FOREST AND ADJACENT BURN IN THE TILLAMOOK BURN AREA OF NORTHWESTERN OREGON[1]

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Introduction

The approximately 300,000 acre Tillamook Burn in the northern Oregon Coast Range has been the scene of three major fires. The area burned first in 1933, in a holocaustic fire that covered 244,706 acres and destroyed approximately ten billion board feet of timber (Morris, 1936). Most of the area burned again in 1939, and again in 1945. The later fires killed many patches of green forest missed or subject to ground fires only in the preceding fires, and increased the total acreage by extending the boundaries at various places. Descriptions and statistics of the 1933 fire include those by Morris (1936), Isaac (1936), McArdle (1933), Cronemiller (1933) and others.

The fires were exceedingly severe and entirely destroyed the forest vegetation over most of the area, with one major exception. One block of unburned timber, approximately 25,000 acres in size, remained in the center of the Burn area following the 1933 fire. The two subsequent major fires reduced this so-called "green island" to approximately 2,500 acres, the major reduction occurring in 1939. While there were some ground and spot fires in the edges of this remaining stand of forest, the bulk of it was free of any fire damage.

This forest is now being logged. Quantitative studies of forest communities in Oregon as a whole are rare and none exist in the literature for the northern half of the Oregon Coast Range. The only records of the pre-Burn forest in this part of the Coast Range were early timber cruises. The study reported here was carried out in the summers of 1955 and 1956 to obtain information on various habitats and environmental conditions within this remaining forest and on the relative importance of its component species. For purposes of comparison, similar data were taken in adjacent areas in the Burn which had been burned only in 1945.

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Description and History of Area

The topography in the part of the Oregon Coast Range occupied by the main Burn is rugged, consisting of narrow ridges and steep-walled valleys. The topography is highly dissected by streams which have eroded down through soft Cenozoic sandstones and around intrusive lava masses which form the skeletons of the sharp ridges. Slopes of 30° to 50° are common and the more or less level areas of the ridge tops are frequently less than ¼ mile in width. General elevations of the higher points range from 2800 to 3500 feet above sea level, while the main valleys of two major streams of the area lie approximately 600-1000 feet above sea level.

The area of this study lies in the southwest portion of Township 1 North, Range 6 West and in the extreme northwest portion of Township 1 South, Range 6 West, Willamette Meridian. It lies along a major ridge running south-southwest, north-northeast between the heads of two major streams, as shown in Figure 1. The ridge crest varies in elevation from 2900 to 3500 feet above sea level. Several prominent secondary ridges protrude toward the northwest and southeast at more or less right angles to the line of the main ridge. Figure 2 shows the northwest slope of the area analyzed, the general appearance of this portion of the Burn, and the relative locations of the forest and burn areas studied.

The coniferous forest of the Oregon Coast Range is included in the Cedar-Hemlock association of the Coast Forest Formation by Weaver and Clements (1938), in the Pacific Douglas fir of the Cedar-Hemlock Forest by Shantz and Zon (1924), and in the Pacific Coastal Forest Formation by Oosting (1956). Over most of its area it is characterized by tall, often luxuriant forests containing such species as Douglas fir (*Pseudotsuga taxifolia*), western hemlock (*Tsuga heterophylla*), western red cedar (*Thuja plicata*) and various true firs (*Abies* spp.), with Sitka spruce (*Picea sitchensis*) occurring on lower slopes near the Pacific Ocean. In Oregon, this forest occurs over much of the Coast Range and the western slopes of the middle and northern Cascade Mountains.

The behavior of these forest species in succession has been studied by various workers. Prob-

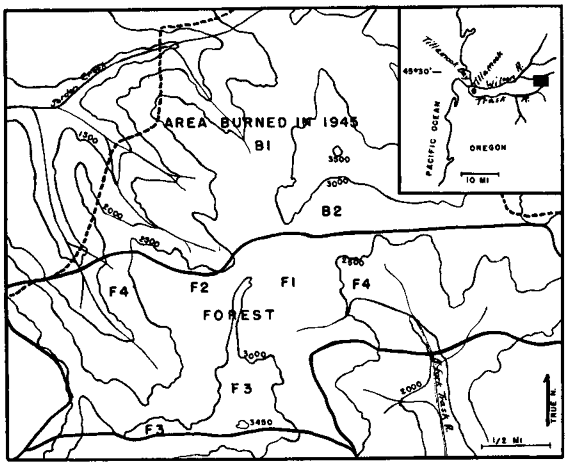

FIG. 1. Map of study area, showing contour intervals of 500 feet, boundaries of the forest, and the areas sampled. Inset map of portion of Oregon Coast; rectangle represents location of enlarged section. Area designations: F 1 and F 2, forest sample area between 2500 and 3000 feet; F 3, forest sampled above 3000 feet; F 4, forest sampled below 2500 feet; B 1 and B 2, burn sample areas.

FIG. 2. Northwestern exposure of burn area of this study; forest on first ridge in the background is the F 2 sample area.

ably the most comprehensive study of this pattern is that by Munger (1940). The shade-intolerant Douglas fir invades areas that have been cleared by fire or logging following various herb and shrub stages. Vast areas are at present covered by forest of this species almost alone. After a sufficient time without disturbance, over much of the area the shade tolerant species, western hemlock, western red cedar and the true firs, invade the Douglas fir stands and eventually replace Douglas fir as mature trees of this latter die and fall. Dominance by the shade tolerant species is then maintained until logging or fire starts the cycle again. Munger (*op. cit.*) from studies of a large number of forest stands of different ages in Washington, suggests that, in absence of disturbance, the process of conversion from a stand of pure Douglas fir to hemlock and associated species would take place in perhaps five centuries. This basic pattern may not hold true on drier sites, south slopes, etc. and variations are discussed by the Forest Soils Committee of the Douglas Fir Region (1957). Few studies are available on species' behavior in the successional shrub and herbaceous stages. One of the more complete is that by Isaac (1940).

