

## REVEGETATION AFTER LOGGING AND BURNING IN THE DOUGLAS FIR REGION OF WESTERN WASHINGTON.<sup>1</sup>

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During the summer of 1926 some 80 plots were established on logged and burned areas in the Douglas fir region of Western Washington. These plots were established primarily to study germination, survival and establishment of the Douglas fir and other coniferous seedlings. At the time they were laid out, however, full data were also taken on the density and specific makeup of their vegetative cover as well as slope, exposure, soil and time and degree of burn.

These plots were located on the cutting areas of several logging companies (see Table 1 and Fig. 1) operating chiefly on private land. They were laid out only on those areas whose cutting and fire history was accurately known (not later than the spring of 1924) and were permanently staked for future observation. All of them were  $8\frac{1}{4} \times 33$  feet in size giving an area of  $1/160$  of an acre. The time of burning of these plots varied from the spring of 1924 to the spring of 1926 and was usually done in April (spring), July (summer) or October (fall). Burning occurred immediately or shortly after cutting. The author's judgment served as the basis for the designations, severely, moderately and lightly burned. This is an admittedly unsatisfactory method but so far no quantitative method of determining the severity of a slash fire has been devised. The reliability of the conclusions drawn varies with the number of plots observed under each burning date and the number of areas on which these plots were observed (Table 1).

### Density of Vegetative Cover.

The density of the vegetation covering each plot was estimated according to the method used in grazing reconnaissance in the Forest Service, a fully vegetated area being considered

<sup>1</sup> This work was done while the writer was in the employ of the Pacific Northwest Forest Experiment Station, U. S. Forest Service. The study was not, however, a regular project of that Station but was carried along with other duties. The writer alone is responsible for the facts here recorded and the conclusions reached. Thanks are due the Director of the Pacific Northwest Forest Experiment Station for permission to publish.

100 per cent cover. There are many difficulties inherent in the method but none better is available for field work. "Foliage cover" was used rather than "basal cover,"<sup>2</sup> as very few of the species were bunch forming grasses or sedges.

The average density of vegetation increased with time: Spring 1926, 4%; Fall 1925, 15%; Summer 1925, 18%; Spring 1925, 43%; Fall 1924, 57%; Spring 1924, 70% (see Fig. 2). Whether the flattening of the curve at the Summer 1925 burning was due to local causes (all of the plots in this burn were located on one area) or whether in mid-summer the extremely dry slash caused an unusually complete burn, cannot be decided from the data in hand.

TABLE I.  
SUMMARY OF PLOTS LAID OUT ON LOGGING AREAS—SUMMER OF 1928.

Logging Company	Time of Burning						Total Plots
	1926	1925			1924		
	Spring	Fall	Summer	Spring	Fall	Spring	
Mud Bay Logging Co.....	4	1	.....	4	.....	.....	9
Phoenix Logging Co.....	4	7	.....	4	.....	.....	14
Hama Hama Logging Co.....	.....	.....	.....	7	.....	3	10
Webb Logging & Timber Co.....	.....	16	.....	.....	.....	.....	16
Elbe Lumber & Shingle Co.....	.....	.....	10	.....	.....	.....	10
Pacific National Lumber Co.....	.....	10	.....	.....	.....	.....	10
St. Paul & Tacoma Co.....	.....	5	.....	.....	6	.....	11
Total number of Areas..	2	5	1	3	1	1	13
Total number of Plots..	8	39	10	14	6	3	80

When the percentages of total vegetative cover on all the plots of different degrees of burning (severe, moderate, light and unburned) are averaged, we get a very interesting result which may be summarized as follows: severe burn (9 plots) 37.3 per cent density; moderate burn (33 plots) 46.6 per cent; light burn (23 plots) 35.7 per cent; unburned (8 plots) 20.8 per cent. One would expect, contrary to the above, that unburned and lightly burned plots would have a greater amount of vegetation than the moderately and severely burned plots. On looking over the plot descriptions, however, it is noted that most of the unburned and lightly burned plots were laid out on areas

<sup>2</sup> Sarvis, J. T. Composition and density of the native vegetation in the vicinity of the Northern Great Plains Field Station. Jour. Agr. Res. 19:63-72. 1920.

