trees. The two are associated where the valleys are broad enough to have much of a floodplain.

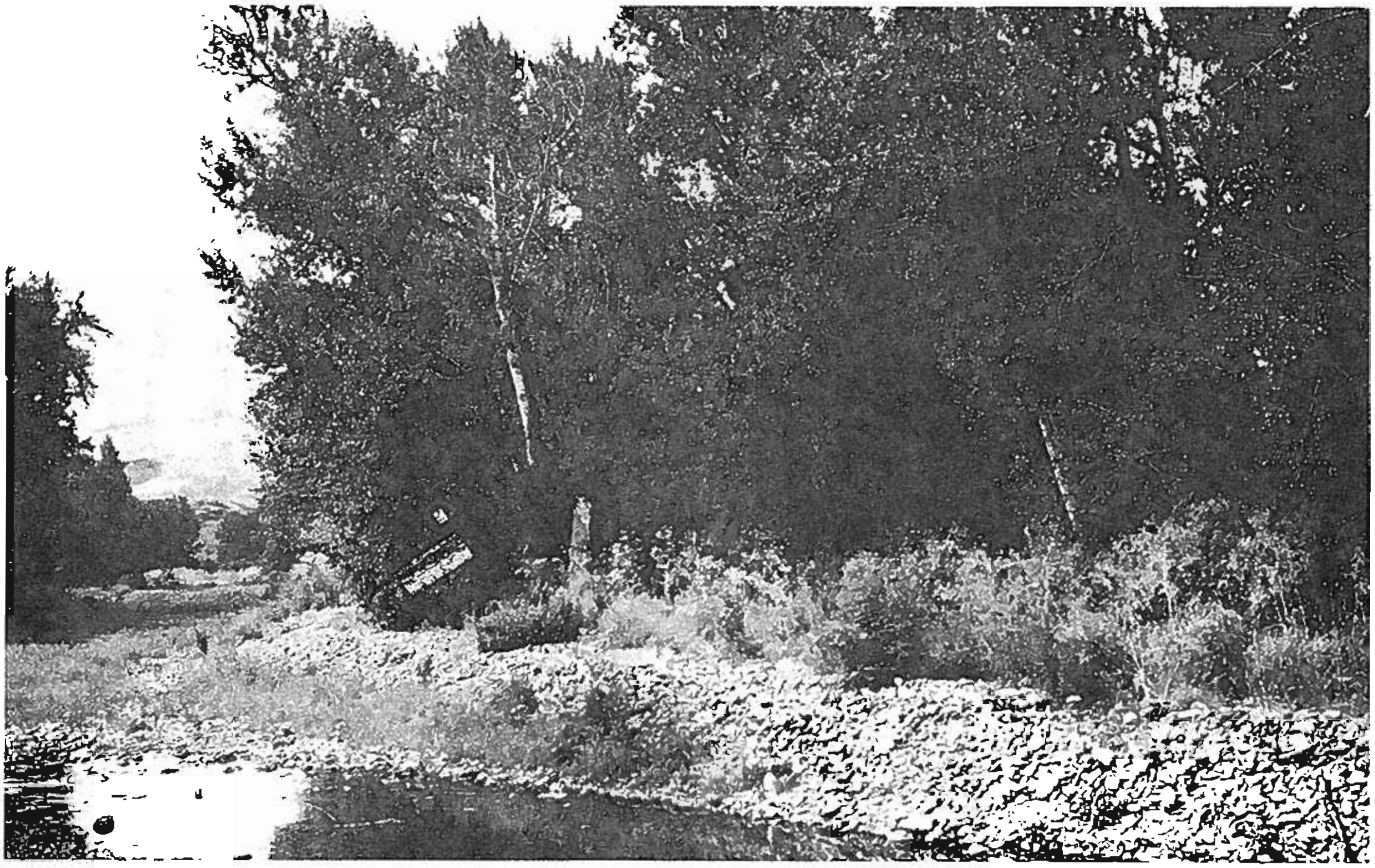
At its lower end, this strip typically abuts the *Celtis douglasii* h.t. on alluvial cobble that is deposited at the mouth of the valley. The *Agropyron-Festuca* or *Agropyron Poa* h.t. occur on contiguous valley sides, depending on the degree of exposure to the sun.

Other special soils

Purshia tridentata-Agropyron spicatum h.t.

Natural vegetation in the *Purshia-Agropyron* h.t. consists of an open medium-shrub layer of *Purshia tridentata; Agropyron spicatum* provides most of the bulk of the herb

36. Small stand of the *Populus tremuloides* phase of the *Crataegus-Heracleum* association in which the *Populus* overstory has recently died. Root sprouts of the *Populus* can be expected to appear within a few years. Shawnee, Whitman County, Washington.



37. *Populus trichocarpa-Cicuta douglasii* stand on Lapwai Creek just south of Lapwai, Idaho. The tall herb showing at the edge of the stand is mostly *Cicuta*.

layer below. *Artemisia* is poorly represented, if at all, and *Festuca idahoensis* is lacking.

This h.t. is not well represented in Washington, and occurs as small fragments. It is best considered a xerophytic segregate of the *Purshia-Festuca* h.t. Like the latter, it is found chiefly along the eastern base of the Cascade Mountains. Typically, the soil is a very stony loam, but stand 127 (appendix B-9) is remarkable for its occurrence on dune sand having the lowest moisture equivalent (2.9%) of any stand in this study. Stand 79 is unusual for the absence of *Poa secunda;* this fact may be related to the unusually high coverage of *Balsamorhiza sagittata* (26%) which, combined with a high coverage of *Agropyron spicatum* (88%), may have created too much shade for the heliophytic *Poa.*

The soil of stand 29 is a Malaga gravelly stony loam, a Regosol-Brown intergrade and a Typic Torriorthent:

A11 0-7.5cm Dark brown (10YR 3/3m) gravelly loam; mostly single-grained, with fine granular structure weakly developed between the single grains

A12 7.5-20cm Dark brown (10YR 3/3m) gravelly loam; compact, massive, breaking into small to medium weak blocks, with structural faces formed by rock-soil interfaces

A3 20-57.5cm Dark brown (7.5YR 3/4m) gravelly loam; more massive than the above; becoming extremely stony

C 57.5-77.5cm Dark yellowish brown (10YR 4/4m) singly grained with a high percentage of fine gravel

D 77.5cm+ Clean, slightly water-worn gravel and stones of mixed origin. (by W. A. Starr).

At stand 127, the soil is a Quincy sand, a Regosol and a Typic Torripsamment:

C1 0-3" Grayish brown (10YR 5/2m) or light gray (10YR 7/2d) sand; single grained; nonsticky, nonplastic, friable, loose; pH 6.8; abundant roots; clear wavy boundary

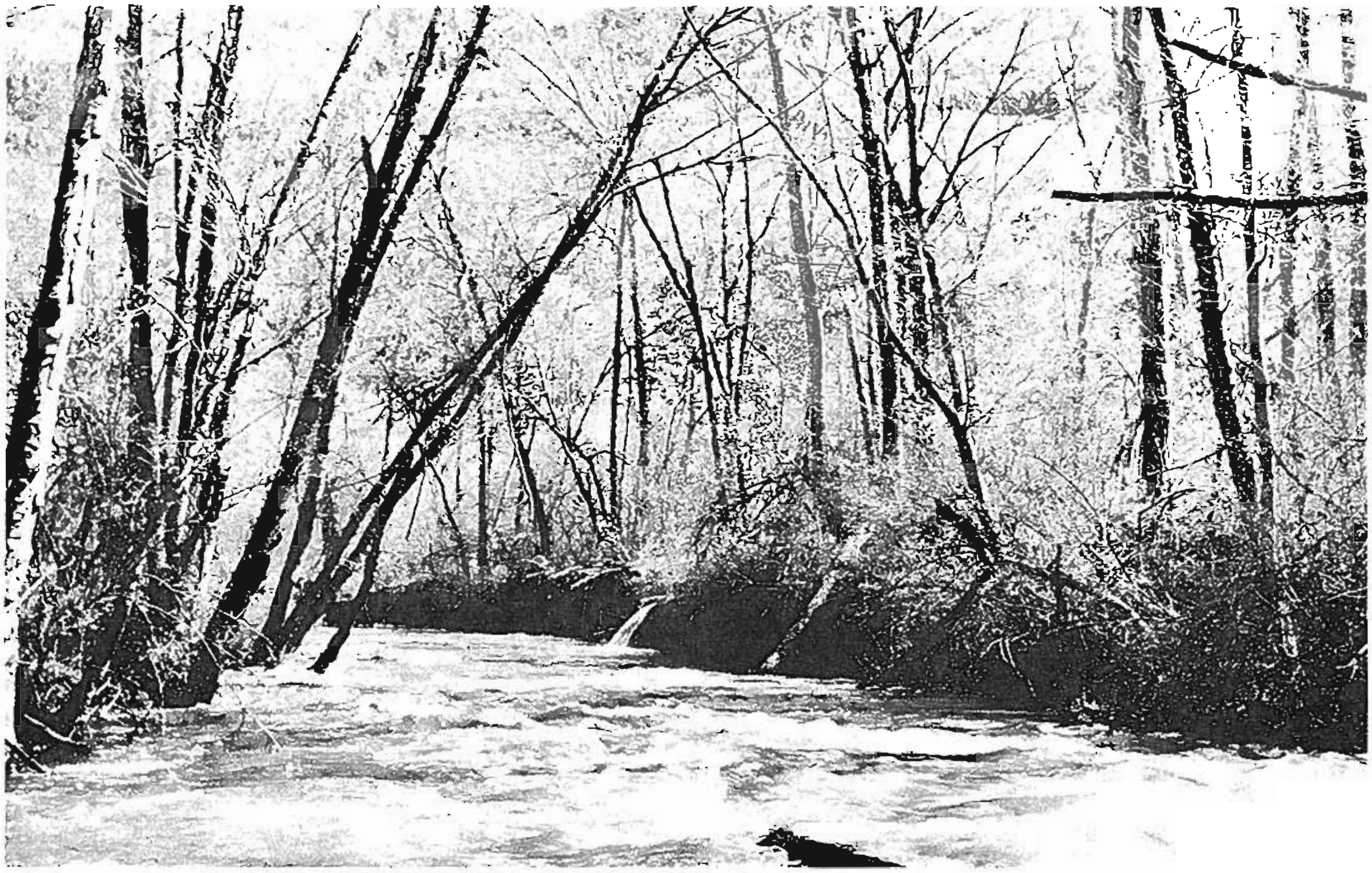
C2 3-10" Light brownish gray (10YR 6/2m) or light gray (10YR 7/2d) sand; single grained; nonsticky, nonplastic, friable, loose; pH 6.8; numerous roots; clear wavy boundary

C3 10"+ Same as above horizon except that there are no noticeable roots at this depth (by W. A. Starr).

A stand of the *Purshia-Agropyron* association has been observed just a little northeast of Ola, Idaho, and another in McMurty Hollow, 2 miles west of Paradise, Utah.

Artemisia tripartita-Agropyron spicatum h.t.

Within the *Artemisia tripartita-Festuca* zone, occasional small areas are too exposed to sun and wind to meet the requirements of *Festuca idahoensis,* although nearly all other members of the *Artemisia tripartita-Festuca* as-



38. *Alnus tenuifolia* forest on Asotin Creek, Asotin County, Washington, in spring aspect.

sociation extend onto such sites. These areas lacking the *Festuca* are recognized as the *Artemisia tripartita-Agropyron* h.t., and a stand in excellent condition is analyzed in appendix B-7. As the east-facing slope bearing this stand turned northward, there was a fairly abrupt ecotone with a contiguous *Artemisia tripartita-Festuca* stand.

The soil at stand 100 is a Disautel loam, a Chestnut and a Calcic Haploxeroll:

A11 0-3" Very dark grayish brown (10YR 3/2m) or grayish brown (10YR 5/2d) loam; weak medium and coarse granular with some medium platy in the upper 0.5"; nonsticky, nonplastic, friable, soft; pH 7.0; abundant roots; clear wavy boundary

A12 3-9" Very dark grayish brown (10YR 3/2m) or grayish brown (10YR 5/2d) loam; weak medium and coarse subangular blocky; nonsticky, nonplastic, friable, soft; pH 7.0; abundant roots; clear wavy boundary

B1 9-13" Dark grayish brown (2.5Y 4/2m) or grayish brown (2.5Y 5/2d) gravelly loam; moderate medium subangular blocky; pH 7.4; frequent stones; numerous roots; clear wavy boundary

B2 13-20" Pale olive (5Y 6/3m) or light brownish gray (2.5Y 6/2d) sandy clay loam; moderate medium subangular blocky; sticky, plastic, firm, slightly hard; pH 7.6; numerous roots; clear wavy boundary

B3 20-28" Very pale brown (10YR 7/3m) or light gray (10YR 7/2d) gravelly fine sandy loam with frequent stones; mixed weak fine subangular blocky and medium fine granular; nonsticky, nonplastic, slightly firm, slightly hard; pH 7.9; frequent small roots; clear wavy boundary

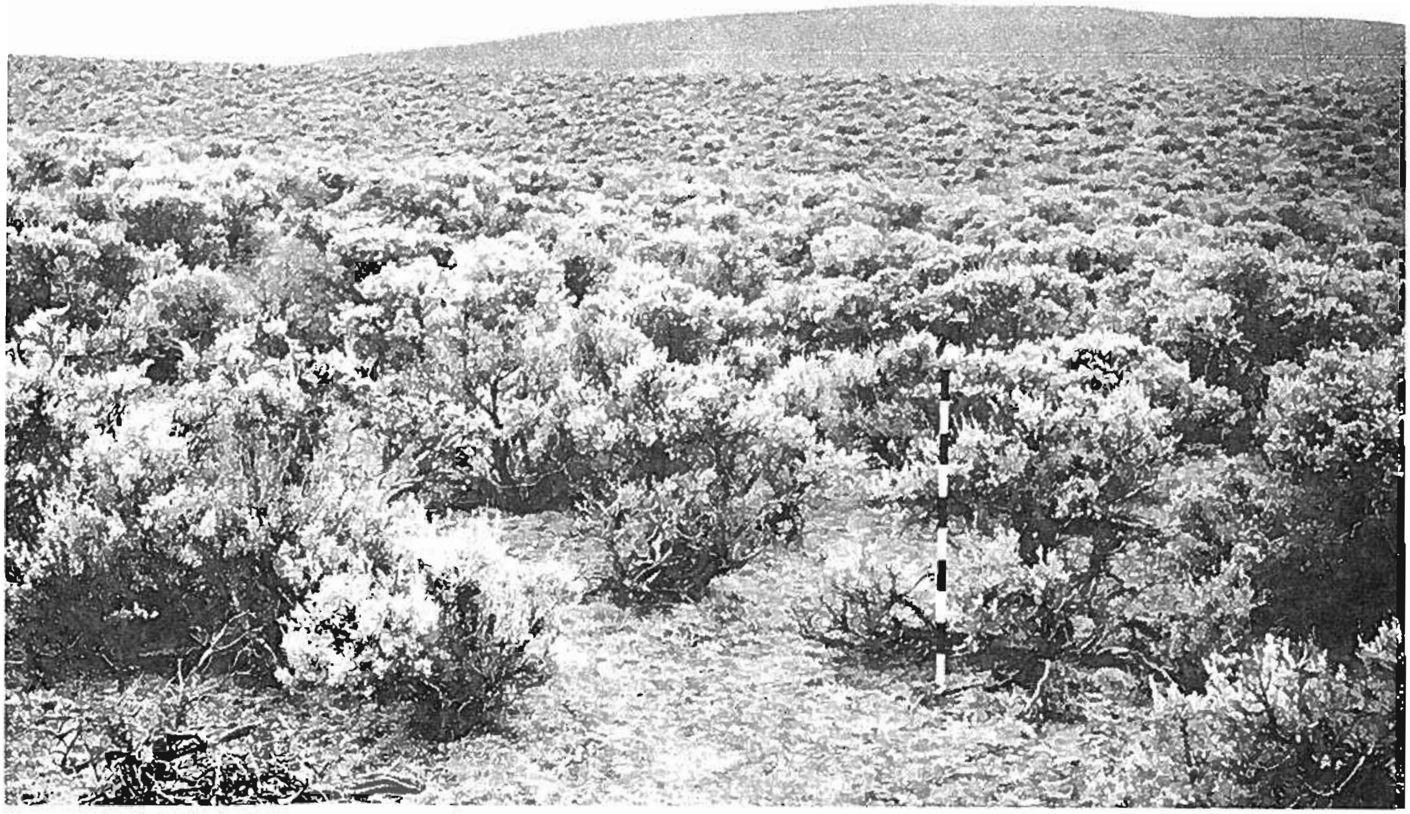
Cca 28"+ Very pale brown (10YR 7/2m) or white (10YR 8/2d) gravelly sandy loam with frequent stones; massive; nonsticky, nonplastic, firm, slightly hard; pH 8.7; occasional roots; highly calcareous (by W. A. Starr).

In Washington, the *Artemisia tripartita-Agropyron* h.t. is apparently confined to the *Artemisia tripartita-Festuca* zone. A closely similar type of community has been observed in an exclosure in the Sheep Experiment Station near Dubois, Idaho.

Artemisia tridentata-Poa secunda h.t.

In the *Artemisia tridentata-Poa secunda* association, the two species after which the unit is named comprise nearly all the vascular vegetation. Perennial grasses larger than the *Poa* are represented almost entirely by *Sitanion hystrix*, and even this species has low presence and negligible volume.

The most usual features of the association are the virtual lack of large grasses and the high density of the *Artemisia* (fig. 39). Here *Artemisia tridentata* has high-



39. *Artemisia tridentata-Poa secunda* stand 146.

er coverage than in any other type of undisturbed vegetation in Washington (appendix B-2). The extreme scarcity of perennial forbs, the low species diversity, and the low coverage sums are also noteworthy (appendices B-2 and E).

Chrysothamnus viscidiflorus, a common but minor associate of *Artemisia tridentata* elsewhere is lacking. Also, in most upland associations of steppe and shrub-steppe in Washington, *Bromus tectorum* occurs sparingly but regularly in undisturbed microsites. In the *Artemisia tridentata-Poa* association *B. tectorum* is practically unrepresented except where the surface has been severely disturbed. In stands in good condition, the small amounts of *Bromus* present, together with most of the *Descurainia*, is aggregated under the shrubs where the *Poa* is better developed. The favorableness of this microsite persists for several years after the shrub dies.

The status of this association is not clear. It was first thought to have been derived from the *Artemisia tridentata-Agropyron* association, with grazing having completely eliminated the larger grasses and forbs and allowed the *Artemisia* to increase in density and dominance. This interpretation had to be abandoned when many ecotones with *Artemisia tridentata-Agropyron* stands were found. These were sharp, and much too sinuous to be considered a result of locally intensified animal use. At the same time, they had no more of the plant species favored by grazing on one side of the ecotone than on the other. Severely grazed stands of *Artemisia tridentata-Agropyron* such as in fig. 5 have the *Poa* layer destroyed, *Bromus* is well represented, and always scattered remnants of *Agropyron* can be found well back under the larger bushes.

No aspect of the field characters of the soil profiles, or of their chemical analyses, provides a physical explanation of the distinctiveness of the *Artemisia tridentata-Poa* h.t. It is tentatively considered an edaphic climax because it alternates with stands of the presumed zonal association, and the two are separated by sharp ecotones that must result from some subtle soil condition not yet studied. Whatever inhibits *Agropyron* must indirectly allow the accumulation of more than normal amounts of subsoil moisture in winter; otherwise, the h.t. would not support such a heavy stand of *Artemisia tridentata*, which requires a continuous supply of soil moisture throughout the year.

Despite the high continuity of the *Poa* layer, the low volume of fuel created when its shoots dry in summer normally does not allow fire to spread across a stand of *Artemisia tridentata-Poa*. Since the discontinuous canopies of the *Artemisia* require more grass litter than *Poa* can provide to ignite them and keep a fire spreading, *Artemisia tridentata-Poa* stands are essentially nonflammable. Fire commonly sweeps across an *Artemisia tridentata-Agropyron* stand consuming the shoots of all herbs and shrubs, then stops abruptly at the irregular ecotone with an *Artemisia tridentata-Poa* stand.

At stand 146, the soil profile is a Warden very fine sandy loam, a Sierozem and a Mollic Camborthid:

A11 0-3" Dark brown (10YR 3/3m) very fine sandy loam; moderate medium angular blocky; nonsticky, nonplastic, friable, soft; pH 7.2; abundant roots; clear smooth boundary

A12 3-8" Pale brown (10YR 6/3d) or brown (10YR 4/3m) very fine sandy loam; massive; nonsticky, nonplastic, firm, slightly hard; pH 7.5; numerous roots; abrupt wavy boundary

A13 8-12" Pale brown (10YR 7/3d) or brown (10YR 4/3m) very fine sandy loam; weak medium and fine subangular blocky; nonsticky, nonplastic, friable, soft; pH 8.2; numerous roots; clear wavy boundary

ACca 12-22" Very pale brown (10YR 7/3d) or brown (10YR 5/3m) very fine sandy loam; massive; nonsticky, nonplastic, firm, hard; pH 8.4; strongly calcareous; occasional roots; clear wavy boundary

C1ca 22-27" Light gray (10YR 7/2d) or light brownish gray (10YR 6/2m) very fine sandy loam; single grain; nonsticky, nonplastic, friable, soft; pH 8.6; strongly calcareous with frequent lime-cemented nodules; occasional roots; clear wavy boundary

C2ca 27-35" Light gray (10YR 7/2d) or light brownish gray (10YR 6/2m) very fine sandy loam; massive; nonsticky, nonplastic, firm, slightly hard; pH 9.0; occasional roots; clear wavy boundary

C3ca 35-39" Very pale brown (10YR 7/3d) or pale brown (10YR 6/3m) very fine sandy loam; single grain; nonsticky, nonplastic, friable, soft; pH 8.9; strongly calcareous; no roots; clear irregular boundary

C4ca 39"+ Similar to above, except with frequent nodules cemented with lime, and containing 15% angular basalt gravel; pH 8.9; boundary not determined (by W. A. Starr).

The profile at stand 164 is also a Sierozem and a Mollic Camborthid, but a Warden loam:

A11 0-5" Pale brown (10YR 6/3d) or dark brown (10YR 3/3m) loam; weak medium and fine subangular blocky with a tendency to weak medium platy, and occasionally vesicular in upper part; slightly sticky, nonplastic, friable soft; pH 7.8; abundant roots; clear wavy boundary

A11 5-9" Light yellowish brown (10YR 6/4d) or dark yellowish brown (10YR 3/4m) silt loam; moderate medium and coarse subangular blocky; slightly sticky, slightly plastic, moderately firm, slightly hard; pH 7.8; numerous roots; clear wavy boundary

AC 9-20" Pale brown (10YR 6/3d) or dark brown (10YR 3/3m) silt loam; massive; slightly sticky, nonplastic, firm, slightly hard; pH 8.5; occasional roots; clear wavy boundary

C1ca 20-30" Light gray (10YR 7/2d) or brown (10YR 5/3m) silt loam; massive; slightly sticky, nonplastic, firm, slightly hard; pH 8.5; highly calcareous; occasional roots; clear wavy boundary

C2ca 30-41" Light gray (10YR 7/2d) or pale brown (10YR 6/3m) very fine sandy loam; massive; nonsticky, nonplastic, friable, soft; pH 8.5; highly calcareous; occasional roots; abrupt wavy boundary

C3ca 41"+ Light gray (10YR 7/2d) or grayish brown (10YR 5/2m) silt loam; massive; slightly sticky, nonplastic, firm, hard; pH 8.3; highly calcareous with streaks and seams of lime firming a weakly converted brittle horizon with thin lenses of lime at upper surface; no roots; boundary not determined (by W. A. Starr).

The *Artemisia tridentata-Poa* stands studied are all in the Yakima River and Cold Creek Valleys, but the h.t. is also represented along the north bank of the Columbia River where the latter forms the boundary between Washington and Oregon. The h.t. is therefore confined to the hottest and driest part of the *Artemisia tridentata-Agropyron* zone, more so than any other h.t. In British Columbia it extends as far north as the Kamloops area (78).

Through the kindness of J. H. Robertson I had opportunity to examine an exclosure that had been maintained for 25 years on the floor of Paradise Valley north of Winnemucca, Nevada. The vegetation was essentially identical with the *Artemisia tridentata-Poa* association as described for Washington. *Poa secunda* was the principal grass; *Sitanion hystrix* was very sparingly represented. In this valley, *Agropyron spicatum* entered the vegetation mosaic only on the slopes bordering this valley floor.

This *Artemisia tridentata-Poa secunda* association must not be confused with the "*Artemisia tridentata-Poa secunda*" association described by Smith (109) for western Wyoming. The latter not only has the ecologically distinctive *A. tridentata* var. *vaseyana* as the shrub, but has a rich flora and occurs in the fringes of forest land.

Grayia spinosa-Poa secunda h.t.

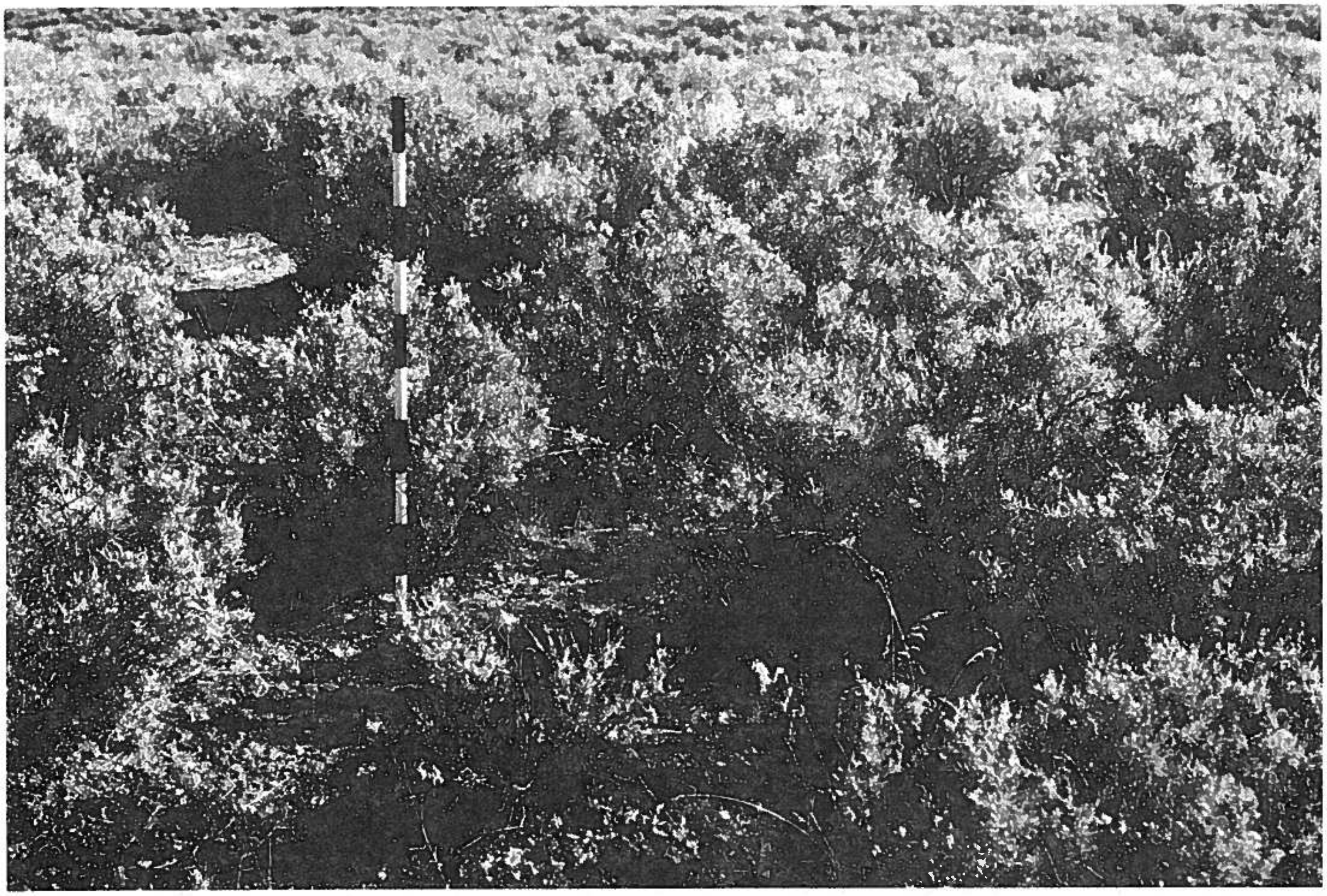
The *Grayia spinosa-Poa secunda* association consists of very little but a layer of *Grayia* and a layer of *Poa* (fig. 40).

Diligent search has failed to reveal a single *Grayia* plant in Washington with fewer than 16 xylem layers, although seeds are produced in great numbers and germinate readily in the laboratory. Since the old plants sprout readily after being burned off at the ground surface, and the spiny character of the twigs is insurance against excessive grazing by livestock, there is little to prevent plants from living to a great age. In this context, the rarity of successful germinations is not necessarily serious for population maintenance.

Species diversity in this association is very low (appendices B-16 and E), as in the *Artemisia tridentata-Poa* association, to which it is very closely related.

Grayia is highly palatable to livestock, but is more easily killed by herbicides than is *Artemisia*. Before sacrificing this valuable species by blanket spraying of the landscape on the assumption that the elimination of *Artemisia* results in net long-term improvement of rangeland, some account should be taken of its peculiar chemical composition as this relates to animal nutrition. *Grayia* is a deciduous shrub that accumulates so much K and Mg in its leaves that the pH of the soil beneath the bushes is raised by the heavy loads of these ions in the decomposing litter (100).

Although no evident soil characteristics distinguish this h.t., the sparsity of its representation within the borders of the large area of the *Artemisia-Agropyron* zone suggests its interpretation as an edaphic climax.



40. *Grayia-Poa* stand 145.

The soil profile at stand 145 is a Warden very fine sandy loam, ash subsoil phase, and a Mollic Camborthid in the Sierozem Great Soil Group:

A11 0-3″ Very pale brown (10YR 7/2d) or brown (10YR 4/3m) very fine sandy loam; weak medium subangular blocky; nonsticky, nonplastic, friable, soft; pH 7.7; frequent roots; clear wavy boundary

A12 3-7″ Pale brown (10YR 6/3d) or brown (10YR 4/3m) very fine sandy loam; moderate medium and coarse angular blocky; nonsticky, nonplastic, firm, slightly hard; pH 7.6; frequent roots; clear wavy boundary

A13 7-11″ Pale brown (10YR 6/3d) or brown (10YR 4/3m) very fine sandy loam; weak medium and fine angular blocky; nonsticky, nonplastic, friable, soft; pH 7.9; frequent roots; clear wavy boundary

AC1 11-22″ Pale brown (10YR 6/3d) or dark grayish brown (10YR 4/2m) very fine sandy loam; massive; nonsticky, nonplastic, slightly firm, slightly hard; pH 8.3; abundant roots; clear irregular boundary

AC2 22-27″ Light gray (10YR 7/2d) or dark grayish brown (10YR 4/2m) very fine sandy loam; massive; nonsticky, nonplastic, slightly firm, slightly hard; pH 8.5; numerous roots; clear wavy boundary

$IIC1_{va}$ 27-37″ White (10YR 8/2d) or light gray (10YR 7/2m) very fine sandy loam; moderate medium and coarse prismatic, with prisms tapered; nonsticky, nonplastic; very firm, very hard; pH 8.9; occasional roots; abrupt wavy boundary

$IIC3_{va}$ 48″+ Similar to above but including 10% angular basaltic gravel. (by W. A. Starr).

The distribution of *Grayia* in Washington is centered on the lowest and driest part of the *Artemisia tridentata-Agropyron* zone, without extending to the margin of this zone at any point. Pure stands of *Grayia-Poa* are very rare, but intermediates with the *Artemisia tridentata-Poa* and *Artemisia tridentata-Agropyron* association are common.

Eurotia lanata-Poa secunda h.t.

In relatively undisturbed condition, the vascular vegetation of the *Eurotia-Poa* h.t. consists mainly of *Eurotia lanata* and *Poa secunda*. The soils are all highly calcareous regosols related to the Sierozem Great Soil Group.

Eurotia, a shrub about 3dm tall that has white-woolly leaves persisting throughout the year, forms an open stand (fig. 41). The lower layer of *Poa secunda* was fairly continuous between and under the *Eurotia* bushes before the advent of livestock grazing. The community is markedly impoverished floristically; only 5-6 species of vascular plants occur in the 40 tenth-meter plots, and scarcely more than half of these are indigenes (appendices B-16 and E).

All of this vegetation has been heavily grazed because:

1. the soft twigs and leaves are palatable
2. both persist through seasons when other forage is low in quality
3. the stands are small and widely scattered
4. sharp-edged stones that discourage hooved animals are absent.

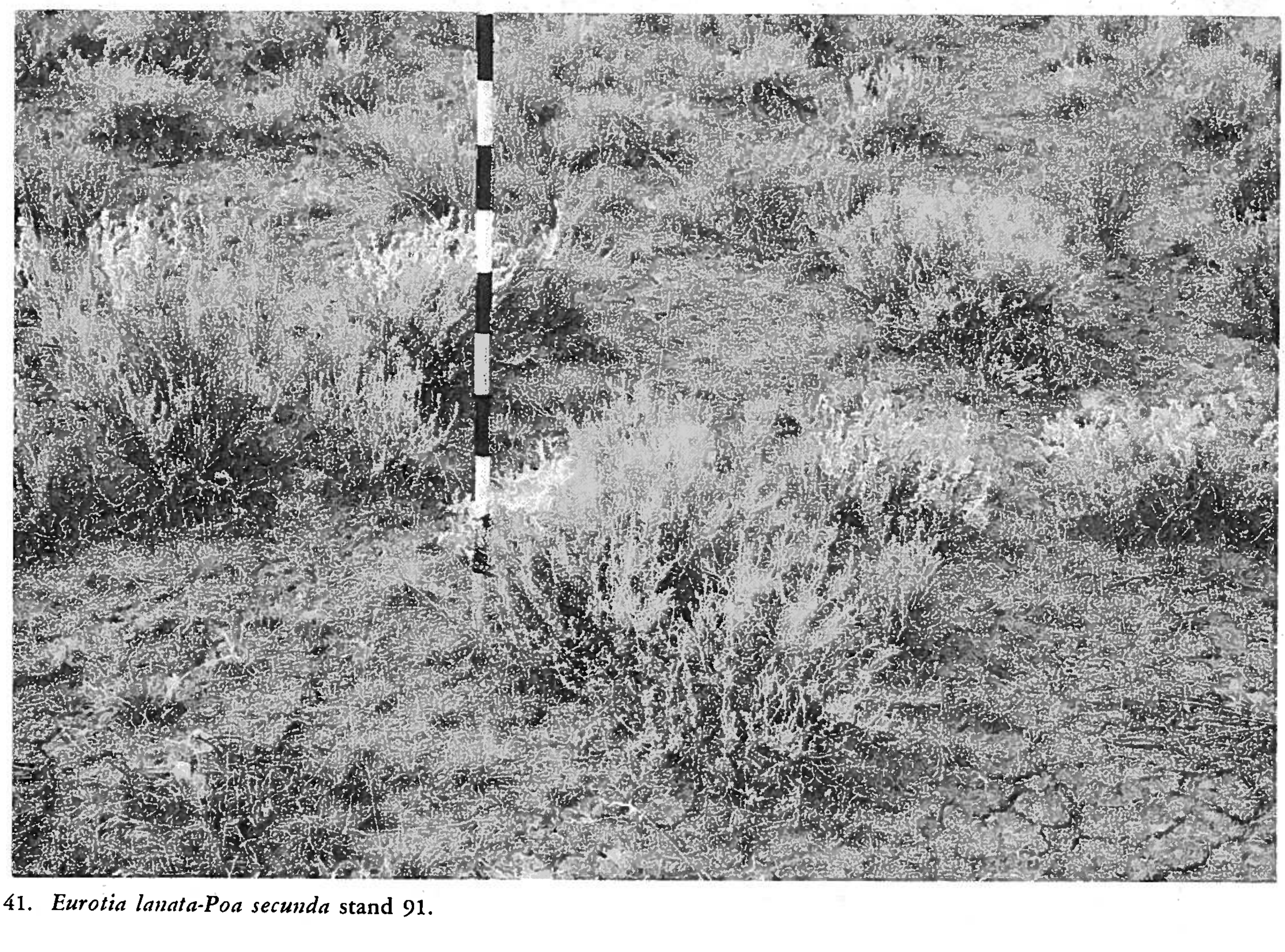
Even when the shoots of *Eurotia* are regularly kept to a uniform pad of stubble about 2cm high and several decimeters in diameter, the plants persist remarkably. The associated *Poa,* to which the attention of the animals next turns, always fares worse, so that *Poa* is usually sparse in relation to the suspected potential quantity. *Bromus tectorum* has invaded the h.t. profusely, probably in proportion to the reduction of *Poa.*

It is interesting to note that in Nevada, Robocker (105) consistently found no *Bromus tectorum* in disturbed stands of *Eurotia,* even though other weeds had invaded in consequence of overgrazing. In climates of Nevada, however, *Bromus* is generally less aggressive than it is in Washington. Stand 198 represents an analysis in a very small exclosure that had been severely overgrazed; the exclosure had been erected about 10 years before analysis. The recovery of *Eurotia* and increase of *Poa* in those few years was remarkable.

But for the very limited areas of the stands, the *Eurotia-Poa* association would be a very important range resource in Washington. The dominant shrub has high palatability in winter, and tolerates use. However, as the individual stands are too small to manage separately, they will continue to get more than their share of grazing pressure, since grazing must be adjusted to the optimal use of less palatable vegetation that always dominates the vegetation matrix.

Eurotia seedlings are abundant. On abandoned cropland at the southern foot of Saddle Mountain in Grant County this plant has vigorously invaded abandoned fields in the *Artemisia tridentata-Agropyron* (with *Grayia*) h.t. This suggests a promising possibility of using this plant when rehabilitating *Artemisia-Agropyron* areas by seeding.

The *Eurotia-Poa* h.t. in Washington occurs as small, sharply delimited areas which may be situated on bajada-like slopes along the flanks of mountains (e.g., stand 144), on midslopes of a mountain (e.g., stand 167), or most commonly at the shoulder where a steep slope gives way



41. *Eurotia lanata-Poa secunda* stand 91.

to gentle topography (e.g., fig. 42). The *Eurotia-Poa* association is considered an edaphic climax, since it has never been found on zonal soils, and the stands contain no seedlings of other species that might be possible successors.

Although *Eurotia* sometimes occurs mixed with other shrubs, usually the ecotones with other communities variously dominated by *Artemisia tridentata, Agropyron spicatum* and *Grayia*, are quite sharp (fig. 42). Despite this, pedologists have found no correspondingly sharp differences in the soil profiles on either side of the ecotones in the field nor in laboratory analyses of the soils. Somewhat stony sandy loams appear to be modal for the h.t. Although it is not highly diagnostic, the soil profiles are usually calcareous to the surface and therefore slightly to moderately alkaline. In Washington, none have been found with significant amounts of salts or Na at any level. Whereas the pH of surface soils in the *Artemisia tridentata-Agropyron* h.t. rarely rises to 7.1, the pH of *Eurotia* soils ranges from 7.1-8.0. Laboratory tests by Hilton (51) indicating that germination is slightly favored by adding a small amount of NaCl to the wetting medium must not be interpreted that *Eurotia* is even a weak halophyte under field conditions in Washington, as it may be in the southern Rockies (67).

A thorough glass-house study compared the upper 20cm of soil from contiguous *Eurotia-Poa* and *Artemisia tridentata-Agropyron* stands (the upper ecotone of the *Eurotia-Poa* stand in fig. 42). The work was done at the Plant Ecology Laboratory at Washington State University by E. W. C. Moore, who kindly made the unpublished results available to the writer. *Agropyron spicatum,* which in the field stops abruptly at the edge of an *Eurotia* stand, was used as a test plant. The *Agropyron* was grown in the two soils separately, in the same soils after diluting them with chernozemic loess, and in the chernozemic loess alone. Some cultures were treated with N+P+K+S, and some with these nutrients individually. Still others were given heavy charges of $CaCO_3$. Certain replicates were kept at about field capacity continuously; others were allowed to dry to the wilting coefficient occasionally.

Agropyron responses to each treatment were nearly the same on all soils. The only statistically significant difference was that dry matter production increased slightly more on the *Eurotia* soils following any adition of N or P. Thus it seems clearly established that the individuality of the *Eurotia-Poa* h.t. is not to be attributed to excessive $CaCO_3$ nor to a deficiency of any of N, P, K or S. Neither is any deleterious substance present. In Utah, Gates, et. al. (44) likewise were unable to find significant differences when *Eurotia* and contiguous h.ts. were compared on the opposite sides of sharp ecotones.

