Robert E. Frenkel, Department of Geography,
Oregon State University, Corvallis, Oregon 97331

and

Eric F. Heinitz, Lt. (j.g.), U.S. Coast Guard, Marine Inspection Office,
Battery Park Building, New York, New York 10004

Composition and Structure of Oregon Ash (*Fraxinus latifolia*) Forest in William L. Finley National Wildlife Refuge, Oregon

Abstract

We describe two Oregon ash (*Fraxinus latifolia*) plant communities at William L. Finley National Wildlife Refuge in the central Willamette Valley which differ in habitat, composition, and structure. The *Fraxinus latifolia/Carex obnupta* community type, with many young trees (average core age 59 years) of small diameter (average 14 cm dbh), has an open understory of scattered *C. obnupta* patches and occupies moist overflow sites. The more floristically rich *Fraxinus latifolia/Symphoricarpos albus* community type, with large diameter (average 20 cm dbh) and older trees (average core age 72 years), has a thick shrub understory and occupies better drained, but still moist, sites. Both forest community types are young; however, the *C. obnupta* community has recently expanded into former wet prairie with cessation of aboriginal burning and historic grazing.

Introduction

Oregon ash (*Fraxinus latifolia* Benth.) ranges from northern Washington to the San Bernardino Mountains, California. Forests dominated by Oregon ash are particularly well developed in the interior valleys of western Oregon where the species occupies riparian strips and adjacent poorly drained bottom lands. Associated moist site trees are *Acer macrophyllum, Alnus rubra, Populus trichocarpa,* and *Salix* spp., while *Abies grandis, Pseudotsuga menziesii,* and *Quercus garryana* may be present on drier sites (Franklin and Dyrness 1973, Owston in press). Although seldom extensive, *Fraxinus* forests are prominent landscape features, providing a major forest component to riparian habitat and benefitting fish, wildlife, and recreational resources (Frenkel *et al.* 1985). Surprisingly, characteristics of these forests have not previously been examined.

A modified maritime climate prevails over the Willamette Valley with wet, mild winters and warm, relatively dry summers, and a slight rain shadow effect. Representative climatic data, following the standardized system of Walter and Lieth (1967), are summarized in Figure 1 for Hyslop Agronomy Farm, Corvallis. Based on precipitation and temperature criteria, surplus moisture occurs from September to June. In riparian and bottom land habitats typically occupied by *Fraxinus,* this surplus is accentuated by seasonal flooding from December to April and by high water tables in early summer. Potential anaerobic conditions may occur as suggested by gleying in soil profiles. A brief drought period ensues during the summer months when soils may desiccate for short periods; but, extensive drought is not present.

Soils of central Willamette Valley *Fraxinus* forests are most commonly grouped in the Waldo-Bashaw association, poorly drained silty clay loams and clays. The principal soil series related to the Refuge ash forests is Bashaw silty clay, a deep, poorly drained soil with montmorillonite clays classified as a Typic Pelloxerert. The black, heavy, silty clay loam surface layer reaches depths of between 25 and 40 cm. Underlying horizons are black to very dark gray with a layer of silty clay above clay. When wet, the soil becomes very sticky and plastic. Upon drying it cracks and becomes very hard (Knezevich 1975).

One of the best examples of Oregon ash forest is in William L. Finley National Wildlife Refuge, 16 km south of Corvallis in the central Willamette Valley, where *Fraxinus* spans a strip approximately 400 m wide adjacent to Muddy Creek and Gray Creek and nearby shallow swales and overflow lands (Figure 2). The trees are thickly draped by foliose lichens *Evernia prunastri* (L.) Ach., *Ramalina menziesii* Tayl., *Usnea ceratina* Ach., and *U. subfloridana* reflecting moist atmospheric conditions.

Vegetation in the Refuge is typical of the interior valleys of western Oregon (Franklin and Dyrness 1973); several physiognomic types

