EARLY STAGES OF PLANT SUCCESSION FOLLOWING LOGGING AND BURNING IN THE WESTERN CASCADES OF OREGON

C. T. DYRNESS

Forestry Sciences Laboratory, Pacific Northwest Forest and Range Experiment Stution Forest Service, U.S. Department of Agriculture, Corvallis, Oregon 97330

Abstract. Vegetative changes were documented for 7 years on permanent milacre plots located in three clearcut logged units in the western Cascade Mountains of Oregon. Plant cover and composition were observed the year prior to logging the old-growth *Pseudotsuga menziesii* forest, after logging but before burning, and during each of five growing seasons following broadcast slash burning. Total plant cover was 15.2, 49.3, and 79.5% in the first, second and fifth years after slash burning, respectively. Invading herbaceous species dominated from the second through fourth growing seasons after burning but by the fifth year residual herbaceous species regained dominance.

Differences in disturbance from logging and burning strongly influenced successional trends. In undisturbed soil areas, residual species, such as *Acer circinatum, Oxalis oregana,* and *Gaultheira shallon,* dominated. Areas disturbed by logging but unburned supported a wide variety of both residual and invader species. Light to severely burned sites were largely occupied by invaders such as *Ceanothus velutinus, Epilobium angustifolium,* and *E. paniculatum.*

Although often obscured by varying degrees of disturbance, relationships between early stages of succession and prelogging plant community were discernible. For example, of the species considered characteristic of five undisturbed plant communities, only 13 percent were absent from the plots 5 years after burning. The invaders *Ceanothus velutinus, Agoseris grandiflora,* and *Gnaphalium microcephalum* var. *thermale* were restricted to sites previously supporting rather xeric communities; while *Rubus leucodermis* and *Anaphalis margaritacea* were found on *plots* characteristic of the more mesic communities.

INTRODUCTION

Intensive studies of the effects of clearcutting old-growth Douglas-fir *(Pseudotsuga menziesii)* [1] on streamflow, vegetation, and soils have been underway in the H. J. Andrews Experimental Forest since 1962. One of these studies has involved following yearly changes in plant cover and species composition on permanent plots established one year before logging was initiated. Areas studied include a completely clearcut 237-acre experimental watershed and three relatively small clearcut units situated in a companion watershed. This paper summarizes results of 7 years of observation within the three small clearcut units: before logging, after logging but before slash burning, and during each of five growing seasons following slash burning. A preliminary report covering results of the first three sampling periods has already appeared (Dyrness 1965).

Previous studies of secondary succession foliowing clearcut logging in the Douglas-fir region have primarily described broad successional stages based on reconnaissance data — (Kienholz 1929, Ingram 1931, and Isaac 1940). Investigators have generally observed vegetation on a number of clearcut logged areas, ranging in age from recently logged to the oldest available rather than following vegetative changes on the same site over a period of years. They have then attempted to reconstruct successional sequences from data which may have been obtained from a wide range of sites. Only broad successional stages may be discerned by this approach since vegetation on disturbed sites is influenced not only by age of disturbance, but also by differences in such uncontrolled variables as soil, elevation, and severity of disturbance. The successional stages commonly described may be placed in three main categories: (1) moss-liverwort, (2) annual weeds and short-lived perennials, and (3) shrubs and tree seedlings.

Morris (1958) and Steen (1966) concentrated on defining the effects of slash burning on early successional stages. Both found that during the first 5 to 7 years, shrub cover was more abundant in unburned areas than on adjacent burned sites. Their findings indicated that herbaceous cover was about the same on burned and unburned sites, although species composition often differed appreciably.

Recent studies have dealt with the autecology of two species which are impsrtant in postlogging succession iii the western Cascades. Zavitkovski and Newton (1968) found stands of *Ceanothus velutinus* to be much more common on south-facing slopes which 'they attributed to the species' adaptation to dry sites plus the more complete burning characteristic of such slopes. They could find no increase in total nitrogen levels in the surface soil under *C. velutinus* but did find it to be a prolific producer of nitrogen-rich litter. West and Chilcote (1968), working in Oregon Coast Ranges clearcuts, found *Senecio sy1vaticus* rapidly invaded recently burned units, reached a peak 2 years after slash burning, and virtually disappeared thereafter. This brief period of

[1] scientific names follow Franklin and Dyrness (1970).

Senecio dominance was attributed to: (1) an abundance of small, aerially disseminated seed allowing for massive invasion; and (2) its low competitive ability and high nutrient requirement, both conditions being satisfied only soon after slash burning.

STUDY AREA

The clearcuts studied are located within a 250-acre (117 ha) experimental watershed and range from 1,700 to 2,900 feet (518 to 884 m) in elevation and 13 to 20 acres (5 to 8 ha) in size. Slopes are generally moderately steep, averaging approximately 60%. Bedrock in the area, characteristic of low elevations in this section of the western Cascades, is made up of a variety of tuffs and breccias. Soils are dominantly loam-textured Regosols developed in generally deep deposits of colluvial material.

Annual precipitation averages approximately 90 inches (2,286 mm). Typically, very little rainfall occurs during June, July, and August. Prior to logging, the timber stand was comprised of old-growth Pseudotsuga menziesii (300 to 500 years old) accompanied by substantial amounts of Tsuga heterophylla in a variety of age classes. Other less important tree species included Thuja plicata, *Pinus* lambertiana, Taxus brevifolia, Acer macrophyllum, Cornus *nuttallii,* and Castanopsis chrysophylla.

Five distinct understory communities were identified at the time of the prelogging sampling. These communities are named for understory dominants and, listed in order of increasing effective moisture, are: (1) Rhododendron macrophyllum-Gaultheria shallon — characterized by very dense shrub cover and a poorly developed herbaceous layer; (2) Acer circinatum–Gaultheria shallon — generally associated with patches of second-growth Douglas-fir and typically with high shrub and low herb cover; (3) Acer circinatum-Berberis nervosa — characterized by a moderately dense shrub and small tree layer over very scattered herbaceous plants; (4) Coptis *laciniata*-found under a dense hemlock overstory and exhibiting both a sparse shrub layer and a sparse herb layer; (5) Polystichum munitum-occupying moist streamside and north-facing sites and identified by lush growth of a variety of herbaceous plants.

For a more complete summary of information on climate, geology, soil, and undisturbed vegetation of the area, the interested reader may consult Rothacher, Dymess, and Fredriksen (1967).

METHODS

During the summer of 1962, prior to logging, 61 permanent milacre (0.0004 ha) plots were established in the three cutting units. These plots were placed at 100-foot (30.5-m) intervals along randomly located transects which extended across the entire unit, virtually sampling the entire range of site conditions.

The milacre plots were square, 6.6 feet (2.01 m) on a side, with one-quarter of the large plot subdivided into nine subplots, each 1.1 foot (335.3 cm) square. Crown cover of all tall shrubs and trees up to 20 feet (6.1 rn) in height occurring within the milacre plot was estimated and recorded by species. Percent crown cover of herbaceous and low shrub (< 2 feet tall) species occurring on each 1.1-foot subplot was also estimated and recorded by species. Plots were inventoried in late July or early August each year from 1962 through 1968.

Species were classed as either invaders or residual following logging on the basis of results of the prelogging sampling plus reliance on knowledge of undisturbed forest vegetation of the area gained in other studies. The most obvious definition of invading species, i.e. species not present in the original, unlogged stand, does not always hold. For example, Rubus parviflorus and Epilobium angustifolium, present in very small quantities in the stand before logging, are nevertheless classed as invading species simply because they were restricted to severely disturbed sites, such as tree windthrow areas, in the unlogged stand. Residual species, on the other hand, were those present on undisturbed sites before logging, even if only in very small quantities.

