



Pacific
Northwest
Research
Station

Science Update

RESTORING COMPLEXITY: Second-Growth Forests and Habitat Diversity



IN SUMMARY

Old-growth forests supply many important values, including critical habitat for some wildlife species. These forests are most useful for some wildlife species when they exist in large blocks. But many areas dedicated to old-growth values on federal lands are fragmented by patches of second-growth forests planted after timber harvest. These second-growth forests are often dense stands of Douglas-fir with little structural diversity.

When—and if—these conifer plantations develop the characteristics of old-growth forests, then large parts of the forested landscape will function as complex, old forests. Such complex forests would more likely support

the full range of biodiversity associated with old-growth forests than would stands with simple structure.

Recent research by scientists with the USDA Forest Service Pacific Northwest Research Station (PNW) and by other scientists offers intriguing insights into the processes of forest development. These findings suggest that managers have options. One option is to let conifer plantations develop old-growth characteristics as a result of natural events over time. Another option is to thin stands in order to restore habitat diversity more quickly.

The science findings are explained inside.

As conifer plantations mature, are they likely to develop the complexity, diversity, and ecological values of old-growth forests?

After years of scientific study, the exact definition of an old-growth forest is still an issue of some debate. But there is general agreement on the main characteristics—large live trees; large dead trees (snags) and large fallen trees; trees of varying ages, sizes, and species; a deep, complex canopy; and patches of young trees, shrubs, and herbs on the forest floor.

Many old-growth forests on federal lands were fragmented by timber harvests before old growth's ecological values were recognized. In the resulting mosaic, the development of the plantations will be an important factor affecting what ecological values will be provided by these landscapes. If the conifer plantations can develop some old-growth characteristics, then it is likely that the broader forest landscape will provide the ecological values of old-growth forests.

Old-growth forests are complex in every sense of the word—in vertical and horizontal structure, and in terms of biodiversity and energy flow. The dominant trees have deep crowns

The old-growth forest's structural complexity is the key to its biological diversity.

that support a canopy community of small mammals, birds, bats, insects, spiders, mosses, and lichens. Standing dead trees (snags) and smaller trees of various ages, sizes, and species create a patchy, multilayered canopy.

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In some places, the deep canopy reaches the forest floor. The forest floor is bumpy with fallen trees and patches of shrubs, plants, mosses, and fungi, and the ground is crawling with spiders, mollusks, and soil arthropods as well as reptiles, amphibians, and mammals.

The old-growth forest's structural complexity is the key to its biological diversity. Complex habitats support a diversity of organisms that could not coexist in simpler



The old-growth forest floor is bumpy with fallen trees and patches of shrubs, plants, mosses, and fungi. Photo by Tom Iraci



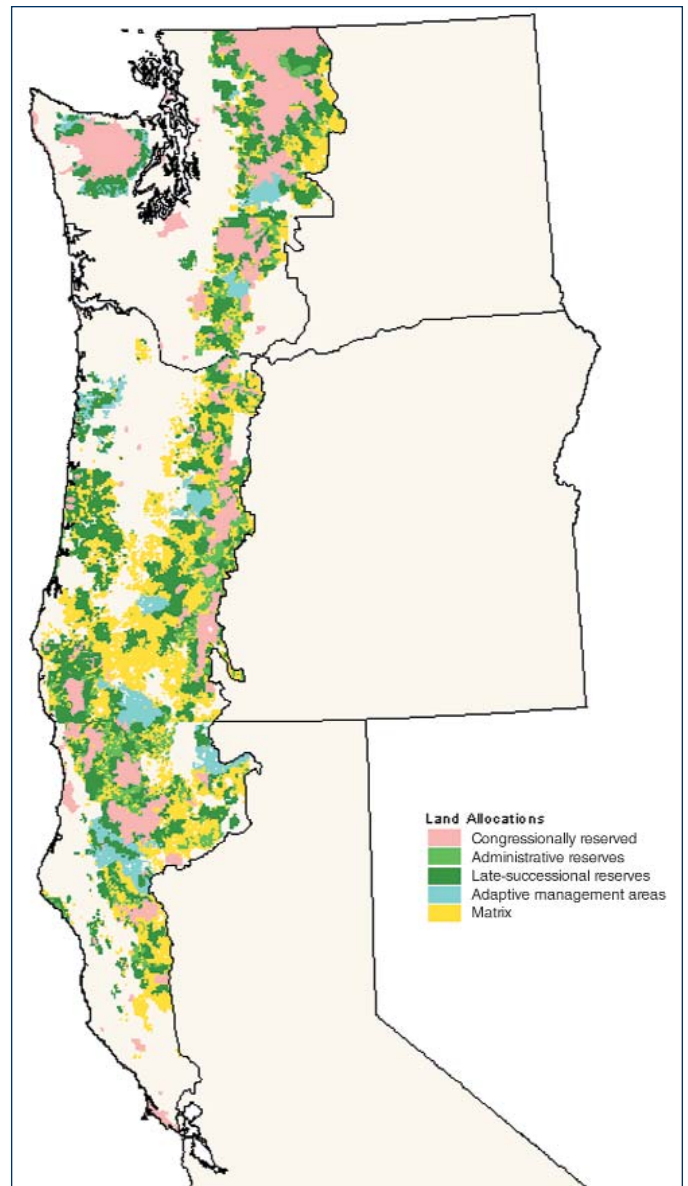
Puget oregonian (top) and warty jumping-slugs (bottom). Two of the mollusk species closely associated with old-growth forests within the range of the spotted owl. Photos by Bill Leonard

