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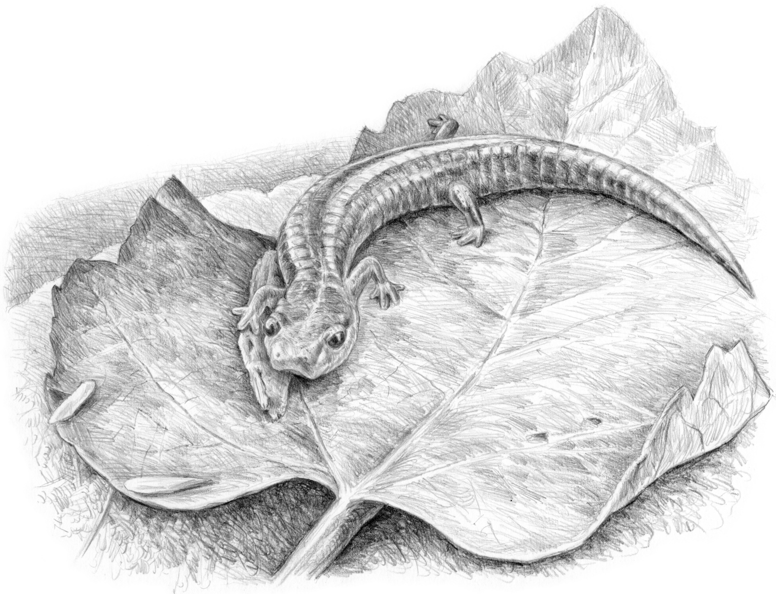
their time on land in the forest. And even those that do need open water for breeding frequently depend on the temporary pools found in forests. These pools dry up in the summer after the trees leaf out and draw the water up to their leaves. As a result of their temporary nature, these ponds are free of fish—a perfect habitat for amphibian eggs to be laid and larvae to develop. Other amphibians do not need open water at all; they lay their eggs in the damp earth or in moist rotting logs.

Bury decided to focus on amphibians to test the claims of abundant wildlife in logged forests. He compared old-growth redwood sites in California with redwood sites logged between six and fifteen years previously. He found more individuals and greater biomass of all amphibians in the old-growth forests. In addition, he found a number of species that either were only found in the old-growth forests or were very strongly associated with them. Consider these five as indicator species for old growth in California: tailed frogs, Olympic torrent salamanders, Pacific giant salamanders, Ensatina salamanders, and slender salamanders. It is highly likely that these delightful species have been living in association with the western old-growth forests for millions of years.

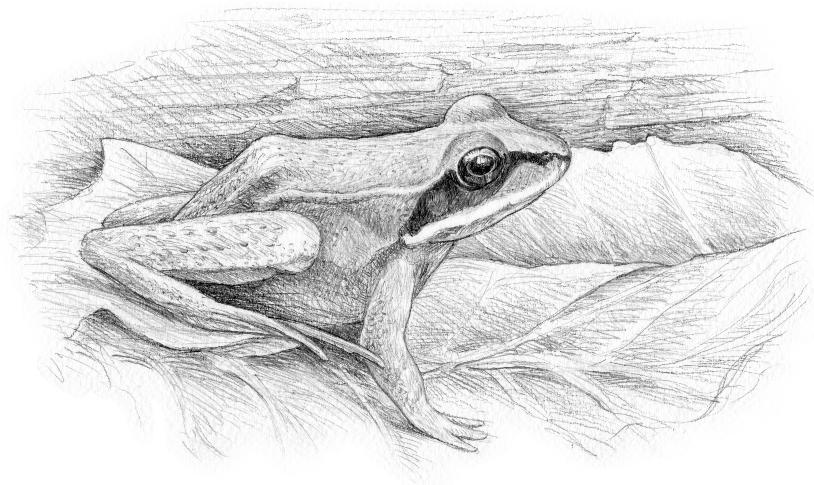
If you are one of these five amphibians, a recently logged forest is not a healthy place for you. But why not? What is it about old-growth forests that these species need? Amphibians are all thin skinned and require a moist environment. They don't necessarily need a pond or a stream; many species live entirely ground-based lives, but the ground must be cool and damp, and crevices, root channels, or fissures must give them access to the cool, damp layers. Looking more specifically at the five indicator species, we know that the tailed frog needs clear, cold, fast streams. While most frogs lay their eggs and leave them, the female tailed frog harbors her fertilized eggs within her body; otherwise they would be swept downstream. She is seven years



An eastern red-backed salamander, a common woodland creature.

old before she reaches sexual maturity, and she may live up to fourteen years. Logging in her habitat could expose her stream to sun and silt, making it too warm for her or her offspring to survive. Likewise, the Olympic torrent salamander needs cold, clean water; springs bubbling up from the ground in a shady forest or the sprayed margins of a shady waterfall are both habitats that suit it. The other three salamanders on the list are all without lungs. They cannot take a breath. They get the oxygen they need and release their waste gases through their skin. But their skin must be moist for this trick to work. So dry equals dead for these and many other species of salamanders.

It is not really big old trees that these amphibians need so much as it is the habitat created within an old-growth forest with big old trees. The ancient forest creates a moist environment with smaller fluctuations in temperature and humidity. Logging, by



Wood frog, found in forests of the eastern United States.

contrast, increases the light reaching the ground, causing higher soil temperatures and resulting in faster drying of the forest floor. This could mean death for a lungless salamander, especially if the soil has been compacted by logging equipment and no underground alleys of refuge have been left intact.