Before logging, the three cutting units differed in

TABLE 1. Understory plant communities occupying plots on three cutting units in a single watershed before logging **(1962)**

Prelogging community	Unit 1	Unit 2	Unit 3	Watershed totals	Understory vegetation cover			
					Trees	Shrubs	Herbs	Total
	No. of plots				Percent cover			
Rhododendron macrophyllum-*Gaultheria shallon*	**4**	7	0	**11**	7.8	**60.6**	18.3	**86.7**
Acer circinatum-Gaultheria *shallon*	8	3	0	**11**	24.4	**25.6**	**45.8**	95.8
Acer circinatum-Berberis nervosa	**I**	**5**	4	10	**9.0**	**42.2**	**15.5**	**66.7**
Coptis laciniata	**2**	**7**	3	**12**	**11.9**	**2.7**	**6.3**	**20.9**
Polystichum munitum	4	**4**	**3**	**11**	30.8	14.7	**47.4**	**92.9**
Unclassified	**2**	**1**	3	**6**	**25.7**	5.0	**21.0**	**51.7**
Total	**21**	**27**	13	**61**				

TABLE 2. Cover and frequency values for all plant species encountered on permanent milacre plots in three clear-cut units during the growing seasons of 1962 (before logging), 1963 (first-year after logging),-and 1964-68 (after slash burning)

PLANT SPECIES	1962		1963		1964		1965		1966		1967		1968	
	Cover	Freq.	Cover	Freq.	Cover	Freq.	Cover	Freq.	Cover	Freq.	Cover	Freq.	Cover	Freq.
	.....		.....		.....		.....Per cent.							
TREES														
Pseudotsuga menziesii (Mirb.) Franco	0.1	9.8	0.2	16.4	0.3	29.3	0.3	22.0	0.4	37.7	0.8	39.3	1.1	32.8
Tsuga heterophylla (Raf.) Sarg.	8.7	45.9	1.2	16.4	0.7	19.7	0.7	21.3	0.8	27.9	1.0	23.0	1.3	19.7
Thuja plicata Donn	3.0	9.9	0.5	1.6	0	0	0.1	3.3	a	1.6	a	1.6		1.6
Taxus brevifolia Nutt.	2.5	14.8	0.1	3.3		1.6	0.1	4.9	0.2	8.2	0.2	11.5	0.4	16.4
Acer macrophyllum Pursh	0.2	3.3	0.3	3.3	1.1	4.9	1.3	3.3	2.1	4.9	2.2	6.6	2.3	6.6
Cornus nuttallii Aud. ex T. & G.	2.6	4.9		1.6	0	0	0	0	a	3.3	0.2	6.6	0.4	6.6
Castanopsis chrysophylla (Dougl.) A. DC.	0.6	11.5	0.1	3.3	0	0		1.6	a	3.3	0.1	3.3	0.3	4.9
TOTAL TREES (net)	17.6	73.8	2.3	36.1	2.1	45.9	2.4	44.3	3.5	55.7	4.2	59.0	5.8	57.4
TALL SHRUBS-RESIDUALS														
Acer circinatum Pursh	15.0	45.9	2.0	27.9	0.5	13.1	1.8	16.4	1.7	18.0	2.7	14.8	3.4	18.0
Rhododendron macrophyllum G. Don	8.5	29.5	1.0	18.0	0.2	13.1	0.8	11.5	0.8	11.5	1.2	16.4	1.8	14.8
Vaccinium parvifolium Smith	2.8	32.8	0.5	14.8	0.2	6.6	0.2	9.8	0.2	9.8	0.3	14.8	0.4	11.5
Corylus cornuta var. *californica* (DC.) Sharp	0.1	1.6	0	0	0	0	0	0	0	0	0	0	0	0
Rosa gymnocarpa Nutt.	0.1	1.6	0	0	0	0	0	0	0	0	0	0	0	0
Holodiscus discolor (Pursh) Maxim.	0	0	0	0	0	0	0	0	0	0	0	0		1.6
INVADERS														
Ceanothus velutinus Dougl. ex Hook.	0	0	0	0	0.3	24.6	0.6	24.6	1.3	29.5	2.1	27.9	7.5	31.5
Ceanothus integerrimus H. & A.	0	0	0	0	0	0	0	0	a	3.3	a	3.3	0.2	3.3
Ceanothus sanguineus Pursh	0	0	0	0		3.3	0.1	3.3	0.1	3.3	0.1	4.9	0.2	8.2
Rubus parviflorus Nutt.	0.1	1.6	0	0	0.1	6.6	0.4	8.2	0.6	14.8	1.3	18.0	2.0	23.0
Rubus leucodermis Dougl. ex T. & G.	0.3	1.6		3.3	0.1	8.2	0.1	6.6	0.4	9.8	0.4	16.4	0.7	16.4
Salix sp. [Tourn.] L.	0	0	0	0	0	0		1.6	0.1	6.6	0.2	9.8	0.5	6.6
Sambucus cerulea Raf.	0	0	0	0	0	0	0.1	3.3	0.1	6.6	0.1	8.2	0.4	6.6
Ribes sanguineum Pursh	0	0	0	0		1.6		1.6	a	3.3	8.1	3.3	0.1	1.6
TOTAL TALL SHRUBS (net)	26.1	73.8	3.6	47.5	1.4	50.8	4.0	60.7	5.3	72.1	9.0	80.3	16.8	78.7
LOW SHRUBS. HERBS, GRASSES-RESIDUALS														
Rubus ursinus Cham. & Schlecht.	0.6	5.5	0.2	3.1	1.2	7.3	2.9	16.2	4.3	21.5	7.1	28.8	12.6	37.2
Trientalis latifolia Hook.	0.2	3.3	0.3	4.2	0.7	16.8	1.7	18.2	2.8	30.2	5.4	35.9	7.5	36.6
Linnaea borealis L. var. *longiflora* Torr.	1.7	16.8	0.1	2.6	0.9	4.9	2.5	7.7	3.7	9.3	5.1	10.4	6.3	11.5
Whipplea modesta Torr.	0.4	3.6	0.1	0.9		1.5	0.4	4.0	0.9	6.0	2.6	9.5	5.2	12.2
Hieracium albiflorum Hook.	0	0	0	0		0.9	0.4	4.4	0.6	11.3	2.0	16.0	3.6	25.7
Oxalis oregana Nutt. ex T. & G.	0.7	3.8	0.2	2.4	0.8	2.7	1.1	2.9	1.3	3.3	1.7	3.1	1.8	3.3
Galium triflorum Michx.	0.4	4.2		1.1	0.6	3.5	0.9	6.2	1.4	9.7	1.6	9.7	1.8	11.3
Viola sempervirens Greene	0.1	1.6		0.2		0.4	0.1	1.1	0.1	1.5	0.1	1.3	0.2	2.0
Rubus nivalis Dougl. ex Hook.	0.7	5.7	0.1	2.4	0.2	2.6	0.6	4.6	0.8	5.8	0.7	6.0	1.1	4.7
Coptis laciniata Gray	1.3	13.7	0.3	6.0	0.4	6.6	0.7	7.1	0.6	6.4	0.9	7.3	1.0	6.6
Vancouveria hexandra (Hook.) Morr. & Dec.	0.5	3.8		0.9	0.3	1.1	0.3	1.3	0.3	1.1	0.2	0.7	0.4	1.3
Festuca occidenralis Hook.	0.3	1.8		1.3	0.3	1.5	0.2	0.9	a	0.4	0.1	0.6	0.4	1.5
Tiarella unifoliata Hook.	0.1	1.3		0.2	0.2	1.3		0.4	0.1	0.9	0.1	0.9	0	0
Trillium ovatum Pursh	0.1	0.9		0.6	0	b		0.2	a	0.2	a	0.2	0.1	0.4
Achlys triphylla (Smith) DC.	0.1	0.6	0	b		0.2	0	0	a	0.2	a	0.2		0.2
Smilacina stellata (L.) Desf.	0	b	0	0	0	0	0	0	0	0	0	0		0.2
Adiantum pedatum L.	0	b	0	0	0	0	0	0	a	0.2	a	0.4		0.2
Asarum caudatum Lindl.	0	b	0	0	0	0	0	0	0	0	0	0		0.2
Blechnum spicant (L.) With.	0	0	0	0	0	b	0	b	0	b	0	b	0	b
Polystichum munitum (Kaulf.) Presl	6.9	20.2	1.1	6.0	0.7	3.8	1.2	5.1	1.5	8.0	1.7	7.1	2.5	6.9
Gaultheria shallon Pursh	5.9	20.2	1.1	5.8	0.5	4.0	1.3	5.8	1.6	6.4	2.2	7.7	3.0	9.5
Berberis nervosa Pursh	5.8	26.2	0.7	7.1	0.6	7.5	1.1	11.8	1.5	11.7	2.1	13.3	2.9	15.9
Athyrium filix-femina (L.) Roth	0.4	0.9	0	0	0	0	0	0	a	0.2	a	0.4	0.1	0.9
Xerophyllum tenax (Pursh) Nutt.	0.3	1.1	0	0	0	0	0	0	0	b	0	b	0	b
Chimaphila umbellata (L.) Bart. var. *occidentalis* (Rydb.) Blake	0.2	3.1		0.9	0	b		0.2	0	b	0	b	0	b
Anemone deltoidea Hook.	0.1	0.9	0	b	0	b	0	0	0	b	0	b	0	b
Goodyera oblongifolia Raf.	0.2	1.8	0	0	0	0	0	0	0	0	0	0	0	0
Pyrola asarifolia Michx.	0.1	1.8		0.4	0	b		0.2	a	0.2	0	b	0	0