The forest described in this paper is estimated to be around 300 years old and no record of any disturbance prior to 1933 can be found. No fire scars were seen on trees or rotting logs and stumps within the forest itself. Before the 1933 fire, there had been no logging in the forest and no roads. During fire fighting operations, fire roads were cleared along some of the major ridges, but in most instances these ran between standing trees, opening the canopy little if any. Recently, as logging operations were begun in the green forest, several truck roads were opened up through the center of the forest. All sampling was kept well back from the various roads and burned edges.

The burned area included here lies on the same major ridge as does the forest (Figures 1 and 2). As noted previously, it was burned only in 1945, but the fire was sufficiently severe that no living trees remain over much of the area. In common with the rest of the burn, it has been subject to salvage logging of dead trees and falling of snags. The ground surface is littered with fallen trees, limbs, etc., chiefly the result of these activities since most of the fire-killed trees remained standing. A high amount of ground disturbance has resulted from the logging operations in some places, but the major roads, loading areas, etc. were still conspicuous at the time this study was made and were avoided in sampling. It is this relatively small segment of the Tillamook Burn that is intended in further references to "burn" in this paper.

PROCEDURES AND METHODS

Observations were made in the forest and the 1945 burn to obtain general qualitative descriptions and to note conspicuously different habitats in each.

Vegetational analyses

From observation, the forest interior was divided into three main habitats: (1) drained upland: by far the bulk of the area; (2) streamside: streams within the forest were exceedingly small since this was steep terrain near a ridge top; however, shaded small watercourses occurred which were at least moist throughout the summer; and (3) marsh meadow: in a very few places the topographic pattern was such that downhill drainage was impeded and marshy areas developed; these areas contained no open ponds, but were covered by a network of small streams. The ground remained completely saturated throughout the summer. Two such meadows were found in the main forest, each approximately two acres in size.

In the burn, the main habitats included: (1) drained upland; (2) streamside: these streams were much like those of the forest, but showed more tendency to become completely dry during mid-summer; and (3) three marshy areas similar in general description to, but smaller than, those of the forest.

Since the streamsides and marsh meadows were small, variable and few in number, no attempt was made to obtain quantitative data in them. Species were listed and collected in each of these minor habitats.

Quantitative sampling of all species in both areas was restricted to drained upland between 2500 and 3000 feet elevation. A generally southeastern exposure and a generally northwestern exposure were sampled in both forest and burn (see Figure 1).

Lines of nested quadrats of the following sizes were used in the forest: trees: 10 meters by 10 meters; shrubs: 4 meters by 4 meters; and herbs: 1 meter by 1 meter. The quadrats were located approximately 100 feet apart along paced compass lines. The compass lines to be used were located on aerial photographs of the forest and were so directed as to stay well away from roads and the burn-forest edge. Since this study was concerned with drained upland forest, pace counting was discontinued whenever streams were encountered on a compass line and resumed beyond obvious effects of the stream (usually a matter of 10-15 feet). The lines of quadrats were located approximately 200 feet apart. 100 quadrats were run on the northwestern and southeastern slopes respectively.

Individual trees over four inches dbh were recorded by species and diameter. Trees between 1 foot in height and 4 inches dbh were considered "saplings" and counted in the shrub quadrats, and individuals between 1 inch and 1 foot in height were considered "seedlings" and counted in the herb quadrats. Shrubs and herbs were listed by presence only. More information on each species' relative position would have been obtained by some measure of cover or abundance, but members of each group varied among themselves so much as to size, shape and number of stems that early attempts at this were abandoned on the grounds that they would yield meaningless data.

The elevation and slope angle were recorded at each quadrat.

A special problem was created by the presence of a relatively high amount of dead Douglas fir trees scattered throughout the forest. To assess something of their importance these trees or snags were counted and measured if they were still covered with a fairly thick intact bark and if they were over an estimated fifty feet in height. Data for live and dead Douglas fir were recorded separately.

Fifty more tree quadrats were run in forest above 3000 feet and below 2500 feet to obtain information on the two trees not common in the main forest, Pacific yew (*Taxus brevifolia*) and Noble Fir (*Abies procera*).

Sample methods in the burn were identical with those in the forest with the exception that no tree-sized quadrats were employed. The only trees present were less than 4 inches dbh; these were counted in either the shrub or herb quadrat and their heights estimated.

Herbaceous and shrub species were collected and their identification checked with specimens in the University of Oregon Herbarium. Thanks are due Dr. L. E. Detling of the University of Oregon Herbarium for the identification of sedges and rushes. Nomenclature of grasses follows that of Hitchcock and Chase (1950) of carices that of Mackenzie (1940) and of the rest of the species that of Peck (1941).

Environmental analyses

Environmental records were kept continuously during the summer of 1956 for the purpose of comparing conditions of forest and burn. A few pilot comparative records were made in 1955; these showed a pattern similar to those of 1956 and are not presented here.

Forty maximum-minimum registering thermometers were set up in the study area, ten each on the western and eastern slopes of the forest and burn. The instruments were fastened on stakes at a level of three feet above the ground surface. In the burn, they were placed in specially built shelters which allowed free air movement, but protected them from direct sun. In the forest, the thermometers were not shielded, but were so placed that they were in continuous shade. Readings were made at two or three day intervals from late June to early September, 1956.

On the same days that the maximum-minimum thermometers were read, relative humidity measurements were made in the forest and burn with sling psychrometers. Three readings were taken near noon at various spots in both areas and the results for each averaged. Burn and forest measurements were made simultaneously when possible; usually fifteen or twenty minutes elapsed between readings in the two areas.