Most of the research on old-growth forests, and old-growth-dependent amphibians in particular, has been done in the western United States, but a study was done on lungless salamanders in Missouri that compared old-growth (more than 120 years old), second-growth (70 to 80 years old), and regeneration-cut (less than 5 years old) forests. The researchers found mostly southern red-backed salamanders: an average of 488 salamanders per acre in the old-growth forests, 96 per acre in the second-growth forests, and zero in the regeneration-cut forests. Those numbers are hard to argue with.

One likely reason for the greater success of the salamanders in the old-growth forests is that these forests have larger logs on the forest floor, in later stages of decay. Big old decaying logs mean a damp environment protected from extremes in temperature, and more insects. Both shelter and food are available for the salamanders. It may seem strange to think of them this way, but salamanders can be imagined as the large carnivorous predators of the forest floor. Many insects, some quite tiny, are deadwood dependent, and these insects, in turn, may be fed on by woodland ground beetles. The salamanders in this forest-floor world might serve as the top predators, keeping the predator beetle populations in check. But they themselves might also become food—for an opossum or a ground-feeding bird.

The researchers in Missouri concluded: "Management activities based on commercial rotations could result in lower plethodontid densities due to lack of suitable habitat. Increasing the rotation length in managed forests would provide older, mature forests that play a critical role in maintaining relatively high densities of plethodontid salamanders."

The term *plethodontid* refers to a salamander in the genus *Plethodon*. If you live in the eastern United States and you head to the woods today, roll over a log, and find a salamander, chances are very, very good it will be a plethodontid—probably a red-backed salamander. Of the 380 species of lungless salamanders, 55 are in the genus *Plethodon*. None of them need open water, as all are completely terrestrial. If you survey salamanders in the northeastern United States, you will likely find a maximum of 5 species, but if you survey them in the southern Appalachians you could find as many as 25 different kinds. This difference in biodiversity is because the land that was once under glaciers is still in recovery, while the southern Appalachians had cove forest refuges where salamanders could survive the ice age, evolve into new species during their isolation, and then recolonize new habitat as the broad-leaved trees dispersed again. As a result of this history, our southeastern US forests have a greater diversity of amphibians than any other temperate forests on earth, and

The spotted salamander, which usually makes its home in a hardwood forest.

all terrestrial salamanders reach their peak populations in old-growth forests except for two exceedingly rare species found only on rocky outcrops.

Northern red-backed salamanders have a very interesting and well-studied social system. Like humans, they often form monogamous pairs. The females are more attracted to large males, males that have a prey-rich territory, and males that do not bear odors from other females. Females can discover how prey-rich a male's territory is by squashing his fecal pellets and seeing what he has been feeding on. Once a pair has formed, the male will punish the female if she has foraged with another male, which he can sense by detecting the other male's odor on her skin. Punishment takes the form of threat postures and nipping.

In one study comparing old-growth forests with variously disturbed forests in New York, researchers found that northern red-backed salamander populations had recovered sixty years after disturbance (unless the forests were converted to coniferous types); however, that study had very small sample numbers.

Although red-backed salamanders are still common, overall lungless salamander populations have declined, and we still don't know exactly why. Is it climate change, invasive earthworms, pathogens, or habitat loss? Or is it a combination of some or all of these? These organisms are in trouble, and we still don't fully understand the role they play in an ecosystem.

Hartwell Welsh and Sam Droege suggest that these salamanders might be the ideal organism for monitoring the health of a forest due to their abundance, longevity, site fidelity, small territory size, and sensitivity to air and water pollution. Also, because of their harmlessness and their location on the forest floor, they are relatively easy to sample. To some, a healthy forest might be defined as fast tree-growth rates and straight-grained wood for harvesting, but to researchers such as Welsh and Droege, salamanders are a better indicator of health since they reflect the forest's balance of other small organisms, leaf litter, moisture, acidity, and soil structure.

Sources on pages 197–98.