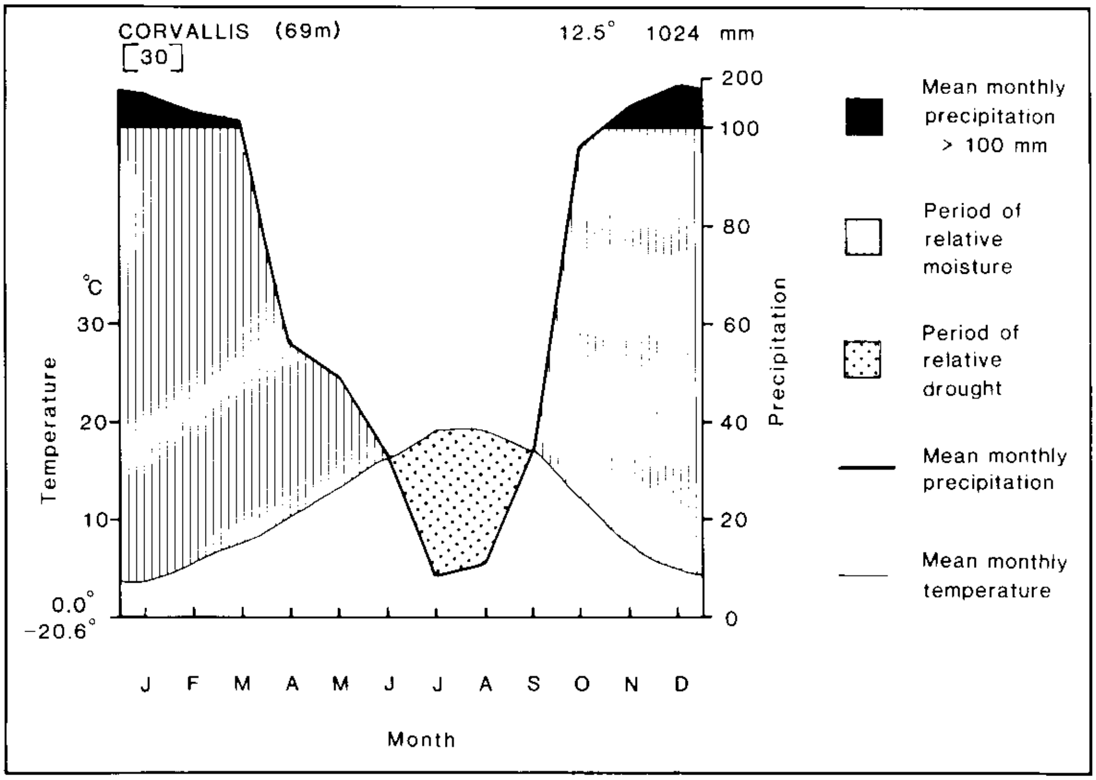

Figure 1. Climograph for Hyslop Agronomy Farm, Corvallis, Oregon, following the standardized Walter and Lieth system.

mapped by Exler (1982) are generalized in Figure 2. Oak woodland, dominated by *Quercus garryana,* has been described and classified by Thilenius (1968) and is the closest of these types in structure and composition to the ash forest. Thilenius identified four oak community types in the interior valleys of western Oregon which, in order of increasing moisture, are: *Rhus diversiloba; Amelanchier alnifolia/Symphoricarpos albus; Prunus avium/Symphoricarpos albus;* and *Corylus cornuta* var. *californica/Polystichum munitum.* All are regarded as seral and occupy well drained slopes and ridges.

Wet prairie, maintained as grassland by historic fire and grazing, is also considered seral, but to *Fraxinus* forest (Moir and Mika 1972, Franklin and Dyrness 1973, Towle 1982, Marshall 1985). These heavily disturbed prairies, dominated by *Deschampsia caespitosa, Hordeum brachyantherum* and *Carex* spp., contain many alien species and bear little structural resemblance to ash forest.

The *Fraxinus latifolia* forest is transitional in moisture status between oak woodland and wet prairie. Prior to early settlement, *Fraxinus* forests fringed almost all water courses in the Willamette Valley. The General Lands Office township and range survey conducted in the Refuge area in 1853, documents a 100 m wide strip of *Fraxinus* forest along Muddy Creek. Survey notes and plat maps are available and were examined at the Oregon State Office of the Bureau of Land Management. Additionally, historic accounts of the Refuge area and old aerial and ground photographs show many of the present stands more limited in extent than present. Aboriginal burning apparently kept *Fraxinus* from expanding into prairie (Habeck 1961, Johannessen *et al.* 1971, Towle 1982). In the late-19th century, intense grazing by livestock replaced fire as a dominant influence in the Refuge area (Towle 1982). Gradually, grazing intensity diminished and, in the early 1960's, ceased altogether (personal communication John Cornely, Refuge Biologist).