TABLE 2.—Continued

PLANT SPECIES	1962		1963		1964		1965		1966		1967		1968	
	Cover	Freq.	Cover	Freq.	Cover	Freq.	Cover	Freq.	Cover	Freq.	Cover	Freq.	Cover	Freq.
Synthyris reniformis (Dougl.) Benth.	0.1	1.1	0	[b]	0	[b]	0	0	0	0	0	0	0	0
Chimaphila menziesii (R. Br.) Spreng.	[a]	0.90	0	0	0	0	0	0	0	0	0	0	0	0
Clintonia uniflora (Schult.) Kunth	[a]	0.20	0	0	0	0	0	0	0	0	0	0	0	0
Disporum hookeri var. *oreganum* (Wats.) Q. Jones	[a]	0.2	[a]	0.20	0	0	0	0	0	0	0	0	0	0
Circaea alpina L.	0	[b]	0	0	0	[b]	0	[b]	0	0	0	0	0	0
INVADERS														
Epilobium angustifolium L.	0.1	0.7	0	0	1.0	5.8	11.4	30.1	16.1	54.3	19.4	57.4	19.0	54.3
Epilobium paniculatum Nutt.	0	0	0	0	0.6	8.6	6.5	35.9	6.9	49.5	8.5	46.5	7.3	35.0
Senecio sylvaticus L.	0	[b]	[a]	0.2	1.7	14.6	8.4	49.9	0.1	9.8	0.1	3.1	1.7	17.3
Anaphalis margaritacea (L.) B. & H.	0	0	0	0	[a]	0.4	0.2	1.3	0.4	2.7	1.2	4.9	2.0	6.0
Agoseris grandiflora (Nutt.) Greene	0	0	0	0	0	0	0.1	0.4	0.1	1.1	0.4	1.6	0.9	4.9
Lactuca serriola L.	0	0	0	0	0	0	[a]	0.2	0.2	3.8	0.1	2.4	0.7	4.4
Epilobium watsonii Barbey	0	0	0	0	0.9	6.9	2.9	25.1	1.6	23.7	0.5	9.5	0.7	7.7
Cirsium vulgare (Savi) Airy-Shaw	0	0	0	0	0	0	0.1	1.5	0.3	4.0	0.2	2.0	0.6	3.5
Campanula scouleri Hook.	0	0	0	0	0.1	1.1	0.2	1.8	0.4	2.2	0.4	2.4	0.6	2.7
Gnaphalium microcephalum Nutt. var. *thermale* (E. Nels.) Cronq.	0	0	0	0	0	0	[a]	0.2	[a]	0.2	0.3	2.6	0.6	4.7
Tellima grandiflora (Pursh) Dougl.	0	0	0	0	0	0	0.1	0.4	0.1	0.9	0.2	1.3	0.4	2.2
Cirsium brevistylum Cronq.	0	0	0	0	0	0	[a]	0.9	0.1	0.6	0.2	2.2	0.3	1.5
Lotus crassifolius (Benth.) Greene	0	0	0	0	0	[b]	[a]	0.2	0.4	0.9	0.1	0.6	0.2	0.7
Dicentra formosa (Andr.) Walpers	0	0	0	0	0.1	0.9	0.3	1.6	0.3	1.6	0.2	1.3	0.2	1.3
Collomia heterophylla Hook.	0	0	0	0	0	0	0	0	0	0	0	0	1	0.6
Apocynum androsaemifolium L.	0	0	0	0	0	0	0	0	0	[b]	0.2	0.6	0.1	0.6
Aralia californica Wats.	0	0	0	0	0	0	0	0	0	[a]	0.2	0.1	0.4	
Fragaria sp. [Tourn.] L.	0	0	0	0	0	0	0	0	[a]	0.4	0.1	0.4	0.1	0.7
Acraea rubra (Ait.) Willd.	0	0	0	0	0	0	0	0	0	0	0	0	0	~0.2
Epilobium minutum Lindl. ex Hook.	0	0	0	0	0	0	0.1	0.9		0.6	0	0	[a]	0.7
Bromus ciliatus L.	0	0	0	0	0	0	0	0	0	0	0	[b]		0.6
Luzula campestris (L.) DC.	0	0	0	0	0	[b]	0	[b]	[a]	0.4	0	[b]		0.6
Montia sibirica (L.) Howell	0	0	0	0	0.1	1.3	0.1	1.6	[a]	0.7	[a]	0.2	[a]	0.7
Madia madioides (Nutt.) Grecne	0	0	0	0	0	0	0	0	0	[b]	0	0	[a]	0.2
Holcus lanatus L.	0	0	0	0	0	0	0	0	0	0	0	0	0	~0.2
Sonchus asper (L.) Hill	0	0	0	0	0	0	0	[b]	0	[b]	[a]	0.2	0	0
Lathyrus palyphyllus Nutt. ex T. & G.	0	0	0	0	0	0	0	0	[a]	0.2	0	[b]	0	[b]
Iris tenax Dougl.	0	0	0	0	0	[b]	0	[b]	0	[b]	0	[b]	0	[b]
Agrostis alba L. var. *palustris* (Huds.) Pers.	0	0	0	0	0	0	0	[b]	0	[b]	0	[b]	0	[b]
Carex laeviculmis Meinsh.	0	0	0	0	0	0	0	[b]	0	0	0	0	0	0
Symphoricarpos mollis Nutt. var. *hesperius* (G. N. Jones) Cronq.	0	0	0	0	0	[b]	0	0	0	0	0	0	0	0
TOTAL HERB LAYER (net)	25.9	70.1	4.4	27.9	11.7	52.6	42.9	83.2	44.7	88.2	49.3	92.7	56.9	93.8
TOTAL OF TREE. SHRUBS. AND HERB LAYER COVER (net)	69.6		10.3		15.2		49.3		53.4		62.5		79.5	
GROUND CONDITION														
Moss	21.5	77.8	1.9	11.7	0.7	4.0	1.9	9.8	3.4	17.5	1.7	9.7	1.9	7.5
Litter	93.8	99.6	80.9	97.8	64.9	92.4	65.2	93.1	63.2	95.3	66.6	96.2	67.9	91.3
Bare Ground	2.7	7.5	16.0	35.7	29.0	55.7	27.9	53.0	30.4	60.3	28.1	56.5	27.4	50.8
Stones	2.8	15.5	3.2	16.8	6.1	30.4	6.3	31.0	6.2	32.2	5.3	27.7	4.6	24.0

[a] Value less than 0.05.
[b] Present in trace amounts.

both total understory cover and, to a lesser extent, species composition. These observed differences are mostly attributable to differences in the distribution of understory communities occupying the areas (Table 1). Thus, Unit 3 had the lowest total understory cover *(55%)* with over half the plots supporting vegetation classed as *Acer circinatum-Berberis nervosa* or *Coptis laciniata,* both characterized by sparse plant cover. Unit 1, which had highest amounts of understory cover before logging (85%), largely supported those communities having dense shrub or herb layers. Following logging, however, differences among the three cutting units were not as readily apparent; and by the fifth year after slash burning,

all three units were fairly similar in their gross coverage characteristics.

Data for the three cutting units were combined; therefore results presented represent all 61 acres (25 ha) which were clearcut logged within the 250-acre (101-ha) watershed.

RESULTS

General successional trends

A total of 81 vascular plant species were encountered on the plots between 1962 and 1968. Forty-eight species occurred befcre logging; 6 yr after logging there were 72. Most of the increase in number of plant species occurred during the first 3 years following slash burning (1964 to 1966) when totals were 48, 59, and 67 respectively.

Relatively few prelogging species were absent 5-6 yr after logging (Table 2). Those which were fairly widely distributed before logging but disappeared from the plots include *Rosa gymnocarpa, Disporum hookeri var. oreganum, Goodyera oblongifolia, Pyrola asarifolia, Synthyris reniformis,* and *Chimaphila menziesii.*

All tree species present in the understory before logging were still represented on the plots 3–5 yr following slash burning, and no additional species had invaded the units (Table 2). Tolerant tree species, such as *Tsuga heterophylla,* were greatly reduced in coverage by logging and burning. However, there was a gradual, constant increase in coverage of these residual tree species, although cover values 5 yr after slash burning were still below predisturbance levels (Fig. 1). On the other hand, cover of intolerant species, such as *Pseudotsuga menziesii,* increased substantially after logging and burning. A large portion of the *P. menziesii* cover is contributed by seedlings planted soon after slash burning.