6

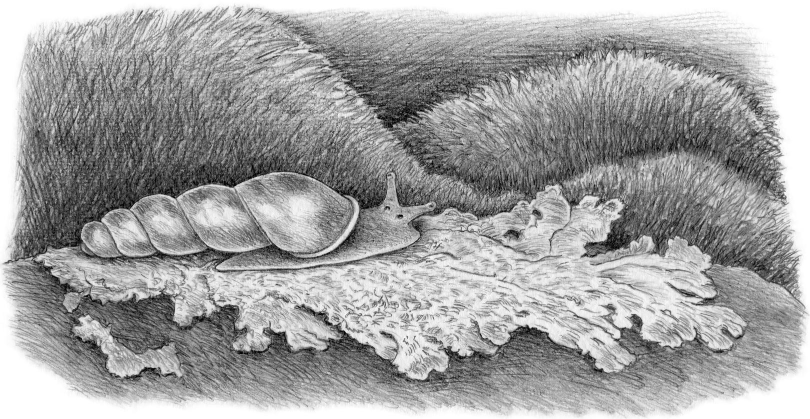
Snails in the Forest

When you love the forest ecosystem and speak out on its behalf, you may be asked to visit forests, speak to groups, and be on committees. This is how I found myself on the Citizens Advisory Committee of the Chesapeake and Pocomoke State Forests in Maryland. This committee was formed to comply with requirements for Forest Stewardship Certification (FSC) of the forests. The committee was supposed to include a dozen representatives: a degreed ecologist (me), a person involved with a wildlife organization, a person involved with tourism, a representative from a conservation organization, a student with natural resource interest from a local university, a local waterman, a representative from one of the local indigenous tribes, a local hunter, a person involved with a local recreational business, a timber products operator, a person employed by a local forest product industry, and a licensed forester associated with a private business interest. I was on the committee for almost ten years, and we met a few times a year. Most of the time no more than four people from the committee were present. I saw the tourism representative once, and the hunter a few times. I never saw the indigenous person or the waterman. The timber products operator (a logger) was at every meeting. A number of times we were the only two committee members present.

Our primary duty was to comment on the annual work plan that described the timber harvests scheduled for the coming year. I took my duties seriously, and I tried to personally visit the forests where final harvests were planned. One forest in particular concerned me; it was right next to a recreational trail, and it contained many mature trees, including white oaks, southern red oaks, hickories, loblolly pines, short-leaf pines, red maples, and black gums. It wasn't an old-growth forest, but it was older than most in the area. Understory trees included dogwood, holly, and serviceberry. The shrub layer included mountain laurel and blueberry.

Once a year when the FSC auditors came through, we would be invited to attend field audits to examine the forest management firsthand. One particular audit experience stayed with me vividly. We visited the forest of particular concern to me, which I had suggested removing from the work plan. The trucks had just left, and not a single tree had been left standing. To me it looked like death and devastation, but judging by the comments from the forest managers and the auditors, there was no problem. As we headed back to the van, I knew that I must represent the citizens and the organisms that couldn't do so themselves. I stepped onto a stump more than 2 feet wide and got everyone's attention.

"When I look at the forest surrounding this clear-cut, all I see are young pines. This forest was one of the oldest and most diverse in the area. You claim to be managing this state forest for a combination of mature pine and oak, but that is exactly what you just removed. A few weeks ago this was a seed- and insect-filled forest—ideal habitat for many birds and other animals. Where are those animals now? There were no invasive species at all in this



Carychium exile, the old-growth indicator snail.

forest. Will we be able to say the same thing ten years from now? Will the white oaks ever again get as large as this one at my feet?" (It was close to a hundred years old.) My stump speech was over, no one said a word, and we continued our walk back to the van.

Later, I thought I should have asked them if anyone from the Advisory Committee, besides me, had visited the forest before the cut. But I already knew the answer to that. It was no.

When I think of that forest today, I think of the snails. None of us there that day, with our degrees and our state jobs, gave any thought to the snails. We had no idea what snail species were there, or in what abundance. The snails were never surveyed, or considered in the logging plans, or mentioned in my speech. But now that I have read the work of Daniel Douglas, I think of the snails.

Douglas examined the snail species in three forested areas of Kentucky. In each area he compared the snails found in an old-growth forest with those found in a nearby younger forest. At each site he collected from ten 1-hectare plots. Some snails were collected by hand, and others were collected by filling bags with leaf litter that was then dried, sieved, and examined by hand. In

Triodopsis tridentata, the disturbed-forest indicator snail.

total he collected more than three thousand snails. Using microscopes and keys, he identified seventy species of snail, all of them native. In every case the older forests contained more snail species. Overall, eighteen of the species were most common in old-growth forests. One of them in particular, *Carychium exile*, was the strongest indicator of an old-growth forest. I know that many things are compared to a grain of rice, but this little thing is literally the length (1.7 millimeters), color, and shape of a grain of white rice.

Another of the snail species, *Triodopsis tridentata*, was a strong indicator that a forest had been logged. This species, with a flat, reddish-brown shell and a dark-colored creature living inside, is almost the width of a dime—much larger than the tiny, white old-growth indicator.

Since they have both male and female reproductive structures, snails can self-reproduce, but normally they don't. In fact, snails are quite promiscuous and an average snail has mated with two to six different partners. Sperm is delivered in a packet called a spermatophore, which contains more than a million tiny sperm cells. It takes a snail three to four weeks to prepare and replenish a new spermatophore after one has been delivered. The female structures of a snail can store the multiple various spermatophores and control which ones will be used to fertilize its eggs.

Seventeen of the twenty indicator species for undisturbed old-growth forests were micro-snails, meaning they were less than 5 millimeters in size. Micro-snails are great indicators to use because they stay in one area for their whole lives, but this trait also makes them vulnerable to local extinction because they can neither escape from disturbance events taking place in the forest nor recolonize quickly after a disturbance. Douglas believes that some land snail species may become locally extinct from forests that are managed through intensive forestry, such as clear-cutting. And at the very least, disturbance of an old-growth forest leaves behind a different snail community, as his list of old-growth indicator snails shows.