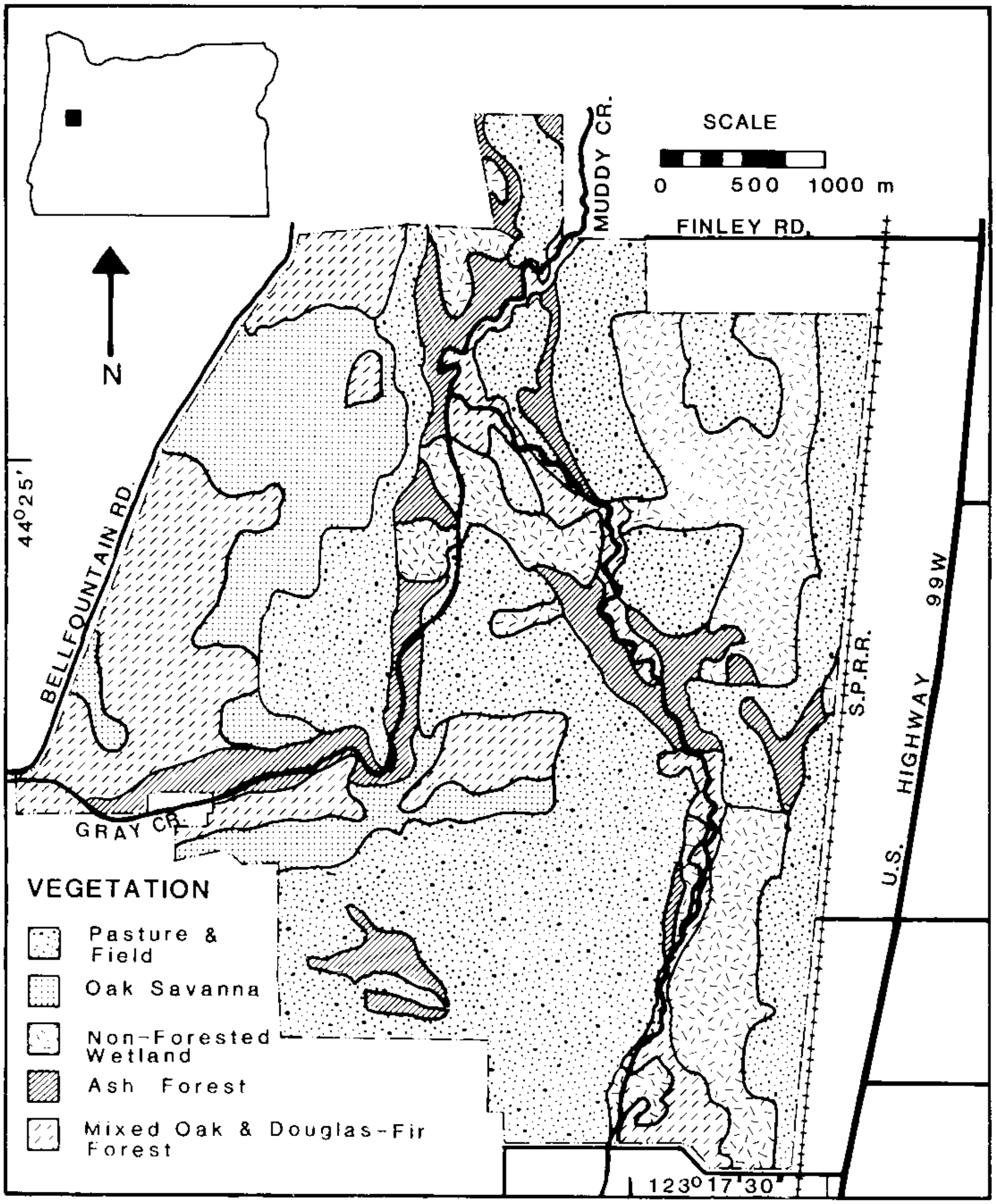

Figure 2. Vegetation of W. L. Finley National Wildlife Refuge generalized after Exler (1982) and location in Oregon.

Unchecked by fire and cattle, ash invaded prairie, setting the stage for the present vegetation.

The questions addressed in this paper are based on the above relationships: (1) What are the structure and composition of *Fraxinus* forests in the Finley Refuge? (2) How does the distribution of *Fraxinus* forests relate to the moisture gradient? (3) What is the relationship between

Fraxinus forests and *Quercus* forests? (4) How does the present distribution reflect historic practices of burning and grazing?

METHODS

To gain familiarity with the range in composition and structure of ash forests, a general survey of *Fraxinus* forest distribution was first conducted throughout the Willamette Valley. In 1982, 19 stands were selected in the W. L. Finley National Wildlife Refuge based on their relative homogeneity in habitat, composition, structure, and adequacy of stand size. Because of its accessibility and extent, one additional stand was located at The Nature Conservancy Cogswell-Foster Preserve, 19 km southeast of the Refuge.

Circular, 12.6 m radius macroplots of 500 m^2 were located randomly within selected stands, one macroplot per stand, and the following data recorded for live and dead trees: total percent canopy cover; percent canopy cover by species; diameter at breast height (dbh) of all trees by species >5 cm dbh; number of "reproductive" stems per macroplot (stems <5 cm dbh); number and dbh of downed dead wood >5 cm dbh; vigor class (vigorous, impaired, dead); and height and increment core-age of two-to-four of the largest diameter ash trees in each macroplot. Core-ages were determined in the field with the aid of hand lens. Only in a few cases were multiple cores taken from the same tree. Understory composition was recorded from 12, one m^2 microplots placed at four, seven, and ten meter intervals along four transects set in cardinal directions within the macroplot. Cover was estimated for each species by Daubenmire (1959) canopy cover classes. Taxonomy and nomenclature follow Hitchcock and Cronquist (1973). We use the term 'community' to define a general assemblage of plants and 'community type' or 'type' for the abstract classificatory unit comparable to the plant association.

