THE ECOLOGY OF OLD-GROWTH DOUGLAS-FIR FORESTS*

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INTRODUCIlON

Old-growth forests in the Douglas-fir region are distinguished primarily by several structural characteristics including a wide range of tree sizes and ages, a deep multilayered crown canopy, large individual trees, and accumulations of coarse woody debris including snags and down logs of large dimension. Old-growth forests are compositionally diverse and include many species for which it is optimum habitat. Old-growth forests are productive although the bulk of the energy is used for respiration. Wood accumulations tend to be stable, with growth at least balancing mortality. Nutrient losses and erosion are generally low in old-growth watersheds. The large trees, snags, and logs are the key structural features of old-growth.

In the Pacific Northwest, old-growth forests connote stands of 250-750 years old that contain variable numbers of large Douglas-fir *(Pseudofsugu mendesfi).* Our objective is to provide a more specific working definition of old-growth Douglas-fir forests using information at hand, Current field work is revealing infinite variations in old-growth forests, yet some general characteristics of compostion, structure, function, and age of the ecosystem can be used to put limits on this diverse concept.

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Our scope is confined to the Douglas-fir region of the Pacific Northwest-areas at low to moderate elevations west of the Cascade Range where Douglas-fir is or can be a dominant species. It is important to remember that old-growth forests in other regions have their own characteristic composition, structure, and function. Old-growth forests of Ponderosa Pine *(Pinus ponderosa)* or Lodgepole Pine *(Pinus contorta),* for example contrast sharply with those of the Douglas-fir region.

HOW MUCH OLD-GROWTH FOREST IS THERE IN THE DOUGLAS-FIR REGION?

The Douglas-fir region had about 15 million acres of old-growth forest in the early 1800's. This figure is based on an estimated 25 million acres of commercial forest land, 60-70 percent of which were characteristically in old-growth based on age class distributions in Mt. Rainier and Olympic National Parks. The Society of American Foresters' Task Force estimates around 5 million acres of this old-growth remains.

Approximately 1 million acres of old-growth forest are reserved in western Washington and Oregon within National Parks, Wilderness Areas, and Research Natural Areas. Much of this acreage is subalpine forest at higher elevations, so there is considerably less than 1 million acres of old-growth Douglas-fir. Most of the old-growth forests are reserved in western Washington in the Olympic, Mt. Rainier, and North Cascade National Parks, and in the Glacier Peak and Alpine Lakes Wilderness Areas.

A DEFINITION OF OLD-GROWTH FORESTS IN THE DOUGLAS-FIR REGION

It is clear that a simple, precise definition of old-growth forest is unlikely. It is necessary to use a variety of characteristics or criteria because there is wide variability in values for a given characteristic. An interim definition of old-growth Douglas-fir in the Western Hemlock zone (Old-growth Definition Task Force 1986) is:

1. Two or (commonly) more tree species with a wide range in size and age and often including a long-lived sera1 dominant (for example, Douglas-fir) and shadetolerant associate (for example, Western Hemlock, *Tsuga heterophylla);*

2. Individual live Douglas-fir trees (more than 8/acre) that are either old (>200years) or have become large (>32 in. d.b.h.);

3. Relatively high density of shade-tolerant associates (>12/acre) of medium size (>16 in d.b.h.);

4. A deep, multilayered canopy; and

5. Significant coarse woody debris, including snags (>4/acre which are >20 in. d.b.h. and over 15 ft. tall) and downed logs (>15 tons/acre including 4 pieces >24 in. diameter and ≥ 50 ft. long).

Old-growth stands also have a number of other attributes, such as a rich diversity of plants and animals, some of which are found primarily in old-growth forests.

Age alone is often an unsatisfactory criterion of old-growth conditions, because structural features characteristic of old-growth stands develop over different amounts of time, depending on site conditions and stand history. For example, large live trees can grow relatively rapidly on high-site lands. Douglas-fir site I land in the Oregon Coast Ranges may produce trees of 40 inches in diameter in 100 years, although the trees may lack decadence (for example, broken tops). On poor sites, trees that large may take 200 years to develop and overall stand characteristics may develop even more slowly. On Douglas-fir site III lands, old-growth tree and stand characteristics emerge at around 200 years old, ± 50 years.

Stand history also plays an important role. Understocked stands produce larger trees earlier, other site conditions being equal. Stands developing after clearcutting will typically take longer to develop appropriate levels of snags and downed logs since few, if any, are carried over from the prior stand. This is in marked contrast to stands destroyed by natural disturbances, such as fire and wind.

Most of the old-growth stands in the Douglas-fir region Rave developed over 250-750 years since their origin. The most common age classes are probably between 400 and 500 years in the Cascade Range. Stands with Douglas-fir trees over l000 years old are occasionally encountered, however (Hemstrom and Franklin 1982). Senescence may appear in some old-gowth forests, although it appears that old-growth stands of Douglas-fir typically remain intact for 700 to 800 years. On the other hand, some stands may break up at 500 years, while others last well over 1000 years.

