A STUDY OF VEGETATION CHANGE ON THE GRAVELLY PRAIRIES OF PIERCE AND THURSTON COUNTIES, WESTERN WASHINGTON

by

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Approved by ______________________________

Department ______________________________

Date ______________________________

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I. INTRODUCTION

There are in Pierce and Thurston counties of Western Washington large areas of open land that have been known for over a century as "prairies". To find such grass- and forb-covered tracts in the midst of the Humid Transition (Piper, 1906) forests of the Puget Sound basin is both unexpected and puzzling. Thus, these grasslands present intriguing problems in floristics and ecology.

According to Curtis (1959) and Conard (1952) the term prairie originated with the early French voyagers. Conard reports that the word is still in use in France and Quebec meaning a grassland. These early explorers had no other term in their vocabulary which would apply to the vast grasslands of central North America. The term "prairie" has been used for many years to designate a wide range of vegetational and topographic situations. The usage of the term is usually loose and vague, and as Conard (1952) points out, its use varies from one locality to another. In Iowa the true prairie is one dominated by a particular phytosociological association (Conard, 1952). In Wisconsin (Curtis, 1959) a prairie is considered an open area covered by low growing plants, dominated by grass and grass-like species, one-half of which are true grasses, with less than one tree per acre. The student of the prairie or grassland develops his own definition of prairie, based on the type of soil, the amount of precipitation, and the dominant species, or some combination of these three features.

The term prairie is not correctly applicable to the grasslands of Western Washington if the defining features of soil, rainfall, and species composition are taken into account. Prairie, however, seems to be the most popular name. The early travelers and explorers referred to these grasslands as prairies probably because they, like the French voyagers, knew no other term which would adequately apply. The compilers of the Land Office Survey of the 1850s also called them prairies. At the present time the latest edition of the U. S. Geologic Survey maps (1958) refer to these open treeless grasslands as prairies, e.g., Mound Prairie, Ruth Prairie. Because of the previous local usage, and the current generalized nature of the term, I see no difficulty in continuing to call these tracts of grassland vegetation "prairies".

Whenever the word "prairie" is used in this thesis, it is in reference to the grasslands of Western Washington which have been formed upon the gravelly outwash plains of the last major Pleistocene glaciation.

When a botanist views these extensive grassy flats for the first time, he is bound to frame a number of questions pertaining to the nature and origin of such vegetational nonconformities. One of the most striking features is the apparent encroachment upon the prairies by Douglas fir. How long has this invasion been taking place? Were the prairies always in this state of flux, the Douglas fir never having been able to enter the prairies? If this is the case, what prevents the firs from eliminating the prairies? Is this a recent invasion by the Douglas fir? If this influx is recent, what caused it?

Other questions come to mind. What has been the successional pattern of the vegetation for the past 10,000 years since the withdrawal of the Vashon Glacier? Could it be that these prairies have been forested at some time in their history? Could the nonconformity be for climatic or pedological reasons?

Certain genera such as Balsamorhiza, Sisyrinchium, Zygadenus, Camassia, Dodecatheon, Lomatium and perennial Festuca are represented on the prairies. The species of these genera are usually elements of Eastern Washington and southern floras. They are unusual for the Humid Transition forest west of the Cascade Range. Why are these genera present? What factors have acted upon this habitat to give them their characteristic vegetation patterns?

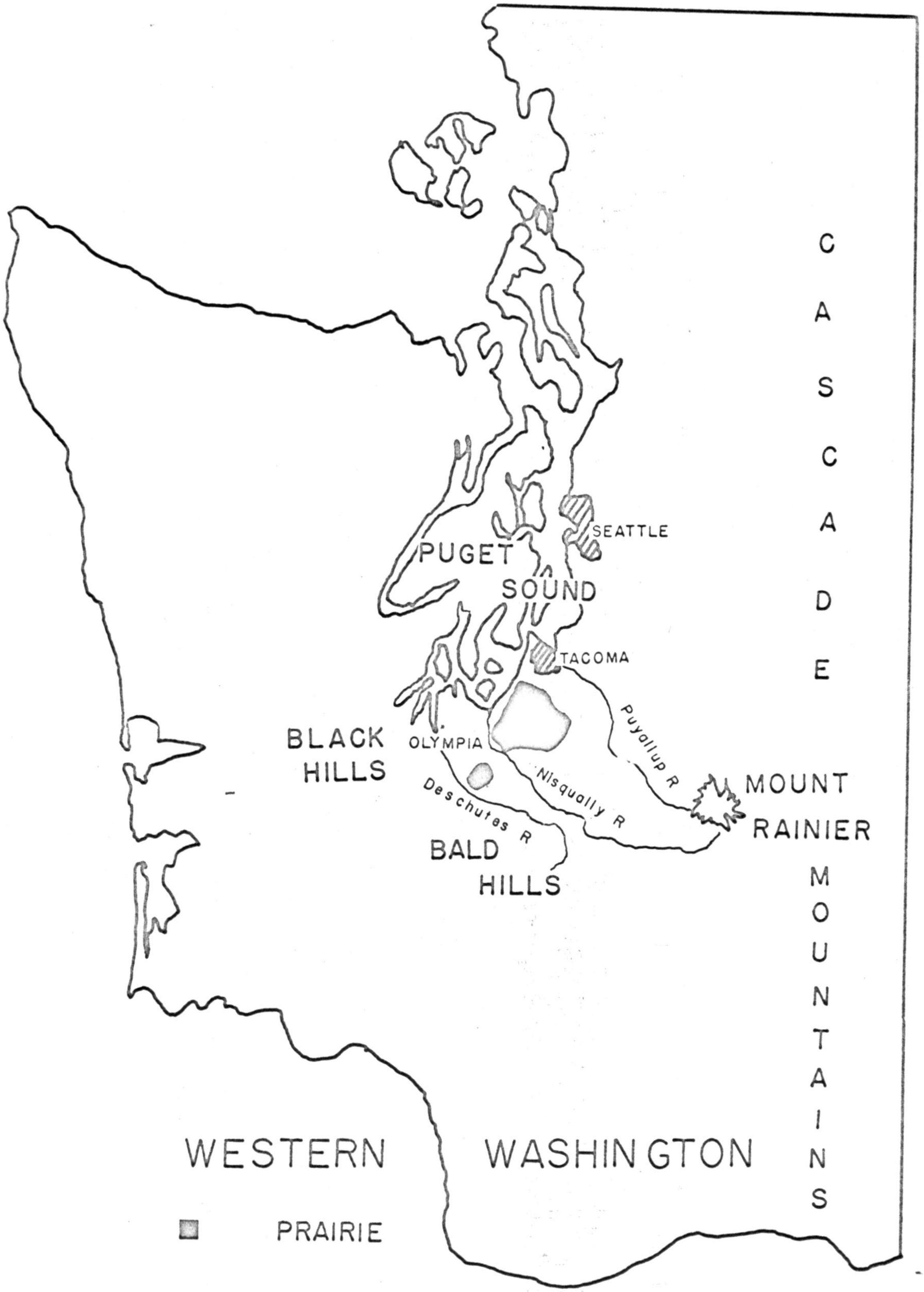
The historical approach has been chosen as a means of seeking the possible answers to these questions. By the historical approach is meant a search through the recorded human history of the region for descriptions of the vegetation at various periods. From this record it should be possible to find changes in vegetation patterns and to infer some of the environmental causes of the changes.

Little botanical research has been done on the area. Piper (1906) was the only person to treat the floristics of the area in any detail. Jones (1936) dealt with the gravelly prairies of Mason County. Rigg (1918), Hansen (1947), and Becking (1957) briefly discuss the prairie vegetation. There has been no significant ecological work done on the prairies of Western Washington. There are two papers on the soils, (Nikiforoff, 1936 and Renny and MacLauchlan, 1957). There is also an interesting paper on the effect of vegetation upon soil of the Quillayute Prairie in Clallam

County (Lotspeich, _et al_, 1960). Local and regional histories and miscellaneous archives provide the richest sources of general views of the prairies and surrounding forest since the beginning of the 19th century.

Rather than attempt a superficial coverage of the entire prairie formation in Western Washington, I am restricting the study mainly to the Wier Prairie in Thurston County, Washington. This relatively undisturbed sample is typical of the gravelly prairies; other gravelly prairies of Western Washington lie in similar glacial outwash and are under the influence of the same macroclimatic phenomena.

Cain and Castro (1959) have emphasized in precise terms how broad the scope of a primary survey should be. They felt that an investigator should consider not only what takes place but also why the observed patterns exist. Often a more significant gain from the preliminary survey is the unearthing of problems and their formulation in precise terms so that they may be studied more efficiently later. It is hoped that this thesis approaches both goals.



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WESTERN WASHINGTON
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Figure 1

II. PHYSIOGRAPHY

The gravelly prairies of Western Washington are situated in the southern end of the Puget Sound basin (see Figure 1, p. 5). They comprise some 168,000 acres in Pierce and Thurston Counties (Renny and MacLauchlan, 1957).

Geology and Topography

The geologic events of the Cenozoic Era were important in the development of the topography and vegetation of the prairies of Western Washington. During the Eocene period, the Black and Bald Hills were formed. Later in the Cenozoic, during the Oligocene and Miocene, volcanic activity began which led to the formation of the Cascade Mountains. The vulcanism has continued to the present time; Glacier Peak erupted 6,700 years ago, and Mount St. Helens erupted in the early 19th century. The formation and uplift of the Coast Range and the Cascade Mountains gave the region the major topographic features that affect the present climate.

The Pleistocene was a period of alternating glacial and non-glacial intervals. The final glacial period gave the prairies their characteristic topography. The topography has been modified somewhat by post-glacial erosion. The sequence of glaciations during the Pleistocene in the Puget Sound lowland has been divided into four major glacial periods (Crandle, Mullineaux and Waldron, 1958). The three earlier glaciations and their nonglacial intervals had no effect upon the present vegetation because deposited material of the last glacier, the Vashon, completely overlays products of the earlier glaciations. The only exposures of the previous glacial deposits are on erosion escarpments and on bluffs along Puget Sound. The prairies were formed upon the glacial outwash plains of the Vashon Glacier.

Wier Prairie

Wier Prairie is in central Thurston County, one and one-half miles north of the town of Rainier near the intersection of the Fourth Standard Parallel and the Willamette Meridian in sec. 1, T16N, R1W; sec. 5, 6, T16N, R1E; sec. 25, 26, T17N, R1W; sec. 30, 31, 32, 33, T17N, R1E. It is about 1,380 acres in extent.

To the south and southeast of Wier Prairie is glacial material which is ground and terminal moraine. The Bald Hills are about three miles to the south and may be considered an east-west extension of the Cascade Mountains. Low hills of terminal morainic material pitted with what appear to be glacial kettles surround the area from the southeast to the northeast (Bretz, 1913). To the north are forested hills of outwash material. The northwest boundary of the prairie meets another range of morainic hills. The western edge of the prairie is bounded by the Deschutes River. An erosion escarpment about 50 feet high marks this boundary.

The prairie is located on three different levels, each level a terrace of the same gravelly plateau. The highest level, $\pm$ 500 feet, slopes to the southwest. To the north the second level of the prairie is 50 feet lower. The third prairie is at an elevation of about 400 feet. There are steep north-facing forested slopes between the terraces.

The Wier Prairie is in the drainage system of the Deschutes River which runs north into Puget Sound. There are no permanent streams on Wier Prairie; most of the drainage appears to be internal. There are no lakes or bogs in the prairies like those near the prairies at Roy and Spanaway in Pierce County. There are, however, numerous small lakes and bogs in the general vicinity, lying in pockets of ground and terminal moraines to the northeast and to the north.

III. VEGETATION

Prehistoric Vegetation

The post-glacial forest succession on the Wier and other prairies in the Puget Sound basin begins with the recession of the Vashon Glacier. Radiocarbon dating of basal peat in the sediments of Lake Washington (King County) places the minimum date for withdrawal of the Vashon ice sheet at 13,650 years ago (Rigg and Gould, 1957). The glacier receded at its southern border before this time. By analyzing vertical boring of peat bogs for pollen content, it is possible to make some conclusions concerning post-glacial forest succession. Pollen studies of post-Pleistocene bogs are the only good source of information concerning the surrounding vegetation from the initiation of the bog to the beginning of human exploration at the start of the 19th century.

The interpretation of pollen profiles however involves many variables which should be recognized before serious conclusions may be reached. Good discussions of the dangers of misinterpretation of pollen profiles are given by Voss (1934), Sears (1930), and Cain (1939).

Hansen (1947a, 1947b, 1938) examined ten peat bogs in the Puget Sound basin. Bogs at Rainier, Tenino, Olympia, and Parkland are of interest to us because of their proximity to the prairies. Three bogs lie near the Wier Prairie, and a fourth is on the prairie at Parkland. Pollen analysis of these four bogs gives a picture of the forest succession adjacent to the prairies.

The Rainier bog is located a few miles north of the town of Rainier, Thurston County, Washington, and about ten miles northeast of Tenino. The analysis of the bog shows a high percentage of Pinus contorta pollen at the base of the bog. At the time of the deposition of the Glacier Peak volcanic ash layer, 6,700 years ago (Rigg and Gould, 1957), the P. contorta had been replaced by Pseudotsuga menziesii. At the same time, traces of Quercus and Pinus ponderosa pollen had begun to appear. In the section of the profile above the ash, the Pseudotsuga menziesii reached its peak and began to decline. This was accompanied by a rise in the percentage of Tsuga pollen.

The Tenino bog is located in a depression near the top of a small hill of glacial drift in sec. 18, T16N, R1W, one and one-half miles north of Tenino in Thurston County. The profile shows at its base a high percentage of Pinus contorta pollen. As its percentage decreases, the per cent of Pseudotsuga pollen increases. Above the ash layer, low percentages of Quercus and Pinus ponderosa pollen appear. Absence of the hemlock is due to low summer precipitation (Hansen, 1947a).

A few miles south of the city of Olympia is a bog which shows pollen distributions in its profile similar to the other two without Quercus pollen. According to Hansen (1947a), the Western Hemlock failed to supersede the Douglas fir because of the gravelly soil.

The fourth bog is located in sections 7, 8, 17, 19, T19N, R3E in Pierce County one mile west of Parkland. The profile is similar to those of the three bogs in Thurston County. The lodgepole pine again was superseded by the Douglas fir just before the deposition of the ash. This was accompanied by an increase in the amount of oak, grass, and composite pollen.

The reservations regarding the reliability of pollen sampling make it possible that the prairies were never forested and that the pollen of the various species was blown to the bog or that the trees grew in the vicinity of the bog. Though there is little doubt that the oak was not common, it is possible that its representation in pollen profiles is not indicative of its true abundance. A probable scheme of succession is as follows: The first invading species was *Pinus contorta*. This species is well suited to the conditions at the fluctuating, but gradually retreating, ice front (Hansen, 1947a). Among its attributes are its ability to bear seed at an early age, its prolific seed production, and its wide range of soil tolerances. Shortly before the deposition of the Glacier Peak ash, the Douglas fir increased for a period of several thousand years. At about the time of the Douglas fir peak, the grasses, composites, and oak became better established in the area. The prairies, today, probably look much as they did then, but they were much more extensive than at present.

Prairie Vegetation During Recorded History

A picture of the prairie vegetation during the 18th century can be reconstructed from the writings of early settlers and explorers in the region.

Early recorded observations of the vegetation are in diaries, journals and recollections of older residents, early settlers, and explorers. In most cases the observers were not trained botanists. Their generalizations about the vegetation could not give an accurate account from a botanical standpoint. Fortunately, however, several exploring expeditions, such as the Wilkes expedition and the Stevens Railroad survey, employed trained botanists who described the prairies and expressed stimulating ideas about them.

In assessing the recollections of the early settlers, caution must be used. Their reminiscences might be exaggerated because of the passage of time since the observations were made. However, if considered carefully, the reminiscences prove to be valuable sources of information.

The men who wrote these accounts were drawn to the Pacific Northwest for several reasons. First, there was the establishment at Nisqually of the Hudson's Bay Company Fort. Second, there were the numerous exploring expeditions sent to investigate the various potentials of the Northwest. The third attraction was that of settlement. Many of the early immigrants came up from the Willamette Valley in Oregon. Some were brought down from the Red River Territory, Canada, by the Hudson's Bay Company. The fourth motive was to collect plant materials for horticultural use; the most prominent collectors were the Scotsmen, Archibald Menzies, David Douglas, and John Jeffrey. Of these, only the latter reached the prairies.

One of the most valuable documents found was the transcript of the settlement between the Puget's Sound Agricultural Company and the United States government. However, the record must be assessed with caution because of the probability of bias on the part of witnesses.

In order to correlate the events and observations with dates, a chronology is presented. The dates do not represent all of the important events in Northwest history. Only those events which have been important in the development of the prairies are mentioned here. The dates go only to 1917. Man had wrought the most significant alterations since the Vashon glaciation by 1917.

<u>Dates and Events (Meany in Leighton, 1918) and Judson, (1913)</u>

1792 Vancouver Expedition

1825 Establishment of Fort Vancouver on the Columbia River

1827 Establishment of Fort Langley on the Fraser River

1832 Establishment of Fort Nisqually

1839 Establishment of the Puget's Sound Agricultural Company at Nisqually

1840 Arrival of missionaries at Nisqually

1841 Wilkes' expedition and first American overland emigration

1845 Settlement at Tumwater

1849 Establishment of Fort Steilacoom

1853 Stevens' exploration for the Northern Pacific Railway

1869 Settlement between the United States and Hudson's Bay Company, Puget's Sound Agricultural Company

1898 First military use (Spanish American War)

1917 Establishment of Fort Lewis by the United States Army

Nisqually Plains. Archibald Menzies was one of the first botanists to reach the Northwest coast. He was attached to the Vancouver expedition of 1790 to 1795 as the surgeon and naturalist. In 1792 the expedition made a thorough exploration of Puget Sound. On May 28, 1792, Menzies states (Newcombe, 1923) that they reached a large bay so flat and shallow that they could not approach near the shore. This, according to Newcombe, was the mouth of the Nisqually River. The expedition again passed the Nisqually River on May 26 of the same year without disembarking. This was as close as Menzies came to the prairies.

David Douglas, the celebrated Scottish botanist, made two excursions to the Northwest coast. The first was during the years 1823-1827. On his first trip he made an arduous journey up the Chehalis River in November of 1825. This was as close as he got to the region of the Nisqually Plains (Royal Horticultural Soc., 1959), until his second trip during the years 1829-1833.

In early February of 1833, Douglas undertook a journey to Puget Sound. During this trip his object was to determine positions of headlands along the coast and altitudes of mountains in the interior. He collected 200 species of mosses and some algae (Hooker, 1836). Very little is known of this trip for shortly thereafter all but a few of his records were lost in the rapids of the Fraser River. It is possible that Douglas did reach the prairies for Archibald McDonald, an employee of the Hudson's Bay Company, wrote: "Early in March, 1833, he (Douglas) met me at Puget's Sound, and we returned together to Fort Vancouver" (Hooker, 1836).

The earliest description of the prairies was that given by Dr. William Frazer Tolmie during his residence at Fort Nisqually while in the employ of the Hudson's Bay Company in 1833. In August of that year he recorded in his diary:

> Had a long walk on the prairie in the afternoon and came upon a portion new to me where winding elevations carpeted with young oaks and brake and clothed with pines are not unfrequent. Marshy hollows were also formed of small extent (Tolmie, 1833).

On his trip to Mount Rainier he again gives a description in his journal. "The shade of a lofty pine beautifully interspersed and surrounded with oaks and through the gaps in the arch we see the broad plain extending southward to the Nisqually." Later, on the same trip: "The point of wood now became broader and the intervening plain degenerated into prairie."