where there was (1) considerable exposed mineral soil (skidways), (2) much disturbed soil mixed with duff and debris, or (3) a heavy cover of duff, debris, etc. None of such areas are

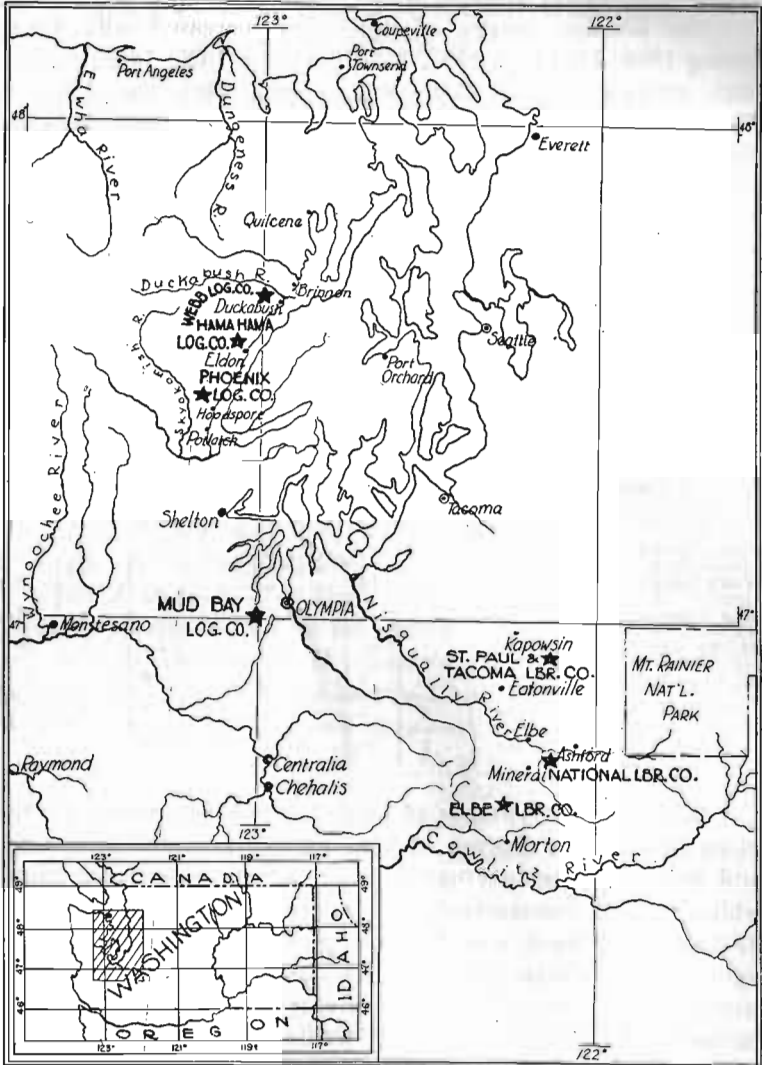


FIG. 1.—Map of the Puget Sound region, Washington, showing the location of the logging companies on whose cuttings plots were laid out. The cross-hatched area in the inset is shown on the large scale map.

favorable for the early establishment of an abundance of vegetation. The bare mineral soil of a skidway or the disturbed soil mixed with duff and debris usually means that the species

present on that area in the virgin timber have been destroyed by logging; hence there is little chance for an early reappearance of the original species, though weeds may seed in later in abundance. An area covered by duff and debris is also disturbed and the original species may be destroyed or covered up. Moreover, much debris prevents the seeding in of outside species for many years and such areas remain unvegetated the longest of any. It is difficult to get plots of all degrees of severity of burn and unburned on the same area. The above conditions (1, 2 and 3) are almost never found on moderately burned plots while severely burned plots are usually areas of heavy slash burned quite clean, the effect of which is accurately indicated, I believe, in the lesser amount of vegetation on the severely burned plots (37.3%) as compared to the moderately burned plots (46.6%). It must be remembered, however, that severe burning lessens the amount of shrubby and herbaceous vegetation which may live through the fire but may even favor the coming in of the seeds of wind distributed weedy species by clearing the ground of duff and debris and exposing the mineral soil in a favorable seed bed. Time very soon obliterates any differences in the amount of vegetation on burns of different degrees of severity.