Prior to analysis, mean percent cover was transformed to octave values (Gauch 1982). Floristic data were used to classify macroplots into community types with the aid of several multivariate programs including: TABORD, which structures phytosociological data in the form of an association table based on sample similarity (Maarel *et al.* 1978); CLUSTER, a polythetic agglomerative clustering program using a Bray-Curtis dissimilarity measure and a flexible fusion strategy, $B = -0.25$ (Boesch 1977, Keniston 1978); and TWINSPAN, an iterative polythetic divisive technique based on reciprocal averaging (Hill 1979a). Additionally, we analyzed floristic data with DECORANA, an ordination achieved by detrended correspondence analysis (Hill 1979b). Within-community similarity was determined by an abundance-weighted similarity ratio (Maarel *et al.* 1978).

Species diversity was analyzed by PRHILL, an unpublished computer program developed by B. G. Smith that calculates jackknife estimates of M. O. Hill's diversity numbers (Hill 1973, Alatalo 1981, Heltsche and Forrester 1983) for each community type. By simulation, Heltsche and Forrester have shown that jackknife estimates of diversity permit comparison of communities under a wide variety of plot sizes. Four measures of diversity are displayed: mean number of species per macroplot; expected total number of species in a community type (N_0); inverse of Simpson's diversity index (N_2); and M. O. Hill's evenness ratio (N_2/N_1).

Tree diameter data were grouped in 5 cm diameter classes and plotted by frequency histograms for each macroplot and subsequently aggregated by community type. Basal area and density were determined from measured trees in each plot. An age-size relationship, calculated from 60 trees, was used to characterize the age structure of plant community types. A variety of average community characteristics were assessed with Student's t-test in which significance was judged at $p = 0.05$.

RESULTS

Plant Communities

The *Fraxinus latifolia/Carex obnupta* and the *Fraxinus latifolia/Symphoricarpos albus* community types are identified based on floristic classification (Table 1 and Figure 3). Both community types show a relatively low level of within-community similarity, averaging 61 percent (Table 2). This heterogeneity is further demonstrated by spread-out plot distribution in the ordination (Figure 4), the types being distinguished more by differences in species abundance than by species presence-absence. Since classifications based on TABORD and CLUSTER were in close agreement, only the CLUSTER classification is

TABLE 1. Percent constancy and mean percent cover in *Fraxinus latifolia* community types. Only species with at least two percent cover in a community type are included.

Stratum and Species	Community Type *Fraxinus latifolia/ Carex obnupta* (n=9) const./mean cov.	*Fraxinus latifolia/ Symphoricarpos albus* (n=11) const./mean cov.
TREES		
Fraxinus latifolia	100/84	100/80
Quercus garryana	—	27/ 6
SHRUBS		
Crataegus douglasii	56/ T	27/ 4
Spiraea douglasii	44/ 2	36/ 2
Rubus ursinus	33/ T	91/22
Rosa eglanteria	33/ T	64/ 6
Symphoricarpos albus	22/ T	82/26
Lonicera involucrata	—	18/ 3
HERBS		
Carex obnupta	89/36	45/10
Galium trifidum	89/ 2	64/ 4
Carex deweyana	78/ 4	73/10
Eleocharis acicularis	67/ 4	55/ 2
Ranunculus uncinatus	67/ 2	100/ 4
Stellaria calycantha	56/ T	82/ 4
Oenanthe sarmentosa	33/12	27/ 3
Elymus glaucus	33/ 4	45/ 1
Carex unilateralis	33/ 3	45/ 8
Carex leporina	33/ 2	18/ T
Veronica scutellata	33/ T	55/ 2
Montia sibirica	22/ T	64/14
Tellima grandiflora	22/ T	55/ 4
Stachys cooleyae	22/ T	27/ 3
Myosotis laxa	22/ T	9/ 2
Geum macrophyllum	11/ T	82/ 3
Agrostis tenuis	11/ T	64/ 5
Galium aparine	11/ T	64/ 4
Polysticum munitum	—	55/ 4
Perideridia gairdneri	—	55/ 3

TABLE 2. Selected floristic characteristics of *Fraxinus latifolia* community types.[a]

Characteristic	Community Type *Carex obnupta* (n=9)	*Symphoricarpos albus* (n=11)
Within-Community Similarity (%)	66.1	56.8
Mean No. Species per Macroplot	13.7	22.5
Total No. Species Expected in Type (N_0)	50.8 s.e. = 3.2	66.9 s.e. = 4.2
Inverse of Simpson's Diversity Index (N_2)	14.7 s.e. = 1.6	32.9 s.e. = 2.5
Evenness Index $\frac{(N_2)}{(N_1)}$	0.525	0.743

[a]Within-community similarity is based on an abundance-weighted similarity ratio (Maarel *et al.* 1978). Diversity indexes are based on PRHILL (see methods).

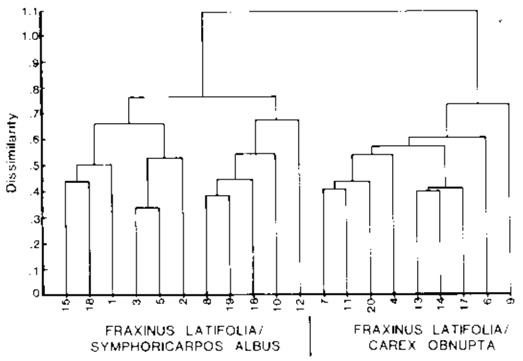

Figure 3. Cluster dendrogram based on CLUSTER (Keniston 1978) using the Bray-Curtis dissimilarity index and flexible clustering strategy, B = −0.25.