In 1841 the United States Exploring Expedition reached Puget Sound under the command of Charles Wilkes, U. S. N. With the expedition were two botanists, Dr. Charles Pickering and Mr. W. D. Brackenridge. Both Wilkes and Brackenridge have described the area about Fort Nisqually in some detail.

Upon arriving in May 1841, Wilkes made the following description (Wilkes, 1844):

> The shore rises abruptly, to a height of about two hundred feet, and on the top of the ascent is an extensive plain, covered with pine, oak, and ash trees, scattered here and there so as to form a park-like scene.

The mission house visited by Wilkes was said to be located on the borders of an extensive and beautiful prairie. Later he stated that

> The best land occurs where the prairies are intersected or broken by belts of woods, that have a dense undergrowth, consisting of Hazel, Spiraea, Cornus, and Prunus. On the borders of the belts are scattered oaks and some ash, arbutus, birch, and poplars, and in some places yew is to be found; but the predominant character of the vegetation is of the tribe coniferae.

While at Nisqually the expedition broke up into smaller groups each going to a different area in the Northwest. Wilkes went south across the prairies to the Cowlitz holdings of the Hudson's Bay Company. Along the way he described the character of the country. Leaving the Fort he stated: "The direction of our route was nearly south over the plain, passing occasionally a pretty lawn, and groves of oak and ash trees." At this point the group crossed the Nisqually River. The country on the other side he described as follows: "Our route then continued through most beautiful park scenery, with the prairie now and then opening to view, in which many magnificent pines grew detached. The prairie was covered with a profusion of flowers." Soon the Deschutes River was crossed, and the group camped. Upon leaving the campsite Wilkes wrote, "The park scenery increased in beauty." From this point on the group left the region under consideration, though he reported extensive prairies which he called "Cammass plains" on the way to the Cowlitz farm.

Brackenridge, one of the two botanists on the expedition, also had much to say considering the general aspect of the prairie and its vegetation. On May 13, 1841, shortly after the expedition's arrival, he wrote: "Fort Nesqually [sic] lays inland a good half mile from the Bay on the plains or margin of the extensive prairies which stretch back into the interior 15 or 20 miles" (Brackenridge, 1931). Brackenridge continued:

> The plains were at this season one complete sheet of flowers, principally of the following genera: Ranunculus, Scilla camass , Bartsia, Balsamorhiza, Lupinus, Collinsia, with many other small annuals. These plains are intersected with and broken in upon by belts or clumps of Spruce trees, with a dense undergroth [sic] of Hazel, Cornus, Spiraea, and Prunus, with a few scattered oaks which stud the plains.

The next day he made a trip out on the plains where he "fell in with two species of Populus, a birch and an Arbutus, perhaps A. tomentosa, Arbutus [= Arctostaphalos uva-ursi] and a small Ledum, the latter rare the former abundant in boggy places."

Shortly after this he and several others went on a journey to the interior of Washington. May 20 he observed several specimens of a large pine, the height of which he estimated to be 130 feet. "The habit of this pine resembles that of Pinus resinosa [more] than any other that I know." (The pine was possibly P. ponderosa which is found on the prairies near Spanaway on the route that he might have taken to the interior).

There are many similarities between the journals of Wilkes and Brackenridge. Wilkes, not trained as a botanist, possibly asked Brackenridge to identify the plants which he saw.

Sir George Simpson in his narrative of a journey round the world tells of what he saw of the prairies. He states that the country between the Cowlitz River and Puget Sound "consists of an alternation of plains and belts of wood" (Simpson, 1847). "Beyond the Checaylis [sic] to the north the plains became more extensive." As he approached the Nisqually River, he noticed the Mima Mound phenomenon which has caught the fancy of many people since.

"We passed over a space of ten or twelve miles in length, covered with thousands of mounds . . . Whatever has been their origin, they must be very ancient, inasmuch as many of them bear large trees." Describing the Nisqually area Simpson said that "on the borders of an arm of the sea of about two miles in width are undulating plains of excellent pasturage presenting a pretty variety of copses of oak and placid lakes and abounding in Chevreuil and other game."

In May 1850, John Jeffrey was hired by a group of Scottish botanists and horticulturists to go to the Pacific Northwest and collect plants along essentially the same route as that followed by David Douglas. Jeffrey signed a three-year contract with the group. One of the stipulations of the contract was that he keep a diary of his travels. The diary has never been found, and it is possible that it was never kept. All that is known of his travels is from a few letters and the few specimens that he somehow managed to return to England.

James Douglas at Fort Victoria wrote to John Ballenden, Chief Factor at Vancouver, on May 21, 1852, that John Jeffrey was "on the eve of proceeding on his professional pursuits by way of Nisqually and Cowlitz."

We know that Jeffrey reached the prairie because he collected plants there from June 7 to 13, 1852.

Theodore Winthrope briefly described the prairies in an account (1862) of his trip across the Cascade Mountains. "First through an open forest, sprinkled with lakes and opening into great prairies." He went on to say, "This rough way would be enlivened by a prairie, with beds of fern for my repose, and long grass for my tiring beasts--grass long as macaroni. I rode on, now under the low oaks, now over ripe prairie."

Dr. J. G. Cooper, connected with the Stevens Survey of the 48th Parallel, was the next botanist to reach the prairies. Of the prairies he said (Cooper and Suckley, 1859):

> The smooth prairies, dotted with groves of oaks, which in the distance look like orchards, seem so much like old farms that it is hard to resist the illusion that we are in a land cultivated for hundreds of years, and adorned by the highest art, though the luxuriant and brilliant vegetation far excels any natural growth in the East. Nothing seems wanting but the presence of civilized man, though it must be acknowledged that he oftener mars than improves the lovely face of nature.
>
> Prairies are often visible to the waters edge, interspersed with evergreen forests and extending as an elevated plateau to the base of the rugged and snowy mountains that rise like walls on the east and west.

Cooper mentions the encroachment upon the prairies by Douglas fir. Speaking of Quercus garryana, he says, "they belong to the prairies and are being crowded out by the extension of the spruces over them." Continuing his description of the prairies he wrote, "Scattered over the surface are rounded hills, looking like islands in the level plain, and covered with groves of the usual fir, which sometimes grows on the slopes of the terraces" (Cooper, 1859).

On August 10, 1853, Lieutenant William Trowbridge made a trip from Fort Steilacoom on Puget Sound to Cowlitz Landing. About this trip he says (Trowbridge, 1853):

> Our road from steilacomb [sic] to Fords lay for the greater part of the way across prairie land with pine and oak trees dotted here and there, in groves and standing alone, so as to present the most beautiful pictures to the eye that can be imagined, but the poor soil prevents their cultivation and their beauty is spoiled in the imagination by the knowledge of their worthlessness.

He further states that the plains on the west side of the river were of the same character as those on the east side.

Reminiscences of pioneers have been used sparingly because they may not be accurate. Two sources, however, offer evidence that the Douglas fir forest was encroaching upon the prairies in the 1850s.

The first of these is from the writings of Ezra Meeker (1907).

> An interesting feature of the intervening space between the old and the newer fort [Fort Nisqually] is the dense growth of fir timber averaging nearly two feet in diameter and in some cases fully three, and over a hundred feet high on what was prairie when the early fort builders began work.

This old fort was founded in 1833, Meeker made the above observation in about 1903. During the next 70 years, there was a great invasion by Douglas fir. ". . . One of the many little prairies boldly thrust itself over the almost precipitous hillside 20 years ago, today it has been driven backward a full mile by a growth of firs.

Another pioneer, James Sales, born in the area in 1853, also notices the change in the prairies. Quoted from Hunt (1916) he says "that when he was a boy there were almost no fir trees. Only occasional patches of oaks broke the open vistas."

In 1863 after the United States had taken the area to the 54th Parallel, the Hudson's Bay Company and the Puget's Sound Agricultural

Company filed claims for settlement against the United States for these holdings in United States territory. The settlement was determined by a joint commission of Britain and the United States. In the course of the hearing some interesting evidence was presented. In 1852 a map of the Puget's Sound Agricultural Company's holding at Nisqually was compiled. It showed the distribution of forested areas and prairies at that time. Though the map is not accurate due to crude surveying methods, it does give a reasonable picture of the distribution of forest and prairie. This map, somewhat modified, has been reproduced in Figure 2, p. 22. For the purpose of orientation, I have shown present-day localities which did not exist when the original map was made. Figure 3, p. 23, shows the present-day distribution of forest and woodland. Comparisons of the two maps give a graphic picture of the change that the prairies have undergone.

The investigation of the joint commission also included questioning of many witnesses, local residents, employees of the claimants, and people who had knowledge of the area. The majority of the questions was asked in order to discover the actual value of the holdings of the company (British and American Joint Comm., 1868).

The testimony of one witness, Stephen Judson, criticizes the map as follows (British and American Joint Comm., 1868):

> Question: What is the number of oak trees per acre?
> Answer: I should say, taking the claim altogether, about three oak trees to the acre.
> Question: Is not the oak timber scattered over large portions that are marked as prairie on the map? [This is the map from which Figure 2 was made.]
> Answer: It is.

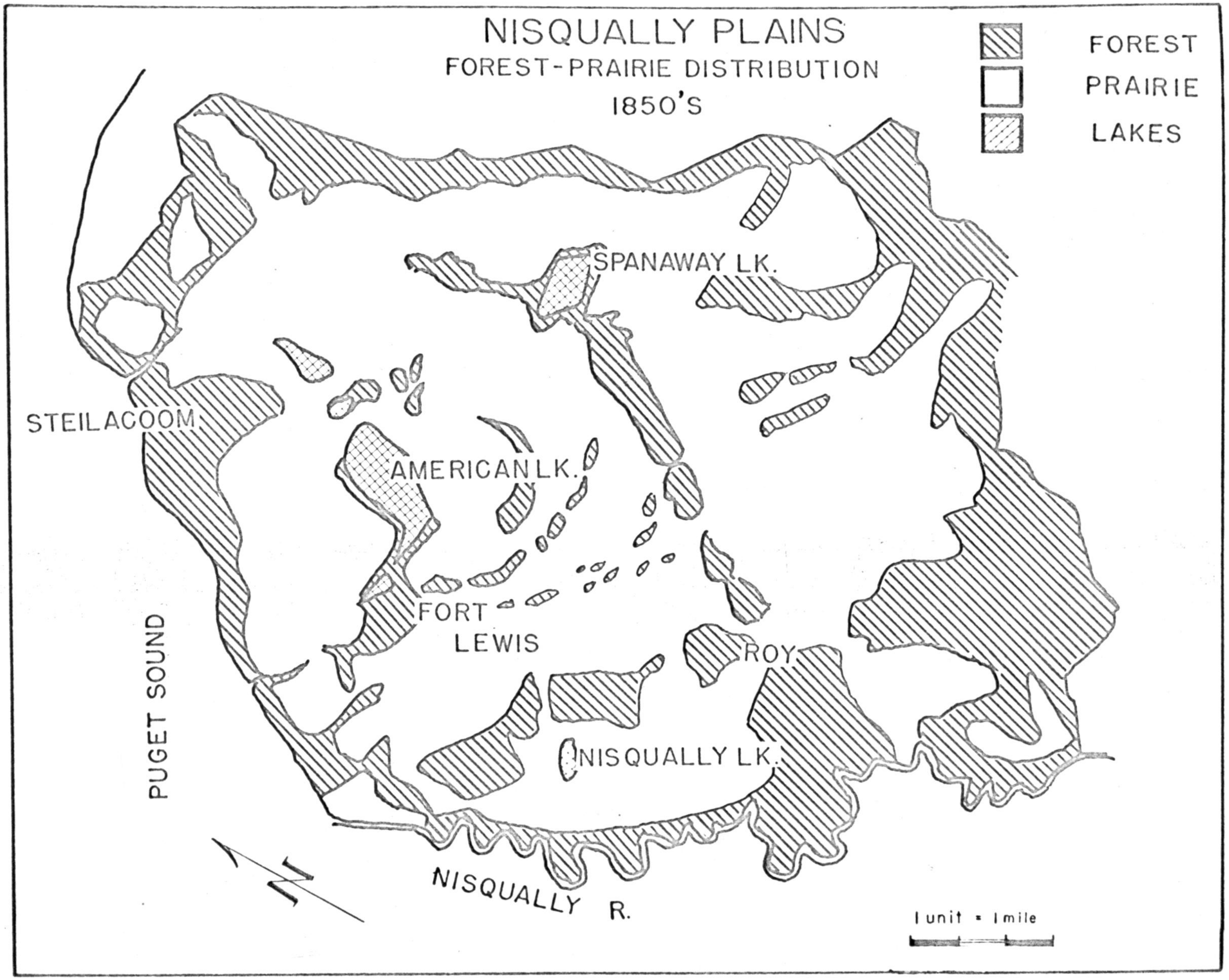

NISQUALLY PLAINS
FOREST-PRAIRIE DISTRIBUTION
1850'S
FOREST
PRAIRIE
LAKES
SPANAWAY LK.
STEILACOOM
AMERICAN LK.
FORT
LEWIS
ROY
NISQUALLY LK.
PUGET SOUND
NISQUALLY R.
1 unit = 1 mile

Figure 2

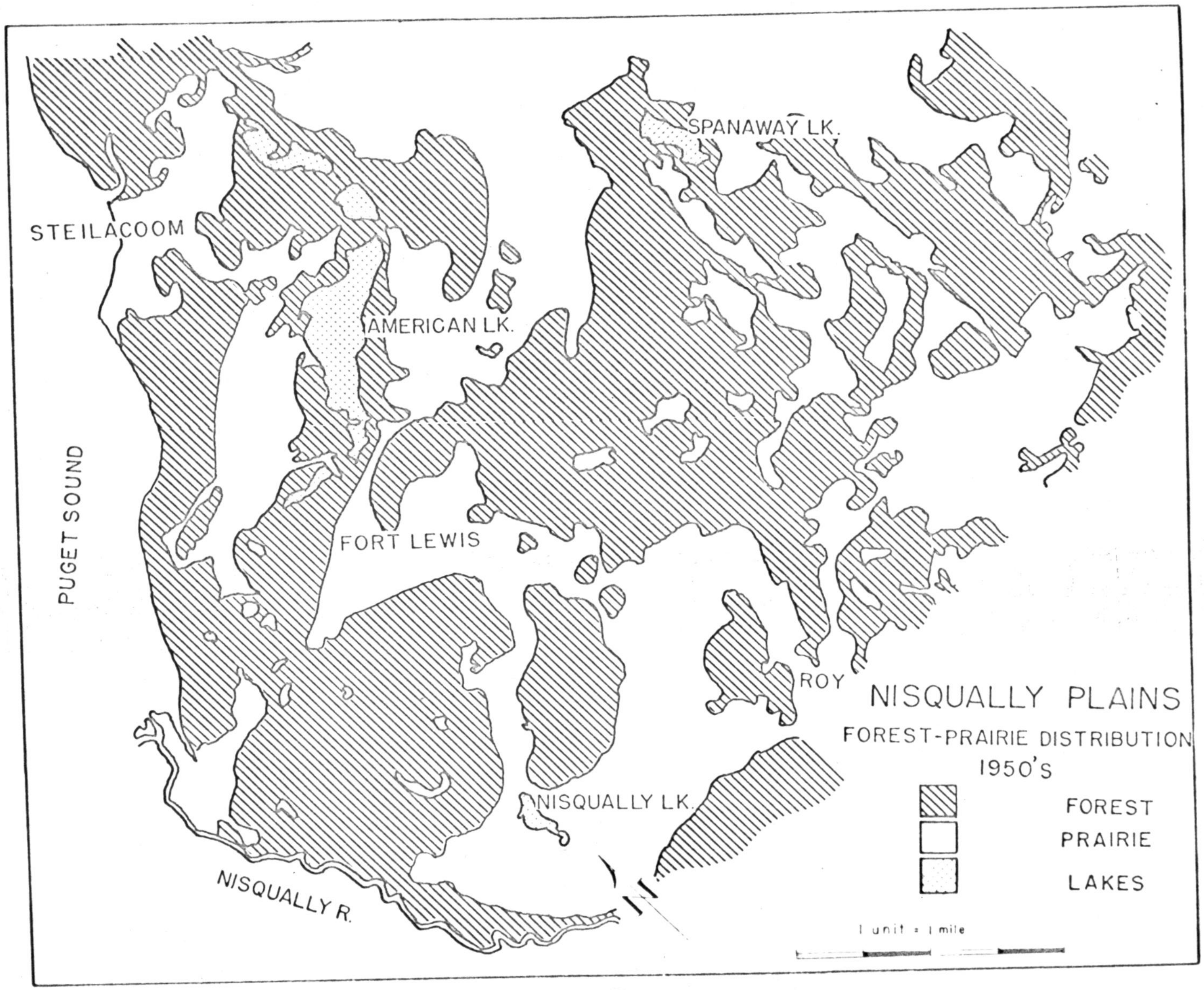

SPANAWAY LK.
STEILACOOM
AMERICAN LK.
PUGET SOUND
FORT LEWIS
ROY
NISQUALLY PLAINS
FOREST-PRAIRIE DISTRIBUTION
1950's
FOREST
PRAIRIE
LAKES
NISQUALLY LK.
N
NISQUALLY R.
1 unit = 1 mile

Figure 3

Judson's opinions suggest that the plains were not as extensive as shown on the map. He was the only witness who felt that the map was not a fair representation. However, since the map was made some ten years before the hearing, I am led to believe that it gave a reasonably accurate picture of the vegetation. Even if the prairies were smaller than the map indicates, the vegetational change, through the encroachment of the Douglas fir forest, is still striking.

The following description of the prairie was given in a letter to the Commissioner General, Land Office, Washington City, D. C., written by James Tilton, Surveyor General, Washington Territory (British and American Joint Comm., 1868):

> The Nisqually claim consists of a very extensive plain, being generally prairie, with arable lands upon the bottoms or low swales of the prairie; but its general character is not fertile. It is considered admirably adopted to the raising of cattle and sheep: much of the land is also suitable for grain. The prairie is very irregular in shape, has many belts of timber in and running through it, and a growth of small oaks of excellent quality for shipbuilding is thinly scattered over it.
>
> The claim as defined by the map, contains about 167,000 acres, of which about 80,000 acres is prairie or oak openings, and the rest a dense forest of fir, cedar and other coniferous woods.

Wier Prairie. The history of the Wier Prairie is somewhat more obscure than that of the prairies in Pierce County. Thomas W. Glascow and Thomas Linklighter took up claim there in 1847. According to Rathbun (1895) the settlement of the prairies did not really begin until the organization of Thurston County in 1852. T. B. Speek also resided on a farm on the Tenalquot Plains, as Wier Prairie was then called.

The best sources of information about Wier Prairie are the Land Office Surveys. The surveys in the area were run over a period of several years, 1851, 1853, 1855. The spread of dates is due to the method used. When a survey of an area was first run, the range and township lines were placed. Then the surveyors returned to each township and range to do the sections. From the data given by the surveyors and from the plots compiled by them, I compiled a map showing the distribution of forest and prairie. This map was checked by comparing it with the distribution of the soils. If one assumes that soil of the Spanaway series originally supported prairie vegetation and that the Douglas fir invaded the region from other soil types, the forest border of the 1850s coincides fairly well with the distribution of the soil. In most cases the forest border and the distribution of soils show that invasion started some time prior to the survey. The topography also correlates fairly well; that is, north-facing slopes and rough topography were forested then as now. The drafting of the map was not too difficult because the surveyor, as he traversed the section line, made note of the distance to the section corner when he passed from prairie to woodland or woodland to prairie. The use of Land Office Surveys is valuable in determining the nature of the vegetation at the time the survey was run. For the use of surveys in the reconstruction of vegetation, the reader is referred to work by Bourdo (1956), Kilburn (1959), Kenoyer (1929, 1939, 1942), and Habeck (1961).