environments. Old-growth forests supply nesting and roosting habitat for spotted owls, nesting habitat for marbled murrelets (where the forests are close enough to the Pacific coast), truffles for red-backed voles and flying squirrels, and food and cover for many other species, including rare mollusks such as the Puget oregonian land snail and the warty jumping-slug.

The development of old-growth values in conifer plantations is of particular concern in the late-successional reserves (LSRs), designated on some federal forest lands in Oregon and Washington. The LSRs were designed to be large, unfragmented areas where complex, older forests could provide habitat for wildlife. These areas were chosen for their locations in the regional landscape and for their existing old-growth forests in order to meet legal requirements for maintaining viable populations of native wildlife throughout the region.

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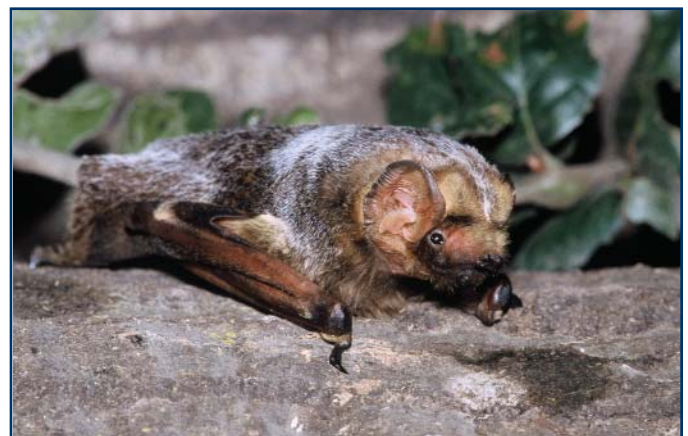
The intention is that the reserves will eventually become all old-growth forests. But some timber harvesting had already occurred in parts of these areas before they



A network of late-successional reserves (LSRs) was established on federal forest lands in the range of the spotted owl. Because of logging before LSRs were designated, slightly more than one-quarter of the LSR acres are currently dense conifer plantations (about 1,533,000 out of 5,849,000 acres).

Key Findings

- Many old-growth trees grew more rapidly in their first 50 years than young trees in unthinned conifer plantations are growing today. Tree-ring studies show that in many old-growth forests, the dominant trees often gained diameter rapidly in their first 50 years.
- In dense, uniform, conifer plantations, one or more variable-density thinnings could promote increases in biological diversity in the next one to three decades. The thinning likely would accelerate the development of some old-growth characteristics, perhaps by decades (compared to stand development without the thinning).
- Habitat improvement activities can increase the likelihood that stands develop the vertical and horizontal complexity typical of old-growth forests. These activities include creating snags, adding large pieces of wood when necessary, and underplanting with several tree species, especially shade-tolerant conifers where they are absent.
- Trees grown in dense plantations are most responsive to thinning when they are less than 80 years old. The options for accelerating forest development may diminish substantially if stands are not thinned when young.