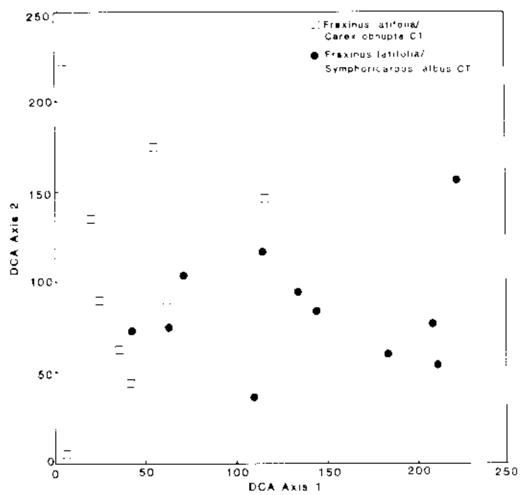

Figure 4. Detrended correspondence analysis ordination of W. L. Finley National Wildlife Refuge *Fraxinus latifolia* macroplots. CLUSTER and TABORD community classification is superimposed by symbol.

displayed. Several floristically different macroplots were classified differently by TWINSPAN when compared to the TABORD and CLUSTER classifications.

The *Fraxinus latifolia/Carex obnupta* community type is marked by low shrub cover (3%) and high cover and constancy of *Carex obnupta.* Other common species include *C. deweyana, Eleocharis acicularis,* and *Galium trifidum* (Table 1). *Carex obnupta* typically grows in dense patches ranging in size from one to several square meters and exhibits total macroplot cover often in excess of 60 percent. Bare ground is usually conspicuous, averaging 23 percent of the plot area (Table 3). Species richness is lower than in the *Symphoricarpos albus* type, averaging 13.7 species per macroplot (Table 2). The jackknife estimate of community richness, or total number of species expected in a community type, is 50.8 species and is less than in the *S. albus* type. The inverse of Simpson's diversity index is 14.7 and evenness index is 0.525 suggesting a relatively simple community with high dominance by a few species. The *Fraxinus* overstory canopy is commonly closed, reducing summer insolation at ground level. Although no measurements were made, we observed extended periods of spring flooding, depressed topography, and soils with high clay content and low permeability. This community type is usually situated away from main water courses in overflow lands.

The *Fraxinus latifolia/Symphoricarpos albus* community type has a prominent shrub cover (Tables 1 and 3) with *Symphoricarpos albus, Rubus ursinus,* and *Rosa eglanteria* having high constancy and/or cover (Table 1). Characteristic herbs with high constancy or cover include *Ranunculus uncinatus, Stellaria calycantha, Montia sibirica,* and *Galium aparine* (Table 1). *Quercus garryana* occurs in three plots as a codominant. The *S. albus* community type, with a within-type similarity of 57 percent (Table 2), is less floristically homogeneous than the *C. obnupta* type (within-type similarity 66%). Mean species richness per macroplot is 22.5 species. A jackknife community richness estimate of 66.9 species suggests a richer type than the *C. obnupta* type and the inverse of Simpson's diversity index of 32.9 and an evenness index of 0.737 indicates that dominance is shared by several species and there is more evenness in species abundance than in the *C. obnupta* community. The *S. albus* community, with a more open canopy and less flooding than the *C. obnupta* community, has a mean bare ground cover per plot of 2 percent (Table 3). The *S. albus* community often occupies natural levees adjacent to streams and margins of the ash forest where it abuts agricultural fields. Both locations are associated with somewhat coarser textured soils.

Fraxinus forest plots are ordinated by detrended correspondence analysis (DCA) yielding four eigenvalues (0.34, 0.17, 0.09, 0.05). The principal two ordination axes are displayed in Figure 4 together with the superimposed

TABLE 3. Selected structural characteristics of *Fraxinus latifolia* plant community types.

Characteristic	Community Type *Carex obnupta* (n=9)	*Symphoricarpos albus* (n=11)	t[a]
Mean Total Tree Cover (%)	83.9	79.4	1.66
Mean Total Shrub Cover (%)	3.1	70.5	4.01 *
Mean Bare Ground (%)	22.6	2.4	3.51 *
Mean Litter (%)	53.8	67.9	1.80
Mean No. Down Dead Trees (ha^{-1})	218	136	1.37
Mean Dens. Total Trees (ha^{-1})	2446	1358	3.46 *
Mean Dens. Live Trees (ha^{-1})	1824	1012	3.44 *
Mean Dens. Vigorous Trees (ha^{-1})	1484	848	3.19 *
Mean Dens. Dying/Dead Trees (ha^{-1})	962	511	3.01 *
Mean Dens. Stand. Dead Trees (ha^{-1})	626	346	2.38 *
Mean Dens. Reprod. Stems (ha^{-1})	2274	854	2.98 *
Mean Stem Diameter (cm)	14.1	19.7	1.96
Mean Stand Basal Area (m^2 ha^{-1})	32.2	31.4	0.25
Mean *Fraxinus* Core Age (yrs)	59.3	72.2	3.52 *

