AN ABSTRACT OF THE THESIS OF

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Title: GROWTH AND REPLACEMENT PATTERNS OCCurring AMONG SELECTED DOMINANT SPECIES ASSOCIATED WITH PLANT SUCCESSION ON DOUGLAS FIR CLEAR-CUTS

Abstract approved: Dr. W. W. Chilcote

Growth and replacement patterns of four successionally important species occurring on Douglas fir clear-cuts were investigated from September 1964 to June 1967. The study was carried out on the Marys Peak watershed located near Corvallis, Oregon.

Species used in the study include Holcus lanatus, Senecio jacobaea, Lotus crassifolius var. subglaber, and Berberis nervosa. During the summer of 1964, 24 transects, each consisting of eight square-foot plots, were established on three separate clear-cuts. These 24 transects consisted of three replications of eight distinct types of vegetation, which include the above species in both pure and mixed stands. Each of the 24 transects was sampled 11 times over a three year period, to detect changes in vegetational structure and composition.
In order to detect even slight changes in vegetation, a new sampling device was invented. This device employs the point frame principle, and may be used to sample vegetation up to four feet in height. The sampling device contains five pins which may be lowered 25 times within a square-foot area. Tape measures are attached to each pin so that the height of each contact may be easily read.

Results of the sampling show that, in general, the species studied grow better and more vigorously in mixed stands than in pure stands, and that competition does not appear to be an important factor in species replacement during the early stages of plant succession on Douglas fir clear-cuts in the watershed area. It is suggested that the behavior of a species on a young clear-cut is more dependent on its own ecology and changing soil factors than on competition from other species.

It is further suggested that vegetation occurring on clear-cuts is usually not homogeneous in nature, but more often has a mosaic-like pattern, being made up of many smaller vegetational units which differ from each other in both structure and composition. It is recommended that much further study needs to be done on the ecology of successionaly important species before plant succession of Douglas fir clear-cuts can be well understood.
Growth and Replacement Patterns Occurring Among Selected Dominant Species Associated with Plant Succession on Douglas Fir Clear-Cuts

by

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GROWTH AND REPLACEMENT PATTERNS OCCURRING AMONG SELECTED DOMINANT SPECIES ASSOCIATED WITH PLANT SUCCESSION ON DOUGLAS FIR CLEAR-CUTS

I. INTRODUCTION

Douglas fir clear-cuts provide an unusually good opportunity to study secondary succession. Normally the history of each clear-cut is easily obtainable, so that it is possible to know the date the cut was made, the type of logging used, and whether or not it was burned after logging. Often, in one locality, it is possible to study a number of clear-cuts of various ages so that several stages of the successional sequence may be sampled simultaneously. Additional observations can usually be made to discover how the successional patterns vary with elevation, slope, aspect, and other factors. Finally, it is often possible to assume that the vegetation surrounding a clear-cut is similar to that originally occupying the cut area.

Most work concerned with plant succession on Douglas fir clear-cuts has been of a general nature, with the objective of learning the successional sequence associated with a given area. These studies often employ many clear-cuts, and it has usually been necessary to sample each as if it contained a nearly homogeneous unit of vegetation. However as more detailed studies of clear-cut succession are initiated, it becomes feasible to treat each clear-cut as
having a more heterogeneous vegetation which is divided into distinct units or stands.

A particularly thorough investigation of plant succession on Douglas fir clear-cuts has been carried out on the Marys Peak watershed by Dr. Chilcote and his graduate students. Through this work, a fairly consistent pattern of plant succession was established for the watershed and surrounding area. However, even after this general successional pattern was known, there still remained many unanswered questions concerning the details of the process. In particular, there was a lack of information as to the method by which one species replaced another.

Accordingly, the present investigation was initiated in the summer of 1964 in order to learn as much as possible about the growth and replacement patterns of a few selected dominant species. To this end, a number of different stands or units of vegetation were selected from three different clear-cuts. Each unit of vegetation, when originally chosen, contained either a dominant species in a pure stand or a mixture of dominant species. In order to detect even small changes in vegetation on the selected areas to be sampled, it was found necessary to invent and construct a new type of sampling device, which in turn required a new sampling method.
II. REVIEW OF LITERATURE

**Successional Studies**

Frederic E. Clements was probably the most influential of the early American ecologists. During the early nineteen hundreds, he not only described and classified the vegetation of the United States, but he also laid down the fundamental principles of plant succession in his monumental book, *Plant Succession and Indicators* (Clements, 1928). More recently a number of authors, including Oosting (1948), Odum and Odum (1959), and Kershaw (1964), have reviewed and summarized the general principles pertaining to plant succession.

According to Weaver and Clements (1938), a climax association of western hemlock and western red cedar extends from coastal British Columbia, through western Washington and Oregon, and south into northwestern California. Clements believed that the extensive forests of Douglas fir in this area represented a sub-climax species due to fire and would eventually be replaced by both western red cedar and western hemlock in areas free of fire.

Investigations by Morris (1934) have shown that extensive forest fires have indeed been a common part of the history of western Washington and Oregon. He reports that even before the coming of the white man, the Indians burned large areas of valley land every year in the autumn. This was done both to force game out into the
open to be hunted, and to increase visibility for hunting during the remainder of the year. According to early accounts, these fires often raged uncontrolled for many days burning not only the vegetation in the valleys, but also setting fire to large areas of forest in both the Coast and Cascade Mountains. Although the early settlers did not permit the Indians to continue burning valley lands, many fires were still set in the mountains, either by accident or intentionally.

Munger (1940) summarized in more detail the cycle from Douglas fir to hemlock and red cedar. He noted that mature Douglas fir trees seldom live longer than 500 to 600 years, and that Douglas fir forests of this age were in a state of decay and normally had a well developed understory of cedar and hemlock. For these reasons he claimed that the cycle from Douglas fir to hemlock and cedar took from 500 to 600 years.

He explained that Douglas fir forests in a given area are unable to perpetuate themselves because Douglas fir is not tolerant of shade. According to Munger, only very shade tolerant species such as hemlock and cedar are able to maintain themselves under the canopy of Douglas fir, and eventually in this manner, the Douglas fir will be completely replaced in a given area by these more shade tolerant species. Although Munger believed the cycle he described was valid for the more moist areas of western British Columbia and
Washington, he was uncertain if Douglas fir would be replaced by hemlock and cedar on some of the drier areas of western Oregon.

Neiland (1958), working with both mature and burned forests in the Tillamook Burn area, found that mature stands of Douglas fir were being replaced by hemlock, but not by western red cedar.

Sprague and Hanson (1946), working in McDonald Forest located near Corvallis, Oregon, noted that forests of Douglas fir were neither replaced by western red cedar nor by western hemlock. They suggested that in the Willamette Valley and on the east slopes of the Coast Range of Oregon, Douglas fir together with grand fir may be a climax species because these areas are too dry for either hemlock or cedar. They further proposed that grand fir was probably the most important species in forming a climax at lower elevations on moist sites, but Douglas fir was probably a climax species by itself on higher, drier sites.

Although it seems possible that Douglas fir may be a climax species in a few situations, most work supports the belief that this species is highly dependent on some form of disturbance in order to maintain itself. In the past this disturbance came in the form of fire, but in recent times this factor has been greatly reduced. Today logging by clear-cutting largely substitutes for fire as a disturbance in the maintenance of pure stands of Douglas fir. Accordingly, a number of workers have investigated the successional trends upon
Douglas fir clear-cuts.

Kienholz (1929), working in western Washington, divided all vegetation occurring on Douglas fir clear-cuts into three major groups, which include virgin timber herbaceous species, virgin timber shrubby species, and weedy species.

Virgin timber herbaceous species included all herbaceous species found on the clear-cut that were also originally present in the virgin forest. According to Kienholz, these species generally survive logging and slash burning by means of living-underground parts or by seeds buried in the soil. Typical examples of this group given by Kienholz include genera such as Trientalis, Viola, Oxalis, Achlys, Montia, Disporum, and Polystichum. Kienholz found that, in general, this group decreases in cover value with time after clear-cutting, but never becomes completely absent from the area. He felt the decrease of this group was due to the inability of most of these species to withstand the more xeric conditions found after cutting. He also noted that some of the surviving members of this group had a much altered appearance. For example, *Trientalis europaea* growing on clear-cuts had smaller, more curled, thickened leaves and shorter, thicker stems than their counterparts growing in the forest. It was assumed that these modifications represent adaptations made by the plant to a more xeric environment.