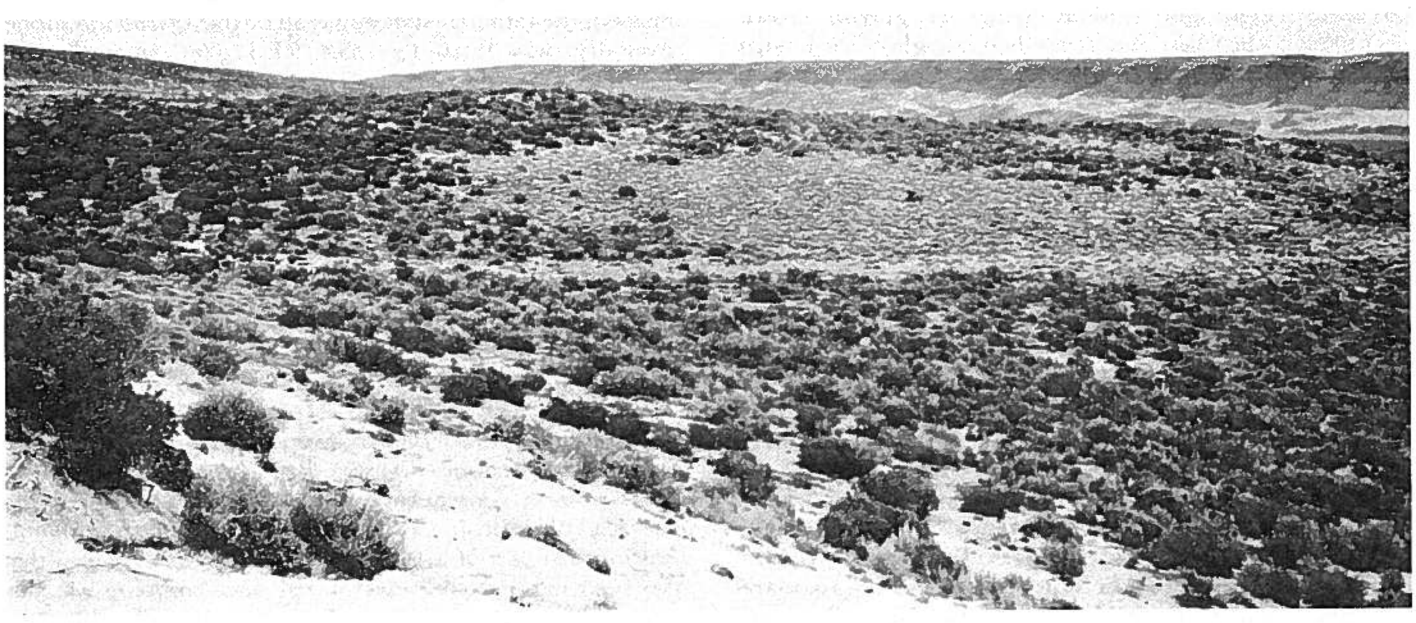
The profile at stand 198 is a Sagemoor very fine sandy loam, a Sierozem and a Xerollic Camborthid:

A11 0-7cm Light yellowish brown (10YR 6/4d) or dark yellowish brown (10YR 3/4m) very fine sandy loam with few coarse sand and fine gravel particles; vesicular, especially in the first 2cm; meq/100g Ca, Mg, K & Na: 8.6, 5.8, 1.1 & 0.1; pH 7.1; roots abundant

A12 7-38cm Very pale brown (10YR 7/4d) or dark yellowish brown (10YR 4/4m) very fine sandy loam with occasional basaltic fine gravel; very weak angular blocky; noncalcareous; meq/100g, Ca, Mg, K & Na: 12.0, 6.2, 0.8 and 0.3; pH 7.2; numerous roots

AC1 38-46cm Very pale brown (10YR 7/3d) or brown (10YR 5/3m) very fine sandy loam with few basaltic fine gravel particles; very weak coarse to medium subangular blocky; very friable with occasional slightly compacted nodules that are finer in texture and more compacted than above; meq/100g Ca, Mg, K & Na: 19.9, 6.6, 0.1 and 0.2; pH 7.7; numerous roots

AC2ca 46-53cm Light gray (10YR 7/1d) or light brown-



42. The ellipse of light gray vegetation is a *Eurotia lanata-Poa secunda* stand. To the left is a dark-colored *Grayia-Poa* stand. Elsewhere, the landscape supports *Artemisia tridentata-Agropyron* steppe. South of Kennewick, Benton County, Washington.

ish gray (10YR 6/2m) very fine sandy loam with occasional small basaltic gravel particles; numerous slightly cemented nodules of finer texture and darker color than the main mass; moderately to highly calcareous with mycelia of lime; meq/100g Ca, Mg, K and Na: 58.3, 5.0, 0.1 & 0.2; pH 8.4; very few roots

AC3cam 53-58cm Light gray (10YR 7/2d) or light brownish gray (10YR 6/2m) silt loam; firm hard caliche, slightly cemented and compacted, brittle, tending to break out in horizontal plates and reduce to thin laminations; the reduced structure tends to be vesicular and medium to fine strong, sharp, angular blocky; highly calcareous; pH 8.2; occasional roots and old root channels

C1sa 58-135cm Light gray to white (10YR 7/2-8/2d) or light brownish gray to pale brown (10YR 6/2-6/3m) stratified silts and sands

C2 135-166cm Light gray (10YR 7/2d) or grayish brown (10YR 5/2m) stratified silts and sands with some streaks of white (10YR 8/1d or m); pH 8.1-8.3 (by W. A. Starr).

Another stand, observed at the northeastern flank of Rattlesnake Mountain in Benton County, was on Arrowsmith sandy loam, a Calcisol and a Typic Camborthid:

A1 0-2.5″ Pale brown (10YR 6/3d) or brown (10YR 4/m) sandy loam; weak coarse platy with vesicular crust 0.5″ thick; very friable when moist; abundant roots; abrupt smooth boundary

C1 2.5-12″ Pale brown (10YR 6/3d) or brown (10YR 4/3m) sandy loam; coarse prismatic structure; friable when moist; calcareous; roots plentiful; smooth boundary

C2 12-22″ Light gray (2.5Y 7/2d) or grayish brown (2.5Y 5/2m) silt loam; massive; slightly hard when dry, firm when moist; few roots; abrupt, smooth boundary

C3 22-28″ Light gray (10YR 7/2d) or grayish brown (10YR 5/2m) very fine sandy loam; slightly hard when dry, firm when moist; roots plentiful; abrupt smooth boundary

C4 28-46″ Light gray (10YR 7/2d) or dark grayish brown (10YR 4/2m) coarse sandy loam; massive; soft when dry; roots common; abrupt smooth boundary

C5 46-54″ Light gray (2.5Y 7/2d) or grayish brown (2.5Y 5/2m) very fine sandy loam; massive, with few fine pores; slightly hard when dry, firm when moist; few roots (by W. A. Starr).

In Washington, *Eurotia* has a smaller range than *Grayia* and is confined even more closely to the center of the *Artemisia-Agropyron* zone, where there is least rainfall and most heat: eastern Yakima County, Benton County; western Franklin County and southern Grant County. Cotton (19) refers to *Eurotia* in Douglas County, but I have been unable to confirm this occurrence.

The Washington stands of both *Eurotia* and *Grayia* represent the northernmost outposts of species that are best represented in the vegetation of the Great Basin of Utah and Nevada. The Washington stands certainly are relics of a northern extension up the intermountain trough in the post-Wisconsin Hypsithermal period.

Sporobolus cryptandrus-Poa secunda h.t.

Sporobolus cryptandrus and *Poa secunda* comprise nearly all the perennial grass in stands of the *Sporobolus-Poa* association. Widely scattered individuals of *Chrysothamnus nauseosus* are usually present, but no other shrubs are evident.

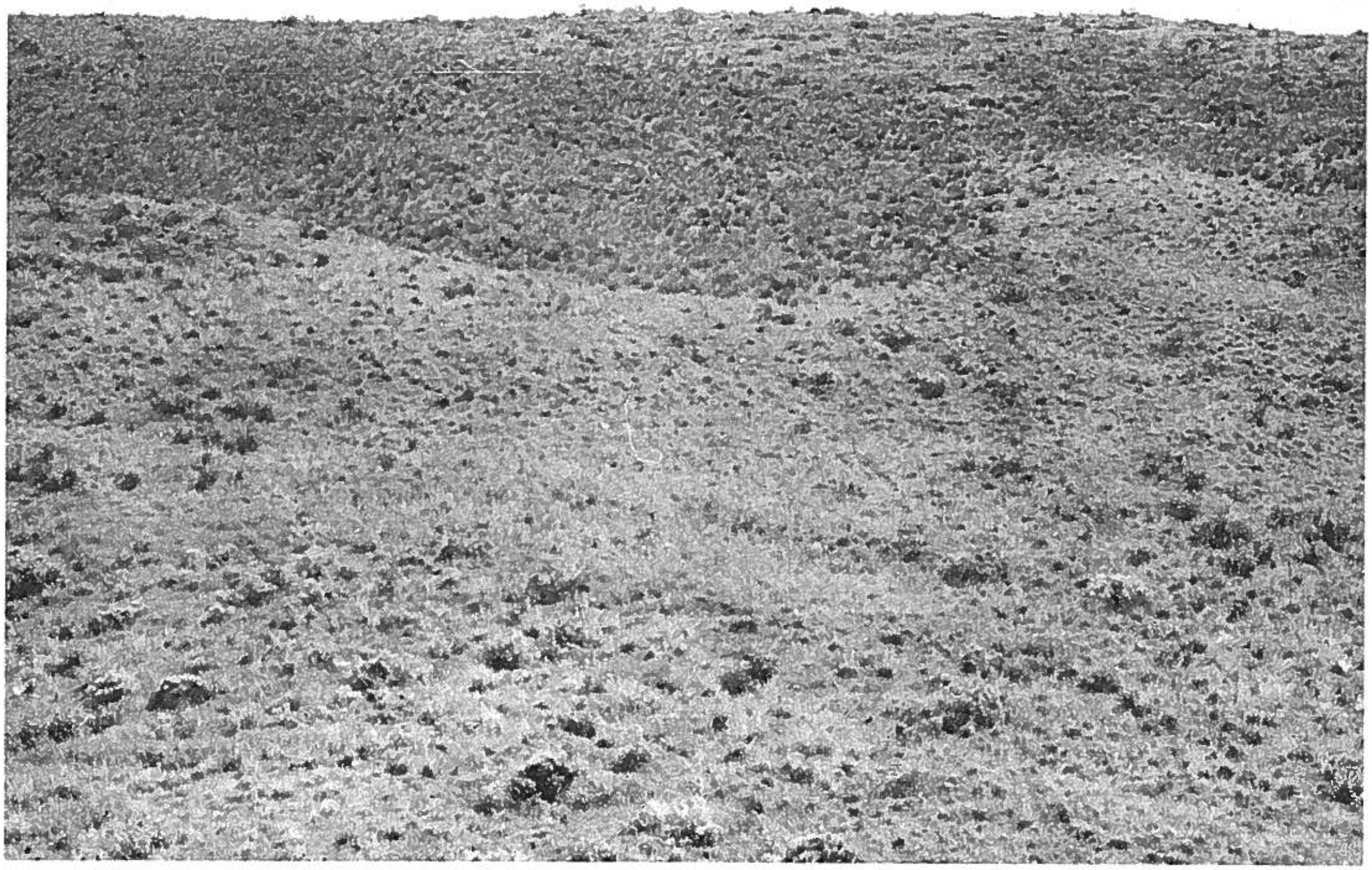
Sporobolus is unique among our larger grasses for its delayed inception of growth in spring, and this has an important bearing on the condition of the existing stands. Cattle and horses eat the grass with relish, both when it is green in early summer and in autumn after rains have softened the standing cured shoots. Nearly all *Sporobolus* stands show signs of heavy grazing. The spaces between the large bunches support mainly those small annuals that typically increase or invade because of heavy animal use, especially *Bromus tectorum, Erodium cicutarium, Draba* and *Holosteum* (appendix B-17). The scarcity of *Poa secunda* is interpreted as a result of its earliness, which concentrates grazing on this species in spring when the previous summer's shoots of *Sporobolus* have become leached by winter rains and no longer attract animals, and the new shoots have not yet appeared.

Ranchers commonly value an interspersion of *Sporobolus* and *Agropyron* stands in a grazing unit. *Agropyron* provides good feed early; then as it dries, the developing *Sporobolus* extends the period of green forage well into summer. The lateness of the phenology of *Sporobolus* is illustrated by comparative notes made in a mixed stand on June 20. At that time, *Stipa comata* fruits were partly disseminated, *Agropyron* fruits were not yet ripe enough for any dissemination, and *Sporobolus* was only in the pollination stage.

The productivity of *Sporobolus* appears to suffer little from use that is heavy enough to replace the associated *Poa secunda* with alien annuals. In two stands where the *Sporobolus* was well developed, and little *Poa* remained, the terminal standing crop of the *Sporobolus* alone, oven-dry, was 170.0 ($\pm$ 16.4 S.E.) g/m^2/yr, and 115.0 ($\pm$10.0) g/m^2/yr. The first of these values was obtained in stand 183 (appendix B-17). In a very small part of the other stand, there was enough *Poa* in 3m^2 to yield dry matter at the rate of 3.47 g/m^2/yr. This much *Poa* compares favorably with values for the same species in virgin *Agropyron-Poa* stands (appendix C), but *Sporobolus* yields substantially more than *Agropyron*.

The ecologic status of *Sporobolus* stands is not clear. Sharp ecotones with *Agropyron-Poa* on relatively undisturbed soil and *Sporobolus* on contiguous disturbed areas, show clearly that *Sporobolus* can be seral to *Agropyron* (fig. 43). Also, in places, fenceline comparisons demonstrate that *Sporobolus* can invade the *Agropyron-Poa* h.t. Along the Anatone highway just south of Asotin, this invasion is a consequence of grazing alone. But along the road up Silcott Creek west of Clarkston, *Sporobolus* has invaded part of an abandoned field in a range area that has been intermittently overgrazed since cropping was discontinued. *Agropyron-Poa* vegetation prevails elsewhere in the area.

Sporobolus-dominated stands occur mainly in large valleys where aboriginal villages and camps were abundant.



43. Ecotone between *Sporobolus-Poa* (below) and *Agropyron-Poa* (above) stands. Photo taken in spring after the new foliage of *Agropyron* was well developed, but before any new growth of *Sporobolus* could be seen. There are no manifest differences in percent slope, soil depth, or texture on either side of this sharp and irregular ecotone. Lewiston, Idaho.

Because horses had to be herded closely to minimize theft, excessive grazing of these areas began three quarters of a century before white man arrived. The high coverage of grazing indicators shows that none of the *Sporobolus* stands yet found represents a primary climax, but all are zootic climaxes. In very heavily grazed areas, *Sporobolus* can be completely replaced by *Chrysothamnus nauseosus* with coverage measured as high as 43%.

In still other areas, the existence of sharp and irregular boundaries between contiguous stands of *Agropyron* and *Sporobolus* (fig. 43) seems good evidence for equal status of the two as climax types, with edaphic factors governing the pattern. Thus it is tentatively concluded that the *Sporobolus-Poa* association is an edaphic climax in certain places; elsewhere, *Sporobolus* stands are zootic climax or seral. The discussion that follows refers to areas where *Sporobolus* is suspected of being an edaphic climax.

Large areas of *Sporobolus* are often found on sandy or gravelly soils. This suggests a possible textural component to habitat differentiation. Accordingly, a trip was taken along roadways where *Agropyron* and *Sporobolus* stands are abundantly interspersed, and in the first 20 stands of each type, the first 10 cm of mineral soil was sampled. Moisture equivalents, used as a criterion of effective texture, revealed a range for the Agropyron stands of 15-28%, and a range for the *Sporobolus* stands of 15-29%, except one value that fell to 9%. Thus, the water-retaining capacities of the soils seem to offer nothing to explain the community mosaic. Another series of moisture equivalent determinations that extended to a depth of 5 dm showed no more difference between the h.ts. In connection with texture it is worth noting that northeast of the Blue Mountains, Sporobolus extends beyond the limits of the Agropyron-Poa zone far up into the edge of the contiguous *Agropyron-Festuca* zone as an invader of gravelly fill along the margins of the paved highway.

A comparative glasshouse study was made of the growth of grasses in soil from an *Agropyron-Poa* stand and from what appeared to be a *Sporobolus-Poa* habitat. Both were along the Snake River west of Clarkston, Washington. Seedlings of *Agropyron spicatum, Sporobolus cryptandrus,* and *Stipa comata* were grown separately in each soil type. Some cultures were fertilized with (200 lb N/acre + 200 lb P/acre + 100 lb K/acre); others were unfertilized controls. After the experiment was concluded, tests showed the fertilizer raised conductivity to a negligible extent—

from 0.54 to 1.06 mmho/cm.

Among the controls, *Agropyron* and *Stipa* grew better on *Agropyron-Poa* soil, but *Sporobolus* grew equally well on both soils. The addition of N, P and K about doubled the growth of all three grasses on *Agropyron-Poa* soil, but induced only insignificant increases on *Sporobolus-Poa* soil. Even with fertilization, production of all three grasses on the *Sporobolus* soil was not as high as on the unfertilized *Agropyron-Poa* soil. Clearly, this *Sporobolus* soil had some limiting condition that was not alleviated by adding N, P and K; the limitation was less serious for *Sporobolus* than for *Agropyron* and *Stipa.*

A second glasshouse experiment performed by T. S. Bakshi was designed to determine if certain micronutrients might be deficient in *Sporobolus-Poa soil.* In this test, only *Agropyron spicatum* was grown, and all cultures were supplied with macronutrients as above. B, Mo, Zn, Cu, Mn and Fe were added separately to individual sets of replicates, but growth was essentially identical with other cultures to which all micronutrients were added.

Since in the first experiment P was added as $CaHPO_4$ and K added as K_2SO_4, both Ca and S deficiencies can also be discounted. Thus five macronutrients and six micronutrients were tested without showing nutrient deficiency as a limiting factor in the *Sporobolus-Poa* soil tested. Possibly some nutrient not yet tested was deficient, or a toxic substance was present, or glasshouse environment gave results inapplicable to field conditions.

After the above studies were made, routine chemical analysis of many steppe soils became available. When the data from four *Sporobolus* sites were compared with data from 17 sites where *Stipa comata* was the leading grass and 17 additional stands where *Agropyron* dominated, the results showed that Mg and possibly K were relatively low in *the Sporobolus soils* (table 8).

Table 8. Analyses of the upper 20 cm of mineral soil in stands dominated by different grasses, with standard errors.

Dominant grass	No. stands	Meq/100g soil & S.E. K	Mg
Sporobulus	4	1.12±.09	.62±.02
Stipa	17	3.73±.51	1.57±.28
Agropyron	17	1.16±.05	3.52+.33

Further biological assays of a series of *Sporobolus* soils would be desirable, testing the responses of the grasses to Mg and K additions under conditions more like those in the field. *Sporobolus* soils can be used for grain, orchards, and irrigated pastures as well as for natural grazing land. Evidently, any soil limitations for these crops are readily overcome where competition is minimized; yet small differences in soils can make large differences in the success of competing species.

Sporobolus stands are subject to replacement or modification by disturbance. An abandoned dirt road crossing *Sporobolus* stand 183 (appendix B-17) has been colonized by *Aristida longiseta.* Again, a fenceline along the Snake River suggests that *Stipa comata, Helianthus annuus* and *Opuntia polyacantha* have all increased in consequence of heavy grazing of a *Sporobolus* stand. Perhaps the mixed stands of *Sporobolus* and *Stipa* in appendix B-17 reflect a partial replacement of the more palatable *Sporobolus* by the less palatable *Stipa.*

The relations between *Sporobolus* and *Stipa comata* seem approximately reversed in widely separated parts of the Washington steppe. In the eastern end of the *Agropyron-Poa* zone, *Sporobolus* is much more abundant than *Stipa.* The latter appears capable of replacing the former with disturbance. Far to the northwest in the Okanogan Valley, where there are extensive tracts of *Artemisia tridentata-Stipa* and *Pursia-Stipa* h.ts. the *Sporobolus* is a minor species that becomes conspicuous only on the disturbed *Stipa* soils.

Stand 83 is on Farrell fine sandy loam, a Regosol-Chestnut intergrade and a Calcic Haploxeroll:

A11 0-0.5″ Black (10YR 2/1m) fine sandy loam; very weak medium and fine granular; very friable, loose, nonsticky, nonplastic; pH 7.6; abundant roots; clear smooth boundary

A12 0.5-10″ Dark brown (7.5YR 3/2m) fine sandy loam; weak medium to coarse subangular blocky; friable, loose, nonsticky, nonplastic; pH 7.8; numerous roots; clear wavy boundary

AC 10-17″ Brown (10YR 5/3d) or dark brown (10YR 4/3m) sandy loam; weak medium and fine subangular blocky, reducing to weak medium granular; friable, loose, nonsticky, nonplastic; pH 7.8; numerous roots; gradual irregular boundary

C1 17-22″ Pale brown (10YR 6/3d) or dark brown (10YR 4/3m) sandy loam; moderate medium and fine subangular blocky; slightly compact, firm, slightly hard, nonsticky, nonplastic; pH 8.1; occasional roots; gradual irregular boundary

C2ca 22-27″+ Light gray (10YR 7/2d) or grayish brown (10YR 5/2m) sandy loam; moderate medium and fine subangular blocky; firm, slightly hard, nonsticky, nonplastic; calcareous, pH 8.4; occasional roots (by W. A. Starr).

Stand 93 is on a Farrell loam, a Regosol-Brown intergrade and a Calcic Haploxeroll:

A11 0-2″ Very dark grayish brown (10YR 3/2m) or light brownish gray (10YR 6/2d) loam; weak medium platy; nonsticky, nonplastic, friable, soft; pH 7.8; abundant roots; abrupt smooth boundary

A12 2-8″ Light brownish gray (10YR 6/2d) or dark brown (10YR 3/3m) loam; moderate medium and coarse angular blocky; nonsticky, nonplastic, firm, hard; pH 7.7; numerous roots; clear wavy boundary

AC 8-14″ Pale brown (10YR 6/3d) or brown (10YR 4/3m) loam; weak medium and coarse angular blocky; nonsticky, nonplastic, firm, slightly hard; pH 7.9; numerous roots; clear wavy boundary

C1 14-26″ Light brownish gray (10YR 6/2d) or pale brown (10YR 6/3m) gravelly loam; weak medium and fine angular blocky; nonsticky, nonplastic, friable, slightly hard; pH 7.9; frequent roots; clear wavy boundary

C2 26-36″ Light gray (10YR 7/2d) or dark grayish brown (10YR 4/2m) gravelly fine sandy loam; massive; slightly compact; pH 7.9; distinct basalt stone line in bottom of horizon; abrupt wavy boundary

Dca 36"+ White (10YR 8/2d) or dark grayish brown (10YR 4/2m) very fine sandy loam; loose, single grain; pH 9.3; numerous gravel; calcareous (by W. A. Starr).

The *Sporobolus-Poa* h.t. is found in the *Agropyron-Poa* zone from near Wawawai, Washington, up the Snake River to at least the mouth of the Salmon River in Idaho, and up the Clearwater River to about Spalding, Idaho. In general, the h.t. does not ascend the valley slopes very far above the river, but southwest of Clarkston it rises 350m above the Snake River.

Aristida longiseta-Poa secunda h.t.

In the *Aristida-Poa* association, *Aristida longiseta* and *Poa secunda* are the vascular plants with the highest coverage. *Chrysothamnus nauseosus* occurs very widely spaced.

The *Aristida-Poa* association is one of four types of steppe in Washington that are essentially identical but for the substitution of the major dominant grass. The other three are *Agropyron-Poa, Stipa-Poa* and *Sporobolus-Poa.*

Recognition of the *Aristida-Poa* association as a climax rests on two observations:

1. A large stand (appendix B-17, stand 184, and fig. 44) has been located that contains very little of species such as *Bromus tectorum* and *Chrysothamnus nauseosus* that gain representation under heavy disturbance then persist indefinitely.

2. Just north of Lyon's Ferry, stands of *Agropyron-Poa* and *Aristida-Poa* alternate within short space; both show equal abundance of those annuals that indicate heavy grazing, and thus appear to have equal permanence.

On the other hand, there is no doubt but that in certain habitats *Aristida* plays a seral role. As said before, *Aristida* has invaded and dominated an abandoned roadway through a *Sporobolus* habitat. Furthermore, cattle will not eat *Aristida* if other grasses are available, so it is a potential increaser.

No readily apparent character distinguishes the loamy to gravelly soils of the *Aristida* h.t. from those of the *Agropyron-Poa* h.t. However, the latter is the ubiquitous matrix in the area mapped as *Agropyron-Poa* zone (fig. 1), whereas the former occupies small, highly disjunct areas. This pattern suggests that some subtle soil abnormality determines the size and distribution of the *Aristida* communities, so they are accordingly interpreted as edaphic climaxes, at least in part.

The stand shown in fig. 35 is on Chard silt loam, a Calcic Haploxeroll in the Brown Great Soil Group:

44. *Aristida longiseta-Poa secunda* stand (#184), June 12, with *Astralagus inflexus* at lower right, white inflorescences of *Achillea,* and *Chrysothamnus nauseosus* bushes in the distance.

A11 0-3″ Very dark brown (10YR 2/2m) silt loam; moderate medium and fine platy; slightly sticky, nonplastic, friable, soft; abundant roots; abrupt smooth boundary

A12 3-7″ Dark brown (10YR 3/3m) very fine sandy loam; mixed weak coarse subangular blocky and medium coarse platy; nonsticky, nonplastic, friable, soft; abundant roots; clear wavy boundary

AC1 7-17″ Dark brown (10YR 3/3m) very fine sandy loam; moderate medium and coarse angular blocky; nonsticky, nonplastic, friable, soft; numerous roots; clear wavy boundary

AC2 17-26″ Dark grayish brown (10YR 4/2m) very fine sandy loam; weak coarse platy, reducing to weak medium and fine granular; nonsticky, nonplastic, friable, soft; frequent roots; clear wavy boundary

C1ca 26-37″ Grayish brown (10YR 5/2m) fine sandy loam; weak medium and fine subangular blocky; nonsticky, nonplastic, friable, loose; calcareous with slightly hard lime nodules; numerous roots; clear wavy boundary

C2ca 37″+ Grayish brown (10YR 5/2m) fine sandy loam; weak fine angular blocky; nonsticky, nonplastic, friable, loose; calcareous, occasional roots (by W. A. Starr).

In Washington the *Aristida-Poa* h.t. has been observed in only the Snake, lower Grand Ronde, and lower Palouse River valleys, and even in these areas this h.t. is uncommon. To the southeast, however, in the lower Salmon River Valley in Idaho, stands occur in abundance.

Rhus glabra-Agropyron spicatum h.t.
Rhus glabra-Sporobolus cryptandrus h.t.
Rhus glabra-Aristida longiseta h.t.

Rhus glabra is a common shrub locally on colluvial and sandy alluvial soils in canyons. Nearly all the stands have been badly disturbed by grazing, owing to their proximity to water. *Bromus tectorum* with other annuals such as *Erodium circutarium* comprise most of the herbaceous vegetation. On very rare occasions, stands have been found, especially in the lower Grand Ronde Valley, where there is a fairly high degree of perennial grass cover. In all such stands, a single species dominated—*Agropyron spicatum* (fig. 45), or *Sporobolus cryptandrus,* or *Aristada*

45. *Rhus glabra-Agropyron spicatum* stand. Big Canyon Creek, north of Pittsburgh Landing on the Snake River, Idaho County, Idaho. In grazed stands, the *Rhus* is at least twice this tall. The conspicuous die back is everywhere evident.

longiseta. From their strong tendency to segregate elsewhere, it is assumed that these indicate ecologically distinctive environments and that at least three h.ts. are represented by *Rhus* thickets. Disturbance has been so nearly universal that not enough stands have been found to determine the extent of vegetation differentiation, or the controlling soil factors. For practical purposes, only a *Rhus glabra-Bromus* tectorum zootic climax can be recognized in Washington, but it is possible that farther up the Snake River, enough vegetation could still be found to be worth study.

Popular opinion among range technicians is that the wholly unpalatable *Rhus* is an invader or at least an increaser in rangelands. Duplicate photos taken 18 years apart in the lower valley of Potlatch Creek, Latah County, Idaho, have shown no change in the several large and discrete thickets that can be compared critically from the same vantage point. Another pair of photos taken in Wawawai Canyon (fig. 46, 47) shows considerable change during a 10-year interval, but with areal gains and losses by *Rhus* rather well balanced. Thus the concrete evidence available does not support the invader or increaser hypothesis.

The patchy distribution of *Rhus* stands and their restriction to sandy or stony soils warrant designating them as one or more edaphic climaxes.

This vegetation occurs in the eastern extremity of the *Agropyron-Poa* zone, and in the *Artemisia tridentata-Agropyron* zone as it occurs in the Okanogan Valley.

Celtis douglasii-Bromus tectorum h.t.

Colluvial cones and aprons along the major canyon walls in the *Agropyron-Poa* zone support many small, open stands of *Celtis douglasii,* a low deciduous tree (fig. 48). *Celtis* may grow so close to the river that the base of the trunk is inundated at high-water stages.

Owing to the attractiveness of the shade these trees furnish in hot summer weather, grazing animals have loitered beneath the trees until all vestiges of natural vegetation have been exterminated. Undoubtedly, the soil has been much altered by compaction and manuring. Only *Bromus tectorum* has ever been found abundant in this zootic climax. The edaphic and climatic requirements of this and the *Rhus* community are so similar that they often occur adjacent to each other, but they tend to remain remarkably discrete.

The *Celtis-Bromus* h.t. is rather well confined to the Snake River Valley in eastern Washington, extending but a short way up each tributary, and not rising far above the valley floor. It is found from the mouth of the Palouse River up the Snake to at least the Oregon border. It reappears in the western segment of the *Agropyron-Poa zone* along the Columbia River.

PARKS IN THE LOWER FOREST ZONES

Festuca idahoensis-Eriogonum heracleoides h.t.

Grassland with *Festuca idahoensis* and *Eriogonum heracleoides* associated, but not including any shrub larger than the *Eriogonum,* characterizes the *Festuca-Eriogonum* h.t. When the *Agropyron-Festuca* assoctiaion occurs on somewhat stony soil it may contain *Eriogonum heracleoides,* and often *Balsamorhiza sagittata* or *Allium* or *Lomatium macrocarpus.* These stands never contain the "forest species" *Antennaria rosea* or *Castilleja miniata.* Also, the *Festuca-Eriogonum* h.t. has not been identified except in the Okanogan Mountain area.

On approaching the Okanogan Mountains from any of the relatively dry steppe zones, one encounters a belt of *Artemisia tripartita-Festuca* meadow-steppe that encircles these mountains near lower timberline. Entering the mountains still further, the proportion of forest-covered land increases. Steppe vegetation becomes restricted to local areas too dry for trees. In the upper part of this steppe-forest mosaic, the *Artemisia* drops out of the herbaceous cover, leaving most of its associates to continue to higher elevation as parks (i.e., unforested openings) in the montane forest. The inclusion here of these meadow-like communities that lie beyond the main range of *Artemisia tripartita* is largely a matter of convenience. Although such vegetation may not qualify as "steppe," it interfingers with the *Artemisia tripartita-Festuca* association and merits consideration if only to understand the limits of that association.

As most of the *Festuca-Eriogonum* h.t. is situated farther in the mountains, the temperature is presumed to be lower than that of the *Artemisia tripartita-Festuca* h.t. In a study of the annual cycle of soil temperature and moisture in representative stands of these associations (27) the soil at both 50 and 100cm depth proved to be consistently colder in the *Festuca-Eriogonum* community. Apparently, the frozen soil surface in the latter stand greatly retarded the infiltration of precipitation, thus delaying the rehydration of subsoil that had been exhausted of its moisture in summer. Possibly this protracted dryness of the subsoil is responsible for the general failure of *Artemisia tripartita* to invade the h.t. The stand of *Artemisia tripartita-Festuca* studied the same year was less drouthy in autumn, even though farther from the mountains and under lower rainfall. Clones of *Artemisia tripartita* that are occasionally met in parks otherwise supporting the *Festuca-Eriogonum* association may be relics of an upward invasion in the post-Wisconsin Hypsithermal period.

Eriogonum heracleoides is a much lower shrub than *Artemisia tripartita* and plays no role in determining the physiognomy of the *Festuca-Eriogonum* association (fig. 49). It is often very sparingly represented. As stated before, the elimination of *Purshia* from *Purshia-Festuca* stands by fire produces a community very much like the *Festuca-Eriogonum* association until Purshia reinvades the burn. But since *Purshia-Festuca* h.ts. occur only from the Okanogan River westward, whereas the *Festuca-Eriogonum* h.t. appears to occur only east of the river and at higher altitudes, there is no opportunity for confusion.

Although no productivity studies have been made, the *Festuca-Eriogonum* association appears to be about equal to the closely related *Artemisia tripartita-Festuca* association. The former makes an important contribution to the forage available to livestock in the Okanogan Mountains, despite its limited area.

The soil at stand 99 is a Conconully gravelly fine sandy loam, a Regosol-Chestnut intergrade and a Typic Haploxeroll:

A11 0-14″ Brown (10YR 4/3d) or dark brown (10YR 3/3m) gravelly fine sandy loam; weak fine granular; nonsticky, nonplastic, friable, soft; pH 7.0; abundant roots, clear wavy boundary

A12 14-19″ Brown (10YR 5/3d) or dark brown (10YR 3/3m) gravelly fine sandy loam; single grain, nonsticky, nonplastic, friable, loose; pH 6.5; roots numerous; clear wavy boundary

C1 19-36″ Brown (7.5YR 4/2d) or dark brown (7.5YR 3/2m) gravelly sandy loam; single grain; nonsticky, nonplastic, friable, loose; pH 6.7; many roots; clear wavy boundary

C2 36″+ Yellowish brown (10YR 5/4d) or dark yellowish brown (10YR 4/4m) gravelly loamy sand; single grain; nonsticky, nonplastic, friable, loose; occasional roots (by W. A. Starr).

Stand 102 is associated with a Mires loam, a Prairie soil and a Mollic Vitrandept:

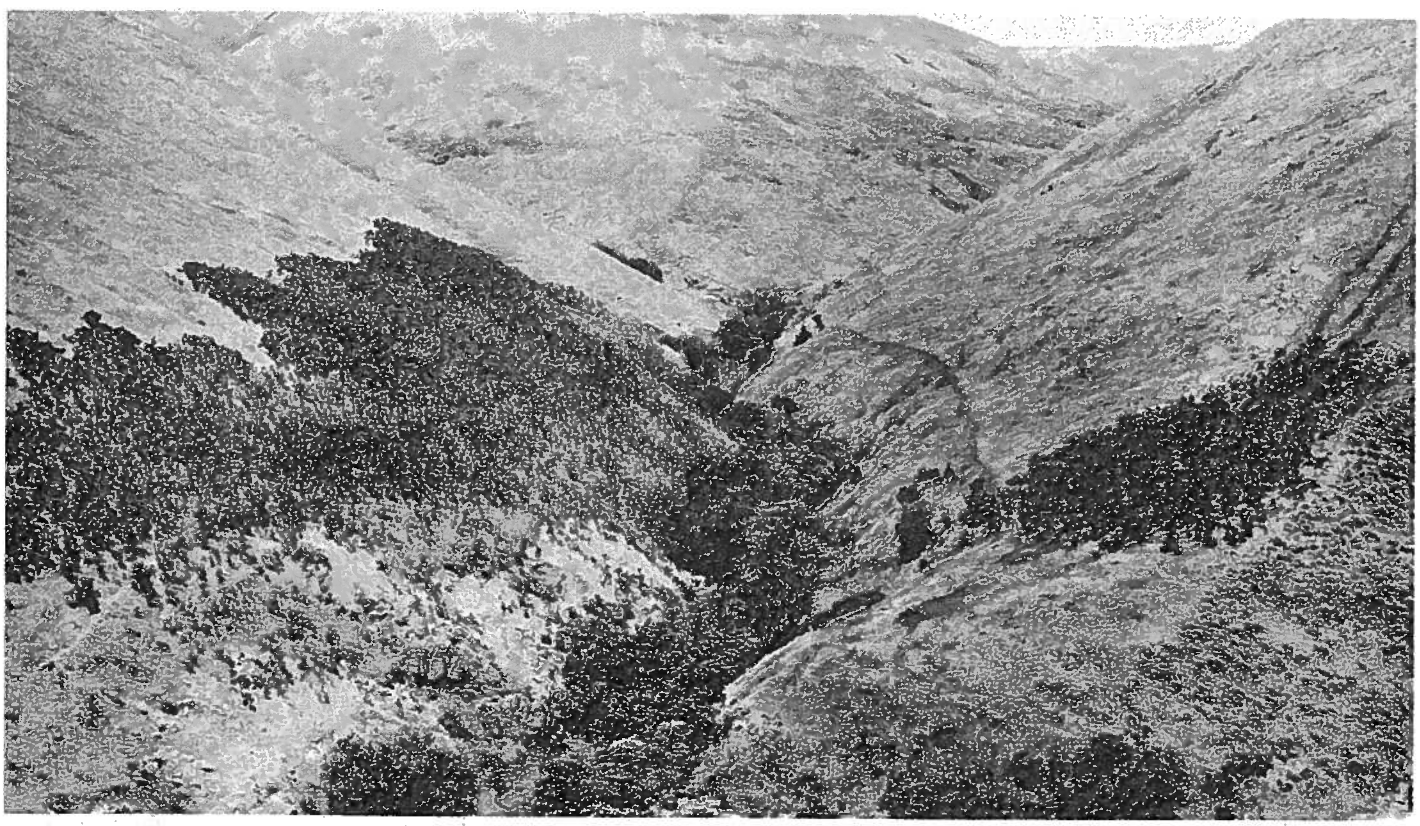
A11 0-8″ Very dark brown (10YR 2/2d) or black (10YR 2/1m) loam; weak fine and medium granular; nonsticky, nonplastic, friable, soft; pH 7.1; abundant roots; clear wavy boundary

A12 8-13″ Very dark grayish brown (10YR 3/2d) or very dark brown (10YR 2/2m) loam with occasional stones; weak medium and fine subangular blocky; nonsticky, nonplastic, friable, soft; pH 7.5; numerous roots; clear wavy boundary

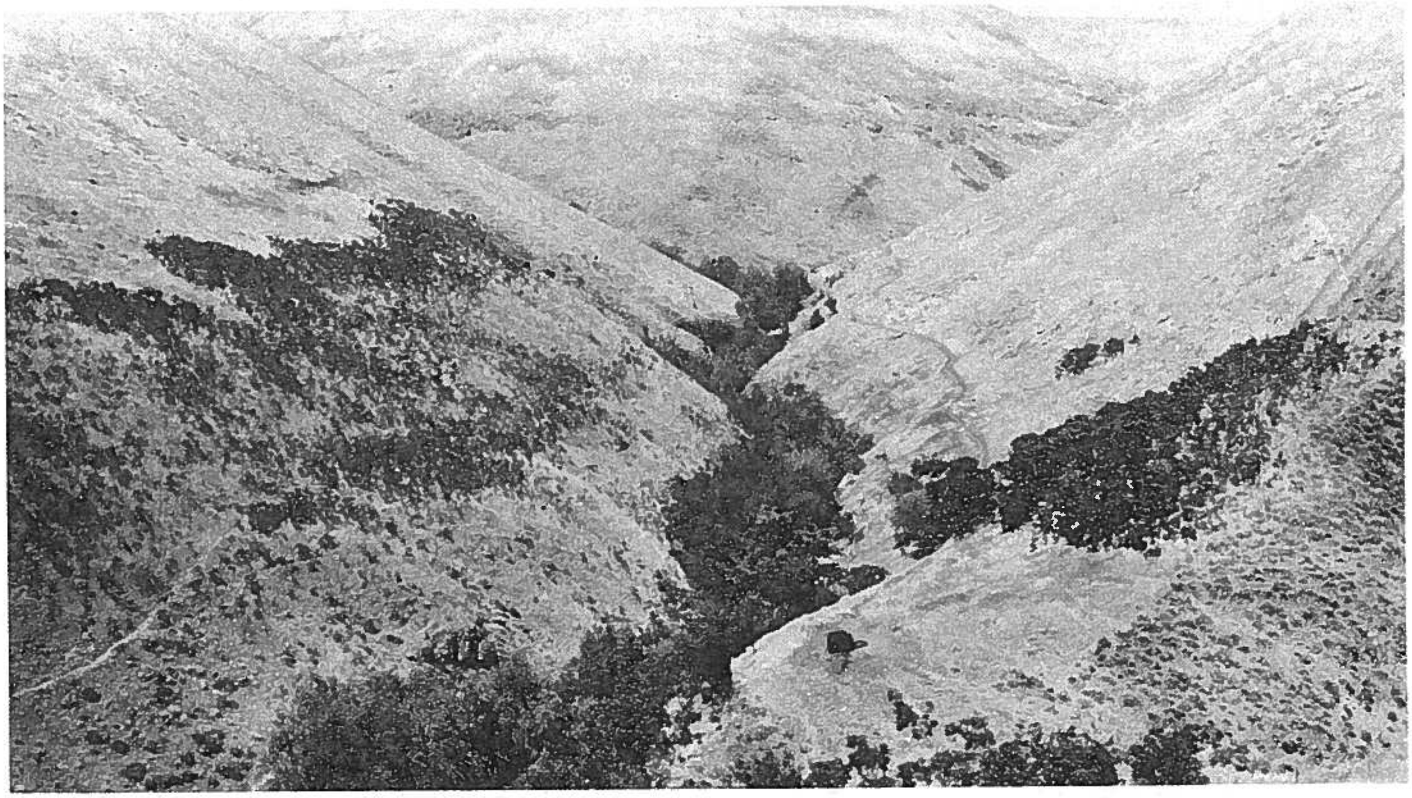
AC 13-23″ Brown (10YR 5-3d) or dark brown (10YR 3/3m) gravelly loamy sand, with the larger gravels in lower part of horizon lime-coated; single grain; nonsticky, nonplastic; friable, loose; pH 7.9; occasional roots; clear wavy boundary

Cca 23″+ Multicolored gray, brown and olive gravelly sand with all gravel lime-coated; single grain; nonsticky, noplastic, friable, loose; pH 8.4; no roots (by W. A. Starr).

The *Festuca-Eriogonum* h.t. has been found from eastern Okanogan County and northern Ferry County to the vicinity of Spokane.

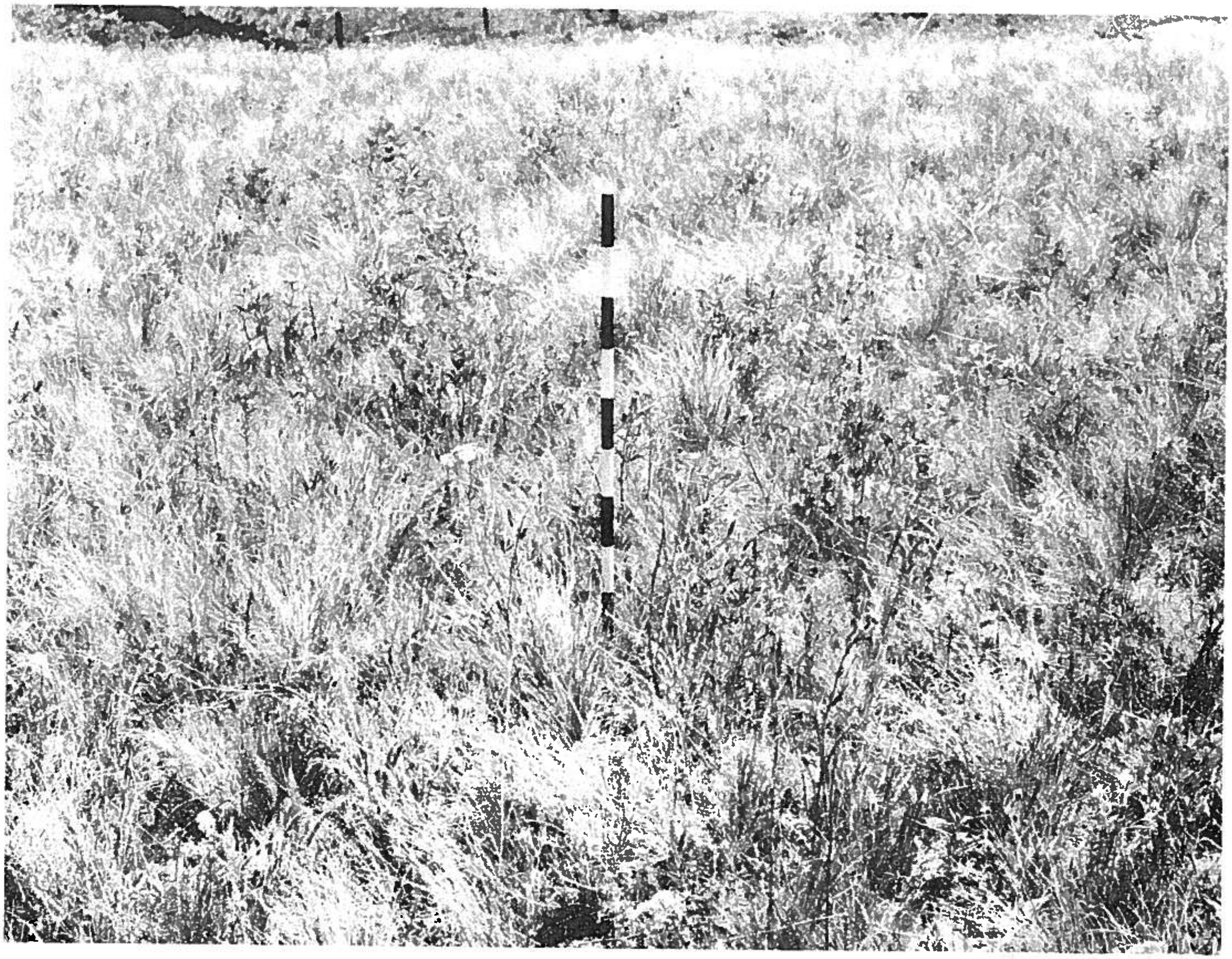


46. A vegetation mosaic with mesophytic shrubs along an intermittent rivulet, dark patches of *Rhus glabra* on either side, a gray *Artemisia rigida-Poa* stand in the lower right hand corner, and the remainder of the area supporting degraded *Agropyron spicatum-Poa* vegetation. Wawawai Canyon, Whitman County, Washington.



