



Figure 34.—Large, stable, woody debris increases the habitat value of a pool for salmonids.



Figure 35.—Salmonids use the stable wood on the flood plain as protective cover during winter floods.

When winter storms cause streams to flood, the pool-riffle sequences or stairstep stream profile is transformed into a continuous, high-velocity torrent, and there is little protection for salmonids from moving bedload sediment or swift, turbulent waters. During these unpredictable but brief periods, slack water refuges are associated almost exclusively with such large, woody debris as fallen trees and with standing vegetation in riparian flood plains (fig. 35). All three species of salmonids enter these debris-enhanced refuges until streamflows subside. Large, woody debris may also expand the feeding space by creating or enhancing the amount of slow-moving or standing water in organic-rich flood plains, even along the smallest streams (Bustard and Narver 1975a, 1975b).

Management Impacts on Fallen Trees

The Douglas-fir forests of the Pacific Northwest evolved with a continuing deposition of fallen trees to the forest floor and to streams. Fallen trees may periodically have been partially destroyed by fire but were ultimately replaced during development of successive stands (Harris and others 1982, Swanson and Lienkaemper 1978).

What will happen to the Douglas-fir ecosystem when fallen trees are no longer added, as will be the case under intensive forest management with increased utilization of wood fiber? And what will happen under short rotation management, when large trees are no longer produced?

These questions—and others that we do not yet know to ask—can be answered only through careful research. Until such research has been done, we only speculate. Our speculation in turn can be based only on what we know about the functions of fallen trees. These functions relate to the size, shape, placement, porosity, and cohesiveness of a fallen tree; its suite of functions is altered when any one of these factors is changed (Fellin 1980). We can thus begin to consider how stand management will affect each function.

On Land

Trees in an unmanaged forest generally fall randomly, although a storm or catastrophic event, such as the explosion of Mount St. Helens, sometimes causes all the trees to fall in one direction over a substantial area. Diversity results from the common random placement; some fallen trees lie along a slope, others across it. Trees that fell two centuries ago are mixed with those that fell two decades ago, 2 years ago, and 2 days ago. Some fell on the ground, some across others; some are whole, some broken. The resultant diversity provides a myriad of habitats in both time and space.

Machine entry in a stand reduces diversity because heavy equipment fragments and scatters class IV and V rotten wood. Class I and II trees may be salvaged or cut for firewood; class III trees that hang together and are not removed as salvage or firewood tend to become bunched or aligned along the direction of skidding. Habitat diversity declines to a fraction of what had been available (Eckholm 1975); probably fewer kinds of organisms can thrive. Further, because woody substrates serve as long-term soil organic material and nutrient reservoirs, increasingly intensive timber management, coupled with shorter rotations, could significantly alter the role of decaying wood in the nutrient cycling processes.

A forest manager can take steps to maintain the present diversity of fallen trees on a site. Machine trails can be designed to minimize the scattering of class IV and V trees. Wood utilization standards can be adjusted to leave a good representation of younger classes. Some trees—both defective and sound trees for built-in diversity—can be left to become fallen trees of the future. Where necessary, burning of slash can be designed and timed to minimize destruction of woody residue. These are all feasible practices, but they will cost money. Hence, the forest manager needs to know how a stand will benefit from the fallen trees over the long run.

In Streams

When fallen trees and other large pieces of wood are removed from stream channels and riparian zones by massive debris torrents or excessive postlogging channel cleanup, carrying capacity for salmonids in winter is reduced (Bisson and Sedell, in press; Swanson and Lienkaemper 1978; Toews and Moore 1982). In turn, the smolt yield of anadromous salmonids is reduced the next spring. Sedell and others (1982b) examined the long-term history of debris management. They concluded that the systematic removal of fallen trees and debris jams for navigation and transportation of logs in the late 19th and early 20th centuries destroyed a major structural component of fish habitat in intermediate to large rivers.

Enhancement or mitigation efforts designed to improve fish passage by removing debris jams and logging slash have resulted in declines in wintering populations of salmonids in small streams⁴ (Bryant 1982, Lestelle 1978). The decline in the summer rearing capacity of a stream for coho salmon is a direct result of less large wood that provides cover and forms pools in streams (Bisson and Sedell, in press).

⁴ Elliott, S. T. Ecology of rearing fish. Annual performance report, study OIB. Alaska Department of Fish and Game; 1979; 19: 39-52.

Hall, James D.; Baker, Calvin O. Biological impacts of organic debris in Pacific Northwest streams: Proceedings of workshop 1; 1975 September; Corvallis, OR. Oregon State University; 13 p.

Research Needs

Recent and current research in old-growth forest is revealing much about the roles and qualities of fallen trees. Understanding this information may allow use of fallen trees as sensitive barometers of the "habitat health" of a stand (Harris and others 1982). To learn how the functions of fallen trees differ in an old-growth stand, a clearcut, and a young stand, we need to compare the characteristics and inhabitants of fallen trees in such areas. The physical qualities of a fallen tree-moisture, temperature, nutrient content, pH--are likely to change markedly with stand removal, regeneration, and regrowth. We need to learn how the plants and animals change with such alterations within and around a fallen tree. We especially need to know much more about the fallen tree-soil interface, probably the single most important habitat niche for the survival of organisms in drastically altered stands. To fully interpret the long-term significance of fallen trees and the old-growth forests from which they come, we need to learn more about their contribution to the forest ecosystem as a whole and to the quality of the soil in particular.