OLD-GROWTH FORESTS ARE COMPOSITIONALLY DIVERSE ECOSYSTEMS

Suggestions have been made in the past that old-growth forests lack biological diversity. They were sometimes termed "biological deserts," perhaps because of past emphasis on game species. Recent research has clearly shown, however, that oldgrowth forests have substantial diversity in plants, vertebrate and invertebrate animals, and aquatic organisms.

The diversity of old-growth forests is well illustrated with vertebrate animals. In the Douglas-fir region, many species make primary use of old-growth forests (Hams, Maser, and McKee 1982); 16 species of birds and mammals find optimum habitat in such forests (Franklin, and others 1981). Several of these species are unusual, including the foliage-feeding Red Tree Vole *(Arborimus longicaudus)* (Hams 1984). Occurtence of several species is highly correlated with old-growth forest. The North Spotted Owl *(Strix occidentalis caurina)* is the best known example.

Research strongly indicates that Spotted Owls are dependent on old-growth for survival (Gutiérrez 1985). The issue of dependency on old-growth habitat continues to be a major topic of research for the Spotted Owl and other species. The relatively high overall diversity and strong association of some species with old-growth forest is characteristic of other groups of organisms in addition to vertebrates.

The major point is that old-growth forests are biologically diverse ecosystems. From a biological standpoint, such a conclusion should have been obvious from the beginning. With the large areas of old-growth forest in existence for such long time periods, it is logical to assume that a significant number of species have become adapted to such habitat. It is also reasonable to expect that some of these species have become dependent on the specialized conditions associated with old-growth for their survival.

Finally, it is important to note that the most biologically diverse stage of succession in the Douglas-fir region is usually the open, cutover, or burned site prior to closure of the tree canopy. The least biologically diverse stage is the fully stocked young forest, that is, from closure of the canopy to near culmination of mean annual increment.

OLD-GROWTH FORESTS ARE PRODUCIIVE

Old-growth forests are typically productive ecosystems in terms of the total quantity of energy fixed per unit area per unit time (for example, per acre per year). Old-growth forests could be viewed, along with any other stage in forest succession, as healthy, vital ecosystems, fixing and processing large amounts of solar energy.

It is important to distinguish here between productivity as measured by ecologists and by foresters. Gross production in ecological terms is equivalent to the amount of energy fixed photosynthetically per unit area per unit time. Ecologists define net primary production as the biomass increment plus mortality, including litterfall and materials removed by grazing. A forester's definition of productivity (wood increment) is, therefore, generally limited to only a portion of the ecologist's net productivity and comments on the low productivity of old-growth forests really refers to the relatively low levels of new wood production.

It is logical to conclude that old-growth forests tend to be stable in terms of their biomass or board-foot accumulation. Foresters have long recognized the basic stability of wood accumulations in old-growth forests, hence the expression "storing wood on the stump." We have also begun to realize that significant tree and forest growth goes on well beyond culmination of mean annual increment (Williamson and Price 197l). Indeed, by cutting forests at culmination, we are really cutting them as they make the transition from ecologically young to ecologically mature forests; growth and biomass accumulation are far from complete at such a stage.

Wood accumulations in old-growth forests are usually stable over the long run. Stands generally will not disappear in decades or even centuries as a result of mortality and diseases.

OLD-GROWTH FORESTS ARE CONSERVATORS

Probably more data are available on the protective functioning of old-growth forests than any other functional aspect. This would include their role in maintaining water quality and conserving nutrients and soil. Old-growth forest systems are highly retentive of nutrients. Large amounts are tied up in living and dead organic material and are released only slowly. Internal recycling is rapid. Nutrient levels leaching into ground water and appearing in streams are, therefore, very low (Sollins and others 1980). Soil erosion is also typically low compared to the earliest stages in forest succession. The combination of low losses of dissolved nutrients and of particulate matter explains the high quality of water characteristic of old-growth watersheds (Swanson and others 1982a).

Old-growth forests also affect water yield, but a recent study indicates the effect may not be as simple or obvious as previously supposed. In an earlier synthesis of old-growth characteristics (Franklin and others 1981), old and young forests were assumed to have similar effects on water cycles, for example on transpiration losses. Harr (1982) recently reminded us of the importance of cloud and fog condensation in tree canopies in some regions. In a portion of the Bull Run watershed for the city of Portland, Oregon, fog drip from the natural forest cover may contribute up to 30 percent (35 ins.) of the measurable precipitation per year. This was discovered after clearcutting some experimental watersheds resulted in reduced rather than increased water yields. Since old-growth forests typically have deep, multilayered canopies and high leaf areas, we can expect them to be more effective than young forests at condensing and precipitating moisture and atmospheric particulates.

