species. The genus *Acalypta* contains moss-feeding species found throughout the Northern Hemisphere; three occur in the H. J. Andrews Forest.

*Acalypta lillianis*, apparently a relict of colder times, is found in mosses growing on the cool, high, rocky ridges. While the only specimen collected from the forest is flightless, winged individuals of this species are known to occur elsewhere. The second species, *A. mera*, is found at lower elevations in mosses growing on the ground in more open sites. It is usually flightless, but about five percent of the individuals of both sexes are fully winged and able to disperse should the necessity arise. The third species, *Acalypta saundersi*, has been found only in the flightless state. It appears to occur in mosses in truly mature forests, its wing reduction seemingly a response to habitat stability. A group of species of *Acalypta* that closely resembles *saundersi* and that are also flightless are found in other areas of long-term stability–the Ozark and Great Smoky Mountains in the United States, the Mexican Plateau, parts of Europe, and parts of eastern Asia, including Japan. No fully winged individuals of these species have ever been collected.

Other insect orders found in this forest have flightless species, such as those found among the Hemiptera (true bugs). The beetles are well represented: 824 species collected to date, and some of these are flightless. Snails and slugs are common inhabitants of forests, and a group of flightless ground beetles (Carabidae), including *Cychrus tuberculatus* and several species of *Scaphinotus*, are specialized predators of these terrestrial molluscs. Besides beetles, other orders of insects contain flightless species found in the forest, and we will certainly discover more.

The old-growth forests of the Pacific Northwest, with trees of enormous height and mass, diverse shrubs and forbs, and large accumulations of coarse, woody debris, provide many habitats. The highly varied and deep litter and soils supply resources for a diverse and characteristic fauna. Meadows, openings, ridges, streams, and springs add to the variety. The number of arthropod species conservatively represents more than three-quarters of all species of higher life forms (plants, invertebrates, and vertebrates) found there. Persistence of the later successional stage has provided habitats not found in earlier stages, whose durations are usually brief. What we see today in the fauna is, in part, the product of long-term stability, even though the persistent components of the habitats are themselves the product of change. In the midst of the controversy swirling around old-growth forests of the Pacific Northwest, it is important to remember that there is more to the forest than the trees.

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*Dr. John D. Lattin is Professor of Entomology at Oregon State University and Director of the Systematic Entomology Laboratory at Oregon State University. Dr. Lattin has compiled a reading list on the topic of old-growth forests, which can be obtained by writing or calling the Xerces Society.* *The support of NSF BSR 8514325 is acknowledged.*



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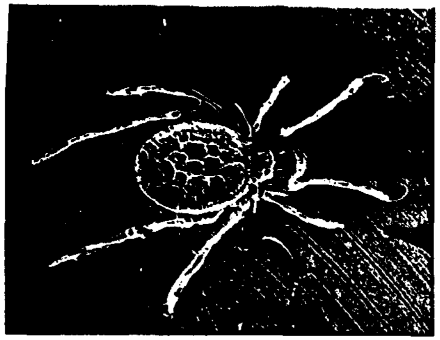
# One Hundred Twenty Thousand Little Legs

*Andrew Moldenke*

Nowhere are the critical roles of insects and other invertebrates easier to understand, yet more poorly investigated, than in forest soil. Proper growth of forest trees depends on receiving appropriate nutrient levels and water from the roots. The metabolic activity of fungi and bacteria liberate nutrients through litter decomposition and chemical transformations of the soil. Experiments have shown that insects and other microarthropods control these rates.

No one has ever counted the number of kinds of bacteria and fungi under a single tree in the forest; no ecologist knows just how many chemical transformation processes are necessary for the full recycling of nutrients. We do know, however, that in undisturbed forests there are 200 to 250 species of invertebrates per square meter of forest soil in the Pacific Northwest–probably literally thousands of kinds in all the microhabitats of a square mile of forest. There are 100,000 to

*Dead logs are crucial for forest health. The final step in nutrient recycling is uptake of nutrients by mycorrhizal fungi, which pass nutrients to the trees in exchange for photosynthetic sugar pumped to the roots. Here the mycorrhizal fungus* Russula emetica *is attached to the roots of western hemlock. Photograph © 1990 by Gary Braasch.*



*Odontodamaeus veriornatus is one of the larger (750 microns or about .03 inch) fungivorous oribatid mites. There are 100,000 to 200,000 oribatid mites per square meter of undisturbed Pacific Northwest forest. Scanning electron micrograph by A. H. Soeldner.*

200,000 oribatid mites per square meter of undisturbed forest, including perhaps as many as 75 species. Forest ecosystems cannot afford to lose species such as these, which are involved in critical nutrient recycling.

