Conserving Biodiversity Through Sustainable Forestry

A Guide To Applying NCSSF Research

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Improving the scientific basis for environmental decisionmaking

The National Commission on Science For Sustainable Forestry (NCSSF) operates under the auspices of the National Council for Science and the Environment (NCSE), a non-advocacy, not-for-profit organization dedicated to improving the scientific basis for environmental decision making.

NCSE promotes interdisciplinary research that connects the life, physical, and social sciences and engineering.

Communication and outreach are integral components of these collaborative research efforts that link scientific results to the needs of decision makers.

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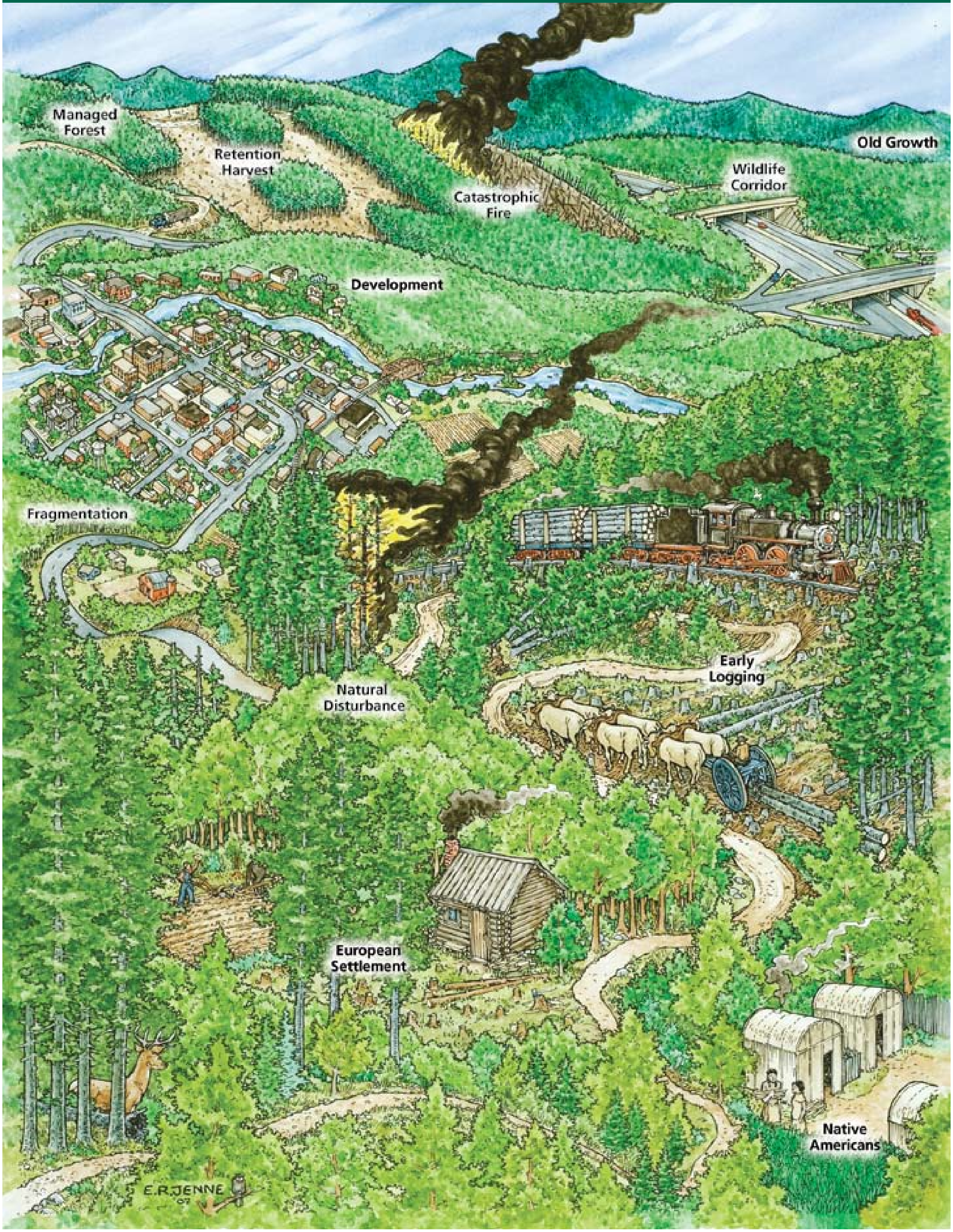
Old-growth Western Hemlock, Pacific Coastal Forest
Photo: Jon Martin