Kienholz's second group, virgin timber shrubby species,
includes all shrubby or woody species found originally in the forest and later remaining on the clear-cut. These species often regenerate by means of sprouts from underground root or stem tissue. The composition of this group after cutting, according to Kienholz, will depend to a large extent on how much fire and injury species of this group are subjected to, and on the tolerance of each species to withstand these disturbances. Eventually the species of this group together with trees will dominate the clear cut, and most of the species of the other two groups will decline or drop out due to the increasing shade.

Kienholz designates his last group as weed species. This group includes all species which are normally absent or rare in the virgin forest. Species of this group usually are transported to the clear-cut by means of light seeds or fruits that are easily blown by the wind. Normally, these seeds have little stored food material and germinate best on burned or bare-ground areas. Since these species must be brought into the clear-cut from other areas, the early composition of the weedy species found on the clear-cut will depend to a large extent on the composition and distance to near-by seed sources. Some representative genera mentioned by Kienholz include Senecio, Cirsium, Epilobium, Hieracium, and Crepis. Kienholz noted that these species are practically absent from the clear-cut immediately after cutting but increase very rapidly in
cover value during the first few years. Often in the first years of succession, members of this group will dominate all others. Eventually, however, these species will be "shaded-out" by the tree and shrub species.

Kienholz found that the total vegetation on the clear-cut increased rapidly from the time of cutting, although he noted a definite slowdown in the rate of increase during the second year. He found no consistent difference in total density of vegetation on south or north slopes or with the degree of slope.

Mueller-Dombois (1959), working on Vancouver Island, recognized only two groups of species occurring on Douglas fir clear-cuts. These groups included remnant virgin vegetation and new weed vegetation. The remnant virgin vegetation group is equivalent to both the virgin timber herbaceous species and the virgin timber shrubby species used by Kienholz. According to Mueller-Dombois the remnant vegetation is so characteristic of a clear-cut that it may be used to determine the climax association existing on the area before cutting. On the other hand, he claimed that weedy species had little or no diagnostic value.

Bailey (1966), working in the southern Oregon Coast Range, also claimed that he could recognize climax associations or habitat types on the basis of remnant vegetation only. His work stresses the importance of recognizing that highly disturbed areas on a clear-cut
have a very different vegetational history from only slightly disturbed areas occurring on the same clear-cut. He found that undisturbed areas tend to have a high cover value for remnant species with only a few weedy species mixed in. Typical genera of remnant species found in these undisturbed areas include *Polystichum*, *Oxalis*, *Gaultheria*, *Berberis*, *Acer*, and *Montia*. Bailey found that, in general, this group steadily increased in cover value from the time of cutting. The species which increased the most in this group were mostly woody in nature, while the few that declined were herbaceous.

Bailey further found that highly disturbed areas tended to have high cover values for weedy species including such genera as *Senecio*, *Cirsium*, *Erechtites*, *Epilobium*, *Hypochoeris*, and *Crepis*. In general, succession on these disturbed areas proceeded from weedy species to woody remnant species and then to conifers, or else the successional pattern progressed directly from weedy species to conifers.

Isaac (1940), investigating clear-cuts in western Washington and Oregon over an eight-year period, noted that many of the weed species growing on these clear-cuts consisted of exotics from other countries. Common examples named by him include *Cytisus scoparius*, *Digitalis purpurea*, *Senecio vulgaris*, *Cirsium vulgare*, *Hypericum perforatum* and a number of grasses all originating from Europe, and also *Erechtites prenanthoides* from Australia. Among
these weedy species he noted that some species, for example
species of *Senecio* and *Epilobium*, increased in cover very rapidly
within a year or two, forming large populations which dominated
the clear-cut and then vanished from the same area as rapidly as
they had come. He was not able to explain why these species acted
in such a manner, but noted that the effect was often so great that
the total vegetational cover on a clear-cut would decrease signifi-
cantly as these species dropped out.

Like Kienholz, Isaac observed a definite trend toward a de-
crease in herbaceous cover and an increase in brush species as the
clear-cut matured with age.

Yerkes (1958) investigated the west slopes of the Cascades on
nine north-facing and five south-facing clear-cuts. In general, he
found little uniformity in the vegetation sampled. Only one species
(*Epilobium augustifolium*) was common to all fourteen units. Also,
he was unable to find any consistent variation of cover trends due to
either burning or elevation. However, he did observe that annuals
tend to dominate the clear-cut for the first year or two, but are soon
replaced largely by perennials. Also, herbaceous species appeared
to be dominant up to five years after cutting, but shortly after this
five year period were replaced by woody species in dominance.

Chilcote (1962) and Brown (1963) have worked out the major
successional trends occurring on Douglas fir clear-cuts on Marys
Peak. In general they found that during the first five years after cutting, Senecio sylvaticus dominated on the clear-cut during the second year. *Lotus crassifolius var. subglaber* and *Cirsium vulgare* dominated during the third, and *Lotus* together with *Holcus lanatus* dominated during the fourth and fifth years. During this period certain remnant species such as *Berberis nervosa*, *Galtheria shallon*, and *Acer circinatum* were observed to have very low cover values immediately after cutting and burning, but these cover values were observed to increase steadily with age after cutting.

The total cover on the clear-cut was found to increase rapidly from the time of cutting. However, a slight depression in total cover occurred during about the third year. In most cases this drop in total cover seemed to be attributable to *Senecio sylvaticus* which rapidly built up to large populations in a period of about a year and then disappeared from the area the following year. It was further noted by Chilcote and Brown that in the early stages of succession, relatively few species dominate, while in the later stages, other species play an increasingly important role. For example, it was found that during the second year after cutting and burning, four dominant species contributed 97 percent of the total vegetational cover, but by the fourth year after cutting the four leading species made up only 58 percent of the total vegetational cover.

Chilcote, together with several of his graduate students, has
investigated the autecology of some of the leading dominant species occurring on the clear-cuts in the Marys Peak area. West (1962) attempted to relate the dramatic decline in populations of Senecio sylvaticus to changes of soil nutrient levels. Robinson (1964) has described air and soil temperature microenvironments associated with leading dominants in the early stages of plant succession. And Drew is currently writing a thesis describing the soil moisture relationships of important species found on the clear-cuts.

Sampling by the Point Quadrat

The methods used by the aforesaid authors in obtaining their data varied considerably. In most cases, these workers made visual estimates of cover or abundance, using quadrats which ranged widely in size. Munger (1940) and Mueller-Dombois (1959) used comparatively large quadrats of 1/4 or 1/5 acre respectively. Bailey (1966) and Kienholz (1928) used far smaller quadrats of 6 by 30 feet and 8-1/4 by 33 feet respectively, while Yerkes (1958) used four milacre circular plots. Neiland (1958) employed a series of nested quadrats ranging in size from ten by ten meters down to one square meter. Of the workers cited, only Chilcote (1962) and Brown (1963) used a method which does not depend directly on visual estimates and which does not involve the use of conventional quadrats. These authors appear to be the first to use the point quadrat
method in sampling plant succession on Douglas fir areas.

As shown above, ecologists have sampled vegetation by means of quadrats varying widely in both shape and size. This lack of uniform quadrat size has made it difficult to compare results obtained in ecological studies. One solution is the use of the point quadrat method. The point quadrat represents the extreme limit to which a quadrat can be reduced. With this method the quadrat is represented by a point and is virtually without area. In practice a narrow rod or pin is lowered vertically through the vegetation. All plants touched by the pin lie over a single point on the ground, and information concerning the composition of the vegetation can be provided by recording all such contacts. A further advantage of the point quadrat method is that it reduces the subjectivity of the observer to determining only if a plant has or has not been touched as the pin is lowered.

The uses of the point frame method, and its comparison to other sampling methods, has been extensively reviewed by Goodall (1952), and also by Brown (1954). In the following review the origin, development, and various modifications of the point frame apparatus are emphasized.

The point quadrat method appears to have originated in New Zealand in 1925, where it was used by Cockayne (Goodall, 1952; Levy and Madden, 1933). Cockayne did not publish a description of
his method, but did make an indirect reference to it in an early paper (Cockayne, 1926). Other published works have explained that Cockayne used the toe-cap of his boot for a point (Brown, 1954; Levy and Madden, 1933). Apparently he sampled grassland vegetation by walking across it, and recording each species found under the tip of his boot as he walked.