Tall shrub composition consisted of six residual and eight invading species (Table 2). All have gradually increased their coverage since clash burning (Fig. 1). Residual tall shrubs were dominant until the fifth year after slash burning when invading shrub cover surged ahead, largely because of major increases in *Ceanothus velutinus* (7.48% cover in 1968). The most important residual shrubs are *Acer circinatum, Rhododendron macrophyllum,* and *Vaccinium parvifolium.*

In 1968, there were 30 invader and 25 residua1 species in the herbaceous layer (Table 2). Residual herbs and low shrubs were dominant during the first two years after logging and slash burning {Fig. 1). During the ensuing three years (1965-67), cover of invading herbs surpassed that of the residual species, although the latter were making rapid gains. Five growing seasons after slash burning (1968), residual herbs and low shrubs had regained dominance by a considerable margin over the invaders. Principal invading herbaceous species include *Anaphalis margaritacea, Epilobium angustifolium, Epilobium paniculatum,* and *Senecio sy lvaticus.* Residual species carried over from the originai stand which have shown substantial increases in cover and frequency include *Rubus ursinus, Linnaea borealis var. longiflora, Oxalis oregana, Trientalis latifolia, Galium triflorum,* and *Hieracium albiflorum.* Residual species showing large decreases in cover as a result of log-

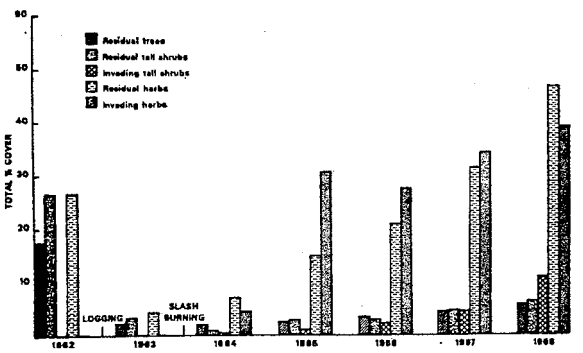

FIG. 1. Total percent crown cover contributed by trees, residual tall shrubs, invading tall shrubs, residual low shrubs and herbs, and invading low shrubs and herbs in three clearcut units during the growing seasons of 1962 (before logging), 1963 (first year after logging), and 1964-1968 (after slash burning).

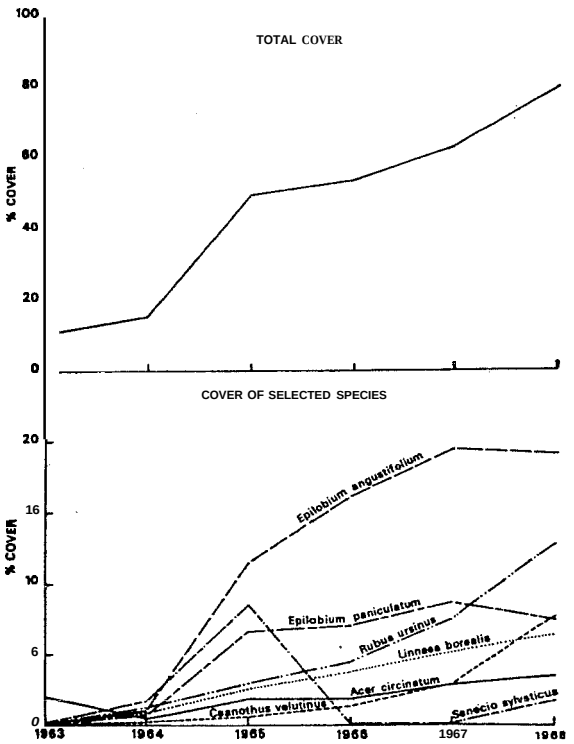

FIG. 2. Total plant cover and cover for selected important species on three clearcut units during the growing seasons of 1963 (first year after logging) and 1964-1968 (after slash burning).

ging include *Polystichum muniturn, Gaultheria shallon,* and *Berberis nervosa.* Although still below prelogging levels, these species have been slowly increasing their coverage each year following slash burning. Residual species which in 1968 had approximately the same distribution and cover as before logging are *Coptis laciniata, Vancouveria hexandra, Viola sempervirens,* and *Rubus nivalis.*

The general trend in plant cover during the 6 yr after logging is shown in Figure 2. The greatest increase occurred two growing seasons after slash burning when total plant cover more than tripled (from approximately 15 to 50%). This dramatic increase can be attributed largely to rapid expansion of invading herbaceous species such as *Epilobium angustifolium, E. paniculatum,* and *Senecio sylvaticus.* However, many residual species, e.g., *Rubus ursinus* and *Linnaea borealis* var. *longiflora,* also increased their coverage at the same time. Increases measured during the third and fourth growing seasons were more modest, amounting to approximately 2 and 4%, respectively. A principal reason for the small increase in cover during the third season was the decrease in *Senecio sylvaticus* cover to 0.1% from 8.4% the previous year (Fig. 2). The sizable cover increase five seasons after siash burning reiiects rapid expansion of *Ceanothus velutinus* and certain residual species -such as *Rubus ursinus.*

The effect of burning and logging disturbance on plant succession

Following broadcast slash burning, plots were classified into four logging and burning disturbance classes: (1) undisturbed—10 plots, (2) disturbed but unburned—21 plots, (3) lightly burned—23 plots, and (4) severely burned—7 plots.

An analysis of average total cover by disturbance class for the five growing seasons shows that plots with largely undisturbed soil conditions have had consistently higher cover values (Fig. 3). The difference was especially noticeable one year after slash burning (1964) when cover on the undisturbed plots was two and five times that found on disturbed-unburned and lightly burned plots, respectively. Although disturbed-unburned plots had considerably more cover than those in lightly burned areas the first year after slash burning, subsequent differences in total cover have been small (Fig. 3). Total cover on severely burned plots, which started at very low levels, has consistently lagged behind cover values for plots in the other condition classes. The substantially lower amounts of tree cover present on severely burned plots has also been striking.

Plant cover on undisturbed soil tends to be dominated by residual species. The occurrence of some of these species has been reduced by logging, but other residual species have responded to removal of the overstory tree layer by greatly increasing their coverage. Species which are largely restricted to areas of undisturbed soil include *Acer circinatum, Vaccinium parvifolium, Tsuga heterophylla, Oxalis oregana,* and *Gaultheria shallon* (Fig. 4). Species not restricted to undisturbed sites but occurring there in greatest quantities include *Cornus nuttallii, Taxus brevifolia, Linnaea borealis* var. *longiflora, Polystichum muniturn,* and *Rubus ursinus.*

The yearly increase in cover on undisturbed plots is partially due to gradual encroachment of invading, largely herbaceous species, as well as expansion of residual species (Figs. 4 and 5). The only shrub invading undisturbed plots in appreciable quantities was *Ceanothus velutinus.* Although heat generated by burning has been found to be an important factor in aiding the germination of *Ceanothus velutinus* seeds (Gratkowski 1962), apparently insolation on unburned sites also is often sufficient to stimulate germination. The most important invading herbs have

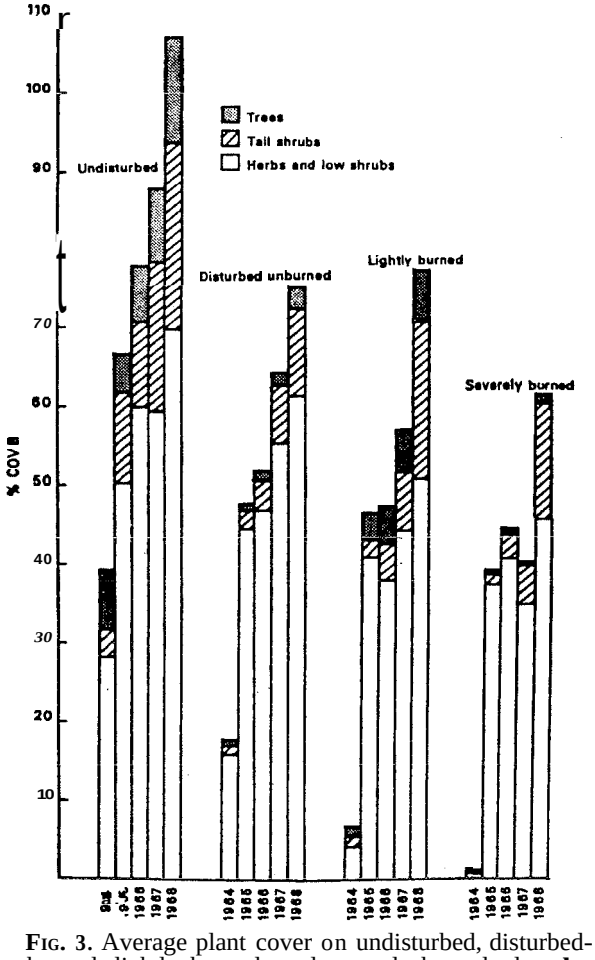

FIG. 3. Average plant cover on undisturbed, disturbed-unburned, lightly burned, and severely burned plots located in three clearcut units during the first 5 years after slash burning (1966-1968).