Retention harvest, Washington State Photo: Jerry Franklin

Development in the New Hampshire Ossipee Pine Barrens
Photo: Joseph Klemenitovich

Thinning and underburning restoration, Oregon
Photo: Bernard Borman, USDA PNW FS

Bottomlands, Altamaha River, Georgia Photo: Beth Young



From the trail at the lower left to the road in the distance, this landscape includes some of the historical and contemporary factors influencing forest biodiversity conservation. Enjoy the trip as you explore the guidebook.

WHY WAS THIS GUIDEBOOK WRITTEN?

This guidebook was written to promote communication and understanding about forest biodiversity (Glossary) among researchers, practitioners, landowners, managers, and policymakers. Its purpose is to strengthen the link between scientific understanding of biodiversity and its practical application in forest management. Although there are gaps in our knowledge, forest practices and policies that can be beneficial to biodiversity are constantly being developed and tested. This guidebook will help improve forest management by making biodiversity science easier to understand and illustrating on-the-ground applications. It emphasizes the reasons why biodiversity conservation and sustainable forestry (Glossary) are important.

WHO SHOULD READ THIS GUIDEBOOK?

Anyone who is interested in forests and forest management practices should benefit from reading this book. It offers forest owners, practitioners, managers, and policymakers some advanced scientific knowledge and practical tools for biodiversity conservation and sustainable forestry. The following examples illustrate various situations that forest managers face and suggest guidebook chapters that should be particularly useful in each situation. Brief chapter descriptions are included in "Overview of the Guidebook" below.


BUSINESS FORESTER*

I'm a business forester. *I manage plantation forestlands that must provide a reasonable return on investment. I realize that these forests are much more than mere fiber farms, but has anyone figured out how to enhance biodiversity in intensively managed forests and still make a profit?*

Recommended chapters: 6, 7, 1, 2 and 3.

I'm a service or consulting forester. *I work primarily with family forest owners and see the need for management practices that conserve biodiversity. It's not that the owners I work with don't care; it's more a situation where we all want to do the right thing and need to understand how to do it. Is there something here that I can use in my work with forest owners?*

Recommended chapters: 1, 2, 3, 4 and 6.


SERVICE OR CONSULTING FORESTER*

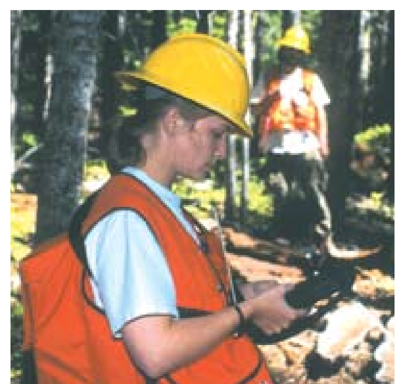

FAMILY FOREST OWNER*

I'm a family forest owner. *I've owned my property for quite a while. I know what it's like to make annual payments. My acreage had no merchantable timber when I bought it, but I've planted and thinned and the trees have grown. Over the years, I've listened to professional foresters and done what they recommended. It's been a lot of work and now I want to generate some income, but there's all this talk about managing forests sustainably and protecting biodiversity. What's this all about?*

Recommended chapters: 1, 2, 3, 4 and 6.

I'm a government forester. *I live and work in a rural, forest-dependent community close to a large metropolitan area. Local citizens are feeling a lot of pressure to develop the surrounding forestland. What was once a remote little town is rapidly becoming a bedroom community. Development includes 1-to-5-acre upscale suburban homesteads, a new subdivision for 85 homes, and plans to widen the connecting state highway. Town officials are coming to my agency for advice. Is there information here that can help?*

Recommended chapters: 1, 3, 7, 8 and 9.