In our conifer forests, the pioneering work of Forest Service mycologist Jim Trappe has shown that most essential nutrients are passed to trees through a network of symbiotic fungi known as mycorrhizae. Mycorrhizae may be microscopic fungi deep within the tree roots, dense sheaths of fungal tissue wrapped around the root tips, or even meter-wide mats of woven fungal hyphae permeating the soil while attached to the tree root. There might be as many as 150 different kinds of mycorrhizae on the roots of a single Douglas-fir tree. Different kinds of mycorrhizae provide different services to the tree, such as nutrient uptake and resistance to drought and disease.

The mycorrhizae don't act alone. Many different types of soil bacteria and fungi are required to perform the many transformations necessary to break down the complex organic chemicals in litter, wood, and carcasses. The role of soil invertebrates is to facilitate these processes by stimulating the growth of microbes, mixing the substrates, aerating the soil, and transporting spores and living fungal hyphae to a place where they can grow, thereby driving the succession of the myriad different microbial species living in the soil.

The strikingly-colored millipede *Harpaphe haydeniana* is a crucial ecosystem link. It grazes on fallen conifer needles, and by crunching up many plant cells, mixes their contents with the bacteria in its gut. Then it deposits a fecal pellet, which is attacked by a different set of bacteria which further the decomposition process. The fecal pellet is invaded by fungi, eaten by a smaller arthropod like the chocolate-brown oribatid mite *Odontodamaeus veriornatus*, exposed to yet a different set of enzymes and gut bacteria, and transformed into smaller fecal pellets. Then, perhaps, an immature *Harpaphe* engulfs many tiny fecal pellets, mixes them with the mineral soil, and starts the whole cascading fragmentation process over again.

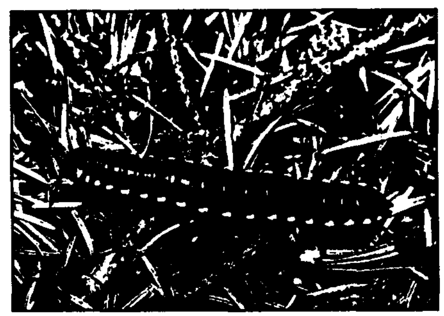
The numbers and kinds of soil fauna are so large that forest managers and soil scientists mistakenly take them for granted. U.S. Forest Service silviculturalists have learned that examination of the diverse forest understory can reveal critical aspects of soil type and moisture availability more efficiently than chemical tests.



Likewise, soil invertebrates can be used as "biological probes" of soil processes that operate over time scales and spatial scales that are difficult to monitor in the field.

Chemical tests measure chemical concentrations at a moment in time, and seldom distinguish between what is there and what is available for tree growth. Tree growth integrates all the numerous factors affecting a tree over decades; it is difficult to distinguish soil-related factors from all the other types. Most soil creatures have surprisingly long life cycles: (*Odontodamaeus* probably one year; *Harpaphe* probably several years). Their growth rates integrate over several months in small areas of forest soil many of the properties important for tree growth.

Soil arthropods respond clearly to soil properties relevant to their ways of life: soil temperature, moisture, fungal abundance, limiting nutrients, [illegible] strong preferences in the stages of forest succession and their populations respond numerically to abundance of resources. Because most of them have very limited mobility, they highlight localized distributions of nutrients. Using a statistical program that allows comparison of the relative abundance of large numbers of species, it is possible for me to examine a sample of arthropods extracted from the soil and to deduce not only what sort of forest they came from, but how far the soil was from the nearest tree and even sometimes the species of that tree.



*The cyanide-producing 3- to 3½-inch millipede,* Harpaphe haydeniana, *is a conspicuous part of Northwest conifer forests. By feeding on fallen needles, it starts the lengthy decomposition process necessary for nutrient recycling. Photographed in the H. J. Andrews Experimental Forest by Trygve Steen.*

My colleagues and I are using microarthropods to examine questions of "biological legacy": how long does the biochemical signature of an individual tree remain imprinted on the local soil ecosystem once it blows down or is cut? Does this legacy influence the pattern of vegetational change that occurs, perhaps even determining the species of tree that takes its place? Do management practices such as slash-burning and the use of herbicides have long-lasting effects on the soil that can be detected years or even decades later? If we are managing forests for posterity, and not for short-term gain, we need to know the answers to these sorts of questions.

Biodiversity will always be of interest to museum scientists like me, but public support for insect diversity is concentrated on showy species. It is the maintenance of the total diversity that keeps ecosystems running effectively. More scientists need to develop techniques that show managers of federal lands the utility of using biodiversity as a practical tool.