[a]* indicates significance at p=0.05

TABORD and CLUSTER community classification. Lacking quantitative environmental measurements, it is difficult to interpret these axes. Plots in the *Carex obnupta* community type are on the left of the ordination and *Symphoricarpos* community type plots on the right. The principal axis (DCA axis 1) may indicate persistence of moisture. *Symphoricarpos albus* stands are associated with drier and more coarse textured soils characteristic of natural levees and gently sloping margins of bottomlands. Figure 5 shows a relatively weak positive relation ($r=0.53$, $p=0.020$) between ash core-age and DCA axis 1 score, suggesting correspondence between older ash stands and assumed drier sites.

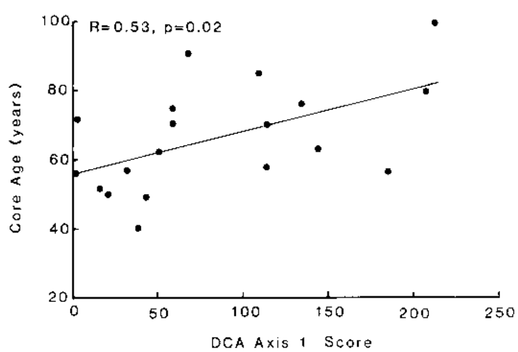

Figure 5. Relation between detrended correspondence analysis ordination principal axis score (DCA Axis 1) and core age of largest *Fraxinus* trees in each macroplot.

Structure

The two community types are distinct in tree diameter, density, number of "reproductive stems," and size structure (Table 3 and Figure 6). The *Fraxinus latifolia/Carex obnupta* community type exhibits many trees less than 15 cm dbh, few trees greater than 30 cm dbh, and a moderate number of standing dead trees 5-15 cm dbh. This structural pattern is shown in Figure 6 aggregated for all nine *Carex* community type plots. Mean total tree density is 2446 ha^{-1}. Although the proportion of vigorous to impaired to dead trees remains about the same in the two communities (about 61:13:26 respectively), there are more standing dead and down trees in the *Carex* type than in the *Symphoricarpos* type. The *Carex* plots also have a large number of reproductive stems (a mean of 2274 stems ha^{-1}).

The 11 plots allocated to the *Fraxinus latifolia/Symphoricarpos albus* community type, on the other hand, exhibit a more even distribution of stem diameters, fewer trees with diameters less than 5 cm dbh, a larger number of trees exceeding 30 cm dbh (Figure 6), a slightly more open canopy, and a fewer standing impaired and

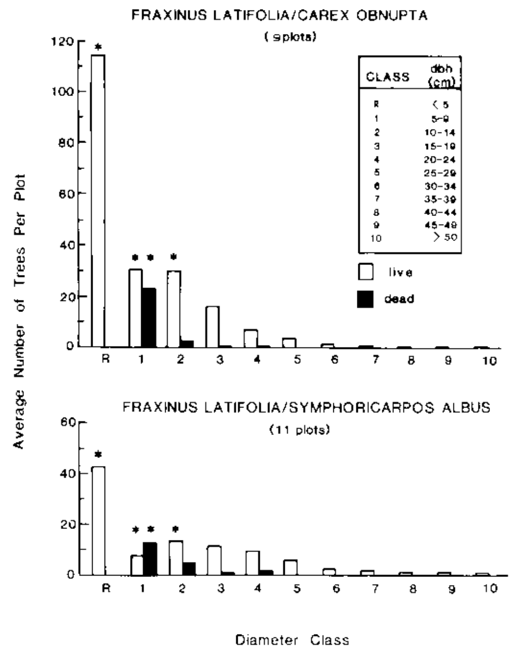

Figure 6. Tree size distribution in *Fraxinus latifolia/Carex obnupta* and *Fraxinus latifolia/Symphoricarpos albus* plant community types. Asterisk (*) indicates significantly different (p = 0.05) size class between the two communities.

dead trees than are present in the *C. obnupta* community type (Table 3). A total density of 1358 ha − 1 is significantly less than the density of the *C. obnupta* community. Although the two communities are structurally distinct, community basal area, reflecting both diameter and density, is not significantly different, 32.2 m2 ha − 1 for the *Carex* and 31.4 m2 ha − 1 for the *Symphoricarpos* community.

