Dispersal Characteristics of Old-Growth Soil Arthropods: The Potential for Loss of Diversity and Biological Function

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Management practices of Northwest forests drastically affect abundance and species composition of the small arthropods (insects, spiders, and their relatives) that regulate soil microstructure and elemental recycling. Burrowing arthropods provide channels in which roots grow and nonburrowing arthropod species can enter the soil matrix. Detritus-feeding species facilitate nutrient release by increasing the surface area available for microbial attack. In normal densities, microbe-feeding species increase the rate of microbial growth and litter decomposition. Predaceous taxa control the competitive balance between fungi and bacteria.

Most species of soil fauna show strong preferences for conditions prevailing at particular stages of forest succession. Studies underway at the Andrews Experimental Forest (western Cascade Mountains, Oregon) demonstrate that the typical practice of clearcutting and burning reduces total arthropods in the soil by about 90%. The immediate effect of this process on species richness is a function of both fire intensity and patchiness of the habitat, as well as the fire. Random sampling often reveals a decrease of nearly all the species, but sampling within potential refuges (inside punky [decayed, dry] tree trunks, under heavily decayed logs) reveals that many species have the potential to survive the fire in favorable locations. The surviving individuals soon are joined by the highly mobile species that characterize habitats disturbed by humans and forest fires. Superficial examination of the abundant species reveals few taxa in common with the old growth until the new canopy is well-formed (20–40 years later).

Many invertebrate species that prefer old growth are flightless—not only the most abundant taxa (e.g., springtails, oribatid mites, predaceous mites), but also groups normally characterized by efficient flight. Wingless species of flies (i.e., phorids, cecidomyiids, sciarids, and tipulids), wasps (i.e., diapriids and ceraphronids), beetles (i.e., carabids, cicindelids, curculionids, and pselaphids) and bugs (i.e., tingids) that characterize the old-growth fauna have winged relations that abound in the early successional stages.

When natural disturbances like winter blowdown and forest fires were the major disturbances to the Vancouveran forest, disturbed patches frequently were small, and they probably encompassed many refugia; the ratio of edge to disturbance area was high and recolonization relatively easy. In the infrequent events when huge forest fires occurred, observation tells us that fire intensity was very patchy and that numerous partially burned enclosures remained. Under present conditions of widespread timber harvest with slash burning and very restricted islands of old growth, the distances required for successful immigration may well be limiting. The immigration rates of soil taxa, the practice of burning litter after clearcutting, the types and long-term success of refugia during fires, and the practice of leaving "green islands" (with undisturbed litter) in clearcuts all require critical investigation. If old growth is to remain as restricted islands scattered over the landscape, island biogeography theory tells us that extinctions of taxa are bound to occur. If many of these species cannot re-colonize due to their wingless condition, transplantation of litter between sites may be necessary to assure continuing persistence of critical species.

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Density and Diversity of Soil Arthropods as "Biological Probes" of Complex Soil Phenomena

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Soil is both a resource and a habitat for the plants and animals of the forest. When we use the word *forest*, we usually think only of trees and wood resources. However, we must also think of the thousands of species of animals that live in, on, and under the trees, and of their functions in the forest ecosystem. No part of the forest ecosystem is more diverse than the arthropods that inhabit the soil (Anderson. 1975. Proc. V Int. Coll. Soil Zool.). The most abundant Oregon soil arthropods are oribatid mites (250,000/m^2; 75–100 species/m^2) and springtails (50,000/m^2; 20–30 species/m^2). These abundances and species counts approximate or exceed diversities reported from any terrestrial ecosystem in the world (Petersen and Luxton. 1982. *Oikos* 39:287–388), probably, in large part, because of the depth and complexity of litter in the Northwest. A single core (7.5-cm diameter) is likely to contain over 50 species and a one-ft^2 sample, 200–250 species, especially if taken from old-growth forests.