GOVERNMENT FORESTER

Tom Iraci

*© Photos courtesy of Ben Meadows Company, Janesville, WI


POLICYMAKER

Bob Szaro

I'm a policymaker.
I help establish laws, regulations, and rules that reflect public consensus on how forests can be managed to conserve the values that they represent. I know the science of biodiversity is continuing to evolve, but I need information that will result in decisions that best protect the long-term public interest in conservation and sustainable natural resource management.

Recommended chapters: 1, 3, 5, 7 and 8.

WHAT'S THE BASIS OF THE GUIDEBOOK?

The guidebook highlights the latest research on biodiversity and sustainable forestry sponsored by the National Commission on Science for Sustainable Forestry (NCSSF). It includes topics that the Commission members have identified as important elements of forest biodiversity. Some serious gaps in scientific knowledge about many of these topics have been filled by NCSSF-sponsored research projects that produced new scientific findings and practical tools for applying those findings in the field. The Commission selected and funded knowledgeable and experienced researchers as project leaders, and the guidebook is based largely on their research results and scientific opinions, along with the expertise of Commission Members (listed on the inside front cover). However, the Commission did not attempt to evaluate the scientific accuracy of the projects, nor does it promote any particular scientific school of thought.

The Commission acknowledges that the project reports don't include everything there is to know about particular forest biodiversity topics, nor were they intended to. NCSSF project researchers are all recognized experts in their fields who were chosen through national requests for proposals and a rigorous and competitive review process. The Commission recognizes that it might have sponsored many other important scientific studies on these same topics if unlimited resources had been available.

A complete listing of all the NCSSF project reports is included in the appendix under *To Learn More* (pages 167-168). There you will find the name of the project or projects that formed the basis of each chapter and the lead project author or authors. All of these project reports can be viewed and downloaded at the NCSSF website (www.ncssf.org) unless otherwise noted.

OVERVIEW OF THE GUIDEBOOK

The guidebook includes three major sections:

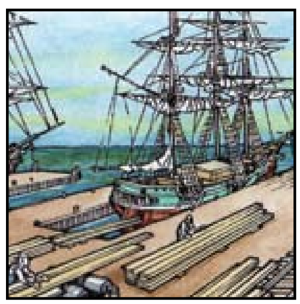
- **Section I: Factors Influencing Biodiversity**
- **Section II: Tools for Landowners and Managers**
- **Section III: Appendix**

Each chapter examines a specific topic, answering three questions:

- *Why is this topic important?*
- *What's known about this topic (but not everything)?*
- *How can that knowledge be used in forest management?*

In Section I, Factors Influencing Biodiversity, the guidebook looks at how biodiversity is influenced by forest history, non-native invasive species, forest fragmentation, and old-growth. Each chapter offers suggestions for using this knowledge to improve biodiversity.

Chapter 1, "Forest History and Biodiversity," describes the origins of today's forest policies and how that history has led to a growing interest in biodiversity

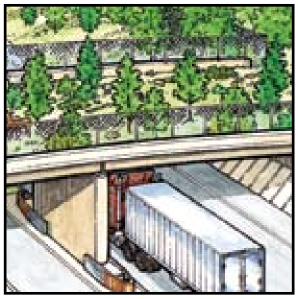


and sustainable forestry. The guidebook begins with this topic because it's the foundation for why things are the way they are. Chapter 1 doesn't stop with history, but goes on to describe restoration strategies that are being created and tested to conserve biodiversity in the major forest regions of the United States.