Hoary bat clings to tree bark. Photo by Bill Leonard

STUDIES ON MANAGING YOUNG STANDS



Station scientists are studying alternative silvicultural treatments for young managed stands, in order to learn if management treatments could promote more biologically diverse forests. In one study on the Willamette National Forest in Oregon, scientists began with dense plantations of Douglas-fir 35 to 45 years old (top).



Treatments being studied include light thin (center), light thin with gaps (not shown), and heavy thin (bottom). Additional actions will include underplanting and snag creation. Followup studies are being done on tree growth, plant diversity, down wood, small mammals, amphibians, birds, snags, mushrooms, arthropods, and public perceptions.



Photos by Dave Pilz



Crowded trees are tall but skinny; little vegetation grows on the forest floor.
Photo by R. Alan Hoffmeister

were designated as LSRs. These harvested areas are now plantations, usually less than 80 years old.

PNW Research Station Director Tom Mills points out that recent scientific research indicates that if the plantations in the LSRs are treated with the proper types of thinning and some other management actions, the actions may accelerate the development of some old-growth characteristics by decades. Some benefits in biological diversity could occur within the next two or three decades.

The management objective for the areas is the essential starting point. The scientists who reviewed the *Northwest Forest Plan* alternatives felt that if the choice was made to do nothing in these areas, there would be significant risk to the overall goals of the plan. “Does ‘reserve’ mean hands-off?” asks Mills. “Or does it mean reserved for certain objectives, so that some hands-on activities could be permitted if they help achieve the goals?”

Are forest plantations likely to develop into old growth if they are left alone?

Some old-growth forests started after moderate-to-severe natural disturbances, such as forest fires, major windstorms, and disease outbreaks. After disturbances, patches of live trees and many recently fallen trees remained and prevented dense, uniform regeneration of young trees. A few trees survived, and young trees that had been in the understory grew rapidly after the disturbance.



Understory plant species. Photos: left by Tom Iraci, center and right by Joe Kraft

Tree-ring studies show that the dominant trees in some old-growth forests grew rapidly in their first 50 to 80 years of life, quickly gaining diameter and height. This kind of growth occurred when trees were widely spaced, with little competition from other trees. With open space around their crowns, these trees kept more branches than they would have if other trees had been growing close to them. They developed crowns that were both wide and deep.

As the trees grew, the canopies began to close. But when old trees died and canopies opened again, deep crowns redeveloped through epicormic branching. In this process, older Douglas-firs develop branches from dormant buds on their trunks when they are exposed to light, and these branches, along with younger, shade-tolerant trees, help to create a bottom-loaded canopy.

The disturbances people created through clearcut logging, slash burning, and planting were much different from natural disturbances.

In old-growth forests, the dominant trees have considerable variation in age because they started growing anywhere from several years to decades after the disturbance that either killed the previous forest or opened canopy gaps. However, some old-growth forests developed initially as more even-aged stands, especially after severe disturbances, showing again that there are many pathways in natural forest development.

Andrew Carey, chief research biologist and biodiversity team leader for PNW, explains that the disturbances people created through clearcut logging, slash burning, and planting were much different from natural disturbances such as wildfire, windstorms, floods, droughts, root rot, and insect outbreaks. Few biological legacies

such as snags and fallen trees were left, and usually a single tree species was planted, most often Douglas-fir, with the trees uniformly spaced and all one age. Foresters intended to thin these closely planted trees 10 to 20 years later, in order to select the strongest trees and give them space to grow.

“These hand-planted second-growth stands are much more dense than stands nature typically would have created,” Carey points out.

Again, variability makes it impossible to predict precisely the course of events in any one place. Without active management of plantations, disturbances such as windstorms, ice storms, root rot, insect infestations, and fire would likely occur over the next century. These events would either put plantations on a pathway that leads to complexity or would kill enough trees that a new stand would begin to grow. These disturbances are unpredictable, but it is fairly certain that a number of these events would occur in any forest over a two-century time span.