Coring ash trees is extremely difficult because of the toughness of the wood; furthermore, trees older than 100 years frequently had rotted centers and could not be aged. Because of these problems, only two-to-four of the largest, and presumably oldest, ash trees in each plot were cored. Age sampling was not representative of the total forest age structure. A weak positive relation exists between age and diameter for all plots ($r = 0.49$, $p = 0.000$). There is a somewhat stronger age-diameter relationship for the *Carex* plots ($r = 0.60$, $p = 0.0000$) than for the *Symphoricarpos* plots ($r = 0.47$, $p = 0.010$). The *Carex* communities with a mean core age of 59.3 years for the oldest ash trees, are significantly younger than the *Symphoricarpos* communities with a mean core age of at least 72.2 years. Because of the difficulty in aging trees older than 100 years, the relationships presented above are conservative; in other words, the distinction based on age between community types is at least as great as presented.

Discussion

The vegetation mosaic in the Willamette Valley, consisting of prairie, deciduous forest, and evergreen forest, has been heavily modified by man, both historically and presently (Johannessen *et al.* 1971, Towle 1982). Published studies of these types are few and their characteristics, environmental and successional relationships are only provisionally known (Franklin and Dyrness 1973). Both temporal and environmental gradients are evident. Temporally, wet prairie succeeds to deciduous *Fraxinus* forest on poorly drained moist sites (Moir and Mika 1972, Marshall 1985). Furthermore, following disturbance, dry sites are occupied serally by dry prairie, deciduous *Quercus garryana* forest, and ultimately by *Pseudotsuga menziesii* forest—a somewhat indeterminant successional sequence (Sprague and Hansen 1946, Franklin and Dyrness 1973). Environmentally, a moisture gradient may also be recognized in which the sequence with decreasing moisture is marsh, wet prairie, *Fraxinus* forest, *Quercus* forest (Boss 1983, Moir and Mika 1972, Thilenius 1968). In the Willamette Valley, ash forest appears to have a terminal position along the seral gradient and a central position along the moisture gradient. Our study of the composition and structure of *Fraxinus latifolia* forest in the Finley Refuge relates this moist forest type to these two gradients.

With respect to the moisture gradient, central Willamette Valley ash communities are assumed to respond to differences in inundation and drainage. Of the two identified community types, the *Carex obnupta* type occupies poorly drained bottom lands, is dense, and exhibits strong dominance by small diameter and relatively young *Fraxinus* trees. The *Symphoricarpos albus* type is found on natural levees and gentle slopes adjacent to overflow areas, is more open, and is dominated by larger and older *Fraxinus* trees than in the *Carex* type. Lower species diversity and higher dominance in the *Carex* type than in the *Symphoricarpos* type agrees with observations that overflow areas have greater anaerobic conditions leading to stressed vascular plants (Lee *et al.* 1985).

Compositionally, the *Fraxinus* community types were heterogeneous and shared many species. These types occupy habitats intermediate in moisture status between drier *Quercus garryana* forest sites (Thilenius 1968) and more hydric wet prairie and palustrine marsh sites (Moir and Mika 1972, Marshall 1985, Boss 1983). Understory composition of the more mesic *Quercus garryana* communities shows some, but not close, resemblance to the *Symphoricarpos albus* community type. The lack of similarity is probably because a full range of intermediate stands between those examined by Thilenius (1968) and those reported upon here were not sampled. Likewise, ash stands share many species with nearby wet prairies, including *Spiraea douglasii, Crataegus douglasii, Rosa eglanteria, Eleocharis acicularis,* and *Carex unilateralis.*

With respect to a seral gradient, ash forest appears to have a terminal position. *Fraxinus latifolia* is the major reproducing tree in each community. A dioecious species, *F. latifolia* is a prolific seeder in open stands but reproductively more limited in closed stands. Stump sprouts are common, especially where stems have been damaged (Owston in press). Ash is recognized as intolerant to moderately tolerant of shade, yet the distribution of *Fraxinus* throughout all size classes in both community types suggests a multiple age canopy with self replacement. Detailed age structure, however, was not examined. The relatively young age and high density of the *Fraxinus latifolia/Carex obnupta* community type suggests recent occupancy of the sites. There was no evidence of cut stumps or rotting logs. The more open and older *Symphoricarpos* type, with several ash trees in excess of 100 years and large diameter woody debris, indicates greater stand age but still stability in dominance, since *Fraxinus* continues to dominate both reproduction and overstory canopy.

As recently as 70 years ago, the ash forest in the Refuge area was limited to the immediate riparian strip of Muddy and Gray Greek. In combination, burning and grazing historically restricted the ash forest to a narrow riparian forest along natural levees within which *Quercus garryana* also flourished (Habeck 1961, Johannessen *et al.* 1971). The *Fraxinus latifolia/Symphoricarpos albus* type along the Muddy Creek today represents historic continuity with the earlier forested riparian strip. The present *Carex* community type, representing more recent encroachment into prairie, does not appear to have this historic continuity.

Floristic and structural analysis of *Fraxinus latifolia* forest in William L. Finley National Wildlife Refuge sheds light on history of the ash forest in the central Willamette Valley and its position with respect to temporal and environmental gradients. The present extensive ash forest on moist sites in the Refuge area is a relatively recent feature resulting from succession following the cessation of burning and grazing.