47. Repeat of photograph in figure 46 taken 10 years later. The large patch of *Rhus* on the left is markedly thinner. On the right, a new patch has become established just beyond the old large clone.

48. *Celtis douglasii* stand on an alluvial fan opposite the mouth of Alpowa creek. Whitman County, Washington.



49. *Festuca idahoensis-Eriogonum heracleoides* stand 102.

OTHER TYPES OF VEGETATION

Dune vegetation

Small dunes or dune-clusters derived from sandbars occur sporadically along the Columbia River where it follows the base of the Cascades, then along its course westward from Wallula to the Dalles, and along the Snake River at least as far up as the mouth of the Palouse River. A moderate-sized dune area occurs remote from any river in south central Adams County west of Washtucna. Large dune complexes derived from glacio-fluvial deposits are found in west central Benton County north of Richland, southern Franklin County, and to the south of Moses Lake.

Harris (49) briefly described the nature of the dune vegetation south of Moses Lake, the area which soon thereafter was flooded by water behind O'Sullivan Dam. Typically, these dunes had *Psoralea lanceolata* on their active windward faces, a fringe of *Salix* at the dune crest, and *Rumex venosus* on the lee slopes. Where the dunes were encroaching on water, a line of deciduous shrubs (*Rosa woodsii* and *Ribes aureum*) followed along the foot of the lee slope. Rather well stabilized dune surfaces bore *Chrysothamnus nauseosus, C. viscidiflorus, Artemisia tridentata, Grayia spinosa, Oryzopsis hymenoides,* and *Bromus tectorum.* Later, Johnsgard (64) indicated some of the early effects of the raised water table on these plant communities. He recognized a *Psoralea-Oryzopsis* community on the upper dune slopes where wind action is important, and a *Bromus tectorum-Chrysothamnus* zone on the lower dune slopes.

I have made a single reconnaissance trip on foot into the dunes of southern Franklin County. Broad windswept summits of high dunes supported little but scattered clones of the strongly rhizomatous *Elymus flavescens. Psoralea lanceolata* was fairly conspicuous, chiefly on windward slopes that were actively eroding. The slip faces of active dunes supported extensive clones of *Rumex venosus* or *Agropyron dasystachyum.* A moderately old stabilized surface, somewhat below the average height of the larger dunes, was dominated by *Chrysothamnus nauseosus, C. viscidiflorus, Agropyron dasystachyum, Oryzopsis hymenoides, Koeleria cristata* and *Poa secunda. Achillea millefolium lanulosa* was the only well-represented perennial forb here. Annuals included *Erisymum, Microsteris gracilis, Descurainia pinnata* and *Holosteum umbellatum.* What were interpreted as very old surfaces, relatively level and lying far below the average height of the large dunes, supported stands of the *Artemisia tridentata-Stipa comata* association. Scattered bushes of *Purshia tridentata* were marginal to them on slightly less stable soil.

The unique feature of these Franklin County dunes is *Juniperus occidentalis,* which forms tracts of savanna of variable size separated by tracts of moving dunes. The trees, which attain a maximum height of about 7m, are branched to the very sand surface so that the lowest branches are horizontal on the sand. A protected disc of litter and duff beneath the canopy of each tree is thickly populated with *Bromus tectorum.* Between the trees the sand is stabilized by *Purshia tridentata, Artemisia tridentata, Chrysothamnus* spp., *Eriogonum niveum, Agropyron dasystachyum, Poa secunda, Phlox longifolia, Balsamorhiza careyana, Cymopteris terebinthinus, Calochortus macrocarpus, Lithophragma bulbifera* and *Erisymum,* none of which assumes dominance.

Vegetation of rock crevices

Canyons cut by permanent rivers and those cut during the brief but violent episodes of glacial flooding have left many cliffs exposed in the steppe region. The joint planes in the exposed rock faces provide crevices that are the characteristic habitats of certain species such as *Cheilanthes feei, Woodsia oregana* and *Pentstemon triphyllus.* Botanists have long been aware that the cliff habitat is one to which rare plants may be confined. These often are relics near extinction because of climatic change in recent geologic time. This is true for eastern Washington. For example, a disjunct population of *Pityrogramma triangularis,* a fern common from British Columbia to California along the Pacific Coast occurs far inland as a crevice plant in the granite that outcrops at Granite Point in the *Agropyron-Poa* zone 20km southwest of Pullman, a habitat essentially destroyed in constructing a dam. Again, the northern extremity of the range of *Glossopetalon nevadense stipuliferum* is on basaltic cliffs just west of Clarkston.

Despite its special botanical interest and significance for interpreting past changes in climate, cliff vegetation has not received special attention in eastern Washington.

Vegetation of talus slopes

Most cliffs are partly covered by talus that has accumulated at their bases. For the most part, the prevailing aridity has prevented weathering from reducing rock fragments to sizes small enough to serve as a significant soil moisture reservoir. Therefore, the talus slopes are typically bare of all but lichens and occasional mosses in the crevices. In the *Artemisia-Agropyron* zone, very open stands of *Amelanchier alnifolia* provide a distinctive talus vegetation in places, as in Moses Coulee. Elsewhere, narrow stripes of stable, relatively fine-textured debris that has resulted from lateral segregation during downward migration have become rather well vegetated. Near Vantage, *Grayia spinosa* and *Bromus tectorum* characterize such stripes, alternating with barren coarser textured material.

Since the precipitation that falls on talus slopes penetrates quickly to depths where it can evaporate but slowly, a good store of moisture situated deeply is available to plants that get established at the margin of the talus slope. Relatively mesophytic shrubs tend to form a narrow garland about talus slopes; species such as *Philadelphus lewisii, Prunus virginiana melanocarpa, Amelanchier alnifolia* and *Rosa* are especially conspicuous here.

Pond vegetation

Within that part of the steppe overridden by glacial ice, as well as the area affected by the melt waters, there are a multitude of ponds. Some are rock-lined and others have sand or mud bottoms; some are saline and others fresh, some are temporary and others permanent, and the size of the wetland systems varies greatly. The vascular vegetation associated with these ponds has been studied very little.

Small intra-dune ponds in the area that was soon to be flooded by water behind O'Sullivan Dam were described briefly by Harris (49). The most typical sequence of vegetation zones related to water depth was:

1. *Spartina gracilis,* the highest zone of hydrophytic vegetation,
2. *Distichlis stricta-Scirpus nevadensis,* barely above the water surface,
3. *Juncus balticus-Carex douglasii-Scirpus americanus-Eleocharis macrostachya,* in water 0-3 dm deep,
4. *Scirpus acutus-Typha latifolia,* in water 3-9 dm deep
5. *Potamogeton pectinatus-Ceratophyllum demersum-Myriophyllum exalbans,* in deeper water.

Zones 2 and 3 above also formed extensive marshes where large sand flats occurred at appropriate distances above the water table.

When surveying the same area 2 years after the reservoir behind the dam had started to fill, Johnsgard (64) recognized a *Distichlis stricta-Carex douglasii* marsh in the wet sand bordering the new shorelines. The proportion of *Carex* diminished in proportion to the degree of water level fluctuation resulting from the summer draw-down of irrigation water.

Artemisia tridentata ssp. *vaseyana* in Washington

This study did not include those types of mountain parks that are found far above lower timberline. However, mention should be made of park vegetation which contains *Artemisia tridentata* ssp. *vaseyana,* since so much of the steppe vegetation of Wyoming and Idaho is dominated by that taxon. This variety is the cold-requiring diploid ancestor of the heat-requiring *A. t.* ssp. *tridentata* (113). In eastern Washington, it occurs as a dominant of topographic climaxes at altitudes where surfaces not strongly exposed to sun and wind have *Pseudotsuga menziesii* and *Abies lasiocarpa* as climax dominants. These parks extend from Calispell Peak in Stevens County westward across the Okanogan Mountains, thence southward in the Cascades almost to the Columbia River, and reappear in the Blue Mountains.

Artemisia tridentata ssp. *tridentata extends* but a short way up into the lower edge of the forested foothills, so there is a disjunction in the two varieties in Washington. By contrast, from western Montana to southeastern Idaho and Wyoming the altitude ranges of the two varieties overlap.

Festuca idahoensis and *Agropyron spicatum* are still the important grasses associated with *A. t.* ssp. *vaseyana* in Washington, but the temperature here is so low that *Bromus tectorum* is no longer the conspicuous grass of heavily grazed areas.

The "*Artemisia tridentata*"-*Festuca idahoensis* association listed by Smith (109) for west central Wyoming may correlate with the *A. t.* ssp. *vaseyana-Festuca idahoensis* communities of Washington.

Camassia marshes

Over a wide area in west central North America, seasonal marshes supported dense populations of *Camassia quamash*. From a distance, the blue flowers of this liliaceous herb made the lowlands appear as though covered with a sheet of water in late spring.

The farinaceous bulbs of this plant were the most important item of plant food in the aboriginal diet. Each summer as the marshes started to dry, the Indians came and camped by them while the women dug the bulbs with sharpened sticks. Great quantities were steam-roasted, with some then dried for later use. There is no indication of over-exploitation by the Indians. Possibly, the churning of the soil facilitated the establishment of new plants from seeds of those missed by the diggers. White man's use was less direct but more devastating. With little grain available to feed the first pigs brought into the new country, fenced-off camas meadows provided good forage for these animals while the supply of bulbs lasted. Artificial drainage elsewhere converted much of the marshes to cropland.

In consequence of this history, little can be learned regarding the synecologic relations of *Camassia quamash*. Many of the remaining fragmentary populations are associated with herbs primarily characteristic of the meadow steppe associations to which a few species of *Carex, Equisetum* and *Juncus balticus* may be added. In still wetter situations, the associates are completely helophytic.

The marshy habitats favorable to dense populations of this plant occurred in the meadow steppe zones and from here far up into the mountains, as high as the lower part of the *Abies lasiocarpa* belt. Most populations at high altitude have plants with distinctly lighter blue (sky blue) flowers than in the low altitude (intense ultramarine) populations.

DISCUSSION OF CERTAIN CONCEPTS

Ecologic significance of coverage sums

Steppe vegetation in eastern Washington presents a luxurious physiognomy in peripheral areas which are almost cool and moist enough to support forest. In the hottest and driest part of the rainshadow of the Cascades the vegetation is conspicuously more sparse. These relations between climate and vegetation are reflected chiefly when comparison is restricted to climatic climaxes. It is convenient to quantify this aspect of vegetation by simply summing the coverages of all the vascular plants, or by summing the coverages of only the perennial forbs (appendix E). Of the two parameters, the sum of the coverage of all species seems to vary the more regularly and to be more proportionate to impressions gained from long working with this vegetation.

The summed coverages of all species also correlate rather well with the summed coverages of just the perennial grasses other than *Poa secunda,* and bear an inverse relation to the latter.

The sandy soil associations have relatively high values for summed coverages, suggesting that the limitations of sandy soils are not primarily moisture relations. Lithosols as a group are most distinct in regard to their relatively low coverage sums. This is most obviously interpreted as a result of the low water-storage capacity of the substrate here.

Despite the very good correlation between total coverage sums and the climatic gradient, or degree of mesophytism in general, and the relatively good correlation even when life forms are segregated, there is no useful degree of correlation between total coverage sums and dry matter production.

Species diversity

A previous bulletin (29) showed that species diversity, i.e., the richness of the vascular flora per unit land area when habitat diversification is not allowed to complicate comparisons, varies with altitudinal climates in those forests surrounding the steppe region on the north, east and south. In those forests, the maximum diversity is centered on the *Pseudotsuga* and *Abies grandis* belts, i.e., a little below the middle of the altitudinal suite of forest associations. When diversity of just the tree stratum in stable vegetation is considered, there is no altitudinal gradient. But in unstable stands, tree diversity increases from lower timberline to the subalpine forest belt. Data for the steppe region are now available to join with those from the forest to broaden the scope of generalizations.

In using data from appendix B, alien species have been excluded from consideration. Since the stands selected for study have been disturbed very little if at all, it seems unlikely that the few individuals of alien species that have gained representation could have eliminated any natives, especially since all are small annuals. To have included these aliens would have increased apparent diversity somewhat in proportion to the degree of disturbance, whereas natural diversity that can be attributed more to climate and/or soil has more fundamental significance.

Median numbers of indigenes encountered in evaluating coverage in 40 plots, each $0.1m^2$, have been presented on a comparative basis in appendix E. These data are directly comparable to those that were presented for the adjacent forests, except that the forest values may tend to be slightly higher since 50 plots of the same size were used in the coverage analyses.

In stable vegetation of the steppe region, diversity increases directly with moisture status. The maximum diversity is in steppe communities that occur just below lower timberline (appendix E). Thus the generalization is warranted that in eastern Washington, when stable vegetation is studied along an altitudinal gradient, with attention restricted to normal soils and topography, species diversity increases from the most arid part of the steppe to the margin of forest, and continues increasing until a maximum is reached in the *Pseudotsuga menziesii* and *Abies grandis* forests. Above these, a progressive decline leads to low values again in the subalpine forests that cap the mountain summits of this area.

Altitude versus aspect

In forest vegetation, the phenomenon of interfingering between contiguous altitudinal zones has long been recognized in the mountains of western North America (22). Certain vegetation belts, at least, reach their highest limits as peninsulas that ascend exposed slopes and ridges, whereas they extend farthest down into dry climates by taking advantage of north-facing slopes and stream margins. Blumer (9) considered this characteristic of all vegetation types in the southern Rockies. In the northern Rocky mountain forests, this feature characterizes only the lower part of the altitudinal sequence of forest zones (29). No information seems available regarding the existence of this phenomenon in steppe vegetation in western North America.

If attention is confined to associations that play the role of climatic climaxes, the altitude-aspect pattern referred to above holds regularly for the steppe communities in eastern Washington. The only clear exceptions are in the wet edge of the *Artemisia tridentata-Festuca* h.t. Along the transect from Othello to Hooper, the easternmost outpost of this h.t. is on a steep, colluvial *north*-facing slope in the *Agropyron-Festuca* zone a few km west of Hooper. Where the same ecotone may be observed in the rainshadow of the Blue Mountains, there is again no relationship between the marginal stands of *Artemisia tridentata-Festuca* and topography. To the north, where the *Artemisia tridentata-Festuca* h.t. penetrates the *Artemisia tripartita-Festuca* zone, it extends farthest up the moisture gradient on soils that are stony or gravelly (e.g., stand 32), rather than on topography with maximum exposure to sun and wind.

Since *Artemisia tridentata* is a major dominant that grows abundantly until it reaches the limits of its ecologic amplitude (26), it is an important species for defining ecosystem limits. The failures of the altitude-aspect rule indicated above therefore reflect only the unique behavior of this species at the wet margin of its range.

Ecologic problems involved in *Artemisia* eradication

The elimination of the mainly unpalatable *Artemisia tridentata* from rangeland where it shares dominance with perennial grasses is an attractive idea to most ranchers and range technicians, but not to Blaisdell (7). Evidence from a wide area supports contentions that removal of this shrub increases dry matter production by the herbs that remain (17, 58, 62, 66, 104), and makes the grass more readily available to livestock.

Several ecologically significant points are generally omitted from this optimistic outlook:

1. There is little to indicate the extent to which the grass increase measured shortly after shrub eradication is maintained. It could result largely from the green-manuring effect of the shallower part of the *Artemisia* root systems and therefore be but a temporary phenomenon. Where fire is used to eliminate *Artemisia* the stimulation can be attributed to the fire itself, for a protracted increase in production can be observed following steppe fires outside the range of this shrub.

2. The protection afforded many grass plants by dense clumps of shrubs is the sole reason why any perennial grass remains on much of the depleted range. *Artemisia* elimination opens the way to complete destruction of perennial grass by over use.

3. Studies in Washington (27) have shown that for more than 4 months in summer, *Artemisia tridentata* uses only what water has percolated through the soil profile below the reach of grass roots. This deep moisture supply is recharged every few years when there is enough precipitation to wet the soil deeper than the grass roots can penetrate. Nearly all herbs associated with this shrub aestivate from about June to October. During this time *Artemisia* is actively drawing water from the subsoil, photosynthesizing, and elaborating proteins and other compounds necessary to develop sizeable inflorescences with pollen and fruits. But for the activities of this plant, vegetation activity is virtually suspended, and all the extremely high energy supply of this season would be wasted. These plants are therefore responsible for more than doubling the thickness of the soil profile that is actively involved in mineral cycling, and in creating litter and humus that is important in the cycling process as well as in soil moisture relations. The question should be raised: To what extent does the removal of this shrub allow some minerals to migrate permanently below the reach of grass roots in the years when there is downward percolation below this depth, and thereby reduce the mineral store in the surjacent horizons? Even though shrub elimination might tend to increase the depth of grass root penetration, the increase would represent only a small fraction of the volume formerly kept active by the shrub alone.

4. Many birds require woody plants as nesting or as perching sites, so removing *Artemisia* eliminates certain elements of the avifauna. While rearing their young, these birds make a heavy drain on insect populations that have no such controls after the birds are eliminated from the community. In New Zealand, it has been suspected that range deterioration has reduced native birds and thus allowed the increase of insects that damage the residual grass (35). The interrelationships among birds, small mammals, insects and plants obviously need clarification.

5. When *Artemisia* is removed by herbicidal sprays, certain perennial broadleaved forbs are heavily damaged or eliminated (8, 3, 59, 85). This loss is generally ignored on the tacit assumption that the unharmed grass, which supplies nearly all the domestic animal's food, and which may produce more because competition is lessened (3), is the only component of economic significance. However, depending on the kind of vegetation and type of animal involved, spray removal of *Artemisia* may "entirely destroy many desirable species and allow their replacement by inferior species," and "forage production may be seriously reduced for a period of several years" (8). In western Colorado, herbicides reduced forb production by 95%, yet these forbs contained more protein than the best of the forage grasses (3). Furthermore, in most steppes, these forbs are already present in suboptimal quantities for sheep grazing, and their elimination tends to restrict the use of rangelands even more to cattle use. Such a restriction could become embarassing if it became desirable to alter land-use patterns. In Europe, it has been shown that the occasional bites of common pasture weeds that cattle eat have a tonic-like effect on their physiology that is far out of proportion to the quantity of foliage ingested. Accordingly, it has been recommended that certain weed seeds be incorporated when planting new grass leys (50). This raises a question about the possible stimulative value of the broad-leaved forbs eliminated when sprays (but not fire) are used to kill *Artemisia tridentata*.

6. In some areas, *Artemisia* promotes the uniform accumulation of snow and delays its melting; both are desirable from the standpoint of range management (61).

Several of the consequences of *Artemisia* removal enumerated above involve an important ecologic principle. The more diversified the biota of an area, the more completely the environmental resources are being used, and the better the community is buffered against disease and weather hazards. Simplification of shrub-steppe vegetation by removing a major component that contributes a distinctive life-form and phenology, and is necessary for other species to remain in the community, cannot fail to have significant consequences. If herbicides are used to eliminate *Artemisia,* other species are also eliminated. Rather than focus interest on just the quantity of grass available and acceptable to one class of domestic animal, these points should be studied broadly.

Anthropogenic vegetation and successional convergence

It is common for vegetation trends following disturbance to lead back to the primary climax originally occupying the habitat, once the disturbance ceases. However, in the Washington steppe, two aliens are capable of assuming dominance as grazing pressure eliminates native perennial grasses. These two show no evidence of yielding to a reinvasion of the natives once the grazing stops. Both of these species, the annual *Bromus tectorum* and the perennial *Poa pratensis,* have wide ecologic amplitudes, but their requirements are more complementary than competitive. *Poa* becomes the dominant of zootic climaxes in wetter habitats; *Bromus* takes over the drier. In other words, with uniformly heavy grazing, retrogressive succession would ordinarily lead in either of two directions, ending with the dominance of one or the other of these grasses. The two zootic climaxes will be considered separately.

The *Bromus tectorum* zootic climax

Bromus tectorum, a winter annual growing mainly 2-3 (sometimes 10) dm tall, has proven exceptionally well preadapted to the steppe environments of Washington. It was introduced into the state in about 1890 (74). Within a decade it was well established at low elevations in the Okanogan Valley (46). Elsewhere, it was still strongly confined to railroad right-of-ways (20). I have examined a number of photographs taken in eastern Washington by H. L. Shantz in 1916 and nearly all of them show manifestly overgrazed vegetation. Those photographs of areas that would undoubtedly show *Bromus tectorum* abundant if rephotographed today have been segregated. In thirty of these I can see no evidence of *Bromus,* even though the still smaller *Plantago patagonica* is identifiable. Five others show *Bromus* rather clearly. All of these were taken near Pasco or Connell; both are in the *Artemisia tridentata-Agropyron* zone. Thus, the evidence is that as late as 1916 *Bromus* was locally abundant in the Pasco-Connell area but not in other parts of the steppe Shantz visited. Photographs not showing *Bromus* were taken at Coulee City, Ellensburg, Lind, Mesa, Riparia, Toppenish, Lewiston (Idaho), and some were of other places near both Pasco and Connell. Weaver (125) did not mention the *Bromus* in describing the steppe vegetation of southeastern Washington after studying it for three summers, 1912-1914, which agrees perfectly with the evidence provided by Shantz' photographs.

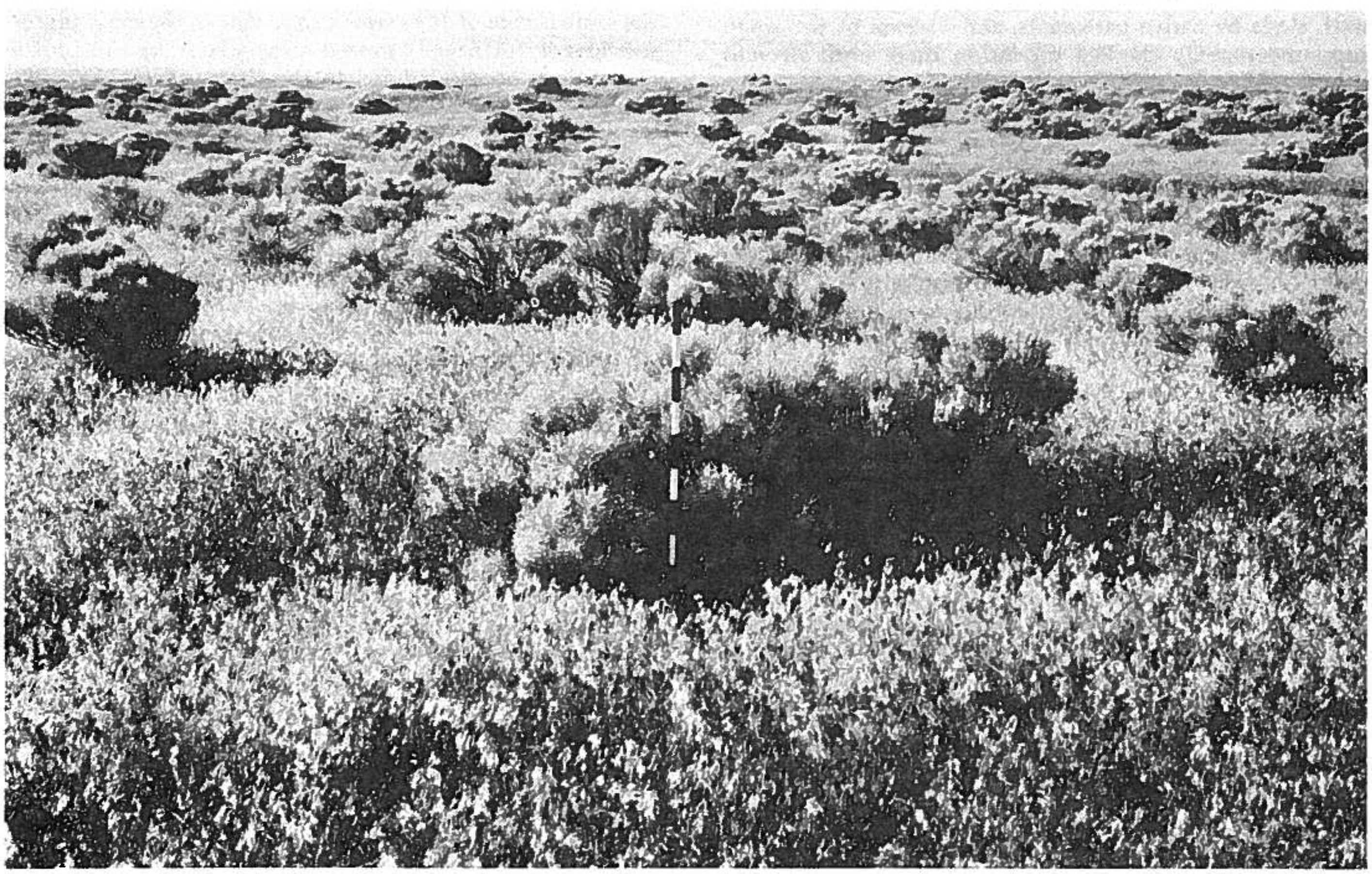
Since the time of those observations, *Bromus* has become ubiquitous throughout the steppe, and in the adjacent forest it may be found as high as the *Abies lasiocarpa-Pachistima* h.t. With the exception of two h.ts., *Festuca-Symphoricarpos* and *Festuca-Rosa,* it is the most universal plant to take possession of herb-dominated uplands when they are grazed excessively, or when they are abandoned after cultivation. On abandoned fields in the driest climates, *Bromus* is commonly preceded by *Salsola kali* and/or *Sisymbrium altissimum.* Both are tumbleweeds and can disseminate seeds over a field within a few months after the last crop has been harvested. But seedlings of these annuals are no match for the competition afforded by the less mobile *Bromus,* and both are reduced to a very minor role if not eliminated after about the second year. In the most arid part of the steppe region, *Bromus tectorum* is the sole representative of its genus in these communities. In the less arid parts, other alien annuals in the same genus have moderate success in competition with *B. tectorum.* Still other annuals are always well represented in the *Bromus tectorum* community, even if they remain minor members. Recently *Taeniatherum asperum,* another alien annual grass, has demonstrated its ability to displace *Bromus tectorum,* at least in part. As yet it is too early to evaluate the ultimate role of this species in our vegetation.

On abandoned fields (fig. 50), or on rangelands where steep slopes or sandy soil favor a churning of the soil surface by hooves, *Chrysothamnus nauseosus albicaulis* becomes a conspicuous member of the *Bromus* community; coverage rises to as much as 43%. Since grazing animals completely avoid *Chrysothamnus* but relish *Bromus*, especially early in spring, the invasion of *Chrysothamnus* represents a second level of degeneration below the replacement of perennial grasses.

There is no concrete evidence that *Bromus tectorum* ever relinquishes an area to indigenes, once it is established. As of this writing a small area devastated by salting or bedding sheep prior to 1911, but thereafter virtually isolated from grazing, is still covered with *Bromus* but closely invested by a dense stand of the *Agropyron-Poa* association in quite good condition. Again, at the Larson exclosure, which represents the same h.t., a small strip of cropland abandoned nearly 50 years ago, lightly grazed until 10 years ago, then given complete protection, has only a few (but very large!) bunches of *Agropyron* scattered about. Since there are no small individuals, these plants probably represent establishment in the first year or two after abandonment, but before the *Bromus* stand reached full density. In fact, *Bromus* may not have reached either of these *Agropyron-Poa* areas when disturbance was discontinued.

Comparative studies of soil moisture use at the Larson exclosure showed that the rates of water use by contiguous stands of *Bromus* and of *Agropyron-Poa* were essentially identical through the sampling depth, i.e., 1 meter. Also, there was almost exactly equal production of dry matter when the terminal standing crop of shoot material was sampled. Rickard's report (97) of a standing crop of 102 g/m^2 for *Bromus tectorum* on a site where the *Artemisia tridentata-Agropyron* association had been destroyed, also compares closely with the 103.6 g which I obtained (appendix C) in a nearby virgin stand of the climatic climax. Thus the *Bromus* community seems to leave no unused surplus of the crucial soil moisture resource that might permit reinvasion by *Agropyron.*

One gains the impression that each period of excessive



50. *Bromus tectorum-Chrysothamnus nauseosus* on an *Artemisia tridentata-Stipa comata* habitat east of Pasco, Franklin County, Washington. Communities closely similar to this in structure can be found on a wide variety of habitat types that have been severely disturbed.

grazing that reduces the native perennial forage species and allows a corresponding increase of *Bromus* represents another irreversible step in range deterioration. The native species seem not only poorly adapted to withstand grazing, but their seedlings cannot meet the competition of this alien. Part of the *Bromus'* success must be attributed to the earliness of its seasonal development (57). After germination at the start of the rainy season in autumn, its roots continue to elongate during winter (48). Thus, the plant can take full advantage of the warm spring and early summer while the soil is still moist. A root system capable of extending past 2 meters is also a valuable adjunct in competition (57).

Dillon (36) has described an interesting contrast in the invasion of two sides of the earth fill for a railway track in the *Agropyron-Festuca* zone just west of Prescott, Washington. After 64 years, the humus-rich silt loam used in making the fill supports a plant cover composed chiefly of *Bromus tectorum* and *Centaurea diffusa* on the south-facing (60%) slope. During the same time span, the north-facing slope with the same steepness and soil material has developed a good cover composed chiefly of *Agropyron spicatum* and *Poa secunda*. No *Festuca idahoensis* has yet appeared on the north slope, and no perennial herbs of any kind have become established on the south slope. *Bromus tectorum* probably had not yet reached this site to interfere with a prompt invasion of the moist north slope by native perennials, and dryness of the south slope undoubtedly checked succession there until *Bromus* arrived. Since its spread along railways was rapid in the early years, it may have arrived rather quickly, once this railway was completed.

If fire sweeps a stand of *Bromus tectorum* at a crucial time during seed ripening, it can greatly reduce the density of the succeeding stand. At the Larson exclosure, analysis of one representative plot 20 x 50 cm on the unburned side of a fire line, and another plot 100 x 100 cm immediately opposite in the burned area, yielded the following data, calculated to a square meter basis:

	Number of *Bromus* plants	Terminal standing crop: g, oven-dry
Unburned	9,180	143.5
Burned	327	187.6

Although density was reduced to less than 4% of normal in the first post-burn season, production was increased. Since most of the production is attributable to *Bromus*, it is obvious that the few seeds surviving the fire had produced enormous individuals. In the second post-burn season, population density appeared no different on the two sides of the burn line, so no further analyses were made.

Animals graze *Bromus tectorum* readily and made good gains in weight, especially in the spring (2). At this season, very close grazing by sheep can completely prevent the plant from producing seed (21). This fact has been used to reduce the amount of *Bromus tectorum* in alfalfa fields (70, 83). The cured straw holds little attraction for grazers, but there is evidence that it has surprisingly high nutritive value when animals are forced to live upon it (60). The major disadvantage of rangelands dominated by this annual appears to be the high variation in production from year to year (89). However, the degree of such variation has not yet been studied in Washington, where the environment seems most ideally suited to this species. The high flammability of *Bromus* is considered another undesirable feature of the plant.

Although an alien, *Bromus tectorum* must be considered a member of most climax steppe communities in Washington. In undisturbed vegetation, the populations are very sparse and the plants dwarfed, sometimes not more than 2 cm tall, and bearing but a single spikelet. But these plants can be found everywhere (appendix B), including places where there has been no disturbance by man or livestock. The most compelling evidence is its occurrence atop cliff-rimmed buttes that are scalable by humans only with difficulty. The only other alien that shares this status is *Draba verna*, which is almost as common on such buttes. Beatley (5) reports a homologous assimiliation of *Bromus rubens* into desert communities in southern Nevada. In a very limited way, these communities in Washington and Nevada seem as permanently modified by these successful immigrants as is evident on a much grander scale in the vegetation of Hawaii and New Zealand.

The *Poa pratensis* zootic climax

The ecologic status of *Poa pratensis* (and essentially the same is true of *P. compressa*) is that of the most aggressive invader of heavily grazed areas where the soil profile has no lime accumulation. In the *Festuca-Symphoricarpos* and *Festuca-Rosa* zones, all h.ts. except those that are lithosolic, and hence so dry as to favor *Bromus tectorum*, are invaded by *Poa* as overgrazing weakens the indigenes. Although livestock readily eat *Poa*, it is exceptionally tolerant of grazing. Each period of heavy use seems to increase irreversibly the proportion of *Poa pratensis* and/or *P. compressa* in the vegetation. And where this type of disturbance is long continued a relatively pure sward dominated by these rhizomatous aliens becomes established.

As in temperate eastern North America, *Taraxacum* is a common constitutent of this zootic climax. The area having the potentiality of developing a *Poa* sward includes not only the two steppe zones indicated above, but extends far into the series of forest zones adjacent to the steppe, on deep loams (29). Knott's (75) comment that any habitat that will support a *Poa pratensis* sod will grow any of the woody plants of game value in Washington is indefensible. *Purshia tridentata* and *Ceanothus sanguineus*, both very important browse species in eastern Washington, are totally unrepresented in the *Festuca-Symphoricarpos* and *Festuca-Rosa* zones and have not been grown there artificially.

Bromus tectorum is not completely excluded from disturbed areas in the *Poa* domain. However, this *Bromus* requires almost completely denuded soil surfaces to get established, then yields readily to other plants as a closed cover develops. Other annual species of *Bromus*, especially *B. brizaeformis*, *B. japonicus*, and *B. mollis*, are relatively more successful than *B. tectorum* here. Even these are only early invaders in retrogression; all give way to *Poa* later.

With *Bromus tectorum* and *Poa pratensis* so generally increasing, seemingly irreversibly, following each episode of excessive grazing or other disturbance, it is evident that a wide array of steppe associations degenerate toward one or the other of two communities that show little geographic diversity (fig. 50). Sharp floristic and physiognomic differences among primary climaxes are weakened progressively to produce a web of minor variation centered on either *Bromus* or *Poa* as the dominant. Such convergence in consequence of disturbance has been noted in other regions (56, 6, 16, 127). Implications for the continuum doctrine have been detailed elsewhere (26).

In Washington, there is no evidence to support claims (12, 34, 40, 47, 126) that *Artemisia tridentata* and *Opuntia polyacantha* have increased their ranges since the advent of white man. In fact, the range of *Artemisia tridentata* may have been reduced by promiscuous burning during the early period of settlement in Washington, as Poulton (94) has suspected in Oregon. The extant range could not have been reduced very much, however; otherwise, there would not be such a close relation between the zonal pattern and climate as is demonstrable.

Desert and steppe concepts as applied to Washington

An area coinciding approximately with the combined *Artemisia tridentata-Agropyron* and *Artemisia tridentata-Festuca* zones in Washington is often referred to as a "desert" by the local populace. A combination of hot dry summers (with air temperatures up to 48 C and mean monthly precipitation as low as 3 mm) rattlesnakes, horned lizards, scorpions, tarantulas and cacti seem to evoke this classification, to the nonbotanist, especially.

In his extremely abbreviated comments, Weaver (125) used the expression "desert scrub" for this vegetation, and made no mention of associated herbs.

Shantz (107) referred to *Artemisia tridentata*-dominated vegetation throughout the intermountain area as "sagebrush desert" and "northern desert shrub." He likewise made no mention of associated perennial grasses. The only associates of *Artemisia tridentata* he mentioned are two alien annuals, *Bromus tectorum* and *Erodium cicutarium*! From this description, and his type photo (107 p.22), it is evident that he was familiar with only excessively grazed stands. The writer has seen most of the unpublished photographs Shantz took while surveying Washington to obtain material for the Atlas of American Agriculture. All show severely depleted stands. Since most of his pictures were taken near railway stations, it appears that limited means of travel confined his observations to places where animals converging on railheads for shipment would probably have caused maximum devastation. With this biased information, it is not difficult to understand why the term "desert" seemed appropriate to him. Perhaps this also explains Weaver's biased concept of the natural vegetation of these zones.

It is remarkable that Shreve (108) excluded the Columbia Basin area from his "Great Basin Desert" (and from his concept of desert, in general), although he included vegetation outside the Great Basin in southern Idaho and Oregon that is closely similar in physiognomy, floristics and ecology. In so doing, he split the "northern desert shrub" of Shantz, without saying why.

In contrast with Shreve and Shantz, Weaver and Clements (126) and Oosting (86) characterized the natural vegetation of arid Washington as "grassland."

There are no universally acceptable definitions of these terms among scientists. From the standpoint of ecologic plant geography, reasonable limits would be to consider *desert* as regions too dry to support a noticeable cover of perennial grasses on zonal soils, and *steppe* as regions with moisture relations adequate to support an appreciable cover of perennial grasses on zonal soil, yet not enough for arborescent vegetation. Since even the driest part of eastern Washington can support a heavy cover of perennial grasses wherever there is a zonal soil, a continuous film of cryptogams covers the soil surface, and at least 0.7 metric tons/ha/yr of dry matter is produced, its classification as steppe rather than desert seems preferable.

Physiognomy and steppe classification

From a purely descriptive standpoint, "shrub steppe" has often been used to designate communities consisting of one or more layers of perennial grass above which there rises a conspicuous but discontinuous layer of shrubs (see 76, 128). Communities with *Purshia, Artemisia tridentata* and perhaps *A. tripartita* illustrate shrub steppe physiognomy in Washington.

In central Europe, the margins of the steppe region, where dryness is barely sufficient to exclude trees, are frequently referred to as "meadow steppe" (or "prairie steppe" or "sylvo-steppe") owing to the denseness of the herbage and the relatively high proportion of broad-leaved forbs and grasses (76). In Washington, all climatic climaxes of the peripheral zones of steppe vegetation except for *Artemisia tridentata-Apropyron* clearly fit into the meadow-steppe category. However, some of these associations are also shrub steppe (e.g., *Purshia-Festuca* and *Artemisia tripartita-Festuca* associations) whereas others are not (e.g., *Festuca-Hieraceum, Festuca-Symphoricarpos* and *Festuca-Rosa* associations).

Thus, the two concepts are not mutually exclusive. Shrub steppe is a physiognomic but not an ecologic unit. On the other hand, meadow steppe is relatively homogeneous as to ecology (always reflecting maximal water supplies for steppe vegetation), and has a substantial measure of physiognomic homogeneity (a very dense plant cover with a rich component of broad-leaved forbs). Meadow steppe can be distinguished from drier steppe communities where the grass cover is sparser, more narrow-leaved, and accompanied by few broad-leaved forbs, by alluding to the latter as "true steppe."

This distinction between meadow steppe and true steppe in Washington is reflected equally well in the mid-continental steppe. There, dense stands of *Andropogon, Panicum virgatum, Sorghastrum nutans* and other grasses, with heavy admixtures of forbs (*Helianthus, Liatris, Rudbeckia, Silphium,* etc.) occupy a broad zone just west of the temperate forest border. In the drier areas near the Rockies, a true steppe occurs with *Stipa comata, Agropyron* *smithii, Bouteloua gracilis,* etc., as dominants, and forbs poorly represented.

Those theoretical classifications of vegetation types in which it is assumed that the woody elements of xerophytic vegetation increase in stature as aridity decreases are embarassed by the fact that "shrub steppe" in Washington ranges from our most xerophytic zonal vegetation (*Artemisia tridentata-Agropyron* association) to the zonal vegetation of climates barely too dry for forest (i.e., *Purshia-Festuca* association). Furthermore, under the shrub-steppe category there is obviously no satisfactory correlation between the height of shrubs on zonal soils and the supply of moisture.

Correlations between climate and vegetation

The general correlation between major vegetation regions of the earth and the gross pattern of the earth's climates has been quite well recognized since Alexander von Humboldt called this to the attention to the scientific world so forcibly early in the 19th century. Since then, plant geographers and climatologists have made many attempts to define universally critical points along climatic gradients to construct a universal classification of climates that would correlate closely with the earth's vegetation pattern. These attempts have been marked with negligible success.

Recently, the feasibility of this endeavor has been challenged. A counter hypothesis proposes that although a fairly precise climatic characterization of a particular vegetation ecotone has proven possible, each ecotone has its own combination of climatic parameters so that the critical point along a climatic gradient that correlates with one particular ecotone may not be critical anywhere else over the earth's surface (23). The present more detailed study of steppe zones in eastern Washington and northern Idaho permits a more critical assessment of these hypotheses.

In Appendix A, the climates of the steppe zones have been classified according to six climatic classifications that have been proposed for universal application. It is evident that not one of them shows correlation between climate and areas defined on the basis of the stable vegetation of zonal soils. There is no homogeneity within a zone, and there is extensive overlapping between them.

Thornthwaite's (114) classification allegedly involves the most ecologically rational approach to balancing precipitation against heat-determined water need. If the arbitrary values on the Moisture Index scale do not correlate with ecotones, the question arises whether different values along the scales might prove significant. When the monthly Moisture Index values were tabulated for each steppe zone, there was invariably an overlapping of values between contiguous zones. When the Moisture Index was plotted against mean monthly temperature, the families of curves for contiguous zones never segregated throughout their annual cycles. On the other hand, when P or P/T+10 are plotted, the families of curves often segregate completely at one season at least, suggesting that there are real differences in the environmental water balance, and that simple data are ecologically more meaningful than Thornthwaite's complicated and theoretically more rational method of manipulating climatic data.

In the foregoing paragraph, P refers to median precipitation. When *mean* monthly precipitation is compared between zones, ranges always overlap. But when *median* monthly values are compared, there is nearly always a segregation for more than one month. Thus the conclusion of others that the use of mean precipitation values in arid regions is unrealistic is substantiated. A single deluge, most of which is lost as runoff, raises the mean precipitation values for many years in areas where rainfall is normally low. From an ecologic standpoint, median precipitation is much more rational than the mean values which Thornthwaite's method uses.

In comparing the climates of steppe zones, it was noted that monthly values for P and P/T+10 show about the same order of difference between continguous zones. If including temperature data in the climatic expression does not enhance the degree of differentiation, we must conclude that in the Columbia Basin, temperature differences among the zones are far less important than precipitation differences.

Thornthwaite's (114) Temperature Efficiency Index was intended to indicate monthly temperatures in terms of their effect on plant growth. In the *Festuca-Symphoricarpos* zone about Pullman, December, January and February are too cold to provide any physiologically effective heat, according to Thornthwaite's method of evaluation, yet many days during these months are warm enough to allow photosynthesis and the slow growth of many of the steppe herbs (see fig. 9). Possibly a better way of using temperature data would be to consider only daytime values (i.e., daily maxima) rather than mean daily temperatures, for the positive effects of warmth above threshold values during the days are not offset by negative effects when temperatures drop below these values.

Although universal climatic classifications fail, there exist climatic parameters that permit quantitative definitions of the zones of steppe vegetation. These parameters are ecologically rational, for they nearly always concern the environmental water balance, and it is well established that in arid climates, small differences in the amount and timing of moisture deficits are critical for vegetation.