Soil surface temperatures were determined at the same time the relative humidity records were made, using mercury-in-glass thermometers. These were inserted approximately ½ inch under the forest surface litter and in the burn were placed under surface litter or ½ inch in the soil if no litter was present.

A standard thirty-inch Weather Bureau rain gauge was placed in an unobstructed location in the burn.

Soil samples were taken in mid-August, 1956, following ten days without precipitation. A total of 60 samples was taken, 15 each from the two slopes in both forest anl burn. Each final sample was a composite of three samples taken within a square meter area at each location. In the forest, the upper litter layer which could often be lifted intact was removed and the samples taken from the six inches below that. In the burn, surface debris was brushed away and the samples taken from the upper six inches. Samples were placed in airtight sacks and weighed when taken in from the field. Colorimetric pH determinations were made in the field using a LaMotte-Morgan field testing kit. Percentage moisture was calculated on the basis of oven-dry weight and the samples were then ground and sieved. Loss on ignition was determined and laboratory analysis made of available phosphorous and potassium content.

Results and Discussion

The data were first analyzed on the basis of southeastern exposure versus northwestern exposure in both forest and burn. In most cases, little or no difference was found in either vegetation or measured environmental factors on these two exposures. Obviously, the greatest variation was between forest and burn, and the data presented are the total burn and total forest values, derived by combining the results of the 100 quadrats on each exposure in each vegetation type, and by combining the various environmental measures on each exposure in each type. Wide variations between any values on the basis of exposure are noted in the discussion.

Tree Composition

The general appearance of the forest interior can be seen in Figure 3. This photograph was chosen as fairly typical of the forest with respect to trees in particular.

Fig. 3. Forest interior, in area of low amounts of understory growth.

The top of the canopy was estimated to be between 125 and 150 feet high. As is common in this type of coniferous forest, the main bulk of the canopy, although dense, was quite shallow in vertical extent, and the long limbless trunks of the larger trees, plus fairly low numbers of seedlings and saplings, gave the forest a park-like appearance. The forest-grown Douglas fir had no living branches for over two-thirds of their height, while the larger hemlocks, although possessing a much greater extent of branch growth, were free of branches for an estimated distance of 15 to 20 feet above the forest floor.

The amount of tree litter on the forest floor was extensive. Needles, twigs, branches and fallen trees were abundant. One conspicuous aspect of the forest was the high amount of dead Douglas fir in all stages of decay from stumps and fallen trees so far rotted that they crumbled to the touch, through nearly barkless rotting snags 20 to 30 feet tall, to trees still covered with solid bark with intact tops and branches still occupying a place in the canopy. In Figure 3, the two large trees in the immediate foreground at the right and the left margins of the picture are dead Douglas fir. Trees such as these occurred in amounts averaging 11 per acre, and in the forest as a whole, one-third of the canopy height Douglas fir was dead. The writer was unable to find any figures to compare with these, but it would seem that the amount was higher than under "average" conditions, due to the unique location of the forest in the center of a vast burn. Furniss (1936, 1937) notes the tremendous build-up of populations of Douglas fir bark beetle (*Dendroctonus pseudotsugae*) in dead trees following the 1933 fire and states that after a couple of years, the beetles were no longer attracted to the dead trees, but attacked healthy green timber in the vicinity.

Another striking feature of the forest was the favored place of growth of western hemlock.

TABLE I. Summarization of data for tree species in the 200 forest quadrats between 2500 and 3000 feet elevation. Size classes given in density/100 quadrats; inches d.b.h. above 4". Seedlings and saplings counted in the herb and shrub quadrats, respectively.

Species	Relative			Impor-tance Value*	Size Classes					
	Den-sity	Fre-quency	Basal Area		Seed-lings	Sap-lings	4-20	21-40	41-60	60+
Western Hemlock	66.9	59.3	24.1	150.3	105	72	120	72	36	1
Douglas fir	30.6	36.7	72.4	139.8	—	—	1	17	52	5
Noble Fir	2.5	4.0	3.4	9.9	2	1	3	1		2

Total trees: 483; Total Frequency: 300; Total Basal Area: 2467.32 sq. ft.

*Sum of relative density, relative frequency, and relative basal area.

This is an exceedingly shade tolerant species and while it germinates on the forest floor, it seemed to germinate and grow best on decaying Douglas fir, either on rotting logs and stumps or on the bases of standing dead or living trees. This characteristic was consistent throughout the forest. The tortuous path of roots as they grew over the Douglas fir surface and finally into the ground was at times fantastic. Many of the most successful western hemlock grew on the bases of dead or living standing Douglas fir. This apparently has been common in the past as many of the large western hemlocks had irregular scars at one side of the trunk base, while others incompletely encircled the rotting remains of stumps which presumably were Douglas fir. Tall hemlocks, growing partly on the bases of Douglas fir trees, often had branches that almost encircled the "host" tree, these branches scraping bark from the Douglas fir as they were blown by the wind. Whenever leafy hemlock branches had invaded the crowns of Douglas fir, shaded lower branches of the latter were dead and the shallow crowns further reduced in depth.

It will be noted that western red cedar does not appear in the above discussion nor in the quadrat data to follow. Shantz and Zon (1924), Weaver and Clements (1938) and others call this general forest the "Cedar-Hemlock forest," but western red cedar seems uncommon in most parts of the northern Oregon Coast Range forests, except in poorly drained sites, and western hemlock is nearly completely dominant on drained sites. This was true in the present forest where the cedar was found only twice on drained areas but was common at the edges of the marshy meadows. Merkle (1951) describes this same condition on a peak south of the Tillamook Burn in the Coast Range; Dirks-Edmunds (1952), working in an apparently older forest at lower elevations south of the Tillamook Burn, and Munger (1940) working in Washington in the Olympic Peninsula forests, both note low amounts of western red cedar in the forests studied.