From these beginnings Levy and Madden (1933) invented a more sophisticated device for sampling by the point method. Their device consisted of a frame approximately two feet high, supported by two vertical legs, and connected by two horizontal bars. The two horizontal bars contained ten vertical holes, each two inches apart, through which pins could be lowered. With this frame pins were lowered one at a time, and hits on the vegetation were recorded. As Levy and others have pointed out, this sampling device may be used to take data in several ways (Brown, 1954; Goodall, 1952; Levy and Madden, 1933).

A. Record only the first species hit by each pin, so that only one hit is recorded for each pin that is lowered.

B. Record all species hit by the lowering of each pin, so that several different hits on as many different species may be recorded for each pin that is lowered.

C. Record all hits made on all species as the pin is lowered, so that many hits may be recorded on each of several
species as each pin is lowered.

Method "B" can be used to determine the percent cover of a species on a sampled area by calculating the number of points per hundred examined at which contact was made with the species. Method "A" can be used in the same way to determine percent cover, but although this method is rapid, it has the disadvantage of under-estimating cover values for low growing plants. Method "C" is the most time consuming, but is useful in determining percentage of sward. This value refers to the percentage each species plays in making up the vegetation. Frequently, percentage of sward as determined by the point frame method is compared to percentage of sward as determined by clipping and weighing studies.

Since the introduction of the ten point frame by Levy and Madden (1933), many similar but modified sampling devices have been invented. The original point frames were built relatively close to the ground, and for this reason, were best suited to sampling grassland vegetation. Some investigators have built similar but larger point frames for the purpose of sampling brush species (Cook and Box, 1961; Brum and Box, 1963). One of the largest ten point frames has been built and used by Cook and Box (1961). This frame is about five feet long and four feet high. It contains ten vertical pins spaced evenly six inches apart.
Other investigators have altered the original point frame by changing the ten pins from a vertical position to an inclined position with the pins at a forty-five degree angle (Arny, 1944; Arny and Schmid, 1942; Drew, 1944; Hughes, 1962; Newton, 1964; Tinney, Aamodt, and Ahlgren, 1937; Winkworth, 1955). Some of these workers claim that inclined pins give better accuracy (Tinney, Aamodt, and Ahlgren, 1937). According to Cain and Castro (1959), vertical pins distort results of broadleaved species relative to grass, and inclined pins lack this distortion. Moreover, Cain and Castro point out that inclined pins record more interceptions resulting in better accuracy and that the downward visibility of the pins is improved.

Tinney, Aamodt, and Ahlgren (1937) found that when percent of sward, as determined by the point frame method, is compared to percentage of sward as determined by clipping and weighing, inclined pins gave better accuracy. Drew (1944) obtained better accuracy with inclined pins, providing the vegetation was less than four inches in height. However, with vegetation over four inches in height, better accuracy was obtained using vertical pins. Arny and Schmid (1942) and also Sprague and Myers (1945) found that they were unable to make reliable comparisons between percentage of sward using the point frame method and percentage of sward using the clipping and weighing method, unless correction factors were
applied to the point frame data. Arny (1944) and also Sprague and Myers (1945) further pointed out that any such correction factors vary not only with the species of plant but also with the stage of growth of each species.

Goodall (1952) has pointed out that data derived from inclined pins is hard to interpret visually and that, in general, data taken from inclined pins has little advantage over that taken with vertical pins. For these reasons, Goodall condemns the use of inclined pins for most purposes.

Although ten pins are normally used as a set in a point frame, the number of pins used in point quadrat sampling may vary a great deal. Some investigators use only a single point in sampling vegetation, as did Cockayne. Blackman (1935) has pointed out that theoretically, sampling by a single pin should be more accurate than sampling with pins used in sets of ten, provided an equal number of pins are used. Investigations by Crocker and Tiver (1948) and also by Winkworth (1955) have shown that sampling by a single pin is approximately three times as efficient as sampling by a device with ten pins in a set. That is, only one third the number of pins need be lowered with the single pin method as with ten pins in a set in order to obtain the same accuracy. The most common method of using a single pin is the so called "step-point" method, recently reviewed by Evans and Love (1957). With this method, a notch is
cut in the front of the observer's boot and a metal pin or rod is lowered through the notch until it makes contact with the vegetation. The boot is held at an angle with the toe off the ground so that the sampled vegetation will not be disturbed. Samples are taken at a predetermined number of paces. According to Evans and Love, the "step-point" method is about six times faster than the ten point frame for the same accuracy, however this method can only be used on low-growing vegetation.

Eden and Bond (1945), working in Ceylon, sampled higher vegetation using a different single point method. Eden did his sampling by dropping a meat skewer into the vegetation. The skewer was held lightly with the arm outstretched and dropped vertically with eyes shut or fixed on the horizon. All plants impaled by the skewer were recorded and then the skewer was dropped again at a predetermined number of paces. If the skewer failed to become embedded vertically in the ground, it was dropped again.

Point frames using more than ten pins in a set normally have the pins arranged in several rows. Reppert, Morris, and Graham (1962) used a frame containing thirty inclined pins arranged in five rows with six pins in each row for sampling grassland vegetation.

Ellison (1942) has employed a point frame containing twenty pins on a sliding bar. The sliding bar may be stopped in any of twenty positions so that four hundred lowerings may be made each
time the apparatus is placed on the ground.

Other workers have improved the point frame by the addition of pin brakes. Smith (1959) made pin brakes out of clock spring metal and installed them on the point frame in such a way that the pins would stay in place in any lowered position due to friction with the spring, yet were free to move easily when pushed by hand. Heady and Rader (1958) made similar pin brakes out of leather and wood blocks. These pin brakes are useful as they allow the investigator to take his hand off the pin without having it slide to the ground as is the case with most point frames.

Nerney (1960) attached a bicycle wheel to a ten point frame to be used on the grasslands. The wheel was equipped with a clicker so that not only was the point frame easier to transport but it also automatically measured distance as well as indicated the position the frame should be placed for sampling.

Some point frames do not employ any type of pins or rods. An ocular point frame designed by Chilcote consists of two sets of cross hairs forming a square with twenty-five points with three inch spacing between points (Stanton, 1960). This type of frame has the advantage that it is much faster to use than the conventional pin type of point frame, but on the other hand, it has the disadvantage that only data on "top hits" may be obtained.

A few investigators have attempted to combine cover data
obtained with the point frame with height data (Evans and Jones, 1958; Heady, 1957; Heady and Rader, 1958; Pasto, Allison, and Washko, 1957; Reppert, Morris, and Graham, 1962). Heady and Rader (1958) attached rulers to their ten point frame in such a way that they could measure the height of plants being sampled. This was done by placing a finger on the pin across from the zero mark on the ruler as the point of the pin made contact with the species being sampled. If the pin was then pushed all the way to the ground, the distance traveled by the finger on the pin could be measured and this distance would equal the height of the plant. However, this sampling device is limited to low vegetation because the rulers and the distance traveled by the pins was less than ten inches.

Wilson (1959) has attempted to get a three dimensional understanding of the structure of vegetation through the use of a sampling apparatus employing both vertical and horizontal pin positions. Wilson's device contains only one pin which may be lowered both vertically and horizontally over a grid-like pattern. The pin is calibrated with click-stops at one centimeter intervals along its length, so that both vertical and horizontal distance measurements may be taken. This type of sampling device gives detailed information as to plant structure, but is time consuming and tedious to use.
III. DESCRIPTION OF THE AREA

Location

Marys Peak is the highest mountain in the Coast Range with an elevation of 4,097 feet. It is located in west central Oregon near the western margin of Benton County. The present study was conducted on the Corvallis watershed area which includes the Rock Creek and Griffith Creek drainage systems, situated on the eastern slope of Marys Peak. The watershed lies within Sections 7, 18, 19, and 30, Township 12 south, Range 6 west and Sections 10-16, 21-28, and 34-36, Township 12 south, Range 7 west, of the Willamette Meridian. This area may be reached by driving approximately six miles southwest of Philomath on Highway 34.