In plantations, small to intermediate disturbances can lead to structural diversity or can begin to unravel the stands, depending on many variable factors. Root rot and windthrow could create small openings, which could lead to structural diversity if seeds of shade-tolerant trees are present. This response depends on the plantation’s size and the stands surrounding it. Trees in dense stands often are not very sturdy and are prone to blowdown or “snowdown.” Again, the stand may respond by developing complexity or may begin to unravel, depending on many factors. If trees over a large area are destroyed, it can be a major setback in that forest’s development.

“Society doesn’t appear to be willing to let nature use all of its tools. Generally society is not willing to let wildfires change these stands the way nature did in the past, for example,” comments Mills.

THINNED STANDS SHOW DIFFERENCES IN TREE SIZE AND UNDERSTORY DEVELOPMENT

These three second-growth stands, located in the Oregon Coast Range, are about the same age (25 to 30 years). The only major difference is that two stands were precommercially thinned (center and bottom), and one was not (top photo). The treated stands were thinned to different densities.

A few years after the thinning, the stands have major differences in tree size, range of variability, and understory development.

In the unthinned stand (top), tree density is 491 trees per acre, and the average tree diameter is 8 inches. Tree density is 185 trees per acre in the moderate density stand (center), and the average tree diameter is 13 inches. In the more heavily thinned stand (bottom), tree density is 105 trees per acre, and the average tree diameter is 15 inches, almost double the average in the first stand.

Both thinned stands (center and bottom) have a greater range of variability in the sizes of trees than the unthinned stand (top), where the trees are fairly uniform in size. The mixture of large and small trees will provide diversity as the forest grows.

The unthinned stand (top) has almost no green plants on the ground, only dead branches and needles. A few plants are growing in the moderately thinned stand (center). In the more heavily thinned stand (bottom), many green plants, forest shrubs, and small trees are growing. The small trees will likely develop into an understory with different layers, and the green plants will provide more diversity on the forest floor, characteristics that in turn can support a diversity of wildlife species.



Photos by R. Alan Hoffmeister

Can forest management help conifer plantations develop old-growth characteristics faster than the stands would if left alone?

“Yes, there are options,” says Mills. “When it’s properly designed, variable-density thinning can accelerate the development of old-growth characteristics.”

Logging and planting imitated natural forest development processes in some ways, but were not the same as natural processes. Plantations were planned to maximize timber production. But forest managers can use the data on density, growth rates, and ages in old-growth stands to design silvicultural options that could put some forest plantations on different pathways likely to lead to greater forest complexity and habitat diversity.

Thinning to develop old-growth characteristics is different from thinning to maximize timber production. Timber management uses evenly spaced thinning to produce uniform stands, and removes just enough trees to maximize the growth in volume of the stand as a whole, rather than maximize the growth in volume per tree.

The complex structure of old-growth forests is the result of variability. Variable spacing allows some trees the chance to gain diameter rapidly in their early decades,

The complex structure of old-growth forests is the result of variability.

not just height, and to keep more live branches. Patchy mortality makes holes in the developing forest, allowing other trees to grow. These trees begin to create a forest of many species, ages, and sizes. Therefore, if thinning treatments are intended to accelerate the development of old-growth characteristics, the spacing should vary.

When the goal is forest complexity, “there is no one standard procedure,” comments Carey. But he offers some suggestions. Variable-density thinning can be done by thinning to different densities in ¼- to 1-acre patches, by leaving small ¼- to ½-acre unthinned areas, and in other places creating very small—up to ¼ acre at most—gaps. The small gaps will let in light without increasing susceptibility to windthrow. In young plantations, small gaps will encourage the growth of herbs,

shrubs, and understory trees, and large, open-grown trees. In the unthinned or lightly thinned areas, shade-tolerant trees like hemlocks will grow under the dominant trees. Just as natural processes are variable, a thinning design is site-specific and depends on the characteristics and landscape context of the individual stands.

Studies show that when variable-density thinning is used, thinned stands usually have better developed understories, higher shrub densities, a greater richness of understory plant species, and more plant cover than unthinned stands. Well-developed understories provide habitat for birds such as the dark-eyed junco, Hammond’s flycatchers, and chestnut-backed chickadees.