The summarization of tree data derived from quadrat analysis of the forest areas is presented in Table I. The shrub and herb data are deferred to a later section to be compared with similar data from the burn. Figures included in Table I are based on the 200 quadrats run between 2500 and 3000 feet elevation.

The relative importance values of western hemlock and Douglas fir are seen to be high and very close in value; however, these values are the result of diametrically opposed species' behavior. The value for western hemlock was high because of the density of the species, the relative figure being 67 percent of the total density of all species, while Douglas fir with only 31 percent of the total density, possessed 72 percent of the total basal area.

The living Douglas fir occur only in the larger size classes; no seedlings or saplings were found in any of the quadrats and none were seen in the forest outside the quadrats. The one Douglas fir which was found in the lowest tree size class was in a somewhat open area in which a large Douglas fir had fallen. The majority of Douglas firs were in the two largest size classes, with five individuals over 60 inches d.b.h. recorded.

Western hemlock occurred almost alone in the three smaller size classes, but was present in all categories. One specimen measuring over 60 inches d.b.h. was encountered. Over half of the individuals of this species were in the 4 to 20 d.b.h. class, but a fairly large percentage occurred in the 20 to 40 d.b.h. class. Trees of this latter size extended into the canopy. Western hemlock was exceedingly vigorous in the forest and only an occasional dead tree was encountered. These latter were chiefly found in instances in which the decaying stump or log on which they had been growing had collapsed before the hemlocks were well rooted in the soil.

Noble fir was undoubtedly inadequately sampled in these stands with so few individuals encountered in the quadrats, but it can be seen that it was relatively unimportant. Specimens of the first four size classes were not as vigorous as were those of western hemlock; the saplings and individuals in the 4 to 20 inches d.b.h. class tended to have few branches and these concentrated in a rather flat crown, and all of the smaller saplings and seedlings were twisted and somewhat gnarled in appearance.

Observation revealed that noble fir became much more abundant as elevation increased. The extent of completely undisturbed forest between 3000 feet and 3450 feet (the highest point in the forest) was small, but it was believed that some information on the relative place of the three major tree species could be obtained there. Consequently, 50 tree quadrats were run above 3000 feet wherever solid stands occurred. It had also been noted that Pacific yew had been picked up only in the quadrats near 2500 feet and that it was not seen above 2600 feet in this forest. To include a little more information on this understory tree, 50 more tree quadrats were run below 2500 feet. The tree data from the 300 quadrats were then arranged on the basis of elevation. The total elevation range of 2200 feet to 3400 feet was divided into blocks of 150 feet each, and values of relative density, relative frequency and relative basal area were calculated for trees occurring in quadrats within each elevation block. Thirty or more quadrats occurred in all of the elevation blocks with the exception of the two highest. These were low, due to the small size of the area, and so were combined to give a somewhat more adequate picture. Figure 4 shows the position of the species with respect to elevation.

Western hemlock remained more or less constant throughout the altitudinal range. The relative drop indicated in the highest blocks is due to the greatly increased importance of noble fir, since the absolute density, frequency and basal area of hemlock were even higher than in the lower stands. Douglas fir held a fairly constant position until noble fir began to increase around 3000 feet and fell sharply after that. Absolute numbers of Douglas fir were decreased to a density of 24 trees per hundred quadrats, and a frequency of 20 percent, while the average basal area remained nearly the same.

The major change in species composition was found in the greatly increased importance of noble fir. The species was represented in all size classes, but with highest numbers in the largest class and twenty individuals over 60 inches d.b.h.

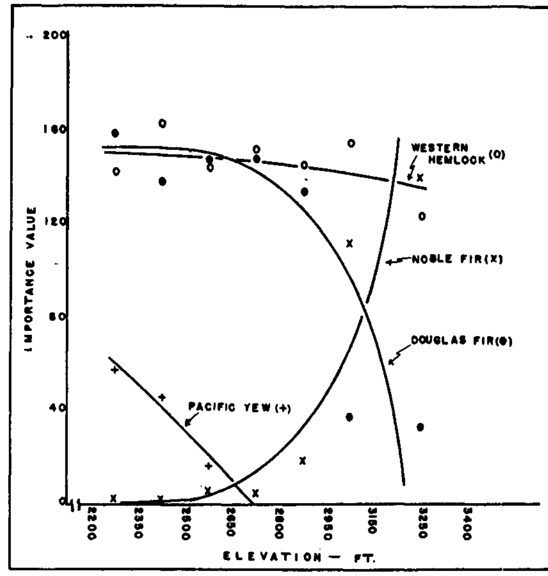

FIG. 4. Importance values of trees in altitudinal blocks of 150 feet each (highest block, 300 feet). Values for Pacific yew in density/100 quadrats.

One of the largest noble fir seen in the area, although not in the quadrats measured 87.2 inches d.b.h. These larger trees were estimated to be approximately 200 feet tall. These bases of their small rounded crowns were somewhat above the main bulk of the Douglas fir-western hemlock canopy, causing the top of the canopy to be quite irregular and also allowing greater amounts of light to reach the forest floor than found under the tighter cover of the lower stands. Smaller trees of noble fir were not numerous.

Hansen (1947) states that stands of noble fir are common on some of the higher points in the Oregon Coast Range. In a study of vegetation of Mary's Peak (the highest point in the range and approximately 70 miles south of the Tillamook Burn forest), Merkle (1951) found that noble fir was sparse below 2500 feet, scattered between 2500 and 3400 feet elevation, the most common species above 3400 feet in all size classes and in almost pure stand between 3600 and 3800. Verbal information from persons associated with the lumber industry in the Tillamook Burn area confirmed that green forest patches on other points of 3000 feet or over contained substantial amounts of noble fir.