#### **Specific Makeup of the Vegetation on the Plots.**

The species found on the plots after burning consist of those which are present in the virgin timber before cutting and burning and those which are not present in the virgin timber but are seeded in from the outside. The degree to which the different virgin timber species are able to withstand injury or killing by the fire varies greatly and determines the abundance with which such species are present immediately after fires of different degrees of severity. The woody species may be only partially killed, the larger stems and crowns sprouting out again after the fire. Usually the aerial part is killed and sprouting takes place from the roots and crown. The herbaceous species invariably have their aerial parts destroyed by a fire of any severity but their underground roots or stems as well as their seeds often survive a fire which is not too severe. The ability of those species not in the virgin timber to revegetate a burned area is dependent chiefly upon their nearness to the burned area; the mobility of their seeds or fruits and the number and viability

of such seeds or fruits. These facts make it necessary to group the plants found on plots into several groups.

Group I, called the *virgin timber herbaceous species*, is made up of a group of herbs found in varying numbers in the virgin timber and surviving the fire chiefly through underground parts. The ferns are particularly prominent on recently burned plots. This group as a whole, however, is unable to withstand the much more xeric conditions of the burned plot as compared with the virgin timber and is most abundant shortly after the fire, gradually becoming less and less abundant.

Group II, called the *virgin timber shrubby species*, is made up of small trees, shrubs and creepers present in the virgin timber which survive the fire with varying degrees of success and sprout again from unkilld stems, crowns and roots. As a group they are much more able to thrive under the changed conditions of the burned areas and often grow in much greater profusion after the fire than in the virgin timber. This is particularly true of the blackberry.

Group III includes the *weedy species*, most of which are not found at all in the virgin timber but which seed in abundantly and often dominate the area, particularly on mineral soil exposed by disturbance or by severe fire. All are characterized by tufted fruits or seeds except *Carex* and the grasses.

A small but difficult miscellaneous group of three species consists of bracken fern, *Viola* and *Trientalis*. Bracken fern is an herbaceous plant found in the virgin timber but after burning it frequently dominates the area completely and is usually abundant wherever present at all. Because of this and because of its prevalence on waste lands it is classed with the weeds. *Viola* and *Trientalis* are found in the virgin timber but they persist after burning on most of the plots though never in any great abundance. They are classed with the virgin timber herbaceous species. The specimens of *Trientalis* found growing on the burned plots are dwarfed with small, curled, thickened leaves crowded on short, thick stems not at all the delicate, thin-leaved plant of the virgin timber.

The principal species in each of the above groups are listed below in the order of their frequency of occurrence on the plots. The number following each name indicates the number of plots (out of a total of 80) on which the species was found.

## I. VIRGIN TIMBER HERBACEOUS SPECIES.

*Polystichum manitum* (38), sword fern*Trientalis latifolia* (32)*Viola* spp. (22)*Oxalis* spp. (10)*Bikukulla formosa* (9), bleeding heart*Disporum oregonum* (8)*Achlys triphylla* (7), vanilla leaf*Montia asarifolia* (7), miner's lettuce

## II. VIRGIN TIMBER SHRUBBY SPECIES.

*Berberis* spp. (56), Oregon grape*Rubus macropetalus* (52), blackberry*Gaultheria shallon* (43), salal*Sambucus* spp. (25), elderberry*Vaccinium* spp. (18), huckleberry*Vaccinium ovatum* (8), evergreen huckleberry*Acer circinatum* (7), vine maple

## III. WEEDS.

*Senecio vulgaris* (67)*Epilobium angustifolium* (52), perennial fireweed*Epilobium* (annuals) (41)*Crepis* spp. (13)*Cirsium* spp. (10), thistle*Hieracium albiflorum* (9), hawkweed.**Evaluating the Density and Frequency of These Groups.**

From field notes the density of the different species found on the plots was determined. These notes consisted of the per cent density of the total vegetation and also the density of the principal species on the basis of 100 per cent for the plot, while

TABLE II.

DENSITY OF THE VEGETATION ON PLOTS BURNED AT DIFFERENT TIMES.