The existence of a clearly defined climatic mosaic (fig. 1) on the gradual slopes of the Columbia Basin was one of the most unexpected results of this study. Previous climate maps have shown somewhat concentric belts of climate in the basin, with all meadow steppe types falling into about the same belt. It is suggested that the interplay of air masses having different properties and paths of movement controls the mosaic, for there is no steepening of topographic nor edaphic gradients at these well defined vegetational discontinuities.

Correlations between soil and vegetation

The ecosystem concept implies a degree of interdependence among climate, soil, plant life and animal life such that any alteration of one component of the system sooner or later requires readjustments in the others. Logic might therefore lead one to expect that climatic climaxes would correlate with zonal soils, whereas edaphic climaxes would occupy azonal and intrazonal soils, and that each distinctive type of vegetation would be associated with a distinctive type of soil. Vegetation and soil classifications should thus harmonize within a transcending ecosystem classification. However, an abundance of data in this report show that in the steppe region of Washington there is no useful degree of correlation between vegetation classification and soil classification in their present states of development (see also 29). Some examples follow:

Among the 16 stands of the *Artemisia tripartita-Festuca* association in which soil profiles have been classified (appendix B-7), 13 soil series are represented. These series are distributed among Brown, Chestnut, Chernozem and Prairie Great Soil Groups, and represent Typic Haploxeroll, Calcic Entic Haploxeroll, Calcic Pachic Haploxeroll, Typic Argixeroll, Calcic Argixeroll, and Typic Palexeroll.

Among the 14 stands of the *Artemisia tridentata-Agropyron* association in which soil profiles have been classified (appendix B-1), 7 soil series are represented. These are distributed among Sierozem, Brown, Brown-Chestnut intergrade and Solodized Solonetz Great Soil Groups, and represent Mollic Camborthid, Lithic Mollic Camborthid, Calcic Haploxeroll and Natric Haploxeroll.

Looking at the problem from the reverse point of view, Ritzville silt loam supports stands in the *Artemisia tridentata-Agropyron, Artemisia tridentata-Festuca, Artemisia tripartita-Festuca, Agropyron-Poa* and *Agropyron-Festuca* associations. Brown soils support stands in the *Artemisia tridentata-Agropyron, Artemisia tridentata-Festuca, Artemisia tripartita-Festuca, Agropyron-Poa, Agropyron-Festuca* and *Stipa-Poa* associations. Mollic Camborthids support *Artemisia tridentata-Agropyron, Artemisia tridentata-Poa, Artemisia tridentata-Stipa, Purshia-Stipa, Stipa-Poa, Grayia-Poa* and *Agropyron-Poa* associations.

In Oregon, Poulton (94) suspected strongly that the natural range of *Artemisia tridentata* has been reduced by fire. It is possible that some stands I have classified as *Agropyron-Poa* might have been *Artemisia tridentata-Agropyron* stands that were burned so long ago that every vestige of the *Artemisia* has been effaced, and thus the soil profile incorrectly ascribed to the *Agropyron-Poa h.t.* The same confusion might be possible regarding the *Artemisia tridentata-Stipa* and *Stipa-Poa* h.ts. However, the soil-vegetation discrepancies here are no greater than elsewhere in the steppe where fire could not possibly have resulted in faulty classification.

The failure of vegetation and soil classifications to coincide does not necessarily indicate a lack of correlation between *any* soil properties and the vegetation pattern. Even at the broad level of investigation just completed, certain quantitative correlations between vegetation types and soil properties have been demonstrated, although this was only a secondary objective and attention has been spread over a very large spectrum of vegetation. There is considerable ground for optimism in anticipating that an intensive level of synecologic study focussed on this problem will uncover critical aspects of soil that are consistently correlated with each ecotone except those where one climatic climax gives way to another. The important point is that *those soil properties suspected of playing important roles in vegetation differentiation are not among the characters emphasized in soil classification.*

For example, depth to free lime, which is considered a significant element in soil description and classification, varies from 7.5-94cm in the *Artemisia tridentata-Agropyron* stands studied. On the other hand, annual cycles of soil moisture, aeration and temperature, and solute balances, are extremely important for vegetation; and these are not amenable to ocular appraisal, especially at one time.

Insofar as interrelations within one ecosystem type are concerned, the evidence is incontrovertable that each plant association has a rather broad ecologic amplitude regarding many soil properties (including most of the visible ones emphasized in soil classification), with a narrower amplitude of tolerance for others (e.g., fertility and the soil moisture regime). We must conclude that either the structure of vegetation is insensitive to many soil properties, or that different combinations of soil properties add up to the same ecologic sum.

At the start of disturbance in a pristine landscape, different levels of disturbance within the same h.t. increase the number of community types apparent in the landscape. But as the same type of disturbance approaches a high level of intensity everywhere, a reverse trend sets in. H.ts. that originally supported different kinds of primary climaxes come to foster the same type of disclimax (as indicated earlier in this report). Thus, early in landscape retrogression, soils with equivalent potentialities may support a variety of communities, whereas late in retrogression, soils with different potentialities may support essentially the same vegetation type. The situation is so complex that vegetation, climate and soil must all be considered in evaluating a badly disturbed landscape.

Although the evident characters of soils show a very low degree of correlation with vegetation in the Washington steppe as well as in other parts of the world, there are reports of good correlation in still other areas. Apparently, there is no universally applicable conclusion, except that the situation must be worked out independently in each area.

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APPENDIX A. CLIMATIC CLASSIFICATIONS OF ZONES

Appendix A. Climatic classifications of weather stations in steppe zones. Mean rather than median precipitation values are used in all the systems. The symbol / is used where the data are intermediate between categories and should be interpreted as "or". The last three columns on the right are calculations used in Thornthwaite's (1948) classification assuming 6 inches of soil moisture storage. Evapotranspiration, water surplus and water deficit is in inches.

Zone and Weather Station	Köppen 1936	Swain 1938	Meigs 1953	Holdridge 1964	Thornthwaite 1948	Months of water deficit	Annual surpl. or deficit	Annual Evapo.
Artemisia tridentata-Agropyron								
Ephrata	BSks	8.2a	Sc03	Cool temp. desert scrub	$EB'_2db'_2$	6	0.1	8.3
Hartline	Dsad	8.2b	Sc03	Cool temp. desert scrub	$EB'_1db'_3$	6	0	11.0
Kennewick	BSks	8.2a	Ac03	Warm temp. desert scrub	$EB'_2db'_3$	6	0	7.5
Okanogan	Dsad	8.2b	Sc03	Cool temp. grassl./dry scrub	$DB'_1sb'_2$	-	---	----
Oroville	Csad	8.2b	Ac03	Cool temp. grassl./dry scrub	$DB'_1db'_2$	6	0	11.6
Prosser	BSks	8.1a	Sc03	Cool temp. desert scrub	$EB'_2db'_3$	5	0	7.7
Trinidad	BSks	8.2a	Sc03	Cool temp. desert scrub	$EB'_2sb'_2$	6	0	8.1
Wahluke	BSks	8.2a	Ac03	Warm temp. desert scrub	$EB'_2db'_2$	-	---	----
Wapato	BSks	8.2a	Ac03	Cool temp. desert scrub	$EB'_1d(b'_2/b'_3)$	5	0	7.2
Wilson Creek	BSks	8.1b	Ac03	Cool temp. grassl./dry scrub	$DB'_1sb'_2$	8	0	9.3
Artemisia tridentata-Festuca								
Hatton 10E	Csad	8.1b	Sc03	Cool temp. grassl./dry scrub	$EB'_1db'_2$	5	0	9.8
Lind	Csad	8.2b	Sc03	Cool temp. grassl./dry scrub	$DB'_1sb'_2$	7	0.3	10.0
Odessa	Dsbd	8.1b	Sc03	Cool temp. grassl./dry scrub	$C_1B'_1sb'_2$	6	-0.1	10.7
Agropyron-Festuca								
Dayton	Csbd	8.1b	(moist)	Cool temp. grassl./dry scrub	$C_2B'_1sb'_2$	6	4.5	15.1
Lacrosse	Csbd	8.1b	(moist)	Cool temp. grassl./dry scrub	$DB'_1sb'_2$	6	1.1	13.1
Pomeroy	Csbd	8.1c	(moist)	Cool temp. grassl./dry scrub	$C_1B'_1sb'_3$	7	2.3	14.5
Walla Walla	Csad	8.2b	(moist)	Cool temp. grassl./dry scrub	$C_1B'_1sb'_3$	6	0.2	14.5
Agropyron-Poa								
Clarkston Hts.	Csadx	8.(2/4)b	Sc13	Warm temp. thorn scrub	$DB'_1db'_3$	6	0	13.1
Lewiston	Csadx	8.2b	Sc13	Warm temp. thorn scrub	$DB'_2sb'_2$	-	---	----
Wawawai	Csad	8.4c	(moist)	Warm temp. dry forest	$C_1B'_2sb'_2$	-	---	----
Festuca-Rosa								
Grangeville, Idaho	Csbdx	6.1a	(moist)	Cool temp. moist forest	$C_2B'_1sb'_2$	5	1.6	17.9
Nezperce, Idaho	Dsbd	8.1c	(moist)	Cool temp. grassl./dry scrub	$C_2B'_1sb'_2$	5	3.5	16.5
Festuca-Symphoricarpos								
Cheney	Csbd	8.1b	(moist)	Cool temp. grassl./dry scrub	$C_1B'_1s_2b'_2$	-	---	----
Moscow	Csbd	6.1a	(moist)	Cool temp. grassl./dry scrub	$C_2B'_1s_2b'_2$	5	6.6	15.6
Pullman	Csbd	6.2a	(moist)	Cool temp. grassl./dry scrub	$C_2B'_1s_2b'_2$	6	4.6	14.8
Rosalia	Csbd	8.1c	(moist)	Cool temp. grassl./dry scrub	$C_1B'_1s_2b'_2$	6	3.6	14.7
Artemisia tripartita-Festuca								
Davenport	Dsbd	8.1b	(moist)	Cool temp. grassl./dry scrub	$C_1B'_1sb'_2$	7	2.8	13.9
Nespelem	Dsbd	8.1b	Sc03	Cool temp. grassl./dry scrub	$DB'_1sb'_2$	6	0.1	19.3
Sprague	Csbd	8.1b	(moist)	Cool temp. grassl./dry scrub	$DB'_1sb'_3$	6	1.4	13.3
Waterville	Dsbd	8.1b	Sc02	Cool temp. grassl./dry scrub	$DB'_1sb'_2$	6	0.2	11.4
Wilbur	Dsbd	8.1b	Sc02	Cool temp. grassl./dry scrub	$DB'_1sb'_2$	6	0.3	12.5
Purshia-Festuca								
Bickleton	Csbd	8.1b	Sc12	Cool temp. grassl./dry scrub	$DB'_1sb'_2$	6	0.7	11.3
Festuca-Hieraceum								
Goldendale	Csbd	8.1b	(moist)	Cool temp. grassl./dry scrub	$C_1B'_1s_2b'_3$	6	-6.7	12.6

APPENDIX B. ASSOCIATION TABLES WITH ENVIRONMENTAL DATA

To indicate soil classifications according to USDA 1938, the following abbreviations will be used:

Bn = Brown	Pr = Prairie
Cm = Chernozem	Re = Regosol
Ct = Chestnut	Sz = Sierozem
Gr = Grumusol	So = Solodized solonetz
Li = Lithosol(ic)	x = intergrade with
Pl = Planosol	

To indicate soil classifications according to USDA 1960, the following abbreviations will be used:

Adjectives		Nouns	
a = abruptic	m = mollic	Agn = Argindoll	Pal = Palexeroll
c = calcic	n = natric	Agx = Argixeroll	Tnt = Torriorthent
e = entic	p = pachic	Cam = Camborthid	Tps = Torripsamment
g = glosso-boralfic	t = typic	Hap = Haploxeroll	Vit = Vitrandept
h = haplic	v = vertic	Dur = Durixeroll	Xth = Xerorthent
l = lithic		Nat = Natrixeroll	Xps = Xeropsamment

To indicate soil texture, the following abbreviations will be used:

C = clay	P = pumicy
Co = coarse	Sa = sand(y)
F = fine	Si = silt(y)
Gr = gravel(ly)	St = stony
Gt = grit(ty)	V = very
L = loam	

Complete profile descriptions are available for those stands where the color of the darkest horizon is given.

In the plant data, the number to the left of the dot is percent coverage where the value exceeded 0.5%, with + to left of dot indicating coverage of 0.5% or less.

Number to right of dot is percent frequency.
+ indicates presence in stand but only outside of microplots.
+ indicates alien taxa.
* = uncorrelated soil series.

Table B-1. *Artemisia tridentata-Agropyron spicatum* association.

Stand number	19	20	42	43	12	13	14	26	27	9	10	28	34	16	193
County	Grant	Frank	Bento	Bento	Yakim	Adams	Adams	Yakim	Yakim	Kitti	Yakim	Yakim	Dougl	Kitti	Okano
Township and section	19N19	14N3	11N11	11N11	7N18	19N34	16N16	12N29	21N35	17N18	9N7	11N3	25N24	17N18	32N4
Range	23E	29E	25E	25E	22E	33E	30E	21E	23E	22E	20E	23E	27E	22E	25E
Altitude in meters	563	319	549	369	644	470	389	453	592	609	347	244	631	604	307
Aspect and percent slope	0	N8	NE38	ENE7	SW15	S10	NW2	N9	N13	N27	W19	NNW15	ENE9	SSE12	N43
Soil Classification — USDA 1938	Sz	Sz	Sz	RexSz	Br	Br	Br	Br	Br	CtxBn	CtxBr	CtxBr	CtxBr	So	---
Series	Ephra	Starb	Shano	Shano	Ritzv	Ritzv	Ritzv	Ritzv	Benge	Rensl	Rensl	Rensl	Rensl	Wyme*	---
Textural Class	FSaL	VFSaL	SiL	SiL	SiL	SiL	SiL	VFSaL	VFSaL	SiL	SiL	VFSaL	SiL	SiL	-----
USDA 1960	mCam	ImCam	mCam	mCam	cHap	cHap	cHap	cHap	cHap	cHap	cHap	cHap	cHap	nHap	-----
pH 1st decimeter	6.7	6.7	6.5	6.4	6.2	6.9	6.7	6.3	7.1	6.1	6.6	---	---	6.3	6.5
pH 5th decimeter	8.0	7.7	7.2	7.1	7.0	8.0	6.9	6.9	7.9	7.5	7.4	---	---	---	6.3
Mean moisture equiv., upper 5 dm	16.2	11.6	15.2	16.5	20.5	18.8	17.6	21.8	22.5	24.5	20.3	18.9	24.2	24.5	7.1
Darkest horizon (10YRm)	3/3	4/2	3/3	3/3	3/2	3.5/3	3/2	3/4	3/3	3/2	3/3	3/3	4/3	3/2	---
MEDIUM SHRUBS															
Artemisia tridentata tridentata	9·16	9·20	20·48	6·20	5·14	11·38	16·42	16·55	18·38	9·30	19·45	8·18	12·38	26·43	10·25
Artemisia tripartita	·	·	·	·	·	·	·	·	+	·	·	+·2	3·18	·	+·2
Chrysothamnus nauseosus albicaulis	·	·	·	·	+	·	·	·	+	·	·	+	+·2	+	·
Chrysothamnus viscidiflorus	+	·	+	·	+	4·9	·	·	·	+	+	·	+·3	+	·
Grayia spinosa	·	·	+	·	·	·	·	+	·	·	·	·	·	+	·
Purshia tridentata	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+
Tetradymia canescens	+	·	·	·	+	2·10	·	·	·	·	·	+·5	·	·	·
LOW SHRUBS															
Arenaria congesta cephaloidea	·	·	·	·	·	·	·	·	·	·	·	·	3·28	·	·
Erigeron filifolius	·	·	1·2	3·18	+	5·43	3·40	·	·	·	+·8	+	·	·	+·2
Erigeron linearis	·	·	+	·	+·4	·	·	·	·	+·2	·	·	+	+	·
Erigeron piperianus	1·14	+·2	+	+	·	2·35	2·38	·	·	·	·	·	·	·	·
Eriogonum heracleoides	·	·	·	·	·	·	·	·	·	·	·	·	·	·	2·10
Eriogonum niveum	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+·5
Eriogonum strictum proliferum	·	+·2	·	·	·	1·10	·	+	·	·	·	·	·	+	·
Haplopappus stenophyllus	·	·	·	·	·	·	·	·	·	·	·	·	·	+·3	·
Pediocactus simpsonii	·	·	·	·	·	·	·	·	·	·	·	·	·	+	·
Phlox longifolia	·	+·2	+	6·52	+·28	12·65	7·60	+·2	12·99	3·85	+	4·35	6·35	·	+

(Continued)

Table B-1. *Artemisia tridentata-Agropyron spicatum* association. (One additional stand of this association is included in table B-7 on p. 105.) continued

Stand number	19	20	42	43	12	13	14	26	27	9	10	28	34	16	19[illegible]
PERENNIAL GRAMINOIDS															
Agropyron spicatum	46·82	35·72	52·85	49·85	44·88	36·70	41·90	41·82	63·98	58·99	45·90	64·99	75·98	50·82	33·8
Poa cusickii	·	+	6·15	+	2·10	·	·	2·10	9·25	18·68	·	6·18	·	2·15	·
Poa secunda	29·94	61·99	30·98	28·99	44·99	36·99	55·99	40·99	50·99	32·99	40·99	47·99	63·99	13·70	53·9
Oryzopsis hymenoides	·	+	·	·	·	1·8	·	·	·	·	·	·	·	·	·
Sitanion hysterix	·	·	·	·	+	+	·	+·2	·	·	+	·	·	+	·
Stipa comata	13·42	2·10	4·8	+·2	·	·	9·40	2·8	+	·	·	+	8·40	·	4·2
Stipa thurberiana	3·18	·	+	+·8	14·28	·	·	5·20	·	·	+	·	·	4·10	·
PERENNIAL FORBS															
Achillea millefolium lanulosa	·	+	·	·	·	+·8	·	·	+	·	·	+	1·2	·	+·[illegible]
Allium acuminatum	·	·	·	·	·	·	·	·	·	+·2	·	·	·	+·20	·
Antennaria dimorpha	+·6	+·2	·	+·2	+·4	+·2	+	·	1·50	+·10	+·5	+·10	+·2	·	·
Antennaria rosea	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+·5
Arabis holboellii pendulocarpa	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+
Astragalus lentiginosus	·	·	·	·	+	·	·	·	·	·	·	·	·	·	·
Astragalus purshii	·	·	+	·	·	+·2	·	·	·	·	+	+	·	·	·
Astragalus reventus	·	·	·	·	·	·	·	·	·	+	·	·	·	·	·
Astragalus spaldingii	·	·	+	·	·	+	·	·	·	+	·	·	33·68	·	·
Astragalus speirocarpus	·	·	·	·	+	·	·	+	·	·	·	·	·	4·18	·
Astragalus stenophyllus	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Balsamorhiza careyana	·	·	·	+	+	+	+	·	+	·	+	+	·	·	·
Balsamorhiza sagittata	·	·	·	·	·	·	·	·	·	·	·	·	+	·	1·1
Brodiaea douglasii	·	·	+·2	+·5	+·16	·	·	·	+·2	+·5	+	1·5	·	·	·
Calochortus macrocarpus	1·2	+·5	·	+·10	+·4	·	+	+	1·18	+	2·22	·	+·15	·	+·8
Castilleja thompsonii	+·2	+	·	·	·	+	·	·	·	2·12	·	·	+·10	+	·
Chaenactis douglasii	·	·	·	·	·	·	·	·	·	·	+	·	·	·	·
Comandra umbellata pallida	·	·	·	·	+	·	·	·	·	·	·	·	2·8	·	·
Crepis atribarba atribarba	·	+	·	·	·	·	·	·	·	·	·	·	·	·	+·5
Crepis atribarba originalis	+	·	·	+	·	+·2	+·2	+	·	+·2	·	+	·	·	·
Delphinium nuttallianum	·	+	·	·	·	·	+	·	·	·	·	·	·	·	+·8
Dodecatheon conjugens	·	·	·	·	·	·	·	·	·	·	·	·	+	·	2·5
Erigeron poliospermus	+	·	+	·	·	·	·	·	·	·	+	·	·	·	·
Erigeron pumilus intermedius	+·2	·	·	·	+	+	+	·	·	·	·	·	1·10	·	·
Eriophyllum lanatum	·	·	·	·	·	+·2	+	·	·	·	·	·	·	·	·
Frasera albicaulis	·	·	·	·	·	·	·	·	·	·	·	·	+	·	·
Fritillaria pudica	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+
Helianthella uniflora douglasii	·	·	+	+·2	·	·	·	·	·	·	+·5	·	·	·	·
Lithophragma bulbifera	·	+·5	+·2	·	·	·	·	·	·	8·85	+	7·99	+·8	·	2·6[illegible]
Lithospermum ruderale	·	·	·	·	·	2·3	+	·	+	·	·	+·2	·	·	·
Lomatium canbyi	·	·	·	·	·	·	·	·	·	·	·	·	·	+	·
Lomatium farinosum	·	·	·	·	·	·	·	·	·	+	·	·	·	·	·
Lomatium geyeri	·	·	·	·	·	·	·	·	·	+·5	·	·	·	·	·
Lomatium grayii	·	·	·	+	·	·	·	·	·	·	·	·	·	·	·
Lomatium macrocarpum	·	1·32	·	+·2	+	·	+·5	·	·	·	·	·	·	·	2·7[illegible]
Lomatium triternatum	·	+·7	·	·	+	·	+·2	·	+·2	3·45	·	+·2	·	·	·
Lomatium	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+·2
Lupinus laxiflorus laxiflorus	·	·	·	+	+	·	·	·	·	·	·	·	·	·	·
Lupinus leucophyllus leucophyllus	·	·	+	·	·	·	·	·	·	·	·	·	·	·	·
Lupinus sulphureus subsaccatus	·	·	·	·	·	·	·	·	·	+	·	+·5	·	·	·
Mertensia oblongifolia	·	·	·	·	·	·	·	·	·	1·30	·	·	+·8	·	·
Microseris troximoides	·	+·2	·	+	+	·	+	·	+·2	3·45	+	+·5	3·20	·	·
Ranunculus glaberrimus	·	·	·	·	·	·	·	·	·	+·13	·	1·32	·	·	·
Saxifraga occidentalis	·	·	·	·	·	·	·	·	·	·	·	·	·	·	8·72
Selaginella wallacei	·	·	·	·	·	·	·	·	·	·	·	·	·	·	5·22
Senecio integerrimus exaltatus	·	·	·	·	·	·	·	·	·	·	·	·	+	·	·

(Continued)

Table B-1. *Artemisia tridentata-Agropyron spicatum* association. continued

Stand number	19	20	42	43	12	13	14	26	27	9	10	28	34	16	193
Sisyrinchium inflatum	•	•	•	•	+	•	•	•	•	•	•	•	•	•	•
Townsendia florifer	•	•	+	+	+	•	•	•	+	•	+	+	•	•	•
Zigadenus venenosus gramineus	•	•	•	•	+	•	•	•	•	•	•	•	•	•	•
ANNUALS															
Amsinckia lycopsoides	•	•	+	•	•	•	•	•	•	•	•	•	•	•	•
†*Bromus tectorum*	+·2	+·12	1·45	+·50	+·2	1·35	1·35	+·2	+·20	•	+·12	•	+·13	1·30	•
Chenopodium leptophyllum	+	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Collinsia parviflora	•	•	•	•	•	•	•	•	•	+·8	•	•	+·3	+·3	•
Cryptantha ambigua	+	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Cryptantha flaccida	•	•	+·2	•	•	•	•	•	•	•	•	•	•	•	•
Cryptantha pterocarya	•	•	•	+·2	•	•	•	•	•	+·2	•	•	•	1·45	•
Collomia linearis	•	•	•	•	•	•	•	•	•	•	•	•	•	+·13	•
Descurainina pinnata	•	+·2	+·18	+·20	•	+·8	+	+·2	•	•	+·2	•	+·5	1·48	•
Draba verna	•	+·10	+	+·8	•	+·10	+	•	•	•	+	+·10	•	•	1·40
Epilobium paniculatum	•	•	•	•	•	1·23	•	+	+·2	•	•	•	•	•	•
Festuca octoflora	+·4	+	2·92	2·95	•	2·65	•	+	•	•	•	•	•	•	•
Festuca pacifica	+·10	1·52	2·92	4·85	+·6	2·60	•	+·5	+·12	+·2	+·18	•	+·5	+·20	•
Gayophytum humilis	•	•	•	•	•	•	•	•	•	•	•	+·5	•	•	•
Gilia minutiflora	1·28	+·7	•	•	•	+·13	+	+·2	1·25	•	1·35	•	+·3	+·15	•
†*Lactuca serriola (seedlings only)*	•	•	•	•	+·4	•	•	•	+·2	•	•	•	+·5	•	•
Lagophylla ramosissima	•	•	+·2	+·2	•	•	•	•	•	•	•	•	•	•	•
Lappula redowskii	+·4	+·2	+·8	+·22	+·10	+·2	+·10	+	+·8	•	+·10	•	+·5	•	•
Linanthus pharnaceoides	1·26	+·12	+	+	+·50	+·18	•	•	1·28	•	1·31	•	+·8	•	•
Linanthus septentrionalis	•	•	•	•	•	•	•	•	•	•	•	+·2	•	•	•
Madia exigua	•	•	•	•	•	•	•	•	•	•	+·2	•	•	•	•
Microsteris gracilis	•	+·2	•	•	•	+·2	•	•	•	+·10	•	•	+	•	2·65
Myosurus aristatus	•	+·7	•	•	•	2·65	2·63	•	•	+	•	+·12	•	•	•
Oenothera andina	•	•	•	•	•	•	•	•	•	•	+	•	•	•	•
Pectocarya linearis penicillata	+·14	+·5	•	•	•	+·3	•	•	•	•	•	•	+·3	•	•
Phacelia linearis	•	•	•	•	•	•	•	•	•	•	+	•	•	•	•
Plagiobothrys tenellus	•	•	•	•	•	•	•	•	•	•	•	+·10	•	•	•
Plantago patagonica	14·92	8·90	•	•	•	•	•	•	•	•	•	•	4·73	•	•
Plectritis macrocera	•	•	•	•	•	•	•	•	•	•	•	•	•	+·8	•
†*Sisymbrium altissimum*	•	•	•	+	•	+	•	•	•	•	•	•	+	•	•
INDIGENES IN 40 PLOTS ($4m^2$)	17	23	14	19	13	27	12	11	15	21	13	20	27	15	22
TOTAL COVERAGE OF PERENNIAL FORBS	1	1	+	+	+	2	+	+	2	17	2	9	40	4	20
TOTAL COVERAGE	118	117	118	98	109	120	136	106	156	137	108	138	214	102	125

Table B-2. *Artemisia tridentata-Poa secunda* (stands 146-192) and *Artemisia tridentata-Festuca idahoensis* (stands 11-39) assocs.

Stand number		146	164	165	166	191	192	11	15	18	30	32	39
County		Bento	Bento	Grant	Bento	Bento	Bento	Adams	Adams	Adams	Linco	Adams	Asoti
Township and Section		12N4	-----	16N20	9N15	-----	-----	18N23	17N6	17N25	21N8	20N19	10N26
Range		24E	---	26E	27E	---	---	33E	33E	32E	33E	35E	44E
Altitude in meters		382	336	326	241	302	299	483	461	502	485	597	960
Aspect and percent slope		N6	SSE4	NE14	NE4	0	0	W14	SW5	W23	N24	0	0
Soil Classification	USDA 1938 Series	Sz Warde	Sz Warde	--- -----	--- -----	--- -----	--- -----	Bn Ritzv	Bn Ritzv	Bn Starb	BnxRe Farre	BnxRe Starb	So Wies*
	Textural Class	VFSaL	L	-----	-----	-----	-----	SiL	CSiL	SiL	VFSaL	CSiL	SiL
	USDA 1960	mCam	mCam	-----	-----	-----	-----	cHap	cHap	ImCam	cHap	ImCam	tNat
pH	1st decimeter	6.4	7.2	6.8	6.7	6.6	6.8	7.2	6.9	6.8	---	---	6.7
	5th decimeter	7.7	7.7	7.3	7.3	7.7	7.2	7.3	7.1	7.9	---	---	7.9
Mean moisture equiv., upper 5 dm		18.1	16.3	9.2	15.2	6.2	6.0	20.2	17.9	18.9	17.6	22.1	30.9

(Continued)

Table B-2. *Artemisia tridentata-Poa secunda* (stands 146-192) and *Artemisia tridentata-Festuca idahoensis* (stands 11-39) assocs. cont.

Stand number	146	164	165	166	191	192	11	15	18	30	32	39
Darkest horizon (10YRm)	3/3	3/3	---	---	---	---	4/2	3/3	3/3	3/3	3/2	2/1
MEDIUM SHRUBS												
Artemisia tridentata tridentata	35·55	31·58	18·42	38·73	8·19	13·24	13·45	25·56	9·24	8·12	17·23	8·10
Artemisia tripartita	·	·	·	·	·	·	4·10	·	·	+	+·5	·
Chrysothamnus nauseosus albicaulis	·	·	·	·	+	1·8	·	·	+	·	+	+
Chrysothamnus viscidiflorus	·	·	·	·	·	·	+	+·2	+	+·3	+	+
Grayia spinosa	+	·	+	·	·	·	·	·	·	·	·	·
Purshia tridentata	·	·	·	·	·	+	·	·	·	·	·	·
Tetradymia canescens	·	·	·	·	·	·	+	1·2	+	3·5	1·8	·
LOW SHRUBS												
Erigeron filifolius	·	·	·	·	·	·	+	+	·	+	+	·
Erigeron linearis	·	·	·	·	·	·	·	·	+	·	·	·
Erigeron piperianus	·	+·2	·	·	·	·	2·30	1·6	+	·	·	·
Eriogonum heracleoides	·	·	·	·	·	·	·	·	·	+	·	·
Eriogonum sphaerocephalum	·	·	·	·	·	·	·	·	·	+	·	·
Phlox hoodii	·	·	·	·	·	+	·	·	·	·	·	·
Phylox longifolia	+	·	+·2	·	·	·	+	2·30	·	6·52	+·8	+·20
PERENNIAL GRAMINOIDS												
Agropyron spicatum	·	·	·	+	·	·	39·75	40·78	59·96	2·5	22·68	78·99
Festuca idahoensis	·	·	·	·	·	·	23·70	9·22	9·22	68·99	64·93	30·92
Oryzopsis hymenoides	+	·	·	·	·	·	·	·	+	·	·	·
Poa secunda	47·99	41·99	46·99	48·98	51·99	47·99	38·99	44·99	50·99	6·82	45·99	9·88
Sitanion hysterix	1·8	+·2	+	·	·	·	·	·	·	·	·	·
Stipa comata	·	·	·	·	·	·	·	1·6	+	24·80	·	·
PERENNIAL FORBS												
Achillea millefolium lanulosa	·	·	·	·	·	·	+	·	+	·	5·33	2·40
Antennaria dimorpha	·	·	·	·	·	·	+·13	·	+·6	+	·	·
Arabis holboellii	·	·	·	·	·	·	·	·	·	+	·	·
Astragalus collinus	·	·	·	·	·	·	·	·	·	·	·	+
Astragalus lentiginosus	·	·	·	·	·	·	·	·	·	+	·	·
Astragalus purshii	·	·	·	·	·	·	·	·	·	+	+	·
Astragalus spaldingii	·	·	·	·	·	·	1·2	2·12	·	+	+	3·38
Balsamorhiza careyana	+	+	·	·	·	·	·	+	+	·	+	·
Brodiaea douglasii	·	·	·	·	·	·	·	·	·	·	·	+·8
Calochortus macrocarpus	·	·	1·22	·	·	·	+	·	·	1·18	·	+
Castilleja cusickii	·	·	·	·	·	·	+	·	·	·	·	·
Castilleja thompsonii	·	·	·	·	·	·	·	+	·	+·2	+	·
Crepis acuminata	·	·	·	·	·	·	·	·	+	·	·	+
Delphinium nuttallianum	·	·	·	·	·	·	·	·	·	·	+·15	·
Erigeron corymbosus	·	·	·	·	·	·	·	·	·	·	·	+
Erigeron pumilus intermidius	·	·	+	·	·	·	+·2	+·2	+	+	+·8	1·28
Eriophyllum lanatum	·	·	·	·	·	·	+	+	·	·	·	·
Fritillaria pudica	·	·	·	·	·	·	·	·	·	+	·	·
Linum perenne	·	·	·	·	·	·	·	·	·	·	·	+
Lithophragma bulbifera	·	·	·	·	·	+·15	+	·	+·4	·	1·35	+·2
Lithospermum ruderale	·	·	·	·	·	·	1·5	1·8	+	+	+	·
Lomatium ambiguum	·	·	·	·	·	·	·	·	·	·	·	+
Lomatium cous	·	·	·	·	·	·	·	·	·	·	·	+
Lomatium gormani	·	·	·	·	·	·	·	·	·	·	·	+
Lomatium macrocarpum	·	·	·	·	·	·	1·8	+	·	+	+	+
Lomatium triternatum	·	·	·	·	·	·	+·2	+·8	·	+	+·5	+
Lupinus sericeus asotinensis	·	·	·	·	·	·	·	·	·	·	·	+
Lupinus sulphureus sulphureus	·	·	·	·	·	·	·	·	·	+	·	·

(Continued)

Table B-2. *Artemisia tridentata-Poa secunda* (stands 146-192) and *Artemisia tridentata-Festuca idahoensis* (stands 11-39) assocs. cont.

Stand number	146	164	165	166	191	192	11	15	18	30	32	39
Microseris troximoides	·	·	·	·	·	·	+·8	·	·	+	+·2	+·10
Senecio integerrimus exaltatus	·	·	·	·	·	·	·	·	·	·	+	·
†*Taraxacum*	·	·	·	·	·	·	·	·	·	·	·	+
Townsendia florifer	+	·	·	·	·	·	·	·	·	·	·	·
ANNUALS												
Agoseris heterophylla	·	·	·	·	·	·	·	·	·	·	1·30	+
†*Agrostis interrupta*	·	·	·	·	·	·	·	·	·	·	·	+
†*Alyssum alyssoides*	·	·	·	·	·	·	·	·	·	·	·	1·52
Amsinckia intermedia	·	·	·	·	·	·	·	·	+·2	·	·	·
†*Bromus brizaeformis*	·	·	·	·	·	·	·	·	·	·	·	+·2
†*Bromus japonicus*	·	·	·	·	·	·	·	·	·	·	·	+·18
†*Bromus tectorum*	+·5	2·60	8·99	2·82	3·95	5·98	1·33	2·64	1·18	8·70	1·33	1·28
†*Camelina microcarpa*	·	·	·	·	·	·	·	·	·	·	·	+
Collomia linearis	·	·	·	·	·	·	·	·	·	·	·	+
Descurainia filipes	2·65	·	+·2	2·72	1·28	+·2	·	+·4	+·10	+	·	·
Draba verna	·	·	+·8	+	2·98	3·92	·	·	+·2	5·92	14·99	3·95
Epilobium paniculatum	·	·	·	·	·	·	+·8	·	+·12	·	9·93	+·10
†*Erodium cicutarium*	·	·	·	·	·	·	·	·	·	·	·	+·2
Festuca octoflora	·	·	·	1·40	·	·	·	+	1·26	+	+·5	+·18
Festuca pacifica	·	·	2·10	2·72	·	·	·	1·46	1·12	1·50	1·25	+·20
Gilia minutiflora	·	·	+·2	·	+	·	·	·	1·42	·	·	·
†*Holosteum umbellatum*	·	·	·	·	·	·	·	·	·	·	·	+
†*Lactuca serriola (seedlings only)*	·	·	·	+·2	·	·	+·8	·	+·4	·	+·5	2·70
Lagophylla ramosissima	·	·	·	·	·	·	·	·	+	·	·	·
Lappula redowskii	+·2	·	·	·	·	+·2	+·2	·	+	·	+·5	+
Lepidium	·	·	·	·	·	·	·	·	·	·	·	+
Linanthus pharnaceoides	·	·	·	·	·	·	1·33	·	+	·	+·8	·
Madia exigua	·	·	·	·	·	·	·	·	·	·	+·2	·
Microsteris gracilis	·	·	+·5	+·2	+·5	2·92	+·8	+·2	·	2·62	+·15	·
Montia linearis	·	·	·	·	·	·	·	·	·	·	+·13	·
†*Myosotis micrantha*	·	·	·	·	·	·	·	·	·	·	·	+·35
Myosurus aristatus	·	·	·	·	·	·	2·38	+·2	+·8	1·30	4·99	·
Pectocarya linearis penicillata	·	·	·	+·2	·	·	·	·	+·2	·	+·10	·
Plantago patagonica	·	·	·	·	·	·	3·83	·	1·6	2·65	12·98	4·82
†*Sisymbrium altissimum*	·	·	·	·	·	+·5	·	·	·	·	+·2	·
†*Tragopogon dubius*	·	·	·	·	·	·	·	·	·	·	+·2	·
INDIGENES IN 40 PLOTS ($4m^2$)	5	4	9	7	5	8	19	17	16	15	26	16
TOTAL COVERAGE OF PERENNIAL FORBS	+	+	1	0	0	+	3	3	+	1	6	6
TOTAL COVERAGE	85	74	75	93	65	71	129	129	132	137	197	142

Table B-3. *Agropyron spicatum-Poa secunda* (stands 56-159) and *Agropyron spicatum-Poa secunda*, Lithosolic phase (stands 97-181) associations.

		56	88	119	121	122	149	150	159	97	109	143	181
Stand number		56	88	119	121	122	149	150	159	97	109	143	181
County		Asoti	Frank	Adams	Colum	Garfi	Walla	Adams	Frank	Asoti	Whitm	Whitm	Garfi
Township and Section		11N29	12N11	16N32	12N19	12N16	11N3	15N28	11N17	10N21	14N6	16N2	12N16
Range		45E	33E	36E	39E	40E	34E	36E	33E	44E	44E	43E	40E
Altitude in meters		354	398	479	306	455	354	303	212	835	722	657	492
Aspect and percent slope		NNW16	SE31	SSE51	W16	SW16	S43	SW12	SW11	S31	S29	SSE35	WSW10
Soil Classification	USDA 1938	RexBr	Sz	Br	Br	Ct	Br	Br	Br	LixPr	---	LixPr	---
	Series	Farre	Shano	Ritzc	Farre	Walla	Ritzv	Benge	Ritzv	Bakeo	-----	Bakeo	-----
	Textural Class	VFSaL	SiL	VFSaL	L	SiL	SiL	VFSaL	VFSaL	SiL	---	SiL	---
	USDA 1960	cHap	mCam	ceHap	cHap	tHap	cHap	cHap	cHap	IAgx	---	IHap	---

(Continued)

Table B-3. *Agropyron spicatum-Poa secunda* (stands 56-159) and *Agropyron spicatum-Poa secunda*, Lithosolic phase (stands 97-181) associations. continued.

Stand number	56	88	119	121	122	149	150	159	97	109	143	181
pH 1st decimeter	7.1	6.9	7.9	7.3	6.8	7.0	6.7	6.8	6.6	6.3	6.4	6.9
pH 5th decimeter	7.2	7.3	7.8	7.7	7.4	7.3	7.2	7.2	---	---	---	---
Mean moisture equiv., upper 5 dm	18.0	16.6	16.7	16.4	23.0	17.1	19.9	15.9	28.0	21.2	21.5	20.3
Darkest horizon (10YRm)	3/2	3/3	4/2	3/2	2/2	4/3	3/3	3/2	3/2	---	3/3	---
MEDIUM SHRUBS												
Chrysothamnus nauseosus albicaulis	1·5	+	3·5	+	+	+	+·2	·	·	·	·	·
Chrysothamnus viscidiflorus	·	·	·	+	·	·	·	2·8	·	·	·	·
LOW SHRUBS												
Erigeron filifolius	·	·	·	+	·	·	·	·	·	·	·	·
Erigeron linearis	·	·	·	·	·	+	·	·	·	·	·	·
Erigeron piperianus	·	+	·	·	·	·	·	·	·	·	·	·
Eriogonum heracleoides	·	·	·	·	·	·	·	·	+	·	1·10	·
Eriogonum niveum	·	·	·	·	·	·	·	·	·	·	+·2	·
Opuntia polyacantha	·	·	·	·	·	·	·	·	+·2	·	·	·
Phlox longifolia	2·50	·	+·10	8·75	6·73	+·2	·	·	·	·	·	+·2
PERENNIAL GRAMINOIDS												
Agropyron spicatum	86·99	64·98	72·99	69·99	83·99	66·95	49·95	58·99	47·90	69·99	70·99	38·98
Elymus cinereus	·	·	+	·	·	·	·	·	·	·	·	·
Poa secunda	39·99	30·99	17·98	24·99	23·99	44·99	34·99	31·99	5·55	29·99	18·99	29·99
Stipa comata	·	3·8	·	·	·	·	·	·	·	·	·	·
PERENNIAL FORBS												
Archillea millefolium lanulosa	1·20	+	2·13	+	9·75	+·5	·	·	1·8	·	·	·
Agoseris glauca	+	·	·	·	·	·	·	·	·	·	·	·
Agoseris grandiflora	·	·	·	·	·	·	·	·	·	+	·	·
Allium acuminatum	·	·	·	·	·	·	·	·	12·99	3·55	5·70	·
Allium tolmei tolmei	·	·	·	·	·	·	·	·	+	·	·	·
Antennaria dimorpha	·	·	·	·	·	·	·	·	·	·	·	2·50
Astragalus inflexus	+	·	·	·	·	·	·	·	·	·	·	·
Astragalus spaldingii	·	+·2	·	7·35	+·5	·	·	·	·	·	·	+·2
Balsamorhiza careyana	·	+	1·5	·	·	+	·	+	·	·	·	·
Balsamorhiza sagittata	·	·	·	·	·	·	·	·	·	·	+·2	·
Balsamorhiza serrata	·	·	·	·	·	·	·	·	+	·	·	3·30
Brodiaea douglasii	+	+	·	·	+·15	·	·	·	·	·	·	·
Calochortus macrocarpus	·	+	·	·	·	·	+·8	+·8	·	·	·	·
Cirsium undulatum	·	·	·	·	·	·	·	·	+	·	·	·
Erigeron pumilus intermedius	+·12	1·10	+	+·5	·	+·15	·	·	·	·	·	·
Erisymum asperum	+	·	·	·	·	·	·	·	·	·	·	·
Linum perenne	·	+	·	·	·	+·2	·	·	·	·	·	·
Lithophragma bulbifera	2·45	·	·	·	4·70	·	2·92	·	·	2·35	2·70	+·5
Lithospermum ruderale	·	·	·	·	·	+	·	·	·	·	·	·
Lomatium gormanii	·	·	·	·	·	·	·	·	·	·	·	1·22
Lomatium macrocarpum	·	1·20	·	1·23	1·5	+	+·2	+·18	4·42	16·80	·	1·12
Lomatium triternatum	+·2	·	·	·	+·8	·	·	·	·	·	·	·
Lomatium	·	·	·	·	·	·	·	·	+·2	·	·	·
Lupinus leucophyllus	·	+	·	·	+	·	·	·	·	·	·	·
Microseris troximoides	·	·	·	·	+·5	·	·	·	·	·	·	·
Orobanche uniflora	·	·	·	·	·	·	·	·	+	·	·	·
Scutellaria angustifolia	·	·	·	·	·	·	·	·	+	·	·	·
†*Tragopogon dubius*	+	+·2	·	+	2·23	·	+·2	·	+·2	+·2	+·8	·
Zygadenus venenosus gramineus	·	·	·	·	·	·	·	·	3·23	·	·	·

(Continued)

Table B-3. *Agropyron spicatum-Poa secunda* (stands 56-159) and *Agropyron spicatum-Poa secunda*, Lithosolic phase (stands 97-181) associations. continued

Stand number	56	88	119	121	122	149	150	159	97	109	143	181
ANNUALS												
Agoseris heterophylla	•	•	•	•	1•45	•	•	•	•	•	1•28	•
†*Alyssum alyssoides*	•	•	•	•	•	•	•	•	4•99	•	•	•
†*Arabidopsis thalliana*	•	•	•	•	•	•	•	•	•	•	1•30	•
Blepharipappus scaber	•	•	•	•	•	•	•	•	1•23	•	•	•
†*Bromus brizaeformis*	•	•	•	•	•	•	•	•	+•15	+•10	1•22	•
†*Bromus japonicus*	+•5	•	•	•	•	•	•	•	4•99	+•15	+•18	•
†*Bromus mollis*	1•25	•	•	•	•	•	•	•	•	•	•	•
†*Bromus racemosus*	•	•	•	•	•	•	•	•	+	•	•	•
†*Bromus tectorum*	+•20	3•85	5•99	3•100	+•15	3•92	4•95	4•99	1•45	2•82	3•99	2•90
Collinsia parviflora	•	•	•	•	•	•	•	•	•	1•30	•	•
Collomia linearis	•	•	•	•	•	•	•	•	+•2	•	•	•
Cryptantha flaccida	•	•	•	•	•	•	•	•	•	•	+	•
Descurainia pinnata	+	•	+	•	•	•	•	•	•	•	•	•
Draba verna	6•99	+•15	+•10	3•100	4•99	+•2	3•99	+•20	2•80	6•99	10•99	2•92
†*Elymus caput-medusae*	•	•	•	•	•	•	•	•	•	•	+	•
Epilobium paniculatum	+•12	•	•	•	•	+•2	4•95	•	•	1•35	•	•
†*Erodium cicutarium*	+•18	•	•	•	1•23	•	•	•	•	•	•	•
Festuca octoflora	2•82	2•88	+•2	2•95	1•55	•	•	2•72	•	•	•	•
Festuca pacifica	1•38	1•22	•	2•93	1•55	2•98	•	2•72	•	2•62	1•30	1•22
Helianthus annuus	•	•	•	•	+•2	•	•	•	•	•	•	•
†*Holosteum umbellatum*	9•99	•	•	1•53	3•80	•	3•99	•	•	+•2	+	+•2
Idahoa scapigera	•	•	•	•	•	•	•	•	•	+•2	+•2	•
†*Lactuca serriola (seedlings only)*	+•15	•	+•2	+•18	1•35	•	+•2	•	+•5	1•32	1•28	+•5
Lappula redowskii	•	•	•	•	•	+•10	•	•	•	•	•	•
Linanthus pharnaceoides	•	+•5	•	•	•	•	•	•	•	•	•	•
†*Lithospermum arvense*	•	•	•	•	•	•	•	•	•	•	+•2	•
Miscrosteris gracilis	•	•	•	•	•	•	•	•	1•23	•	•	+•20
Plantago patagonica	3•99	11•99	2•58	2•98	3•99	2•70	8•92	2•70	•	•	•	•
†*Sisymbrium altissimum*	•	•	•	+•8	•	•	•	•	•	•	•	•
Stellaria nitens	2•90	•	•	•	•	•	•	•	•	•	•	•
†*Vicia villosa*	•	•	•	•	•	•	•	•	•	3•30	•	•
INDIGENES IN 40 PLOTS ($4m^2$)	14	11	9	10	16	11	9	9	12	10	11	12
TOTAL COVERAGE OF PERENNIAL FORBS	3	2	2	8	16	+	2	+	20	21	7	7
TOTAL COVERAGE	155	116	102	122	143	117	107	101	85	135	114	79

Table B-4. *Agropyron spicatum-Festuca idahoensis* association.