As Kilburn (1959) points out, the accuracy of the map compiled from Land Office Surveys decreases proportionately with the distance from the section line. This is because the surveys did not transverse the interior of the section. The forest boundaries were doubtless drawn in by inspection. Thus, the map I have compiled is not as detailed as desired. However, it can be used to compare recent (1850 to the present) changes in the distribution of vegetation. The originals of Land Office Surveys are on file at the U. S. Bureau of Land Management, Spokane, Washington. The present map was constructed from microfilmed copies of the originals located at the Bureau of Maps and Surveys, Department of Natural Resources, Olympia, Washington.

The map showing present-day distribution of forest and prairie was drawn from Soil Conservation Service aerial photographs taken in 1953 and 1954.

In 1943 the United States Army ordered a "declaration of taking" and added the Rainier Training Area to their holdings (Hansen, 1961). This region included portions of the Wier Prairie. All records of land ownership, even those of the Tax Assessor's office, in this region are missing.

Present Vegetation

The vegetation of the Wier Prairie may be assigned into four major zones: (1) the prairie, (2) the oak woodland, (3) the Douglas fir, (4) the transitions between the prairie and the oak and Douglas fir zones. The transition zones are designated as oak transition and Douglas fir transition.

Indices of species frequency were compiled for prairie, oak woodland, Douglas fir transition, and oak transition (Tables 1, p. 34, 2, p. 41, 3, p. 50, 4, p. 52). Sampling of the Douglas fir zone was omitted because there was no duplication of species of this zone with the other zones. The purpose of the sampling was to quantify recognizable changes in frequency of the commoner species found in all four zones.

The method was as follows: In 1960 and the spring of 1961 plants of the area were collected, and a list of species growing on the prairies was compiled (see Appendix, p.102). The vegetation samples were taken June 3 at a time when both the early and the late-blooming species were identifiable. The zones to be sampled were selected with the aid of an aerial photograph. Three separate areas were chosen in each zone. Within each zone 20 tosses were made with a wire hoop of 0.25 square meters in area thrown at random. This method of sampling was based on the frequency analysis technique of Raunkiaer (Phillips, 1959). Only species rooted within the hoop were counted. An analysis of variance of the mean of the total number of hits showed that the samples from each of the zones were from four different populations. There were no significant differences in the three samples of each area, so they may be considered random.

Upon first examination the prairie appears to be composed

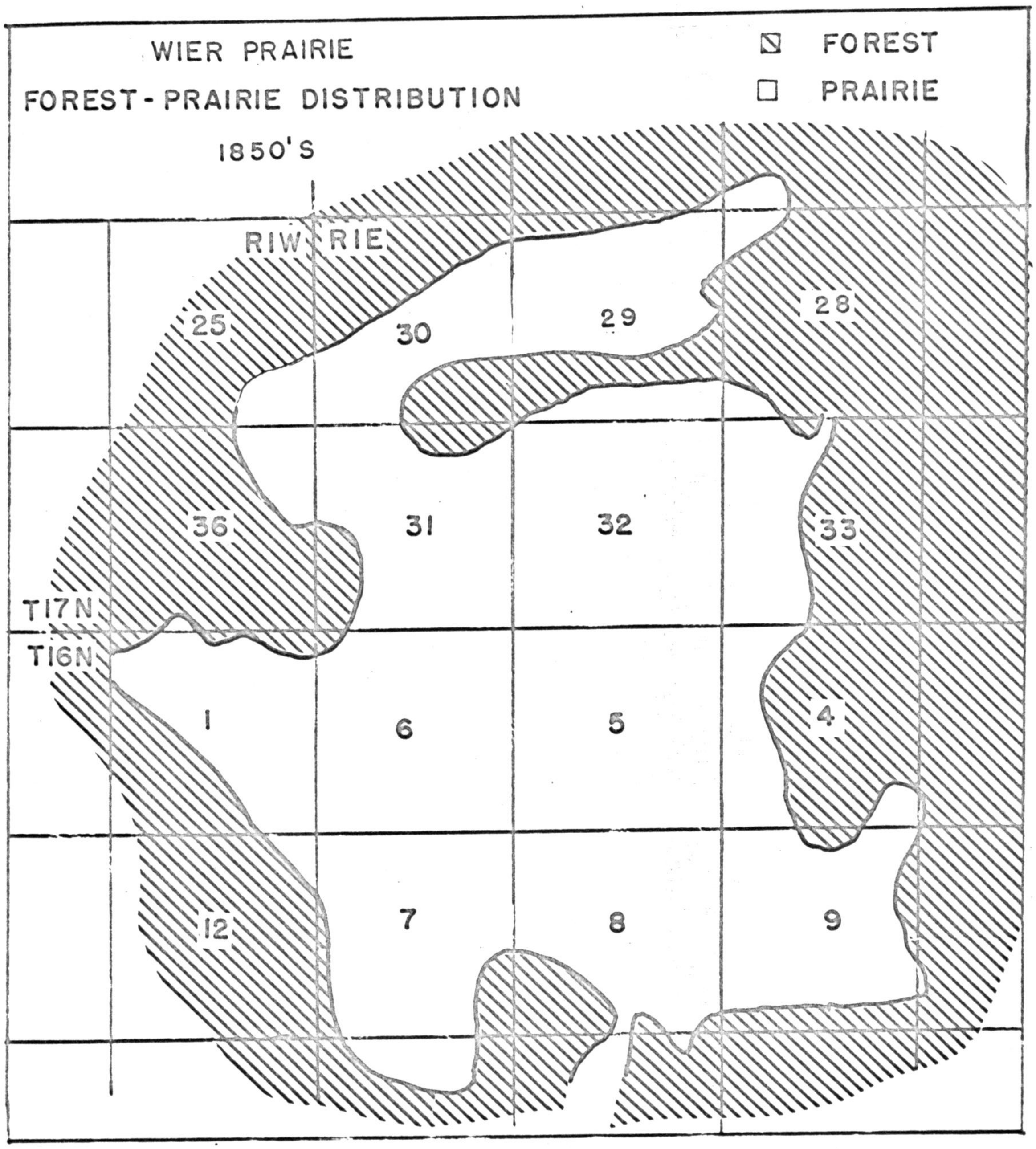

WIER PRAIRIE
FOREST-PRAIRIE DISTRIBUTION
1850'S
FOREST
PRAIRIE
RIW
RIE
T17N
T16N
25
30
29
28
36
31
32
33
1
6
5
4
12
7
8
9

Figure 4

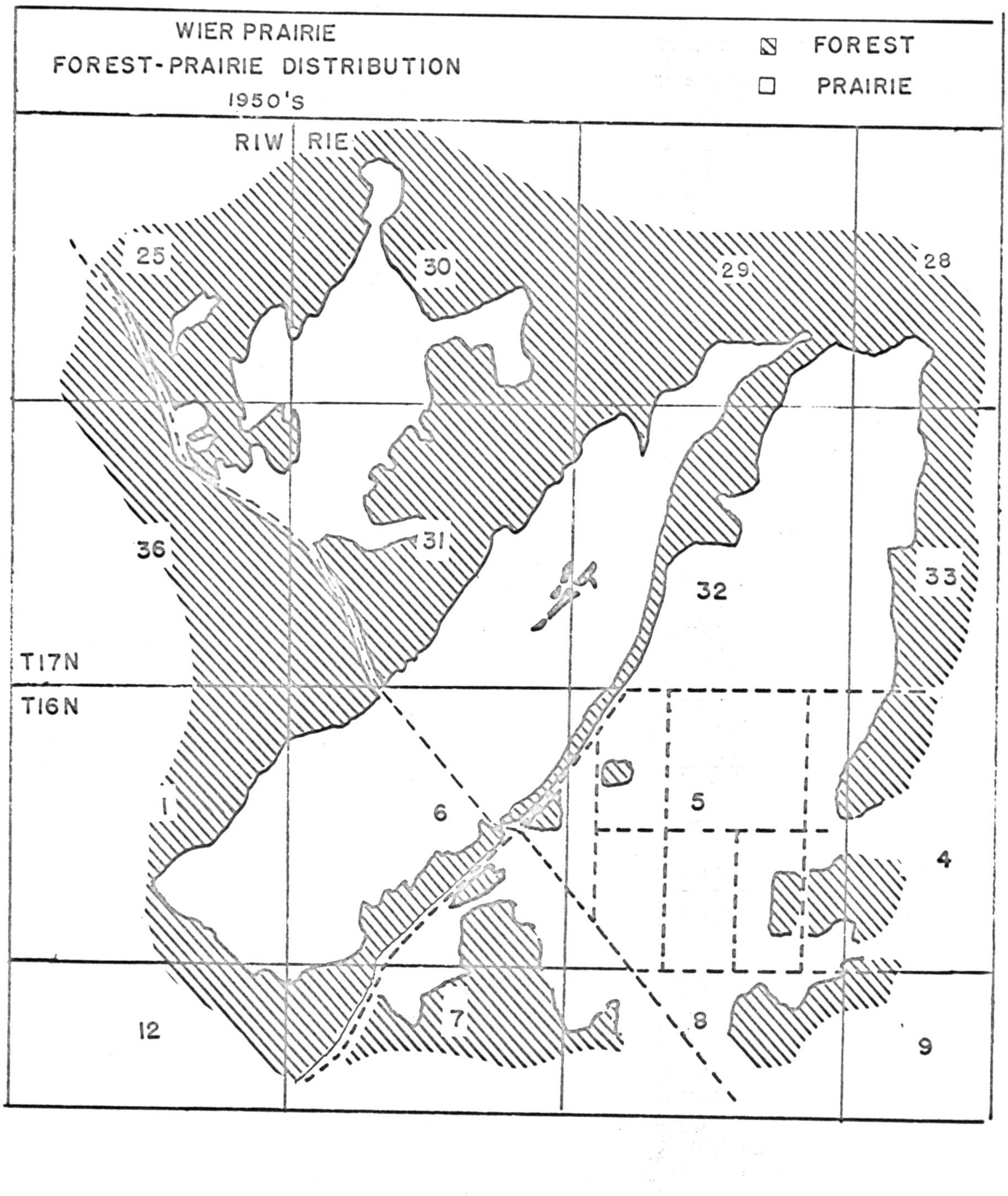

WIER PRAIRIE
FOREST-PRAIRIE DISTRIBUTION
1950'S
FOREST
PRAIRIE
R1W
R1E
25
30
29
28
36
31
32
33
T17N
T16N
1
6
5
4
12
7
8
9

Figure 5

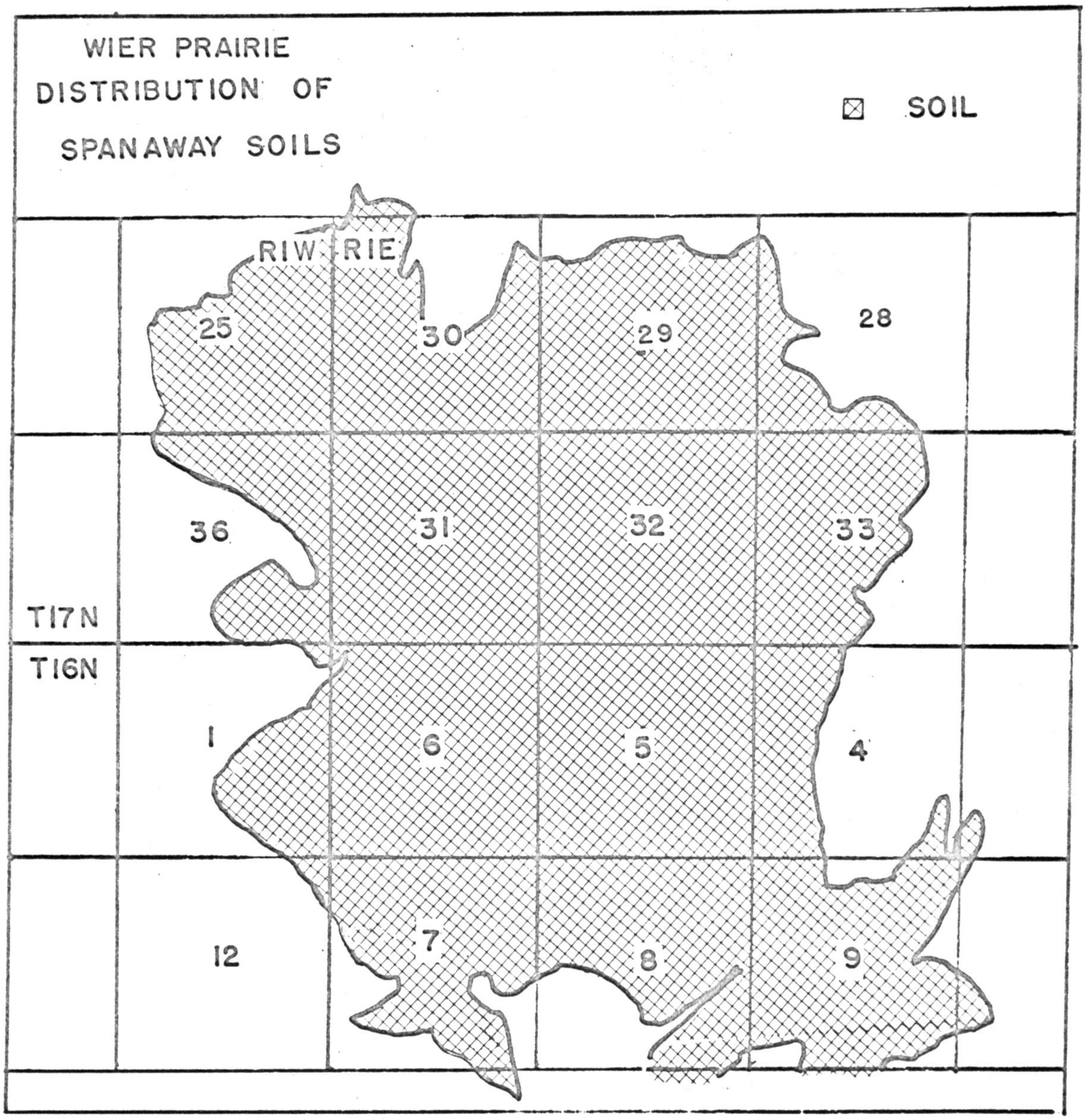

WIER PRAIRIE
DISTRIBUTION OF
SPANAWAY SOILS
SOIL
RIW RIE
25
30
29
28
36
31
32
33
T17N
T16N
1
6
5
4
12
7
8
9

Figure 6

predominantly of grasses. When looking across Wier Prairie, one sees mainly Festuca idahoensis*, with occasional colonies of Poa pratensis on small raised hummocks. Looking more closely, Aira caryophyllea is a common and abundant species among its larger neighbors. Without much searching Panicum pacificum could be found. Two grass-like species, Carex inops and Luzula multiflora, were also found.

The tall prairie grasses in the spring hide a variety of forbs. The most frequently encountered forb is the weedy adventive, Hypochaeris radicata. Scotch broom, Cytisus scoparius, is the only common shrub. It is most common on the upper prairie (see Figure 10, p. 36). Figures 7-12 show the general nature of the prairie vegetation.

The vegetation of the prairie changes markedly following disturbance by grazing and the United States Army. Certain small areas of Wier Prairie contain what I would consider the original prairie vegetation. Those few weedy species present in such areas seem to be growing with difficulty. The present remnants of what may have constituted the original prairie vegetation are composed of bunches of Festuca idahoensis. The intervening space is covered by a thick layer of Rhacomitrium canescens (see Figures 13 and 14, p. 38); Carex inops and occasionally Luzula multiflora grow through the moss cover. Forbs such as Dodecatheon herdersonii, Camassia

---

*Authorship of species given in species list in the Appendix, p.102.

quamash, Saxifrage integrifolia, Sisyrinchium idahoense, Armeria maritima, Viola adunca, V. praemorsa, Zygadenus venenosus, Balsamorhiza deltoidea also grow up through the moss. These forbs appear to be adapted to existence in a thick moss cover as their leaves extend above the moss. The original prairie must have been a closed community with a high resistance to invasion by weeds. This is indicated in the photograph of the relic of the original prairie vegetation on page 39, Figure 15. Hypochaeris pictured here typically grows with its basal leaves flat on the ground. In the thick moss of the original prairie it produces its leaves in funnel-like rosettes in the moss. The fewer specimens of Hypochaeris radicata and other weeds on the relictual sites indicate the closed nature of the original community. Wherever the moss cover has been disturbed, the frequency of weedy species increases. Figure 9, page 36, shows Agrostis diegoensis in the disturbed moss. The parallel strips of A. diegoensis are growing in the tracks made by a vehicle.

The aspect of the prairie changes with the season. In early spring it appears blue in color due to the great numbers of Camassia quamash in bloom. As spring progresses the color changes. The earlier blooming species die back, and the yellow and white composites and Scotch broom flower. By the middle of July the prairie takes on an arid appearance. All the herbaceous vegetation has dried up by this time.

The percentage of cover for all species computed from a line transect was 72. This means that only one quarter of the soil surface is devoid of vegetation. The high percentage of cover confirms the impression of the prairie vegetation as a closed community.

The vegetation samples of the prairie were taken at the following locations: NW 1/4 sec. 32, T17N, R1E. Two samples in the SW 1/4 sec. 33 were taken.

The major arborescent species in the oak woodland is the white oak, Quercus garryana. An occasional Douglas fir is also found here. The shrubby species found in this zone are Cytisus scoparius, Symphoricarpus alba, and the repent Arctostaphylos uva-ursi. The herbaceous species of this zone are also present in the prairie zone, but the frequencies are much different (Table 2, p. 41). The three most frequent species are Carex inops, Festuca idahoensis, and Fragaria bracteata. Arctostaphylos is the fourth most frequently encountered species. Hypochaeris radicata was not encountered here though it was prevalent in the other zones. The time of flowering appears to be about the same in the several zones. One of the last species to bloom in the oak woodland is Habenaria unalaschensis var. elata. This species is restricted to the oak zone and blooms during July. Figures 16-19, pp. 42-44, show the vegetation of the oak woodland.