Groups of Species	Time of Burning					
	Spring 1926	Fall 1925	Summer 1925	Spring 1925	Fall 1924	Spring 1924
Virgin timber (herbaceous)..	3.0	2.3	3.4	4.6	0.3	1.7
Virgin timber (shrubby).....	1.0	4.0	4.2	19.0	1.0	15.0
Weeds .....	0.3	7.8	11.4	20.9	56.0	52.0

the less important species were listed as being present. From these notes the density of each species has since been calculated. Thus if the density of the total vegetative cover on a plot was 75% and this was made up of 75% *Epilobium angustifolium*, 10% *Rubus macropetalus*, 5% *Gaultheria shallon* and 10% of

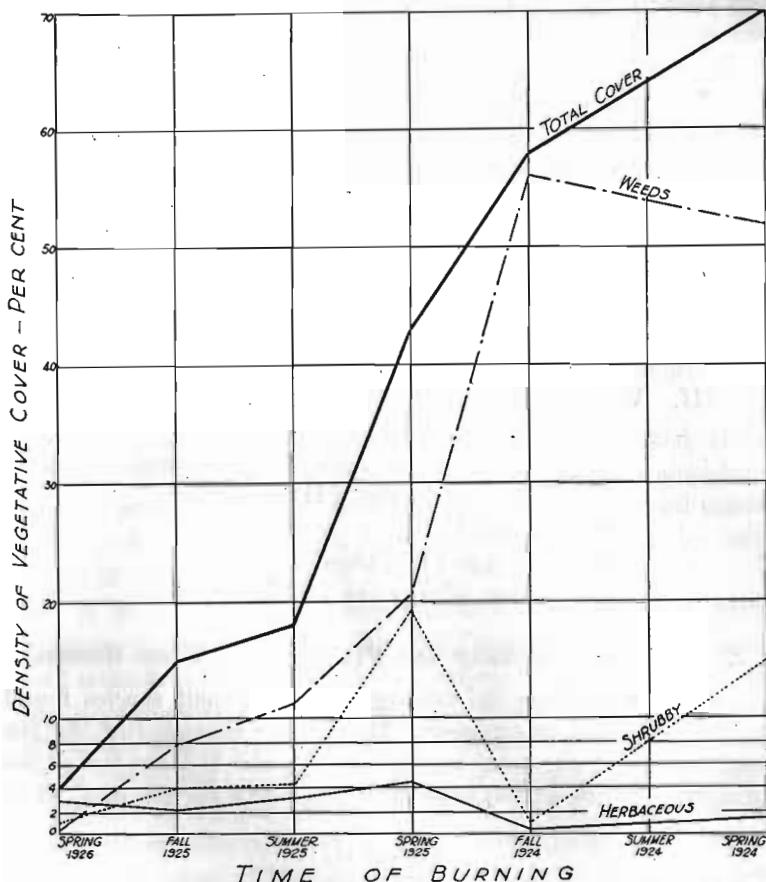


FIG. 2.—Average density of the total vegetative cover and the density of the three groups of species on the plots burned at different times.

other species consisting of *Berberis* spp., *Senecio vulgaris*, *Vaccinium* spp. and *Oxalis* spp. (total 100%) the actual density was calculated as follows:

$$\begin{aligned}
 \textit{Epilobium angustifolium} \text{ (75\% of 75\%)} &= 56.25\% \\
 \textit{Rubus macropetalus} \text{ (10 of 75\%)} &= 7.50\% \\
 \textit{Gaultheria shallon} \text{ (5\% of 75\%)} &= 3.75\%
 \end{aligned}$$

The remaining 10% was arbitrarily divided among the other species:

<i>Berberis spp.</i>	=	2.00%
<i>Senecio vulgaris</i>	=	2.00%
<i>Vaccinium spp.</i>	=	2.00%
<i>Oxalis spp.</i>	=	1.50%
		Total = 75.00%

Because of the difficulty of estimating accurately the per cent of density of the less important species without resorting to the extremely laborious method of cutting all of the vegetation on a plot, sorting it according to species and determining the dry weight, the above method was used because much greater areas could be sampled even though the method was less accurate. The figures obtained are a quantitative measure of the actual amount of each species present and when grouped into the three groups discussed above and averaged for all the plots of a certain burning date we get the results given in Table II and shown graphically in Fig. 2.