A final comment on the protective functions of old-growth forests concerns their role in insect, disease, and fire control. Old-growth forests are sometimes described as insect- and disease-ridden ecosystems that are a hazard to adjacent managed forests, or as forest systems that increase fire risks. In the Douglas-fir region, old-growth forests rarely appear to provide reservoirs of pathogens hazardous to managed stands. In general, contrasting forest conditions have different arrays of insects and diseases. Those that might be common in the old-growth stands (for example, dwarf mistletoes or shoestring root rot) can either be isolated or have low rates of spread. Intensively-managed young forests are proving to have a number of pest problems but few are likely to have their source in adjacent natural forests. Similarly, fire risks are very low in old-growth Douglas-fir forests because of several factors, including the type of microclimate created within the forest. Once fires are ignited in old-growth forests, however, they are difficult to control because of heavy fuel loading and abundant snags that help spread the fire.

OLD-GROW FORESTS ARE STRUCTURALLY DIVERSE

Structural diversity is the characteristic where the greatest contrasts are found between intensively-managed commercial timber stands and unmanaged forests, including old-growth. Wide ranges in tree size, dense and deep forest canopies, and abundant dead wood are common structural features of old-growth stands (Franklin and others 1981).

Old-growth canopies are commonly multistoried or continuous to near ground level. Dead wood in the form of snags and downed logs is generally common or abundant. Although a notable part of old-growth stands, such material is actually common in unmanaged stands in all successional stages in the Douglas-fir region.

The obvious structural elements characteristic of the old-growth forest are the large live trees, large snags, and large downed logs on land and in streams. This is "important because many of the special features of composition and function found in old-growth forests relate to these structural elements. Managers can use these structural features as critical elements in developing and applying management schemes. It is noteworthy that 2 of the tree structures (snags and logs) are composed of dead wood. Dead wood plays extremely important roles in natural ecosystems.

Live old-growth trees are commonly 40-60 ins. in diameter and 160-270 ft. tall. Long-lived sera1 species, such as Douglas-fir or Western Redcedar *(Thuja plicata)*, provide structures of more functional value than do some climax species, such as Western Hemlock and Pacific Silver Fir *(Abies amabilis)*. The climax species do not attain comparable sizes or persist as long as snags and downed logs

As befits their antiquity, live old-growth trees tend to be individualisitc with large branch systems and deep crowns and often have multiple or dead tops and heart rots. All of these characteristics contribute to their value as habitat for animals and other plants (Franklin and others 1981).

Many of the distinct compositional features of old-growth forests–plants and animals–are related to the tree canopies. Almost every surface of an old-growth Douglas-fir is occupied by epiphytic plants. More than 100 species of mosses and lichens function as these epiphytes.

The canopy of an old-growth Douglas-fir forest harbors large numbers of invertebrates of many species. A single stand may have more than 1500 species. A minority of species spend their entire cycle in the canopy: Araneida, Acarina, Homoptera, Collembola, Neuroptera, Thysanoptera, and Psocoptera. Other species of Lepidoptera, Hymenoptera, Diptera, and Coleoptera occur as eggs, larvae, and pupae in the canopy. But the adults can and do move out of the canopy. The majority of species encountered in the canopy are adults that spend their immature stages on the forest floor or in streams.

Several vertebrates depend heavily on the old-growth canopy as sites for nesting, feeding, and protection. Well-known examples are the Northern Spotted Owl, Northern Flying Squirrel *(Glaucomys sabrinus)*, and Red Tree Vole. The Vole may live for many generations in the same tree. The role that the large branch systems and organic accumulations play in providing suitable habitat should not be overlooked.

Large snags are best known for their value as wildlife habitat but are also important in carbon and nutrient cycles. Large, hard snags (>24 ins. in diameter and 50 ft. tall) are particularly valuable sites for primary cavity excavators. Snags in the Blue Mountains of Oregon and Washington are primary locations for cavities that are used by 63 species of vertebrates-39 birds and 24 mammals (Thomas and others 1979). Uses include sites for nesting and overwintering, locations for courtship rituals, and food sources.

Thomas and others (1979) indicate a direct correlation between numbers of snags and related populations since suitable nesting sites are generally thought to limit populations. Mannan and others (1980) confirm this for hole-nesting birds in western Oregon. The large, hard snags required by primary excavators, such as the Pileated Woodpecker *(Dyocopus pileatus)*, are especially important. Such snags will be hard to perpetuate in managed stands (because of smaller trees and programs for salvaging wood and reducing fire and safety hazards). Yet such snags are also suited to other wildlife species and will produce soft snags through the process of deterioration. Snags representing a variety of decay classes are needed in a stand to meet the differing requirements of vertebrates since not all use the same material. One special attribute of old-growth and large (natural) second-growth stands is that they provide the necessary array of snags with varying levels of decay, whereas young stands on cutover areas do not.