Acknowledgments

We wish to thank Palmer Sekora, Refuge Complex Manager, and John Cornely, Biologist at William L. Finley National Wildlife Refuge, for their logistic assistance throughout this project. Sherry Pittman identified lichen specimens for which we are grateful. Particular thanks are extended to Bradley G. Smith who provided program PRHILL for an analysis of diversity and many good suggestions for the paper. We also appreciate readings by Diana Bodker and Charles Halpern. We are especially thankful for many constructive and helpful suggestions from two anonymous and very dedicated reviewers.

Literature Cited

Alatalo, R. V. 1981. Problems in the measurement of evenness in ecology. Oikos 37:199-204.

Boesch, D. F. 1977. Application of numerical classification in ecological investigations of water pollution. Virg. Inst. Marine Sci. Spec. Sci. Rep. 77. EPA, Environ. Res. Center, Corvallis, Oregon.

Boss, T. R. 1983. Vegetation ecology and net primary productivity of selected freshwater wetlands in Oregon. Oregon State University, Corvallis. Ph.D. Dissertation.

Daubenmire, R. F. 1959. A canopy-coverage method of vegetation analysis. Northw. Sci. 33:43-66.

Exler, R. 1982. William L. Finley National Wildlife Refuge Vegetation. A color map designed by the Cartographic Service, Dept. Geogr., Oregon State University, Corvallis.

Franklin, J. F., and C. T. Dyrness. 1973. Natural vegetation of Oregon and Washington. USDA For. Serv. Gen. Tech. Rep. PNW-8, Pacific Northw. For. Range Exp. Sta., Portland, Oregon.

Frenkel, R. E., S. N. Wickramaratne, and E. F. Heinitz. 1985. Vegetation and Land Cover Change in the Willamette River Greenway in Benton and Linn Counties, Oregon: 1972-1981. Yearbook Assoc. Pacific Coast Geogr. 46:63-77.

Gauch, H. G., Jr. 1982. Multvariate Analysis in Community Ecology. Cambridge University Press, Cambridge.

Habeck, J. R. 1961. The original vegetation of the mid-Willamette Valley, Oregon. Northw. Sci. 35:65-77.

Heltsche, J. F., and N. E. Forrester. 1983. Estimating species richness using the jackknife procedure. Biometrics 39:1-11.

Hill, M. O. 1973. Diversity and evenness: a unifying notation and its consequences. Ecol. 54:427-432.

__________. 1979a. TWINSPAN—a FORTRAN program for arranging multivariate data in an ordered two-way table by classification of the individuals and attributes. Ecol. and Systematics, Cornell University, Ithaca, New York.

__________. 1979b. DECORANA—a FORTRAN program for detrended correspondence analysis and reciprocal averaging. Ecol. and Systematics, Cornell University, Ithaca, New York.

Hitchcock, C. L., and A. S. Cronquist. 1973. Flora of the Pacific Northwest. University of Washington Press, Seattle.

Johannessen, C. L., W. A. Davenport, A. Millet, and S. McWilliams. 1971. The vegetation of the Willamette Valley. Ann. Assoc. Amer. Geogr. 61:286-302.

Received 21 November 1986
Accepted for publication 8 July 1987

Keniston, J. A. 1978. Program CLUSTER: an aid to numerical classification using the CDC CYBER computer. Unpublished report. Pleuronectid Proj. Tech. Rep. 2, Oregon State University Sea Grant Progr., Corvallis.

Knezevich, C. A. 1975. Soil Survey of Benton County Area, Oregon. USDA Soil Cons. Serv., Washington, D.C.

Lee, L. C., T. M. Hinckley, and M. L. Scott. 1985. Plant water status relationships among major floodplain sites of the Flathead River, Montana. Wetlands 5:15-34.

Maarel, E. van der, J. G. M. Janssen, and J. M. W. Louppen. 1978. TABORD, a program for structuring phytosociological tables. Vegetatio 83:143-156.

Marshall, J. L. 1985. Value assessment of Jackson-Frazier Wetland. Oregon State University, Corvallis. M.S. Thesis.

Moir, W., and P. Mika. 1972. Prairie vegetation of the Willamette Valley, Benton County, Oregon. Unpublished report on file at USDA For. Serv. Forestry Sci. Lab., Corvallis, Oregon.

Owston, P. W. In press. Oleaceae, olive family, *Fraxinus latifolia* Benth., Oregon ash. Editorial draft for Silvics Manual on file at the USDA For. Serv. Forestry Sci. Lab., Corvallis, Oregon.

Thilenius, J. F. 1968. The *Quercus garryana* forests of the Willamette Valley, Oregon. Ecol. 49:1124-1133.

Towle, J. C. 1982. Changing geography of Willamette Valley woodland. Oregon Hist. Quart. 83:66-87.

Sprague, F. L. and H. P. Hansen. 1946. Forest succession in the McDonald Forest, Willamette Valley, Oregon locality. Northw. Sci. 20:89-98.

Walter, H., and H. Lieth. 1967. Klimadiagramm-Weltatlas. VEB Gustav Fischer Verlag, Jena.