Data for trees of the burn area are summarized in Table II. These are broken down by the southeastern and northwestern exposures; the values were rather widely divergent, probably due to the fact that the southeastern area was closer to the forest than was the northwestern area. Only two Douglas fir and three western hemlock were found in the seedling class, so the data presented represent only the sapling class. The numbers are low as there are no seed sources left in the areas themselves and reseeding has been dependent on the main forest, but they show the greater success of the vigorous, but shade intolerant, Douglas fir in establishment in open sites.

TABLE II. Summarization of saplings on the southeastern and northwestern burn exposures. Density per 100 quad.

Species	Density		% Frequency		Ave. Ht.	
	SE	NW	SE	NW	SE	NW
Western hemlock	42	12	23	10	1.7′	2.1′
Douglas fir	128	50	61	35	2.5′	3.2′
Noble fir	5	2	5	2	2.3′	3.5′

Shrub and Herb Composition

The complete species list of shrubs and herbs in the burn and forest habitats studied are presented in Tables III and IV.

The shrub and herb layers in the forest varied widely. The almost total lack of understory shown in Figure 3 represents one end of the scale of abundance, while the other end may be seen in Figure 5. Even more dense shrub stands were found at times, with *Acer circinnatum* forming dense thickets up to 15 feet in height. Between such extremes were areas devoid of shrubs, but with a dense herbaceous growth. As has been noted in other studies of heavy forest, the herb and shrub layers increased in abundance and height in direct relation to the increase of sunlight reaching the forest floor; places in which the canopy had been broken by loss of a canopy tree were underlain with dense shrub and herb growth. The spatial shifting process of the shrub layer was well illustrated in several openings in the center of which was a large rotting stump or snag. Dense shrub growth had filled the original opening following falling of the tree. Around the edges of such openings and within them wherever young hemlocks had apparently increased in size after having been freed of competition from that particular canopy tree, thickets of dead stems of the huckleberries and vine maple could be seen, apparently having been killed as the opening began to be filled with new tree growth.

Vaccinium membranaceum was the only shrub able to grow throughout most of the upland forest area. In heavy stands of unbroken forest on the ridge tops, where understory was at its lowest, *V. membranaceum* at times appeared only as a single stem under 18 inches tall in the quadrats. On steep slopes and in areas where dead Douglas

TABLE III. Shrub and herb composition of upland forest and burn; figures represent percent frequency in 200 quadrats in each area. An asterisk signifies the species was present in the quadrat area, but not in the quadrats.

Species	Forest	Burn
SHRUBS		
Menziesia ferruginea	5	
Sorbus sitchensis	1	
Vaccinium membranaceum	76	51
Vaccinium parvifolium	45	32
Acer circinnatum	43	61
Berberis nervosa	37	34
Rosa gymnocarpa	10	7
Gaultheria Shallon	4	5
Rubus niavlis	2	2
Rubus spectabilis	1	12
Rubus vitifolius	1	49
Solix Scouleriana		56
Rubus parviflorus		29
Arctostaphylos Uva-ursi		11
Sambucus glauca		6
Ribes lacustre		4
Ribes sanguineum		4
Sambucus callicarpa		2
Rosa rubiginosa		*
Rubus thyrsanthus		*
HERBS		
Listera cordata	18	
Anemone Lyallii	3	
Corallorhiza mertensiana	3	
Corallorhiza maculata	2	
Goodyera decipiens	3	
Moneses uniflora	3	
Struthiopsis spicant	3	
Circaea pacifica	2	
Monotropa uniflora	*	
Hypopitys latisquama	*	
Coptis laciniata	91	4
Streptopus curvipes	73	4
Clintonia uniflora	67	8
Tiarella trifoliata	55	1
Vancouveria hexandra	55	37
Achlys triphylla	55	33
Disporum Smithii	53	28
Smilacina racemosa	40	11
Viola sempervirens	39	24
Oxalis oregana	38	38
Maianthemum bifolium var. *kamtschaticum*	30	14
Cornus canadensis	14	8
Viola glabella	13	4
Trillium ovatum	12	3
Anemone deltoidea	10	5
Linnaea borealis var. *americana*	6	2
Polystichum munitum	4	2
Asarum caudatum	2	13
Trientalis latifolia	2	60
Galium oreganum	1	8
Xerophyllum tenax	1	5
Campanula Scouleri	1	5
Luzula parviflora	1	40
Epilobium angustifolium		91
Anaphalis margaritacea var. *occidentalis*		76
Hieracium albiflorum		70
Lupinus polyphyllus		70
Carex microptera		65
Scrophularia californica		42
Lotus stipularis		40
Luzula campestris		25
Hypochaeris radicata		23
Carex Mertensii		20
Deschampsia elongata		14
Poa trivialis		11
Agropyron repens		10
Fragaria bracteata		9

TABLE III. (Continued)

Species	Forest	Burn
Carex californica		8
Stachys Emersoni		7
Carex integra		7
Trisetum canescens		6
Agrostis exarata		6
Senecio vulgaris		5
Cirsium lanceolata		4
Stellaria crispa		4
Cirsium edule		3
Galium triflorum		3
Epilobium paniculatum		3
Festuca rubra		2
Montia sibirica		2
Pteridium aquilinum var. *pubescens*		2
Lilium columbianum		2
Actaea spicata		1
Adenocaulon bicolor		1
Bromus sitchensis		1
Osmarhiza nuda		1
Sisyrinchium Douglasii		1
Bromus laevipes		1
Chimaphila Menziesii		1
Pedicularis racemosa		1
Pyrola bracteata		*
Satureja Douglasii		*
Cirsium arvense		*
Aquilegia formosa		*

FIG. 5. Forest interior, in area of dense shrub and herb growth. Shrubs shown are chiefly *Vaccinium membranaceum*.

fir crowns in the canopy allowed increased light to reach the forest floor, the species grew to four and five feet in height and had as many as 125 separate stems per shrub quadrat. In these latter areas, *Acer circinnatum* and *Vaccinium parvifolium* also grew luxuriantly. *A. circinnatum* especially increased as logging and fire roads and the forest edges were approached. *Berberis nervosa* only rarely occurred with the above three shrubs, but tended to occupy rocky outcrop areas and seemingly drier regions within the forest.