Climate

The rainfall pattern in the study area, as with Oregon in general, is markedly different in summer and winter. In winter a strong low pressure area develops in the north Pacific, so that the prevailing westerly winds bring a series of cyclonic storms to the Oregon coast. During much of this season, the relatively moist, warm air from the ocean condenses as rain as it passes over the Coast Range.

In summer the situation changes and the Aleutian low weakens
and disappears, while at the same time the Pacific high moves northward from Hawaii. These shifts result in a much reduced rainfall during the summer season.

Along the west side of the Coast Range the annual rainfall is about 70 inches. However, as the winds pass over the mountains, precipitation increases to as high as 130 inches. The moving air then drops to lower elevations as it reaches the east side of the Coast Range, and precipitation drops to about 40 inches on the western margin of the Willamette Valley.

A rain gauge is maintained by the City of Corvallis on the eastern boundary of the watershed. Data from this station indicates that at lower elevations of about 500 feet, the annual precipitation is approximately 68 inches. However, the amount of rainfall within the study area is greater at higher elevations.

Hermann (1965) found that at 1,700 feet elevation, the average annual rainfall on a clear-cut (measured over a two year period) was about 75 inches. He further found that distribution of this rainfall was very uneven. It averaged about 8 inches per month during the winter, and only 1 inch per month in the summer.

Temperature measurements taken on the same clear-cut in a weather shelter 4.5 feet above the ground, showed that maximum temperatures taken during the months of July and August averaged about 80°F. Minimum temperatures taken during the months of
December and January averaged about 38°F.

Geology

The geology of Marys Peak has been described by both Baldwin (1964) and by Roberts (1953). According to Baldwin, the oldest rocks in the Marys Peak area are those of the Siletz River volcanic series. This series is of early Eocene age, and consists of basalt that was extruded upon the ocean floor. Because this series was subjected to rapid underwater cooling, it is often associated with pillow lava and zeolite minerals.

Most of the Siletz River volcanic series is covered by the Tyee formation. This formation covers much of the Coast Range and consists of sandstone and sandy siltstone of middle Eocene age.

During the late Oligocene or early Miocene, the Tyee formation of Marys Peak was intruded by a large sill of over 1,000 feet in thickness. This sill consisted mostly of igneous granophyric gabbro and diorite, and has been described in detail by Roberts (1953). During the late Cenozoic uplift of the Coast Range, most of the sedimentary rock overlying the sill was eroded away so that the top of Marys Peak consisted of a cap of igneous rock, with only a small remnant of Tyee formation left near the summit. According to Baldwin, nearly every prominent peak in the central Coast Range is associated with a similar sill.
Vegetation

The plant communities occurring on Marys Peak have been described by only a few people. Merkle (1948) recognized four distinct communities occurring above 2,500 feet. These included a grassland community found only near the summit, a hemlock-noble fir-Douglas fir community found on the north and northwest slopes, a Douglas fir-noble fir found on the east slopes, and a Douglas fir community found on the south and southeast slopes. Of the communities outlined by Merkle, the watershed is probably described best as a Douglas fir community.

Bailey (1966) has described the vegetation on the watershed area as being *Pseudotsuga menziesii*-*Acer circinatum* community. He further states that under the system used by Corliss and Dyrness, the same area would be classified as having a *Pseudotsuga/Acer/Gaultheria* community.

Anderson (1967) has recently completed a study of Vine Maple communities occurring on Marys Peak. In this study, he has divided the watershed area into the following five communities:

1. *Corylus californica/Bromus vulgaris*
2. *Acer circinatum/Gaultheria shallon*
   
   *Corylus californica-Holodiscus discolor* subtype
   
   *Tsuga heterophylla/Xerophyllum tenax* subtype
3. **Holodiscus discolor/Gaultheria shallon**

4. **Acer circinatum/Polystichum munitum**

5. **Oxalis oregana**

The dominant tree species in the first three communities was Douglas fir, while hemlock in combination with Douglas fir dominated the last two communities. However, Anderson did not use these dominant tree species in naming his communities, because in some cases it was not possible to determine which tree species would become climax. In general, Anderson believed that grand fir would be the climax tree at low elevations, and hemlock would be the climax tree at somewhat higher elevations on relatively moist areas.

**History**

Until 1920, much of the watershed area was owned by private logging interests. At this time, citizens concerned about the future of the Corvallis water supply initiated a program to purchase land within the watershed. Accordingly, 2,000 acres were bought by the city, and the remaining land (about 6,900 acres) was put under the administration of the Forest Service (U.S.F.S., n.d.). From 1920 until 1952 all logging operations were discontinued, and the watershed area was kept in a natural state during this time.

In the winter of 1949-50, severe storms caused heavy concentrations of blowdown timber in the Marys Peak area. These winter
storms were followed by an exceptionally dry summer, which resulted in an epidemic of Douglas fir bark beetles. In order to save the watershed from possible destruction by insects or even by fire, an orderly system of logging was initiated in 1953. Logging operations were carried out only in the insect infected and blowdown areas, and clear-cuts were confined to a small size of 10 to 20 acres. By 1959 almost all logging operations ceased after some 44 clear-cuts had been made.

The Columbus Day storm of 1962 blew down a total of 32 million board feet of timber. In order to avoid a repeated beetle infestation similar to that experienced in 1949-50, logging was again initiated to salvage as much downed timber as possible.
IV. METHODS

During the summer of 1964, four species were selected for intensive study, because of their importance in the successional sequence on the Marys Peak watershed. These four species included *Holcus lanatus*, *Lotus crassifolius* var. subglaber, *Senecio jacobaea*, and *Berberis nervosa*. After a general survey of clear-cuts occurring on the watershed, three were selected as being best suited for investigating the above species in both pure and mixed stands.

The youngest of the three clear-cuts was cut and burned in 1958 and has an elevation of 1350 feet. This clear-cut is designated as number 31 by the United States Forest Service. On this clear-cut nine sample areas were located and marked. These sample areas included three stands of pure *Holcus*, three stands of *Lotus*, and three stands of a mixture of both *Holcus* and *Lotus*.

The second clear-cut (number 20) was cut in 1955, burned in 1956, and has an elevation of 1300 feet. Twelve areas to be sampled were located on this cut, and included three stands of pure *Senecio jacobaea*, three stands of mixed *Holcus* and *Senecio*, three stands containing a mixture of *Holcus*, *Senecio*, and *Lotus*, and three stands of mixed *Lotus* and *Berberis nervosa*. The remaining clear-cut (number 22) was cut and burned in 1956, and has an elevation of 1500 feet (Figure 1). On this clear-cut three mixed stands of *Lotus* and
Figure 1. A Douglas fir clear-cut used in study, with Marys Peak in background.
Senecio were located and marked to be sampled.

Altogether, 24 sample areas were located and marked with stakes. These areas included three replications of eight distinct types of vegetation.

In order to detect any changes in vegetational structure that might occur on the sample areas, it was necessary to design and build a new type of sampling device. Accordingly, a modified point frame was built capable of taking accurate cover and height data on small, intensely sampled plots.

This sampling device, as it exists in its present form (Figures 2, 3), consists of a square steel frame (18 inches on each side) suspended 40 inches above the ground by four legs. Upon the square frame is mounted a metal bar with five vertical pins, spaced evenly at three inch intervals. The sliding bar may be stopped at any of five positions, so that 25 pin lowerings are possible in an area of one square foot. Each vertical pin is equipped with a tape measure so that height measurements may be taken.

Each of the five pins consists of a flexible steel rod 58 inches long by 1/4 inch in diameter, with a point at the lower end. The blade of a standard six foot measuring tape is attached near the top of each pin, while the body of the measuring tape is mounted on the sliding metal bar. The arrangement of the tape measures allows the heights of all contacts with the vegetation to be read directly as
Figure 2. Author using sampling device.
Figure 3. Close-up view of sampling device.
the pins are lowered.

Each vertical pin is also equipped with a fully adjustable pin break (Figure 4). These are made in such a way that as a metal cover is screwed down it causes short sections of surgical tubing to press against the sides of the vertical pins. By adjusting the screws on the metal covers the pin breaks may be set so that the pins move freely, but will not slide of their own weight. The metal covers may be quickly removed in the field if replacement of worn tubing becomes necessary.