Research on fallen trees in streams needs to address the quality and quantity of the woody debris that is required in riparian zones to maintain or enhance the aquatic ecosystem. Because saturated wood decomposes slowly, it accumulates on the bottom of a stream to become a site of nitrogen fixation and nitrogen, to form habitat, and to help capture and hold leaf litter that in turn is a source of energy for the stream ecosystem. How many live trees are needed (and of what diameter) to provide a future source of fallen trees in a stream for structure, nutrient cycling, and fish habitat? Although most fisheries biologists have focused their attention on wood in streams, of equal importance is the large wood (quality and quantity) along channel margins and in overflow areas because this is the winter habitat of the salmonids.

In summation, we must not sacrifice the options of future generations on the altar of cost-effectiveness through decisions based on insufficient data. It is the professional charge of researchers to obtain the needed data and of managers to apply it.

Epilog

When thinking of and dealing with diversity in a forest, conventional vision focuses on structure and habitat. Diversity, however, has another dimension-one that is only now being perceived: function. The basic components of structural and functional diversity are inseparably interwoven in a forest. A broadened philosophical view of management-a forest versus a commodity-is necessary if certain structurally related functions, such as retention of water and cycling of nutrients in large, fallen trees, are to be options in managed forests of the future.

(Maser and Trappe 1984)

Common and Scientific Names

Plants:	
Alder	<i>Alnus</i> spp.
Douglas-fir	<i>Pseudotsuga menziesii</i> (Mirb.) Franco
Huckleberry	<i>Vaccinium</i> spp.
Oregon oxalis	<i>Oxalis oregana</i> Nutt. ex T. and G.
Salal	<i>Gaultheria shallon</i> Pursh
Sitka spruce	<i>Picea sitchensis</i> (Bong.) Carr.
Western hemlock	<i>Tsuga heterophylla</i> (Raf.) Sarg.
Invertebrates:	
Carpenter ant	<i>Camponotus</i> spp.
Common earwig	<i>Forficula auricularia</i> L.
Douglas-fir beetle	<i>Dendroctonus pseudotsugae</i> Hopkins
Golden buprestid	<i>Buprestis aurulenta</i> L.
Pacific dampwood termite	<i>Zootermopsis angusticollis</i> (Hagen)
Pacific folding-door spider	<i>Antrodiaetus pacificus</i> (Simon)
Ponderous borer	<i>frgates spiculaus</i> (Le Conte)
Redbellied checkered beetle	<i>Enoclerus spehegeus</i> F.
Vertebrates:	
Beaver	<i>Castor canadensis</i> Kuhl
Black-tailed deer	<i>Odocoileus hemionus</i> Rafinesque
California red-backed vole	<i>Clethrionomys californicus</i> (Merriam)
California slender salamander	<i>Batrachoseps attenuatus</i> (Eschscholtz)
Clouded salamander	<i>Aneides ferreus</i> Cope
Coho salmon	<i>Oncorhynchus kisutch</i> (Walbaum)
Cutthroat trout	<i>Salmo clarki</i> Richardson
Oregon salamander	<i>Ensatina eschscholtzi</i> Gray
Oregon slender salamander	<i>Batrachoseps wrighti</i> (Bishop)
Shrew-mole	<i>Neurotrichus gibbsi</i> (Baird)
Steelhead trout	<i>Salmo gairdneri</i> Richardson
Trowbridge shrew	<i>Sorex trowbridgei</i> Baird

Acknowledgments

The following people critically read and improved the manuscript: Michael Castellano, Jerry F. Franklin, Donald K. Grayson C. Y. Li, Randy Molina, and Robert F. Tarrant. Pen and ink illustrations were prepared by Paula Reid. Phyllis Taylor-Hill typed the various drafts. The research was partially funded by the National Science Foundation Grant DEB 80-04562. We are grateful for the help.

This paper is contribution No. 1 of the cooperative project, "The Fallen Tree-An Extension of the Live Tree," that involves the U.S. Department of the Interior, Bureau of Land Management; U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; Oregon State University, Department of Forest Science; U.S. Department of Agriculture, Agricultural Research Service; and Oregon Department of Fish and Wildlife.

The interdisciplinary nature of the work reported in this paper evokes the fond memory of our friend, colleague, and teacher, Gerry S. Strickler. Gerry's life of research was dedicated to understanding how different organisms in wildlands interact with each other and their environment. And he left us with a greater appreciation of the importance of cause-and-effect relationships between humans and forests.

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Large, fallen trees in various stages of decay contribute much-needed diversity to terrestrial and aquatic habitats in western forests. When most biological activity in soil is limited by low moisture availability in summer, the fallen tree-soil interface offers a relatively cool, moist habitat for animals and a substrate for microbial and root activity. Intensified utilization and management can deprive future forests of large, fallen trees. The impact of this loss on habitat diversity and on long-term forest productivity must be determined because managers need sound information on which to base resource management decisions.

Keywords: Fallen trees, decay (wood), decomposition, old-growth stands, Douglas-fir, *Pseudotsuga menziesii*, mycorrhizae, soil moisture.

The **Forest Service** of the U.S. Department of Agriculture is dedicated to the principle of multiple use management of the Nation's forest resources for sustained yields of wood, water, forage, wildlife, and recreation. Through forestry research, cooperation with the States and private forest owners, and management of the National Forests and National Grasslands, it strives — as directed by Congress — to provide increasingly greater service to a growing Nation.

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