Within the oak woodland there are several old individuals among the younger oak trees (Figure 19, p. 44). Seedling oak and firs are occasionally encountered in the woods beneath the older

TABLE 1

PRAIRIE ZONE, SPECIES FREQUENCY

SPECIES	FREQUENCY (%)
Hypochaeris radicata	85
Rhacomitrium canescens	75
Aira caryophyllea	45
Carex inops	43
Festuca idahoensis	40
Polytrichium juniperinum	37
Lotus micranthus	28
Holcus lanatus	23
Trifolium dubium	22
Luzula multiflora	21
Hieracium albiflorum	16
Agrostis diegoensis	15
Teesdalia nudicaulis	13
Eriophyllum lanatum	15
Hypericum perforatum	10
Chrysanthemum leucanthemum	11
Festuca megalura	10
Plantago lanceolata	10
Microseris lacinata	8
Panicum pacificum	8
Prunella vulgaris	8
Danthonia californica	5
Rumex acetosella	4
Lomatium utriculatum	4
Zygadenus venenosus	4
Fragaria bracteata	3
Achillea lanulosa	1.6
Antennaria neglecta var. howellii	1.6
Apocynum androsaemifolium	1.6
Bromus mollis	1.6
Elymus sp.	1.6
Poa pratensis	1.6

SPECIES SPORADICALLY PRESENT BUT NOT COUNTED

Armeria maritima
Camassia quamash
Dodecatheon hendersonii
Fritillaria lanceolata
Lithophragma parviflora
Lupinus lepidus
Potentilla gracilis
Saxifraga integrifolia
Sisyrinchium idahoense
Viola adunca

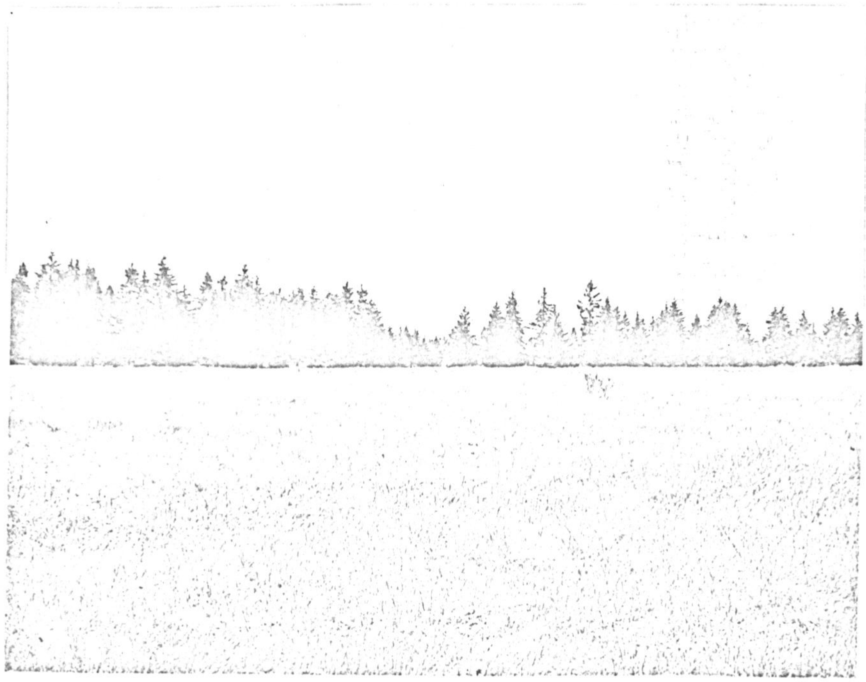


Figure 7. View across the middle Wier Prairie.

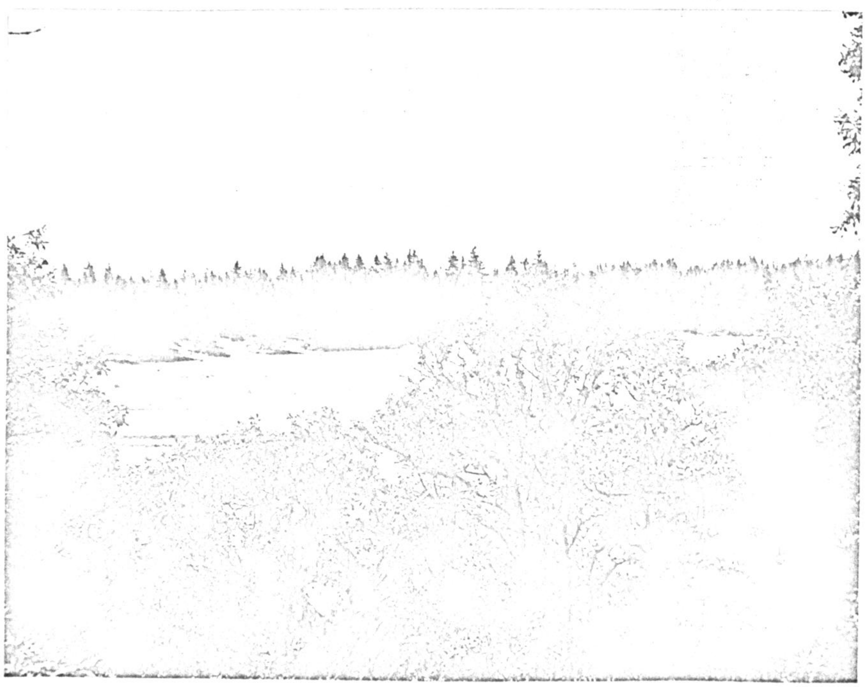


Figure 8. View of middle Wier Prairie from the upper prairie.

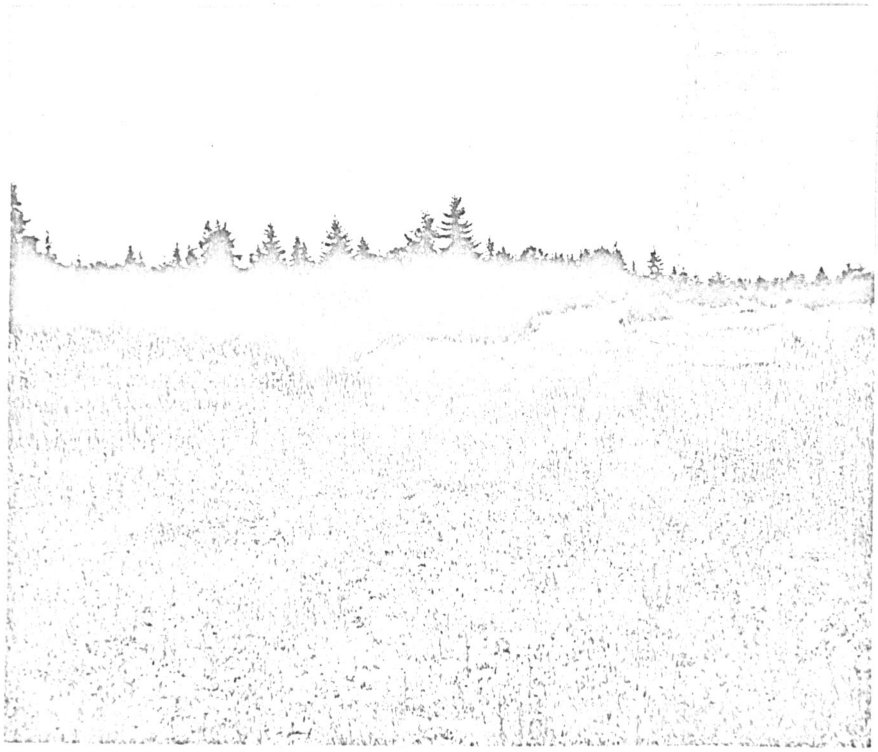


Figure 9. Disturbed area with Agrostis diegoensis in tank tracks.

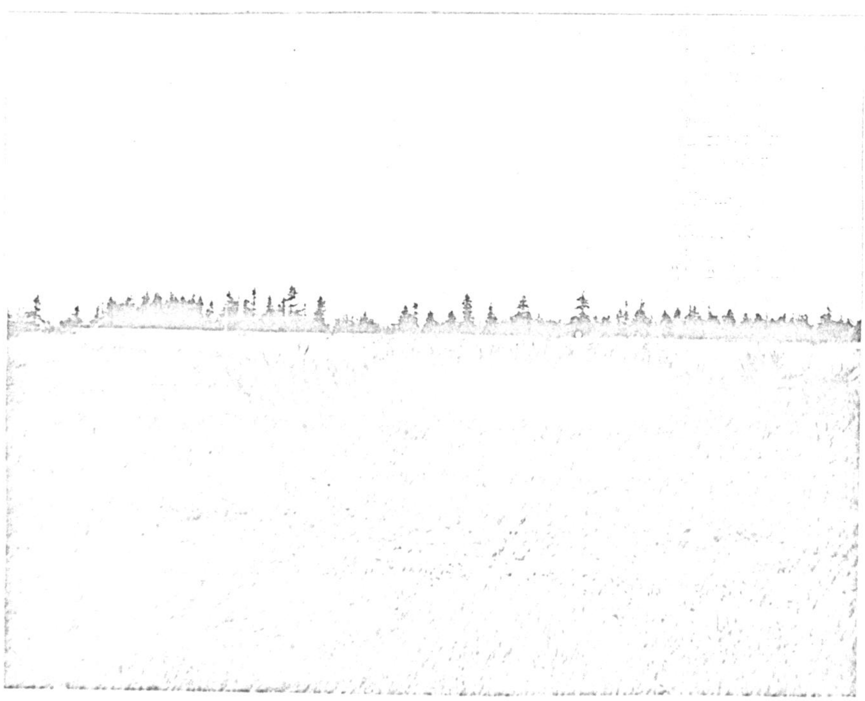


Figure 10. Wier Prairie with Cytisus scooparious in the foreground.

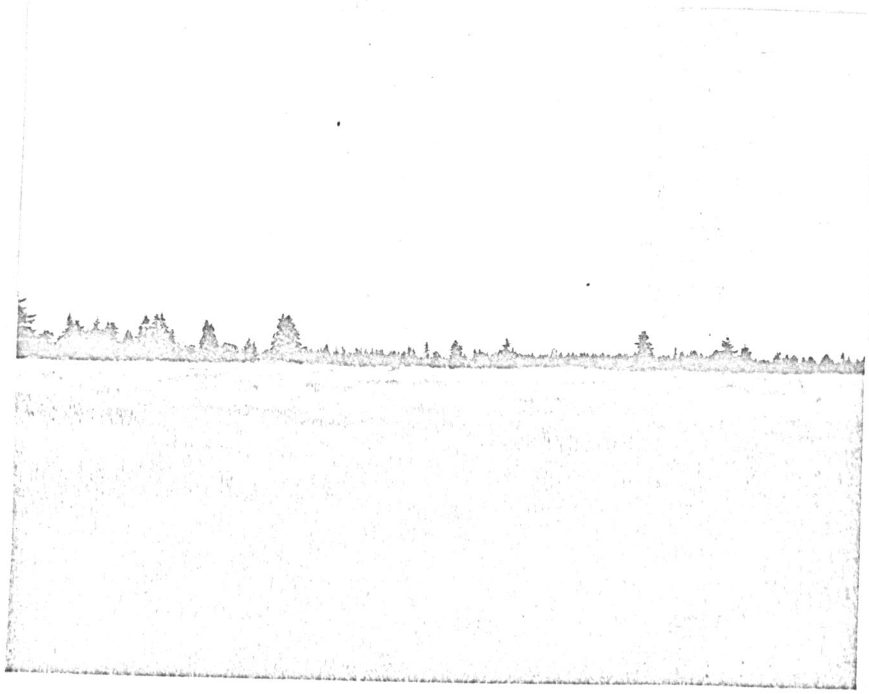


Figure 11. View across upper Wier Prairie facing northeast.

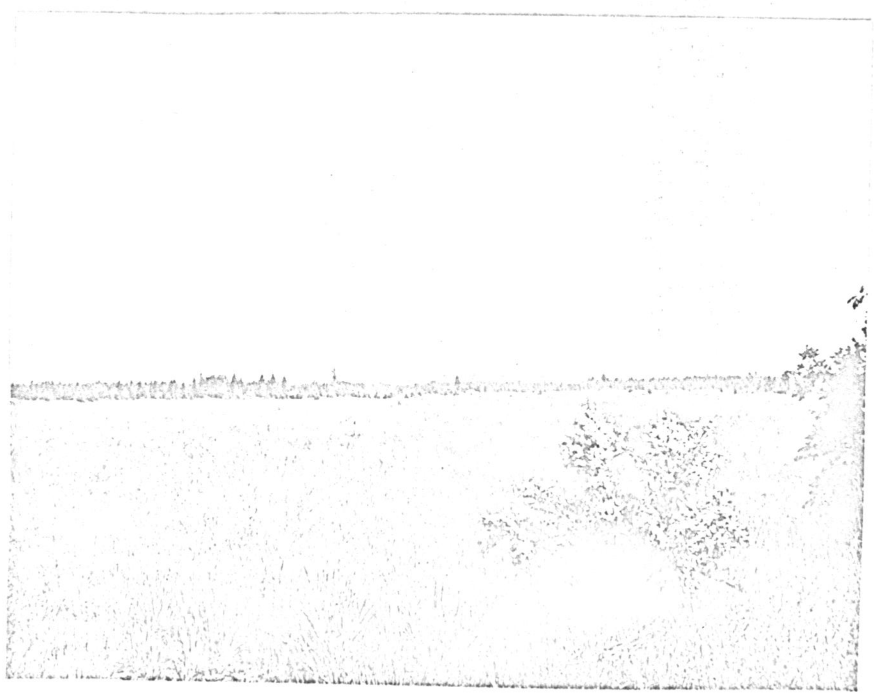


Figure 12. View looking south towards farmed portion of Wier Prairie and the Bald Hills.

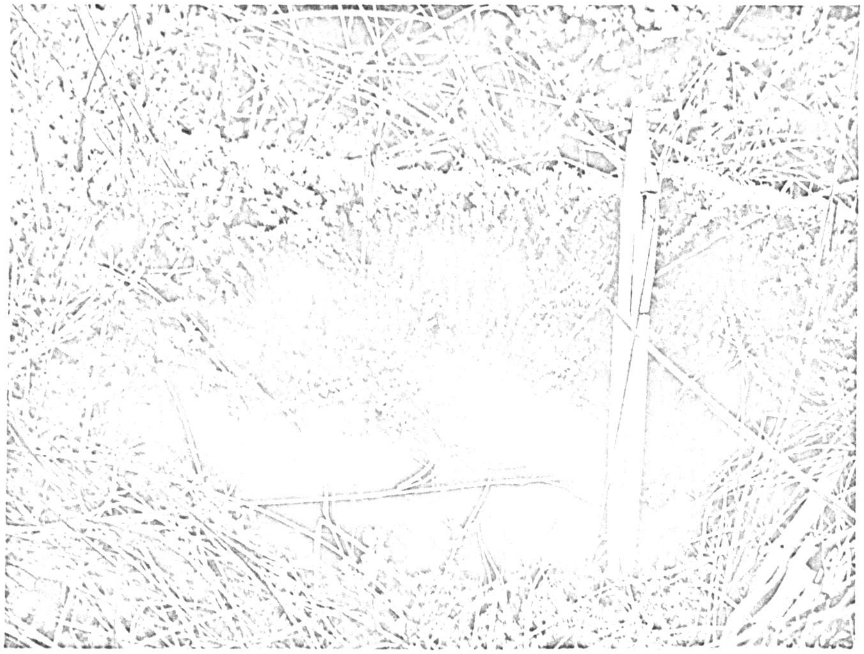


Figure 13. Thick layer of Rhacomitrium canescens var. ericoides. The pen is about 5 1/2 inches long.

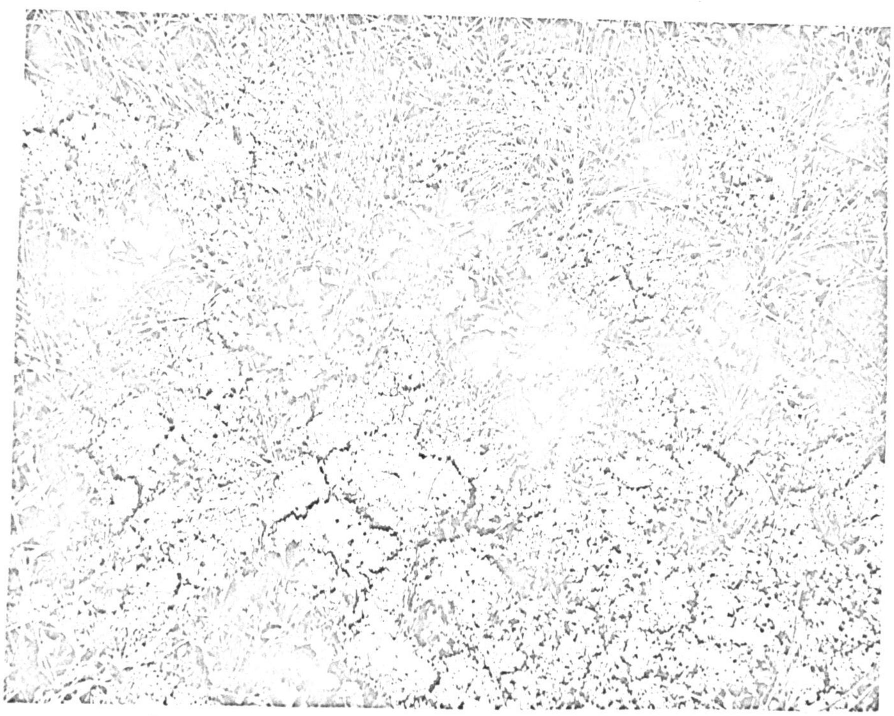


Figure 14. View of well-developed moss layer.

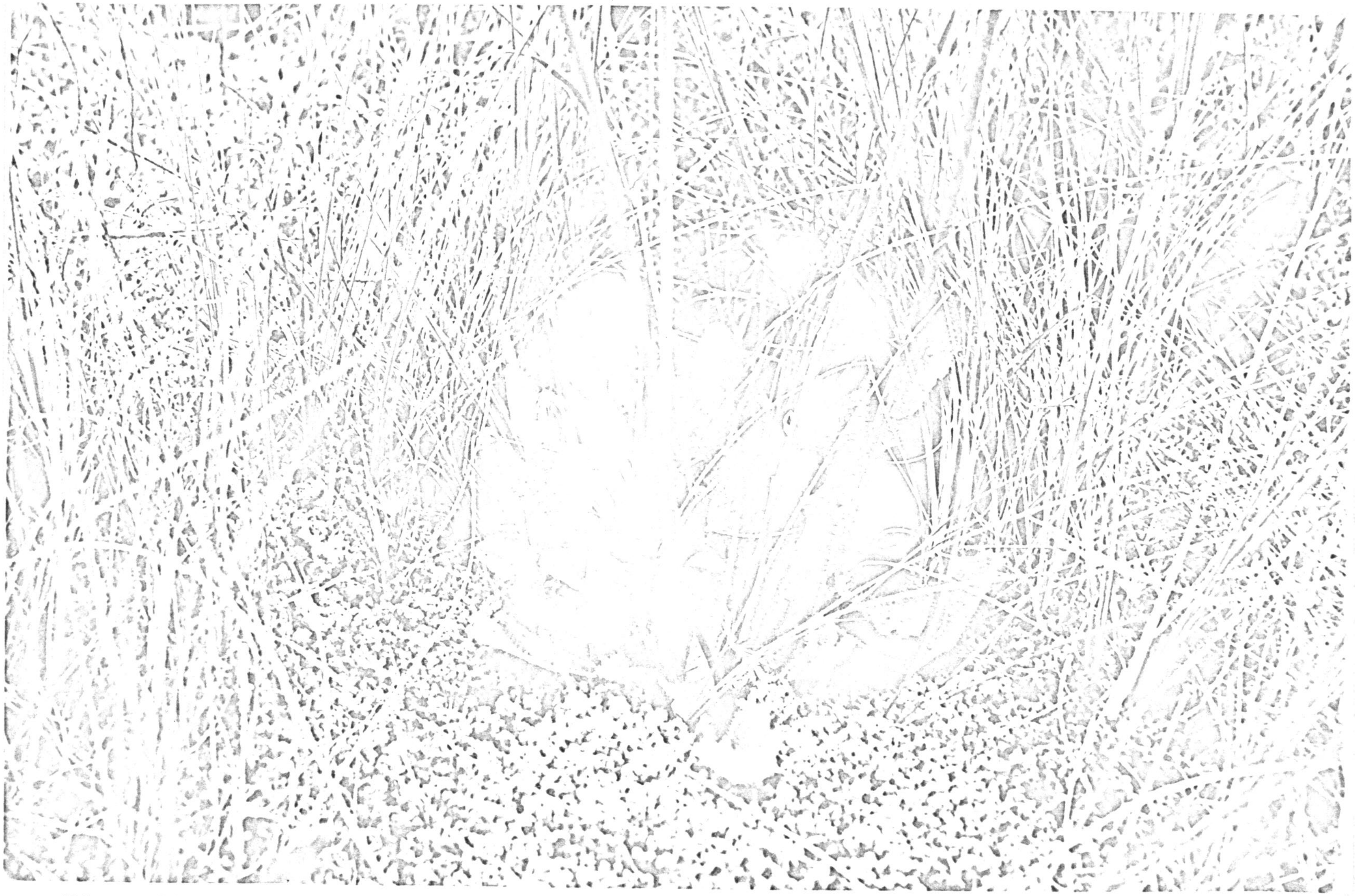


Figure 15. Hypochaeris radicata forced to grow its leaves at an angle to the surface.

trees (Figure 20, p. 45).