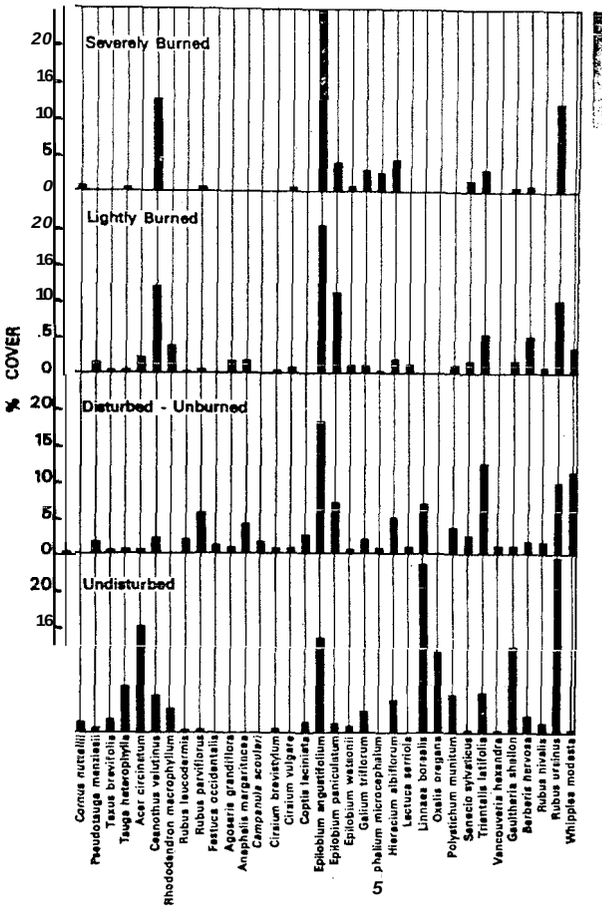

FIG. 4. Percent cover for important plant species occurring on undisturbed, disturbed-unburned, lightly burned, and severely burned plots located in three clearcut units during the fifth growing season after slash burning (1968).

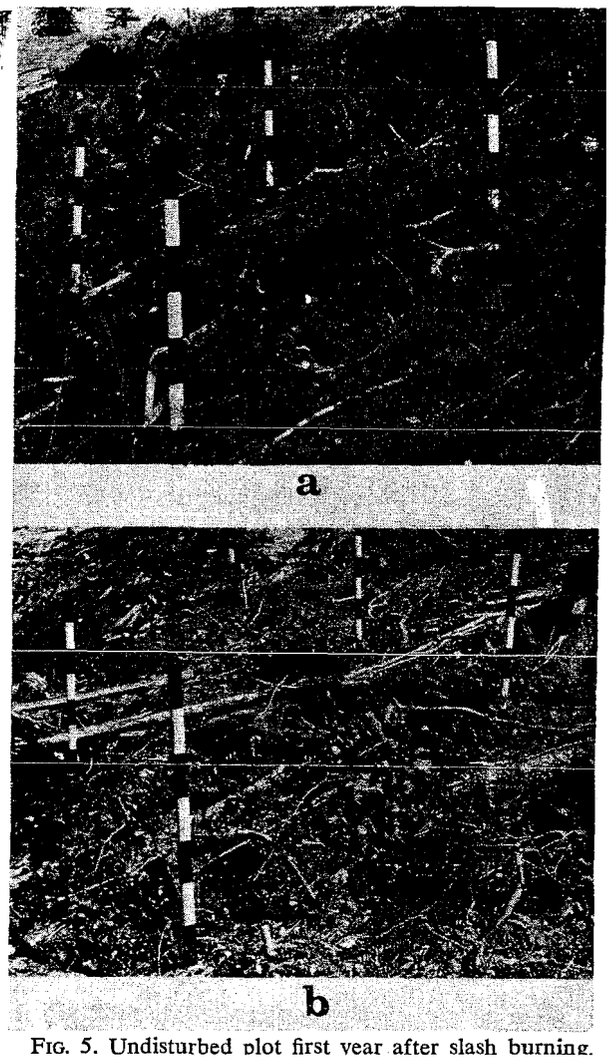

FIG. 5. Undisturbed plot first year after slash burning. 1964 (b) and in 1968 (a). Residual low shrubs, *Gaultheria shallon, Berberis nervosa,* and *Rubus ursinus,* approximately tripled in cover during the elapsed 5 years. Two residual herbaceous species, *Linnaea borealis* and *Trientalis latifolia,* present in 1964 also showed great increases in cover by 1968. Invading species in 1964 consisted of small amounts of *Senecio sylvaticus* and *Epilobium watsonii.* By 1968, large amounts of *E. paniculatum* and *E. angustifolium* were also present.

been Epilobiums, principally *Epilobium angustifoliurn.*

Disturbed-unburned soil areas are characterized by a large number of plant species, both invaders and residuals. This is due *largely* to exposure of a bare mineral soil seedbed coupled with the absence of burning, which allows certain fire-sensitive plants to persist. Five seasons after burning, 56 plant species were encountered on disturbed-unburned plots, as compared with 48 on lightly burned, 39 on undisturbed, and only 24 species on severely burned plots.

Residual herbaceous species which have shown a marked preference for disturbed-unburned sites include the grasses, principally *Festuca occidentalis,* as well as *Coptis laciniata, Trientalis latifolia, Vancouveria hexandra, Viola sempervirens,* and *Whipplea modesta* (Figs. 4 and 6). Invading herbaceous species occurring most frequently in disturbed-unburned areas are *Anaphalis margaritacea,* and *Campanula scouleri.Campanula scouleri* has been unusually site specific and is confined to disturbed-unburned sites.

Disturbed-unburned plots are characterized by a large number of shrub and tree species, but most were present in minor quantities five seasons after slash burning (Fig. 4). The absence of *Rhododendron macrophyllum* is a simple consequence of iis absence from these plots before logging and burning. Shrubs markedly preferring disturbed-unburned sites include *Rubus parviflorus* and *R. leucodermis. Ceanothus velutinus* cover was lowest on these plots.

Plant cover on burned soil tended toward dominance by both herbaceous and woody invading species. Although more species were found on lightly burned sites, some major invaders were most abun-

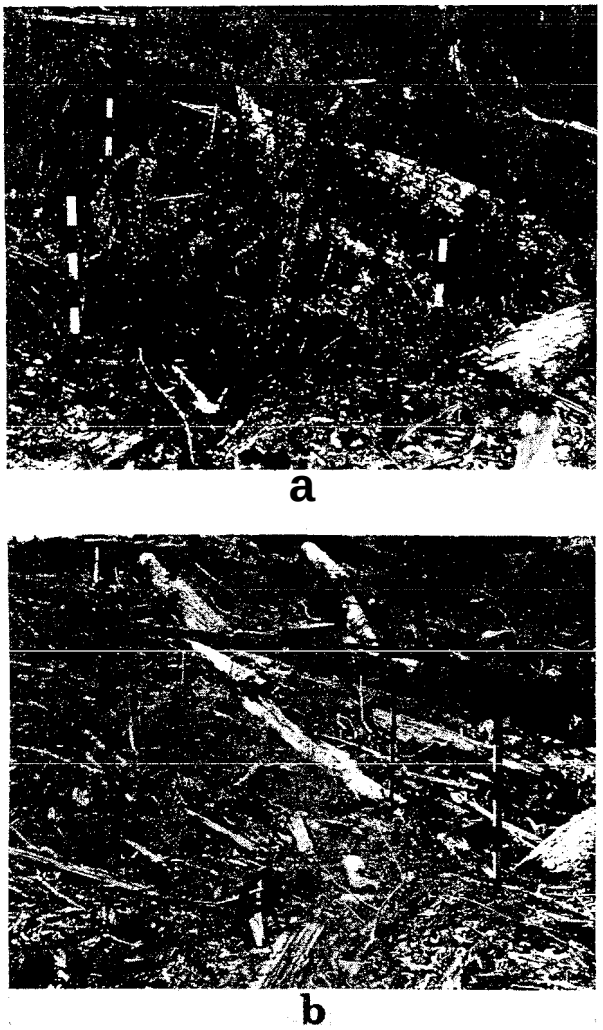

FIG. 6. Disturbed-unburned plot first year after slash burcing, 1964 (b), and in 1968 (a). Residual species showing dramatic increases in cover during the 5 years are *Linnaea borealis, Hieracium albiflorum, Trientalis latifolia,* and *Whipplea modesta.* Residuals showing little change include *Berberis nervosa* and *Rubus nivalis.* Significant invading species in 1964 were *Senecio sylvaricus* (not present in 1968) and *Anaphalis margaritacea* which greatly increased its cover to 31% by 1968. *Epilobium angustifolium,* not present in 1964, had also established itself by 1968.

dant in severely burned areas (Fig. 4). By far the most important invading herb on both lightly and severely burned sites was *Epilobium angustifolium* (Fig. 7). Other herbaceous invaders common to both burning classes include *E. paniculatum, E. watsonii, Cirsium vulgare, Gnaphalium microcephalum* var. *thermale,* and *Senecio sylvaticus.* As in the Oregon Coast Ranges (West and Chilcote 1968), *Senecio sylvaticus* coverage increased rapidly to about 15% in 1965 (two seasons after burning), decreased to negligible amounts in 1966 and 1967, and then increased moderately (to about 1.5%) in 1968. Invading herbs present in lightly burned areas but not found on severely burned sites include *Agoseris grandiflora, Anaphalis margaritacea, Cirsium brevistylum,* and *Lactuca serriola.*

Numbers of residual herbaceous species were significantly reduced in burned areas, below those on unburned sites. The most important residuals in both burned classes were *Galium triflorum, Hieracium albiflorum, Trientalis latifolia,* and *Rubus ursinus. Rubus nivalis* and *Whipplea modesta* have been restricted to lightly burned plots (Fig. 4).