In order to determine how consistently the various species and groups of species were in their appearance on all of the plots observed the number of times they occurred was counted and this figure divided by the number of plots on which observations were made. This frequency figure indicates how consistently certain species or groups appeared but does not indicate the density of those species or groups on the burns of different dates. (See Table III and Fig. 3).

TABLE III.

FREQUENCY OF APPEARANCE OF THE DIFFERENT GROUPS OF SPECIES ON PLOTS BURNED AT DIFFERENT TIMES.

Groups of Species	Time of Burning					
	Spring 1926	Fall 1925	Summer 1925	Spring 1925	Fall 1924	Spring 1924
Virgin timber (herbaceous) ..	1.9	2.3	3.3	1.3	.33	1.0
Virgin timber (shrubby).....	2.0	2.9	3.0	3.0	1.0	3.3
Weeds .....	0.6	2.5	4.0	3.3	3.7	4.0

The data presented in Table II and III and represented graphically in Figure 2 and Figure 3 when examined in relation

to each other bring out certain facts which point the way toward a better understanding of the revegetation of areas after logging and burning. The limited number and distribution of the plots and the short period over which the observations extend make

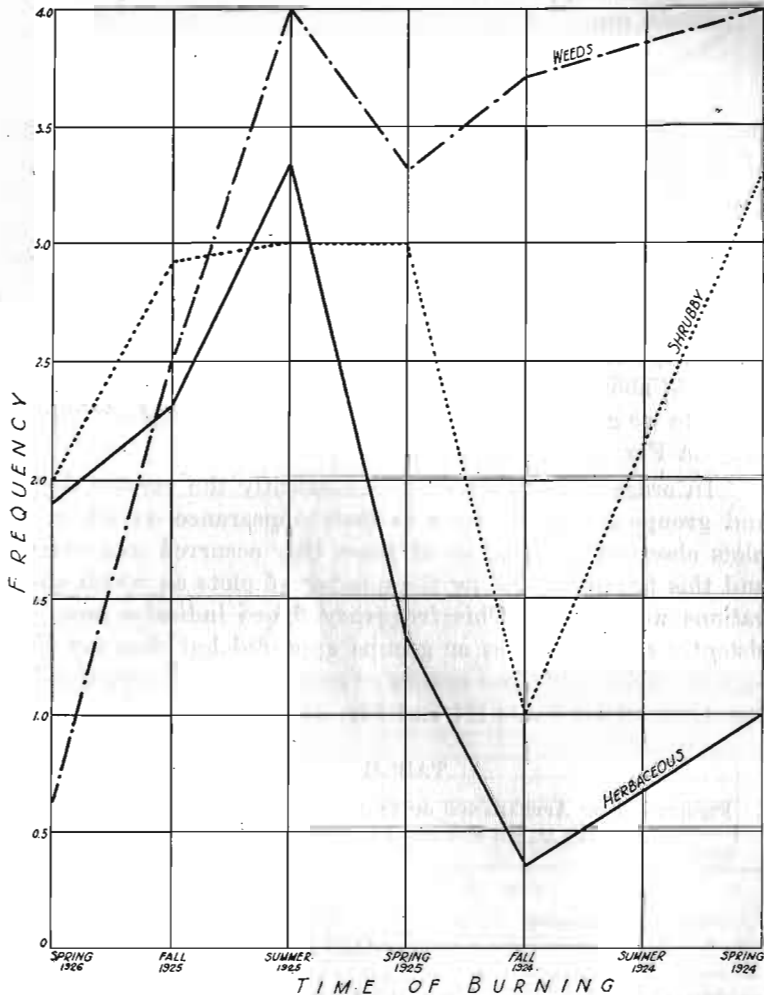


FIG. 3.—Frequency of occurrence of the three groups of species on the plots burned at different times.

the conclusions reached tentative in nature, subject to later modification and verification. The author believes, however, that in the light of observation made on other areas that the conclusions reached are essentially correct.

These conclusions may be summarized as follows:

(1) The density of all of the groups of species as well as the total vegetative cover is low on the plots burned recently. The total vegetative cover rises steadily and rapidly as the plots become older.