It is likely, based on Petersen and Luxton's review of world soil fauna, that temperate soil diversity equals or exceeds that of tropic soil. Southward estimates that about 80 percent of the temperate forest insect fauna spend a significant portion of their life cycles in the soil. In absolute terms, then, it is quite probable that the highest levels of terrestrial diversity anywhere on earth occur in the soils of our temperate forests.

Every time you take a step in a mature Oregon forest, your foot is being supported on the backs of 16,000 invertebrates held up by an average total of 120,000 legs. Just think how many creatures it takes to support a single tree.

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*Dr. Andrew Moldenke is a research biologist and teacher in the Department of Entomology at Oregon State University. His interest lies in the interactions of invertebrates and their environment, particularly the subjects of pollination ecology and soil fauna.*

# NEWS BRIEFS

This fall, Sierra Club Books will publish ***Butterfly Gardening: Creating Summer Magic in Your Garden,*** by the Xerces Society and the Smithsonian Institution. Advance orders will be filled at that time.

The book features more than 100 close-up color photographs of butterflies and flowers, garden design diagrams, a master plant list, and essays by leading butterfly, gardening, and conservation experts. The book, which will sell for $18.95 retail, is available to Xerces Society members for $14.95 plus $2.50 shipping and handling. If you are not a member, you may join Xerces now and order the book at the discounted price. To order, send a $17.45 check or money order to: The Xerces Society, 10 S.W. Ash Street, Portland, OR 97204.

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An **Oregon Silverspot Butterfly Recovery Team** has been reconstituted and is actively working on conservation measures for the species and its habitat. *Speyeria xerene hippolyta* is a threatened butterfly that lives along the Pacific coast from southern Washington to northern California. Its habitat is endangered by development and forest succession.

The team includes Xerces Society members Paul Hammond, Cathy Macdonald, Dennis Murphy, Paul Opler, and Katrin Snow. For more information: Paul Opler, United States Fish and Wildlife Service (USFWS) Office of Information Transfer, 1025 Pennock Place, Suite 212, Fort Collins, CO 80524, (303) 493-8401.



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Five cave-dwelling invertebrates are being included in a habitat conservation plan for Austin, Texas. The Tooth Cave pseudoscorpion (***Microcreagris texana***), Tooth Cave spider (***Leptoneta myopica***), Bee Creek Cave harvestman (***Texella reddelli***), Tooth Cave ground beetle (***Rhadine persephone***), and Kretschmarr Cave mold beetle (***Texamaurops reddelli***) were added to the federal Endangered Species List in September, 1988, because of threats to one or more of the few caves they inhabit.

According to Dr. Charles W. Sexton of the City of Austin Environmental and Conservation Services Department, these species are highly adapted to their cave environments and are members of a very fragile ecosystem subject to disturbance from a number of sources, including development, application of herbicides and pesticides to the drainage area of caves, human visitation, and litter.

The Balcones Canyonlands Habitat Conservation Plan (BCHCP–formerly the Austin Regional HCP) was conceived in the latter part of 1988 as an appropriate strategy to provide a reasonable balance between protection of endangered species and economic development in the area. The group intends to complete its plan and receive a Section 10(a) permit from the USFWS by the winter of 1991. For more information, including a list of available documents and maps: City of Austin, Environmental and Conservation Services Department, c/o BCHCP Secretary, P.O. Box 1088, Austin, TX 78767, (512) 499-2658.

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Gregory R. Ballmer, an entomologist at the University of California, Riverside, has petitioned the USFWS for action to list a rare fly (***Rhaphiomidas terminatus abdominalis***) as an endangered species. According to a fact sheet available through Ballmer, *Rhaphiomidas* consists of 23 species and subspecies confined to the southwestern United States and northwestern Mexico. Adult *Rhaphiomidas* are about an inch long, fly rapidly, and can hover like a hummingbird while drinking nectar from flowers. Larvae live in sand and probably require one year to mature; their feeding habits are not known.

Fourteen species and subspecies are known from California. One species, R. *trochilus*, which formerly occurred at the Antioch dunes, may be extinct. The closest relative of *R. t. abdominalis* is *terminatus terminatus*, which formerly occurred in coastal dunes of Los Angeles County and is presumed extinct.

*R. t. abdominalis* currently inhabits about 640 acres within the cities of Colton, Rialto, and San Bernadino, and adjacent unincorporated portions of San Bernadino County. Known former populations in Bloomington and Mira Loma have been extirpated. Current threats to remaining habitat include construction, trash dumping, off-road recreational vehicles, soil disturbance due to grading or plowing, and invasion by nonnative plants. For more information: Gregory R. Ballmer, Department of Entomology, University of California, Riverside, CA 92521.