The sliding bar is fastened at both ends to a metal track, which in turn is fastened to the square metal frame. The sliding bar is equipped with click stops at three inch intervals so that it may be exactly positioned. Once the bar is in place, it cannot be moved until the release buttons are pressed at each end of the bar.

The legs of the point frame are 48 inches long and are made of metal pipe with an outside diameter of 21/32 of an inch. Each leg may be quickly and easily adjusted for height by means of a thumb screw, so that the point frame will stand solidly on uneven ground (Figure 5).

While the sampling device was under construction, one transect was marked with stakes in each of the 24 sample areas. These transects consisted of eight consecutive one-square-foot plots spaced at three inch intervals. The transects were made one foot
Figure 4. Close-up view of sampling device showing tape measures and pin breaks.

Figure 5. Close-up view of sampling device showing leg adjustment.
wide to correspond to the width of the pin row on the sampling device. The use of a transect two or more feet wide was rejected, because of the physical difficulty of sampling a wider area without disturbing the vegetation by walking or stepping on it. It was decided to use eight-square-foot plots to a transect on a somewhat arbitrary basis; however, this number is convenient as it results in an even 200 pin lowerings per transect.

All transects of the 24 sample areas were located on nearly level ground, so that the sampling device could be easily positioned and height measurements would be as accurate as possible. The transects were also oriented in an east-west direction and sampling was always done with the observer standing on the north side of the transect so that trampling would not cause changes in shade patterns within the sample plots. The first square-foot plot to be sampled was always located at the east end of the transect.

In order to locate the point frame exactly over the same series of plots each time data was taken, a string was tied between two stakes centered at each end of the transect. The sampling device was always positioned with its center pin just touching the string so that the sampling device would always be centered over the middle of the transect. Knots tied in the string at appropriate intervals were used to indicate the proper distance from the east stake to each plot on the transect.
All of the 24 transects were sampled at the following times:
September 1964, early May (some late April), June, July, and
September of 1965, and also of 1966, and May and June of 1967. On
all of these dates, both cover and height data were taken on all tran-
sects.

Cover data was taken by lowering each pin into the vegetation
and recording each species hit by the lowered pin. Height data was
taken by recording the height of the first hit made on each species
as each pin was lowered. If no species were hit as a pin was
lowered, the type of ground surface (i.e. litter, wood, bare ground,
rock) was recorded instead.

Photographs of all transects were also taken in the spring and
late summer during the three years the study was in progress.
These photographs were always taken from the same position, so
that it would be possible to observe visually vegetational changes
occurring on relatively small areas over a period of years.
V. RESULTS

The raw data taken in the present study may be analyzed to show height and cover information separately, and this has been done in some of the more detailed graphs. However, for most purposes it is useful and convenient to combine the cover and height figures into one number representing volume of foliage. The term volume of foliage is used here to mean the approximate volume necessary to enclose the foliage, and does not refer to the actual volume of leaf and stem tissue.

Starting with the formula \( \text{volume} = (\text{area})(\text{height}) \), an additional formula has been derived to express the approximate number of cubic feet the foliage of any given species outlines on a square-foot plot. Because the pins of the sampling device cover an area of one square foot, it is possible to make a correlation between the number of pin contacts made with a species and the ground area occupied by that species. This area may be derived by the following formula:

\[
A = \frac{C}{25}
\]

where

\( A = \text{Area in square feet occupied by a species on a one square-foot plot.} \)
\[ C = \text{Number of pin contacts made with the species within the one foot-square plot.} \]

If, for example, all 25 pins lowered in a square-foot plot made contact with a sampled species, then this species would be considered to occupy 100 percent of the area or one square foot. By the same formula, a species with only five pin hits would be considered to occupy only .2 square feet of ground area.

The average height in feet a species has on a one-square-foot plot can be determined with the following formula:

\[ H = \frac{TH}{12 \ C} \]

where

\[ H = \text{Average height of species on a square-foot plot.} \]

\[ TH = \text{Total height in inches of all contacts made with the species on the square-foot plot.} \]

\[ C = \text{Number of pin contacts made with the species within the one-foot-square plot.} \]

When the two above halves are combined, the following completed formula, expressing volume in cubic feet, is obtained:

\[ V = \left( \frac{C}{25} \right) \left( \frac{TH}{12C} \right) \]
This formula may be simplified to,

\[ V = \frac{TH}{300} \]

With the above formula, foliage values were calculated for all square-foot plots on all 24 transects. These calculations were made for all species used in the study on all dates on which data was taken. In order to further summarize the data, all foliage values pertaining to a given species and taken on a single transect were added together. In this way it was possible to use a single number to express, for any given species, the total volume of foliage occurring on any transect on any given date. Appendix 1 gives the foliage values for every date on which data was taken and for all species occurring on each of the 24 transects.

The data pertaining to Holcus is derived from 12 separate transects. These transects consisted, at the beginning of the study, of three replications of the following types of vegetation: pure Holcus, Holcus mixed with Senecio, Holcus mixed with Lotus, and Holcus mixed with both Senecio and Lotus.

The data from the three transects originally consisting of pure Holcus is summarized in Figures 6 and 7. Figure 6 shows that the average foliage value for Holcus was about 10.1 cubic feet per transect in 1964. This value dropped to about 2 cubic feet during the
Figure 6. Mean foliage values taken on transects originally consisting of Holcus from Sept. 1964 to June 1967. Solid lines indicate values for Holcus, dashed for Senecio. Vertical bars indicate range of values between transects.
following year, and then dropped to nearly 0 by the summer of 1966.

On the same set of transects, Senecio was the only species to become significantly important during the course of the study. Senecio was absent from all three transects during the summer of 1964. However, it increased to an average value of almost 1 cubic foot per transect during the summer of 1965, and by the summer of 1966 the foliage value had increased to an average of 2.4 cubic feet per transect.

Although the vertical range bars used in Figure 6 show a certain amount of variation among the transects, the general pattern described for Holcus and Senecio appear consistent.

Figure 7 gives a detailed representation of the vegetational structure occurring on one of the Holcus transects. The three graphs comprising this figure represents the vegetation as it existed in the late summer of 1964, 1965, and 1966. On these graphs the Holcus and Senecio vegetation occurring on each of the eight square-foot plots of the transect are represented by irregular geometric forms. These geometric forms are drawn by dividing the data for any given plot into ten-inch height classes of 0 to 10 inches, 10 to 20 inches, 20 to 30 inches, and 30 to 40 inches. The number of contacts within a given height class is plotted at the median value of the class, so that points are plotted at 5, 15, 25, and 35 inches.
Figure 7. Diagramatic representation of vegetational structure found on a transect originally consisting of *Holcus*. Upper, middle, and lower graphs represent the transect as it appeared Sept. 1964, Sept. 1965, and Sept. 1966 respectively. Solid figures represent *Holcus*, hatched figures represent *Senecio*. See text for further explanation.
The wider the figure is at any on these values, the more contacts were made in the corresponding height class. Therefore, these figures show the range over which top hits were made and also indicate the relative number of contacts made in each height class. A photographic record of the same transect is shown in Figure 8.

Figure 9 summarizes the data from three transects which, at the beginning of the study, consisted of a mixture of Holcus and Senecio. At the start of the study there was an average of 6.7 cubic feet of Holcus on each transect. By the summer of 1965 this average had dropped to .7 cubic feet, and during the summer of 1966 Holcus was completely absent from all plots.

The behavior of Holcus in stands mixed with Lotus can be seen in Figure 10. In this case, the average value for Holcus on the three transects during September at the beginning of the study was about 6.8 cubic feet. During the following year this value dropped to 1.6 cubic feet, and by the summer of 1966 it had dropped to about .9 cubic feet.

In Figure 11, the behavior of Holcus in mixed stands of both Senecio and Lotus is given. At the beginning of the study, these transects had an average of almost 9 cubic feet of Holcus per transect. By the following summer, this average had declined to 3.4 cubic feet, and by the summer of 1966 the average value was only .5 cubic feet.
Figure 8. Photographic record of a transect originally consisting of Holcus.
Figure 9. Mean foliage values taken on transects originally consisting of *Holcus* and *Senecio* from Sept. 1964 to June 1967. Solid lines indicate values for *Holcus*, dashed for *Senecio*. Vertical bars indicate range of values between transects.
Figure 10. Mean volume values taken on transects originally consisting of Holcus and Lotus from Sept. 1964 to June 1967. Solid lines indicate values for Holcus, dotted for Lotus, and dashed for Senecio. Vertical bars indicate range of values between transects.
Figure 11. Mean foliage values taken on transects originally consisting of Holcus, Senecio, and Lotus from Sept. 1964 to June 1967. Solid lines indicate values for Holcus, dashed for Senecio, and dotted for Lotus. Vertical bars indicate range of values between transects.
Figures 6 through 11 also show the general seasonal growth pattern of Holcus. It is seen that Holcus reaches its highest foliage values between the months of July and September. In winter the foliage values drop to nearly zero, as most of the above ground portions of Holcus die back. By May, Holcus begins to grow again and reaches its highest rate of growth sometime during the month of June.