Where shrub growth was exceedingly dense, few of the herbaceous species occurred, with the exception of the highly frequent *Coptis laciniata.* This species, although widespread, actually contributed little to the total bulk of herbs since few of the individuals were over two or three inches high. The herbs restricted to the forest (*Listera cordata, Anemone Lyallii,* etc.) occurred chiefly in the most heavily shaded areas on the ridge tops, where shrubs and other herbs were negligible. Two of the saprophytes, *Monotropa uniflora* and *Hypopitys latisquama* were fairly common, but do not occur in the quadrat data, since they came up after forest sampling had been completed. In areas intermediate in appearance between those occupied by dense shrub growth and those with little understory vegetation, *Streptopus curvipes, Clintonia uniflora, Tiarella trifoliata, Vancouveria hexandra, Achlys triphylla, Disporum Smithii* and *Smilacina racemosa* formed a dense cover. In such areas, the leaves of Achlys were often arranged in a mosiac and formed an almost solid layer about eight inches above the ground surface.

While mosses were not collected or listed, it was observed that they were in very low amount throughout the upland forest.

Ferns were comparatively rare in this forest, except along the streams and on moist slopes immediately above the streams. There, *Polystichum munitum* and *Struthiopsis spicant* occurred at the upper levels, with increasing amounts of *Dryopteris Linnaeana* and *Cystopteris fragilis* closer to the stream and dense growths of *Adiantum pedatum* in the moist streambeds and on moist banks.

The most conspicuous member of the streamside vegetation was *Oplopanax horrida* which grew in dense thickets covering over the smaller streams and extending a short distance upslope from them.

The forest marsh-meadows were open areas apparently too wet for tree growth. A dense spongy cushion of mosses and liverworts grew over the entire central region of the meadows. A tall lush vegetation dominated by *Pleuropogon refractus, Scirpus microcarpus, Juncus effusus* var. *brunneus* and *Stenanthium occidentale* grew in the bryophyte region. Progressing toward the meadow edges, dominance changed to one by *Stachys ciliata* and then to one by *Senecio triangularis* as the forest-meadow border was reached.

The general appearance of the vegetation of the burn can be seen in Figure 2, and a closer view in Figure 6. Two extremes of ground cover were commonly encountered. At one extreme were areas of dense shrub and herb growth with 90 to 100 percent ground cover, and at the other extreme areas of sparse vegetation with as high as 65 percent bare ground. The former cover condition occurred in small ground depressions, while the

TABLE IV. Shrub and herbs of streamsides and marsh meadows of forest and burn.

Forest only	Moist to Wet, Unshaded Habitats Forest and Burn	Burn only
Caltha biflora	*Angelica arguta*	*Salix sessilifolia*
Boykinia elata	*Epilobium glandulosum*	*Salix sitchensis*
Cardamine Breweri var. *orbicularis*	*Glyceria elata*	*Equisetum arvense*
Mitella caulescens	*Habenaria stricta*	*Geum macrophyllum*
Montia cordifolia	*Juncus effusus* var. *brunneus*	*Hydrophyllum teniupes*
Stenanthium occidentale	*Mimulus dentatus*	*Juncus falcatus*
Forest Streamsides shaded	*Pleuropogon refractus*	*Lathyrus polyphyllus*
	Petasites speciosa	*Montia diffusa*
	Polygonum bistortoides	*Oenanthe sarmentosa*
Oplopanax horrida	*Ranunculus Bongardii*	*Ranunculus orthorhyncus*
Cystopteris fragilis	*Senecio triangularis*	*Stellaria borealis*
Galium aparine	*Scirpus microcarpus*	*Streptopus amplexicaulis*
Adenocaulon bicolor	*Stachys ciliata*	*Typha latifolia*
Dryopteris Linnaeana	*Trautvetteria grandis*	*Tolmiea Menziesii*
Adiantum pedatum	*Veronica americana*	*Tellima grandiflora*
	Veratrum caudatum	*Vicia gigantea*
		Veronica scutellata

latter occurred on more prominent areas, especially on the crests of small ridges.

FIG. 6. Vegetation of the 1945 burn. White flowers are those of *Anaphalis margaritacea* var. *occidentalis.*

In general, the height of the herbaceous vegetation varied between one and one-half to three feet, while the shrubs were approximately four to five feet in height. Shrub growth was not dense except along the streams; on the uplands, the huckleberries and vine maple grew in tight separate clumps rather than in the sprawling form found in the forest. *Salix Scouleriana* was frequent throughout the upland burn surveyed, growing up to ten feet in height.

Epilobium angustifolium was not only the most frequent herb, but being a large leafy plant (up to four feet tall in sheltered locations) made up a high percentage of the bulk of the herbs. This species, along with *Anaphalis margaritaceae* var. *occidentalis, Hieracium albiflorum, Lupinus polyphyllous,* and *Scrophularia californica,* all fairly large plants, were by far the most conspicuous herbs in the burn.