Douglas fir surrounds the prairie and oak woodland. The Douglas fir forms so dense a canopy that there is little or no undergrowth except along the immediate border between the fir and the prairie, where the canopy is open and light can filter through (Figure 23, p. 46). The only arborescent species in these recently forested areas is *Pseudotsuga menziesii*. The shrub layer is composed of *Symphoricarpus albus* and *Osmaronia cerasiformis*. The herbaceous plants include *Goodyera oblongifolia*, *Corallorhiza maculata*, and *Sanicula crassicaulis*. Some of the mosses are *Rytidiadelphus triquetrus* and *Eurhynchium oreganum*.

As I walked from the prairie into old, well established Douglas fir, I encountered a flora more typical of the Douglas fir understory. Trees such as *Acer macrophyllum*, *A. circinatum*, *Salix scouleriana*, *Cornus nuttallii*, and shrubs, such as *Corylus cornuta* var. *californica*, *Holodiscus discolor*, *Amelanchier florida*, *Gaultheria shallon*, *Berberis nervosa*, *B. aquifolium*, *Vaccinium parviflorium* are encountered. The species of the Douglas fir zone do not penetrate the prairies. An exception to this is an occasional individual of *Sanicula crassicaulis* in the Douglas fir transition zone (and of course *Pseudotsuga*). The most striking feature of this zone is its sharp boundary at the edge of the prairie (Figure 22, p. 46).

I subdivided the transition zone into the oak transition and

TABLE 2

OAK WOODLAND ZONE, SPECIES FREQUENCY

SPECIES	FREQUENCY (%)
Carex inops	72
Festuca idahoensis	33
Fragaria bracteata	29
Arctostaphylos uva-ursi	23
Cytisus scoparius	18
Hieracium albiflorum	16
Prunella vulgaris	16
Lomatium triternatum	16
Poa pratensis	16
Danthonia californica	11
Holcus lanatus	11
Eriophyllum lanatum	10
Eurhynchium oreganum	10
Microseris lacinata	10
Aira caryophyllea	8
Lotus micranthus	8
Polytrichium juniperinum	8
Rhacomitrium canescens	8
Ranunculus occidentalis	8
Rumex acetosella	8
Achillea lanulosa	6
Elymus	6
Geranium	6
Galium	5
Rytidiadelphus triquetrus	5
Habenaria unalaschensis var. elata	3
Lomatium utriculatum	3
Viola adunca	3
Trifolium dubium	3
Antennaria neglecta var. howellii	1.6
Bromus mollis	1.6
Camassia quamash	1.6
Teesdalia nudicaulis	1.6
Luzula multiflora	1.6
Panicum pacificum	1.6
Viola praemorsa	1.6

Figure 16. View of edge of oak woodland, Wier Prairie.

Figure 17. View of the interior of the oak woodland, Wier Prairie.

Figure 18. Quercus garryana, Wier Prairie.

Figure 19. Old *Quercus garryana*, Wier Prairie.

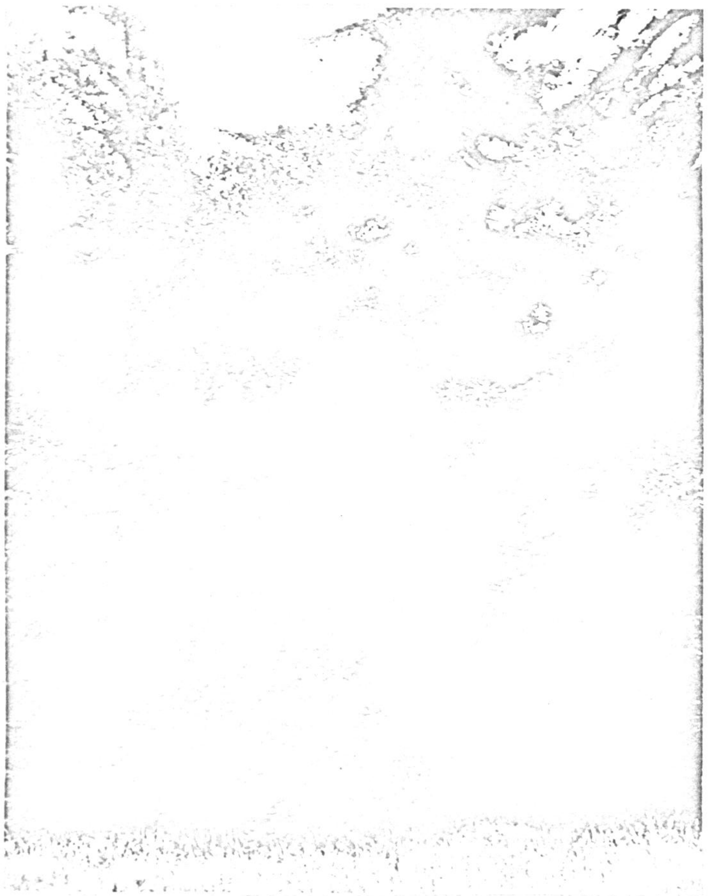


Figure 20. Oak tree surrounded by Douglas fir.

Figure 21. Douglas fir transition zone.

Figure 22. Exterior view of Douglas fir woodland.

Figure 23. Interior view of Douglas fir woodland.

the Douglas fir transition. The floristic composition of these zones is similar to that of the prairie, though the species frequencies are different. The cause of the variation in frequency is not known.

In the oak transition zone one vegetation sample was taken in SW 1/4 sec. 32 and two in the NE 1/4 sec. 32, T17N, R1E. Fragaria bracteata which shows the highest frequency (29) in the oak zone and the lowest (3) in the prairie shows a frequency of 27 in the oak transition (Table 3, p. 50). These frequencies indicate the "preference" of the species for the oak woodland.

Two samples for the Douglas fir transition zone were taken in SW 1/4 sec. 33 and one in the NW 1/4 sec. 22, T17N, R1E. Weedy species, such as Hypochaeris radicata and Aira caryophyllea have high frequencies in the Douglas fir transition zone, indicating a disturbed site. It is in this zone where Pteridium aquilinum is most frequently found.

An area of interest is the Quercus-Pseudotsuga stand on the steep north-facing slope between the upper and middle prairies. During the summer of 1960 a portion of the slope was logged. By counting the growth rings on the Douglas fir, the ages of the fir and oak were compared. Scheffer (1959) devised a formula whereby the approximate age of the oak may be determined. The age of the oak is obtained by multiplying the diameter in inches by eleven; this product is the approximate age in years.

AGE IN YEARS

Douglas Fir		Oak*	
1	34	1	83
2	42	2	70
3	39	3	80
4	29	4	95
5	27	5	132
6	37	6	96
7	35	7	129
8	67	8	111
9	86		
Average age = 44.6 years		Average age = 97 years	

*Estimated by Scheffer's formula

The relative ages of these two species indicate that the Douglas fir was a comparatively new invader of the slope. The oak had been present some 50 years before the Douglas fir.

Ecological Characteristics of Species

The ecological characteristics of some of the major species of the prairie and the Douglas fir zones are important to an understanding of the reaction they would exhibit to environmental phenomena such as fire and drought.

Trees. Perhaps the most important feature of *Pseudotsuga menziesii* is its reaction to fire. Judd (1915) points out that due to its thick bark an adult Douglas fir suffers little damage from fire. Harlow and Harrar (1941) contend that this is not always the case. Although the thick bark does protect the tree, the crown is highly imflammable. A young seedling would not be able to survive a fire. Many of the larger isolated trees in the prairie have their branches some distance above the ground. If a seedling were able to reach an age at which the imflammable crown was high above the ground without getting burned, it might be able to withstand prairie fires. Germination of Douglas fir is good in both mineral and humus soil, and dense thickets will spring up provided fire is excluded (Harlow and Harrar, 1941). Seeds from Douglas fir grew well when removed to plantation sites of better soil (Munger and Morris, 1936). The seeds came from trees in a sparse slow-growing stand on the prairies near Lakeview in Pierce County. The progeny showed none of the effects of the poor soil.

An important ecological feature of *Quercus garryana* is its means of reproduction. Large crops of seed are produced annually, but germination and establishment is poor because of the inability of the seeds to penetrate the sod. According to Harlow and Harrar (1941) and Scheffer (1960) Garry oak reproduces best by stump sprouts and root suckers. By this means new stands are quickly re-established after fire. The Garry oak therefore would seem to have a distinct advantage over Douglas fir which reproduces only by seeds. Garry oak does best where rainfall is less than 30 inches per year and where the summer humidity is low (Harlow and Harrar, 1941).

Grasses and Grass-like Species. The perennial cespitose bunch

TABLE 3

OAK WOODLAND TRANSITION ZONE, SPECIES FREQUENCY

SPECIES	FREQUENCY (%)
Rhacomitrium canescens	57
Aira caryophyllea	49
Festuca idahoensis	43
Hypochaeris radicata	40
Carex inops	31
Fragaria bracteata	27
Arctostaphylos uva-ursi	25
Holcus lanatus	23
Hypericum perforatum	23
Danthonia californica	22
Ranunculus occidentalis	21
Panicum pacificum	18
Polytrichium juniperinum	18
Prunella vulgaris	18
Rumex acetosella	18
Microseris lacinata	15
Achillea lanulosa	13
Lomatium utriculatum	13
Hieracium albiflorum	11
Luzula multiflora	11
Camassia quamash	10
Teesdalia nudicaulis	10
Lotus micranthus	10
Eriophyllum lanatum	6
Trifolium dubium	6
Festuca megalura	5
Chrysanthemum leucanthemum	5
Agrostis diegoensis	5
Bromus carinatus	3
Bromus mollis	3
Viola adunca	3
Antennaria neglecta var. howellii	1.6
Cerastium arvense	1.6
Linanthus bicolor	1.6
Plantago lanceolata	1.6
Eurhynchium oreganum	1.6
Poa pratensis	1.6
Viola praemorsa	1.6

TABLE 4

DOUGLAS FIR TRANSITION ZONE, SPECIES FREQUENCY

SPECIES	FREQUENCY(%)
Hypochaeris radicata	83
Aira caryophyllea	76
Trifolium dubium	60
Rhacomitrium canescens	40
Festuca megalura	38
Plantago lanceolata	35
Carex inops	33
Polytrichium juniperinum	31
Holcus lanatus	30
Danthonia californica	28
Linanthus bicolor	16
Teesdalia nudicaulis	13
Agrostis diegoensis	13
Pteridium aquilinum	13
Festuca idahoensis	11
Fragaria bracteata	11
Luzula multiflora	11
Hypericum perforatum	10
Lotus micranthus	8
Eriopnyllum lanatum	3
Camassia quamash	6
Panicum pacificum	6
Rumex acetosella	6
Ranunculus occidentalis	5
Apocynum androsaemifolium	3
Arctostaphylos uva-ursi	3
Poa pratensis	3
Bromus mollis	1.6
Cytisus scoparius	1.6
Eurhynchium oreganum	1.6
Microseris lacinata	1.6
Pseudotsuga menziesii (seedling)	1.6

Figure 24. Oak woodland-prairie border.

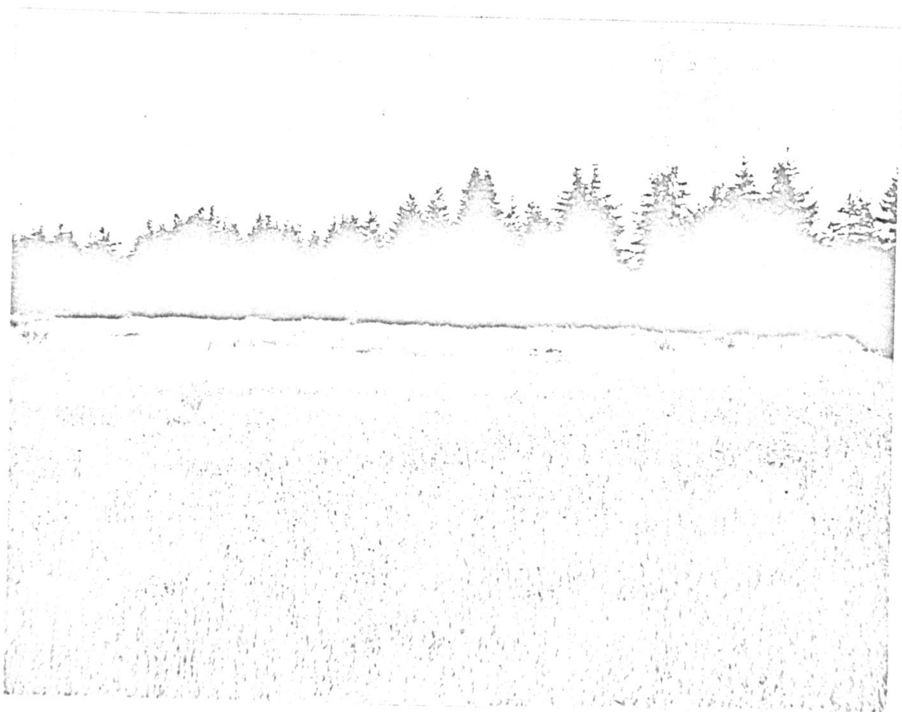


Figure 25. Douglas fir-prairie border.

Figure 26. Scattered Douglas firs in Wier Prairie.

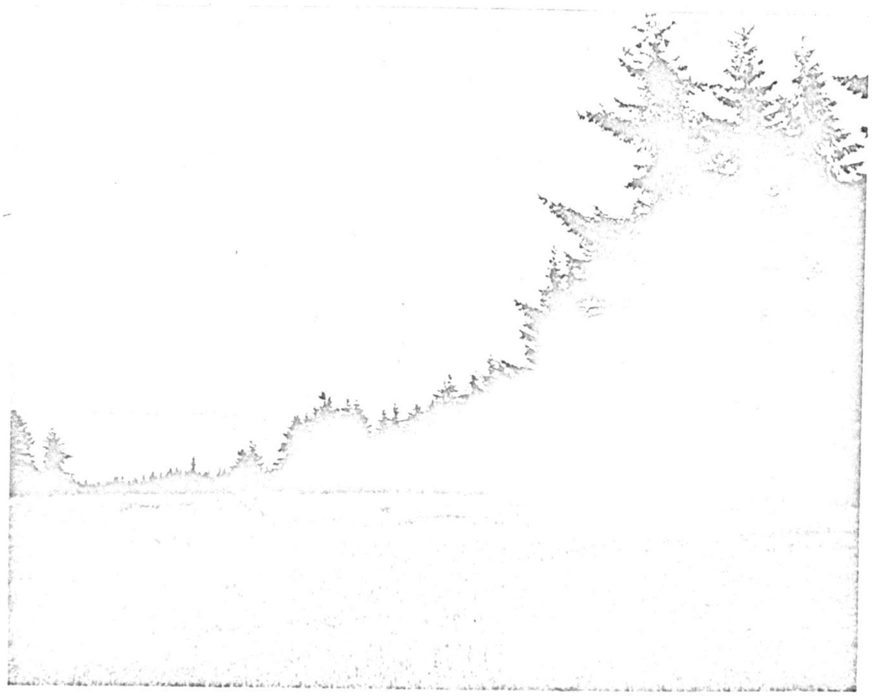


Figure 27. Douglas fir transition zone.

Figure 28. Wier Prairie showing Douglas fir seedling and Cytisus scopari us.

Figure 29. Douglas fir seedling, Wier Prairie.

Figure 30. Douglas fir seedlings in oak woodland.

grass, Festuca idahoensis, assumes its typical growth form on the prairies. Apparently there is no vegetative reproduction by rhizomes. Sarvas (in Lutz, 1956) reports that Festuca ovina, a closely related species, reproduces from basal buds as well as from seeds after fire. Careful check of F. idahoensis growing in burned areas might show this same feature. If basal buds were found, it would indicate the species would have a better chance of surviving fire. Carex inops is a cespitose perennial sedge which reproduces vegetatively by stout rootstocks.

Forbs. Three features of the native forbs upon the prairie make them adapted to their environment. First, many bloom early. Second, many possess the geophyte type of life form (Raunkiaer, 1935). And third, they are perennial.

Mosses. The moss Polytrichum juniperinum is said to have deep rhizoids which aid in reproduction of the species following a fire (Sarvas in Lutz, 1956). Some species of mosses are able to survive fires (Ahlgren and Ahlgren, 1960). In the New Jersey pine barrens gentle burning favors the development of a bryophytic-lichen layer (Moul and Buell, 1955).

Weedy Species. The white men brought with him many weedy species. There may have been three points of entry. Since Fort Nisqually and Steilacoom were the first localities on the Sound where Caucasians first settled, it is possible that many of the weeds entered here. For many years these localities were seaports where most supplies were landed. The second portal could have been

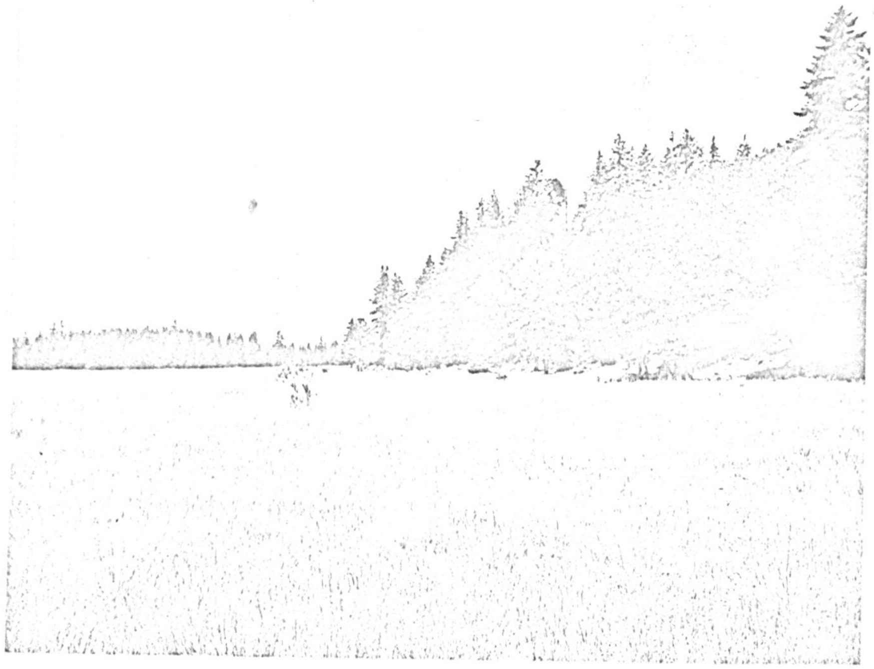


Figure 31. View of base of steep north-facing erosion slope, Wier Prairie.