The life histories and ecologies of many snails have never been studied; hence we must often generalize when we talk about snails. Snails can live for a number of years. They need an environmental source of calcium to build their shells. If no limestone is available in the environment, the snails may depend on deciduous trees that have leaves with a high calcium content, such as maple or dogwood. The snails themselves may then become an important source of calcium for small vertebrates such as shrews and salamanders. Snails may eat living plant material or litter on the forest floor. The presence of non-native worms in a forest may be detrimental because it reduces both these food sources. Snails also eat fungi and lichens, including the small calicioid lichens I discuss later in the book. This is not always detrimental to lichen populations, however, since the snails may also carry and disperse fragments of the lichens (in the same way that birds function as both predators and dispersers of plants).

Table 2. **Snail species that are indicators for old-growth forests in central and eastern Kentucky**

Carychium exile
Carychium nannodes
Cochilocopa moreseana
Collumella simplex
Gastrocopta armifera
Gastrocopta contracta
Gastrocopta pentodon
Gastrocopta procera
Gastrodonta interna
Glyphyalinia indentata
Glyphyalinia wheatleyi
Guppya sterkii
Haplotrema concavum
Hawaii miniscula
Mesomphix cupreus
Patera appressa
Punctum minutissimum
Striatura ferrea
Vallonia exentrica
Vertigo parvula

About one-quarter of southeastern US snail species are found in association with coarse woody debris (98 out of 401 species). Older forests generally contain higher levels of woody debris. Particular snail species are also found in association with woody debris from particular tree species. Therefore, simplifying a forest from a diverse native mixture to a forest managed for just one, or a few, marketable tree species has negative impacts on snail diversity. Forest management techniques, such as thinning, may also change microhabitats and create drought-like conditions that have negative impacts on forest snails. Douglas concludes, and it should come as no surprise, that "older and less disturbed forests are likely important for preserving biological diversity."

Here, then, is my stump speech for snails: "You snails who just lost your habitat, you snails baking in the sun, you snails who just got crushed beneath the logging machinery, I speak for you, too. I vow that in some places you shall be left in peace."

Sources on page 198.

7

Insects in the Forest

Have you ever been aware as you walked through a forest that everything you saw, heard, and even smelled was largely the result of insects? I wasn't, until Tim Schowalter enlightened me. I'm not talking just about pollinators here, as important as they are. Tim helped me see how the structure of old-growth forests before human intervention depended on the leaf-eating insects.

Just as we need large-animal predators to keep smaller prey species in check, we also need insects to keep plants in check. Instead of thinking of our native leaf-eating insects as injurious to plants, imagine them instead as tiny gardeners trimming here and there. These gardeners specialize in either the cone-bearing evergreen trees or the broad-leaved trees, but never both. Among those that specialize in the broad-leaved trees, some work on the whole group while others may work their whole lives on just one species in the group (like the yew trimmer in Kew Gardens). I'm having fun with the gardener concept here, but you know I'm talking about insects that feed only on particular kinds of leaves.

Trees, just like animal prey species, do not want to be someone's dinner, of course, but unlike voles, trees cannot run away. They are rooted in place and fight back primarily with the chemicals they produce. Their ability to do this has evolved over tens of millions of years. If not for being eaten, the trees would never have evolved to produce those chemical weapons. Tree leaves smell different from one another because of their specialized anti-insect chemistry. We have insects to thank for the pungent smell of a walnut leaf or the delight of breathing balsam-fir air on a cool, sunny day.

Ah, but the leaf-eating insects have another wild card—many of them have evolved the ability to detoxify those chemical weapons. Just as only a certain type of tree has the capacity to produce a certain type of chemical, only certain types of insects have the metabolic equipment to detoxify those chemicals. No tree can do it all, and no insect can do it all. The result of this arms race is that we have insects that feed only on cherry trees, insects that feed only on oak trees, insects that feed only on hemlocks, and so on.

When one tree species is highly successful, it is in danger of taking over the whole forest canopy. The insect species that feed specifically on that tree species then become more abundant too (because of the abundance of their "prey") and trim it back even more, thus keeping it in check and leaving space for other tree species. So the insects allow greater numbers of tree species to coexist. And greater diversity of tree species means greater diversity of leaf-eating insects (specialized gardeners) like tree crickets and katydids. And the forest sings with their songs. And the quieter leaf-eating insects, like the caterpillars, feed the birds that sing the song of the forest for them. The leaf-eating insects are a hugely important food source for migrating birds such as warblers. The birds are on the side of the trees in this game of thrones.

The leaf-eating insects have other foes as well, such as the predatory spiders and insects. Just like human hunters, spiders can either wait in ambush or go in search of a meal. It's a spider's smorgasbord up there in the canopy. And then there are the parasitoids. These flying insects do not kill the leaf eaters themselves; they pass that job along to their offspring. The parasitoids fly through the canopy sniffing for just the sort of leaf eater they specialize in; when they find one, they inject it with their eggs. The leaf eater continues climbing and munching while protecting and incubating the eggs of the parasitoid. Their reward for performing this service is being eaten from the inside out by the larvae when they hatch.