A summary of the behavior of Holcus in both pure and mixed stands is given in Figure 12. In this graph, relative values expressed as percentages are used so that comparisons may be made on all transects containing Holcus. For each set of three replicated transects, Holcus received a value of 100 percent at the beginning of the study (Sept. 1964). The average percentage of loss from the original 100 percent value is recorded for a period of time one year later (Sept. 1965) and two years later (Sept. 1966).

Pure stands of Holcus dropped in foliage value rapidly during the first year of the study to an average of only 20 percent of the original value. By the end of the second year, almost 100 percent of the foliage value for Holcus has been lost.

When Holcus is growing with Senecio, it drops in foliage value more rapidly the first year than it does in pure stands. In this case, the foliage value declined to only 10 percent of the original value during the first year and then declined almost to zero during the
Figure 12. Average percentage of Holcus remaining on transects during Sept. of 1965 and 1966 as compared to original values taken in Sept. 1964. See text for explanation.
second year.

Holcus growing with *Lotus* does not drop in foliage value nearly as rapidly as it does in pure stands or when growing with *Senecio*. In this case, *Holcus* lost only about 24 percent of its original value during the first year of the study and by the summer of 1966 it still maintained about 42 percent of its original foliage value.

*Holcus* growing in mixed stands of both *Senecio* and *Lotus* shows a drop in foliage value which is intermediate between that of *Holcus* growing with *Lotus* and with *Holcus* growing with *Senecio*. *Holcus* dropped to 38 percent of its initial value during the summer of 1965 and dropped to 6 percent of its original value by the summer of 1966.

The data pertaining to *Senecio*, like *Holcus*, is derived from 12 separate transects. These transects consisted of three replications of the following types of vegetation at the start of the study: pure *Senecio*, *Senecio* mixed with *Holcus*, *Senecio* mixed with *Lotus*, and *Senecio* with both *Holcus* and *Lotus*.

The data from the three transects originally consisting of pure *Senecio* is summarized in Figures 13 and 14. As shown in Figure 13, the average foliage value for *Senecio* on pure plots was 9.5 cubic feet at the end of the summer in 1964. This value then declined to 2.3 cubic feet during the summer of 1965, and then rose slightly from this low to 3.1 cubic feet during the summer of 1966. During
Figure 13. Mean foliage values taken on transects originally consisting of *Senecio* from Sept. 1964 to June 1967. Dashed lines indicate values for *Senecio*. Vertical bars indicate range of values between transects.
Figure 14. Diagramatic representation of vegetational structure found on a transect consisting of Senecio. Upper, middle, and lower graphs represent the transect as it appeared Sept. 1964, Sept. 1965, and Sept. 1966 respectively. See text for further explanation.
the course of the study, no other species invaded these three tran-
sects to any significant extent.

Figure 14 gives a diagrammatic view of vegetational structure
occurring on one of the pure Senecio transects. A photographic
record of this same transect can be seen in Figure 15.

On the three transects consisting of a mixture of Senecio and
Holcus, Senecio had a foliage value of about 6.8 cubic feet in 1964
(Figure 9). This value dropped to 2.7 the following year, but then
rose slightly to 3.4 during the summer of 1966. A photographic
record of a transect consisting of a mixture of Holcus and Senecio
can be seen in Figure 16.

In Figure 17 the behavior of Senecio in mixed stands with Lotus
is given. As in the other two cases, Senecio reaches its highest
foliage value in 1964; this value then dropped to a low during 1965,
and recovered somewhat in 1966. In this case the values were 9.1
cubic feet in 1964, 3.4 cubic feet in 1965, and 7.5 cubic feet in 1966.

When Senecio is mixed with both Lotus and Holcus, a similar
pattern (of a drop in foliage value followed by a slight rise) is found
(Figure 11). Here the values were 5.6 cubic feet in 1964, 1.7 cubic
feet in 1965, and 3.6 cubic feet in 1966.

From the above information, it can be seen that Senecio
usually reaches its greatest foliage value in late summer. In winter
the foliage values drop a great deal, because in most cases only the
Figure 15. Photographic record of a transect originally consisting of *Senecio.*
Figure 16. Photographic record of a transect originally consisting of a mixture of *Holcus* and *Senecio*.
Figure 17. Mean foliage values taken on transects consisting of Senecio and Lotus from Sept. 1964 to June 1967. Dashed lines indicate values for Senecio, dotted for Lotus. Vertical bars indicate range of values between transects.
rosette stages survive during this season. By May, Senecio has begun to grow again, and by June it is growing rapidly.

A summary of the behavior of Senecio in both pure and mixed stands is given in Figure 18. Senecio drops in foliage value most rapidly when it is growing in pure stands. In this case, Senecio dropped to 33 percent of its initial value by the end of the second year. Like Holcus, Senecio seems to grow best when it is growing in association with Lotus. Here, Senecio lost only 19 percent of its original value by the summer of 1966.

In stands where Senecio was growing with Holcus, the foliage value for Senecio dropped to about 51 percent of its original value by September of 1966. Senecio growing in mixed stands of both Holcus and Lotus shows (at the end of the summer of 1966) a drop in foliage value which is intermediate between that of Senecio growing with Holcus and that of Senecio growing with Lotus. On mixed stands of Senecio, Holcus, and Lotus, Senecio declined to 63 percent of its initial value by the summer of 1966.

The data for Lotus is derived from transects consisting of pure Lotus, Lotus mixed with Holcus, Lotus mixed with Senecio, and Lotus mixed with both Senecio and Holcus. In addition to these transects, three transects consisting of a combination of Lotus and Berberis were also sampled.

When September foliage values are compared for pure Lotus
Figure 18. Average percentage of Senecio remaining on transects during Sept. of 1965 and 1966 as compared to original values taken in Sept. 1964. See text for explanation.
transects, it is seen that these values dropped from 9.3 cubic feet in 1964 to 4.7 cubic feet the following summer (Figure 19). This value then increased somewhat to 5.1 cubic feet by September of 1966. These three transects were invaded by Senecio during the summer of 1966, reaching a foliage value of 1.3 cubic feet. By May of 1967, this value had increased to almost 1.8 cubic feet.

On the three transects consisting of a mixture of Lotus and Holcus, Lotus foliage values taken in September show a gradual decrease from 1964 to 1966 (Figure 10). These values were 4.5 cubic feet in 1964, 3.3 cubic feet in 1965, and 2.8 cubic feet in 1966. On transects where Lotus was combined with both Holcus and Senecio, a similar decreasing pattern of foliage values for Lotus was encountered (Figure 11). In this case, the September foliage values were 4.0 cubic feet in 1964, 2.2 cubic feet in 1965, and 1.2 cubic feet in 1966.

On transects where Lotus was combined with only Senecio, the pattern varied somewhat from above. In this case, Lotus first lost in foliage value from September 1964 to September 1965, but then gained the foliage value back in September of 1966 (Figure 17). The actual average values were 7.1 cubic feet in 1964, 5.8 cubic feet in 1965, and 7.1 cubic feet in 1966.

Lotus remained relatively constant in foliage values on transects having mixed stands of Lotus and Berberis (Figure 20). The
Figure 19. Mean foliage values taken on transects originally consisting of *Lotus* from Sept. 1964 to June 1967. Dotted lines indicate values for *Lotus*, dashed for *Senecio*. Vertical bars indicate range of values between transects.
Figure 20. Mean foliage values taken on transects consisting of Lotus and Berberis from Sept. 1964 to June 1967. Dotted lines indicate values for Lotus, double solid lines for Berberis. Vertical bars indicate range of values between transects.
foliage values compare as follows for September readings: 7.5 cubic feet in 1964, 6.4 cubic feet in 1965, and 6.9 cubic feet in 1966. A photographic record of a transect consisting of a combination of Lotus and Berberis is shown in Figure 21.