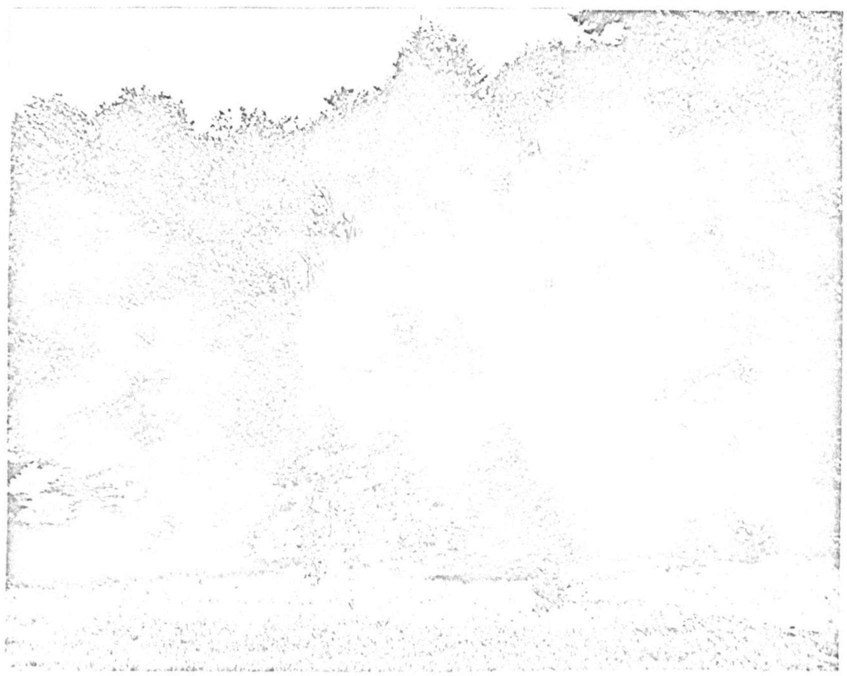


Figure 32. Face view of steep north-facing erosion slope, Wier Prairie.

Figure 33. Top of steep north-facing erosion slope, Wier Prairie.

TABLE 5

PHYTOGEOGRAPHICAL ALLIANCES OF THE FLORA OF THE GRAVELLY PRAIRIES OF WESTERN WASHINGTON (After Piper, 1906)

Species Generally Occurring on the Prairies but not Elsewhere in Washington

Arenaria tenella
Aster curtus
Brodiaea cornoaria
B. pulchella
Collomia tenella
Erythronium oregonum
Godetia amoena
G. quadrivulnera
Grindelia nana var. integrifolia
Iris tenax
Lomatium utriculatum
Lotus formosissimus
Lupinus albicaulis
Lupinus lepidus
Madia minima
Microseris laciniata
Orthocarpus attenuatus
Plectritis congesta
Ranunculus orthorhynchus
Senecio macounii
Solidago missouriensis
Synthris reniformis
Trifolium bifidum
T. tridentatum
Viola howellii

Species Occurring on Both Sides of the Cascade Mountains

Agroseris heterophylla
Alchemilla occidentalis
Antennaria neglecta var. howellii
Athysanus pusillus
Balsamorhiza hookeri
B. deltoidea
Boisduvalia stricta
Brodiaea hyacinthina
Caucalis microcarpa
Ceanothus sanguineus
Collinsia grandiflora
Crocidium multicaule
Erigeron speciosus
Gilia capitata
Githopsis specularioides
Heuchera cylindrica
Hieracium scouleri
Lomatium nudicaule
L. triternatum
Lotus douglasii
Marah oreganus
Microsteris gracilis
Navarretia intertexta
Pectocarya penicillata
Perideridia gairdneri
Pinus ponderosa
Polemonium micranthum
Prunus demissa
Psilocarpus elatior
Quercus garryana
Sedum douglasii
Sidalcea campestris
Silene menziesii
Sisyrinchium idahoense
Specularia rariflorum
Stellaria nitens
Thysanocarpus curvipes
Tonella tenella
Zygadenus venenosus

TABLE 6

SPECIES OF THE FESTUCETUM OF EASTERN WASHINGTON

(Daubenmire, 1942)

Achillea lanulosa	Galium boreale
Agropyron spicatum	Geranium viscosissimum
Astragalus arrectus	Gilia gracilis
A. spaldingii	Haplopappus liatriformis
Balsamorhiza sagittata	Helianthella douglasii
Besseya rubra	Hieracium albertinum
Brodiaea douglasii	Iris missouriensis
Bromus brizaeformis	Koeleria cristata
B. mollis	Lactuca sp.
B. tectorum	Lithophragma bulbifera
Calochortus sp.	L. parviflora
C. elegans	Lithospermum ruderale
Carex geyeri	Lupinus sericeus
Castelleja lutea	Poa pratensis
Collinsia parviflora	Potentilla blaschkeana
Claytonia linearis	Ptilocalais nutans
C. parviflora	Rosa sp.
Draba verna	Senecio columbianus
Epilobium paniculatum	Sisyrinchium inflatum
Erigeron corymbosus	Sieversia ciliata
Erythronium grandiflorum	Solidago missouriensis
Fritillaria pudica	Stellaria nitens
Frasera albicaulis	Symphoricarpos albus
Festuca idahoensis	Zygadenus gramineus

from the south, following the emigration of settlers from the Willamette Valley. Many of the weedy species were doubtless transported in hay and cattle feed which were brought in with some of the Hudson's Bay Company's cattle. In some cases the species were introduced as ornamentals.

Probably the most persistent and widespread weed of the prairie is Hypochaeris radicata. It was introduced into the Northwest shortly before 1904. Mangum (1911) stated that about this time it started to increased rapidly in the Puget Sound country.

The weed Hypericum perforatum is only locally abundant. It is apparently a recent arrival on the prairies. H. perforatum was not recorded in the University of Washington herbarium from the prairie until 1930.

The weedy shrub, Cytisus scoparius, according to Theo. Scheffer (1960), was introduced at Steilacoom as an ornamental. Oldtimers in the area claim to remember when it was common only around Steilacoom.

Other introduced weeds are also worthy of mention. Aira caryophyllea was collected by the Wilkes expedition in 1841. Mangum (1911) reports that when this plant dries up in the summer and fall, it creates a fire hazard on the prairies.

Chrysanthemum leucanthemum was introduced from the eastern United States either as an ornamental or in hay. It has become well established. Spergula arvensis is found occasionally on the prairie, and according to Mangum (1911), it was introduced about 1905.

The indigenous flora of the prairies is more closely allied to Eastern Washington than it is to that of Western Washington. Comparison of the species list here (see Appendix, p.102) with those recorded by Daubenmire (1942) (Table 6, p. 60) for the *Festuca idahoensis* community of Eastern Washington shows close relationship at the generic level; in some cases the species are the same.

To the south of the prairie in the Bald Hills there are open areas dominated by grasses which support a flora similar to that of the prairie. The balds are small oval openings in the Douglas fir forests, seldom more than a few acres in size. At the outer edges are oak trees, with a few madronas (*Arbutus menziesii*). There are generally a few oaks isolated or in groups in the opening itself. *Festuca idahoensis* is the major grass. *Camassia quamash*, *Dodecatheon hendersonii*, and *Fragaria bracteata* are also present. There is a thick layer of *Rhacomitrium canescens* on the ground between the forbs and grasses.

These balds were beyond the reach of glaciation. It is possible that the balds at one time were more extensive and served as a center of dissemination for some of the prairie species in the Puget Sound lowland after recession of the glacier.

Piper (1906) separated the indigenous species of the prairies of Western Washington into two groups: Those which occur only on the prairies in Washington and Oregon and do not generally occur elsewhere

(Table 5, p. 58), and those which range up and down the coast along both sides of the mountains from British Columbia to California (Table 5, p. 58). The latter group reached the Columbia Basin via the Klamath Gap (Piper, 1906). When Piper compiled this list, the ranges of many of these species were not completely known. A survey of collections deposited in the University of Washington herbarium shows that the flora of the prairies has affinities with that of other dry prairies in Northwest Washington at Sequim, in the San Juan Islands, and on the prairies of Whidbey Island. Many of the species on Piper's list such as *Camassia quamash* *Lomatium triternatum*, and *Sisyrinchium idahoense* are found on these prairies. A partial species list for the prairies compiled from Piper (1906), Rigg (1917), my own collections, and specimens in the University of Washington herabrium is found in the Appendix. The nomenclature follows Peck (1961) and Hitchcock, *et al* (1955).

IV. FACTORS EFFECTING VEGETATIONAL CHANGE

The environmental factors which have had an effect upon the prairie vegetation, either from the standpoint of its origin and maintenance, or as causes of encroachment of Douglas fir, may be divided into two major groups, natural factors and human factors.

Natural Factors

Natural factors are those which generally are not associated with man's activities. They include glaciation, soils, climate, and fire. These factors all have been instrumental in the formation and maintenance of the prairies. The first three have remained essentially unchanged; the frequency of fire has changed in the last hundred years.

Glaciation. The glaciation of the region has been important in the formation of the prairies for two reasons. First, by virtue of the parent material it left, the last glaciation gave the soils of the prairies an arid quality in an area of high rainfall; second, glacial activity left a rather sterile soil.

The prairie topography was formed by the outwash alluvium of the Vashon Glacier. Bretz (1913) has given an account of the formation of the Wier Prairie. It is from this source and from Mackin (1961) that the following picture of the genesis of Wier Prairie was formulated.

As the glacier began to recede from its southern terminus, it discharged great quantities of sand, gravel, and larger stones.

Slowly retreating northward a large gravelly plateau was deposited, a portion of which constitutes the higher prairie (500 feet) at the present time. The water discharged then to the south. As the glacier again receded to the north, the plateau was degraded, forming a steep north-facing slope. This degradation was apparently caused by a change in the direction of the flow of water to the west. With the water now flowing in this direction, essentially what may be considered a valley floor was formed with the terrace to the south, forming the south wall and the ice forming the north wall. This "valley floor" forms what is now the middle prairie (450 feet). An ice contact slope remained after the glacier had moved north. This can be seen from the great ice kettles which pit the forested slope between the middle and the lower prairie (500 feet). The third and lower prairie (400 feet) was formed in a manner similar to the middle prairie. In this case the southern wall of the "valley" was the previously formed ice contact slope, the northern wall, glacial ice.

The depth of this gravelly outwash at Wier Prairie is at least 50 feet, as can be seen along the road cut near the town of Rainier. Most of the material is porous, loose, poorly sorted, gravelly sand and gravel with many stones as large as eight to ten inches in diameter. There is very little interstitial material in the subsoil because of the washing action of the glacial water. The porous nature of the alluvium is presumed to produce the arid droughty nature to the soil. Droughty as used here refers to the dryness of the soil.

Soils. The prairies of Western Washington are located upon a particular type of soil which was formed upon gravelly outwash plains. These soils are collectively called the Spanaway Series (Ness, 1958). A description of the profile is as follows (after Ness, 1958):

A_1--0 to 14 inches; very dark grayish-brown gravelly sandy loam with organic content high, consisting largely of well decomposed grass, roots and moss. The structure is very friable and sooty. It is strongly acid.

AC--14 to 18 inches; grayish-brown, very gravelly sand loam, very gravelly and stony. It is less acid than the A_1 horizon.

C--18+ inches; light grayish-brown or light yellowish-gray gravelly sand and gravel. There are stones up to nine to ten inches in diameter.

There are a number of physical features of Spanaway soils which make it suited to prairie-type vegetation. Ness (1958) reports that: (1) during the growing season, the amount of water held in the region of the soil occupied by roots is very low; (2) internal drainage is rapid; (3) loose coarse materials in the lower horizons limit the penetration of roots to the upper 18+ inches of the soil; (4) natural drainage at the time the soil was developed was excessive. These features of the Spanaway series make the soil very droughty.

Mangum (1910) reports the following mechanical analysis of typical fine earth samples of Spanaway gravelly sandy loam:

Fine Gravel	10.9%	Very Fine Sand	7.3%
Coarse Sand	20.2%	Silt	26.0%
Medium Sand	7.1%	Clay	18.9%
Fine Sand	9.5%		

The low productivity of Spanaway soils has been cited often in the literature by Bretz, (1913), Jones, (1936), and Piper, (1906). After their first attempts at agriculture, the early settlers soon realized that the soil was not of the highest quality (Brackenridge, 1931; Tilton, 1867; Trowbridge, 1853; Wilkes, 1841).

Renny and MacLauchlan (1957) report that the Spanaway soil is high in carbonaceous organic matter and low in active humus. They also found certain mineral deficiencies. Available amounts of calcium, phosphorous and magnesium were all found to be low. Forage crops with which they were working responded only to large amounts of lime, two to three tons per acre, and often the beneficial results of the application did not appear until two or three years later. Potassium was often found to be in short supply. Available nitrogen also was very low, possibly due to the high carbon-nitrogen ratio. Responses to application of nitrogen occurred after one or two days.

The nature and characteristics of a soil have a pronounced effect upon the type of vegetation it can support. Two features of the soil of the prairie which have had the greatest effect in determining a particular vegetation type have been the droughty nature and low fertility. This soil is of the type which is developed in cool moist areas under the influence of grass vegetation (Ness, 1958; Nikiforoff, 1936).

The classification of Spanaway soils has met with some controversy. The classification of the large soil groups is based on the degree of profile development, the domination of one soil forming factor over the others, and the age of the soil (Forest Soils Comm., 1957). Many of these characters are difficult to analyze. Consequently, several different views have been formed. Ness (1958) classes the Spanaway soil in the Great Azonal group due to the relatively young age of the soil and the poorly developed profile. Because of the deep unconsolidated material upon which it was formed, it is classed as a regosol. The Pierce County Soil Survey of 1955 classes the Spanaway series in the Zonal group under prairie soils. Nikiforoff (1936) calls them "Black-Brown" soils. He feels that they are not chernozems because they lack a zone of calcium carbonate accumulation. Spanaway soils and similar series are related, according to Nikiforoff, to the black-brown soils of the Palouse region. It will be remembered that the flora of these soils also shows some affinities to the flora of Eastern Washington.

The Forest Soils Committee (1957) classifies these soils as intrazonal. Their distinguishing characters, the dark color and friability, are due to grass vegetation and not the climate and soil factors. They call them Savannah soils.

There are three other series closely related to the Spanaway. These are the Nisqually, Fitch, and Tumwater. Of these the Spanaway seems to have closer affinities to the Fitch series. The Nisqually and Tumwater series are more sandy. The Fitch and Spanaway are of the same gravelly rocky material, the only apparent difference being the lighter color of the Fitch series. The Fitch soils generally occur in small patches around the edges of prairies of Spanaway soil and are forested. According to Ness (1958) Fitch soils were developed under grass vegetation but were invaded by trees many years ago. Apparently, the Fitch soils began as typical Spanaway soil, but because of differences in topography, the area was forested at an early date.

Comparison of the extent of forestation in the 1850s and the soil distribution at the present time shows that there has been an early invasion of the prairies by forests (Figures 5 and 6, pp. 29 and 30). The fact that the trees invade from the outer edges is an indication that the Fitch soils are Spanaway soil which has been forested for a longer period of time.

<u>Post-Glacial Climate</u>. Information on the post-glacial climate of the Northwest is based upon the presence and abundance of pollen in peat bogs. The species found are assumed to be indicative of the climate. Hansen (1956) and Heusser (1953) interpret a warm-dry hypsothermal period from pollen profiles between 2,000 to 5,000 years ago. The effect of this warming and drying manifests itself in the occurrence of grasses and composites in bog profiles near the prairies (Hansen, 1938). The effect of the hypsothermal period appears to have lessened as proximity to the ocean was reached. In

bogs near the coast the warming and drying effect seems to be absent. It is only faintly recorded in the Puget Sound lowland (Hansen, 1947a). In Eastern Washington and Oregon the hypsothermal period is definitely manifested. This would seem to indicate the moderating effect of ocean air. It seems likely that it was during this time that the prairies took on their characteristic vegetation.

Present Climatic Conditions. Thurston and Pierce counties may be divided into three rather distinct precipitation zones. Eastward from the Black Hills, the rainfall is approximately 45 to 60 inches. Just east of Olympia a zone of reduced precipitation extends eastward to the foothills of the Cascade Mountains and northward through the western part of Pierce County. The rainfall in this region is below 45 inches per year. The explanation for this appears to be as follows (Wash. Dept. Agri., 1956): The westerly winds descend after passing over the Coast Range and yield a lessened rainfall and break up of cloud cover. As the winds continue to the east, they reach the foothills of the Cascade Mountains and start ascending. Theerise in altitude is accompanied by increased rainfall.

Representative annual precipitation records for the region of lessened rainfall are from an annual summary of hourly precipitation data. They are the only data available for the region. For comparison, the precipitation for Olympia is included. The data cover a period of nine years. The years in which a few stations did not take data for the entire year were excluded from the table.

YEARLY RAINFALL FROM ANNUAL HOURLY PRECIPITATION DATA

(U. S. Dept. of Comm. Weather Bureau)

Station	1951	1952	1953	1954	1955	1956	1957	1958	1959	Av.
Olympia					57.87	51.44	41.45	52.40	52.92	51.21
Yelm	35.98	21.13	46.30		46.33	36.26	30.84	38.99	38.78	36.82
McChord				36.76	42.07		29.18	37.21	37.93	36.63
McMillian Reservoir	36.77	21.85	49.31		45.20	36.66	35.65	42.71	42.95	38.88

Though the averages are based upon a rather short period of time, they are indicative of the relative amounts of rainfall. When the annual precipitation is high at Olympia, there is a corresponding rise at the other three stations. In 1955, for example, Olympia had 57.87 in./yr., Yelm, 46.33 in., McChord, 42.07 in., and McMillian Reservoir, 45.30 in. In a dry year Olympia had 41.45 in., Yelm, 30.84 in., McChord, 29.18 in., and McMillian Reservoir, 35.65 in. It appears then that the relative amounts of rainfall are fairly static.

Generally, the driest months of the year are June, July, and August, and the wettest November, December, and January. Other important information such as temperatures and length of growing season as determined by frost records is taken from data recorded in Olympia and Tacoma. These stations are closest to the prairies.

TEMPERATURE ^{O}F (U. S. Dept. of Agri., 1941)

	Length of Record	Jan. Av.	July Av.	Max.	Min.
Olympia	37 yr.	38.4	63.3	104	-2
Tacoma	40 yr.	38.8	62.2	98	7

AVERAGE DATES OF KILLING FROST (U. S. Dept. Agri., 1941)

	Length of Record	Last in Spring	First in Fall	Growing Season
Olympia	38 yr.	Apr. 20	Oct. 28	191 days
Tacoma	40 yr.	Mar. 13	Nov. 18	250 days

Fire. There is little doubt that forest fires have occurred as long as there have been forests to burn. Most fires before the advent of man were probably started by lightning. After the advent of white man about 35 per cent of all forest fires were caused by lightning (Judd, 1951). Fluctuations in abundance of Douglas fir pollen in pollen profiles have been attributed to forest fires (Hansen, 1947a). Evidence from peat bogs and fire-scarred tree rings indicates that fires have occurred many times in the past (Judd, 1951).

From 1800 to about 1900 fires were more prevalent than they are today. During that time Indians and perhaps white men set fire to the prairies, and there was no fire protection.

David Douglas made the earliest reference to the use of fire by the Indians (Royal Hort. Soc., 1959). On October 26, 1826, when he was on his way to Northern California, he noticed a scarcity of deer in the Willamette Valley. He explained in his journal that the deer were scarce in the area "in consequence of the plains being burned by the Indians to compel these animals to seek food in certain parts more convenient for hunting."