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There are risks. Exotic plant species such as English holly and thistles can invade thinned stands. However, one result of thinning is the development of richer understories, and exotic plants may be less likely to get established in stands with well-developed understories of conifers, hardwoods, and native plants.

Studies show that thinned forest plantations provide growing conditions similar to those historically found in some developing old-growth forests. However, the studies also show that old-growth forests are highly variable and that they developed along many different pathways.

Given the uncertainty, one option would be to manage for a diversity of pathways rather than to apply one uniform prescription, such as heavy thinning, across the landscape. The use of multiple pathways is also a good way to spread risks, as long as all pathways are equally well thought out.

Natural disturbances will still occur. Uncertainties still exist. We have learned much from decades of research, but there is clearly much we don’t know. Scientists stress the importance of observing how forests respond to management and learning from these results.

Will thinning alone help conifer plantations develop into old-growth habitat for wildlife species?

Other habitat improvement actions in addition to thinning would increase the likelihood that the plantations would develop the complexity and biodiversity of old-growth forests.

Snags and fallen trees are important biological legacies that are missing in many forest plantations, but they can be created by management activities. Some trees cut during thinning may be left on the forest floor to shelter salamanders, voles, and shrews, and eventually to decay. The decaying logs support fungi species that live in symbiotic relationships with tree roots and are essential for tree vigor. A few standing trees might be topped to create live trees with cavities, which are used by cavity-nesting birds and other wildlife.

Existing hardwood trees such as bigleaf maple can be left, or even planted if missing. Maple seeds provide food for small mammals and some bird species. Winter birds such as winter wrens, various woodpeckers, chickadees, and nuthatches eat seeds and insects more likely to be found in mature or old-growth forests.

Developing complex forests from managed stands requires complex management.

Some shade-tolerant conifers, such as western hemlock and western redcedar, can be underplanted after a heavy thinning, introducing different age classes and diverse tree species into the stand. Eventually the hemlocks and cedars will provide some of the multilayered and bottom-loaded canopy characteristic of old-growth forests. In some cases, low-intensity underburning might help to diversify the stand structure.

Developing complex forests from managed stands requires complex management. Foresters and biologists can apply the general scientific principles discussed here to individual, highly variable forests. The actions described would promote forest developmental processes, such as understory development, canopy elaboration, shade-patch and gap development, establishment of shrub and herb layers, and the development of live tree decadence.

In the past, forest plantations often were evaluated only by how fast the trees grew. But the results of variable thinning and legacy retention can be monitored by such



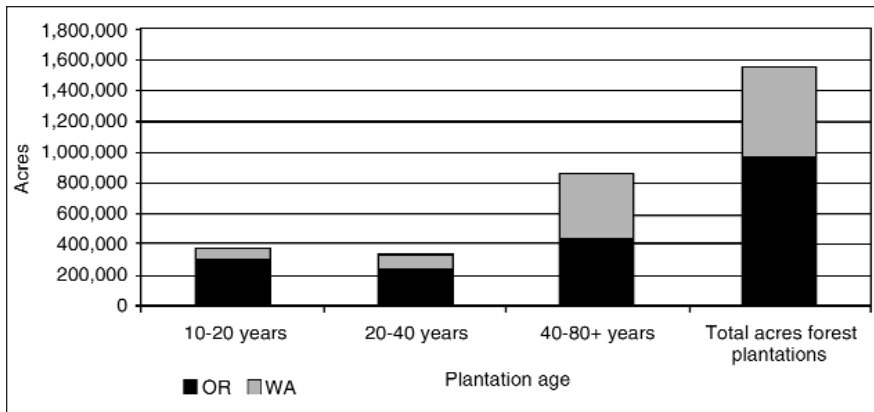
Understory trees add layers to the canopy. Photo by Tom Iraci

biological indicators as the abundance and diversity of the small mammal community on the forest floor, the tree-dwelling small mammal community, and the winter bird community, along with measures of forest structural complexity.