In order to understand the factors that permit so many species to occur in such a small soil volume, we have examined seasonal samples from an experimental design of four successional stages in each of eight different moisture regimes/slope faces of the major mid-elevation Cascade conifer forest types. We have determined the most favored stage in succession and moisture regime, as well as seasonal patterns of life-cycle development for several hundred different soil invertebrates. Many soil species prefer the conditions of old growth over regenerating forest soils, though we know of no species that absolutely requires old growth. Statistical techniques designed to deal with the abundances of large numbers of species readily distinguish old-growth samples from regenerating forests immediately adjacent. Soil arthropods have been shown by numerous researchers to regulate the rates of litter decomposition and nutrient recycling; therefore, such differences could significantly affect long-term site productivity.

The different species of soil arthropods respond to environmental gradients, each in its own way. The great diversity of species in the litter permits us to distinguish samples from similar forest types characterized by different understories; samples from Douglas-fir regrowth, with or without associated alder; and even, at times, the species of overstory tree in a mixed-canopy forest and the distance to the nearest tree trunk. Since many of these arthropod species are widespread geographically, they offer potential as "biological probes" to examine complex soil processes, which are difficult or expensive to analyze with traditional chemical methods. Laboratory tests usually reveal conditions of the instant of sampling; the forest trees must integrate complex changes which operate over decades or centuries. Shorter-term changes in soil conditions probably can be distinguished in arthropod responses long before they are revealed in rates of tree growth and health.

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Litter Spiders as Bio-Indicators of Recovery after Clearcutting in a Western Coniferous Forest

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The litter spiders of the H. J. Andrews Experimental Forest in western Oregon were pitfall-trapped through eight consecutive seasons from June 1982 to May 1984. Traps were placed in 29 mid-elevation sites (1,400–3,000 ft; 450–950 m) that differed from one another with respect to moisture (based on the classification of Dyrness, Franklin, Moir 1974; *Bulletin 4, Coniferous Forest Biome*, USIPB) and succession (6, 19, 31 years after clearcutting, and old growth).

Three objectives were addressed in our study: (1) characterizing the litter spider fauna of 200^{+}-year old growth; (2) determining the response of this fauna to clearcutting; and (3) describing the changes in the litter spider community that occur in the first 31 years after clearcutting.

A total of 8,551 individuals were collected, comprising 93 species, 54 genera and 15 families. Most species were uncommon, represented by less than 20 individuals for the entire collecting effort. The 36 most common species (>25 individuals/species) comprised 95.1% of the total abundance. The species composition and relative abundance of these 36 species exhibited a clear pattern of succession from clearcut to old growth.

The spider community characteristic of old growth and mature second growth includes two species of microweb spiders (*Lepthyphantes zibus, Scironis sima*), a tripline weaver (*Theridion sexpunctatum*), and a trapdoor spider (*Antrodiaetus pugnax*). These species rely on litter-inhabiting insects and mites for food and require relatively constant environmental conditions to survive. When a stand is clearcut, these and all other forest litter spiders disappear, due to the loss of available prey and to the increase in microenvironmental variability characteristic of habitats with little or no canopy cover.

Forest litter spiders are replaced after clearcutting by an entirely different community composed primarily of diurnal pursuit spiders. Three of the most abundant clearcut species (the wolf spiders *Alopecosa kochi, Pardosa californica*, and *Schizocosa mccooki*) are also common in perennial agriculture field crops of the western United States (alfalfa, peppermint); these three species are characterized by high dispersal ability and preference for sunny, open habitats. Wolf spiders prey on the abundance of low-foliar insects found in fresh clearcuts, and are tolerant of wide fluctuations in environmental conditions.

The gradual return of vegetation and leaf litter 10–15 years after clearcutting allows the colonization and survival of shrub-associated spiders, including the diurnal and nocturnal running spiders (*Zelotes fratris, Micaria puritanus*), funnel-web weavers (*Calymmaria emertoni*), and crab spiders (*Xysticus pretiosus*). As succession proceeds further (15–25 years after clearcutting), spiders characteristic of young forests become more common, such as the jumping spider *Neon reticulatus* and the hackled-band weaver *Callobius severus*.

Recovery to a typical forest spider species composition requires a minimum of 30 years after clearcutting for the wettest sites, a figure closely comparable to the recovery rate of plant communities (Schoonmaker and McKee. 1988. *For. Sci.* 34:960–979). For the driest sites, species composition after 31 years is more similar to 6–19 year