		41	60	61	98	118	120	147	148	151	152	153
Stand number		41	60	61	98	118	120	147	148	151	152	153
County		Asoti	Whitm	Whitm	Asoti	Adams	Colum	Walla	Walla	Asoti	Asoti	Asoti
Township and section		10N21	15N6	15N6	10N21	16N32	12N19	12N9	11N10	8N5	8N18	8N9
Range		44E	40E	40E	44E	36E	39E	36E	34E	46E	46E	45E
Altitude in meters		869	450	446	850	482	308	258	354	895	968	902
Aspect and percent slope		ESE15	0	WNW39	NNE47	NNE1	NNE10	NNE13	N39	0	NW6	0
	USDA 1938	Cm	Ct	Ct	Cm	Br	Br	Br	Br	So	Pl	PrxGr
Soil	Series	Weis*	Walla	Walla	Athen	Ritzc	Ritzv	Ritzv	Ritzv	Weis*	Brevi	Goos*
Classification	Textural Class	Sil	Sil	Sil	Sil	Sil	L	Sil	L	Sil	Sil	Stcl
	USDA 1960	tNat	tHap	tHap	cHap	ceHap	cHap	cHap	cHap	ncHap	tPal	vAgx
pH	1st decimeter	---	6.7	6.8	6.3	6.8	6.9	6.3	6.6	7.4	6.2	6.0
	5th decimeter	---	6.8	6.7	6.8	8.0	7.2	6.7	6.8	7.6	7.8	6.4
Mean moisture equiv., upper 5 dm		28.6	19.7	21.4	37.4	21.8	18.1	20.5	20.0	35.4	38.8	41.0
Darkest horizon (10YRm)		3/1	2/2	2/2	2/1	3/3	3/2	3/2	3/2	2/1	2/1	2/1

(Continued)

Table B-4. *Agropyron spicatum-Festuca idahoensis* association. continued

Stand number	41	60	61	98	118	120	147	148	151	152	153
MEDIUM SHRUBS											
Chrysothamnus nauseosus albicaulis	+	1·5	+·2	+	·	+	+	1·12	·	·	·
Chrysothamnus viscidiflorus	·	·	·	·	·	·	+	1·5	·	·	·
LOW SHRUBS											
Antennaria luzuloides	·	·	·	·	·	·	·	·	·	+	·
Erigeron filifolius	·	·	·	·	·	+·2	·	·	·	·	·
Opuntia polyacantha	+·15	·	·	·	·	·	·	·	·	·	·
Phlox longifolia	+·2	5·70	1·28	1·30	1·13	1·55	3·38	+	+·5	·	+·5
PERENNIAL GRAMINOIDS											
Agropyron spicatum	74·99	71·99	37·90	95·99	77·99	34·92	33·99	78·99	86·99	30·68	30·95
Elymus cinereus	·	+	+·2	·	·	·	·	·	·	·	·
Festuca idahoensis	3·12	8·22	61·85	43·99	7·23	75·99	71·98	91·99	48·98	86·99	89·99
Koeleria cristata	·	·	·	·	·	·	·	·	·	4·25	·
Poa cusickii	+	·	·	·	·	·	·	·	·	·	·
Poa secunda	9·98	45·99	36·99	2·38	39·99	23·98	16·99	29·99	8·78	9·75	16·99
PERENNIAL FORBS											
Achillea millefolium lanulosa	1·42	+·8	1·25	9·82	2·50	1·10	3·40	+·2	+	5·28	2·45
Antennaria dimorpha	·	·	·	·	·	+	1·2	·	·	·	·
Arnica fulgens	·	·	·	·	·	·	·	·	·	+·10	·
Astragalus arthuri	·	·	·	·	·	·	·	·	·	·	2·48
Astragalus collinus	·	·	·	·	·	·	·	·	5·35	·	·
Astragalus lentiginosus	+	·	·	·	·	·	·	·	·	·	·
Astragalus spaldingii	·	13·55	3·8	·	+·10	2·18	6·32	+	·	·	·
Balsamorhiza careyana	·	·	·	·	+	·	+	·	·	·	·
Balsamorhiza incana	·	·	·	·	·	·	·	·	·	2·22	5·32
Besseya rubra	·	·	·	+·18	·	·	·	·	·	·	·
Brodiaea douglasii	·	·	·	3·62	·	+·8	2·40	·	·	+·2	·
Calochortus macrocarpus	+	·	·	+·2	·	+·5	·	·	1·30	·	·
Castilleja cusickii	·	·	·	·	·	·	·	·	·	+	·
Cirsium	·	·	·	+	·	·	·	·	·	·	·
Crepis acuminata	·	·	·	+·2	·	·	·	·	·	·	·
Crepis atribarba originalis	+	·	·	·	·	·	·	3·42	+	·	·
Crepis bakeri idahoensis	·	·	·	·	·	·	·	·	·	·	1·12
Crepis	·	·	·	·	·	·	+·2	·	·	·	·
Delphinium nuttallianum	·	·	+	·	·	·	·	·	·	·	·
Erigeron corymbosus	·	+	1·8	12·65	·	·	·	·	·	·	+·8
Erigeron pumilus intermedius	·	·	·	·	·	+·2	·	·	·	·	·
Fritillaria pudica	·	·	·	·	·	·	·	·	+·2	·	+·5
Geum triflorum ciliatum	·	·	·	·	·	·	·	·	·	+	·
Haplopappus liatriformis	·	·	·	·	·	·	·	·	·	3·18	·
Hieraceum albertinum	·	·	·	+·5	·	·	·	·	·	·	·
Linum perenne	·	·	·	·	·	·	·	·	+·8	·	·
Lithophragma bulbifera	2·45	3·92	+·22	4·80	1·48	1·30	2·65	2·99	·	2·75	·
Lithospermum ruderale	·	·	+	·	3·8	·	·	·	·	·	·
Lomatium cous	·	·	·	·	·	·	·	·	·	·	+·2
Lomatium macrocarpum	+·10	·	·	·	·	+·2	1·18	·	·	·	·
Lomatium triternatum	·	+	+	1·25	+·8	+	+·5	3·20	·	3·20	9·68
Lupinus lepidus aridus	·	·	·	·	·	·	·	·	·	·	3·28
Lupinus leucophyllus	·	+	+·2	·	·	+	·	·	·	·	·
Lupinus sericeus asotinensis	·	·	·	2·25	·	·	·	·	1·2	+	1·8
Lupinus sericeus sericeus	·	·	·	·	·	·	+	1·8	·	·	·
Mertensia longiflora	·	·	·	2·40	·	·	·	1·22	·	+·10	+
Microseris nutans	·	·	·	·	·	·	·	·	·	+·8	+·5
Microseris troximoides	+	+	·	+	+	+	+·2	+	+	·	+·2

(Continued)

Table B-4. *Agropyron spicatum-Festuca idahoensis* association. continued

Stand number	41	60	61	98	118	120	147	148	151	152	153
Potentilla gracilis	•	•	•	•	•	•	•	•	+	•	•
Ranunculus glaberrimus	•	•	•	•	•	•	•	•	•	2·60	•
Senecio integerrimus exaltatus	•	•	+	+·8	•	•	+	•	•	•	•
Solidago missouriensis	•	•	•	•	•	•	•	•	+·8	•	•
†*Taraxacum*	•	•	•	+·2	•	•	•	•	•	•	•
†*Tragopogon dubius*	•	•	+·2	+·2	•	+·5	•	+·5	+·2	+·8	•
Vicia americana	•	•	•	•	•	•	•	•	•	5·45	8·60
Zygadenus venenosus gramineus	+	•	•	•	•	•	•	•	•	•	•
ANNUALS											
Agoseris heterophylla	•	+	•	•	+·5	•	•	•	•	•	•
†*Alyssum alyssoides*	•	•	•	•	•	•	•	•	1·38	+·2	1·35
†*Arenaria serpyllifolia*	•	•	•	•	•	•	•	•	•	•	+·5
Blepharipappus scaber	•	•	•	•	•	•	•	•	•	•	1·15
†*Bromus brizaeformis*	+·2	•	•	+	•	•	•	•	+·5	+·18	2·88
†*Bromus japonicus*	1·20	•	•	•	•	•	•	•	•	•	•
†*Bromus mollis*	•	•	•	•	•	•	•	•	•	+·8	1·28
†*Bromus racemosus*	•	•	•	•	•	•	•	•	•	2·70	•
†*Bromus tectorum*	+·2	1·50	2·48	+	3·88	1·52	2·80	4·95	•	1·12	+·2
†*Camelina microcarpa*	•	•	•	•	•	•	•	•	•	•	+
Clarkia pulchella	•	•	•	+·5	•	•	•	•	•	•	•
Collomia linearis	•	•	•	•	•	•	•	•	•	1·35	+·82
Descurainia pinnata	1·30	•	•	•	•	•	•	•	•	•	•
Draba verna	2·85	4·99	8·99	2·70	2·95	2·99	3·97	2·92	2·80	2·88	2·99
Epilobium paniculatum	1·12	+·2	+·5	+·5	+·2	•	•	+·2	•	2·65	•
†*Erodium cicutarium*	+·8	•	•	•	•	•	•	•	+·10	•	•
Festuca octoflora	•	•	•	•	+·5	2·78	•	•	•	•	•
Festuca pacifica	+	+	•	•	1·50	1·50	+·2	•	•	+·8	•
†*Holosteum umbellatum*	•	1·22	1·2	+·10	•	2·85	•	•	1·50	+·10	+·22
†*Lactuca serriola (seedlings only)*	2·72	+·8	+·2	+·5	+·2	+·5	•	•	1·25	1·22	1·32
Lappula redowskii	2·5	•	+·5	•	•	+·2	•	•	•	•	•
†*Lepidium perfoliatum*	+·2	•	•	•	•	•	•	•	•	•	+·2
†*Lithospermum arvense*	•	•	•	•	•	•	•	•	+·2	•	•
Microsteris gracilis	•	•	•	+·15	•	•	1·52	•	•	1·30	2·85
Montia linearis	•	•	•	•	•	•	•	•	•	2·88	•
Montia perfoliata	•	•	+·8	+·10	•	•	•	•	•	•	•
†*Myosotis micrantha*	•	•	•	•	•	•	•	•	•	•	+·10
Myosurus aristatus	•	•	+·4	•	+·8	•	•	•	•	•	•
Plantago patagonica	1·48	+·20	+	•	7·99	2·72	2·75	+·5	•	•	•
†*Sisymbrium altissimum*	4·42	•	+·2	•	•	+·8	•	•	•	•	•
Stellaria nitens	•	+·5	1·60	2·60	•	•	•	•	•	1·38	•
†*Veronica arvensis*	•	•	•	•	•	•	•	•	+·10	1·35	•
INDIGENES IN 40 PLOTS ($4m^2$)	13	12	17	22	16	17	17	14	11	22	21
TOTAL COVERAGE OF PERENNIAL FORBS	3	16	5	33	6	4	15	10	7	22	31
TOTAL COVERAGE	103	152	152	178	143	147	146	216	154	165	176

Table B-5. *Festuca idahoensis-Symphoricarpos albus* (stands 69-163) and *Festuca idahoensis-Rosa nutkana* (stands 136-162) associations. Counties marked with ¥ are in Idaho.

Stand number	69	70	71	72	73	74	75	76	92	106	107	135	155	156	163	136	154	161	162
County	Whitm	Whitm	Whitm	Whitm	Whitm	Whitm	Whitm	Whitm	Whitm	Spoka	Spoka	Whitm	Whitm	Whitm	Whitm	Colum	Asoti	Idah¥	Idah¥
Township & section	15N23	15N23	13N25	13N25	13N25	13N25	14N25	14N19	14N33	21N1	22N25	20N10	14N33	14N33	16N32	10N19	8N28	34N31	36N14
Range	45E	45E	44E	44E	44E	44E	44E	46E	45E	44E	44E	45E	45E	45E	45E	39E	45E	1W	2W
Altitude in meters	775	775	817	826	834	885	747	760	769	760	772	761	795	795	765	612	1098	1156	854
Aspect & % slope	N23	S17	NE9	NNE24	NNE27	N35	WNW21	0	SW21	NW25	SW4	W30	0	N34	S9	N15	NNE15	SW17	NE15
Soil classification																			
USDA 1938	PrxPl	PrxPl	Pr	Pr	Cm	Cm	---	Pr	Pl	Pl	Pr	---	Pr	PrxPl	Pr	---	Pr	---	---
Series	Naff	Naff	Palou	Palou	Athen	Paxat	---	Koste	Garfi	Thatu	Brevi	---	Naff	Pa-at	Palou	---	Brevi	---	---
Textural Class	SiL	SiL	SiL	SiL	SiL	SiL	---	SiL	SiL	SiL	SiL	---	SiL	SiL	SiL	---	SiL	---	---
USDA 1960	tAgx	tAgx	tAgx	tAgx	cHap	tHap	---	tPal	vAgx	gAgn	aPal	---	tAgx	tAgx	tAgx	---	tPal	---	---
pH 1st decimeter	6.6	6.3	6.5	6.5	---	6.7	6.4	6.2	6.6	6.8	6.7	---	6.2	6.1	6.5	6.4	5.6	7.0	---
pH 5th decimeter	6.0	6.2	6.0	6.5	---	6.2	6.1	5.9	5.8	6.5	5.7	---	6.1	5.7	5.9	5.8	5.8	5.5	---
Mean moisture equiv., upper 5 dm	28.6	28.6	31.1	34.3	---	30.4	27.4	31.5	26.2	29.5	29.5	---	27.8	28.4	29.0	29.0	33.5	31.9	---
Darkest horizon (10YRm)	2/1	2/1	---	---	---	---	---	2/1	---	2/1	2/1	---	---	---	2/1	---	2/2	---	---
MEDIUM SHRUBS																			
Amelanchier alnifolia	·	·	·	·	·	·	·	2·2	·	·	·	·	·	1·2	·	·	·	·	·
Crataegus douglasii	1·8	·	·	·	·	·	·	·	·	·	·	·	·	+	·	·	·	·	·
Prunus virginiana melanocarpa	+	·	·	·	+	1·5	·	·	·	·	+	+	·	+·2	·	·	·	·	·
LOW SHRUBS																			
Berberis repens	·	4·60	·	·	·	·	·	·	·	10·80	·	·	·	·	·	·	·	·	·
Phlox longifolia	·	·	·	·	·	3·52	1·23	·	·	·	·	·	·	·	·	·	·	·	·
Phlox speciosa	·	·	·	·	·	·	·	·	·	1·10	1·15	2·18	·	·	·	·	1·5	·	7·62
Rosa nutkana & R. woodsii	12·63	2·25	2·22	·	3·21	1·12	2·15	·	+·5	1·8	4·58	1·15	1·5	1·5	+·5	9·78	+·5	·	·
Spiraea betulifolia	·	·	+	3·27	1·18	+·5	·	·	·	·	·	·	·	·	·	·	·	·	·
Symphoricarpos albus	6·48	26·99	15·92	12·87	6·94	4·32	11·78	+·8	14·98	10·70	2·18	3·35	17·90	6·55	11·78	·	+	·	·
PERENNIAL GRAMINOIDS																			
Agropyron spicatum	88·99	6·25	57·88	78·99	56·99	70·92	79·99	47·95	82·99	62·92	·	52·98	78·98	30·95	77·99	20·92	77·99	41·85	14·62
Bromus carinatus	·	·	·	·	·	·	·	·	·	·	·	·	·	+·2	·	·	·	·	·
Bromus marginatus	·	·	·	·	+	·	·	·	·	·	·	·	·	·	·	·	4·42	·	·
Calamagrostis rubescens	·	·	·	·	·	·	·	·	·	·	·	·	·	28·68	·	·	14·28	·	·
Carex geyeri	·	·	·	·	+	+·8	·	·	·	·	·	·	·	28·92	·	·	·	·	·
Carex praegracilis	·	·	·	+	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Carex rossii	2·28	·	1·25	6·53	1·18	·	·	·	·	·	·	·	·	·	·	·	1·8	·	·
Festuca idahoensis	60·99	53·99	30·72	50·99	58·99	47·99	81·88	42·90	35·98	69·98	41·99	14·55	40·99	26·78	35·85	49·98	30·82	85·99	79·99
Festuca scabrella	·	·	·	·	·	·	·	·	·	30·72	51·75	31·58	·	·	·	·	·	·	·
Koeleria cristata	6·35	2·15	3·28	7·43	14·65	13·72	5·53	+·2	·	·	·	1·10	4·22	1·32	+·15	9·50	6·35	9·60	19·95
†*Phleum pratense*	·	·	·	·	·	·	·	1·15	·	·	·	·	·	·	·	·	+·5	·	·
Poa ampla	1·10	·	53·92	5·23	3·12	4·20	57·95	48·92	·	1·10	·	·	·	·	·	1·10	·	2·5	·
†*Poa compressa*	·	·	·	·	·	·	·	+	·	·	·	·	·	·	·	·	·	·	·
†*Poa pratensis*	·	·	·	·	·	·	·	+	·	·	·	·	·	2·5	·	+	·	·	·
Poa secunda	·	·	·	·	·	6·62	2·30	·	+·10	·	2·40	·	+·5	·	+·8	9·82	6·65	5·55	5·60
Stipa columbiana	·	·	·	4·47	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
PERENNIAL FORBS																			
Achillea millefolium lanulosa	5·75	8·80	10·82	6·83	2·57	3·52	22·98	2·28	15·90	6·48	6·45	4·32	25·90	4·40	9·65	+·5	5·78	4·42	1·25
Agoseris grandiflora	·	·	·	·	·	+	·	·	·	·	·	·	·	·	·	+·5	·	·	·
Allium acuminatum	·	·	·	·	·	·	·	·	+	·	2·60	·	·	·	·	·	·	·	·
Apocynum	·	+·5	·	·	·	·	·	·	·	·	·	+·5	·	·	·	·	·	·	·
Arabis glabra	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+	·	·
Arnica fulgens	·	·	·	·	·	·	·	·	·	·	·	·	+·5	·	49·98	·	·	·	·
Arnica sororia	·	·	5·85	+·10	+	·	+	·	·	·	·	·	·	·	·	·	·	·	·

(Continued)

Table B-5. *Festuca idahoensis-Symphoricarpos albus* (stands 69-163) and *Festuca idahoensis-Rosa nutkana* (stands 136-162) associations. continued.

Stand number	69	70	71	72	73	74	75	76	92	106	107	135	155	156	163	136	154	161	162
Arnica	+·2	·	·	·	·	·	·	1·12	·	·	·	·	·	·	·	·	·	·	·
Astragalus palousensis	·	·	·	·	·	·	·	·	2·18	·	·	·	18·78	5·52	·	·	·	·	·
Astragalus reventus	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	1·5	7·50	·
Astragalus spaldingii	·	5·13	·	·	·	·	·	1·2	·	·	·	·	·	·	·	·	·	·	·
Balsamorhiza sagittata	23·58	10·35	·	·	12·24	5·18	·	24·72	35·72	31·55	41·82	31·60	51·88	22·58	14·45	36·75	15·40	46·90	6·32
Besseya rubra	3·45	·	2·20	7·63	2·27	1·58	+·8	1·10	·	2·12	·	+·5	2·28	6·68	4·28	2·10	2·40	9·70	1·28
Brodiaea douglasii	+·20	·	·	·	1·28	+·18	·	1·35	4·75	1·28	·	4·75	1·58	1·40	2·65	7·99	1·35	1·32	·
Calochortus elegans	2·75	+·8	+·18	1·43	·	2·68	·	1·8	·	·	·	+·2	1·55	·	+·58	·	2·65	+·12	2·95
Calochortus macrocarpus	·	·	·	·	+·12	·	+·20	·	+·5	·	·	·	+·2	·	·	·	·	·	·
Castilleja cusickii	·	7·65	·	·	·	·	·	+·2	·	·	·	·	·	·	·	·	+	·	·
Castilleja hispida	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	7·48	·	·	·
Castilleja lutescens	+·5	·	+	·	5·60	6·48	·	·	+·2	·	2·18	+·2	5·32	1·2	3·40	·	+	+·2	1·12
Castilleja	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Cirsium brevifolium	·	1·20	·	·	+	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Claytonia lanceolata	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+·8	·	1·48
Clematis hirsutissima	+	·	·	4·33	+	·	·	+·2	·	·	·	+	·	+·2	+	·	·	·	·
Comandra umbellata pallida	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	2·25	·	·	·
Crepis acuminata	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+	·	3·30
Crepis runcinata	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+·20
Crepis	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+	·	·	·
Delphinium nuttallianum	·	·	·	·	·	·	·	·	·	+·2	+·18	·	·	·	·	·	1·25	·	1·52
Dodecatheon pauciflorum cusickii	·	·	·	·	+	1·15	·	·	·	·	·	·	·	·	·	·	·	·	3·58
Dodecatheon pauciflorum pauciflorum	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Erigeron corymbosus	·	·	·	2·33	1·6	8·55	·	·	·	·	+	·	·	+·2	·	·	+	·	4·38
Erythronium grandiflorum	·	·	·	1·50	·	2·60	1·38	·	·	·	·	·	·	2·82	·	·	2·45	·	+·10
Frasera albicaulis	·	·	1·12	1·7	4·30	·	1·5	·	·	+	·	·	·	·	+	·	·	+·2	·
Fritillaria pudica	·	·	·	·	+	·	·	·	·	·	·	·	+·2	·	·	·	+·5	·	·
Gaillardia aristata	·	·	+·2	2·27	+·2	+	2·45	+·2	+	·	·	·	·	·	·	·	·	·	·
Galium boreale	2·35	·	11·72	2·57	2·49	+·5	+·5	·	2·20	1·18	·	5·52	1·15	2·52	·	·	·	·	+
Gentiana affinis	·	·	+·2	2·20	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Geranium viscosissimum	24·65	2·20	21·78	3·17	+·30	·	·	16·78	·	6·38	+	+·2	·	4·10	4·18	·	2·10	+	·
Geum triflorum ciliatum	4·38	2·35	14·48	22·90	20·64	23·48	+	28·55	4·28	29·90	11·25	19·70	+·2	8·32	+	+	9·45	11·65	21·75
Haplopappus carthamoides carthamoides	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	2·20	·
Haplopappus liatriformis	+·18	8·40	8·32	8·43	10·57	1·8	10·75	15·75	·	·	·	·	+·5	+·2	·	·	·	·	·
Helianthella uniflora douglasii	5·18	·	·	+·2	2·12	·	·	15·82	3·5	·	·	22·85	31·90	25·85	·	·	26·65	·	·
Heuchera cylindria glabella	·	·	·	+·2	·	+	·	·	·	1·15	+	·	·	+·2	·	·	·	·	·
Hieraceum albertinum	1·10	9·60	+·10	9·63	3·15	6·18	5·18	1·10	1·8	+·5	4·22	17·55	1·12	5·32	11·50	·	·	+·5	·
Hieraceum cynoglossoides	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	10·48	·	+
Iris missouriensis	·	·	29·92	11·60	+	·	+·5	5·40	+	+·8	·	·	1·5	+·2	2·12	·	·	·	·
Lathyrus bijugatus	·	·	·	·	·	·	·	·	·	20·90	·	19·90	·	·	·	·	·	·	·
Lithophragma bulbifera	·	3·28	·	6·77	+	2·95	2·85	·	3·58	1·35	3·100	1·40	·	·	+·2	1·45	2·78	·	2·82
Lithophragma parviflora	·	·	+·2	6·63	1·22	1·42	·	·	4·60	·	+·5	+·18	·	·	1·28	·	+·20	·	+·5
Lithospermum ruderale	+·10	1·5	1·8	·	+·3	3·10	+·2	1·8	·	2·15	1·10	+·5	+·5	+·2	1·10	·	+	+	+
Lomatium dissectum multifidum	13·65	19·75	·	·	+	·	+·2	1·12	2·12	1·5	·	·	10·49	·	1·20	·	·	·	9·35

(Continued)

Table B-5. *Festuca idahoensis-Symphoricarpos albus* (stands 69-163) and *Festuca idahoensis-Rosa nutkana* (stands 136-162) associations. continued.

Stand number	69	70	71	72	73	74	75	76	92	106	107	135	155	156	163	136	154	161	162
Lomatium triternatum	·	1·5	·	·	+·5	·	+·2	+·2	+	·	4·50	1·12	1·12	6·52	·	·	+·2	2·35	1·25
Lomatium	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+·2	·	·	·
Lupinus argenteus argenteus	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	9·70	·	·
Lupinus laxiflorus laxiflorus	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	1·8	1·8
Lupinus leucophyllus	·	·	·	1·30	·	·	·	+	·	·	·	·	·	·	·	·	·	·	·
Lupinus sericeus	5·35	37·99	1·15	·	4·40	6·35	6·28	11·60	4·20	4·30	12·60	1·15	3·22	1·8	9·35	·	·	4·22	9·60
Lupinus sulphureus sulphureus	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	33·93	·	·	·
Lupinus wyethii	·	·	·	·	+·2	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Mertensia longiflora	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+·8	·	+·10
Microseris nutans	·	·	+·2	·	·	+·5	·	·	·	·	+·2	+·2	·	·	·	+·20	+·5	·	·
Perideridia gairdneri	·	·	1·5	1·17	·	3·20	·	·	·	·	·	·	·	·	·	·	1·15	·	·
Potentilla arguta	·	·	2·4	4·17	·	·	·	·	·	+·2	+	·	·	·	·	·	·	·	·
Potentilla gracilis	49·98	27·85	21·82	30·97	46·88	22·65	6·30	30·98	2·68	14·70	+	19·68	5·20	23·95	45·99	+	19·90	13·88	·
Ranunculus glaberrimus	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	1·30	·	·
Senecio integerrimus exaltata	1·42	+·10	·	+·2	1·18	3·48	+·8	+·2	6·70	1·8	8·90	+·12	4·42	5·52	3·45	+·15	+·12	1·18	·
Sidalcea oregana	·	+	8·50	·	+	·	·	·	·	·	·	·	·	+·2	·	·	+	·	·
Silene douglasii douglasii	·	·	·	4·63	·	2·30	·	·	·	·	·	·	·	·	·	·	·	·	·
Silene menziesii	·	·	·	·	·	·	·	·	·	3·42	·	·	·	·	·	·	·	·	·
Silene spaldingii	·	·	·	·	1·24	·	·	·	·	·	·	·	·	·	·	·	·	+·2	·
Sisyrinchium inflatum	·	·	·	·	2·60	·	2·43	+·10	·	·	·	+·8	+·2	·	2·60	2·50	·	+	2·62
Solidago missouriensis	1·8	2·25	·	·	5·21	·	29·80	·	·	·	·	·	·	+·2	·	·	+·5	3·25	·
†*Taraxacum*	+·2	+·2	+·5	·	·	·	·	·	·	·	+·2	+·2	·	+·2	·	·	+·5	+·2	·
†*Tragopogon dubius*	·	·	·	·	1·12	·	·	+	+	+·2	+·2	1·8	·	+·2	·	2·28	·	+·2	+·2
Trifolium macrocephalum	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	2·30	·
Vicia americana	·	·	·	·	·	·	·	·	·	+·2	·	·	·	·	·	·	4·62	·	·
Viola adunca	1·22	·	2·35	+·13	+·2	+·2	·	·	·	·	·	·	·	+·18	·	·	·	·	·
Wyethia amplexicaulis	1·8	·	·	·	·	·	·	·	·	·	·	2·5	·	·	·	+·5	·	·	14·50
Zygadenus venenosus gramineus	+·5	3·35	+·2	1·7	+	1·5	+·5	+·2	·	1·8	·	1·12	·	·	5·62	1·18	1·8	+	·
ANNUALS																			
†*Alyssum alyssoides*	·	·	·	·	+·2	·	·	·	·	·	·	1·48	·	+·2	·	+·5	·	·	·
†*Agrostis interrupta*	·	·	·	·	·	·	·	·	·	+·10	+·5	·	·	·	·	·	·	1·25	·
†*Arenaria serpyllifolia*	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	3·92
†*Bromus brizaeformis*	8·99	·	·	·	+	·	+·2	·	+·2	·	·	·	·	·	+·12	·	2·75	·	2·95
†*Bromus japonicus*	8·99	·	·	·	+·12	2·58	+·15	·	9·99	·	1·42	1·48	2·80	7·72	2·70	2·80	·	+·5	+·2
†*Bromus mollis*	·	·	·	+·2	·	·	1·23	+	·	·	·	+·2	·	·	·	1·25	·	·	+·10
†*Bromus racemosus*	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	3·95
†*Bromus tectorum*	·	·	·	·	·	+	1·2	·	·	+·8	3·68	+·2	+·8	·	·	+·2	·	+·18	·
†*Cerastium viscosum*	·	·	·	·	·	·	·	·	+·2	·	·	·	·	·	·	+·15	·	·	+·20
Clarkia pulchella	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+	·
Collinsia parviflora	1·42	2·75	1·52	+·7	1·42	4·95	+·2	+·10	2·72	1·60	3·90	2·80	2·65	2·62	2·88	1·30	2·75	1·48	1·50
Collomia linearis	·	·	·	·	·	·	·	·	·	·	·	+·2	·	1·45	·	1·45	2·60	+·2	·
Draba verna	·	2·62	+·8	+·3	2·80	3·95	2·65	·	2·90	1·35	2·99	1·42	2·80	1·38	+·18	+·15	2·92	+·5	2·82
Epilobium paniculatum	1·25	1·55	+·10	+·10	+·2	2·78	+·20	+·5	·	+·8	2·50	1·25	+·2	+·20	1·28	+·8	·	1·28	1·2
Festuca pacifica	·	+·5	·	+·3	·	1·5	+·13	·	2·48	·	·	·	·	·	·	1·14	·	·	·
Galium aparine	+·5	·	1·12	·	·	+·2	·	·	·	5·10	1·12	3·30	·	·	+·8	2·65	·	·	·
Gayophytum	·	·	·	·	·	·	·	·	·	·	·	1·15	·	·	·	·	·	·	·
†*Holosteum umbellatum*	·	·	·	·	·	·	·	·	·	·	·	·	+·8	·	+·20	1·30	·	·	·
†*Lactuca serriola (seedlings only)*	+·2	+·5	+·2	·	·	+·5	·	+·2	+·2	+·5	+·8	+·15	+·8	+·10	·	+·20	+·2	1·38	+·5

(Continued)

Table B-5. *Festuca idahoensis-Symphoricarpos albus* (stands 69-163) and *Festuca idahoensis-Rosa nutkana* (stands 136-162) associations. continued.

Stand number	69	70	71	72	73	74	75	76	92	106	107	135	155	156	163	136	154	161	162
†*Lithospermum arvense*	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+·2	·	·
Microsteris gracilis	2·65	1·55	·	·	+	·	·	1·28	+·10	·	1·40	+·8	1·25	+·22	2·68	1·38	2·72	·	+·5
Montia linearis	2·72	·	+·5	1·23	1·42	1·25	1·25	·	+·2	+·5	1·25	·	+·5	2·72	+·12	+·10	+·5	+·2	+·18
Montia perfoliata	·	3·99	·	·	·	·	·	·	+·18	1·38	+·2	+·5	·	·	+·2	·	+·10	·	·
†*Myosotis micrantha*	·	·	·	·	·	·	2·83	·	3·99	2·95	·	1·40	5·95	1·32	·	·	·	1·55	1·30
Plantago patagonica	·	·	·	·	·	+·8	·	·	·	·	·	·	·	·	·	·	·	·	·
Plectritis macrocera	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+·20	·	·	·
Polemonium micrantha	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+·2	·	·
†*Polygonum convolvulus*	·	·	·	·	·	·	·	·	·	·	·	+·2	·	·	·	·	·	·	·
Polygonum	·	·	·	·	·	·	·	·	·	·	·	+·5	·	·	·	·	·	·	·
†*Sisymbrium altissimum*	·	·	1·8	·	·	·	·	·	·	·	·	·	·	+	·	·	·	·	·
Stellaria nitens	·	3·98	+·5	·	1·22	2·78	+·8	·	2·68	+·12	2·78	1·22	1·45	+·15	+·20	+·18	·	+·2	+·18
†*Veronica arvensis*	·	·	·	·	+	+·2	·	·	·	·	·	·	·	·	·	2·72	·	+·10	+·12
†*Vicia villosa*	·	·	·	·	·	·	·	·	·	·	+	·	·	·	·	·	·	·	·
INDIGENES IN 40 PLOTS ($4m^2$)	35	33	36	41	39	43	34	34	28	37	28	41	35	42	33	31	41	30	33
TOTAL COVERAGE OF PERENNIAL FORBS	140	145	137	134	125	101	86	154	87	124	94	147	160	120	165	93	113	106	82
TOTAL COVERAGE	338	250	301	300	272	265	321	295	238	318	211	263	313	257	295	202	262	253	219

Table B-6. Reconnaissance analyses of the *Symphoricarpos* phase of the *Festuca-Symphoricarpos* association in three tracts of steppe in Whitman County, Washington. Values in table refer to coverage classes.

Locality	S 32, T 16N, R 45E							S 33, T 14N, R 45E						S 25, T 13N, R 44E									
Thicket number	240	241	242	243	244	245	246	247	248	249	250	251	252	253	254	255	256	257	258	259	260	261	262
Diameter in meters	6	6	4	12	5	11	13	5	4	10	12	14	9	4	10	12	5	15	8	25	6	5	9
Maximum height in meters	0.5	0.6	0.6	1.0	1.0	1.0	1.0	0.9	1.0	1.2	1.8	2.0	2.4	0.6	0.8	1.0	1.0	1.2	1.8	2.3	2.3	2.4	2.9
Aspect	S	SSW	S	SSE	S	S	SSW	SW	S	SW	SW	SSE	SSW	N	N	N	ESE	ENE	N	NNE	NNW	NNE	ENE
Percent slope	7	9	13	8	8	7	6	5	4	5	8	15	7	20	45	42	30	45	20	6	36	14	27
TALL SHRUBS																							
Crataegus douglasii	·	·	·	·	·	·	·	·	·	·	·	·	·	·	1	·	·	·	·	·	·	·	·
Holodiscus discolor	·	·	·	·	·	·	·	·	·	·	·	·	·	·	1	·	·	·	·	·	·	·	·
MEDIUM SHRUBS																							
Amelanchier alnifolia	·	·	·	·	·	·	·	·	·	·	·	·	·	·	2	·	1	1	·	·	1	1	1
Prunus virginiana melanocarpa	·	·	·	·	·	·	·	·	·	·	2	·	4	1	1	2	2	2	6	4	6	5	4
Rosa nutkana + R. R. woodsii	·	3	1	2	2	3	3	3	4	4	4	5	4	1	5	2	5	4	1	2	·	2	3
Spiraea betulifolia	·	·	·	·	·	·	·	·	·	·	·	·	·	5	4	2	5	1	2	·	1	1	2
Symphoricarpos albus	5	4	5	6	6	5	4	5	5	5	5	5	4	5	5	6	6	6	6	5	2	5	5
PERENNIAL GRAMINOIDS																							
Agropyron spicatum	·	·	1	1	1	1	·	1	·	2	·	1	·	1	·	1	1	1	1	1	·	1	1
†*Alopecurus pratensis*	·	·	·	·	·	·	·	·	·	·	1	·	·	·	·	·	·	·	·	·	·	·	·
†*Bromus commutatus*	·	·	·	·	·	·	·	·	·	·	·	·	·	1	1	1	·	·	1	·	·	·	·
†*Bromus erectus*	·	1	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Carex rossii	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	1	·	·	·
Festuca idahoensis	1	·	1	·	·	·	·	·	·	·	·	·	2	1	1	·	1	·	1	1	·	1	·
Koeleria cristata	·	1	·	·	·	·	·	·	·	·	1	·	·	·	1	·	·	·	·	1	·	·	·
†*Phleum pratense*	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Poa ampla	·	1	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	1	1	·	·	1
†*Poa pratensis*	·	1	·	·	·	·	·	·	1	·	1	·	·	·	·	·	·	·	·	·	·	·	·
PERENNIAL FORBS																							
Achillea millefolium lanulosa	1	1	1	1	·	·	1	1	1	1	1	1	1	1	1	1	1	1	1	1	·	1	1

(Continued)

Table B-6. Reconnaissance analyses of the *Symphoricarpos* phase of the *Festuca-Symphoricarpos* association in three tracts of steppe in Whitman County, Washington. Values in table refer to coverage classes. continued

Thicket number	240	241	242	243	244	245	246	247	248	249	250	251	252	253	254	255	256	257	258	259	260	261	262
Agastache urticifolia	·	·	·	·	·	·	·	·	·	·	·	4	·	·	·	·	·	1	1	1	·	·	1
Allium acuminatum	·	·	·	·	·	·	·	1	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
†*Arctium minus*	·	·	·	·	·	·	·	·	·	·	·	1	·	·	·	·	·	·	·	·	·	·	·
Astragalus palousensis	·	·	·	·	·	·	·	·	·	1	·	·	·	·	·	·	·	·	·	·	·	·	·
Balsamorhiza sagittata	1	3	2	1	1	·	2	3	3	1	1	1	1	·	·	1	·	·	·	·	·	·	·
Besseya rubra	1	1	2	2	2	4	1	·	1	1	1	·	·	1	1	·	1	·	1	1	·	1	·
Castilleja cusickii	·	1	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Castilleja lutescens	1	·	·	·	·	·	·	1	·	1	·	·	·	·	·	·	·	·	·	·	·	·	·
Cirsium brevifolium	·	·	·	·	1	1	3	·	1	·	·	1	1	·	·	·	·	·	·	·	·	·	·
†*Cirsium vulgare*	·	·	1	·	·	·	·	·	·	·	·	·	·	1	·	·	·	·	·	·	·	·	·
Clematis hirsutissima	·	·	·	·	·	·	·	·	·	·	·	·	·	1	·	·	·	·	·	·	·	·	·
Erythronium grandiflorum	·	·	·	·	·	·	·	·	·	·	·	·	·	·	1	·	·	·	·	·	1	·	1
Fraser albicaulis	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	1	·	·	·
Gaillardia aristata	1	1	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Galium boreale	·	·	·	·	·	·	·	·	·	·	·	·	·	1	1	1	1	·	·	1	·	1	1
Gentiana affinis	·	·	·	·	·	·	·	·	·	·	·	·	·	·	1	·	1	·	·	1	1	·	1
Geum triflorum	1	1	·	·	1	·	·	·	·	·	·	·	·	1	·	·	1	·	·	1	·	·	·
Geranium viscosissimum	1	1	·	1	1	·	·	·	·	·	·	·	·	1	1	1	1	1	·	1	·	1	1
Helianthella uniflora douglasii	·	·	·	·	·	·	·	2	2	2	·	1	·	·	·	·	·	·	·	·	·	·	·
Heuchera cylindrica glabella	·	·	·	·	·	·	·	·	·	·	·	·	·	·	1	·	1	·	·	·	·	·	·
Hieraceum albertinum	1	·	·	1	1	·	·	·	·	1	·	·	·	·	·	1	·	·	·	·	·	·	·
Iris missouriensis	·	·	·	·	·	·	·	1	·	·	·	·	2	3	·	·	·	·	1	1	·	1	1
Lomatium dissectum multifidum	·	2	1	1	3	3	5	4	4	5	5	3	5	·	1	1	·	1	·	·	·	·	1
Lithophragma parviflora	·	·	·	·	·	·	·	·	·	·	·	1	·	1	1	·	1	1	1	·	·	·	1
Lithospermum ruderale	1	·	·	·	1	·	·	·	·	·	1	·	·	·	·	·	·	·	·	·	·	·	·
Lupinus sericeus sericeus	1	1	·	·	·	1	·	·	·	·	1	·	·	·	·	·	·	·	·	·	·	·	·
Perideridia gairdneri	1	·	·	·	·	·	·	·	·	·	·	·	1	·	1	·	·	·	·	1	·	·	·
Potentilla arguta	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	1	·	·	1	·	·	·
Potentilla gracilis	1	·	1	·	1	·	1	·	·	·	1	·	1	1	1	·	1	·	·	1	·	·	1
Senecio integerrimus exaltatus	1	1	1	1	2	1	·	2	1	1	1	1	1	·	1	1	·	1	·	·	·	·	·
Sidalcea oregana	·	·	·	·	·	·	·	1	·	·	·	1	·	·	·	·	·	·	·	·	·	·	·
Silene spaldingii	·	·	·	1	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Sisyrinchium inflatum	1	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Solidago serotina	·	·	·	·	·	·	·	·	·	·	·	2	·	·	·	1	·	·	·	·	·	·	·
†*Taraxacum*	·	·	·	·	·	·	·	·	·	·	·	1	·	·	·	·	·	·	·	·	·	·	·
†*Tragopogon dubius*	·	·	1	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Viola adunca	·	·	·	·	·	1	2	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
ANNUALS																							
†*Asperugo procumbens*	·	·	·	·	·	·	·	·	·	·	·	1	·	·	·	·	·	·	·	·	·	·	·
†*Bromus brizaeformis*	·	1	1	·	1	1	·	·	·	·	·	1	·	·	·	·	·	·	·	·	·	·	·
†*Bromus japonicus*	1	3	1	1	1	·	3	·	1	·	1	1	1	·	·	·	·	·	·	·	·	·	·
†*Bromus tectorum*	·	·	·	·	·	·	·	·	1	1	2	1	2	·	·	·	·	·	·	·	·	·	·
Collinsia parviflora	·	·	·	·	·	·	·	·	·	1	1	·	·	1	1	1	·	1	·	·	·	·	·
†*Draba verna*	·	·	·	·	·	·	·	·	·	·	·	·	·	1	1	·	1	·	·	·	1	·	1
Epilobium paniculatum	1	1	1	1	·	1	2	·	1	·	1	1	1	·	·	·	1	·	·	·	·	·	·
Galium aparine	3	3	·	4	3	4	2	3	1	2	3	2	2	1	2	1	1	5	·	·	·	·	·
†*Lactuca serriola*	·	·	·	·	·	·	·	·	·	·	1	·	·	·	·	1	·	·	·	·	·	·	·
Montia perfoliata	1	·	1	·	·	1	·	·	1	1	1	·	1	·	1	1	·	1	·	·	3	·	3
†*Myosotis micrantha*	·	·	·	·	·	·	·	1	1	·	1	1	1	·	·	·	·	·	·	·	·	·	·
†*Sisymbrium altissimum*	·	·	·	2	·	·	·	·	·	·	1	1	1	·	·	1	·	·	·	·	·	·	·
Stellaria nitens	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	1	·	·	·	·	·	·	·
†*Veronica arvensis*	1	·	·	·	·	1	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·

Table B-7. *Artemisia tripartita-Agropyron spicatum* association (stand 100) and *Artemisia tripartita-Festuca idahoensis* association (all other stands).