Two pioneers of the Willamette Valley, Jesse Applegate and S. A. Clarke, have reported (Morris, 1934) that the Indians burned extensively for three reasons. One was to burn in late autumn after the wild wheat, "Lamoro sappolil", had bloomed. The second was in order to drive game together so that it could be more easily hunted. The third was to keep down the undergrowth so that game could be observed and so that hostile war parties could not approach unseen.

In 1833, William Frazer Tolmie recorded in his diary a report of fire on the prairies. During his first stay at Nisqually, he wrote on September 26, 1833, "The Indians again began to bring us venison which has been very scarce since the middle of July when the grass on the prairie, being dry and wintering was nearly all consumed by fire, now, a new and tender crop has arisen which perhaps attracts the deer." Three days later he continued: "The prairie has quite a vernal aspect in those parts which were overrun by fire in summer." According to the Nisqually Journal (1915) on July 17, 1833, all herbage on the prairies was burned for several miles.

September 6, 1834, the plain again was burned, and the sun was obscured for five days (Nisqually Journ., 1915). The Nisqually Journal for July 24, 1835, records fires in the grassy plains near the Fort that "sent up so much smoke that the sun was hidden."

In August of 1853, William P. Trowbridge, a lieutenant in the United States Army, reported on his trip from Fort Steilacoom to Cowlitz Landing that "fires were raging in every part of the forest and immense pine trees were continually falling around us" (Trowbridge, 1853).

The Land Office Survey parties, among their other duties, noted if the timber was burned. In the vicinity of Wier Prairie the surveyors noticed that timber was burned in 1851, 1853, and 1855, each year that the survey was in the area. It is difficult to ascertain whether this was the same burn. Either the fire was a very large one or there were many small fires. For example, in 1853 they made the following notations going east along the southern boundary of sec. 33, T17N, R1E. At 35 chains they left the prairie and entered burned timber. They continued through burned timber in sections 34, 35, and 36. This burn was at least three and one-half miles in one dimension. In September of 1855 at the corner sec. 10, 11, 14, and 15, T16N, R1W the party noted that the timber and undergrowth had been killed by fire.

Cooper (1853) reports that the Indians burned the prairies in order to preserve the ground for game and for the production of Camass, which the Indians used for food. Cooper also reported:

> From its combustibility extensive tracts of this forest get burnt every year, taking fire from friction or any other slight cause. During our ascent of the western slopes of the Cascade range we passed for days through dead forests, perhaps burnt by ignition from the hot ashes which were thrown out from Mount St. Helen's several years before; but large tracts were on fire at the same time, filling the air with smoke, so that we could not see the surrounding country for several days. Large tracts of the eastern slopes of the Coast range are also desolated by the same cause.

This indicates forest fires started by volcanic activity as well as lightning.

Morris (1934, map, p. 135) reported two fires near Olympia in 1868, one to the south and one to the east of the town.

Meeker (1870), speaking about the timber near the head of the Sound, said, "Although much of this [timber] is not available for logging in consequence of many heavy fires having burned the more valuable timber . . ."

In 1902 the Northwest was beset by enormous forest fires. On one day the sun was so obscured by smoke that lights had to be used at noon in Olympia. This same day an inch and a half of ash fell on the streets of Portland, Oregon.

In recent times there have been few fires of large size on the prairies. This may be attributed to two factors. The Indians discontinued burning practices. The military authorities, after taking over the prairies about 1900, have provided the area with rather extensive fire protection.

The only prairie which is burned with any regularity is at Lake Nisqually (Figure 2, p. 22). This prairie is the United States Army artillery impact range. It is either purposely burned by the military authorities as a safety measure, or it is accidentally set on fire by the shelling nearly every year (Hansen, 1961). By comparing the two maps (Figures 2 and 3, pp. 22 and 23) one can see that this area is the only one upon which no apparent encroachment of the Douglas fir on the prairies has taken place in the last 100 years.

A small portion of Wier Prairie was burned in 1957 (sec. 31, T17N, R1E; sec. 6, T16N, R1E) (Hansen, 1961).

It is evident from the general literature on fire that its effect varies from region to region and with the vegetation. The vegetation type nearest the prairies that is similar in any respect is the Festucetum association of the Palouse of Eastern Washington. Daubenmire (1942) studied this vegetation in detail. He reported that after fire the moss-lichen synusium was destroyed and that redevelopment requires several years. The perennial grasses, forbs, and shrubs are killed to the ground but in most cases sprout vigorously the following spring. New growth, according to Daubenmire, makes its appearance about two weeks earlier than that on unburned areas because of greater absorption of solar radiation by the blackened unshaded soil surface.

Human Factors

The human factors are those which are generally associated with man's activities. These factors have been considered from the standpoint of land use by both Indians and whites. Some practices such as use of fire have a direct effect upon the vegetation. The others, such as grazing, have an indirect effect.

Paleo Indians. The exact date of the advent of the Paleo Indian into the Puget Sound region is unknown. Vulcanism and glaciation have destroyed or hidden much of the evidence of early man. The most logical route of entry is by way of the pre-Wisconsin land or ice bridge across the Bering Sea. Warmington (1957) states that artifacts from the Columbia River in the interior of Oregon have been dated at 10,000 years. About 6,000 years ago there appeared to be increased activity by the Indians. The great Fraser River midden at Vancouver, B. C., has been dated at 2100, ± 900, years ago.

Recent Indians. The Nisqually Indians were living on the prairies when the white men arrived. This tribe was one of the few which owned horses on the west side of the Cascade Mountains. Indians of several of the villages located near the Bald Hills were bilingual and spoke both the Sahlish dialect of the west side and the Shapatin of the east side of the Cascade Mountains (Smith, 1940). She also reports that these southern villages had contacts with the Yakima and the Kittitas tribes. The Nisquallies traveled east of the mountains via Cowlitz and Naches Passes (Haeberlin and Gunther, 1930). This cross-mountain travel, undertaken by tribes of both sides of the Cascade Mountains, was for trade purposes.

The main village of the Nisqually Indians was located at the junction of Muck Creek and the Nisqually River in Pierce County. Other villages were near the present towns of Yelm, Rainier, and Roy. Haeberlin and Gunther (1938) report that Indians spent considerable time on the prairies where they were safe from more warlike northern Indians. They state that there were about 2,000 Nisquallies in 1855.

The Nisqually Indians had fire before the white men came; they made fire with a hand drill. They also devised a slow burning torch made of cedar bark, one end of which could be kept burning for several days (Haeberlin and Gunther, 1930).

Much has been written by white men about the Indian's use of fire to control desired types of vegetation. The Nisqually Indians were reluctant in admitting the use of fire. Smith (1940) gives the only reference in anthropological literature to intentional burning. She states that the Nisqually Indians used fire for attracting game at night. She further states that the inland people had great fear of fire and its effect on grazing land and game.

At the time of Tolmie's stay at Fort Nisqually, 1833, the only whites there were Hudson's Bay Company employees. It does not seem plausible that they would set the prairies on fire and endanger their own holdings. The lack of reports of fires set by the white man as opposed to numerous reports of those set by Indians indicates that the red men caused most of the fires.

The Indians acquired horses at about the turn of the 18th century (Cooper, 1853). This agrees fairly well with the idea that the horse reached Eastern Washington about 1730.

The acquisition of horses by the Nisqually Indians was probably by trade with the Indians of Eastern Washington. According to Smith (1940), each family of the prairie groups of the Nisqually tribe owned an average of two to three horses. These horses were treated as pets by the Indians and were gentler than the horses of the Indians to the east. The number of horses present at one time was not great enough to cause much damage to the vegetation. I concluded this by comparing the number of horses per family with the Indian population in 1855.

Agriculture. Of all the activities of white men, agricultural pursuits have been the most important in changing the face of the prairies. Grazing of stock has been foremost.

Gehri (1934) and Cooper (1859) report that deer and elk grazed on the prairies in the early days. The effect of these animals may be considered negligible due to their transitory feeding habits.

The establishment of Fort Nisqually started the great cattle and sheep industry which lasted for many years. An inventory from Hudson's Bay Company account books (Notes, 19--) shows that in the spring of 1833 the company had five pack horses and four oxen. The number of stock rose to about 1,000 head in 1839. This year marked the establishment of the Puget's Sound Agricultural Company. By 1841, Wilkes (1844) reported that the Hudson's Bay Company had 3,000 sheep, 1,500 cattle, and some 400 horses. Two years later, 1843, the account books showed 1,396 horned cattle, 126 horses, and 5,043 sheep. Both Meeker (1905) and Hunt (1916) report that from 1841 to 1846 the company had an average of 5,000 to 8,000 cattle, 6,000 to 10,000 sheep, and 300 horses. The company had an interesting method for handling their stock. Wilkes (1844) reports that the cattle were placed in pens at night for two purposes--first, as protection from wolves, and second, to save the manure. The pens were from one-half to one acre in size and were moved every week. In this manner a large area would be covered in the course of a year. Other sources, Meeker (1905) and Hunt (1916), state that the company attempted to prevent overgrazing by sheep by corraling them in the same manner as the cattle. Rather than prevent overgrazing this practice concentrated overgrazing locally. The stock must have destroyed the structure of the prairie vegetation.

About 1850 when the influx of settlers began, grazing was continued. Most of the settlers (many of them retired employees of Hudson's Bay Company) took up donation claims near the company holdings.

By 1850 American settlement had preceded on the prairies. The Indian war of 1855-56 caused many of the settlers in the interior to move back to the safety of Steilacoom and Fort Nisqually. Early settlers chose the prairies because they were open grasslands and less difficult to clear than the more fertile bottom lands along the Puyallup and Nisqually Rivers. After the river valleys had been settled and cleared, the attention of the immigrants shifted from the prairies.

At present, the only grazing on the military holdings is on the 13th Division Prairie in Pierce County, where 600 head of cattle are grazed.

On the Wier Prairie in Thurston County the first record of grazing was in 1851 when the Land Office Survey party reported seeing herds of cattle on the prairie and in openings among the trees. It can be assumed that grazing preceded this by several years because T. W. Glascow and T. Linklighter started farming on the prairie in 1847. About 1850, T. B. Speek made rawhide chairs on his farm on Wier Prairie, and it is possible that he and his neighbors raised the cattle for this rawhide as well as for milk and meat (Rathbun, 1895). In 1870 part-time farming combined with work in the logging, lumber, and mining industries became common and has persisted to the present.

After 1943, when the United States Army acquired most of Wier Prairie, most farming and grazing has stopped. The only grazing on the area has been by trespass cattle which are never in large numbers (Hansen, 1961).

Cultivation. Cultivation has not been practised to any large degree on the prairies. Wilkes (1844) reports that the farming operations were not large at Fort Nisqually with only 200 acres under cultivation. Most of the farming was done at the Hudson's Bay Company holding at Cowlitz. The early crops were mainly grains. After getting low yields, the land was allowed to return to pasture. In Thurston County, just after the First World War, large areas of Spanaway soils (around Grand Mound and Rochester) were used to grow strawberries. This enterprise, however, has been almost entirely abandoned because of high costs and low yields.

The Thurston and Pierce County Soils Surveys report that the soil is generally used for hay, corn silage, small fruits, and vegetables. For a satisfactory yield, it is necessary to add manure, crop residues, fertilizers, and water.

Logging. In the early days the forests surrounding the prairies in Pierce County were logged (Mangum, 1911). The oak has been logged for use in shipbuilding (British and American Joint Comm., 1869).

Most of the logging in Pierce County was connected with land clearing and local construction. The majority of wholesale logging in the area ceased with the establishment of Fort Lewis in 1917.

Near Wier Prairie the Weyerhaeuser Timber Company logged intermittently in the area from 1918 to about 1938 (for exact times and locations see the following table). Most of the timber was cut in forested regions away from the prairie. Generally, logging does not seem to have had a great effect upon the prairie.

AREAS LOGGED NEAR WIER PRAIRIE
(Weyerhaeuser Timber Co., Tacoma, Wash.)

Description	S. T. R.	Logged
S 1/2 NW:N 1/2 SW	28-17N-1E	1937-38
FR NW 1/4	1-16N-1W	1923-25
FRNENE	2	1930
FRE 1/2 NW:SW 1/4 N of River*	2	1922-24
SW 1/4 S of River	2	1920-23
NENE:SWNE:E 1/2 NW:W 1/2 SW	25-17N-1W	1918-21
SESE	26	1918-21
N 1/2:E 1/2 SW:SE 1/4	35	1928-29

*Deschutes River

Military Use. The United States Army has used the prairies intensively since acquiring the land in 1917 and 1943. Both the prairie and adjacent land are used principally for military maneuvers of various types, most of which involve large vehicles. The effect of vehicles on the vegetation is devastating. The sod and moss are stripped off, leaving bare soil. Small oak trees are flattened by the larger tanks. The effect of this mechanical disturbance of prairie vegetation is similar to that of grazing (Figure 9, p. 36). The exposed soil is invaded by weeds rather than typical prairie vegetation. Fir limbs are cut for use as camouflage, and holes are dug in every conceivable place. One of the prairies used as an impact range is inaccessible to non-military personnel.

V. DISCUSSION

The encroachment of Douglas fir on the prairie lands has coincided with several radical changes in the environment. Palynological research indicates that the land developed characteristic prairie vegetation some time prior to 6,000 years ago and coincided with a period of gradual warming and/or drying. The prairies from their beginnings were limited to the glacial outwash plains of the Vashon Glacier. The Douglas fir were able to become established only in areas of topographical discontinuity such as ice contact slopes and erosion terraces. At the time of the arrival of white men, written descriptions seem to indicate that the prairies were much more extensive than they are at the present time. The verbal descriptions are confirmed by comparing maps compiled about 1850 with those made in 1950, showing the distribution of prairie and forest. Prior to and shortly after the arrival of the explorers and settlers, fires seem to have been common on the prairies. After 1918 the frequency of fires sharply decreased and has never reached the magnitude of those in previous years. From the discussion of the original prairie vegetation it has been indicated that the prairie species are biologically capable of surviving periodic fire.

It is possible that aboriginal man has been in the region since shortly after the recession of the Vashon Glacier. He had the means with which to set fire to the prairies and probably did. The Indians present when the white men settled set fire to the prairies for various reasons. There is reason to assume that they had been setting fires for some time previous to this.

Most of the native species are perennials and have their perennating buds at or below the surface of the soil. In late summer and early fall, when the prairies burned, the native species had completed their seasonal cycle. The Douglas fir could not cope with fire as well as the native prairie species.

Circumstantial evidence indicates that the Douglas fir was virtually stopped in its penetration of the grassland by two other factors besides fire. One was the closed nature of the prairie community, and second was the nature of the soil in combination with lower precipitation of the area.

Abrupt environmental changes have been shown to coincide with he arrival of white men. In a period of about eight years grazing on the prairies increased from several head to 13,000 head of domestic stock. The major effect of grazing was the destruction of the structure of tracts of prairie vegetation. Also at this time many of the weedy species present on the prairie were introduced. Before the introduction of the weeds, the prairie, when disturbed, was able to grow back in the disrupted area. After their introduction, the weeds, because of their wind blown seeds and rapid growth rate, were able to establish themselves in the disturbed areas, thus destroying the integrity of the original prairie vegetation.

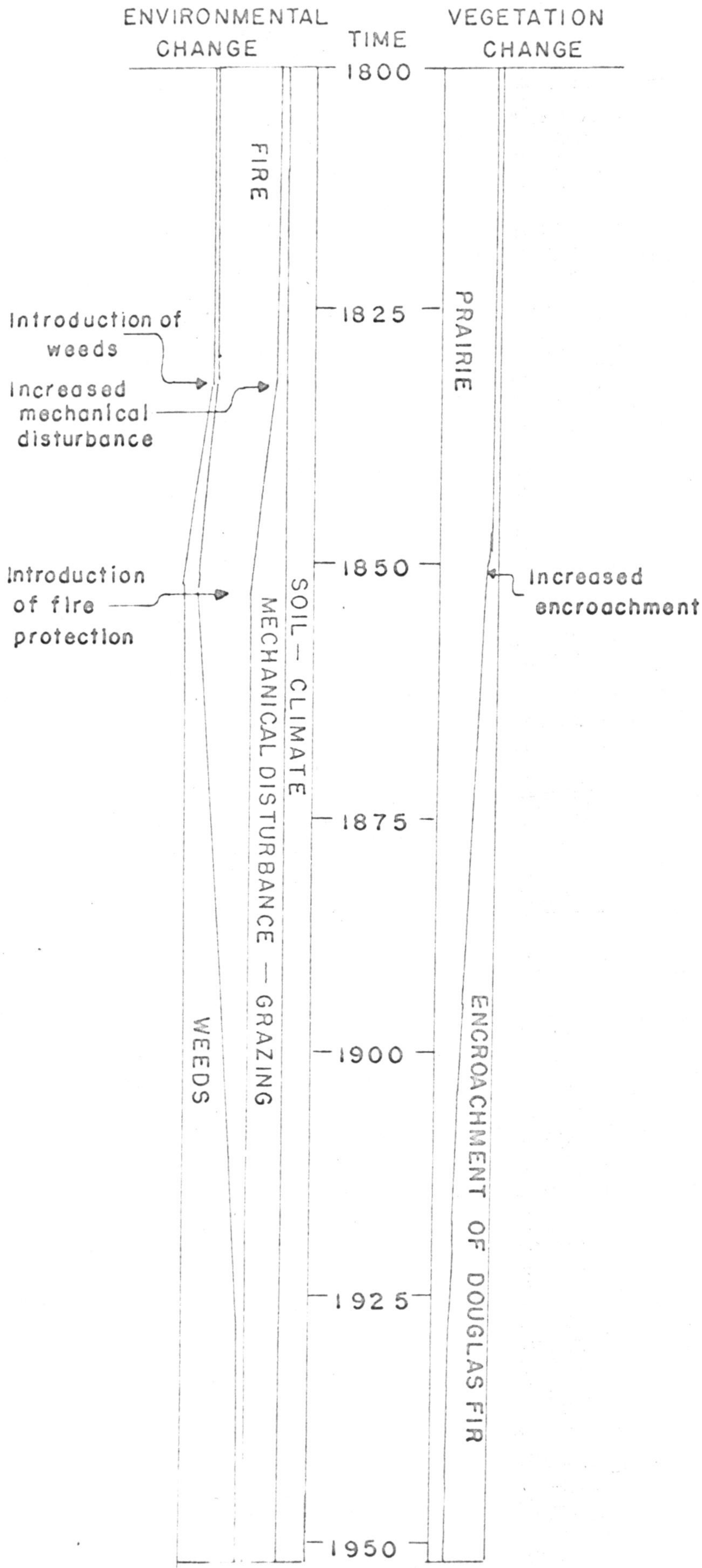
Figure 34 graphically represents my interpretation of change in the prairie vegetation. The width of each line is a subjective representation of the magnitude of the particular feature under consideration. I have depicted the passage of time vertically. For example, at about 1800, encroachment was slight, the prairie larger, the soil-climate complex unchanged, mechanical disturbance (grazing) slight, fire widespread, occurrence of weeds slight. By 1900 the degree of encroachment had increased, the prairie decreased, soil-climate complex unchanged, mechanical disturbance increased, frequency of fire decreased, and occurrence of weeds much increased.

Earlier Theories of the Origin and Maintenance of the Prairies

Cooper (1860) believed that the prairies of Western Washington were the remains of much more extensive prairies. Fires had not been significant in the development or maintenance of the prairies because of occasional large trees he found growing isolated or in small groups on the prairies. He felt that the "perfect" smoothness of the surface of the prairies indicated that they were never forested. His reasoning is as follows: "While in places completely cleared of forests by fires are always found mounds and hollows, left by stumps, and an immediate growth of shrubs and trees follows, showing a tendency to return to forest instead of to form prairies."