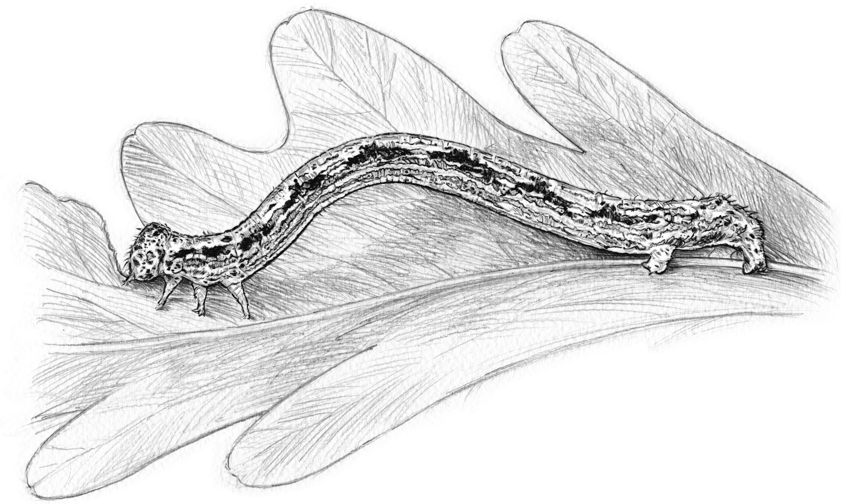
But it's really not as simple as all that (ha!); it's not just a game of win or lose. The leaf eaters may be helping the trees, too. As they chew the leaves, their feces, containing the masticated and digested leaves, are like sprinklings of compost. The sprinkles contain water-soluble nutrients that are then absorbed by the tree for making new leaves. Round and round.

June Jeffries and her team studied the plant-eating insects found on white oak trees in forests of various ages in Missouri, from newly harvested to old growth (more than 313 years old). Starting at ground level they searched the trunk, every twig, and both sides of at least 600 leaves on each sampled tree. They found more than 126 different species of insects, more than 8,200 individual leaf-eating insects in all. At certain times of year, insect species richness and density was higher in the older forests, but more important, a unique community of insects was found in the older forests. Four leaf-eating insects were significantly associated with only the older forests: the curve-lined looper, a twiggy-looking inchworm; the palmerworm, with one narrow and two wide stripes running down its back; the gold-striped leaftier, which makes silk and rolls itself into the leaf; and an oak leaf miner (*Phyllonorycter fitchella*) that is so uncommon I could find no images of it nor a common name.

Furthermore, the mix of insect species found in the forest continued to change, even when the forests hadn't been disturbed for more than two hundred years. Jeffries's team concluded that "adequate conservation of the insect fauna in forests of long-lived trees such as white oak may require longer time periods between timber harvests at the same location (extended rotation time) for some portion of the total forested landscape than is prescribed by current silvicultural practice." In other words, if we have only young forests, we will have only the insect communities found in young forests, and the insect communities that would have come later will come no more, resulting in a loss of biodiversity.

We all know that biodiversity is important. These small insects we are talking about here are the living things that have evolved before us and around us. They add to life's amazement. If we do nothing about what these scientists are telling us as they summarize their careful research, we are the ones responsible for the erosion of biodiversity on planet Earth. We have a choice. It's not that difficult. Save at least a little from the blade, from the plow, from the feller buncher.

But that is just a small part of the insect story in forests. Insects have every type of lifestyle imaginable. They inhabit niches from the very top of the canopy to beneath the forest floor. Of the 1.6 million described and named species of animals on earth, way more than half are insects. And of this multitude of insects, almost half are beetles. There is a story that when evolutionary biologist J. B. S. Haldane was asked what conclusion might be drawn about the nature of the Creator from a study of the creation, he answered, "An inordinate fondness for beetles." To put this comment in perspective, realize that about four hundred thousand beetle species have been identified (with many more likely yet to be discovered) and only nine thousand bird species. Bringing these numbers down to earth and a little closer to home, consider that Great Smoky Mountains National Park



A curve-lined looper, found only in old-growth forests.

shelters 450 species of animals with backbones (this includes mammals, birds, amphibians, and the like), 2,816 species of plants, and more than 4,300 species of insects and spiders. How many of them can you identify?

Some insects, such as those discussed earlier, feed on living trees, while others require deadwood. More than half of all beetle species are in this second group; therefore, when we talk about beetles worldwide that depend on deadwood we are not talking about an insignificant group. We are talking about hundreds of thousands of species—more than all the birds, all the mammals, all the reptiles and amphibians combined. Way more.

And what is it that these poster creatures for biodiversity need in order to live healthy and successful lives? They need deadwood, and size does count: the bigger the better. A number of attributes of large deadwood make beetles want to call it home. Deadwood of large diameter generally contains many different types of habitat, allowing room for all the beetles to occupy their preferred niche.