Lotus was found to have the most dramatic fluctuations in seasonal foliage values of any of the species studied. It normally reached its peak value in July and then decreased steadily during the course of the summer. During winter it dropped to zero value as all above ground tissue would die during this season. Often as late as May Lotus showed little growth in foliage, but by June the growth in foliage was very rapid.

A summary of the behavior of Lotus in both pure and mixed stands is given in Figure 22. Pure stands of Lotus declined to about 50 percent of their original foliage value by the summer of 1965. During the following summer there was a slight increase in foliage value so that 55 percent of the initial amount still remained. In mixed stands of both Lotus and Senecio, Lotus dropped to 81 percent of its original foliage value in 1965, but then recovered the full amount the following year. In stands where Lotus was mixed with Holcus, Lotus declined to 75 percent of its initial value in 1965, and then further dropped to 63 percent of its original value the following year. The most rapid decline over a two year period was found in stands where Lotus was mixed with both Senecio and Holcus. In this
Figure 21. Photographic record of a transect consisting of a mixture of *Lotus* and *Berberis*.
Figure 22. Average percentage of *Lotus* remaining on transects during Sept. of 1965 and 1966 as compared to original values taken in Sept. 1964. See text for explanation.
case, *Lotus* declined to 56 percent of its original value in 1965, and then dropped to only 29 percent of its initial value the following year.

Data on *Berberis* was taken only on the three transects containing mixed stands of *Lotus* and *Berberis*. During the course of the study the foliage values for *Berberis* remained relatively constant. These values always remained between 4.6 and 6.4 cubic feet. Figure 20 shows that the foliage values are always the lowest after winter and highest near the end of summer.
VI. DISCUSSION

Normally a clear-cut cannot be considered as having a uniform environment for plant growth. Variations in degree and type of disturbances, aspect, slope, and soil factors all combine together to produce a variety of microenvironments.

During the very early stages of plant succession, these variations in microenvironments may be masked by a nearly uniform stand of pioneer species. However, in a few years these differences in environment begin to show an increasing effect, so that the vegetation typically takes on a mosaic or patchwork appearance. Areas of the clear-cut which were originally highly disturbed are likely to continue to be occupied by invading species not native to the area, while relatively undisturbed areas are likely to contain an increasing amount of remnant vegetation. The rate of succession can also be expected to vary over the clear-cut, because remnant vegetation is likely to experience less successional change than areas covered by exotic invaders.

These considerations make it necessary to consider the vegetation on a clear-cut not as a single homogeneous unit, but as a mosaic of vegetational units which differ in microenvironments, species composition, and rate of succession.

These vegetational units comprising one or more clear-cuts
might well make a suitable study in itself. An investigation of this type could analyze repeating-vegetational units in regard to both composition and successional trends. Such a study would require the use of many more than the eight types of vegetational units employed in the present investigation. Probably, if a sufficient number of samples were taken, it would be found that many of the vegetational units intergrade to such an extent as to form a continuous series. A possible drawback to this type of approach is that the results from one area may have very limited application to other areas where the vegetational units are somewhat different.

Perhaps, for the present, the best understanding of vegetation covering the largest number of clear-cuts can be gained by studying the species themselves. Information concerning the behavior of a species in both pure and mixed stands can be applied, at least to some extent, to any clear-cut where the species in question is found to grow. For these reasons the author has chosen to place the emphasis of the present investigation on the four species studied, rather than on the eight vegetational units employed. Since Holcus occupies the earliest position in the successional sequence of any species used in this study, it will be considered first.

Holcus is a perennial grass native to Europe. It has become established on the Marys Peak watershed largely because it was introduced as a contaminant with rye grass and straw which are used
as a ground cover to stabilize the soil on road cuts. However, the
glass does not remain restricted to the road sides, and it usually
migrates into young clear-cuts in the surrounding area.

Studies by Chilcote (1962) and also by Brown (1963) have shown
that Holcus never remains abundant on a clear-cut for more than a
few years. Normally, Holcus reaches its peak cover value in the
sixth year and then decreases rapidly during the seventh and eighth
years. From this fact, it would seem reasonable to believe that
Holcus is unable to maintain itself for more than a few years due to
its inability to compete with native species. However, the foregoing
data seems to indicate that after Holcus is established on an area in
a clear-cut, it is unable to maintain itself regardless of competition.

Holcus growing in dense pure stands was found to decrease
dramatically in foliage value the following year. The space vacated
by Holcus was left largely unfilled, and only a few small rosettes of
Senecio were found growing in the general area. It is hard to believe
that such a small number of Senecio rosettes could so completely
disrupt the growth of dense, vigorous stands of Holcus from the
previous year.

Also, it does not seem to matter whether Holcus is growing in
nearly pure stands or in combinations with other species; it always
disappears. The association of Holcus with other species seems to
affect only the rate of decrease in Holcus, but not the final outcome.
Although it is true that Holcus decreases slightly faster in competition with Senecio than it does in pure stands, the rate of decrease is actually slowed when Holcus is growing in association with Lotus (Figure 12).

The rapid build-up of a species on a clear-cut, followed by its own extinction, is not limited to Holcus alone. As mentioned previously, Issac (1940) noted that large populations consisting of annual species of Senecio or Epilobium were often observed to build up rapidly only to be absent the following year for no apparent reason. This same phenomenon has been noted with Senecio sylvaticus on the Marys Peak watershed area by Chilcote (1962), and Brown (1963), and others. It seems likely that the rapid disappearance of these species can only be explained by some change taking place in the soil. Both Chilcote and West (1962) had some success in maintaining Senecio populations above the normal rate of decline by artificially adding nitrogen fertilizer. However, the results were not conclusive, and further work needs to be done in this area.

Probably the decline in Holcus populations is also due to some change in a soil factor, although it is not known what this factor might be. If these declines are associated with declines in available nitrogen levels, then this might explain why Holcus grows better in ...

1 Personal communication
association with \textit{Lotus}, since it is possible that \textit{Lotus} is a fixer of nitrogen.

\textit{Senecio jacobaea}, like \textit{Holcus}, is an exotic species and has only relatively recently become important on Marys Peak. According to Chilcote\textsuperscript{2} it was found only in small amounts on the watershed as late as 1959. However, since this time it has increased very rapidly over the area and is now found growing abundantly on many clear-cuts of different ages.

\textit{Senecio} is well equipped for being rapidly dispersed over a wide area by wind, since this species produces a large number of light seeds. These seeds typically have a well developed pappus and can be blown for great distances by even a moderate amount of wind.

Although \textit{Senecio jacobaea} is classified as a perennial by both Peck (1961) and Gilkey (1967), its behavior on the watershed is usually like that of a biennial. Typically, the rosette stage lasts one full year, before the plant reaches its mature size during the summer of the second year. The mature plant will then usually die the following winter, although a few exceptions have been noted. The author has observed a comparatively few specimens which had living branches on what otherwise appeared to be dead plants from the previous season.

\textsuperscript{2}Personal communication
In Figure 14 the biennial nature of Senecio growing in the watershed area can be observed. During September of 1964 all pure Senecio transects had large fully-mature plants growing on them, which are represented in the upper graph of Figure 14 by relatively large, tall geometric forms. These mature plants produced large quantities of seeds which saturated the area. By the following summer (the mature plants had died during the winter), Senecio was represented mostly by rosettes which had germinated from the seeds formed the previous summer. These rosettes are represented in the middle graph of Figure 14 by geometric forms which show that most of the Senecio was under ten inches in height. By September of 1965, these rosettes had reached mature size, although this second set of mature plants was not as large as the first of 1964.

In general, Senecio plants growing on the watershed seem to have biennial fluctuations in foliage values due to an alternation between rosette and mature stages. This cycle is not as definite as it could be because every stand also has plants that are one year out of phase with the majority. However, this cycle can be seen to some extent on every transect originally containing Senecio. In every case, the foliage values were high in 1964, low in 1965, and then somewhat higher in 1966.

Since all transects with Senecio dropped in foliage value during the summer of 1965, probably due to the biennial cycle, it seems
best to compare only 1966 foliage values with the 1964 foliage values in order to indicate vegetational trends.