Key Questions

Scientists agree on one point about old-growth forests—that we are only beginning to understand complex natural ecosystems and we have much more to learn. Some key questions are:

- What caused the accelerated growth rates in today's old-growth trees when they were young? Possible answers are low stand densities, a head start on competition by a few years, or a favorable climate pattern at the time.
- How common were different pathways in the development of old-growth forests? There seem to have been multiple pathways to old-growth forests, and scientists do not know how typical various pathways were.
- Would today's dense forest plantations develop into old-growth forests if managers take no action and just let natural events take their course? Because so many unpredictable events can occur over several centuries, scientists may never be able to say with absolute certainty exactly what would happen with any one forest.
- What are the exact habitat requirements for species associated with old-growth forests? In many cases, scientists do not yet know the detailed habitat needs for all these species. However, the management techniques described would encourage forest development processes that lead to forest complexity and habitat diversity.



Forest Service databases show that in about half of the forest plantations in LSRs, the trees are big enough for commercial thinning (40 to 80+ years). If some wood products are generated, the wood can pay for the work done.

Does it matter how old the plantations are when they are thinned?

Yes. Trees grown in dense plantations are most responsive to thinning when they are young—less than 80 years old. Thinning before this age generally results in a surge of growth.

The diameters of 100- to 300-year-old trees have been found to be strongly related to their diameter and growth rates when the trees were 50 years old. In some old-growth forests studied, the biggest trees had their

In conifer plantations, some management options could create considerable forest and habitat diversity in the next one to three decades.

fastest diameter growth rate when they were young. After that, their diameter growth rate declined until the trees were about 100 years old, and then generally stayed at the lower level. In other old-growth forests, the tree rings show a different pattern—fast growth when the canopy is open, slower growth while the canopy is closed, and fast growth when the canopy opens again.

Other pathways may also lead to old-growth forests, with some pathways slower than others. Even so, thinning in plantations is very likely to accelerate the development of structural diversity and hence biological diversity in these young forests.

For many densely stocked stands, the options will be more constrained if the stands are not thinned soon. Because some forest plantations are already 50 years

old, there may be only a few years left before the option is greatly diminished for accelerating the development of old-growth characteristics.

“Doing nothing is a choice that has consequences too,” says PNW Station Director Mills. “There will be fewer options if we wait until later to do something.”

If we thin plantations and speed up their development of old-growth characteristics, are there any other benefits produced?

Yes, there can be. In stands 30 to 80 years old, some trees could be removed for forest products. In some stands less than 30 years old, some thinned trees could be removed for posts and poles. The timber revenue could defray some of the cost of the work, while contributing to rural economies.

“This is a good example of compatibility between wood production and ecological objectives,” says Mills. “Multiple values, including ecological and economic values, don’t always have to be at odds if we are creative.” The biodiversity thinnings done so far in research studies have been profitable. This encouraging result suggests that foresters can develop old-growth characteristics and wildlife habitat diversity, while simultaneously generating some economic values from plantations.

In other plantations, the trees are too small to be commercially valuable. On federal forest lands, precommercial thinning in these smaller stands would be paid for with funds appropriated by Congress as part of the USDA Forest Service annual budget.



Small gaps let in light. Photo by R. Alan Hoffmeister

Logging techniques and equipment already exist that can do this work. “There’s a new breed of timber operators,” says team leader Carey. “The loggers have new equipment for the new types of operations.”

Scientists do not suggest that foresters will replicate natural forests through management. But many scientists think that we do know enough to take reasonable management actions to build complex habitats from conifer plantations. These options could create considerable forest and habitat diversity in the next few decades.

“We have choices,” Mills states, “even given the reality that we don’t know as much as we wish we did. Science is giving us knowledge that can help inform those choices.”

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For Further Information

Contact: Andrew Carey, Team Leader, USDA Forest Service, Forestry Sciences Laboratory, 3625 93rd Avenue, Olympia, WA 98512-9193. Phone: 360-753-7688. E-mail: acarey@fs.fed.us. Visit the Pacific Northwest Research Station Web site at: www.fs.fed.us/pnw.



Photo by R. Alan Hoffmeister

Credits:

Writer and editor – Valerie Rapp

Science contributors – Andrew Carey and Thomas Spies, USDA Forest Service, Pacific Northwest Research Station;
Jerry Franklin, University of Washington

Art director – Frank Vanni

Layout – Jenny Beranek

Photography:

Front photo – Tom Iraci

All other credits with photographs

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