(2) The herbaceous group starts high in both density and frequency due chiefly to the high fire survival of the sword fern (*Polystichum munitum*) (Fig. 4). It starts higher on the whole than either the shrub or weed groups but shows a gradual downward trend, becoming consistently less in density and also less in frequency of appearance with increasing age of the plots. It will undoubtedly continue to become less and less in amount because of its inability to withstand the intense heat, bright light and consequent low humidity of the air and low moisture content of the soil of the burned areas as compared to the shady, moist virgin timber. It will probably increase later on as the shrubs shade the ground to a greater extent. The unusually high frequency of this group on the Summer 1925 plots is due to the limited number of plots (all located on the Mud Bay Logging Company holdings) which were on very wet seepage areas high in miner's lettuce (*Montia asarifolia*).

(3) The shrubby species present in the virgin timber start somewhat lower in density than do the herbs (Fig. 2) due to a slower start than the sword fern immediately after the fire. They are fairly high in frequency, however, due largely to Oregon grape (*Berberis spp.*), blackberry (*Rubus macropetalus*) and salal (*Gaultheria shallon*), being present on practically all of the plots soon after the fire. They put up only a few sprouts the first year after the fire but as a group they gradually become more and more abundant until they shade the ground but are in turn crowded out by the conifers. The unusual rise in the density curve in the Spring 1925 is due to the unusually large amount of salal surviving under the rather open stand of second growth so characteristic of the gravelly soils of the Phoenix Logging Company holdings. The low drop in the Fall 1924 is due to a severe burn which was very thickly populated by *Epilobium* and *Senecio vulgaris* as is shown by the rise in the curve for weeds (Fig. 2). The general upward trend of the curve representing the shrubs is evident despite these two cases.

(4) The weeds start very low in both frequency and density due to the fact that they must seed in from the outside but

the curve rises rapidly to a dominant position both as to frequency and density. The abundance of tufted seeds produced by *Epilobium* and tufted fruits by *Senecio* soon seed in these areas particularly where the mineral soil is exposed by disturbance or by severe fires. Observations on older areas indicate the gradual decrease in the weed population as the shrubs and conifers grow up and shade them out.

The most important members of each group of species are fairly consistent in their density on the various plots when compared with that of the group as a whole. We may choose therefore the most abundant species in each of the groups as representative of that group.

TABLE IV.  
DENSITY OF FOUR OF THE PRINCIPAL SPECIES FOUND ON THE PLOTS  
BURNED AT DIFFERENT TIMES.

Species	Time of Burning					
	Spring 1926	Fall 1925	Summer 1925	Spring 1925	Fall 1924	Spring 1924
Sword fern .....	2.5	0.77	0.5	0.21	0.33	0.0
Oregon grape.....	0.25	0.69	1.6	2.3	0.17	2.33
Senecio .....	0.13	5.26	4.8	11.58	9.0	17.66
Perennial fireweed.....	0.0	1.29	3.9	1.0	45.66	15.33

Thus in Figure 4 the sword fern gradually becomes less as the plots become older while Oregon grape gradually rises and *Senecio* starts low but rises very rapidly. If we compare the density of perennial fireweed (*Epilobium angustifolium*) we notice a strikingly interesting fact, namely the reciprocal relationship that exists between *Epilobium* and *Senecio*, the two most important members of the weed group. When there is a high relative density of *Epilobium* there is a low relative density of *Senecio*. This is borne out by many observations of areas some of which are almost pure *Epilobium* with practically no *Senecio* and others pure *Senecio* with practically no *Epilobium*. These areas have been observed within a half mile of each other on areas cut and burned at different times on the St. Paul and Tacoma Lumber Company holdings. Some, as yet unknown factor, allows one species to get started before the other and thus gain complete dominance. Seeding in is probably not a factor as the two species are widely distributed throughout the region

under observation and the tufted seeds or fruits of both are so light as to be blown everywhere in such abundance as to seem almost like a snowstorm during the height of the fruiting season. It does not seem probable that one area is seeded in with one species and not the other and another area the reverse.