The major shrub and herb species in the upland burn fell chiefly into three groups: (1) those also important in the forest (the Vacciniums, Acer, Berberis, Vancouveria, Achlys, Disporum and Oxalis); (2) those present, but of very low frequency, in the forest (*Rubus vitifolius, Trientalis latifolia* and *Luzula parviflora*); and (3) those restricted to the burn, *Salix Scouleriana, Rubus parviflorus, Epilobium angustifolium,* etc.). The number of shrub and herb species of the burn was very high in comparison with the forest. 20 shrubs and 100 herbs occurred in the various burn habitats as opposed to 12 shrubs and 57 herbs in the various forest habitats. The high number of burn species is due both to the overlap of forest herbs and shrubs, and to the higher numbers of species of less than five percent frequency. The latter would be expected in an area such as this where the upland habitat variation ranged from sheltered moist areas to open and nearly bare patches of dry gravelly soil.

Although 13 species of grasses occurred in the burn area (six occurred only along the edges of logging roads and are not listed) the group was infrequent in the upland areas. *Agropyron repens* and *Poa trivialis* occurred chiefly in the more open sites and there formed small clumps, with only one or two flower culms per clump.

The forest herb species which persisted in the burn occurred chiefly in sheltered pockets shaded by down logs and stumps. The appearance of especially *Achlys triphylla* and *Vancouveria hexandra* differed strikingly from that in the forest. 30 plants of Vancouveria were measured as to width of leaves and height in the burn and in the forest. The average values were 1½ in. and 12 in. respectively in the forest and ¾ in. and 6 in. respectively in the burn. The plants were a yellow-green in color as opposed to the clear light green of forest grown plants. *Asarum caudatum*, on the other hand, not only was more frequent on moist slopes in the burn, but averaged larger leaves and more flowers per plant than in the forest.

Marshy areas and small streams had much the same vegetation in the burn, since there was no shade over the streams as found in the forest. Wherever water moved slowly (many of the small streams were choked with logs, limbs, soil deposits, etc.) dense moss-liverwort mats grew over the surface. Growing in these mats were such higher plants as *Habenaria stricta, Angelica arguta, Aruncus sylvester*, etc. *Equisetum arvense*, not found in the forest, grew in dense stands on small flood plains. *Typha latifolia* was found only twice, in small shallow pools. Streams in which the water ran swiftly early in the season and in which little or no surface water showed by late summer, were heavily vegetated with *Salix sessilifolia* and *S. sitchensis*.

As noted earlier, the frequencies of most species did not differ greatly on the two different exposures in each vegetation type. Species of over 30 percent frequency in either area and differing by 20 percent or more between slope exposures are included in the following discussion. *Acer circinnatum* and *Berberis nervosa* were more frequent on the southeastern exposure of both forest and burn. The Vacciniums were of equal frequency on the different exposures within the forest, but nearly twice as frequent on the southeastern exposure as on the northwestern exposure in the burn. Of the forest herbs, *Streptopus curvipes, Tiarella trifoliata* and *Maianthemum bifolium* var. *kamtschaticum* were more frequent on the northwestern slope, while *Disporum Smithii* was about three times as frequent on the southeastern slope. In the burn, *Disporum, Oxalis, Maianthemum, Lotus stipularia* and *Hypochaeris radicata* were each approximately twice as frequent on the northwestern exposure, while *Scrophularia californica* was more frequent on the southeastern exposure.

Environmental data

Measurements of maximum-minimum temperatures made throughout the summer of 1956 in forest and burn are presented in Figure 7. The tempering effect of forest cover is well illustrated as the forest maxima averaged 10°F lower and the minima averaged 2° higher than similar records in the burn. When the different exposures are considered, the forest maxima and minima varied by less than .2°F between the two exposures, while in the burn, the average maximum temperature was 2°F higher and the average minimum 1° higher on the southeastern slope than on the northeastern slope.

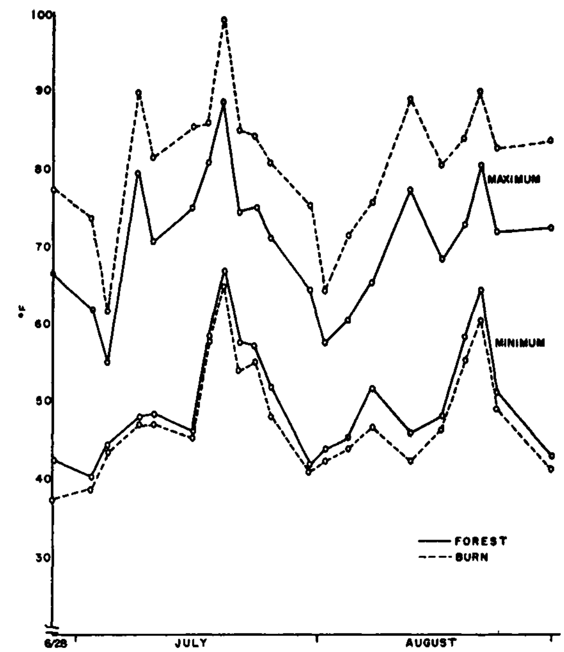

FIG. 7. Maximum and minimum temperatures of forest and burn throughout the summer of 1956. Each value represents the mean of readings from 20 thermometers.

Figure 8 shows the precipitation record and the variation of relative humidity and soil surface temperatures between forest and burn. The soil surface temperatures taken at noon averaged 19° higher in the burn than in the forest. Percent relative humidity varied little between the two sites until early August, although the forest values remained consistently slightly higher than those of the burn. Following fairly heavy precipitation in early August, the relative humidity differences between the two vegetation types widened.

Results of the soil analyses are shown in Table V. Values for loss on ignition and percent moisture were lower in the burn than in the forest. No difference was found between the southeastern and northwestern slopes in the forest as regards soil moisture content, but as shown in the table, moisture percentage at the time the samples were taken was somewhat lower on the southeastern slope than on the northwestern slope. The pH and available potassium values were very similar in forest and burn, while available phosphorus was at least 25% lower in the burn samples than in those from the forest. No significant variation between exposures was found for any soil measurement aside from percent soil moisture.