Stand number	100	4	37	38	5	160	82	104	1	35	117	65	67	2	64	62	63	3	66	68
County	Okano	Dougl	Dougl	Dougl	Okano	Linco	Dougl	Okano	Linco	Linco	Adams	Spoka	Spoka	Dougl	Linco	Linco	Linco	Whitm	Spoka	Linco
Township & section	39N1	26N22	27N18	27N4	33N7	28N27	29N33	38N14	24N26	26N22	16N32	25N1	26N16	23N10	25N9	25N16	25N7	19N2	25N9	25N16
Range	28E	24E	24E	24E	28E	31E	30E	28E	38E	31E	36E	40E	37E	21E	40E	37E	38E	39E	40E	40E
Altitude in meters	1017	839	924	819	660	576	719	713	743	551	479	716	768	963	768	741	741	604	767	748
Aspect & % slope	E43	W5	S7	NE18	ENE8	N31	NNW8	NW10	N31	N28	N51	WSW20	SE6	SE5	W17	0	0	SE22	NE7	ESE5
Soil classification																				
USDA 1938	Ct	CtxRe	Ct	Ct	Ct	---	CtxRe	Ct	Pr	CtxRe	Bn	Ct	---	Pr	Ct	Ct	Ct	Cm	---	Pl
Series	Disau	With*	Touhe	Touhe	Disau	-----	Benge	Tonas	Palou	Strat	Ritzv	Bagda	-----	Water	Drago	Bagda	Athen	Athen	-----	Govan
Textural class	L	SiL	GtL	L	SiL	---	SiL	SiL	SiL	SiL	SiL	SiL	---	SiL	SiL	SiL	SiL	SiL	---	SiL
USDA 1960	cHap	tHap	cpHap	cpHap	cHap	-----	cHap	ceHap	tAgx	cHap	cHap	tHap	-----	tAgx	tHap	cAgx	cHap	cHap	-----	tPal
pH 1st decimeter	6.5	6.3	6.6	6.7	---	6.3	6.5	7.0	6.1	6.6	6.0	6.0	6.1	6.1	6.3	6.6	6.5	---	6.1	6.3
pH 5th decimeter	7.3	6.9	6.9	6.9	6.8	7.2	6.8	7.0	6.4	7.1	6.6	6.5	6.7	6.0	6.1	6.9	7.9	---	6.3	6.4
Mean moisture equiv., upper 5 dm	17.9	16.9	17.3	18.6	14.6	22.9	19.3	14.2	28.2	17.4	20.3	20.5	28.7	20.8	17.2	29.7	27.0	23.6	31.6	29.2
Darkest horizon (10YRm)	3/2	3/2	3/1	2/1	3/2	---	2/2	2/2	2/1	3/2	2/2	2/2	---	2/2	2/2	2/2	2/2	3/1	---	2/2
MEDIUM SHRUBS																				
Artemisia tridentata tridentata	·	·	·	·	+	·	·	·	·	+	·	·	·	·	·	·	·	·	·	·
Artemisia tripartita	17·55	8·46	5·10	16·63	21·92	12·48	18·65	12·60	36·86	7·35	+·2	2·15	+·5	19·63	5·15	8·32	4·25	14·43	18·62	3·28
Chrysothamnus nauseosus albicaulis	·	·	·	+	+	·	·	·	+	·	7·23	·	·	·	·	·	·	+	·	·
Chrysothamnus viscidiflorus	4·10	+·2	+·2	·	1·8	+·2	+·2	·	·	5·13	+	·	·	+	·	+·2	+·2	·	·	+
Ribes cereum cereum	·	·	·	+	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Rosa woodsii ultramontana	·	·	·	·	·	1·8	·	+	+	·	·	·	·	·	·	·	·	·	·	·
Tetradymia canescens	1·5	1·8	·	·	·	·	·	·	+	+	·	·	·	2·5	·	5·22	4·20	·	·	+
LOW SHRUBS																				
Arenaria congesta	·	4·48	3·40	6·88	1·40	+·20	2·45	·	·	+·8	·	·	·	·	·	·	·	·	·	·
Erigeron filifolius	·	·	·	·	+·2	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Erigeron linearis	·	·	+	+·10	·	·	·	·	·	+	·	·	·	+	·	·	·	·	·	·
Eriogonum heracleoides	1·8	1·10	3·5	3·18	+	4·18	+·2	+·2	·	+	·	2·8	2·15	2·13	8·28	1·13	+	+	·	+
Penstemon confertus	·	·	·	·	·	·	·	1·15	·	·	·	·	·	·	·	·	·	·	·	·
Phlox longifolia	·	1·12	5·33	+·15	6·85	2·48	2·55	·	·	4·13	+·5	1·11	+·12	1·25	3·60	1·25	+·2	+	2·28	1·52
PERENNIAL GRAMINOIDS																				
Agropyron spicatum	96·99	69·99	77·99	56·95	43·92	58·98	34·93	81·99	47·96	64·93	21·70	22·48	35·78	17·78	46·95	21·34	15·45	3·15	24·45	6·18
Bromus carinatus	·	·	·	·	·	·	·	·	+·2	·	·	·	·	·	·	·	·	·	·	·
Carex filifolia	·	·	·	·	·	2·15	23·78	·	2·20	·	·	44·99	48·90	+·2	24·72	22·62	28·75	16·38	24·92	4·28
Carex rossii	·	·	·	·	·	·	·	·	1·2	·	·	·	·	·	·	·	·	·	·	·
Elymus cinereus	·	·	·	·	·	·	·	·	2·2	·	·	·	·	·	·	·	·	·	·	+
Festuca idahoensis	·	1·2	1·5	3·13	6·15	11·85	20·50	22·55	26·72	31·78	32·99	52·92	63·88	64·98	73·99	75·98	79·99	81·99	87·99	95·99
Koeleria cristata	5·32	1·8	+	3·18	2·8	12·75	+	3·18	3·14	5·15	·	·	·	5·15	+	·	·	·	·	·
Poa ampla	·	·	+	·	·	·	·	·	+·2	+	·	·	·	·	·	·	·	·	·	3·8
Poa cusickii	·	12·38	5·18	14·80	·	·	·	·	·	·	·	·	·	+	·	·	·	·	·	·
Poa secunda	22·99	9·86	6·70	14·98	43·99	10·82	26·99	16·99	+·4	25·99	12·99	9·99	8·98	9·93	12·95	2·50	10·99	1·45	7·85	6·92
Stipa columbiana	·	·	3·8	1·2	·	·	8·53	·	5·26	·	·	10·30	·	3·13	·	6·28	+·5	+	9·65	2·6
Stipa comata	·	·	·	·	2·62	·	·	·	·	24·53	·	·	·	·	·	·	·	·	·	·
Stipa occidentalis	·	·	·	·	·	·	·	·	·	·	·	·	·	·	1·2	·	·	·	·	·
Stipa thurberiana	·	·	·	·	·	·	·	·	·	·	·	·	·	+	·	·	·	·	·	·
PERENNIAL FORBS																				
Achillea millefolium lanulosa	5·68	+·2	1·10	2·15	+·5	+·12	+·2	4·55	2·36	+·8	+	·	·	+	·	3·30	+·10	·	4·45	4·48
Allium acuminatum	·	·	·	·	·	·	·	·	·	·	·	1·5	·	·	+·2	·	·	·	·	·
Antennaria anaphaloides	·	·	·	·	·	·	·	+	·	·	·	·	·	·	·	·	·	·	·	·
Antennaria dimorpha	·	+·2	+·5	+·5	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·

(Continued)

Table B-7. *Artemisia tripartita-Agropyron spicatum* association (stand 100) and *Artemisia tripartita-Festuca idahoensis* association (all other stands). continued

Stand number	100	4	37	38	5	160	82	104	1	35	117	65	67	2	64	62	63	3	66	6
Antennaria parvifolia	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+·8	·
Antennaria rosea	·	·	·	·	·	+·2	·	2·5	·	·	·	·	·	·	·	·	·	·	·	·
Antennaria stenophylla	·	·	·	·	·	·	·	·	·	·	·	·	+	·	·	·	·	·	·	·
Antennaria umbinella	·	·	·	4·25	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Arabis holboellii	+·15	·	·	·	+·2	·	·	+·18	·	+	·	·	·	·	·	·	·	·	·	·
Arnica sororia	·	·	·	·	·	·	·	·	10·82	·	·	+	·	·	+	2·18	+	·	21·92	9·
Astragalus howellii	1·8	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Astragalus spaldingii	·	1·10	+	·	·	·	·	·	+·2	29·78	+·5	·	·	·	·	5·2	·	+·5	·	+·
Balsamorhiza sagittata	·	·	+	+	·	·	·	35·48	2·4	·	·	·	·	+	+	+	·	2·3	·	·
Besseya rubra	·	·	·	·	·	·	·	·	+·2	·	·	·	·	·	+·5	·	·	·	8·85	+
Brodiaea douglasii	+·2	·	·	·	2·48	5·99	2·55	+·5	·	2·45	·	+·12	·	1·35	+·20	·	+·2	+·3	·	·
Calochortus elegans	·	1·22	+·15	1·28	·	·	·	·	·	·	·	·	·	+·2	·	·	·	·	+·2	·
Calochortus macrocarpus	+·2	1·30	3·45	+·18	4·15	+·5	+·15	+	·	2·50	·	·	1·18	+·8	+	·	+·5	+·10	+·2	+
Castilleja cervina	·	·	·	·	·	·	·	+·2	·	·	·	·	·	·	·	·	·	·	·	·
Castilleja lutescens	·	·	·	·	·	·	·	·	2·24	·	·	·	·	·	·	·	·	·	4·55	·
Castilleja thompsonii	·	1·22	·	1·28	+	1·22	1·15	·	·	2·25	·	·	·	1·15	+	+·5	+·8	·	·	·
Chaenactis douglasii	·	·	+·2	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Cirsium brevifolium	·	·	·	·	·	·	·	·	+·2	·	·	·	·	·	·	·	·	·	·	·
Cirsium undulatum	·	·	·	·	·	·	·	·	·	·	·	+	·	·	·	·	·	·	·	·
Comandra umbellata pallida	·	+·12	·	+·2	+	·	·	2·25	+·4	·	·	·	·	·	+	+	·	·	·	·
Crepis acuminata	·	·	·	·	·	·	·	2·38	·	·	·	·	·	·	·	·	·	·	·	·
Crepis barbigera	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+	·	·	·	·	·
Crepis atribarba originalis	·	1·16	+·5	2·23	+·5	·	+·8	·	·	+·2	·	·	·	·	·	·	·	·	·	·
Crepis	·	·	·	·	·	+	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Delphinium nuttallianum	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+·5	·	·	2·52	·
Dodecatheon conjugens	·	·	·	+	·	·	·	·	+·10	+·2	·	·	·	+	7·62	·	·	·	·	·
Dodecatheon pauci-florum cusickii	·	·	·	·	·	3·78	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Dodecatheon pauci-florum pauciflorum	·	·	·	·	·	·	+·5	·	·	·	·	+·2	·	·	·	·	·	·	·	·
Dodecatheon	·	·	·	·	·	·	·	·	·	·	·	·	+·8	·	·	·	·	·	4·92	·
Erigeron corymbosus	8·75	3·14	1·10	2·50	+·2	3·85	+·8	3·38	6·38	2·23	+	·	2·17	5·50	+·8	1·18	15·88	+	4·38	2·
Erigeron pumilus intermedius	·	2·38	+·5	+·2	+·15	·	+	·	·	+	·	·	·	+·3	·	+·2	·	·	·	·
Fragaria	·	·	·	·	·	·	·	+·2	·	·	·	·	·	·	·	·	·	·	·	·
Frasera albicaulis	·	2·20	1·5	1·13	·	+·8	·	·	+·10	·	·	·	·	·	+·2	2·28	+	·	·	·
Fritillaria pudica	·	·	·	·	+	·	·	·	·	+	·	·	+	·	·	·	·	·	·	·
Gaillardia aristata	·	+	·	·	+	·	·	·	+·8	·	·	·	·	·	·	·	·	·	·	·
Geranium viscosissimum	·	·	·	·	·	·	·	1·2	·	·	·	·	·	·	·	·	·	·	·	·
Geum triflorum ciliatum	·	·	·	·	·	·	·	·	10·44	·	·	·	·	·	+	·	·	·	4·10	·
Halimolobos whitedii	·	+·4	·	·	·	·	·	·	+	·	·	·	·	·	·	·	·	·	·	·
Haplopappus liatriformis	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+·2	·
Hesperochiron pumilus	·	·	·	·	·	·	·	·	2·34	·	·	6·80	22·99	+·8	+·2	4·87	26·99	·	3·99	8·
Heuchera cylindrica glabella	·	·	·	·	·	·	·	·	1·8	·	·	·	·	·	·	·	·	·	·	·
Hieraceum albertinum	·	·	·	·	·	·	·	·	2·16	·	·	·	·	·	·	·	·	·	·	+
Hieraceum cynoglossoides	·	·	·	·	·	+	·	2·12	·	·	·	·	·	·	·	·	·	·	·	·
Linum perenne	·	·	·	·	·	·	·	·	+	·	·	·	·	·	·	·	·	·	·	·

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Table B-7. *Artemisia tripartita-Agropyron spicatum* association (stand 100) and *Artemisia tripartita-Festuca idahoensis* association (all other stands). continued

Stand number	100	4	37	38	5	160	82	104	1	35	117	65	67	2	64	62	63	3	66	68
Lithophragma bulbifera	1·40	2·36	+·8	1·35	1·30	6·95	1·23	+·5	2·48	1·48	1·45	1·45	3·85	2·48	3·90	1·32	+·20	+·17	1·45	·
Lithophragma parviflora	·	·	·	·	·	·	·	·	·	·	·	+	·	·	·	·	·	·	·	·
Lithophragma tenella thompsonii	·	·	·	·	+·8	·	+·10	·	·	·	·	·	·	·	·	·	·	·	·	·
Lithospermum ruderale	+·5	·	+	+	2·2	+	+·2	1·15	1·12	+	+	+	·	·	+	1·2	·	+	+·5	+
Lomatium triternatum	+·18	·	1·10	·	+·2	·	+·10	+·2	+	·	+	+	+·8	·	1·10	+·2	·	·	2·25	·
Lupinus argenteus argenteus	·	·	·	1·10	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Lupinus laxiflorus laxiflorus	·	·	·	·	·	·	·	·	·	+	·	·	·	·	·	·	·	·	·	·
Lupinus leucophyllus	·	·	·	·	1·12	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Lupinus sericeus sericeus	3·15	·	+	·	2·20	9·88	4·43	8·42	22·80	2·13	·	1·2	·	·	+·5	+·2	1·12	+	19·80	7·42
Lupinus sulphureus subsaccatus	·	1·12	+·5	2·14	·	·	·	·	·	·	·	·	·	3·28	·	·	·	·	·	·
Mertensia longiflora	·	·	·	·	·	2·85	2·75	·	·	3·85	·	+	+	·	+·2	·	·	·	·	+
Mertensia oblongifolia	·	+·16	+	2·73	·	·	·	·	·	·	·	·	·	1·35	·	·	·	·	·	·
Microseris nutans	·	+·4	·	·	·	·	·	·	+·2	·	·	·	·	+	·	·	·	·	·	·
Microseris troximoides	·	1·12	+	4·40	+·2	+·2	4·50	·	·	+·5	+	+·15	·	+·5	+·5	·	·	·	1·22	1·8
Orobanche	·	·	+	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Perideridia gairdneri	·	·	·	·	·	·	·	·	1·6	·	·	·	·	·	·	·	·	·	·	·
Potentilla arguta	·	·	·	·	·	·	·	+·2	8·36	·	·	·	·	·	·	·	·	·	·	·
Potentilla gracilis	·	·	·	·	·	·	·	·	8·40	·	·	·	·	·	+	·	·	·	·	·
Ranunculus glaberrimus	·	·	·	·	·	1·30	·	·	+·2	·	·	1·32	·	·	1·38	·	+	·	·	·
Saxifraga integrifolia	·	·	·	·	·	·	·	·	·	·	·	+	·	·	2·35	·	·	·	1·15	·
Senecio integerrimus exaltatus	·	2·14	7·55	+·5	·	·	+·5	·	2·22	·	·	·	·	+	·	+·2	·	·	·	+·2
Silene douglasii douglasii	·	·	·	·	·	·	·	·	1·18	·	·	·	·	·	+	·	·	·	·	·
Silene oregana	·	·	·	·	·	·	·	+	·	·	·	·	·	·	·	·	·	·	·	·
Sisyrinchium inflatum	·	·	·	·	·	·	·	·	2·66	·	·	1·38	3·95	·	5·99	2·75	+	·	4·99	3·90
Solidago missouriensis	·	·	·	·	·	·	·	·	+	·	·	·	·	·	·	·	·	·	·	·
†*Taraxacum*	+·5	·	·	·	·	·	·	+·2	·	·	·	·	·	·	·	·	·	·	·	·
†*Tragopogon dubius*	+·10	+·2	·	·	+·2	+·2	·	2·10	·	·	·	1·30	1·22	·	+·2	·	1·18	+·3	1·12	+·15
Viola nuttallii vallicola	+·15	·	·	·	·	·	·	·	2·34	·	·	·	·	·	+	+·8	+·5	·	1·30	1·30
Zigadenus venenosus gramineus	·	+·10	+·2	+·8	·	·	+	·	1·12	·	·	·	3·55	+·13	+	+	+·8	·	4·99	4·70
ANNUALS																				
Agoseris heterophylla	·	·	·	·	1·30	+·5	+·2	·	·	+·15	+	+·15	+·5	·	·	+·5	+·10	·	·	+·20
†*Agrostis interrupta*	·	·	·	·	·	·	·	·	+	·	·	·	+·5	·	+·8	·	1·55	·	1·42	3·85
Amsinckia menziesii	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+·2
†*Bromus brizaeformis*	·	·	·	·	·	+·5	·	·	·	·	·	·	·	·	·	·	·	·	·	·
†*Bromus commutatus*	·	·	·	·	·	·	·	·	·	·	·	·	·	·	2·85	+·2	+·2	·	·	·
†*Bromus japonicus*	·	·	·	·	·	1·35	·	·	·	·	·	·	1·40	·	·	·	·	·	3·78	+·12
†*Bromus mollis*	·	·	·	·	·	·	·	·	+·2	·	·	·	·	·	·	·	·	·	+·2	·
†*Bromus racemosus*	·	·	·	·	·	+·10	+·2	·	·	·	·	·	+·8	·	·	·	·	·	·	+
†*Bromus tectorum*	+·20	7·78	5·95	+·10	6·82	2·52	+·15	2·45	+·2	1·45	+	1·38	1·65	+·2	+·5	+·5	+·5	4·63	1·50	1·50
†*Capsella bursa-pastoris*	·	·	·	·	·	·	·	·	·	·	·	+·2	·	·	·	·	·	·	·	·
†*Camelina microcarpa*	·	·	·	·	·	·	·	+·2	·	·	·	·	·	·	·	·	·	·	·	1·10
Clarkia pulchella	·	·	·	·	·	+·12	·	·	·	·	·	·	·	·	·	·	·	·	·	·

(Continued)

Table B-7. *Artemisia tripartita-Agropyron spicatum* association (stand 100) and *Artemisia tripartita-Festuca idahoensis* association (all other stands). continued

Stand number	100	4	37	38	5	160	82	104	1	35	117	65	67	2	64	62	63	3	66	68
Collinsia parviflora	2·90	12·92	3·99	2·68	·	2·80	+·13	2·72	6·98	·	·	1·55	2·65	1·45	2·82	1·50	+·8	·	1·30	2·72
Collomia linearis	2·72	·	·	·	2·58	+·12	1·45	3·80	·	1·40	·	·	·	·	·	·	·	·	·	·
Cryptantha torreyana	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+·5
Draba verna	·	·	·	·	·	2·50	2·73	·	1·32	2·99	+·10	+	3·99	·	3·99	2·87	2·99	2·97	3·99	2·75
Descurainia pinnata	·	·	·	+	·	·	·	·	·	·	·	·	·	·	·	·	·	+	·	·
Epilobium paniculatum	+·10	1·28	+·10	1·28	+·15	+·8	+·8	+·10	1·30	+·5	·	1·42	2·70	·	1·48	2·68	1·42	+·8	3·95	+·8
Festuca octoflora	·	·	·	·	+·15	1·32	+·10	·	·	+·20	·	+·12	·	·	·	+·8	1·32	·	·	+·5
Festuca pacifica	·	·	+·3	+·2	+·8	+·18	+·10	·	+·2	·	·	+·18	6·52	·	·	1·15	+·2	1·15	·	+·2
Gayophytum	·	·	·	·	·	+·2	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Gilia minutiflora	·	·	·	+·2	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
†*Lactuca serriola* (seedlings only)	+·5	+·4	·	+·2	+·2	+·2	·	·	·	+·8	+·8	2·68	1·55	·	1·30	+·2	1·40	+·8	1·48	2·70
Lappula redowskii	+·2	2·54	1·25	+·20	·	·	·	+·5	·	+·8	·	·	·	·	·	·	·	·	·	·
Lepidium virginicum	·	·	·	·	·	·	·	+	·	·	·	·	·	·	·	·	·	·	·	·
Linanthus pharnaceoides	·	1·38	+·8	1·25	·	·	+·2	·	·	·	·	·	·	1·30	·	·	·	·	·	·
Linanthus septentrionalis	·	·	·	·	1·50	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Lotus purshianus	·	·	·	·	·	+	·	·	·	·	·	·	·	·	·	·	·	·	+·2	·
Madia exigua	·	·	·	·	+	1·42	·	·	·	·	·	+·10	·	·	·	·	·	·	·	·
Microsteris gracilis	2·70	+·8	·	·	+·2	+·15	1·53	2·85	·	+·10	·	+·20	2·95	·	1·52	+·18	+·8	·	2·62	2·62
Montia linearis	·	·	·	1·24	·	1·30	·	·	2·78	1·40	·	+·15	2·75	·	2·72	·	1·28	·	2·80	1·28
Montia perfoliata	·	·	·	·	·	·	·	·	+·4	·	·	·	·	·	·	·	·	·	·	·
†*Myosotis micrantha*	·	·	·	·	·	·	·	·	·	·	·	+·2	·	·	·	·	·	·	·	·
Myosurus aristatus	·	·	·	·	+·5	+·15	·	·	·	+·18	+·13	·	+·2	·	+·2	+·8	·	·	·	+·5
Oenothera andina	·	·	1·13	1·25	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Orthocarpus hispidus	·	+·6	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Orthocarpus tenuifolius	·	·	·	·	·	·	·	·	1·26	·	·	·	·	·	·	+·10	+·2	·	·	·
Pectocarya linearis penicillata	·	+·4	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Phacelia linearis	·	·	·	·	·	·	·	+·15	·	·	·	·	·	·	·	·	·	·	·	·
Plagiobothrys tenellus	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+·2
Plantago patagonica	3·45	·	+·2	·	2·62	1·38	3·78	1·50	+·4	2·60	·	1·32	·	·	+·12	3·75	2·52	·	1·12	+·18
Polygonum douglasii	1·30	·	·	·	·	·	·	1·38	·	·	·	+·2	·	·	·	·	·	·	+·2	·
Polygonum	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+·2
†*Sisymbrium altissimum*	+·10	·	·	·	·	·	·	·	·	·	·	+	·	·	·	·	·	+	+·5	+·10
Stellaria nitens	·	·	·	·	·	·	·	·	2·44	·	·	+·5	·	·	2·62	+·13	·	+·7	·	·
†*Vicia villosa*	·	·	·	·	·	·	·	·	·	·	·	+·2	·	·	·	·	·	·	·	·
INDIGENES IN 40 PLOTS (4m²)	25	37	31	37	33	37	34	32	49	31	10	29	23	24	31	37	29	14	37	33
TOTAL COVERAGE OF PERENNIAL FORBS	18	18	14	23	12	30	14	62	87	43	1	12	35	13	19	21	43	2	88	39
TOTAL COVERAGE	174	148	132	145	148	153	154	208	221	215	73	160	211	137	205	171	192	124	277	173

Table B-8. *Purshia tridentata-Festuca idahoensis* (stands 77-195), *Festuca idahoensis-Eriogonum heracleoides* (stands 99-105) and *Agropyron spicatum-Eriogonum heracleoides* (stand 101) associations.

Stand number	77	78	91	123	124	125	126	157	194	195	99	102	103	105	101
County	Okano	Okano	Yakim	Klick	Klick	Klick	Chela	Chela	Okano	Okano	Okano	Okano	Okano	Spoka	Okano
Township and section	34N31	35N31	7N28	6N36	5N6	6N36	28N22	27N	32N25	35N17	31N21	40N25	39N15	25N19	40N30
Range	22E	22E	19E	19E	20E	19E	23E	21E	24E	25E	31E	29E	29E	42E	30E
Altitude in meters	573	794	1036	946	841	841	413	397	548	701	792	1131	1314	694	---
Aspect and percent slope	NE13	E23	0	0	0	0	NNW34	N46	NNE37	ENE18	NW30	0	NW15	0	WSW5
Soil Classification USDA 1938	-----	CmxRe	Ct	-----	Ct	Ct	Re	-----	-----	-----	CtxRe	Pr	CmxRe	Cm	CmxRe
Series	-----	Conco	Vanno	-----	Vanno	Vanno	Chela	-----	-----	-----	Conco	Mires	Chesa	Havf*	Chesa
Textural Class	-----	GrSaL	SiL	---	SiL	SiL	PfSaL	---	---	---	FSaL	L	VFSaL	FSaL	FSaL
USDA 1960	-----	tHap	tHap	-----	tHap	tHap	tVit	-----	-----	-----	tHap	mVit	eHap	cHap	eHap
pH 1st decimeter	6.3	6.4	6.2	5.8	5.9	5.8	6.5	6.3	6.1	6.4	5.9	6.6	7.4	6.4	6.8
pH 5th decimeter	6.5	6.5	6.1	6.0	6.0	6.0	7.0	6.5	6.5	6.7	5.9	7.5	7.7	7.2	7.7
Mean moisture equiv., upper 5 dm	18.4	18.9	27.9	25.6	26.7	26.3	14.3	16.5	18.2	21.4	17.6	19.7	21.2	17.4	13.6
Darkest horizon (10YRm)	---	2/2	2/2	---	2/2	2/2	3/2	---	---	---	3/3	2/1	3/1	2/2	2/1
MEDIUM SHRUBS															
Amelanchier alnifolia	.	+	.	.	.	.	.	+	+	.	.	.	.	.	.
Artemisia tripartita	.	.	.	.	.	.	+·2	.	.	+·2	.	.	.	.	.
Chrysothamnus nauseosus albicaulis	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.
Chrysothamnus viscidiflorus	.	.	.	+	.	.	.	.	.	.	.	.	.	.	+
Leptodactylon pungens	.	.	.	.	.	.	+	.	.	.	5·58	+	.	.	.
Prunus virginiana melanocarpa	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Purshia tridentata	25·30	20·48	+	.	.	9·18	14·20	21·35	8·18	15·25	.	.	.	.	.
Ribes cereum	.	.	.	.	.	.	+	.	2·5	.	.	.	.	.	.
Rosa woodsii	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.
Sambucus caerulea	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.
Symphoricarpos albus	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Tetradymia canescens	.	.	+	+	.	.	.	.	.	.	.	+	.	.	.
LOW SHRUBS															
Arenaria congesta	.	.	.	.	.	.	.	.	1·40	1·38	10·95	.	.	.	.
Erigeron filifolius	.	.	.	.	.	.	+·2	.	.	.	.	.	.	.	.
Erigeron linearis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+
Eriogonum douglasii tenue	.	.	.	+	1·5	.	.	.	.	.	.	.	.	.	.
Eriogonum heracleoides	12·45	3·25	18·73	1·8	8·28	5·20	2·18	2·20	.	1·20	7·52	+	3·55	2·5	+·2
Eriogonum niveum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+
Eriogonum strictum proliferum	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.
Pentstemon confertus	.	.	.	.	.	.	.	.	.	.	.	+·2	+	.	.
Phlox longifolia	.	.	+	.	1·15	.	.	.	+	.	5·60	.	.	1·45	.
Phlox speciosa	.	.	.	.	.	.	1·5	2·38	.	.	.	.	.	.	.
Sedum stenopetalum	.	.	.	.	.	.	.	.	.	.	.	.	2·70	.	.
PERENNIAL GRAMINOIDS															
Agropyron spicatum	70·95	65·99	56·95	58·99	68·99	75·95	79·99	80·99	72·99	39·90	64·99	72·99	7·52	7·25	94·99
Carex filifolia	.	.	.	.	.	.	.	.	4·30	.	.	+·5	.	4·20	.
Festuca idahoensis	2·28	66·99	67·98	44·98	20·82	8·48	13·30	41·99	62·99	37·95	56·88	71·99	28·92	95·99	.
Festuca scabrella	.	.	.	.	.	.	.	.	.	.	.	.	82·99	.	.
Koeleria cristata	4·20	2·25	.	.	.	.	+·2	2·18	5·55	2·80	+·2	5·45	6·60	.	1·8
Poa ampla	2·8	.	.	5·52	+·2	10·75	.	+	.	.	.	.	.	1·2	+·2
Poa cusickii	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.
Poa secunda	13·78	.	1·12	8·75	28·85	4·40	46·99	+·2	3·55	26·98	14·99	12·98	8·95	1·22	61·99
Sitanion hysterix	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.
Stipa columbianum	.	.	.	.	.	.	.	.	.	+·8	3·18	.	.	5·32	.
Stipa comata	.	.	.	.	.	.	4·28	.	.	+·5	.	+·2	.	1·8	2·12
Stipa elmeri	4·12	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Stipa lemmoni	3·13	.	.	.	.	.	.	.	.	.	.	.	.	.	.
PERENNIAL FORBS															
Achillea millefolium lanulosa	1·8	+	2·22	.	4·22	4·38	+·2	5·30	+·5	+·2	1·15	1·22	6·85	5·60	3·32

(Continued)

Table B-8. *Purshia tridentata-Festuca idahoensis* (stands 77-195), *Festuca idahoensis-Eriogonum heracleoides* (stands 99-105) and *Agropyron spicatum-Eriogonum heracleoides* (stand 101) associations. continued

Stand number	77	78	91	123	124	125	126	157	194	195	99	102	103	105	101
Agoseris grandiflora	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.
Antennaria rosea	.	+·2	.	.	.	.	4·20	24·85	1·15	1·28	+·8	4·60	1·8	.	+
Arabis holboellii	+·2	.	.	.	.	.	.	+	.	+	+·12	.	+	.	.
Arabis puberula	.	.	.	.	.	.	.	.	.	.	.	.	+·5	.	2·70
Arnica sororia	.	.	.	.	.	.	.	.	.	+	.	2·25	.	3·15	+
Astragalus miser serotina	.	.	.	.	.	.	.	.	.	.	.	.	4·38	.	.
Balsamorhiza careyana	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.
Balsamorhiza sagittata	46·95	27·55	.	.	.	+	1·8	10·30	6·18	20·68	.	.	.	.	.
Brodiaea douglasii	.	.	2·72	+·10	+·18	.	+·20	1·82	6·98	1·40	1·8	.	.	.	.
Calochortus apiculatum	.	.	.	.	.	.	.	1·38	.	.	.	.	.	.	.
Calochortus lyallii	2·75	2·65	.	.	.	.	+·2	.	.	.	.	.	.	.	.
Calochortus macrocarpus	.	.	+·5	2·48	2·50	.	.	.	.	.	.	+·5	.	1·28	.
Calochortus	.	.	.	.	.	.	.	.	2·80	2·92	.	.	.	.	.
Castilleja cervina	.	.	.	.	.	.	.	.	.	+·5	.	.	.	.	.
Castelleja lutescens	.	.	.	.	.	.	.	.	+	.	.	.	.	1·15	.
Castilleja miniata	.	.	.	.	.	.	.	.	.	.	.	+	1·10	.	.
Castilleja thompsonii	.	.	.	.	.	.	.	1·12	.	.	1·15	.	.	.	+
Claytonia lanceolata	+·10	1·50	.	.	.	.	.	2·70	+·10	+·15	.	.	.	.	.
Comandra umbellata pallida	.	.	.	.	.	.	.	+	+·2	.	.	.	.	.	.
Crepis acuminata	.	.	.	.	.	.	.	.	.	.	.	.	1·32	+·2	1·15
Crepis atribarba originalis	+·6	1·18	.	.	+·5	.	+·20	5·88	1·8	1·45	.	1·28	.	.	.
Crepis barbigera	.	.	.	1·5	2·18	.	.	.	.	.	.	.	.	.	.
Delphinium nuttallianum	.	+·10	+·5	.	2·50	.	.	+·8	.	.	.	.	.	.	.
Dodecatheon conjugens	.	.	.	.	.	.	.	2·65	.	.	.	.	.	.	.
Dodecatheon pauciflorum cusickii	.	.	.	.	.	.	.	.	1·50	2·52	.	+·5	.	.	.
Dodecatheon pauciflorum pauciflorum	+·10	.	.	.	.	.	2·28	.	.	2·72	.	.	.	.	.
Erigeron corymbosus	2·18	+·5	.	.	.	.	+·2	2·40	5·50	+·18	+·2	7·82	+·5	4·55	2·35
Erigeron pumilus intermedius	+·4	+	.	.	.	.	+·8	.	.	+·5	+·2	+·2	.	.	.
Erigeron subtrinervis conspicuus	.	.	.	.	.	.	.	.	.	.	.	.	+·5	.	.
Frasera albicaulis	.	.	.	.	.	.	+·5	.	2·40	2·30	.	.	.	2·42	.
Fritillaria pudica	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.
Gaillardia aristata	.	.	.	.	.	.	.	.	.	.	.	.	.	1·18	2·28
Geum triflorum ciliatum	.	.	.	.	.	.	.	.	+	.	.	+·2	.	.	.
Habenaria unalascensis	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.
Haplopappus carthamoides	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.
Hesperochiron	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.
Heuchera cylindrica glabella	.	.	.	.	.	.	.	.	.	.	.	+·12	+·5	.	.
Hieraceum albertinum	+	.	.	.	.	.	.	.	.	.	.	.	.	+·5	.
Hieraceum cynoglossoides	.	.	.	.	+	+	.	.	+	.	.	.	+	.	.
Hydrophyllum capitatum capitatum	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Lathyrus pauciflorus pauciflorus	.	.	.	.	.	.	.	7·38	.	.	.	.	.	.	.
Lesquerella douglasii	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+·15
Lithophragma bulbifera	1·42	.	1·35	7·57	3·68	.	2·60	1·38	1·50	3·80	1·58	.	.	+·10	.
Lithophragma parviflora	.	.	.	14·70	.	+	.	.	.	.	.	.	.	.	.
Lithophragma tenella thompsonii	+·2	+·2	+·5	.	.	.	+·13	.	.	1·55	1·25	.	.	.	.
Lithophragma	.	.	.	.	.	.	.	+·2	.	.	.	.	.	.	.
Lithospermum ruderale	.	+	.	.	.	.	.	+	+·5	.	+·5	+	+	+	+·2
Lomatium ambiguum	+·8	+	.	2·20	6·55	4·50	.	.	.	.	.	.	.	.	.
Lomatium gormanii	.	.	.	2·52	3·48	+·2	.	.	.	.	.	.	.	.	.
Lomatium macrocarpum	.	1·5	.	1·10	+·5	.	.	.	.	.	.	.	.	.	1·22
Lomatium triternatum	.	.	2·20	.	.	.	.	.	+	1·20	.	+·5	2·45	+·2	+·2
Lupinus laxiflorus laxiflorus	.	.	3·38	1·20	4·48	15·65	.	.	.	.	.	.	.	.	.
Lupinus leucophyllus	.	.	.	.	.	.	.	.	.	.	.	.	.	5·50	.
Lupinus sericeus sericeus	.	.	.	.	.	.	.	+·2	2·20	27·95	.	4·45	1·10	.	11·55
Lupinus sulphureus subsaccatus	.	.	.	.	.	.	.	.	.	.	7·35	.	.	.	.
Lupinus	18·82	5·38	.	.	.	.	.	.	.	.	.	.	.	.	.
Mertensia longiflora	1·25	.	.	.	.	.	.	.	.	.	.	.	.	.	.

(Continued)

Table B-8. *Purshia tridentata-Festuca idahoensis* (stands 77-195), *Festuca idahoensis-Eriogonum heracleoides* (stands 99-105) and *Agropyron spicatum-Eriogonum heracleoides* (stand 101) associations. continued

Stand number	77	78	91	123	124	125	126	157	194	195	99	102	103	105	101
Mertensia oblongifolia	·	·	·	·	·	·	·	+	·	·	·	·	·	·	·
Mertensia	·	1·35	·	·	·	·	·	·	·	·	+·5	·	·	·	·
Microseris nutans	·	·	·	·	·	·	·	·	·	+·2	·	·	·	·	·
Microseris troximoides	+·2	·	·	1·15	1·5	+·2	·	·	·	·	3·45	2·52	+·2	+	·
Perideridia gairdneri	·	·	·	·	·	+·3	·	·	·	·	·	·	·	·	·
Phacelia	+·15	+·10	·	·	·	·	·	·	·	·	·	·	·	·	·
Potentilla arguta	·	·	·	·	·	·	·	·	+	+	·	2·15	·	·	·
Potentilla gracilis	·	·	·	·	·	·	·	·	·	·	1·10	·	+	·	·
Ranunculus glaberrimus	·	·	·	·	·	·	+·2	1·45	·	·	·	+·2	·	·	+·12
Saxifraga ferruginea	·	·	·	·	·	·	·	+·20	·	·	·	·	·	·	·
Saxifraga integrifolia	·	·	·	·	·	·	1·15	·	·	·	·	·	·	·	·
Saxifraga	·	·	·	·	·	·	·	·	·	+·10	·	·	·	·	·
Senecio integerrimus exaltatus	3·55	1·30	·	·	·	·	·	·	·	·	·	·	·	1·12	·
Silene douglasii	·	·	·	·	·	·	·	3·32	·	·	·	·	·	·	·
Silene oregana	·	·	·	·	·	·	·	·	+·8	·	·	·	+·2	·	·
Sisyrinchium inflatum	·	·	+·2	·	·	·	·	·	·	·	·	·	·	·	·
Solidago canadensis salebrosa	·	·	·	·	·	·	·	·	·	·	·	·	·	3·12	·
Solidago missouriensis missouriensis	·	·	·	·	·	·	·	·	·	·	·	·	34·98	·	·
†*Taraxacum*	+·2	·	·	·	·	·	·	·	·	·	·	+·5	1·30	+·2	+·8
†*Tragopogon dubius*	5·52	·	·	·	·	·	·	·	·	·	2·42	+·15	·	1·5	1·12
Viola nuttallii	·	·	·	·	·	·	·	·	·	·	·	·	·	1·22	·
Zigadenus venenosus gramineus	·	·	·	·	·	·	·	+	1·20	2·55	·	2·35	·	1·10	·
Zigadenus paniculatus	·	·	·	+·2	·	·	·	·	·	·	·	·	·	·	·
ANNUALS															
Agoseris heterophylla	+·18	·	·	1·20	+·2	1·8	·	·	·	·	·	·	·	+·5	·
†*Agrostis interrupta*	·	·	·	·	·	·	·	·	·	·	·	·	·	1·25	·
†*Bromus japonicus*	·	·	·	1·25	·	+·15	·	·	·	+·2	7·75	·	·	+·2	·
†*Bromus mollis*	·	·	·	·	+·8	·	·	·	·	·	·	·	·	+·8	·
†*Bromus tectorum*	2·72	+	1·45	1·45	4·90	3·55	+·8	·	+·2	+·2	+·10	·	·	·	1·25
Chenopodium leptophyllum oblongifolia	·	·	·	·	·	·	·	·	·	+·2	·	·	·	·	·
Clarkia pulchella	·	·	·	·	+	+	·	·	·	·	·	·	·	·	·
Collinsia parviflora	6·78	1·48	3·95	·	3·93	·	1·28	+·20	1·30	2·72	+·5	·	·	2·80	+·8
Collomia grandiflora	·	·	·	·	+	·	·	·	·	·	·	·	·	·	·
Collomia linearis	2·88	·	2·75	·	+·15	·	·	·	+·10	1·48	+·18	1·55	·	·	2·78
Crocidium multicaule	·	·	·	1·28	2·75	+·15	·	·	·	·	·	·	·	·	·
Cryptantha ambigua	·	·	·	·	·	·	·	·	·	1·55	·	+	·	·	·
Descurainia pinnata	·	+·2	·	·	·	·	·	·	·	·	·	·	·	·	·
Draba verna	·	·	1·38	1·45	2·75	+·10	·	·	·	·	+·2	·	·	3·90	·
Epilobium paniculatum	+·2	+·2	+·5	2·68	11·95	4·45	·	·	·	+·2	+·15	+·2	·	1·28	+·2
Festuca confusa	·	·	·	1·15	·	·	·	·	·	·	·	·	·	·	·
†*Festuca dertonensis*	·	·	·	2·45	·	·	·	·	·	·	·	·	·	·	·
Festuca octoflora	·	·	·	·	·	·	·	·	·	1·52	·	·	·	·	·
Festuca pacifica	·	·	·	·	+·15	·	1·28	·	·	+·5	·	·	·	·	·
Galium aparine	·	·	·	·	·	+	·	·	·	·	·	·	·	·	·
Gayophytum nuttallii lasiospermum	·	·	·	·	·	·	·	·	+·5	·	·	1·22	·	·	·
†*Lactuca serriola (seedlings only)*	·	·	·	·	+·5	·	·	·	·	·	+·10	·	·	1·8	+·5
Lagophylla ramosissima	·	·	+·2	·	·	·	·	·	·	·	·	·	·	·	·
Lappula redowskii	·	·	+·8	·	·	·	·	·	·	·	·	·	·	·	·
†*Lepidium perfoliatum*	1·30	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Linanthus septentrionalis	·	·	·	·	·	·	·	·	·	·	·	1·35	·	·	·
Madia exigua	·	·	·	·	+	·	·	·	+·5	1·58	·	·	·	·	·
Microsteris gracilis	2·70	·	·	+·2	·	·	1·20	+·2	+·2	2·65	+·15	·	·	·	+·5
Montia linearis	·	·	+·8	·	2·60	·	·	·	·	·	·	·	·	1·28	·
Montia perfoliata	·	·	2·75	+·2	+·18	+·8	·	·	·	·	·	·	·	·	·
†*Myosotis micrantha*	·	·	·	·	·	·	·	·	·	·	·	·	·	1·3[illegible]	·

(Continued)

Table B-8. *Purshia tridentata-Festuca idahoensis* (stands 77-195), *Festuca idahoensis-Eriogonum heracleoides* (stands 99-105) and *Agropyron spicatum-Eriogonum heracleoides* (stand 101) associations. continued

Stand number	77	78	91	123	124	125	126	157	194	195	99	102	103	105	101
Plantago patagonica	·	·	·	·	·	·	3·85	·	1·38	1·48	1·48	2·65	·	+·2	·
Polemonium micrantha	·	·	+·2	·	1·32	·	·	·	·	·	·	·	·	·	·
Polygonum douglasii	1·52	+	·	·	·	·	·	·	·	1·40	1·30	·	·	·	+·20
†*Rhinanthus cristi-galli*	·	·	·	·	·	·	·	·	·	·	·	1·42	+·2	·	·
†*Sisymbium altissimum*	+	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Stellaria nitens	·	·	·	+·2	+·8	+·5	·	+·5	·	·	·	·	·	+·12	·
INDIGENES IN 40 PLOTS (4m²)	32	21	22	24	30	18	28	28	30	41	30	28	21	32	22
TOTAL COVERAGE OF PERENNIAL FORBS	79	39	10	31	27	23	10	65	28	65	18	25	51	29	23
TOTAL COVERAGE	228	196	161	157	178	142	175	213	187	196	191	191	187	156	184

Table B-9. *Artemisia tridentata-Stipa comata*, *Purshia tridentata-Stipa comata* and *Purshia tridentata-Agropyron spicatum* associations.