Very few shrub and tree species were present on severely burned plots five seasons after burning (Fig. 4). At this time, invading *Ceanothus velutinus* was by far the most important woody species on both severely and lightly burned sites. Although very scarce on severely burned plots, residual shrubs and trees were more abundant in lightly burned areas; *Acer macrophyllum, A. circinatum,* and *Rhododendron macrophyllum* were common.

Relationship Between successional *pattern and prelogging plant community*

Before logging, each plot was classified into one of five understory communities except where prevented by recent disturbance or atypical vegetation. Each community was represented by 10 to 12 plots (Table 1). Plant cover and frequency data for each growing season have been summarized by prelogging community in an attempt to detect differences in successional trends among the communities.

Because of variations in logging and burning disturbance, relationships between prelogging community and species composition are often obscure, especially for the first few years after tree removal. Naturally, those plots where the forest floor has remained virtually undisturbed support vegetation which most resembles the understory species composition that existed before logging. Very often on undisturbed plots residual species have greatly increased coverage following overstory removal, fully occupied the site, and virtually excluded invaders.

In disturbed-unburned and lightly burned locations, shrub species are frequently the principal component remaining from the prelogging community. On such sites, the herbaceous layer is usually dominated by invading species, and residuals may be relatively inconspicuous (Fig. 8).

Most of the species important in the undisturbed stand have remained, although perhaps not always as conspicuous elements, in the postlogging and burning stand. Only two species considered "characteristic" of one or more of the undisturbed prelogging communities were eliminated from all plots by logging and burning disturbance — Pyrola *asarifolia* and *Synthyris reniformis.* In the case of individual com-

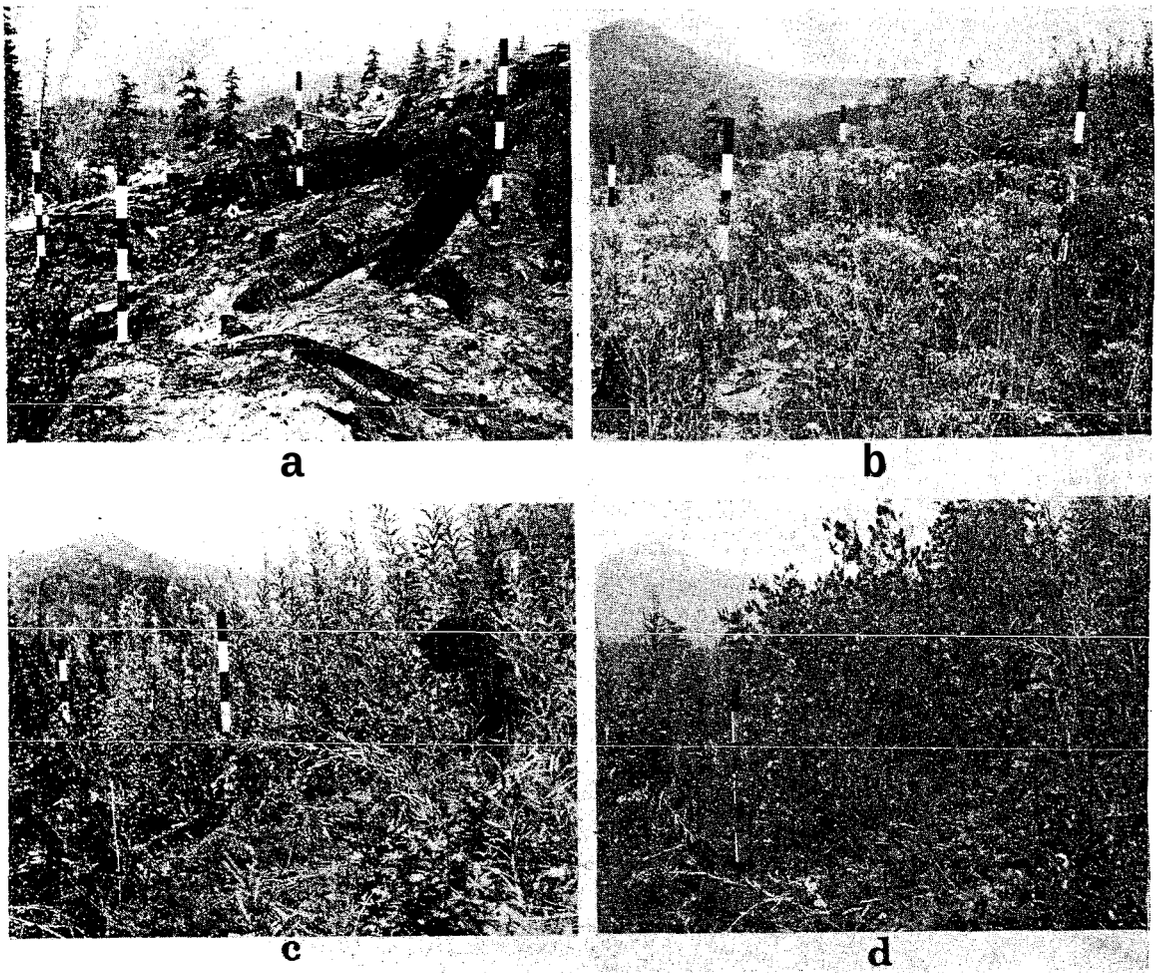

FIG. 7. Lightly burned plot first year after slash burning (a), second year (b), third year (c), and fifth year after slash burning (d). During the first growing season, the plot is virtually bare, containing several *Ceanothus velutinus* seedlings. The second year's vegetation is dominated by *Senecio sylvaticus* (30% cover). Other, less important species include *Epilobium paniculalum* and *E. angustifolium.* During the third growing season, *Senecio* has dropped out of the stand. Dominants are now *E. angustifolium* (37%) and *E. paniculatum* (32%). By the fifth year, *C. yelutinus* is dominant (75%). Important herbaceous species are *E. angustifolium* (38%), *E. paniculatum* (27%), and *Rubus ursinus* (64%).

munities, the number of characteristic species which have dropped out of the stand range from none in the *Rhododendron macrophyllum-Gaultheria shallon* to four in the *Acer circinatum–Gaultheria shallon* community (Table 3). Although decreases in coverage due to disturbance are generally marked, the relative importance of certain species within the five communities is often about the same as before logging. For example, *Acer circinatum* cover 5 yr after slash burning was highest on plots in the *Acer circinatunz–Berberis nervosa* community and lowest on *Coptis laciniata* plots—the same as before iogging (Table 3).

When the prelogging cover values for characteristic species within all five communities are compared with the cover figures 5 yr after burning, we find:

Coverage approximateiy the same—i i.0%
Coverage substantially lower in 1968—54.4%
Coverage substantially higher in 1968—-20.6%
Species absent in 1968—-13.2%

Therefore, in 31.6% or almost one-third of the cases, comparisons show the same or increased cover values for characteristic species 5 yr after slash burning. *Galium triflorum, Trientalis latifolia,* and *Rubus iirsinus* have shown the greatest increase in both cover and distribution.