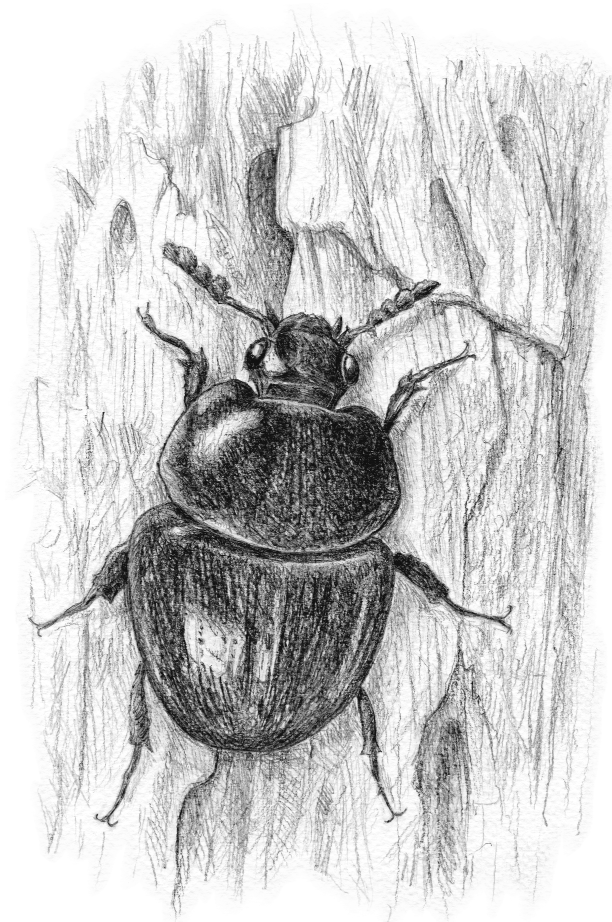
Think of the difference between an efficiency apartment and a villa in France: if you were going to bring a dozen highly creative but very fussy artists together, where would you rather house them? (Scientists, you may make up your own ideal laboratory spaces here. . . .) The musicians need a music room (or two) where they can make noise, the writers need their own private quiet space, the artists need light and space to create without worrying about cleanliness, the cook needs space to prepare meals. And everyone needs a bathroom. You would choose the villa, of course. It is the same with the beetles—so many different species, all with different requirements. The deadwood in a young managed forest is like the efficiency apartment—fine for a few beetle species. But the deadwood in an old-growth forest is like the villa in France—with so many habitats to choose from there is something for even the fussiest beetles. (Instead of grand pianos and internet connections, fussy beetles look for just the right type of fungi rotting the wood, or just the right moisture levels.)

While I'm having fun with this comparison, let's extend it a little further. Both the fussy, artistic humans and the habitat-specific beetles depend on their shelter's permanence; it is part of what makes the place desirable. The artistic humans want to be able to return year after year, perhaps generation after generation, to the villa retreat, if it is around that long. They frequently choose a stable, familiar retreat over new ones that have been in existence for just a year or two. If the villa eventually needed to be demolished but they could occupy a great villa next door, they would easily shift their allegiance there. However, if the retreat space were moved to Kenya, the transition would be difficult, and many of the artists would never show up again. It is much the same with beetles—they need a space that will be there for years; small deadwood decomposes too quickly for them. The larger diameter deadwood that they prefer will decompose in time, of course, but beetles can shift to other deadwood if it exists nearby—which is likely in an old-growth forest. However, if the forest where they live is too heavily disturbed (perhaps by thinning or harvesting), some beetles are not successful at finding another older forest to occupy. They have a limited range of travel.

Most of the studies on beetles in old growth have been done in Scandinavia and Europe. Time and time again, rare beetles are found in the rare habitats of the older forests. Although studies have also been done in the United States linking the presence of large deadfall (also known as coarse woody debris) to beetle diversity and abundance, only one study has proposed using one of these beetles as an old-growth indicator. The proposed indicator is the round fungus beetle *Anistoma inops*, family Leiodidae.

I mentioned earlier just how many, many beetle species exist. In fact, because there are not enough common names to go around, many beetles are called round fungus beetle—3,500 species worldwide and 350 species in North America. These particular little creatures, about the size of a mini chocolate chip, feed on underground fungi and slime molds. The slime molds need a damp environment, and they often grow under the bark of rotting wood. Many more fungal species are found in old-growth forests than in younger forests, so it should be no surprise that this beetle is found there also. Its smooth domed shape allows it to easily squeeze into spaces in the rotting wood. Beetles like this have been found embedded in amber, so we know that they have been around for tens of millions of years, but they may or may not be around much longer—depending on how we choose to treat our forests.

A New Hampshire study conducted by Donald Chandler and Stewart Peck compared the number and species of round fungus beetles found in an old-growth forest called The Bowl with those found in a managed forest, Spring Brook, which had been selectively logged forty years before the study. Although the species differed, the total number of species in each forest was the same



Round fungus beetle—an old-growth indicator?

(thirty-four). The total number of individuals, however, was almost three times higher in the old growth, as shown in the table on pages 64–65.

Many insects feed on the conks (visible fruiting bodies) of shelf or bracket fungi that are instrumental in the decay of coarse woody debris. Because of this association, many of these insects, as well as the fungi on which they feed, are strongly associated with old-growth forests. One such species, the ironclad bark beetle (*Phellopsis obcordata*), is known primarily from old-growth balsam fir, hemlock, and birch forests in the Appalachian Mountains. These bumpy brown beetles play dead and drop to the ground when they are disturbed.

By managing forests so that standing wood is removed before it is allowed to decay, we eliminate large deadwood and at the same time a whole suite of beetle species that depend on large deadwood. We also reduce the food available for woodpeckers, and bears, and ground beetles that search deadwood for these beetles and their grubs. With successive timber-harvesting cycles, an increasing loss of beetle species is likely. These tales of deadwood-dependent beetles from here and abroad point out once again that if we want to keep all the pieces, we need to allow for natural dynamics in the landscape, including the occasional occurrence of pest and disease outbreaks, windthrow, and fire. We also need to allow either places that are not managed or management that offers the opportunity for at least some trees to live to maturity and decay without intervention.