	Artemisia-Stipa											*Purshia-Stipa*					*Purshia-Agropyron*		
Stand number	24	25	36	80	129	130	170	171	188	189	190	21	22	128	137	196	29	79	127
County	Chela	Okano	Grant	Okano	Adams	Chela	Chela	Frank	Okano	Okano	Okano	Okano	Okano	Chela	Frank	Okano	Okano	Okano	Chela
Township & section	28N1	32N18	28N11	34N5	15N32	28N33	27N4	14N3	33N26	36N6	37N19	39N28	35N2	28N22	14N5	35N2	29N24	35N24	27N4
Range	23E	25E	30E	26E	29E	23E	23E	29E	25E	27E	27E	27E	26E	23E	28E	26E	23E	21E	23E
Altitude in meters	232	262	450	444	225	388	380	331	369	284	367	289	342	398	362	341	274	773	388
Aspect & % slope	0	ESE23	WNW7	E14	ENE11	0	0	N19	NNW10	N5	0	WSW9	SSW9	NW4	NE14	N3	WNW2	SW28	NW13
Soil classification																			
USDA 1938	BrxRe	BrxRe	CtxRe	CtxRe	Sz	Re	---	---	---	---	---	BrxRe	BrxRe	Re	Sz	---	BrxRe	ChxRe	Re
Series	Pogue	Ewall	Ellis	Haas*	Royal	Chela	-----	-----	-----	-----	-----	Skaha	Ewall	Chela	Royal	-----	Malag	Conco	Quinc
Textural Class	FSaL	SaL	VFSaL	SiL	FSaL	PFSaL	-----	-----	-----	-----	-----	FSaL	SaL	PSaL	FSa	-----	GrStL	GrSaL	Sa
USDA 1960	tHap	tXps	cHap	tXth	mCam	tVit	-----	-----	-----	-----	-----	tXps	tXps	tVit	mCam	-----	tTnt	tHap	tTnt
pH 1st decimeter	6.2	6.5	6.6	7.9	6.9	6.6	6.6	7.3	5.9	6.2	6.4	6.7	6.5	6.6	7.4	6.1	6.5	6.5	6.5
pH 2nd decimeter	7.0	6.8	7.2	7.9	7.6	7.2	7.1	7.7	6.6	7.6	6.8	7.4	6.8	8.2	7.7	6.8	6.6	6.7	6.8
Mean moisture equiv., upper 5 dm	7.8	6.3	15.7	20.8	9.4	15.2	7.1	8.3	8.7	13.7	10.4	8.1	5.7	20.9	6.7	9.1	12.6	15.8	2.9
Darkest horizon (10YRm)	4.5/2	3.5/2	3/2.5	4/1	3/3	3/3	---	---	---	---	---	3/2	4/2	3/2	3/3	---	3/3	3/3	5/2
MEDIUM SHRUBS																			
Artemisia tridentata tridentata	6·12	2·15	11·25	10·28	15·23	17·45	21·38	+	21·45	5·22	21·38	·	3·8	·	·	+	·	·	·
Artemisia tripartita	·	·	·	·	·	·	·	·	+·2	1·10	·	+·5	·	+	·	+	·	·	·
Chrysothamnus nauseosus albicaulis	+	+	·	·	·	·	·	·	·	·	·	1·10	·	·	·	+	·	·	16·28
Chrysothamnus viscidiflorus	·	·	·	·	+	·	·	·	·	·	·	·	·	·	+·2	·	·	·	·
Leptodactylon pungens	·	·	·	·	·	1·2	·	·	·	·	·	+	1·10	·	·	+	·	·	·
Purshia tridentata	+	+	·	·	·	·	·	·	·	·	·	19·28	12·20	24·33	13·18	20·30	9·15	11·25	15·25
Tetradymia canescens	+	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
LOW SHRUBS																			
Arenaria franklinii	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+·2	·	·	·	·
Artemisia frigida	·	·	·	·	·	·	·	·	·	·	·	4·38	·	·	·	·	·	·	·
Erigeron filifolius	1·10	+·5	+·8	·	·	+·2	+	·	·	+·10	·	·	+	+·5	+·2	·	+	+·2	+
Erigeron linearis	·	·	·	+·18	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Eriogonum heracleoides	·	+	·	·	·	·	·	·	·	2·2	·	·	+	+	·	+	6·25	·	·
Eriogonum niveum	+·2	1·18	·	+	·	·	1·20	·	·	+	·	2·18	1·10	·	+	1·10	+	+·2	3·13
Opuntia fragilis	+	·	·	·	·	·	·	·	·	·	·	+	+	·	·	·	·	·	+·2
Phlox longifolia	·	1·3	·	1·25	+	+·2	·	·	3·40	11·75	2·35	+	·	1·35	4·23	·	·	·	·
PERENNIAL GRAMINOIDS																			
Agropyron spicatum	·	·	·	+	+	·	·	·	·	·	·	·	·	·	2·5	·	32·80	88·99	35·90

(Continued)

Table B-9. *Artemisia tridentata-Stipa comata*, *Purshia tridentata-Stipa comata* and *Purshia tridentata-Agropyron spicatum* assocs. cont.

	Artemisia-Stipa											*Purshia-Stipa*					*Purshia-Agropyron*		
Stand number	24	25	36	80	129	130	170	171	188	189	190	21	22	128	137	196	29	79	127
Koeleria cristata	·	·	+	·	+	·	·	·	·	·	·	·	·	·	3·15	·	·	·	·
Oryzopsis hymenoides	·	·	·	·	+·10	·	+	·	·	·	·	·	·	·	9·15	·	·	·	+·2
Poa ampla	·	·	+	·	·	·	4·8	·	·	·	·	·	·	·	·	·	·	·	·
Poa secunda	28·99	9·73	29·99	24·99	33·99	2·83	26·99	90·99	28·90	32·99	15·98	22·99	19·98	22·99	53·99	32·95	36·95	·	14·53
Sitanion hysterix	·	·	·	·	+	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Sporobolus cryptandrus	·	1·12	·	·	·	·	·	·	·	·	·	+	+	·	·	·	·	·	·
Stipa comata	66·99	74·99	80·99	90·99	80·99	84·99	74·99	53·99	82·99	43·95	88·99	55·99	59·99	85·99	66·93	82·99	·	·	3·13
Stipa elmeri	·	·	·	·	·	·	·	·	·	·	·	·	·	3·20	·	·	·	·	·
Stipa thurberiana	·	·	+	·	·	·	·	·	·	·	·	·	·	·	·	1·12	6·20	·	·
PERENNIAL FORBS																			
Achillea millefolium lanulosa	·	·	+	·	+·2	+·5	+·5	+	·	·	·	·	+·2	+	1·8	·	+	1·20	2·5
Antennaria dimorpha	+·?	·	·	+·2	·	·	·	·	8·82	·	·	1·10	·	·	+·2	·	+·2	+	·
Arabis holboellii	·	·	+	·	·	+·5	+·5	·	·	·	·	+	·	·	·	·	·	·	1·10
†*Artemisia campestris scouleriana*	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+
Astragalus purshii	·	+	·	·	·	·	·	·	·	·	·	2·15	·	+·2	·	·	·	+·2	·
Astragalus spaldingii	·	·	17·38	·	+	·	·	·	·	·	·	·	·	·	+	·	·	·	·
Astragalus sclerocarpus	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+	·	·	·	·
Balsamorhiza careyana	·	·	·	·	·	·	·	·	·	·	·	·	·	·	1·5	·	·	·	·
Balsamorhiza sagittata	+	2·5	·	·	·	·	·	·	·	·	·	·	+	·	·	·	4·8	26·52	·
Brodiaea douglasii	+	·	·	·	·	·	·	·	·	·	·	·	+	+	·	+·2	·	·	·
Calochortus macrocarpus	+	+·8	2·25	+·5	+·2	+·2	·	·	3·75	·	+·12	+·2	·	·	+	1·22	·	+	·
Castilleja thompsonii	·	·	+·2	+	·	·	+	·	·	·	·	·	·	·	·	·	·	·	·
†*Centaurea diffusa* (seedl. only)	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+·5	·
Chaenactis douglasii	·	·	·	·	·	+·2	+	·	·	·	·	·	·	·	·	·	+	·	+·2
Comandra umbellata pallida	·	+	·	·	·	·	·	·	·	·	·	·	·	+	·	·	·	·	·
Crepis atribarba originalis	+·2	+	+	·	·	·	+	·	·	·	·	·	·	+	+	·	·	1·12	·
Crepis barbigera	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+	·	·
Delphinium nuttallianum	·	+	·	·	·	·	·	+·8	·	·	·	·	·	·	·	·	·	·	·
Erigeron pumilus intermedius	+	·	+·2	+·12	·	+·8	·	·	1·15	+·2	·	+	·	1·48	·	·	+	·	·
Eriophyllum lanatum integrifolium	·	·	·	·	+	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Erisymum	·	·	·	·	+	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Frasera albicaulis	·	·	·	·	·	·	·	·	·	·	·	·	·	+	·	·	·	·	·
Fritillaria pudica	·	·	·	·	·	·	·	·	·	·	·	·	+	·	·	·	+·8	·	·
Gaillardia aristata	·	·	·	·	·	·	·	·	·	·	·	·	·	+	·	·	·	·	·
Helianthella uniflora douglasii	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	2·5	·
Hydrophyllum capitatum	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+	·
Lewisia rediviva	·	·	·	·	·	·	·	·	·	3·82	·	+	+	·	·	·	·	·	·
Lithophragma bulbifera	2·10	2·55	·	+·5	·	+·5	·	·	1·22	1·38	1·18	5·95	3·88	·	·	2·70	14·95	·	·
Lithophragma parviflora	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+·8	·	·
Lithophragma tenella thompsonii	·	1·10	·	+·10	·	·	·	·	·	·	·	·	·	+·5	·	1·38	·	·	·
Lithospermum ruderale	·	·	·	·	·	·	+	·	·	·	·	·	·	·	·	·	·	+	·
Lomatium ambiguum	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+·2	+·2	·
Lomatium macrocarpum	·	·	+·2	·	·	·	·	·	·	·	·	+·5	·	·	·	·	5·30	1·12	+·10

(continued)

Table B-9. *Artemisia tridentata-Stipa comata, Purshia tridentata-Stipa comata* and *Purshia-tridentata-Agropyron spicatum* assocs. cont.

	Artemisia-Stipa											*Purshia-Stipa*					*Purshia-Agropyron*		
Stand number	24	25	36	80	129	130	170	171	188	189	190	21	22	128	137	196	29	79	127
Lomatium triternatum	·	·	+	·	·	·	·	·	·	·	·	·	·	+	·	·	·	·	·
Lupinus leucophyllus	·	·	·	·	·	·	·	·	23·65	·	·	·	·	·	·	·	·	·	·
Lupinus sericeus	1·5	·	+·8	+	·	3·20	+	·	·	·	3·22	·	·	1·5	·	·	·	1·5	·
Microseris troximoides	·	·	·	·	·	·	·	·	·	1·12	·	·	+	+·2	·	·	+·2	·	·
Oenothera pallida pallida	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+
Phacelia hastata leucophylla	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+·2	·
Ranunculus glaberrimus	·	·	·	·	·	+·18	·	·	·	·	·	·	·	·	·	·	·	·	·
†*Tragopogon dubius*	·	·	+	+·2	+·2	·	·	·	·	+·2	1·20	·	·	·	·	+·2	+	·	·
Zigadenus venenosus gramineus	·	·	·	·	·	·	·	·	·	·	·	·	+	·	·	·	·	·	·
ANNUALS																			
Agoseris heterophylla	·	·	·	·	·	+·2	·	·	·	·	·	·	·	·	·	·	·	·	·
†*Bromus racemosus*	·	·	·	·	·	·	·	·	·	·	·	·	·	+	·	·	·	·	·
†*Bromus tectorum*	1·32	83·99	1·25	4·88	1·25	9·99	2·90	5·88	·	·	2·85	2·92	1·42	4·58	2·48	1·22	64·99	1·35	5·93
†*Camelina microcarpa*	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+·5	·
Chenopodium leptophyllum	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+·2	·	·	·	+
Collinsia parviflora	·	·	·	·	·	·	·	·	·	·	+·10	·	+·2	+·2	·	+·8	·	·	·
Collomia grandiflora	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	1·50	·
Collomia linearis	+·5	·	+·18	·	·	·	·	·	·	·	·	·	+·2	·	·	+·8	1·38	4·90	·
Cruptantha ambigua	·	+·5	·	·	·	1·28	·	·	·	+·2	+·2	·	·	1·23	·	+·20	·	·	·
Descurainia pinnata	·	·	·	+·5	·	·	·	·	·	·	·	·	·	·	+	·	·	3·68	+·2
Draba verna	·	+·8	3·88	1·42	·	·	·	1·42	·	2·98	+·2	5·85	7·93	·	·	2·68	+·2	·	·
Epilobium paniculatum	·	+·5	·	·	·	1·28	·	·	+·5	+·2	1·25	+	+·2	1·20	·	1·30	·	+·18	·
Festuca octoflora	2·72	+·18	2·73	2·82	1·45	1·53	+·5	·	·	2·98	+·12	2·78	2·98	2·90	·	1·50	·	·	·
Festuca pacifica	3·98	1·60	2·73	·	·	1·35	2·98	·	1·58	2·98	+·12	2·85	3·98	1·45	+·13	1·38	+·12	·	·
Gilia minutiflora	·	·	·	·	+·18	+·2	·	+·2	·	·	·	·	·	·	+·18	·	·	·	·
Gayophytum nuttallii	·	·	·	·	·	1·38	·	·	·	+·2	+·2	·	+·2	4·65	·	·	+·2	·	·
†*Lactuca serriola (seedl. only)*	·	+·3	+·15	·	·	+·2	·	·	·	·	·	·	·	+·2	·	·	·	+·2	·
Lappula redowskii	·	·	·	·	+	·	·	·	·	·	·	·	·	·	2·8	·	·	·	·
Lepidium densiflorum elongatum	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+·18	·
Lepidium virginicum	·	+·2	·	·	·	·	·	·	·	·	·	·	+	·	·	·	·	·	·
Linanthus pharmaceoides	·	·	·	·	·	·	·	·	·	·	·	·	·	+·2	·	+·12	·	·	·
Linanthus septentrionalis	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	1·28	·	·
Linanthus	·	·	·	·	·	·	·	·	·	·	·	·	2·10	·	·	·	·	·	·
Madia exigua	·	·	·	·	·	·	·	·	·	·	·	·	·	1·30	·	·	·	·	·
Madia gracilis	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+	·
Mentzelia albicaulis	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+
Microsteris gracilis	+·13	3·90	+·3	·	·	·	·	·	+·5	1·50	1·40	1·38	2·80	·	·	2·70	+	·	·
†*Myosotis micrantha*	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Myosurus aristatus	·	·	+·10	·	·	·	·	·	·	1·55	+·2	·	·	·	·	·	+·5	·	·
Oenothera andina	·	+	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Orthocarpus barbatus	·	·	·	·	·	·	·	·	·	+	·	·	·	+	·	·	·	·	·
Phacelia linearis	·	+	·	·	·	·	·	·	·	·	·	·	+	·	·	·	·	·	+·2
Plagiobothrys tenellus	·	+	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Plantago patagonica	3·95	3·78	3·83	7·82	+·15	2·75	+·15	2·75	·	3·99	1·50	2·92	4·95	2·88	2·60	1·25	1·28	·	·
Polemonium micranthum	·	1·5	·	·	·	·	·	·	·	·	·	+·5	·	·	·	·	·	·	·
Polygonum douglasii	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+·5	1·55	+·8

(continued)

Table B-9. *Artemisia tridentata-Stipa comata, Purshia tridentata-Stipa comata* and *Purshia tridentata-Agropyron spicatum* assocs. cont.

	Artemisia-Stipa											*Purshia-Stipa*					*Purshia-Agropyron*		
Stand number	24	25	36	80	129	130	170	171	188	189	190	21	22	128	137	196	29	79	127
Salsola kali	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+·8	·	·	·	+·8
Sisymbrium altissimum	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+	+·10	·
INDIGENES IN 40 PLOTS ($4m^2$)	14	19	17	14	9	22	10	6	13	20	17	18	17	20	18	19	21	19	15
TOTAL COVERAGE OF PERENNIAL FORBS	3	5	19	+	+	3	+	+	36	5	5	8	3	2	2	4	23	32	3
TOTAL COVERAGE	118	184	150	139	130	123	130	151	171	110	136	125	119	153	158	149	179	141	94

Table B-10. *Stipa comata-Poa secunda* association (stands 86-169), *Stipa comata-Poa secunda* association, *Eriogonum niveum* phase (stands 172, 199), and *Artemisia tripartita-Stipa comata* association (stands 185-187).

		86	87	168	169	172	199	185	186	187
Stand number		86	87	168	169	172	199	185	186	187
County		Frank	Frank	Adams	Frank	Okano	Okano	Okano	Okano	Okano
Township and section		13N19	12N1	15N25	14N9	30N6	33N4	30N13	31N36	33N3
Range		34E	33E	34E	35E	25E	27E	30E	30E	27E
Altitude in meters		413	412	426	354	341	435	547	554	531
Aspect and percent slope		E13	E13	S4	S14	E4	NE9	WNW20	SSW24	N18
Soil Classification	USDA 1938	Sz	Sz	Bn	Bn	---	---	---	---	---
	Series	Shano	Shano	Wacot	Magal	-----	-----	-----	-----	-----
	Textural Class	VFSaL	VFSaL	LFSa	LSa	-----	-----	-----	-----	-----
	USDA 1960	mCam	mCam	tTnt	cHap	-----	-----	-----	-----	-----
pH	1st decimeter	7.9	7.9	6.5	7.3	6.4	6.1	5.7	6.2	6.0
	5th decimeter	8.1	8.1	7.0	7.5	7.4	7.0	6.5	6.3	6.9
Mean moisture equiv., upper 5 dm		13.8	13.5	8.8	9.1	6.1	8.2	12.3	9.9	10.6
Darkest horizon (10YRm)		3/3	3/3	4/2	3/2	---	---	---	---	---
MEDIUM SHRUBS										
Artemisia tripartita		·	·	·	·	·	·	5·55	7·15	11·58
Chrysothamnus nauseosus albicaulis		2·5	+	4·8	·	·	+·2	+·5	+	·
Chrysothamnus viscidiflorus		+·8	·	1·5	·	·	·	·	·	·
Leptodactylon pungens		·	+·2	+	·	·	·	·	·	·
Rosa		·	·	·	·	·	·	+	·	·
LOW SHRUBS										
Arenaria congesta cephaloidea		·	·	·	·	·	·	·	+·2	4·48
Erigeron piperianus		+	·	·	·	·	·	·	·	·
Eriogonum niveum		+	·	1·12	+	10·70	6·48	·	+	·
Phlox longifolia		·	1·22	+·5	·	·	·	·	·	5·72
PERENNIAL GRAMINOIDS										
Agropyron spicatum		·	1·2	·	·	·	·	·	·	·
Koeleria cristata		+	·	+	+	·	·	·	·	·
Poa secunda		72·99	51·99	71·99	52·99	25·99	36·99	40·99	35·99	10·99
Sporobolus cryptandrus		·	·	·	·	·	·	·	1·5	·
Stipa comata		83·99	95·99	50·99	52·90	1·20	10·82	78·99	62·99	76·99
PERENNIAL FORBS										
Achillea millefolium lanulosa		+·2	+	·	+	·	·	+·5	·	·
Antennaria dimorpha		·	·	+	+	·	·	·	·	·
Astragalus lentiginosus		+	·	·	·	·	·	·	·	·
Balsamorhiza careyana		·	·	+	+	·	·	·	·	·
Calochortus macrocarpus		·	·	·	·	·	+·12	+·20	+·2	1·58
Chaenactis douglasii		·	·	+	·	·	·	·	·	·
Crepis atribarba		·	·	·	·	·	·	·	·	+
Erigeron pumilus intermedius		+	·	·	·	·	+	+·5	·	+·12
Erisymum asperum		·	·	·	+	·	·	·	·	·

(Continued)

Table B-10. *Stipa comata-Poa secunda* association (stands 86-169), *Stipa comata-Poa secunda* association, *Eriogonum niveum* phase (stands 172, 199), and *Artemisia tripartita-Stipa comata* association (stands 185-187). continued

Stand number	86	87	168	169	172	199	185	186	187
Fritillaria pudica	·	·	·	·	·	·	·	·	+
Lewisia rediviva	·	·	·	·	·	·	+	1·32	·
Lithophragma bulbifera	3·42	2·45	4·75	·	2·99	1·55	+·10	1·60	·
Lomatium macrocarpum	+·2	·	·	·	1·10	·	·	+	·
Lupinus leucophyllus	·	·	·	1·8	·	·	+·8	+·2	+·5
Microseris troximoides	·	·	·	·	+·2	+	+·2	·	·
†*Tagopogon dubius*	+·2	3·38	·	+·5	·	·	·	·	·
ANNUALS									
Agoseris heterophylla	·	+	·	·	·	·	+·2	·	·
Bromus tectorum	7·99	14·99	1·52	3·98	+·8	+·2	+·12	1·55	+·2
Conyza canadensis	+·2	·	·	·	·	·	·	·	·
Draba verna	2·98	2·68	2·85	+·10	+·2	+·2	3·99	3·99	+·2
Epilobium paniculatum	·	·	+·5	+·5	·	1·30	+·12	+·20	·
Festuca octoflora	+·10	+·2	·	·	·	·	·	·	·
Festuca pacifica	+·15	·	1·22	·	3·99	+·5	2·99	2·75	·
Gilia (minutiflora?)	·	·	+·15	·	·	·	·	·	·
†*Holosteum umbellatum*	·	·	+·2	·	·	·	·	+·18	·
†*Lactuca serriola (seedl. only)*	·	1·32	+·2	·	·	·	·	·	·
Microsteris gracilis	·	·	·	·	+·8	·	2·82	1·58	+·2
Myosurus aristatus	+·5	·	·	·	·	·	·	·	·
Plantago patagonica	12·99	8·80	2·88	5·99	2·98	2·95	2·72	·	2·62
†*Sisymbrium altissimum*	·	·	·	+	·	·	·	·	·
Stellaria nitens	·	·	·	·	·	·	·	1·12	·
INDIGENES IN 40 PLOTS ($4m^2$)	14	10	13	7	11	11	17	15	12
TOTAL COVERAGE OF PERENNIAL FORBS	3	5	4	1	3	1	+	2	1
TOTAL COVERAGE	181	178	137	113	44	56	132	115	109

Table B-11. *Lithosolic habitats,* in part.

	Artemisia rigida-Poa							*Intermediates*						*Eriogonum thymoides-Poa*					
Stand number	50	49	51	52	114	236	140	112	111	110	89	238	113	45	108	141	47	84	46
County	Linco	Whitm	Adams	Linco	Bento	Whitm	Klick	Grant	Linco	Yakim	Yakim	Dougl	Kitti	Dougl	Yakim	Klick	Klick	Dougl	Dougl
Township & section	22N19	21N34	15N9	26N11	13N23	11N17	6N31	20N7	21N5	7N21	15N5	24N8	17N13	25N31	7N8	7N30	6N11	26N13	26N29
Range	39E	43E	36E	32E	24E	46E	21E	23E	33E	21E	14E	25E	21E	23E	19E	21E	20E	27E	26E
Altitude in meters	632	728	418	664	190	270	831	374	---	601	1320	376	610	754	932	908	934	680	670
Aspect & % slope	SSE6	S17	SSE20	0	0	SE20	N3	SW8	SE9	SE10	S17	NE10	SE10	WSW10	E6	NNE4	0	NNW3	NE6
Soil classification																			
USDA 1938	Litho	Litho	Litho	Litho	Litho	Litho	BnxLi	Litho	Litho	Litho	Litho	Litho	Litho	Litho	Litho	Litho	Litho	Litho	Litho
Series	-----	Gwin	-----	-----	Licks	-----	Bakeo	-----	-----	Bakeo	-----	-----	-----	Gwin	-----	Bakeo	?	-----	Gwin
Textural Class	---	FSaL	---	---	FSaL	---	L	---	---	SiL	---	---	---	L	---	SiL	SiL	---	StL
USDA 1960	-----	IAgx	-----	-----	IHap	-----	IHap	-----	-----	IHap	-----	-----	-----	IAgx	-----	IHap	tAgx	-----	IAgx
pH Upper decimeter	6.3	6.4	---	6.4	6.6	---	6.3	6.5	6.4	---	6.3	---	6.6	5.9	6.6	6.4	6.7	6.6	6.4
Moisture Equiv., upper decimeter	21.4	20.0	----	23.5	14.6	----	17.6	15.0	20.4	18.0	13.7	----	15.1	19.3	19.7	18.0	19.4	20.1	21.3
Depth index in Cm	9.0	11.3	10.8	20.5	----	----	10.5	11.3	6.0	8.9	----	----	----	----	----	19.3	20.7	18.8	7.0
Darkest Horizon (10YRm)	---	3/2	---	---	4/3	---	4/2	---	---	3/3	---	---	---	4/3	---	3/2	3/2	---	3/3
MEDIUM SHRUBS																			
Chrysothamnus nauseosus albicaulis	·	·	·	·	·	1·4	·	·	·	·	·	·	·	·	·	·	·	·	·

(Continued)

Table B-11. *Lithosolic habitats,* in part. continued

	Artemisia rigida-Poa							*Intermediates*						*Eriogonum thymoides-Poa*					
Stand number	50	49	51	52	114	236	140	112	111	110	89	238	113	45	108	141	47	84	46
LOW SHRUBS																			
Arabis cusickii	·	+	·	·	·	·	·	·	·	·	·	+·2	·	1·37	·	·	·	·	+
Arenaria capillaris americana	·	·	·	·	·	·	·	·	·	·	2·60	·	·	·	·	·	·	·	·
Arenaria congesta cephaloidea	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+·2	·
Arenaria franklinii	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+·2	·	+	·	·
Artemisia rigida	29·80	27·72	25·66	14·38	10·33	34·74	10·35	12·38	19·58	13·28	6·20	17·52	9·38	·	·	·	·	·	·
Erigeron linearis	·	·	·	·	·	·	·	·	·	·	1·13	+	·	+	·	·	·	+·2	1·7
Erigeron piperianus	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+·2	·	+	·	·
Eriogonum compositum leianthemum	·	+	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Eriogonum douglasii douglasii	·	·	·	·	·	·	·	·	·	·	+	·	·	·	·	·	·	·	·
Eriogonum douglasii tenue	·	·	·	·	·	·	+·8	·	·	·	·	·	·	·	·	·	23·68	·	·
Eriogonum heracleoides	·	+	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Eriogonum niveum	·	·	·	·	·	+·4	·	·	+·2	·	·	·	·	·	·	·	·	1·2	·
Eriogonum sphaerocephalum	·	·	·	·	·	·	·	·	+·2	·	·	3·16	+·2	·	·	·	·	·	·
Eriogonum thymiodes	·	·	·	·	·	·	·	5·48	4·25	+	2·10	1·12	+·10	3·33	4·32	3·32	·	14·75	1·60
Haplopappus stenophyllus	·	·	·	+·3	·	·	·	·	·	1·8	+	6·54	9·68	8·60	4·65	3·30	+·16	4·42	1·70
Opuntia polyacantha	·	·	·	·	·	1·18	·	·	·	·	·	·	·	·	·	·	·	·	·
Pediocactus simpsonii	·	·	·	·	·	·	·	·	·	·	·	·	+·2	·	·	·	·	·	·
Pentstemon gairdneri	·	·	·	·	·	·	+·2	·	·	·	1·13	+·4	·	+	·	·	+	·	·
Phlox (caespitosa?)	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Phlox hoodii	·	·	·	·	·	·	+·2	·	·	2·48	1·10	+·2	2·10	·	+	+·20	6·56	·	·
Phlox longifolia	·	·	·	·	·	·	·	·	·	·	·	2·22	·	·	·	·	+·4	1·2	·
Phoenicaulis cheiranthoides	·	·	·	·	·	·	·	·	·	+	·	·	·	·	+·2	·	·	·	·
Sedum stenopetalum	·	·	·	·	·	·	·	·	·	·	3·99	·	·	·	·	·	·	·	·
Talinum spinescens	·	·	·	+·5	·	·	·	·	·	·	·	1·6	·	·	·	·	·	+·2	1·33
PERENNIAL GRAMINOIDS																			
Agropyron spicatum	·	+	3·6	·	·	+	·	·	·	·	·	2·6	+·2	·	·	·	·	·	·
Danthonia unispicata	·	·	·	·	·	·	·	·	·	·	3·58	·	·	·	·	·	·	·	·
Oryzopsis hendersoni	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Poa secunda	33·99	13·94	32·99	31·99	31·99	2·22	34·99	20·99	36·99	26·99	2·55	26·96	14·99	9·68	36·99	29·99	38·99	21·99	9·97
Sitanion hordeoides	+	1·6	·	1·8	·	·	·	·	·	1·4	1·10	+·4	2·18	1·15	+·2	1·2	11·60	·	+·3
Stipa columbiana	·	·	·	·	·	·	·	·	·	·	1·8	·	·	·	·	·	·	·	·
Stipa thurberiana	·	·	·	·	·	·	·	+	·	·	·	+	·	·	·	·	·	·	·
PERENNIAL FORBS																			
Allium acuminatum	+·6	+	·	·	·	·	·	·	·	2·28	·	1·18	·	·	·	·	·	+·2	·
Allium douglasii	·	+	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Allium geyeri	·	·	·	+·3	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Allium macrum	·	·	·	·	·	·	+·2	·	·	·	·	·	·	+·2	·	·	·	·	·
Allium	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+	·	·
Antennaria dimorpha	+	·	·	·	·	·	+·2	+	+·2	+·4	·	+	·	·	·	+·2	3·28	·	+·2
Antennaria flagellaris	·	·	·	1·20	·	·	·	·	·	·	2·38	·	+	1·10	+·12	1·30	1·4	·	·
Arabis holboellii	·	·	·	·	·	·	·	·	·	·	+	·	·	·	·	·	·	·	·
Astragalus purshii glareosus	·	+	·	·	·	·	·	·	·	·	·	·	+	·	·	·	·	·	·
Astragalus speirocarpus	·	·	·	·	·	·	·	·	·	+·8	·	·	+	·	·	·	·	·	·
Balsamorhiza hookeri	·	·	·	·	·	·	·	·	·	·	·	3·12	+	·	·	·	·	·	·
Brodiaea douglasii	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+·5	·	+	·	·

(Continued)

Table B-11. *Lithosolic habitats,* in part. continued

	Artemisia rigida-Poa								*Intermediates*					*Eriogonum thymoides-Poa*					
Stand number	50	49	51	52	114	236	140	112	111	110	89	238	113	45	108	141	47	84	46
Calochortus macrocarpus	·	·	·	·	·	·	·	+	·	·	·	·	·	·	·	·	·	·	·
Castilleja thompsonii	·	·	·	·	·	·	·	·	·	·	+	·	+	·	·	·	·	·	·
Chaenactis douglasii	·	·	·	·	·	·	·	·	·	·	·	·	·	+·5	·	·	·	·	+
Crepis atribarbata originalis	·	·	·	·	·	·	·	+	·	·	·	·	·	·	·	·	·	·	·
Crepis modocensis rostrata	·	·	·	·	·	·	·	+	·	·	·	·	·	·	·	·	·	·	·
Delphinium nuttallianum	+	·	1·16	·	·	·	·	+	+·5	·	·	3·20	·	·	·	·	·	+·2	·
Erigeron poliospermus	·	·	·	·	1·18	·	·	+	·	+·20	·	+·2	·	1·20	+·10	·	·	·	·
Ericphyllum lanatum integrifolium	·	·	·	·	·	·	·	·	+	·	·	·	·	·	·	·	·	·	·
Fritillaria pudica	+·6	+	·	+·3	·	·	·	·	·	·	·	+·4	+·12	+·3	·	·	+	·	+
Lewisia rediviva	1·28	·	·	1·10	·	·	+·10	·	1·22	1·32	1·30	+·2	+·2	3·45	·	+·8	·	2·48	5·99
Lithophragma bulbifera	2·48	1·12	9·92	3·63	+·5	+·4	1·20	·	1·28	1·16	+·5	1·18	·	+·2	·	·	6·99	2·75	+·10
Lomatium canbyi	·	·	·	1·10	·	1·16	1·32	3·13	·	·	·	4·42	2·32	5·65	·	·	+·4	·	+
Lomatium farinosum	+·8	·	+·2	+·10	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Lomatium geyeri	·	·	·	·	·	·	·	·	1·38	·	·	+	·	·	·	·	·	·	·
Lomatium gormani	+	2·24	1·14	·	1·45	+·2	+·2	·	+	·	1·45	·	·	·	1·23	·	9·99	·	·
Lomatium grayii	·	·	·	·	·	·	·	·	·	·	+	·	·	·	·	·	·	·	·
Lomatium hambleniae	·	·	·	·	·	·	·	·	·	·	·	1·14	·	1·15	·	·	·	2·35	+·3
Lomatium leptocarpum	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Lomatium macrocarpum	3·26	5·60	·	·	+·2	+·2	+·12	·	+·2	+	·	·	·	·	·	11·99	+·8	·	·
Lomatium triternatum	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Lomatium watsonii	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Lupinus lepidus aridus	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+	·	·
Microseris troximoides	·	·	·	·	·	·	·	+	·	·	+·5	1·8	+·8	·	+	2·38	1·16	·	1·7
Orobanche uniflora	·	·	·	·	·	·	·	·	·	·	+·8	·	·	·	·	·	·	·	·
Ranunculus glaberrimus	+	·	·	+·5	·	·	·	·	·	·	·	+·8	·	·	·	·	+	+·2	+·3
Senecio integerrimus vaseyi	·	·	·	·	·	·	·	·	·	·	·	+	·	·	·	·	·	·	·
Sisyrinchium inflatum	·	·	·	+·3	·	·	·	·	·	9·99	1·35	·	·	·	3·42	·	+	·	·
†*Tragopogon dubius (seedl. only)*	+·16	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Trifolium macrocephalum	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Viol trinervata	·	·	·	·	·	·	·	·	·	·	·	·	1·40	16·95	5·85	4·70	·	·	·
ANNUALS																			
Agoseris heterophylla	·	·	·	·	·	+·4	·	·	·	·	·	·	·	·	·	·	·	·	·
÷*Bromus japonicus*	+	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
†*Bromus mollis*	+	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
†*Bromis tectorum*	+·20	29·99	44·99	1·38	2·98	12·96	+·15	+·2	5·95	1·24	·	+·8	+·2	2·68	2·70	+·2	+·4	1·38	+·10
Clarkia pulchella	+	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Collinsia parviflora	2·78	+·20	·	3·93	·	·	1·32	·	·	·	2·78	+·4	+·5	+	·	1·52	+·8	+·15	·
Collomia linearis	·	·	·	·	·	·	·	+·2	·	·	·	·	·	·	·	·	·	·	·
Crocidium multicaule	·	·	·	·	·	·	1·48	·	·	·	·	·	·	·	1·52	+·10	1·44	·	·
Cryptantha pterocarya	·	·	·	·	·	·	·	+	·	·	·	·	·	·	·	·	·	·	·
Cryptantha torreyana	·	·	·	·	·	·	·	·	·	·	·	·	+·2	·	·	·	·	·	·
Descurainia pinnata	·	·	·	·	+	+·12	·	+	+·2	·	·	+·12	+	·	·	·	·	·	·
÷*Draba verna*	3·92	3·99	12·99	2·93	·	+·4	1·55	·	2·68	·	·	·	·	·	2·95	·	·	+·15	·
Epilobium minutum	·	·	·	·	·	·	·	·	·	·	2·63	·	·	·	·	·	·	·	·
Epilobium paniculatum	2·58	1·16	+·2	6·88	·	+·2	1·28	·	+·10	+·4	+·5	+·10	·	·	+·5	1·25	1·28	1·32	·
†*Erodium cicutarium*	·	·	·	·	·	+·6	·	·	·	·	·	·	·	·	·	·	·	·	·

(Continued)

Table B-11. *Lithosolic habitats,* in part. continued

	Artemisia rigida-Poa							*Intermediates*						*Eriogonum thymoides-Poa*					
Stand number	50	49	51	52	114	236	140	112	111	110	89	238	113	45	108	141	47	84	46
Festuca arida	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Festuca octoflora	·	·	+·2	·	·	+	·	·	·	·	·	·	·	·	·	·	·	·	·
Festuca pacifica	·	1·26	+·6	3·15	+·8	1·26	·	·	+·5	·	·	·	+·15	·	·	·	·	·	·
Gilia minutiflora	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+	·
†*Holosteum umbellatum*	·	·	+	·	·	1·22	·	·	·	·	·	·	·	·	·	·	·	·	·
Idahoa scapigera	+·20	·	·	·	·	·	+·20	·	·	2·60	·	·	1·42	·	·	·	·	·	·
†*Lactuca serriola (seedlings only)*	1·36	1·30	1·56	·	·	1·34	·	·	·	·	·	+·2	·	·	·	·	·	·	+·10
Lappula redowskii	·	·	·	·	·	·	·	·	·	·	·	+·8	·	·	·	·	·	·	·
Lepidium densiflorum elongatum	·	·	·	·	·	·	·	·	·	·	·	+	·	·	·	·	·	·	·
Lepidium virginicum pubescens	·	·	·	·	·	·	·	·	·	·	·	·	·	+·18	·	·	·	·	·
Linanthus pharnaceoides	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+	·
Microsteris gracilis	1·24	+	·	+·10	+·5	3·90	2·72	·	·	2·76	+·5	·	+·20	+·20	1·38	2·72	1·36	2·90	1·43
Montia linearis	+·14	·	·	+·8	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Myosurus aristatus	+	·	·	+·15	·	·	+·5	·	·	+·8	·	+·2	·	·	·	·	·	2·95	·
Oenothera andina	·	·	·	·	·	·	·	+	·	·	·	+·6	·	·	·	·	·	·	+·7
Orthocarpus tenuifolius	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+	·
Pectocarya linearis penicillata	·	·	·	·	·	·	·	·	·	·	·	+·2	·	·	·	·	·	·	·
Phacelia linearis	·	·	·	·	·	+	·	·	·	·	·	·	·	·	·	·	·	·	·
Plantago patagonica	·	·	·	·	·	+·4	·	·	·	·	·	·	·	·	·	·	·	·	·
Plectritis macrocera	·	·	·	·	·	+·2	·	·	·	·	·	·	·	·	·	·	·	·	·
Polemonium micranthum	·	·	·	·	·	·	·	·	·	·	·	·	+·2	·	·	·	·	·	·
Polygonum douglasii	·	1·24	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Rigiopappus leptocladus	·	·	·	·	·	+	·	·	·	·	·	·	·	·	·	·	·	·	·
†*Sisymbrium altissimum*	·	+·4	·	·	·	·	·	+	·	·	·	·	·	·	·	·	·	·	+·13
Stellaria nitens	·	+·6	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
†*Triticum sativum (seedl. only)*	·	·	+·2	·	·	·	·	+·2	·	·	·	·	·	·	·	·	·	·	·
†*Ventenata dubia*	+	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
INDIGENES IN 40 PLOTS ($4m^2$)	14	12	11	21	8	17	19	5	15	16	22	30	20	17	17	15	17	19	14
TOTAL COVERAGE ON PERENNIAL FORBS	6	8	11	6	2	1	2	3	3	13	5	14	3	27	9	16	20	6	6
TOTAL COVERAGE	77	105	128	67	45	57	52	40	69	61	32	72	40	51	59	58	101	53	20

Table B-12. *Lithosolic habitats,* in part.