Often a species may be present on a large number of plots but not be very abundant on those plots, that is have a high

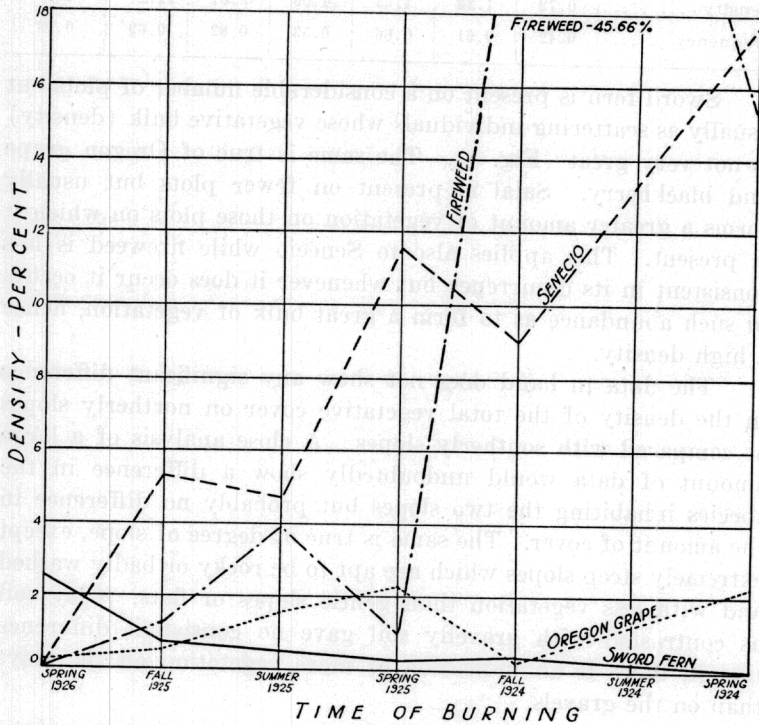


FIG. 4.—Average density of four important species chosen from the three groups of species on the plots burned at different times. The species are: sword fern (*Polystichum munitum*), Oregon grape (*Berberis spp.*), fireweed (*Epilobium angustifolium*), *Senecio vulgaris*.

frequency but a low density. This is more clearly shown by a comparison of the seven most important species found on the plots: sword fern (*Polystichum munitum*), Oregon grape (*Berberis spp.*), blackberry (*Rubus macropetalus*), salal (*Gaultheria shallon*), *Senecio vulgaris*, perennial fireweed (*Epilobium angustifolium*) and bracken fern (*Pteridium aquilinum pubescens*).

TABLE V.  
AVERAGE DENSITY AND FREQUENCY ON ALL PLOTS OF THE SEVEN  
MOST IMPORTANT SPECIES.

DESIGNATION	SPECIES						
	Sword fern	Oregon grape	Black- berry	Salal	Senecio	Fire- weed	Bracken fern
Density .....	0.72	1.22	1.23	4.05	8.07	11.2	4.0
Frequency .....	0.42	0.61	0.66	0.53	0.82	0.69	0.23

Sword fern is present on a considerable number of plots but usually as scattering individuals whose vegetative bulk (density) is not very great (Fig. 5). The same is true of Oregon grape and blackberry. Salal is present on fewer plots but usually forms a greater amount of vegetation on those plots on which it is present. This applies also to Senecio while fireweed is less consistent in its occurrence but whenever it does occur it occurs in such abundance as to form a great bulk of vegetation, hence a high density.

The data in hand does not show any significant difference in the density of the total vegetative cover on northerly slopes as compared with southerly slopes. A close analysis of a large amount of data would undoubtedly show a difference in the species inhabiting the two slopes but probably no difference in the amount of cover. The same is true of degree of slope, except extremely steep slopes which are apt to be rocky or badly washed and with less vegetation than gentle slopes or flats. Clay soil as contrasted with gravelly soil gave no consistent difference though there is an indication of more vegetation on the clays than on the gravels.