Certain broad differences in successional trends among the prelogging communities are detectable 5 yr after slash burning, despite the obscuring effects of widely distributed invading species (Fig. 9). *Ceanothus velutinus* is virtually absent frcm the more moist *Polystichurn munitum* and *Coptis laciniata*

TABLE 3. Cover and frequency values for characteristic plant species on plots representative of five forest communities during the growing seasons of 1962 (before logging) and 1968 (5 years after slash burning)

	Rhododendron macrophyllum-Caultheria shallon				*Acer circinatum-Gaultheria shallon*				*Acer circinatum-Berberis nervosa*				*Coptis laciniata*				*Polysrichum munitum*			
	1962		1968		1962		1968		1962		1968		1962		1968		1962		1968	
Characteristic species	Cover	Freq.	Cover	Freq.	Cover	Freq.	Cover	Freq.	Cover	Freq.	Cover	Freq.	Cover	Freq.	Cover	Freq.	Cover	Freq.	Cover	Freq.
											Per cent									
Acer circinatum	18.2	45.4	2.0	18.2	*22.7	63.6	0.6	18.2	'35.5	100.0	12.1	40.0	0.4	8.3	0	0	* 9.3	46.4	6.2	27.3
Castanopsis chrysophylla	• 0.8	36.4	0.8	9.1	• 1.0	18.2	0.4	9.1	* 1.5	10.8	0.8	10.0	0	0	0	0	0			0
Cornus nuttallii	0	0	0	0	• 6.4	9.1	0.4	9.1	0	0	0.1	10.0	0	0	0.1	8.3	* 3.6	9.1	1.4	9.1
Rhododendron rnacrophyllum	*43.0	100.0	9.9	63.6	1.8	18.2	0	0	1.7	30.0	0	0	0.8	16.7	0.1	8.3	0	0	0.1	9.1
Taxus brevifolia	• 1.4	18.2	0.2	18.2	'10.4	18.2	0	0	* 0.5	10.0	0.3	30.0	• 1.0	25.0	0.2	25.0	0	0	1.4	9.1
Thuja plicata	2.2	18.2	0	0	0	0	0	0	5.0	10.0	0	0	2.1	8.3	0	0	* 7.3	9.1	0	0
Tsuga heterophylla	* 3.4	45.4	0.2	9.1	• 6.5	27.3	0	0	• 2.0	20.0	0.7	10.0	* 7.8	66.7	2.4	41.7	'18.9	63.6	0.3	27.3
Vaccinium parvifolium	* 2.6	45.4	0.6	9.1	• 1.0	36.4	0	0	• 5.0	10.0	0.3	10.0	* 1.4	25.0	0	0	* 3.7	27.3	0.6	18.2
Fesruca occidentalis	0	0	0	0	* 1.1	5.0	1.9	7.1	0	0	0	0	0	0	0	0	0.4	5.0	0.1	1.0
Athyriurn filix-femina	0	0	0	0	0	0	0	0	0	0	0	Tr	0	0	0.1	0.9	* 2.3	5.0	0.3	4.0
Coptis laciniata	* 0.6	11.1	1.1	5.0	0.1	2.0	0	0	* 2.0	23.3	2.0	14.4	* 0.3	4.6	0	0	* 4.3	33.3	2.4	17.2
Galium triflorum	0	0	0.2	2.0	0	Tr	0	0	0	0	1 8	15.6	0	0	0.8	4.6	• 1.2	11.1	6.2	34.3
Linnaea borealis	* 1.3	13.1	6.3	9.1	• 3.1	32.3	1.5	6.1	• 0.3	2.2	0	Tr	* 2.2	16.7	5.4	9.3	* 1.8	24.2	21.2	37.4
Oxalis oregana	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	* 2.7	10.0	10.2	18.2
Polysrichum munitum	* 1.1	3.0	1.4	3.0	* 3.6	16.2	0.2	2.0	*0.5	5.6	0.4	2.2	• 0.3	4.6	0.1	1.8	*30.7	74.8	11.3	28.3
Pyrola asarifolia	0.4	7.1	0	0	0	0	0	0	* 0.1	3.3	0	0	0	0	0	0	0	0	0	0
Synfhyris reniformis	0	0	0	0	• 0.3	5.0	0	0	0	0	0	0	0.1	0.9	0	0	0	0	0	0
Trientalis latifolia	0.1	1.0	4.7	26.3	* 0.6	6.1	5.1	33.3	0	0	13.0	36.7	Tr	0.9	6.4	38.9	0.1	2.0	6.9	38.4
Vancauveria hexandra	0	0	0	0	0	0	0	0	0.1	1.1	0	0	0	0	0	0	* 1.4	11.1	2.3	7.1
Viola sempervierns	0	0	0	0	* 0.2	3.0	0.2	2.0	Tr	1.1	Tr	1.1	0	Tr	0.4	5.6	0.1	4.0	0.4	2.0
Xerophyllum tenax	0	0	0	0	• 1.8	6.1	0	Tr	0	0	0	0	0	0	0	0	0	0	0	0
Chimaphila menziesii	0	0	0	0	0	Tr	0	0	• 0.1	3.3	0	0	0	0.9	0	0	Tr	1.0	0	0
Chimaphila umbellata	* 0.5	7.1	0	Tr	* 0.6	8.1	0	Tr	Tr	1.1	0	0	0	0.9	0	0	0	0	0	0
Caultheria shallon	* 5.4	32.3	0.6	5.0	'25.6	65.7	9.1	27.3	* 1.8	12.2	0.4	3.3	0	0	0	0	0	0	4.8	9.1
Berberis nervosa	• 7.1	38.4	6.3	29.3	* 8.3	34.3	3.9	21.2	'10.2	25.6	2.5	15.6	• 2.9	18.5	1.7	11.1	* 1.7	14.1	0.3	3.0
Rubus nivalis	* 1.3	11.1	1.8	8.1	'1.4	8.1	0.3	3.0	* 0.3	3.3	3.3	8.9	Tr	0.9	0.3	2.8	* 0.9	8.1	0.5	4.0
Rubus ursinus	* 0.1	1.0	7.5	26.3	* 1.4	13.1	19.1	48.5	*Tr	1.1	11.8	27.8	0.1	0.9	3.5	18.5	'0.7	6.1	23.1	68.7

'Considered to be "characteristic species" within this forest community.

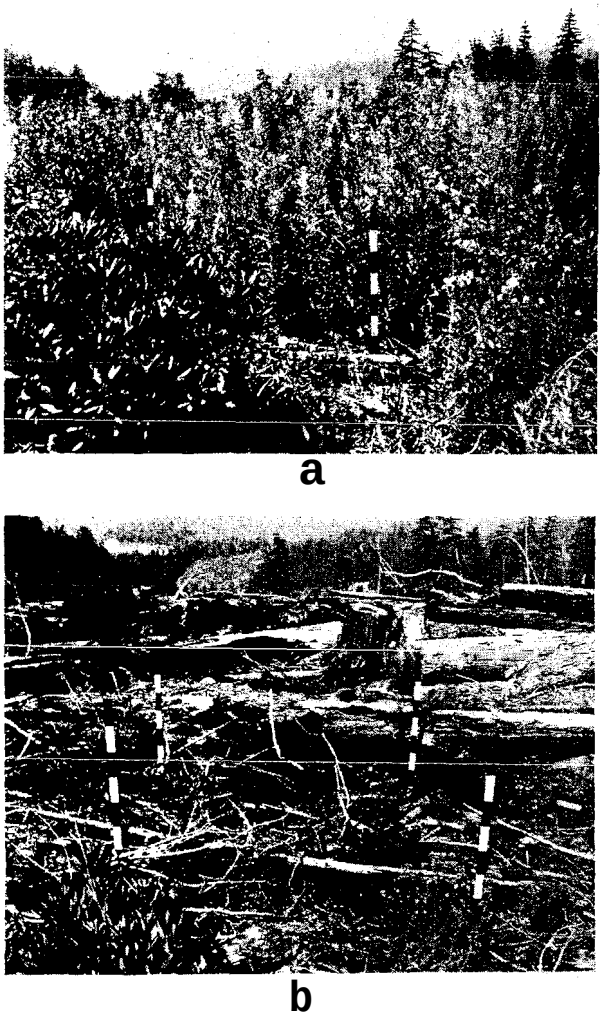

FIG. 8. **A** lightly burned plot typical of the *Rhododendron macrophyllum-Gaultheiia shallon* community the first year after slash burning (b) and 5 years after slash burning (a). *R. macrophyllum* cover increased from 3 to 35% (vs. 85% before logging). Most abundant residual low shrubs, *Berberis nervosa* and *Rubus niyalis,* increased their cover to levels appreciably higher than those measured before logging. By the fifth year after burning, the dominant herbaceous species is *Epilobium angustifolium* with an average cover of 68%.