Large, downed logs serve many important ecological functions on both upland and in streams. On land, downed logs function as wildlife habitat, as sources of organic matter, carbon, and nutrients, as sites for nitrogen fixation, a's nurse logs for plant reproduction, and as impediments to erosion. Logs provide essential habitat for a variety of invertebrates (Deyrup 1975) and vertebrates (Maser and Trappe 1984). They are used as sites for lookouts, feeding, and reproduction, protection and cover, sources and storage of food, and bedding. The high moisture content of logs makes them particularly important as habitat for amphibians.

Maser and others (1979) reported that 178 vertebrates use logs in the Blue Mountains-14 amphibians and reptiles, 115 birds, and 49 mammals. They tabulated use by log decay classes for each species. Logs are considered important in early successional stages as well as in old-growth forests. The persistence of large logs has special importance in providing wildlife with habitat continuity over long periods and through major disturbances.

Logs may contribute significantly to reestablishment of animal populations by providing pathways along which small mammals can venture into clearcuts and other bare areas. This has relevance to the reestablishment of tree seedlings on bared areas since survival and growth of new trees depends on development of appropriate mycorrhizal associations. Surprisingly, fungal symbionts apparently disappear from cutover areas shortly after their host trees are removed (Harvey and others (1976), and the sites must be reinocculated with their spores. Many mycosymbionts have underground fruiting bodies and completely depend on animals for dissemination of spores. Small mammals are the vectors. They consume the fungus and carry spores to new areas, thereby inocculating tree seedlings (Maser and others 1978a, 1978b; Maser & Trappe 1978).

In streams, downed logs function (Swanson and others 1982b; Triska and others 1982) as: components and creators of habitat (and consequently, biological diversity); dissipators of stream flow energy, reducing channel cutting and other erosion; sites for nitrogen fixation; and retention devices to help trap and hold plant litter along stream reaches until it can be used by stream organisms.

In small and intermediate streams in the Pacific Northwest, large debris may be the principal factor determining the characteristics of aquatic habitats. The important role of debris in creating habitat for fish has been reviewed by Narver (1971), Hall and Raker (1975), and others. The wood itself is a habitat or substrate for much biological activity by microbial, invertebrate, and vertebrate organisms.

NOT ALL OLD-GROWTH FORESTS ARE AS ABOVE

General features of old-growth are similar in many other western forest types-the presence of relatively large trees and of dead wood, for example. Details of structure, composition, and age vary widely, however.

Old-growth forests of coastal Sitka Spruce *(Picae sitchensis)*-Western Hemlock have a varied composition in which the Spruce, Alaska-cedar *(Chamaecyparis nootkatensis)*, and Western Redcedar, provide the larger trees and longer-lived dead-wood structures. Old-growth spruce-hemlock forests typically have a better developed understory of herbs and shrubs than younger stands, of great importance for wildlife (Alaback 1982). The ratio of snag to downed log volume is generally lower than in Douglas-fir old-growth forests.

Pine forests probably differ most markedly from Douglas-fir in old-growth characteristics. With Ponderosa Pine, large live old-growth trees and large snags are important, but levels of downed logs are typically low because of frequent tires. Old-growth Lodgepole Pine forests may lack large trees, relative to other types. Snags and downed logs may be abundant but small in size, reflecting maximum tree sizes typical of the site. Senescence and deterioration occur much earlier and more commonly in Lodgepole Pine than in the other old-growth conifer types discussed.

Old-growth forests in the eastern United States also share many characteristics with western old-growth forests. High levels of biological diversity, structural heterogeneity, and functional vitality are characteristic of old-growth, deciduous, hardwood forests. Large, individualistic live trees and major accumulations of dead wood in the form of snags and logs are common. Residual trees carried over from earlier stands may be important as cavity trees.

CONCLUSIONS

Old-growth forests in the Douglas-fir region appear to provide highly specialized habitats that are neither unproductive ecosystems nor biological deserts. There are major contrasts in composition, function, and structural features between old-growth and managed young-growth stands. Differences between old-growth stands and unmanaged young-growth stands are often one of degree because much structural material, such as large snags and logs, is carried over from the old stand to the new stand. Management schemes for old-growth forests can be keyed to 3 structural components: large live trees, large snags, and large downed logs-

When the objjtive is perpetuation of an old-growth forest ecosystem, a minimum amount of disturbance should be allowed. Snags and logs perform important functions and are essential structures. For multiple-use objectives, an increased awareness of the nature and nontimber value of individual trees is important, for example, as potential or current habitat for epiphytic communities and wildlife. The ecological roles of standing dead trees and logs in the functioning and productivity of the forest must also be recognized if we are to do a better job of land stewardship.

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