William Trowbridge (1853) also had ideas about the origin of the prairies. He felt that the burning by the Indians was the cause of the appearance of the prairies. The large trees would burn down, decay, and then the succeeding fires would prevent the growth of the smaller trees.

Mangum (1911) proposed perhaps the most original theory


ENVIRONMENTAL CHANGE
TIME
VEGETATION CHANGE
1800
1825
1850
1875
1900
1925
1950
FIRE
Introduction of weeds
Increased mechanical disturbance
Introduction of fire protection
SOIL — CLIMATE
MECHANICAL DISTURBANCE — GRAZING
WEEDS
PRAIRIE
Increased encroachment
ENCROACHMENT OF DOUGLAS FIR

concerning the maintenance of the prairies. He begins by explaining that oak is not as dependent as Douglas fir upon mycorrhizae. He contends that the fungus, which is associated with the fir, has difficulty establishing itself in the dry soil of the prairie. This he concluded is why the Douglas fir has difficulty in invading the open grassland. He further states that the decaying leaves from the oak furnish humus for other plants and eventually for the Douglas fir.

John Muir (1918), the famous California naturalist, had an opportunity to observe the prairies. He noticed that the ground was dry and gravelly and that the parent material was water-washed pebbles and cobbles of glacial origin--conditions he felt readily explained the absence of trees.

Hansen (1947b) attributes the existence of the prairies to two factors, the porous, gravelly parent material of the soil plus the dry summer months, and the burning of the prairies by periodic fires.

Each theory in itself does not satisfactorily explain the existence of the prairies. Most of the ideas, with the exception of Hansen's, are based upon rather casual observation at a time when the entire picture was not known. The statement by Cooper that fire was not important in the development of the prairies is based on too few facts. The presence of large firs means that particular portion of the prairie had not burned for some time, and that the fir had grown large enough to withstand the occasional burning. It should be realized that fire was not the only factor involved in the prevention of the encroachment of the Douglas fir. The invasion by the Douglas fir was also slowed by the dry infertile soil and the closed prairie community.

Cooper explains why Trowbridge's idea could not be correct. After a forest burns the tendency is to return to forest and not prairie. The idea of a mycological association, as explained by Mangum, should not be rejected. It warrants further investigation.

Hansen (1947b) postulated the most plausible explanation for the existence of the prairies to date. My findings support his ideas as to the origin of the prairies. I have shown that the total annual precipitation is less than in other areas of the Northwest. The absence of moisture in the subsoil makes the upper soil very ry in summer, a time when there is very little rain. My findings indicate that fire was much more prevalent on the prairies when the whites entered the Northwest. Many of these fires were doubtless set by the Indians for a specific purpose. They must have been setting fires deliberately for some time before the coming of the white men.

Problems for Further Investigation

In the course of the investigation, problems have occurred to me which merit investigating; their solutions would greatly aid in understanding the origin and nature of the Western Washington prairies:

1. Further investigation of the peat bogs of the area should

be carried out in order to see what other species were present with the arborescent species. In this way it may be possible to reconstruct more fully the post-glacial vegetation.

2. Investigation of the post-glacial wind direction. If the prevailing storm systems during portions of the post-Pleistocene were from the northwest instead of the southwest, this would put the prairies in a rain shadow of the Olympic Mountains similar to the shadow presently at Sequim.

3. Investigation of soils should be undertaken in detail. Careful comparisons of forested and nonforested Spanaway series soils might give some clues as to whether or not the prairies were ever forested. Two things to look for might be the presence or absence of charcoal in the profile and changes in the physical and chemical properties of the soil which might be irreversible.

4. Fertility studies of the soils should be undertaken. The growth of Douglas fir on Spanaway soil should be studied more carefully.

5. The effect of fire upon the vegetation should be examined and comparisons made between burned and unburned areas. Changes in species compositions and regeneration of species should be investigated.

6. The effect of mechanical disturbances and grazing should be undertaken. Sowing of Douglas fir seeds in undisturbed prairie vegetation and in disturbed sites could be compared. The same sort of study could be undertaken with weedy species.

7. The phytogeography of the species involved should be studied. Comparisons of similar areas on the West Coast from the standpoint of floristic composition and ecology should be investigated. The ranges and centers of distribution of the species involved need to be documented.

A few of the questions posed in the introduction have been answered. To the unanswered questions, the manner of obtaining the answer has been suggested. New problems have been uncovered and the way to their answers pointed out.

Summary

The prairies of Western Washington are being encroached upon by the surrounding Douglas fir forests. The exact cause of this phenomenon is not known. This thesis is a preliminary investigation of these physiographic units, their changes through time and probable causes of the changes. In the course of the investigation most of the existing literature has been reviewed and evaluated. From this has come a restatement of the ideas concerning the origins and maintenance of the prairies and some ideas concerning the causes of encroachment of the Douglas fir. In the earlier literature there were many ideas postulated but few facts to support these ideas. For example, the prairies were said to be in a zone of low precipitation, but the amount of precipitation was not stated. This thesis has attempted to clarify as many of these vague references as possible.

From a review of the palynological literature the post-glacial forest succession in the immediate vicinity of the prairies was determined. The nature and extent of the prairies from 1800 to 1900 was on the basis of the writings, diaries, and journals of early explorers in the region. The Land Office Surveys of the 1850s have greatly aided in giving an objective view of the prairies at that time.

From the above studies the following factors are believed to be involved in the origin and maintenance of the prairies of Western Washington:

1. Drought caused by the occurrence of soil parent material which is porous, sterile, gravelly outwash of glacial origin, and low precipitation in the summer;

2. A hypsothermal period of about 6,000 years ago which aided in the establishment of the present type of vegetation;

3. Frequent burning of the prairies from natural causes, by the Indians and possibly the early white men;

4. The presence of a closed, well adapted original prairie community.

Rapid encroachment by the Douglas fir appears to have been relatively recent (the last hundred years), and its rise in magnitude sudden. This movement onto the prairies coincided with the following environmental changes:

1. The advent of fire protection;

2. Mechanical disturbance of the original community by grazing and other sources;

3. The introduction of weedy species which further disrupted the integrity of the original prairie vegetation.

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APPENDIX

A PARTIAL SPECIES LIST

Most species on this list are found or have been collected on the gravelly prairies of Western Washington. Some are mentioned in the text. The list was compiled from four sources: Piper (1906), Rigg (1917), the University of Washington Herbarium, and my own collection.

	Collector	Collection No. or date
Polypodiaceae		
Polypodium vulgare L. var. occidentale Hook.	FAL	#7
Polystichum munitum (Kaulf.) Presl.	R*	
Pteridium aquilinum (L.) Kuhn. var. pubescens Underw.	FAL	#47
Pinaceae		
Pinus contorta Loud.	R	
P. ponderosa Dougl.	P	
Tsuga heterophylla (Raf.) Sarg.	R	
Pseudotsuga menziesii (Mirb.) Franco.		
Cupressaceae		
Juniperus scopulorum Sarg.	R	
Graminaeae		
Agrostis diegoensis Vasey		
Aira caryophyllea L.	R. C. Bunn	#872
Anthoxanthum odoratum L.	I. C. Otis	#2041
Arrhenatherum elatius (L.) Mert. and Kolk	ICO	#4008
Bromus carniatus H & A	G. N. Jones	#4599
B. ciliatus L.	J. B. Flett	20-6-1897
B. mollis L.	JBF	4-8-1897
Danthonia californica Boland. var. americana (Scribn.) Hitchc.	RCB	#1244
Deschampsia elongata (Hook.) Munro ex. Benth.	JBF	4-8-1897
Elymus glaucus Buckl.	ICO	#2006
Festuca idahoensis Elmer	JBF	22-5-1897
F. megalura Nutt.	L. F. Henderson	24-5-1892
F. occidentalis Hook.	LFH	2-6-1892

*R = Rigg (1917), P = Piper (1906). After the name of a collector has been written out, it is abbreviated.

F. rubra L.	RCB	#1189
Holcus lanatus L.	FAL	
Koeleria cristata (L.) Pers.	RCB	#1226
Panicum capillare L. var. occidentale Rydb.	E. C. Smith	7-1890
P. pacificum Hitch. & Chase	ICO	#1723
P. scribnerianum Nash	ECS	#804
Poa compressa L.	L. C. Andersnn	#814
P. howellii Vasey & Scribn.	JBF	1896
P. pratensis L.	A. R. Kruckeberg	#2739
P. trivailis L.	JBF	1-6-1897
Trisetum cernuum Trin.	LFH	20-7-1892
Cyperaceae		
Carex inops Bailey	C. L. Hitchcock	#3258
Juncaceae		
Luzula multiflora (Retz.) Lej.	FAL	#16
Liliaceae		
Brodiaea coronaria (Salisb.) Jeps.	JBF	13-7-1895
B. hyacinthina (Lindl.) Baker	ICO	#1924
B. pulchella (Salisb.) Greene	P	
Camassia quamash (Pursh.) Wats.	ICO	#2049
Erythronium oregonum Appleg.	CLH	#3259
Fritillaria lanceolata Pursh.	J. W. Thompson	#5154
Trillium chloropetalum (Torr.) Howell	GNJ	#4651
T. ovatum Pursh.	FAL	
Zygadenus venenosus Wats.	GNJ	#4651
Irdaceae		
Iris tenax Dougl.	P	
Sisyrinchium idahoense Bickn.	GNJ	#4609
Orchidaceae		
Corallorhiza maculata Raf.	FAL	#40
Goodyera oblongifolia Raf.	FAL	#2
Habenaria unalaschensis (Spreng) Wats. var. elata (Jeps.) Corr.	FAL	#114
Salicaceae		
Salix scouleriana Barr.		
Betulaceae		
Corylus cornuta Marsh. var. californica (A. DC.) Sharp	R	
Fagaceae		
Quercus garryana Dougl.	GNJ	#4639
Polygonaceae		
Polygonum spergulariaeforme Meisn.	FLH	6-1892
Rumex acetosella L.	FAL	#77
R. maritimum L. var. fueginus (Phil.) Dusen.	P	8-8-1888
Portulaceae		
Claytonia linearis Dougl.	JWT	#5147

Montia perfoliata (Donn.) How.	JWT	#5148
M. parvifolia (Moc.) Greene	M. C. Huntley	#868
Caryophyllaceae		
Arenaria macrophylla Hook.	GNJ	#4632
A. tenella Hook.	P	
Cerastium arvense L.	GNJ	#4623
Sagina occidentalis Wats.	JBF	2-10-1897
Silene menziesii Hook.	P	
S. scouleri Hook. ssp. grandis	ARK	
Spergula arvensis L.	FAL	#92
Spergularia rubra (L.) J & C Presl.	P	8-8-1888
Stellaria media (L.) Cyrill.	JWT	#5147
S. nitens Nutt.	JBF	1-4-1896
Ranunculaceae		
Actaea arguta Nutt.		
Delphinium nuttallii Gray	ARK	#2733
Ranunculus occidentalis Nutt.	GNJ	#4622
R. orthorhynchus Hook.	ICO	#1981
Berberidaceae		
Berberis aquifolium Pursh.	JWT	#10 100
B. nervosa Pursh.		
Papaveraceae		
Meconella oregana Nutt.	JBF	1-4-1896
Cruciferae		
Arabis hirsuta (L.) Scop.	JWT	#10 406
Athysanus pusillus (Hook.) Greene	P	
Cardamine bellidifolia L.	Lyman Benson	#1124
C. oligosperma Nutt.	JWT	#10 098
Teesdalia nudicaulis (L.) R. Br.	GNJ	#4604
Thysanocarpus curvipes Hook.	P	
Crassulaceae		
Sedum douglasii Hook.	P	
Saxifragaceae		
Heuchera cylindrica Dougl.	P	
Lithophragma parviflora (Hook.) Nutt.	ICO	#2048
Saxifraga integrifolia Hook.	GNJ	#6176
Grossulariaceae		
Ribes sanguineum Pursh.	CLH	#3250
Rosaceae		
Alchemilla occidentalis Nutt.	P	
Amelanchier florida Lindl.	LFH	24-5-1892
Crataegus douglasii Lindl.	GNJ	#4642
Fragaria bracteata Hel.	JWT	#5138
Holodiscus discolor (Pursh) Maxim	ICO	#2295
Osmaronia cerasiformis (T & G) Greene	MCH	#873

Potentilla gracilis Dougl		
Prunus demissa (Nutt.) D. Dietr.	P	
Leguminosae		
Cytisus scoparius (L.) Link.	LB	#1445
Lotus americana (Mitt.) Bisch.	JBF	#902
L. douglasii Greene	P	
L. formosissimus Greene	P	
L. micranthus Benth.	GNJ	#1440
Lupinus albicaulis Dougl.	P	
L. lepidus Dougl.	P	
L. micranthus Dougl.	JWT	#10 409
L. rivularis Dougl.	GNJ	#4656
Trifolium bifidum Gray	P	
T. dubium Sibth.		
T. microcephcilum Pursh.	JBF	#905
T. tridentatum Lindl.	JBF	14-7-1896
T. variegatum Nutt.	JBF	#904
T. wormskjollii Lehm.	JBF	20-6-1896
Vicia americana Muhl.	GNJ	#3600
V. angustifolia (L.) Reich.	GNJ	#1439
Geraniaceae		
Erodium cicutarium (L.) L. Hor.	ICO	#1194
Geranium dissectum L.	GNJ	#2107
G. molle L.	GNJ	#4635
Euphorbiaceae		
Euphorbia serpyllifolia Pers.	C. V. Piper	1-9-1891
Celastraceae		
Pachystima myrsinities Raf.	JBF	1-7-1896
Aceraceae		
Acer circinatum Pursh.		
A. macrophyllum Pursh.		
Rhamnaceae		
Ceanothus sanguineus Pursh.	GNJ	#4601
Malvaceae		
Sidalcea campestris Greene	P	
Hypericaceae		
Hypericum perforatum L.	FAL	#69
Violaceae		
Viola adunca J. E. Sm.	GNJ	#4637
V. howellii Gray	P	
V. praemorsa Dougl. ssp. major (Hook.) Baker & Claus.	JBF	10-5-1894
Onagraceae		
Boisduvalia stricta (Gray) Greene		
Epilobium minutum Lindl.	CVP	27-5-1888
Godetia amoena (Lehm.) G. Don	ICO	#2024
G. quadrivulnera (Dougl.) Spach.	JBF	#907

<u>Umbelliferae</u>		
Caucalis microcarpa H. & A.	P	
Lomatium nudicaule (Pursh.) C. & R.	P	
L. triternatum (Pursh.) C.& R.	CVP	8-5-1888
L. utriculatum (Nutt.) G. & R.	ICO	#1900
Perideridia gairdneri (H. & A.) Math	P	
Sanicula crassicaulis Poepp.	JBF	22-5-1897
S. nevadensis Watson	JBF	2-5-1896
<u>Ericaceae</u>		
Arbutus menziesii Pursh.	R	
Arctostaphylos uva-ursi (L.) Spreng.	CLH	23-4-1938
Gaultheria shallon Pursh.	FAL	#52
Vaccinium parvifolium J. E. Sm.	R	
<u>Plumbaginaceae</u>		
Armeria maritima (Mill.) Willd.	GNJ	#4649
<u>Primulaceae</u>		
Dodecatheon hendersonii Gray	ICO	#1830
D. pauciflorum (Dur.) Greene	JWT	#8243
<u>Oleaceae</u>		
Fraxinus latifolia Benth.	GNJ	#4644
<u>Apocynaceae</u>		
A. androsaemifolium L. var. pumilum Gray	F. G. Meyer	#1666
<u>Polemoniaceae</u>		
Collomia grandiflora Dougl.	JBF	12-6-1897
C. heterophylla Hook.	A. A. & E. Heller	#4057
C. tenella Gray	P	
Gilia capitata Dougl.	LFH	22-6-1892
Linanthus bicolor (Nutt.) Greene	JBF	1-6-1896
Microsteris gracilis Hook.	JBF	16-5-1898
Navarretia intertexta (Benth.) Hook.		
N. squarrosa (ESch.) H. & A.	JBF	#909
Polemonium micranthum Benth.	P	
<u>Boraginaceae</u>		
Cryptantha ambigua (Gray) Greene	JBF	#896
Pectocarya penicillata (H. & A.) A. DC	P	
Plagiobothrys figuratus (Piper) Johnst.	ICO	#1887
<u>Labiatae</u>		
Marrubium vulgare L.	JBF	15-9-1896
Mentha arvensis L.	GNJ	#4621
Prunella vulgaris L.	JWT	#12727
<u>Solanaceae</u>		
Solanum dulcamara L.	FGM	#1650

<u>Scrophulariaceae</u>		
Castilleja levisecta Greene M.	ICO	#1894
Orthocarpus attenuatus Gray	P	
O. pusillus Benth.	GNJ	29-3-1934
Parentucellia viscosa (L.) Car.		
Synthyris reniformis (Dougl.)	JWT	30-3-1932
Tonella tenella (Benth.) Hel.	P	
Veronica arvensis L.	JBF	1-5-1895
V. peregrina L.	JBF	2-10-1897
<u>Plantaginaceae</u>		
Plantago lanceolata L.		
P. purshii R. & S.	ICO	#2021
<u>Caprifoliaceae</u>		
Linnaea borealis L. var. americana (Forbes) Rehd.		
Lonicera ciliosa (Pursh.) Poir		
Symphoricarpos albus (L.) Blake		
<u>Valerianaceae</u>		
Plectritis congesta (Lindl.) DC.	M. Hall	20-5-1911
<u>Cucurbitaceae</u>		
Marah oreganus (T. & G.) How.		
<u>Campanulaceae</u>		
Campanula rotundifolia L.	JBF	20-6-1894
C. scouleri Hook. ex A. DC.	JBF	1-7-1894
Githopsis specularioides Nutt.	JBF	31-5-1896
Specularia perfoliata (L.) A. DC	JBF	25-6-1896
S. rariflorum (Nutt.) McVaugh	P	
<u>Compositae</u>		
Achillea lanulosa Nutt.		
Adenocaulon bicolor Hook.	LFH	22-6-1892
Agroseris elata (Nutt.) Greene	LFH	4-8-1888
A. heterophylla (Nutt.) Greene	P	
Antennaria neglecta var. howellii (Greene) Cronq.	P	
Aster curtus Cronq.	JBF	#876
Balsamorhiza hookeri Nutt.	P	
B. deltoidea Nutt.	P	
Chrysanthemum leucanthemum L.	FAL	#95
Crocidium multicaule Hook.	P	
Erigeron cascadensis Hel.	JBF	#1872
E. speciosus (Lindl.) DC.	L R. Abrams	#11514
E. strigosus Muhl.	JBF	2-10-1897
E. subtrinervis DC.	CVP	7-1890
Eriophyllum lanatum (Pursh) Forbes.	GNJ	#1808
Grindelia nana Nutt. var. integrifolia Nutt.	P	

Hieracium albiflorum Hook.	JBF	4-8-1897
H. cynoglossoides Arv.-Touv.	JWT	#7352
H. scouleri Hook.		
Hypochaeris radicata L.	FAL	#127
H. glabra L.	GNJ	#4615
Madia exigna (Sm.) Gray	JBF	1-7-1896
M. madioides (Nutt.) Greene	JBF	8-1896
M. minima (Gray) Keck	P	
Microseris lacinata Schultz-Bip.	ARK	#2736
Psilocarpus elatior Gray	JBF	#895
Senecio macounii Greene	P	
Solidago glutinosa Nutt.	ICO	#1905
S. spathulata var. neomexicana (Gray) Cronq.	E. C. Smith	#886
S. missouriensis Nutt.	E. C. Smith	#1077