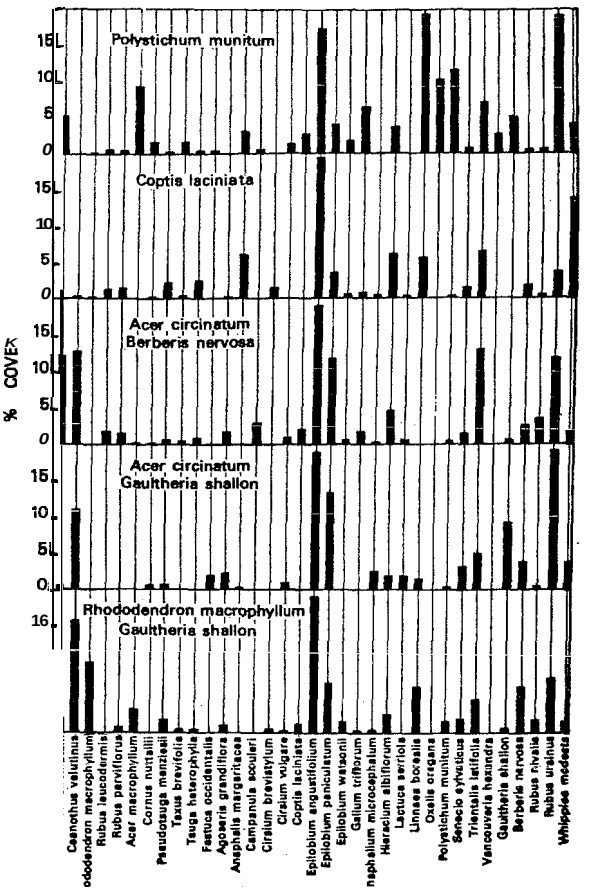

FIG. 9. Percent cover for important plant species occurring on plots representing five forest communities during the fifth growing season after slash burning (1968).

communities. This confirms 0bservations of Zavitkovski and Newton (1968) and others who have ncted its preference for relatively dry sites and burned areas. *Rubus leucodermis* and *Anaphilis margaritacea* are largely restricted to more moist sites characterized by the *Acer circinatuin–Berberis nervosa, Coptis laciniota* and *Polystichum munitum* communities. On the other hand, species such as *Agoseris grandiflora* and *Gnaphalium microcephalum* var. *thermale* are largely restricted to plots supporting dry site com*munities — Rhododendron macrophyllum-Gaultheria shallon* and *Acer circinatum-Gaultheria shallon* (Fig. 9). Other invading species are widely distributed, showing little selectivity for site requirements. *Epi-Iobium angustifolium,* occurring in large amounts on plots which supported all five communities, is the most outstanding example.

DISCUSSION

Many descriptions of secondary succession following logging identify a shrub stage beginning 5–10 yr after logging. Some have described it as a stage of tall shrub and tree codominance, followed by the attainment of sole dominance by trees as shrubs are overtopped. Nothing resembling a shrub stage has been attained when the cutting units studied here are considered as a whole. Even 5 yr after slash burning (1968) tree and tall shrub cover totaled only 22.6% versus 66.9% cover in the herbaceous layer (Table 2). However, average cover values for entire clearcut units may be misleading. On many of the heavily burned, drier sites shrubs dominated by the fifth growing season after slash burning, with much of the cover contributed by *Ceanothus velutinus.* These drier sites typically supported *Rhododendron macro-*

phyllurn-Gaultheria shallon and *Acer circinatum-Gaultheria shallon* understory communities before logging. On the other hand, moister sites, especially those escaping serious disturbance, now support nearly closed stands of ferns, herbs and low shrubs. Herb dominance will probably continue on these areas until trees attain dominance, and it is doubtful that they will ever pass through a "shrub stage."

The resurgence of residual herbaceous species following an initial period of site dominance by invading species has been remarkable. Although invading herbs provided a majority of cover 2-4 yr after burning (Fig. I), residual species regained dominance by the fifth year. Yerke's (1960) conclusions, alter working in a nearby area, differed significantly in that he reported, "Herbaceous survivors formed a relatively unimportant part of the vegetative cover." This discrepancy may be partially due to differences in classification of species as "residual" and "invading.'' For example, Yerkes listed *Hieracium* as an *invader, whereas* it is, in fact. of widespread occurrence in small amounts in undisturbed forests.

It is interesting that when plant distribution data following logging and burning are considered. they appear to correlate with two main site groupings: (1) the drier habitats previously occupied by the *Rhododendron macrophyllum-Caultheria shallon, Acer circinatum-Gaultheria shallon,* and *Acer circinatum-Berberis nervosa* communities, and *(2)* the moister habitats previously occupied by the *Coptir lacinata* and *Polystichum munitum* communities. This apparent site dichotomy is reflected in distribution patterns of a number of invader and residual species including *Ceanothus velutinus, Rubus leucodermis, Agoseris grandiflorus, Anaphalis rnargaritacea. Lactuca serriola, Oxalis oregana,* and *Vancouveria hexandra* (Fig. 9). The *Acer circinatum-Berberis nervosa* and *Coptis laciniata* groupings were previously interpreted as constituting two successional stages within the same hibitat type. However, the substantial differences in sera1 vegetation developing from these two prelogging communities strongly suggests that they are, in fact, indicative of distinctly different effective environments.

Relationships between early stages of secondary succession and plant communities present in *Pseudotsuga menziesii-Tsuga heterophylla* stands before logging have been studied on Vancouver Island by Mueller-Dombois (1965) and in the southern Oregon Coast Ranges by Bailey (1966). In both of these coastal areas, Characteristic forest plants were present in sufficient quantities following logging and burning to permit successful identification of the preexisting communities. An examination of individual milacre plot data in the present study has indicated that correct identification of prelogging communities would only be possible for less than one-half the plots. Ability to recognize vegetation units is, of course, closely tied to degree of logging and burning disturbance. In most cases prelogging communities can be identified in areas with essentially undisturbed and lightly burned ground conditions. However, where the area has been severely disturbed by logging or burning, characteristic species are often so scattered that identification of the prelogging vegetational units becomes extremely difficult. Ability to recognize a prelogging community is also somewhat dependent upon its position within the entire spectrum. For example, communities occupying the most xeric sites (i.e., *Rhododendron macrophyllum-Gaultheria shallon)* and the most mesic (i.e., *Polystichum munitum)* are much easier to identify after logging than it is to recognize those prelogging plant groupings characteristic of intermediate sites.

ACKNOWLEDGMENTS

I wish to thank A. B. Levno for his aid in the collection of field data, J. F. Franklin for many helpful discussions, and A. W. Bailev and W. **O.** Chilcote for their comments on the manuscript.

LITERATURE CITED

Bailey, Arthur Wesley. 1966. Forest associations and secondary plant succession in the southern Oregon Coast Range. Ph.D. Thesis., Ore. State Univ., Corvallis, Ore. 166 p., University Microfilms, Ann Arbor, Mich. (Dissertation Abstr. ***27:*** 2605B-2606B).

Dyrness, C. T. 196.5. The effect of logging and slash burning on understory vegetation in the H. J. Andrews Experimental Forest. Pacific Northwest Forest & Range Exp. Sta. USDA Forest Serv. Res. Note PNW-31. 13 p.

Franklin, Jerry F., and C. T. Dyrness. 1971. A checklist of vascular plants on the H. J. Andrews Experimental Forest, western Oregon. Pacific Northwest Forest & Range Exp. Sta. USDA Forest Serv. Res. Note PNW-138. 37 p.

Gratkowski, Henry John. 1962. Heat as a factor in germination of seeds of' *Ceanothus velutinus var. laevi-.gatus* T. & G. Ph.D. Thesis, Ore. State Univ., Corvallis, Ore. 122 **p.**

Ingram, Douglas C. 1931. Vegetative changes and *grazing* use of Douglas-fir cutover land. **J.** Agr. Res. 43: 387–417.

Isaac, L. A. 1940. Vegetative succession following logging in the Douglas-fir region with special reference to fire. J. Forest. 38: 716–721.

Kienholz, Raymond. 1929. Revegetation after logging and burning in the Douglas-fir region of western Washington. Ill. State Acad. Sci. Trans. 21: 94–108.

Morris, William G. 1958. Influence of slash burning on regeneration, other plant cover, and fire hazard in the Douglas-fir region. USDA Forest Serv. Pacific Northwest Forest & Range Exp. Sta. Res. Pap. 29. 49 p.

Mueller-Dombois, Dieter. 1965. Initial stages of secondary succession in the Coastal Douglas-fir and Western Hemlock Zones. *In* Ecology of Western North America. Vol. 1. ed. by V. J. Krajina, p. 38–41. Univ. Brit. Co!umbia, Dept. Bot.

Rothacher, Jack, C. T. Dyrness, and Richard L. Fredriksen. 1967. Hydrologic and related characteristics of three small watersheds in the Oregon Cascades. USDA Forest Serv. Pacific Northwest Forest & Range Exp. Sta. 54 p.

Steen, Harold K. 1966. Vegetation following slash fires in one western Oregon locality. Northwest Sci. 40: 113–120.

West, Neil E., and William W. Chilcote. 1968. *Senecio sylvaticus* in relation to Douglas-fir clear-cut succession in the Oregon Coast Range. Ecology 49: 1101-1107.

Yerkes, Vern P. 1960. Occurrence of shrubs and herbaceous vegetation after clear cutting old-growth Douglas-fir in the Oregon Cascades. USDA Forest Serv. Pacific Northwest Forest & Range Exp. Sta. Res. Pap. 34. 12 p.

Zavitkovski, J., and M. Newton. 1968. Ecological importance of snowbrush, *Ceanothus velutinus,* in the Oregon Cascades. Ecology 49: 1134-1 145.

☆ U. S. GOVERNMENT PRINTING OFFICE: *1973-797-948 /41* REGION 10