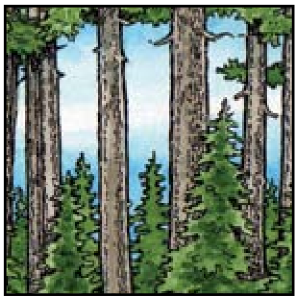
Chapter 2, "Non-native Invasives and Biodiversity," tells about the growing threat to biodiversity from non-native invasive species, due in part to forest history and the fact that the continents and regions of the world have become more connected. Forests are more

vulnerable than ever, and this chapter offers preventive strategies and recognizes gaps in the war against invasives. What's most essential is that we move beyond the attitude that invasives are someone else's job to the recognition that this threat requires the attention of every natural-resource manager.

Chapter 3, "Fragmentation and Biodiversity," goes beyond the historical loss of forestland. It explores the theoretical underpinnings of fragmentation theory and the numerous and complicated effects of fragmentation on biodiversity. The topic is difficult because it's a landscape-scale phenomenon, and we don't always relate well to that scale.

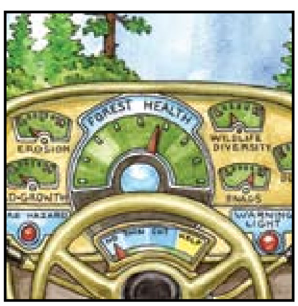


Chapter 4, "Old-growth and Biodiversity," takes the reader to five major forest regions of the United States for an update on the status of old-growth (OG) forests. It describes some OG-adapted species, major threats to OG, how society in each region views OG, and how knowledge of OG can be used in developing management and conservation strategies for public and private forestland.



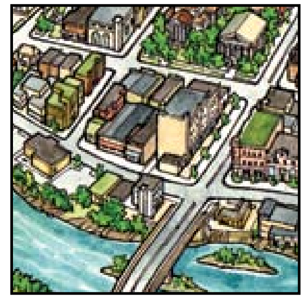
Section II offers tools for improving biodiversity while allowing landowners and managers to achieve their particular objectives. NCSSF has focused its support on research that offers practical applications, and this section is loaded with them. There are tips on selecting biodiversity indicators, enhancing biodiversity in managed forests, scientific advances in landscape-scale planning, how to make better use of adaptive management, and policies that encourage biodiversity.

Chapter 5, "Selecting Indicators for Biodiversity," discusses one of the most difficult topics for forest managers to get a handle on – how to tell if we're successfully maintaining forest biodiversity. It describes a technique for selecting biodiversity indicators at the landscape and local level.

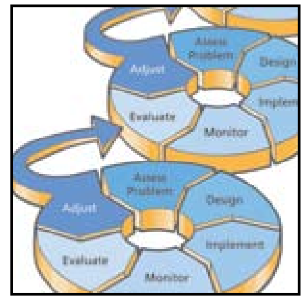


Chapter 6, "Biodiversity in Managed Forests," will interest everyone who practices intensive forestry across the United States. It looks at management practices that support biodiversity in those forests, regardless of the ownership, using loblolly pine and Douglas-fir plantations as examples.

Chapter 7, "Landscape-Scale Planning and Biodiversity," is crucial to sustaining forests and maintaining biodiversity. It describes innovative decision support systems that are being used to help develop a clearer understanding of the effects of alternative forestland management policies on biodiversity.



Chapter 8, "Adaptive Management (AM) and Biodiversity," explores the art/science of a concept that has had a mixed history of success when applied to forestry issues. It focuses on how to ensure the successful use of AM in forest management and offers several on-the-ground examples.



Chapter 9, "Policy that Encourages Biodiversity," summarizes what the Commission believes is important for protecting biodiversity. It explores the question of whether current incentive programs encourage biodiversity-compatible practices and offers policy ideas that will enable private forest owners, who control much of the nation's forestland, to practice biodiversity.

Section III, the Appendix, offers references to help you learn more about each chapter topic, highlights important organizations (NatureServe and The Natural Heritage Network), includes references to reports that support biodiversity conservation (State Wildlife Action Plan), and identifies informative web-based references about Non-timber Forest Products, the Rapid Assessment Scorecard, and the Carbon Sequestration Primer. It also includes a comprehensive glossary and index.

WHAT IS NCSSF?