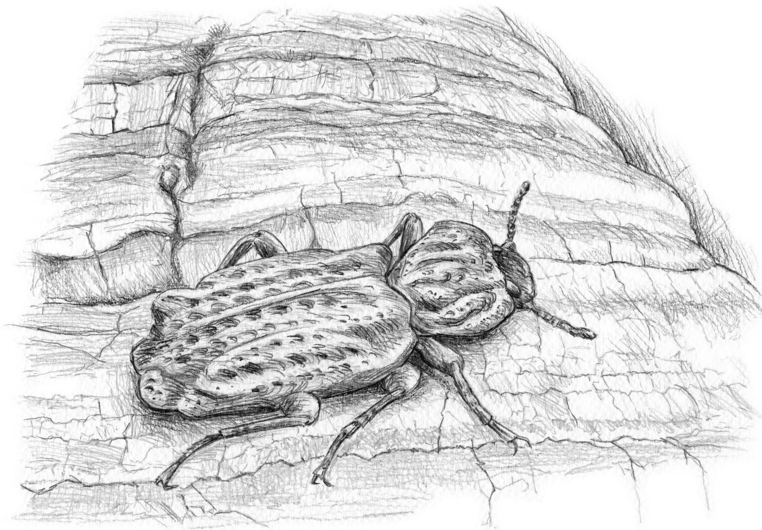
We have discussed insects found on tree leaves and in deadwood, but many more habitats exist in the forest for insects. In almost any place you can imagine, an insect specializes in that habitat. For instance, some beetles are found only in the hollows of living trees. Young, intensively managed, "healthy" forests do not commonly have trees with hollows, so do not look for any of those beetles there.

In addition to deadwood- and fungal-feeding insects, insect predators are found on the forest floor as well. Erika Latty and her team studied the occurrence of a particular category of predaceous beetles—the ground beetles (family Carabidae)—in young, mature, and old-growth forests of northern Wisconsin and the Upper Peninsula of Michigan. They found that overall abundance and diversity of ground beetles didn't differ significantly between forest types, but, again, the old-growth forest

Table 3. **Numbers of individual beetles of different species collected from the forest floor in two New Hampshire forests, old-growth The Bowl and forty-year-old Spring Brook**

Species	The Bowl (old growth)	Spring Brook (managed)
Family Leiodinae		
Anisotoma basalis	54	8
Anisotoma blanchardi	0	1
Anisotoma errans	53	25
Anisotoma geminata	119	20
Anisotoma horni	798	133
Anisotoma inops	46	1
Agathidium assimile	15	4
Agathidium atronitens	17	9
Agathidium sp. near *concinnum*	9	13
Agathidium sp. near *depressum*	5	0
Agathidium sp. near *oniscoides*	70	32
Agathidium parvulum	93	56
Agathidium politum	73	15
Agathidium rusticum	77	35
Agathidium temporale	18	1
Leiodes assimilis	3	5
Leiodes conj	119	77
Leiodes impersonata	0	5
Leiodes mult	2	0
Leiodes soer	48	18
Leiodes vari	9	12
Colentis impunctata	28	31

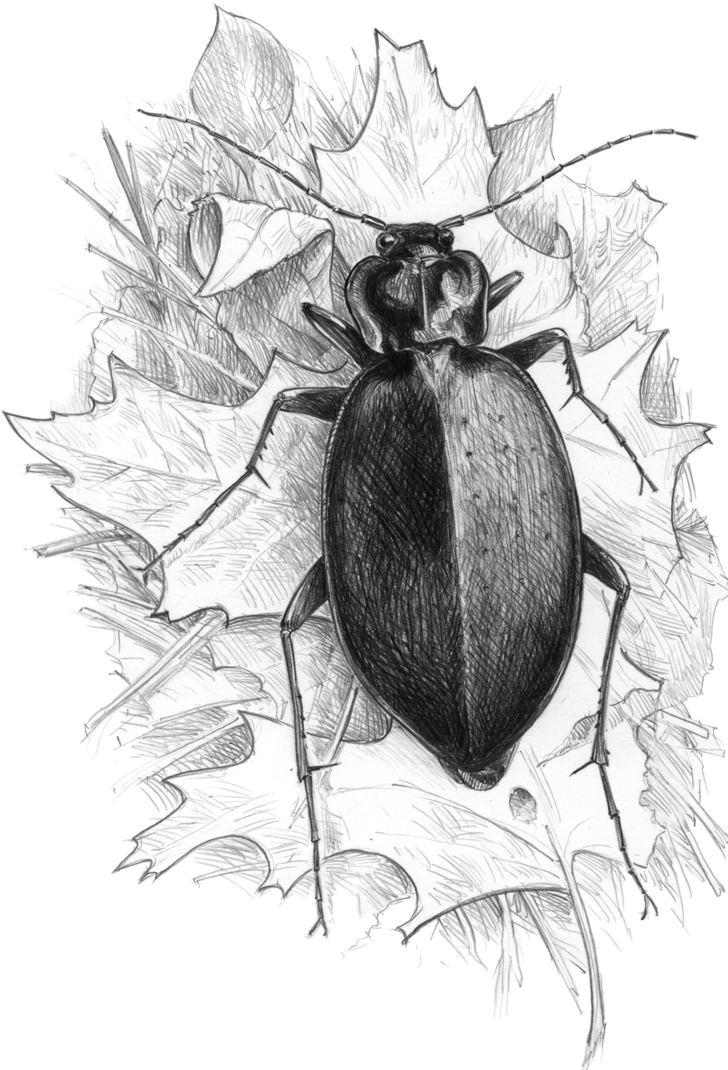
Family Cholevinae		
Catops americanus	305	196
Catops basilaris	1,029	303
Catops gratiosus	165	33
Catops simplex	228	127
Nemadus horni	17	2
Nemadus parasitus	0	3
Prionochaeta opaca	3	0
Sciodrepoides fumatus terminans	28	11
Sciodrepoides watsoni hornianus	36	8
Family Coloninae		
Colon forceps	14	7
Colon hubbardi	7	0
Colon schwarzi	25	54
Colon sp. 4	2	0
Colon sp. 5	1	5
Colon rectum	1	6
Colon sp. 13	0	1
Colon horni	0	9
Total number of species	**34**	**34**
Total number of individuals	**3,517**	**1,266**