When only 1966 foliage values are compared to 1964 foliage values, it appears that Senecio growth performance is poorest in pure stands. This decline in foliage value for Senecio cannot be due to competition from other species, since none were observed to grow either in the transects or in the area immediately surrounding them. In general, the second set of Senecio plants (summer 1966) appeared less crowded and far less vigorous than the first set (summer 1964). It seems likely, therefore, that some change in soil factor is related to the decline of Senecio.

Up until the summer of 1965, Senecio seemed to grow well when mixed with Holcus (Figure 18), but grew poorly after this date. The poorer growth of Senecio after the summer of 1965 can partly be accounted for on the basis that Holcus has largely died out by this date so that the remaining Senecio is left growing in a nearly pure stand. Figure 18 shows that the behavior of Senecio in pure stands and stands mixed with Holcus is essentially the same after the summer of 1965. This is indicated by the nearly parallel lines for these two combinations from 1965 to 1966.

Senecio, like Holcus, grows best when mixed with Lotus. The reason for this is not known, but it seems possible that it may be the result of nitrogen fixation by Lotus. Of the four possible
combinations, Senecio grows second best when mixed with both Lotus and Holcus. This is what would normally be expected, since by the summer of 1966 these transects were mostly a mixture of pure Senecio and Lotus, the Holcus having died out by this time.

Lotus, unlike Holcus and Senecio, is a native species and grows naturally in the forest in the vicinity of the clear-cuts. When growing in the forest, this species seems to favor the "light-spots" or natural openings in the forest canopy. However, from personal observation, Lotus appears to be not nearly as abundant in the forest as it is on the clear-cuts. It would appear that clear-cutting actually enhances the growth of this remnant species.

Most of the year Lotus, a perennial, lives underground; it is only in the summer that foliage of this species is well developed. During May and June, weakly-ascending shoots of this species develop and climb over and above all lower plants in the area. By mid August these same shoots have already started to wilt away, and by mid fall the foliage has completely died back to the ground. Apparently, Lotus is able to absorb enough light energy during the summer to not only maintain itself during the winter, but to also supply most of the food energy necessary to grow a large amount of foliage the following spring.

In general, Lotus seems to grow better in mixed stands than in pure stands (Figure 22). Although it dropped slightly in foliage
value in 1965 when growing in combination with Senecio and Berberis, this value was completely recovered when growing with Senecio, and nearly recovered when growing with Berberis by the summer of 1966.

Lotus also appeared to grow better with Holcus than it did in pure stands (Figure 22). However, on transects where Lotus was mixed with both Senecio and Holcus, the Lotus declined very rapidly in foliage value. This is an unexpected result, and the author is unable to account for it unless it is possible that Holcus and Senecio may interact in some way that is unfavorable to Lotus. It is noted that after 1965, the transects which originally contained only Lotus and Holcus were invaded by increasing amounts of Senecio, resulting in a mixed combination of Lotus, Senecio, and some Holcus. Figure 22 shows that this combination declines rapidly, as in the case of the original mixture of these three species.

Berberis, a native species, is found abundantly both on clear-cuts and in the surrounding forest. Studies by Chilcote show that Berberis is normally present on a clear-cut after cutting and burning, and that it steadily increases in importance as the clear-cut ages.

When Berberis is growing in dense stands, its thick, evergreen leaves form a continuous canopy which allows very little light

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to reach the ground. It seems likely that this year-round cover of darkness produced by Berberis leaves prevents many species from either germinating or growing vigorously. Although general observation has shown that Senecio and Holcus can be found growing in the "holes" in open stands of Berberis, these species are practically absent in stands of Berberis where a dense, continuous canopy has been formed. Certainly, Senecio and Holcus do not mix nearly as freely with Berberis as they do with themselves and Lotus.

Of the species studied, only Lotus was found to be able to grow freely in intimate association with Berberis. This is, no doubt, due to the ability of Lotus to produce shoots in the spring which grow above and over the foliage of Berberis (Figure 21).

From the foregoing description of the four species used in the study, it can be seen that each species has its own distinct ecology which is entirely different from that of the others. Yet the first three species, Holcus, Senecio, and Lotus are all capable of growing in the same environment, and can be found growing in any combination of intimate mixture with each other.

The foliage values for these species are constantly changing with time over the clear-cut, and in some cases one species completely replaces another. However, most of these changes do not appear to be brought about by any form of direct competition, since in general, Holcus, Senecio, and Lotus all grow more vigorously in
mixed stands than in pure stands. Rather, it seems that the vegeta-
tional changes in the early stages of succession on Douglas fir clear-
cuts are more dependent on the ecologies of the species themselves
than on competition.

For example, Holcus becomes established through the intro-
duction of grass seeds and straw on the roadsides leading into a
clear-cut. Although it migrates out onto the clear-cut, building to
a peak value by the fifth or sixth year, it inevitably declines and
disappears. Its disappearance from a specific plot of soil seems
certain regardless as to whether or not there are competing plants
in the area.

The seeds of Senecio are carried by the wind and distributed
over the clear-cut largely by chance. These seeds appear to have
the ability to grow on a large variety of sites where sunlight and
bare ground are available. Senecio grows more vigorously in com-
binations with other species than it does in pure stands, and shows
yearly oscillations in foliage values due to its biennial growth habit.

Both Lotus and Berberis are remnant species and for this
reason their distributions are already partly determined even before
the forest is cut. That is, the distribution of these species before
cutting is likely to have a large influence in determining the distri-
bution of the same species after cutting. If, for example, it is true
that Lotus is found mostly in the "light-spots" or under the openings
in the forest canopy before clear-cutting, then one would expect to see it first appear on the clear-cuts where these "light-spots" had previously existed.

It appears, therefore, that plant succession on Douglas fir clear-cuts is not a simple orderly process, but rather a very complex process affected by a multitude of factors. Although generalized successional schemes can be worked out for Douglas fir clear-cuts, it seems probable that the variation in vegetational structure and composition, both within and between clear-cuts, is so great as to make the construction of any detailed successional scheme for these areas impractical.

For this reason, probably each clear-cut will have to be considered as a separate and unique unit before the details of its successional history can be understood. It will also be necessary to know as much as possible about the aut- and synecology of both the remnant species and the exotic species which might be found on the area. It is the author's opinion that only when these factors are well understood, will it be possible to predict accurately the successional pattern occurring on clear-cuts.

In this study, only a beginning has been made towards the understanding of the ecological behavior of a few species. More work needs to be done, not only on these species, but on the many others which grow abundantly on Douglas fir clear-cuts.
VII. SUMMARY AND CONCLUSIONS

Growth and replacement patterns of four successionaly im-
portant species occurring on Douglas fir clear-cuts were investi-
gated from September 1964 to June 1967. The study was carried out
on the Marys Peak watershed located near Corvallis, Oregon.

Species used in the study include Holcus lanatus, Senecio
jacobaea, Lotus crassifolius var. subglaber, and Berberis nervosa.
During the summer of 1964, 24 transects, each consisting of eight-
square-foot plots, were established on three separate clear-cuts.
These 24 transects consisted of three replications of eight distinct
types of vegetation, which included the above species in both pure
and mixed stands. Each of the 24 transects was sampled 11 times
over a three year period, to detect changes in vegetational structure
and composition.

In order to detect even slight changes in vegetation, a new
sampling device was invented. This device employs the point frame
principle, and may be used to sample vegetation up to four feet in
height. The sampling device contains five pins which may be
lowered 25 times within a square-foot area. Tape measures are
attached to each pin so that the height of each contact may be easily
read.

Results of the sampling show that, in general, the species
studied grow better and more vigorously in mixed stands than in pure stands, and that competition does not appear to be an important factor in species replacement during the early stages of plant succession on Douglas fir clear-cuts in the watershed area. It is suggested that the behavior of a species on a young clear-cut is more dependent on its own ecology and changing soil factors than on competition from other species.

It is further suggested that vegetation occurring on clear-cuts is usually not homogeneous in nature but more often has a mosaic-like pattern, being made up of many smaller vegetational units which differ from each other in both structure and composition. It is recommended that much further study needs to be done on the ecology of successionaly important species before plant succession of Douglas fir clear-cuts can be well understood.

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### Appendix 1. Foliage values for all dates and transects used in study.

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