		Eriog. sphaeroceph.-Poa			*Eriog. doug.-Poa*		*Eriogonum niveum-Poa*					*Eriogonum microthecum-Poa*				
Stand number		44	116	176	90	142	115	85	173	174	175	182	177	178	179	180
County		Bento	Klick	Linco	Yakim	Klick	Whitm	Frank	Whitm	Adams	Adams	Spoka	Whitm	Whitm	Whitm	Whitm
Township & section		11N21	5N33	21N7	10N12	6N36	15N23	14N30	20N9	15N27	15N24	21N27	11N16	11N17	11N17	11N17
Range		25E	21E	33E	14E	19E	38E	37E	39E	36E	37E	43E	45E	45E	45E	45E
Altitude in meters		949	---	481	1113	946	432	279	600	365	331	699	268	228	268	275
Aspect & percent slope		ENE5	W2	N7	NE11	0	SSW7	SSW21	N17	SE9	SW11	S3	SSE58	WSW33	S35	S31
Soil Classification	USDA 1938	Litho	Litho	Litho	Litho	Litho	Litho	Litho	Litho	Lith	Litho	Litho	Litho	Litho	Litho	Litho
	Series	Liksk	Bakeo	-----	-----	Bakeo	-----	Rockl	-----	-----	Bakeo	-----	-----	-----	-----	-----
	Textural Class	SiL	L	---	---	SiL	---	GSiL	---	---	SiL	---	---	---	---	---
	USDA 1960	IHap	IHap	---	---	IHap	---	---	---	---	IHap	---	---	---	---	---

(Continued)

Table B-12. *Lithosolic habitats,* in part. continued

	Eriog. sphaeroceph.-Poa			*Eriog. doug.-Poa*		*Eriogonum niveum-Poa*						*Eriogonum microthecum-Poa*			
Stand number	44	116	176	90	142	115	85	173	174	175	182	177	178	179	180
pH Upper decimeter	6·6	6·7	---	5·9	6·0	6·7	7·4	6·0	6·4	6·5	7·0	7·4	7·5	7·4	7·0
Moisture equivalent, upper decimeter	17·5	17·3	---	18·3	23·6	19·2	21·7	21·5	21·4	20·2	20·9	12·8	11·9	12·5	13·0
Depth Index	---	12·5	---	---	21·1	8·3	6·3	---	7·0	5·6	7·5	4·9	9·8	---	---
Darkest horizon (10YRm)	2/2	3/4	---	---	3/2	---	3/2	---	---	2/2	---	---	---	---	---
MEDIUM SHRUBS															
Chrysothamnus nauseosus albicaulis	·	·	·	·	·	·	+	·	·	+	·	+	·	·	+
LOW SHRUBS															
Arabis cusickii	+	·	·	+	·	·	·	·	·	·	·	·	·	·	·
Arenaria congesta cephaloidea	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Arenaria franklinii	+·2	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Chrysopsis villosa villosa	·	·	·	·	·	·	·	·	·	·	·	·	+	·	·
Erigeron linearis	2·25	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Eriogonum douglasii	·	·	·	6·40	6·30	·	·	·	·	·	·	·	·	·	·
Eriogonum microthecum laxiflorum	·	·	·	·	·	·	·	·	·	·	·	17·45	14·45	15·40	12·42
Eriogonum niveum	·	·	·	·	·	+·2	2·22	7·50	5·32	1·20	14·18	+	+	+	+
Eriogonum sphaerocephalum	4·25	8·40	13·40	·	·	·	·	·	·	·	·	·	·	·	·
Eriogonum thymoides	·	·	+	1·12	·	·	·	·	·	·	·	·	·	·	·
Haplopappus stenophyllus	2·38	6·48	·	·	1·18	·	·	·	·	·	·	·	·	·	·
Opuntia polyacantha	·	·	·	·	·	·	·	·	·	·	·	+·2	+	+	+
Pentstemon garidneri	·	·	·	+·2	·	·	·	·	·	·	·	·	·	·	·
Phlox caespitosa	·	·	·	+	·	·	·	·	·	·	·	·	·	·	·
Phlox hoodii	·	2·20	·	·	10·42	·	·	·	·	·	·	·	·	·	·
Phlox longifolia	+	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Phoenicaulis cheiranthoides	·	·	+	·	·	·	·	·	·	·	·	·	·	·	·
Sedum stenopetalum	·	·	·	·	+·2	·	·	·	·	·	·	·	·	·	·
Talinum spinescens	·	·	·	+·10	·	·	·	·	·	·	·	·	·	·	·
PERENNIAL GRAMINIODS															
Agropyron spicatum	11·40	·	+	·	·	·	·	+·5	+	+	·	2·5	+·2	+·5	+·2
Danthonia unispicata	·	·	·	+·5	·	·	·	·	·	·	·	·	·	·	·
Oryzopsis hendersoni	·	·	·	1·25	·	·	·	·	·	·	·	·	·	·	·
Poa secunda	22·99	28·99	58·99	25·99	23·99	37·99	24·99	26·98	34·99	26·99	36·99	·	2·15	·	+
Sitanion hordeoides	1·10	1·10	·	+·8	+·2	·	·	·	·	·	·	·	·	·	·
Sitanion hysterix	·	·	+	·	·	·	+	·	·	·	·	·	·	·	·
Stipa thurberiana	1·5	·	+·5	·	·	·	·	·	·	·	·	·	·	·	·
PERENNIAL FORBS															
Achillea millefolium lanulosa	·	·	·	·	·	·	·	·	· ·	·	·	·	+	+·2	+·2
Allium acuminatum	·	+	·	+·2	·	·	2·40	·	·	+·10	·	·	·	·	·
Allium macrum	+·22	·	·	·	+	·	·	·	·	·	·	·	·	·	·
Antennaria flagellaris	·	·	·	3·85	1·35	·	·	·	·	·	·	·	·	·	·
Arenaria dimorpha	1·60	·	2·50	·	+·2	·	·	·	·	·	·	·	·	·	·
Astragalus purshii glareosus	+	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Balsamorhiza careyana	+	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Balsamorhiza hookeriana	·	·	·	+	1·12	·	·	·	·	·	·	·	·	·	·
Balsamorhiza rosea	+	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Brodiaea douglasii	·	2·53	·	·	·	·	·	·	·	·	·	·	·	·	·
Chaenactis douglasii	·	·	+	·	·	·	·	·	·	·	·	+·18	+·12	+·2	1·32
Cirsium	·	·	·	·	·	·	·	·	·	·	·	·	+	·	·
Cymopteris terebinthinus	·	·	·	·	·	·	·	·	·	·	·	+	·	·	·
Delphinium nuttallianum	·	·	1·18	·	·	·	·	·	·	·	·	·	·	·	·
Erigeron poliospermus	·	+	+	+·10	·	·	·	·	+	·	·	·	·	·	·

(Continued)

Table B. 12. *Lithosolic habitats*, in part. continued

	Eriog. sphaeroceph.-Poa			*Eriog. doug.-Poa*			*Eriogonum niveum-Poa*					*Eriogonum microthecum-Poa*			
Stand number	44	116	176	90	142	115	85	173	174	175	182	177	178	179	180
Erisymum asperum	·	·	·	·	·	·	·	·	·	·	·	+·18	+	+	+·15
Fritillaria pudica	·	·	+·5	·	+·5	·	·	·	·	·	·	·	+	·	+
Lewisia rediviva	·	·	·	3·60	·	·	·	·	·	·	·	·	·	·	·
Lithophragma bulbifera	·	·	2·70	+·8	1·15	·	·	·	+·5	·	1·32	·	·	·	·
Lomatium canbyi	·	+	·	+·15	·	·	·	·	·	·	·	·	·	·	·
Lomatium farinosum	·	·	·	·	·	·	·	·	2·75	10·90	+·5	·	·	·	·
Lomatium geyeri	·	+·13	·	·	·	·	·	·	·	·	·	·	·	·	·
Lomatium gormani	1·52	·	2·98	·	+	30·99	·	+·2	1·35	·	·	·	·	·	·
Lomatium hambleniae	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Lomatium leptocarpum	·	·	·	6·62	·	·	·	·	·	·	·	·	·	·	·
Lomatium macrocarpum	+	+·2	+·2	·	3·52	·	·	·	·	·	·	·	+	·	·
Lomatium triternatum	·	·	·	1·20	·	·	·	·	·	·	·	·	·	·	·
Lomatium watsoni	·	·	·	·	1·45	·	·	·	·	·	·	·	·	·	·
Lomatium	·	·	·	·	·	·	·	·	·	·	·	·	+	·	·
Lupinus sulphureus subsaccatus	2·10	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Microseris troximoides	·	·	+	2·20	3·43	·	·	·	·	·	·	·	·	·	·
Mentzelia laevicaulis	·	·	·	·	·	·	·	·	·	·	·	+	·	·	·
Orobanche uniflora	·	·	·	·	·	·	·	·	·	·	·	·	+	·	·
Petalostemon ornatum	·	·	·	·	·	·	·	·	·	·	·	+	·	·	·
Phacelia heterophylla	·	·	·	·	·	·	·	·	·	·	·	·	+	·	+
Physaria oregana	·	·	·	·	·	·	·	·	·	·	·	1·15	1·15	1·12	+
Ranunculus glaberrimus	·	·	+·2	·	·	·	·	·	·	·	·	·	·	·	·
Senecio integerrimus exaltatus	+	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Sisyrinchium inflatum	·	·	·	4·80	·	·	·	·	·	·	·	·	·	·	·
†*Tragopogon dubius (seedl. only)*	·	·	·	·	·	·	·	·	·	·	+·10	·	·	·	·
Trifolium macrocephalum	·	·	·	+·2	·	·	·	·	·	·	·	·	·	·	·
Viola trinervata	·	4·73	·	+	7·87	·	·	·	·	·	·	·	·	·	·
ANNUALS															
Agoseris heterophylla	·	·	·	+·2	·	·	·	·	·	·	·	·	·	·	·
†*Alyssum alyssoides*	·	·	·	·	·	·	·	·	·	·	·	2·65	·	·	·
Amsinckia tesellata	·	+·2	·	·	·	·	·	·	·	·	·	+	·	·	·
†*Bromus tectorum*	2·99	1·50	3·99	+·10	·	2·90	12·99	2·50	2·95	2·92	1·55	5·58	4·88	2·52	2·52
Collinsia parviflora	·	·	·	2·92	1·30	·	·	·	·	·	·	·	·	·	·
Conyza canadensis	·	1·40	·	·	·	·	1·45	·	·	·	·	·	·	·	·
Crocidium multicaule	·	·	·	·	+·2	·	·	·	·	·	·	·	·	·	·
Cryptantha flaccida	·	·	·	·	·	·	1·28	·	·	+	·	·	·	·	·
Descurainia pinnata	·	·	·	·	·	·	·	+·5	+	·	·	+·8	·	·	·
Draba verna	+	2·93	1·50	+·5	+·5	2·99	1·20	1·38	+·10	1·22	2·90	+·15	·	·	+·2
Epilobium paniculatum	+·5	+·2	+·12	2·78	+	·	·	·	+·5	·	+·12	·	·	·	·
†*Erodium cicutarium*	·	·	·	·	·	·	1·25	·	·	·	·	·	+·8	1·25	1·35
Festuca arida	·	·	·	+·2	·	·	·	·	·	·	·	·	·	·	·
Festuca pacifica	+·2	+·5	·	+	·	·	+·15	·	+	·	+·10	·	·	·	·
Gilia minutiflora	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
†*Holosteum umbellatum*	·	·	·	·	·	1·22	1·40	1·48	+·2	+·10	2·78	+·28	5·92	1·42	1·44
Idahoa scapigera	·	+·15	·	2·70	1·30	·	·	·	·	·	·	·	·	·	·
†*Lactuca serriola (seedl. only)*	·	·	+·2	·	·	·	1·20	·	+·12	·	+·2	·	·	+·5	+·5
Lagophylla ramosissima	·	·	+·12	·	·	·	·	·	+	·	·	·	·	·	·
Lappula redowskii	·	·	·	·	·	·	+	·	·	·	·	·	·	·	·
Linanthus pharnaceoides	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Madia exigua	·	·	·	·	·	·	+·15	·	·	·	·	·	·	·	·
Microsteris gracilis	·	1·38	·	2·98	1·48	·	·	·	·	·	·	·	·	·	·
Montia linearis	·	·	·	+·5	+·5	·	·	·	·	·	+·5	·	·	·	·
†*Myosotis micrantha*	·	·	·	·	·	·	·	·	·	·	2·90	·	·	·	·
Myosurus aristatus	·	+·8	+·5	·	·	·	·	·	·	·	·	·	·	·	·
Oenothera andina	·	·	·	+·2	·	·	·	·	·	·	·	·	·	·	·

(Continued)

Table B-12. *Lithosolic habitats,* in part. continued

	Eriog. sphaeroceph.-Poa			*Eriog. doug.-Poa*		*Eriogonum niveum-Poa*						*Eriogonum microthecum-Poa*			
Stand number	44	116	176	90	142	115	85	173	174	175	182	177	178	179	180
Orthocarpus tenuifolius	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Plagiobothrys tenellus	·	·	·	·	·	·	·	·	·	·	·	+·20	·	+	+·10
Plantago patagonica	·	·	1·35	·	·	·	·	·	·	·	·	·	·	·	·
Polygonum douglasii	·	·	·	·	·	·	·	·	·	·	+·2	·	+·2	+·5	+·2
†*Sisymbrium altissimum*	·	·	·	·	·	·	·	·	·	·	·	·	+	+	+·5
Stellaria nitens	·	+·2	·	·	·	·	·	·	·	·	+·5	·	·	·	·
INDIGENES IN 40 PLOTS ($4m^2$)	14	17	14	27	20	3	7	5	6	4	11	8	6	6	7
TOTAL COVERAGE OF PERENNIAL FORBS	4	6	7	19	17	30	2	+	3	10	1	1	1	1	1
TOTAL COVERAGE	49	56	83	60	60	72	46	37	44	40	58	27	26	20	17

Table B-13. Coverage estimates of *Sarcobatus vermiculatus-Distichlis stricta* (stands 201-207) and *Elymus cinereus-Distichlis stricta* (stands 208-214) associations.

Stand number	201	202	203	204	205	206	207	208	209	210	211	212	213	214
County	Grant	Yakim	Yakim	Yakim	Walla	Whitm	Dougl	Grant	Yakim	Yakim	Walla	Yakim	Dougl	Dougl
Township and Section	16N33	9N22	10N4	9N11	7N27	19N26	26N17	16N32	10N5	9N34	7N26	7N7	28N7	26N17
Range	25E	19E	17E	21E	34E	40E	28E	25E	17E	19E	34E	21E	27E	28E
MEDIUM SHRUBS														
Artemisia tridentata tridentata	·	·	·	·	·	·	·	2	·	·	·	·	·	·
Chrysothamnus nauseosus albicaulis	·	·	1	·	·	·	·	·	·	1	·	·	·	·
Rosa woodsii ultramontana	·	·	·	·	·	·	·	·	·	·	·	·	1	·
Sarcobatus vermiculatus	4	3	2	3	5	2	3	·	·	·	·	·	·	·
PERENNIAL GRAMINIODS														
Agropyron trachycaulum	·	·	·	·	·	·	·	·	1	·	·	·	1	·
Carex praegracilis	·	1	·	·	·	·	·	·	4	1	2	·	3	1
Distichlis stricta	5	5	6	6	6	6	5	4	4	5	6	5	3	5
Elymus cinereus	·	1	·	·	·	·	·	3	3	2	5	3	3	3
Elymus triticoides	·	·	·	·	·	·	·	·	·	·	·	·	·	1
Equise kansanum	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Hordeum jubatum	·	·	·	·	·	·	·	·	·	·	·	·	1	1
†*Hordeum murinum*	·	·	1	·	·	·	·	·	·	·	·	·	·	·
Hordeum nodosum	·	·	·	·	·	·	·	·	·	·	·	·	1	·
Juncus balticus	·	·	·	·	·	·	·	·	·	·	·	·	1	·
Poa juncifolia	·	1	·	·	·	1	1	·	1	·	·	·	5	·
†*Poa pratensis*	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Spartina gracilis	·	·	·	·	·	1	·	·	·	·	·	·	·	·
PERENNIAL FORBS														
Achillea millefolium lanulosa	·	·	·	·	·	·	·	·	1	1	·	1	1	·
Allium geyeri	·	·	·	·	·	1	·	·	·	·	·	·	·	·
Asclepias speciosa	·	·	·	·	·	·	·	·	·	·	·	·	1	·
Calochortus macrocarpus	·	·	·	·	·	·	·	1	·	·	·	·	·	·
Comandra umbellata	·	·	·	·	·	·	·	·	·	1	·	·	·	·
Crepis runcinata	·	·	·	·	·	·	·	·	1	1	·	·	1	·
Grindelia columbiana	·	·	·	·	·	·	·	·	·	·	·	·	1	·
Hesperochiron californicus	·	·	·	·	·	1	·	·	·	·	·	·	·	·
Iris missouriensis	·	·	·	·	·	·	·	·	1	·	·	·	1	·
Potentilla gracilis permollis	·	·	·	·	·	·	·	·	1	·	·	·	1	·
Sisyrinchium sarmentosum	·	·	·	·	·	·	·	·	1	·	·	·	·	·

(Continued)

Table B-13. Coverage estimates of *Sarcobatus vermiculatus-Distichlis stricta* (stands 201-207) and *Elymus cinereus-Distichlis stricta* (stands 208-214) associations. continued.

Stand number	201	202	203	204	205	206	207	208	209	210	211	212	213	214
Thelypodium sagittatum	·	·	·	·	·	·	1	·	·	·	·	·	1	1
ANNUALS														
†*Agropyron triticeum*	1	·	·	·	·	·	·	·	·	·	·	·	·	·
†*Agrostis interrupta*	·	1	·	·	·	·	·	·	·	·	·	·	·	·
Atriplex truncata	·	·	·	·	·	·	·	·	·	·	·	·	1	·
†*Bassia hyssopifolia*	1	·	·	·	·	·	·	·	·	·	·	·	·	·
†*Bromus japonicus*	·	·	·	·	·	1	·	·	·	·	·	·	·	·
†*Bromus tectorum*	2	1	1	·	1	·	1	3	1	1	·	2	·	·
Chenopodium	·	·	1	·	·	·	·	·	·	·	·	·	·	·
Descurainina pinnata	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Draba verna	·	·	·	·	·	1	·	·	·	·	·	·	·	·
Epilobium paniculatum	·	·	·	·	·	·	1	1	·	·	·	·	·	·
Festuca octoflora	·	·	·	·	·	·	·	1	·	·	·	·	·	·
Festuca (pacifica?)	·	·	1	·	·	·	·	·	·	·	·	·	·	·
Hemizonia pungens septentrionalis	·	·	·	·	1	·	·	·	·	·	1	·	·	·
†*Holosteum umbellatum*	·	·	·	·	·	1	·	·	·	·	·	·	·	·
†*Lactuca serriola (seedl. only)*	·	·	·	·	1	1	1	·	·	·	1	·	·	·
†*Lepidium perfoliatum*	1	·	1	·	1	·	·	·	1	1	·	2	·	·
†*Medicago lupulina*	·	·	·	·	·	·	·	·	1	·	·	·	·	·
†*Melilotus officinalis*	·	·	·	·	·	·	·	·	1	·	·	·	·	·
Montia perfoliata	·	·	·	·	·	1	·	·	·	·	·	·	·	·
†*Polypogon monspeliensis*	·	·	·	·	1	·	·	·	·	·	1	·	1	·
†*Setaria viridis*	·	·	·	·	·	·	·	·	·	·	·	·	1	·
†*Sisymbrium altissimum*	·	·	·	·	·	·	·	·	·	·	·	1	·	·
Suaeda occidentalis	·	·	·	·	·	·	·	·	·	·	·	·	1	·

Table B-14. Coverage estimates in the *Crataegus douglasii-Symphoricarpos albus* association (stands 224-232) and its *Populus tremuloides* phase (stands 233-235). Stand 229 is in Columbia County; all others are in Whitman County, Wash.

Stand number	224	225	226	227	228	229	230	231	232	233	234	235
Township and section	14N5	14N6	15N31	13N6	15N23	10N19	13N4	----	----	16N36	13N6	15N23
Range	44E	44E	45E	44E	44E	39E	44E	----	----	44E	44E	44E
Altitude in meters	695	692	732	----	711	599	792	785	668	707	----	711
Aspect and percent slope	N62	NNE25	ENE59	WNW30	ENE22	NE49	E25	N29	NW41	NE40	NNW38	ENE43
LOW TREES												
Populus tremuloides	·	·	·	·	·	·	·	·	·	4	4	6
TALL SHRUBS												
Amelanchier alnifolia	2	2	1	1	1	2	1	2	·	1	1	1
Crataegus douglasii	6	5	6	6	6	5	5	6	6	3	2	2
Holodiscus discolor	1	·	·	·	·	·	·	·	·	·	·	·
Prunus virginiana melanocarpa	1	1	1	·	1	1	2	2	·	2	1	1
Sambucus caerulea	·	·	·	·	·	·	·	·	·	1	·	·
MEDIUM SHRUBS												
Rosa woodsii & R. nutkana	1	·	1	1	1	·	1	1	1	1	2	1
Spiraea betulifolia lucida	1	3	1	·	·	·	1	1	·	2	2	·
Symphoricarpos albus	1	2	3	3	3	5	4	3	1	5	5	3
LOW SHRUBS												
Berberis repens	·	·	·	1	·	·	·	1	·	·	1	·

(Continued)

Table B-14. Coverage estimates in the *Crataegus douglasii-Symphoricarpos albus* association (stands 224-232) and its *Populus tremuloides* phase (stands 233-235). Stand 229 is in Columbia County; all others are in Whitman County, Wash. continued.

Stand number	224	225	226	227	228	229	230	231	232	233	234	235
PERENNIAL GRAMINOIDS												
Bromus (marginatus?)	1	·	·	·	·	·	·	·	·	·	1	·
Carex geyeri	·	1	·	·	·	·	·	1	·	·	·	·
Festuca occidentalis	·	·	·	·	·	·	1	·	1	·	·	·
†*Poa pratensis*	1	·	2	·	2	·	2	1	6	·	1	3
PERENNIAL FORBS												
Achillea millefolium lanulosa	1	1	1	·	1	·	1	·	1	·	1	·
Agastache urticifolia	1	·	1	·	·	·	·	·	·	1	·	·
†*Arctium minus*	1	·	·	1	1	·	1	1	1	·	·	3
Balsamorhiza sagittata	·	·	·	·	·	·	1	·	·	·	·	·
Besseya rubra	1	1	·	1	1	·	1	·	1	·	·	1
Brodiaea douglasii	·	·	·	·	·	·	·	·	·	·	·	·
†*Cirsium vulgare*	1	·	·	·	1	·	·	·	1	1	·	·
Cystopteris fragilis	1	·	·	·	·	·	·	1	·	·	·	·
Erythronium grandiflorum	1	·	·	·	·	·	·	1	1	·	·	1
Galium boreale	1	1	1	·	1	·	1	·	·	·	1	·
Geranium viscosissimum	1	1	1	·	1	·	1	·	·	·	·	·
Geum triflorum ciliatum	·	·	·	·	1	·	·	·	·	·	·	·
Helianthella uniflora douglasii	·	·	·	·	·	·	1	·	·	·	·	·
Heuchera cylindrica glabella	1	1	·	·	·	·	·	·	·	·	·	·
Hieraceum albertinum	·	·	·	·	1	·	1	·	·	·	·	·
Hydrophyllum capitatum capitatum	1	·	1	1	·	·	·	1	2	·	·	1
Iris missouriensis	1	1	·	·	1	·	1	·	·	·	·	·
Lathyrus bijugatus	·	·	·	·	1	·	·	·	·	·	·	·
Lathyrus pauciflorus	·	·	·	·	1	·	1	·	1	·	·	·
Lithophragma parviflora	1	·	1	1	·	·	1	·	4	1	1	1
Lithospermum ruderale	·	·	·	·	1	·	1	·	1	·	·	·
Lomatium dissectum multifidum	·	·	1	·	1	·	4	·	·	·	·	·
Osmorhiza chilensis	1	·	·	1	1	·	1	2	1	·	·	·
Potentilla arguta	1	1	·	·	1	·	·	·	·	·	·	·
Potentilla gracilis	·	·	·	·	1	·	1	·	·	·	·	·
Prunella vulgaris	1	·	1	·	·	·	·	·	1	·	·	·
Ranunculus uncinatus	·	·	·	·	1	·	·	·	1	·	·	1
Senecio integerrimus exaltatus	·	·	1	·	·	·	1	·	1	·	·	·
Senecio serra	1	1	·	·	1	·	·	1	·	1	·	1
Smilacina racemosa	·	·	·	·	·	1	·	·	·	·	·	·
Solidago missouriensis missouriensis	·	·	·	·	1	·	·	·	1	·	·	·
Stellaria crispa	·	·	·	·	·	·	·	·	1	·	·	·
Stellaria media	·	·	·	·	·	·	·	1	·	·	·	·
†*Taraxacum*	1	·	·	·	1	·	1	·	1	·	·	·
Trillium petiolatum	·	·	·	·	·	·	·	1	1	·	·	·
Urtica dioica	·	·	·	·	·	·	1	·	·	·	·	·
Veratrum californicum	·	·	·	·	·	·	·	·	·	·	·	1
Vicia americana	1	·	1	·	·	·	·	·	·	·	·	·
Viola adunca	1	·	·	·	·	·	·	·	·	·	·	·
ANNUALS												
†*Bromus tectorum*	·	·	1	·	·	·	·	·	·	·	1	·
†*Camelina microcarpa*	·	·	1	·	·	·	·	·	·	·	·	·
Collinsia parviflora	·	1	·	·	·	·	·	·	·	1	·	·
Draba verna	1	·	·	·	·	·	·	·	·	·	·	·
Galium aparine	1	1	2	1	·	2	1	3	1	4	6	·
†*Holosteum umbellatum*	1	·	·	·	·	·	·	·	·	·	·	·
Montia linearis	1	·	1	·	·	·	·	·	·	·	·	·
Montia perfoliata	5	1	5	5	·	6	1	1	1	5	5	·
Tonella floribunda	·	·	·	·	·	·	·	·	·	·	1	·

Table B-15. Coverage estimates in stands representing the *Crataegus douglasii-Heracleum lanatum* association (stands 215-221) and its *Populus tremuloides* phase (stands 222-223). All stands are in Whitman County, Washington.

Stand number	215	216	217	218	219	220	221	222	223
Township and section	14N5	16N32	14N16	16N22	-----	-----	16N36	13N4	16N33
Range	45E	44E	44E	45E	-----	-----	44E	44E	44E
Altitude in meters	716	755	741	752	655	625	674	770	658
Aspect and percent slope	ENE40	---	E62	N23	WSW29	W32	0	0	ENE15
LOW TREES									
Populus tremuloides	.	.	.	.	.	.	1	5	6
TALL SHRUBS									
Amelanchier alnifolia	.	1	3	.	2	.	1	1	2
Cornus stolonifera	.	.	.	.	.	1	.	.	.
Crataegus douglasii	6	5	4	5	6	6	5	4	1
Prunus virginiana melanocarpa	2	2	2	.	2	1	1	.	1
Sambucus caerulea	1	.	.	.	.	.	.	1	.
MEDIUM SHRUBS									
Ribes aureum	.	.	.	.	.	.	.	.	1
Rosa woodsii & R. nutkana	1	1	1	.	.	.	.	1	1
†*Rubus*	.	.	.	1	.	.	.	.	.
Symphoricarpos albus	1	.	2	1	.	.	.	1	1
PERENNIAL GRAMINOIDS									
†*Bromus (inermis?)*	.	.	.	.	.	.	.	1	2
Elymus glaucus	.	.	.	1	.	.	.	.	.
†*Poa pratensis*	.	.	1	1	.	.	.	1	1
PERENNIAL FORBS									
†*Arctium minus*	.	1	1	2	1	1	.	2	.
Circaea alpina	.	.	1	2	.	.	.	.	.
†*Cirsium vulgare*	.	1	1	.	.	.	.	.	.
†*Dipsacus sylvestris*	.	.	.	1	.	.	.	.	.
Geum macrophyllum perincisum	.	.	.	.	.	.	.	1	.
Hackelia jessicae	.	.	.	.	.	.	.	1	.
Heracleum lanatum	4	4	4	6	5	4	2	4	2
Hydrophyllum capitatum capitatum	.	1	1	1	1	.	.	1	1
Hydrophyllum fendleri albifrons	5	.	.	.	2	.	6	2	.
†*Marrubium vulgare*	.	1	.	.	1	.	.	.	.
Lomatium dissectum multifidum	.	.	.	.	.	.	.	.	1
Osmorhiza chilensis	.	.	.	1	.	.	.	1	1
Pteridium aquilinum languinosum	.	.	2	.	.	.	.	.	.
Senecio serra	.	.	.	1	.	.	.	1	1
Smilacina stellata	.	.	2	2	.	2	.	2	.
Stellaria crispa	.	.	.	1	.	.	.	.	6
†*Stellaria media*	1	.	.	.	.	.	.	.	.
†*Taraxacum*	1	.	1	.	.	.	.	1	.
Trillium petiolatum	.	1	.	.	1	.	.	.	.
Urtica dioica	3	5	3	1	2	4	3	4	5
ANNUALS									
†*Bromus tectorum*	.	.	.	.	.	.	.	.	.
Galium aparine	1	1	2	1	1	1	1	1	2
Montia perfoliata	1	5	3	.	1	1	.	1	2

Table B-16. *Grayia spinosa-Poa secunda* association (stand 145) and *Eurotia lanata-Poa secunda* association (stands 144,167 & 198).

Stand number	145	144	167	198
County	Bento	Grant	Grant	Yakim
Township and section	12N4	16N33	15N14	9N34
Range	24E	26E	24E	21E
Altitude in meters	391	163	488	316
Aspect and percent slope	NE6	NNW9	W45	NE9
Soil Classification U.S.D.A. 1938	Sz	---	---	---
Series	Warde	-----	-----	-----
Textural class	VFSaL	-----	-----	VFSaL
U.S.D.A. 1960	mCam	-----	-----	-----
pH 1st Decimeter	6.7	7.3	8.0	7.3
pH 5th Decimeter	6.8	7.5	---	7.5
Mean moisture equivalent, upper 5dm	14.6	15.8	12.6	17.0
Darkest horizon (10YRm)	4/3	---	---	3/4
MEDIUM SHRUBS				
Artemisia tridentata	+	·	·	+·2
Chrysothamnus nauseosus albicaulis	·	·	·	+
Grayia spinosa	37·65	+	+	+
Eurotia lanata	·	6·19	10·82	24·68
LOW SHRUBS				
Erigeron piperianus	·	·	·	+·8
Eriogonum	·	·	+	·
PERENNIAL GRAMINOIDS				
Oryzopsis hymenoides	·	·	+	+·2
Poa secunda	40·99	31·99	21·99	21·99
Sitanion hysterix	1·5	·	·	+
PERENNIAL FORBS				
Astragalus purshii	·	+	·	·
Calochortus macrocarpus	·	+·2	·	·
Chaenactis douglasii	·	·	·	+
Erigeron poliospermus	·	·	+·2	·
Helianthella uniflora douglasii	·	·	·	+
Lomatium macrocarpum	·	·	+	·
Sphaeralcea munroana	·	·	·	1·8
ANNUALS				
†*Bromus tectorum*	5·88	78·99	8·10	6·99
Descurainia pinnata	3·60	+	+·15	·
Draba verna	·	1·42	·	·
Festuca pacifica	+·15	·	·	·
Festuca octoflora	1·25	·	·	·
Lappula redowskii	+·2	·	·	·
Pectocarya linearis penicillata	+·2	·	·	·
†*Sisymbrium altissimum*	·	1·2	·	·
INDIGENES IN 40 PLOTS (4m²)	8	3	4	6
TOTAL COVERAGE OF PERENNIAL FORBS	0	+	+	1
TOTAL COVERAGE	87	117	39	52

Table B-17. *Aristida longiseta-Poa secunda* association (stands 184, 239), *Sporobolus cryptandrus-Poa secunda* association (stands 83, 93, 183, 94), and degraded (?) stands of the latter (stands 96, 95).

Stand number	184	239	83	93	183	94	96	95
County (stand 83 is in Idaho)	Asoti	Asoti	Nezpe	Asoti	Asoti	Asoti	Asoti	Asoti
Township and section	10N16	7N26	36N25	11N25	11N36	11N30	11N30	11N30
Range	46E	46E	5	44E	45E	44E	45E	44E
Altitude in meters	345	304	260	281	375	271	233	271
Aspect and percent slope	NNW19	NNW23	WSW14	SW17	SW27	WNW9	W20	ESE22
Soil Classification — U.S.D.A. 1938	Ch	-----	RexCh	RexBr	-----	VFSaL	RexBr	RexBr
Soil Classification — Series	Chard	-----	Farre	Farre	-----	Farre	Farre	Farre
Soil Classification — Textural class	SiL	-----	FSaL	L	-----	VFSaL	VFSaL	SiL
Soil Classification — U.S.D.A. 1960	cHap	----	cHap	cHap	----	cHap	cHap	cHap
pH 1st Decimeter	6.7	6.9	7.2	7.2	6.7	7.1	6.8	7.7
pH 5th Decimeter	7.4	7.1	7.5	7.5	7.8	7.9	7.4	8.0
Mean moisture equivalent, upper 5dm	16.0	17.0	14.4	16.5	15.1	14.4	13.4	16.1
Darkest horizon (10YRm)	2/2	---	2/1	3/2	---	3/3	3/2	3/2
MEDIUM SHRUBS								
Artemisia tridentata	•	•	•	+	•	•	•	•
Chrysothamnus nauseosus albicaulis	+•5	•	+	13•48	1•2	•	+	•
Chrysothamnus viscidiflorus	•	•	+	•	•	•	1•5	•
Gutierrezia sarothrae	1•5	•	•	•	•	•	•	•
LOW SHRUBS								
Eriogonum niveum	•	3•48	+	•	•	•	•	•
Opuntia polyacantha	•	•	•	+	•	+	+	•
Phlox longifolia	•	•	4•52	+	•	6•72	+•2	•
PERENNIAL GRAMINOIDS								
Agropyron spicatum	•	+	•	+	+	•	•	•
Aristida longiseta	91•99	82•99	•	•	+	•	•	•
Koeleria cristata	+•10	•	•	•	•	•	•	•
†*Poa pratensis*	3•20	•	•	•	•	•	•	•
Poa secunda	34•99	4•95	56•99	4•99	11•99	36•99	61•99	50•99
Sitanion hysterix	+•8	•	•	•	•	•	•	•
Sporobolus cryptandrus	+	2•8	67•98	80•99	89•99	75•99	31•98	12•32
Stipa comata	•	9•40	•	•	•	2•8	54•99	80•99
PERENNIAL FORBS								
Achillea millefolium lanulosa	8•78	1•10	+	•	•	•	+	•
Astragalus inflexus	11•42	+	3•10	•	•	1•2	1•12	•
Brodiaea douglasii	•	+•8	•	•	•	•	+•10	•
Calochortus macrocarpus	•	3•78	+	+	1•10	1•22	+•10	1•23
Cirsium undulatum	+	•	•	•	•	•	•	•
Erigeron pumilus intermedius	1•12	2•38	5•68	+	•	+	•	•
Fritillaria pudica	+•15	•	•	•	•	•	•	•
Linum perenne	+	•	•	•	•	•	•	•
Lithophragma bulbifera	+•18	2•85	•	•	•	•	1•42	•
Lomatium macrocarpum	•	•	+•2	•	+•10	•	•	•
Lupinus leucophyllus	•	•	+	•	•	•	•	•
Lupinus sericeus	•	+•2	•	•	•	•	•	•
Sphaeralcea munroana	+	•	+•5	+	•	+•8	+	•
†*Tragopogon dubius*	1•22	1•20	+	1•10	1•22	1•5	-	+•2
ANNUALS								
Agoseris heterophylla	•	+•5	•	•	•	•	•	•
Amsinckia lycopsoides	•	•	•	•	+•2	•	•	•
†*Arenaria serpyllifolia*	•	+•2	•	•	•	•	•	•

(Continued)

Table B-17. *Aristida longiseta-Poa secunda* association (stands 184, 239), *Sporobolus cryptandrus-Poa secunda* association (stands 83, 93, 183, 94), and degraded (?) stands of the latter (stands 96, 95). continued

Stand number	184	239	83	93	183	94	96	95
†*Bromus brizaeformis*	•	2•75	•	•	•	•	•	•
†*Bromus japonicus*	+•8	2•80	•	•	6•92	•	•	+•8
†*Bromus mollis*	+	1•25	•	•	•	1•32	•	•
†*Bromus racemosus*	•	+•12	•	•	•	•	•	•
†*Bromus tectorum*	2•80	3•95	23•99	22•99	9•99	37•99	13•99	16•99
Draba verna	2•98	2•99	+•5	2•99	2•99	2•99	3•99	3•99
Epilobium paniculatum	•	+•5	•	•	2•80	•	•	•
†*Erodium cicutarium*	2•50	2•98	52•99	3•99	2•80	2•99	3•99	3•99
Festuca megaleura	•	1•27	•	•	•	•	•	•
Festuca octoflora	+•20	2•90	•	•	•	1•25	2•65	•
Festuca pacifica	1•32	2•85	•	•	+•10	•	3•92	•
†*Holosteum umbellatum*	10•99	+•90	2•82	2•80	2•99	3•90	3•95	4•99
†*Lactuca serriola (seedl. only)*	+•2	•	•	+•8	2•99	•	+•5	+•10
†*Lepidium perfoliata*	•	•	•	•	+•18	•	•	•
†*Myosotis micrantha*	•	+•15	•	•	•	•	•	•
Plantago patagonica	3•95	2•75	7•98	8•99	4•12	8•99	17•99	7•99
Stellaria nitens	1•28	1•40	•	•	+•5	•	•	•
†*Veronica arvensis*	+•2	+•20	•	•	+	•	+•2	•
INDIGENES IN 40 PLOTS (4m^2)	16	19	9	5	11	10	13	6
TOTAL COVERAGE OF PERENNIAL FORBS	21	9	8	1	2	3	2	1
TOTAL COVERAGE	171	129	219	135	132	176	193	176

APPENDIX C. PRODUCTIVITY ESTIMATES

Appendix C. Summary of productivity determinations as oven-dry weight of shoot material clipped at approximately the time of maximum development. ± refers to standard errors. All stands long unburned and ungrazed.

Association	Stand	Grams/m^2* All Vasculares	Grams/m^2* Perennial Grasses**
Artemisia tridentata-Stipa	24	-----	23.9 ± 1.4 (13.2 ± 0.8)
Purshia-Stipa	21	-----	39.6 ± 1.9 (9.4 ± 1.5)
Artemisia tridentata-Agropyron	27	71.9	32.6 ± 4.0
Artemisia tridentata-Agropyron	28	-----	43.5 ± 3.3
Artemisia tridentata-Agropyron	10	82.6	49.8 ± 7.5
Artemisia tridentata-Agropyron	43	-----	38.1 ± 5.9
Artemisia tridentata-Agropyron	42	103.6	56.6 ± 3.7
Artemisia tridentata-Agropyron	40	115.0	51.0 ± 5.1
*Bromus tectorum****	--	102 ±5	-----------
Agropyron-Poa (lithosolic)	143	191.9	187.6
Agropyron-Poa	--	98.9	87.9
Agropyron-Poa	56	125.7	104.5 ± 2.9
*Bromus tectorum*****	--	129.3	-----------
Sporobolus-Poa	--	-----	115.2 ± 10.0 (3.5)
Agropyron-Festuca	60	147.1	88.4 ± 7.5
Artemisia tripartita-Festuca	62	144.2	123.2 ± 2.2
Festuca-Symphoricarpos		239.8	72.5
Festuca-Symphoricarpos	--	253.0	-----------
Festuca-Symphoricarpos	--	296.0	104.1 ± 9.4
Festuca-Symphoricarpos	155	368.0	109.4 ± 12.8

*For pounds per acre, multiply by 8.9.

**Figures in parentheses refer to *Poa secunda* only. Other figures in column refer to larger species collectively: *Agropyron*, *Festuca idahoensis*, *Poa cusickii*, *Stipa* spp. and *Sporobolus*.

***Data from Rickard (97) probably representing *Artemisia tridentata-Agropyron* h.t.

****Forty-year-old stand adjacent to stand 56, and sampled in same the same season.

APPENDIX D. COVERAGE SUMS AND SPECIES DIVERSITY

Appendix D. Comparative statistics for certain associations, based on data in Appendix B. Figures represent median values, with the number of stands considered indicated in parentheses.

	All vasculares	Coverage sums: Perennial forbs	Coverage sums: *Poa secunda*	Coverage sums: Other per. grasses	Species of indigenes in 40 plots
Associations of deep upland loams, listed from moist to dry					
Festuca-Symphoricarpos (15)	295	134	+	132	35
Festuca-Rosa (4)	236	100	6	122	32
Festuca-Eriogonum heracleoides (4)	189	27	10	123	29
Purshia-Festuca (10)	182	30	6	115	28
Artemisia tripartita-Festuca (19)	160	21	9	102	32
Agropyron-Festuca (11)	152	10	16	109	17
Artemisia tridentata-Festuca (6)	134	3	41	77	16
Artemisia tridentata-Agropyron (14)	118	2	40	52	17
Agropyron-Poa (8)	116	2	30	68	11
Sporobolus-Poa (4)	156	2	24	78	10
Artemisia tridentata-Poa (6)	74	+	48	0	12
Associations of sandy soils					
Artemisia tripartita-Stipa (3)	115	1	35	76	15
Stipa-Poa (4)	157	4	62	68	10
Artemisia tridentata-Stipa (11)	136	3	28	78	14
Purshia-Stipa (5)	149	3	22	80	18
Associations of lithosols					
Lithosolic Agropyron-Poa (4)	100	14	24	68	12
Eriogonum thymoides-Poa (6)	56	14	25	+	17
Artemisia rigida-Poa (7)	67	6	31	+	14
Eriogonum niveum-Poa (6)	45	2	30	0	6
Eriogonum microthecum-Physaria (4)	23	1	+	+	7

APPENDIX E. SMALL MAMMAL POPULATIONS

Appendix E. Results from trapping small mammals in stands of climax vegetation in eastern Washington (Rickard, 1960). Numbers of animals adjusted to a common base of 675 trap-days. Nomenclature of stands and their numbering have been changed to conform with associations and stand numbers used in this publication.

Association	Stand number	Numbers of animals						
		Lagurus curtatus	*Perognathus parvus*	*Peromyscus maniculatus*	*Reithrodontomys megalotis*	*Microtus montanus*	*Microtus longicaudis*	*Sorex vagrans*
Artemisia rigida-Poa	--	1						
Artemisia rigida-Poa	--		5	22				
Artemisia tridentata-Agropyron	13		32	31				
Agropyron-Poa	--			30	2		1	
Lithosolic Agropyron-Poa	143			25				
Agropyron-Festuca	--		24	11				
Festuca-Symphoricarpos	71					10	2.5	1.3
Festuca-Symphoricarpos	--			7.5				
Festuca-Symph., Symph. phase	--			21.3	1.3		68.7	1.3
Crataegus-Symphoricarpos	--			1.3			1.3	