The National Commission on Science for Sustainable Forestry (NCSSF) was created in 2001. It consists of sixteen leading scientists and forest-management professionals from government, industry, academia, and environmental organizations. Their mission is to improve the scientific basis for sustainable forestry practice, management, and policy in the United States. The Commission members and NCSSF staff are dedicated to:

- filling gaps in scientific understanding of biodiversity and sustainable forestry by supporting research projects
- transforming research results into usable, accessible information for forestry practitioners, managers, and policymakers
- improving communication between producers and users of scientific knowledge.

The Commission's work is guided by three broad principles developed through extensive deliberation, discussion, and consensus-building:

Continuum of Forest Types

The Commissioners believe that forests should be viewed as a continuum, with each type of forest providing benefits to biodiversity and sustainable forestry commensurate with its natural potential and the owner's management goals. The contribution to biodiversity conservation varies with each type of forest along the continuum.

At one end are reserves – large areas protected from development, intended to preserve native species, "wild" ecosystems, and natural processes. They include wilderness areas and other lands set aside within federal forest ownerships and parks. Reserves are necessary but not sufficient to maintain biodiversity. In some regions of the United States that have a small portion of their forests in reserves, biodiversity must be sustained on other kinds of forests.

At the other end of the forest continuum are wood-production forests – plantations that are managed primarily for industrial wood production. Even though most of these forests are privately owned, their management is influenced by landowner rights and responsibilities determined by laws and customs.

Between the ends of the continuum are multi-resource forests with multiple objectives chosen by the landowners. The majority of America's forests are multi-resource, and many are owned and managed by individuals and families. Urban forests represent a special type of multi-resource forest, and they continue to expand as urbanization spreads into less developed rural areas and more of the nation's natural resources become part of urban forest ecosystems.

This continuum of forest types helps our nation meet its economic, environmental, and social objectives.

Public Permission

The Commissioners believe that forest practitioners, landowners, managers, and policymakers serve as stewards of the nation's forests with the permission of the public. The public obviously has more influence over some parts of the forest continuum than others, but its overall influence continues to grow.

Federal forestlands (both reserves and multi-resource forests) are currently being managed with emphasis on biological diversity, and over time they will consist of a mix of old-growth, late-succession habitats, and early-succession habitats (the result of wildfire and other natural disturbances). In contrast, the industrial forest landscape (wood-production forests), with its emphasis on economic profitability, is often missing the later succession elements of biodiversity, but instead provides some of the early- and mid-succession habitats missing in reserves.

An informed public, encouraged to step back and look at a state or region, will see a mix of habitats that represents the forest continuum and one that is likely to provide the suite of benefits that the public wants. The bottom line is that biodiversity depends on a mix of management goals across a landscape and that this approach to biodiversity conservation will meet the public interest.

Keep Forests as Forests

The Commissioners believe that one of the most important threats to forest biodiversity comes from development, and the best way to conserve biodiversity is to keep forestland as forest. The chapters on fragmentation (3) and landscape-scale planning (7) each raise the specter of forest loss due to development. In most cases, however, the "highest and best use" (HBU) of a forest for society is as a forest – for all the values it produces. HBU is an economic market term that rarely considers the value of water, wildlife, biodiversity, recreation, green space, carbon exchange, etc. Keeping forests as forests is more than a slogan – it must become a national goal.

SUMMARY

While this guidebook does offer and advocate management prescriptions, it is primarily a toolbox from which practitioners, landowners, managers, and policymakers can pick and choose what has merit for them. It's the reader's responsibility to use the information and tools in the context of his or her own forest management goals.

We do not know all there is to know about conserving biodiversity and sustainable forestry. However, one thing we know for certain is that new knowledge will continue to change the way we manage our forests. The successful conservation of biodiversity calls for careful observation of how the forest responds to natural and human disturbances and requires adjustments to future management according to those observations.

This chapter describes both forest history and forest restoration ideas that are being studied and attempted in some of the major forest regions in the United States. The regions, which were selected by NCSSF as the subjects of commissioned scientific studies, include:

- The pine barrens, transition hardwoods, and northern hardwoods of the Northeast
- White pine forests of the Lake States
- Coastal plain forests of the Southeast
- Pacific Coastal forests
- Colorado Plateau forests of the Southwest.