#### Raunkiaer's Law of Frequency.

When Raunkiaer's law of frequency as discussed by Kenoyer<sup>3</sup> is applied to the plots burned on various dates it is found that most of the frequency figures fail to fit the formula. Raunkiaer groups the species found on an area which has been adequately sampled, into five groups with frequencies of 1-20 percent, 21-40 percent, 41-60 percent, 61-80 percent, 81-100 percent respectively. These may be designated at A, B, C, D, and E. From thousands of frequencies Raunkiaer obtains the following

<sup>3</sup>Kenoyer, L. A. A study of Raunkiaer's law of frequency. Ecology 8:341-349. 1927.

ratio: 53, 14, 9, 8, 16 or simplified, about 7, 2, 1, 1, 2. That is, the species which are present on only a few plots (1-20 percent) are many in number (53) while those with a higher frequency are less numerous 14, 9 and 8, while those species that are present on all or nearly all of the plots (81-100 percent) are relatively greater in number (16). There are therefore many sporadic species and a few species which dominate the area to such an extent as to hinder other plants from competing with them.

The lack of fit in the frequency figures from the plots under observation may be due to inadequate sampling, or lack of homogeneity of the vegetation on the areas sampled but is most likely

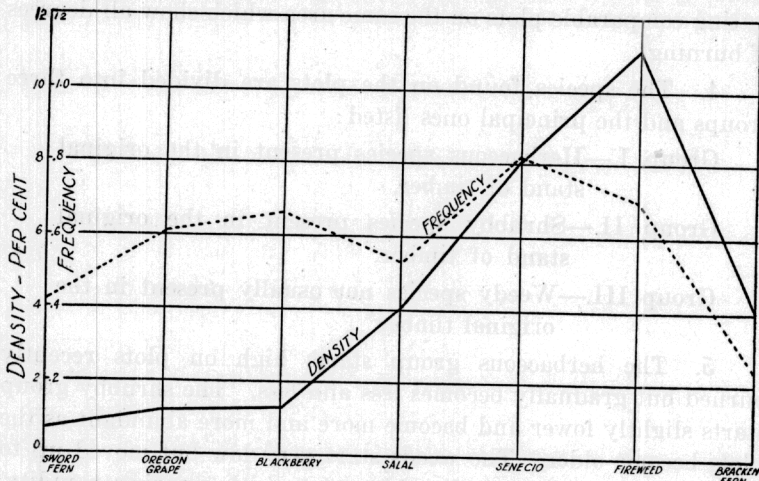


FIG. 5.—Comparison of the density and frequency of occurrence of seven of the most important species found on the plots: sword fern (*Polystichum munitum*), Oregon grape (*Berberis* spp.), blackberry (*Rubus macro-petalus*), salal (*Gaultheria shallon*), *Senecio vulgaris*, fireweed (*Epilobium angustifolium*), bracken fern (*Pteridium aquilinum pubescens*).

due to the fact that the vegetation on these areas has not reached anything like stability and the ratios which were obtained such as: 31, 3, 5, 2, 1 and 11, 7, 2, 4, 1 and 14, 3, 0, 6, 2, and 15, 4, 3, 3, 3, indicate there is a great mixture of species and few or none dominate the areas sufficiently to hinder the development of all except sporadic species. The best fit was obtained on an area burned in the fall of 1924 covered by an almost pure stand of fireweed which dominated the area. The ratio here obtained was 5, 3, 1, 1, 2.

### Summary.

1. The vegetation on 80 plots located on seven different areas and representing six different dates of burning (Spring 1926—Spring 1924) was judged as to density, specific makeup and frequency in the summer of 1926.

2. The density of the total vegetative cover varied directly with the length of time after burning.

3. The plots severely burned show less vegetation than those moderately burned. The plots lightly burned and unburned show less vegetation than those moderately burned. This result is undoubtedly a discrepancy caused by the difficulty of getting comparable plots on the same area which show all degrees of burning.

4. The species found on the plots are divided into three groups and the principal ones listed:

Group I.—Herbaceous species present in the original stand of timber,

Group II.—Shrubby species present in the original stand of timber,

Group III.—Weedy species not usually present in the original timber.

5. The herbaceous group starts high on plots recently burned but gradually becomes less and less. The shrubby group starts slightly lower and become more and more abundant as the plots become older. The weeds start very low but moved up to a dominant position on the older plots with amazing rapidity. They will probably in time give way to the shrubs.

6. No consistent differences in amount of vegetation were noted between north and south slopes, steep or gentle slopes and clay or gravel soils.

7. The species frequency ratios on most of the areas do not fit Raunkiaer's law, thus indicating that the vegetation is in an unstable condition with seldom any species completely dominant over an area.