The ironclad bark beetle, which eats shelf fungus.

hosted a unique community. Five beetle species were considered indicators since as a group they had significant affiliations with the old-growth forests. Because so many beetles exist and so few people talk about them in the field, most species don't even have common names. You would not be corrected by an entomologist if you called each one of these a woodland ground beetle. Given that they look somewhat alike, try separating 47,590 of them into fifty-nine species! That is what these researchers did to determine how forest age influences ground beetles. I only wish they hadn't had to kill all those beetles to do it.

The northern hardwood–hemlock forest type they studied has changed massively in the past few hundred years, as shown in the table on page 68. This forest type now covers only a quarter of the land it did when European settlers arrived in northern Wisconsin and the Upper Peninsula, and only 0.4 percent of that is old-growth forest. These beetles don't have many places left to call home.



The predaceous woodland ground beetle, of which many species exist (based on a photo by Scott Housten).

Table 4. Places a ground beetle can call home: Changes in the forest cover in northern Wisconsin and the Upper Peninsula of Michigan

Forest cover type	Proportion on pre-settlement landscape (%)	Proportion on current landscape (%)
Northern hardwood–hemlock	100	24
Unmanaged	100	0.5
Old-growth	63	0.4
Regenerating	37	0.1
Managed	0	23
≥Sixty years	0	16
Sixty years	0	7

What advice do these researchers give to ensure the preservation of these insect species? I'm sure it will come as no surprise to you: "Given forest reduction at the landscape scale and the nearly 100-percent loss of old-growth forest, we suggest that the conservation of carabid diversity is dependent on maintaining forests in a variety of age classes including late-successional stages."

We are fortunate in the United States that our forest destruction started so recently (just a few hundred years ago). The history of forest abuse in western Europe is altogether different. Simon Grove tells that story: "Forests had scarcely reached their maximum post-glacial extent when farmers started clearing them. Over the following millennia forest cover was drastically reduced, and the structure and composition of remaining fragments greatly altered. By 1000 A.D., there was probably no truly natural forest left in Europe outside Fennoscandia. It was not just wolves, bears, and lynx that retreated as forests were cleared." As the remaining fragments were intensively managed for firewood, poles, and other wood products, the old-growth forests disappeared and along with them many of the old-growth-dependent insects. The result is that many insect species have now vanished from those areas. In the United Kingdom, seventeen deadwood-associated insects are known only from peat deposits (2900 BC) and fossils. None of these species is yet globally extinct, but most now survive only in tiny refugia elsewhere in Europe.

Although forest cover is coming back in some areas of Europe, the beetle loss continues, largely due to intensive forest management that doesn't allow for large old trees to die and rot. The removal of mature timber habitat is considered the main threat for 65 percent of the United Kingdom's 150 threatened woodland insect species. Many of the old-growth-loving beetle species are hanging on in single small patches—or even single large old trees. It's not difficult to imagine how just one unfortunate event could cause further local—and possibly global—extinctions.

Then there are the tiniest creatures on the forest floor, so tiny they can make a meal of bacteria. I am thinking of the mites. There are forty-eight thousand different kinds of mite (try telling *them* apart!), with every lifestyle imaginable, but the ones most likely to be found on the forest floor are the oribatid mites—and there are only six thousand different kinds of them. (Chiggers are mites, but not oribatids.) In a study of mites in differently aged forests in South Carolina and North Carolina, some species were found in the old-growth forests that did not occur in the younger forests, but overall the density of the mites was higher in the younger forest. I wish someone would do this research regarding the chigger mite (family Trombiculidae). If fewer chiggers were found per inch in the ancient forests, we might have many more people interested in preserving them.

Speaking of "problem insects," Latty's study of those many, many beetles found five non-native beetle species—all of them associated with the managed forests but not the old-growth forests. Are the managed forests really the healthiest? Not if you are a native insect or a tree.

So let's ask and answer our recurring questions: In terms of insects, are there any differences between young forests and old-growth forests? Absolutely! Many insects depend on the presence of ancient forests and will become extinct without them. Are there any indicator species that are more likely to be found in old growth? Yes! But good luck trying to tell them apart; this is a job for the experts.

Sources on pages 198–99.

(continued...)

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