These forest regions are presented in the order of their European settlement, which began in the Northeast more than 400 years ago. From the Northeast, we'll follow land-use history as the Lake States were settled. By the end of the nineteenth century, logging had depleted much of the Lake States forests, and settlers began clearing forestland in the Southeast for agriculture, development and wood products. The decline of logging in the Lake States also brought attention to the Southwest and the Pacific Coast. In each case, we'll see how natural and land-use history have changed forests.

These examples illustrate the role of forest history in forest management. If the history of your forest region isn't included, we encourage you to examine it, using the three outline questions that we used in this chapter:

- *How can knowledge of forest history be used to restore biodiversity?*
- *What do we know about the natural and land use history of forests and how has it affected biodiversity?*
- *How can we use our knowledge of forest history to develop management strategies for restoring biodiversity?*

HOW CAN KNOWLEDGE OF FOREST HISTORY BE USED TO RESTORE BIODIVERSITY?

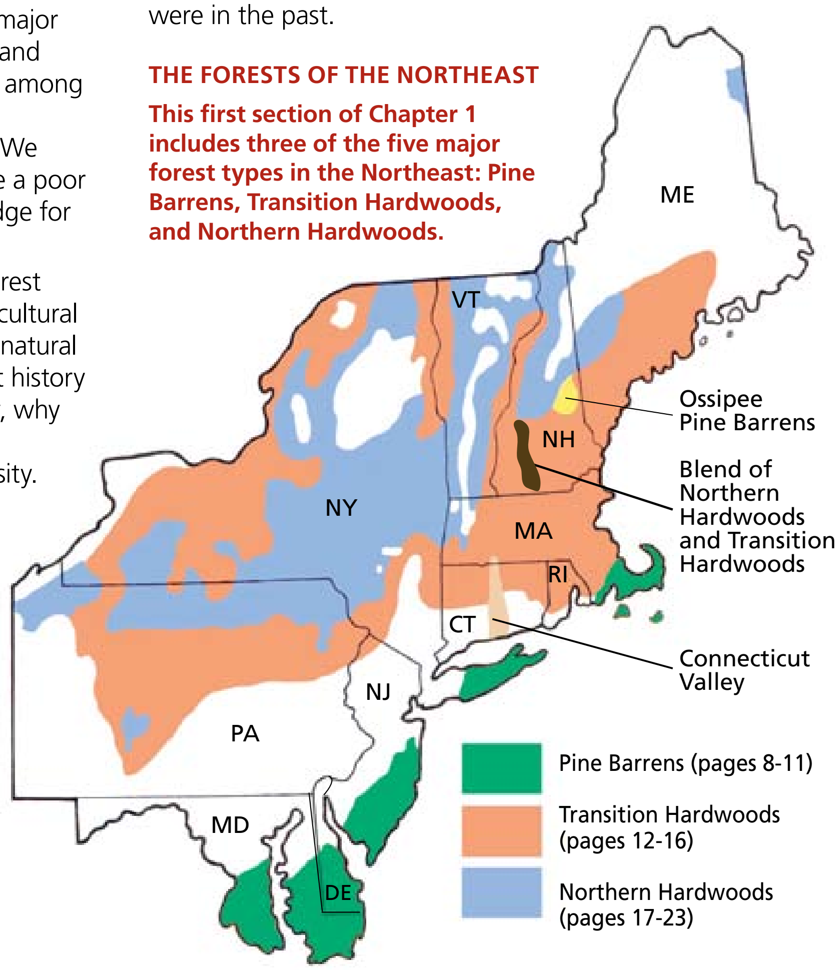
Natural and land-use history have modified forests over time and continue to influence them today. A major challenge to forest scientists, conservationists, and land owners and managers is to understand interactions among forest history, climate, geology and topography and how they control forest structure and composition. We understand some of these interactions, but we have a poor understanding of many implications of this knowledge for sustainable forest management.