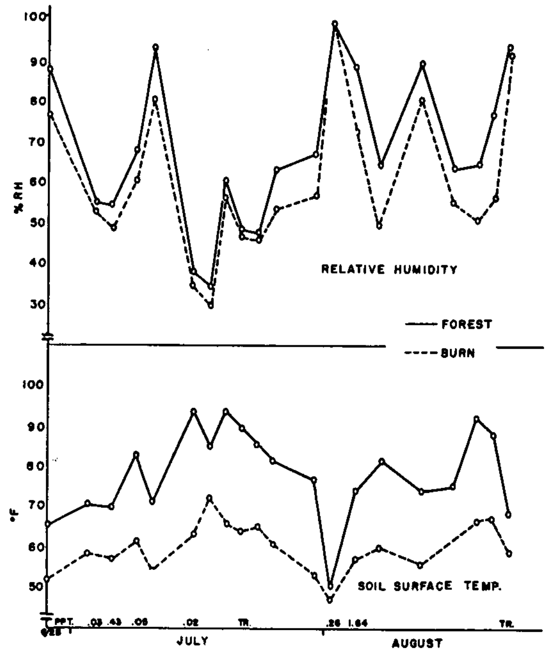

FIG. 8. Relative humidity and soil surface temperatures taken at noon in forest and burn, summer 1956. Each value is the mean of three readings. Precipitation given at lower edge of graph.

TABLE V. Results of soil analyses. Values represent means of 30 samples each with 95% confidence limits. (Values for soil moisture on the two burn slopes are the means of 15 samples each).

	Forest	Burn
Loss on ignition percent dry wt.	29.2±2.19	23.3±2.07
Moisture content percent dry wt.	28.2±2.37	20.4±1.78 (SE 17.5± .97) (NW 24.0±1.03)
pH	4.76	4.93
Avail. Phosphorus mg/100 gm.	4.05± .96	1.62± .19
Avail. Potassium mg/100 gm.	24.74±1.90	23.49±2.39

CONCLUSIONS AND SUMMARY

Vegetational analyses were made in the one remaining large stand of unburned forest in the center of the Tillamook Burn in the northern Oregon Coast Range, and in an adjacent area burned in 1945. The vegetation was sampled by lines of nested quadrats in the upland sites. Species listings were made in minor habitats of streamside and marsh meadow. Physical environmental measurements made in both forest and burn included those of maximum and minimum temperatures, relative humidity, soil surface temperature and analysis of soil as to loss on ignition, percent moisture, pH and available phosphorous and potassium. Both vegetational and environmental measurements were made on a southeastern and a northwestern exposure in the forest and burn.

The main tree species were Douglas fir, western hemlock and noble fir. In the forest samples taken between 2500 and 3000 feet above sea level, the most important species were Douglas fir and western hemlock. Douglas fir dominated in the large size classes and was absent in smaller size classes; dead Douglas fir in all stages of decay were common throughout the forest. Western hemlock had a high relative density and relative frequency, but a low relative basal area. It was present in all size classes, with a preponderance of individuals in the smaller classes. The forest appears to represent a transition stage from a pioneer forest dominated by the shade intolerant Douglas fir to a more mature forest dominated by the highly tolerant western hemlock.

When results for tree samples between 3400 and 2200 feet were evaluated on the basis of 150 feet changes in elevation, it was found that western hemlock was more or less evenly distributed over the entire range; Douglas fir fairly evenly distributed from 2200 to 2900 feet, decreasing thereafter; and that noble fir was rare below 2900 feet, but increased in importance up to the 3400 feet upper limit to become the dominant tree. Pacific yew, the only understory tree of this forest, was encountered near 2500 feet and increased in elevations below that.

The shrub and herb layers in the forest varied from exceedingly dense patches to areas with only a few scattered herbs. The shrub and herb species in the various habitats of forest and burn are compared. Approximately twice as many shrubs and herb species occurred in the burn as occurred in the forest. The chief upland shrubs of the forest, *Vaccinium membranaceum, V. parvifolium,* and *Acer circinnatum,* are also among the major shrubs of the burn. Ten of the forest herbs were not found in the burn, and the remainder appeared in the burn with less than 38 percent frequency. The burn herb flora was chiefly dominated by tall sun-loving species. Variations in species' frequencies on the two different major slopes are noted. Wide variations were few in number.

In general, with respect to temperature, relative humidity and soil moisture, the forest had lower maximum temperatures, slightly higher minimum temperatures, a slightly higher percent relative humidity, and a higher soil moisture content after ten days without precipitation, than the burn.

Loss on ignition and the amount of available phosphorus were higher in the forest samples, while the two areas were similar with respect to pH and available potassium. The two exposures in the forest varied little as to these environmental measurements, while in the burn, the southeastern slope had slightly higher maximum and minimum temperatures and a lower soil moisture content than the northwestern slope.

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THE AVAILABILITY OF PLANT SEEDS TO BOBWHITE QUAIL IN SOUTHERN ILLINOIS[1]

THEODORE A. BOOKHOUT[2]

Studies of food habits of bobwhite quail (*Colinus virginianus* L.) show that seeds of only a few species of plants are commonly used. This could be due either to availability or preference, but little has been published on foods available.

The data herein reported upon resulted from an effort to obtain a reasonably accurate measurement of the availability of plant seeds to bobwhites in six selected sampling areas in southern Illinois from the spring of 1951 through the winter of 1952-53. The research formed part of an intensive, coordinated investigation of the foods and feeding behavior of bobwhites in that region. The objectives of this included: determination of the species and quantity of seeds available by land-use divisions and season, duration of period of availability of the various species of seeds, and relationships between the availability of seeds and their consumption by bobwhites.

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Description of Area

The areas selected for sampling (Fig. 1) lie within the Southern Zone of Illinois which is comprised of the southernmost 34 counties of the

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