Forest restoration science links forest history, forest structure, and maintenance of biodiversity with silvicultural tools. As we will see, forest restoration is related to natural disturbance and forest development regimes. Forest history tells us how and why we arrived where we are now, why restoration is needed and helps us design new management strategies to maintain biological diversity.

Note that restoration does not necessarily mean returning forest ecosystems to some historic benchmark or time period. That would be difficult if not impossible to do because we live in an environment that is not the same, and people in the future will live in environments that are not like that of today. Ecological, social and economic systems are not only different today they are changing more rapidly than ever before. To the degree that future environments, future social needs and future economies can be predicted, they and not the past must shape our restoration efforts. The future cannot be perfectly predicted, but it is more relevant to forest restoration than notions of how things were in the past.

THE FORESTS OF THE NORTHEAST

This first section of Chapter 1 includes three of the five major forest types in the Northeast: Pine Barrens, Transition Hardwoods, and Northern Hardwoods.



INTRODUCTION TO THE PINE BARRENS
(Map, page 7)

Tree Species
- pitch pine *(Pinus rigida)*
- scrub oak *(Quercus ilicifolia)*

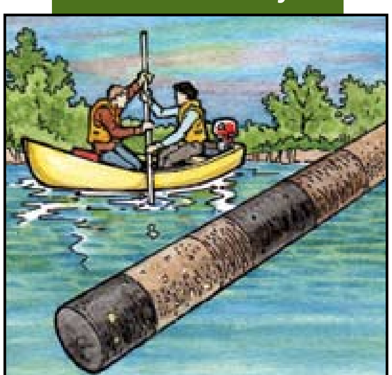
Groundcover Species
- black huckleberry *(Gaylussacia baccata)*
- blueberry *(Vaccinium species)*
- wintergreen *(Gaultheria procumbens)*
- sweetfern *(Comptonia peregrina)*
- bracken fern *(Dennstaedtia punctiloba)*

Location
- Pine Barrens occur on dry sand plains or sandy glacial outwash in major river valleys.
- The flat terrain encourages the spread of wildfires that eliminate its shade-tolerant competitors and provides a new seedbed.

Pitch Pine Requirements:
- mineral soil for establishment from seed
- a relatively shade-free environment
- a stand-replacing fire or management that mimics such a disturbance.

WHAT DO WE KNOW ABOUT THE NATURAL AND LAND-USE HISTORY OF THE PINE BARRENS AND THEIR EFFECT ON BIODIVERSITY?

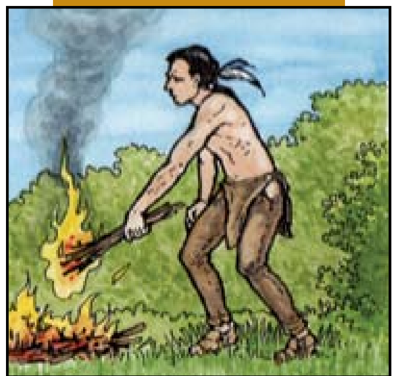
Natural History



Sediment cores from lakes near today's pine barrens indicate that these forests have been present for thousands of years. Prior to European settlement, pine barrens were probably even-aged stands started by large-scale fire disturbances (see Pitch Pine Requirements in Introduction box).

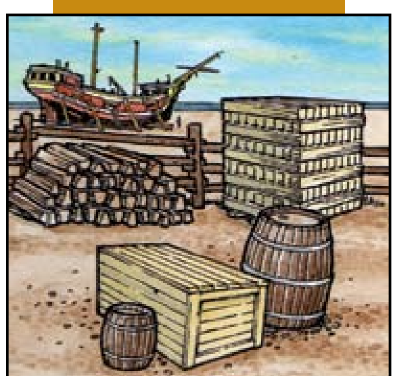
Fires were frequent. In fact, pine barrens have the highest incidence of fire of any northeast forest. Without fire pine-oak forests succeed to oak.

Land Use History

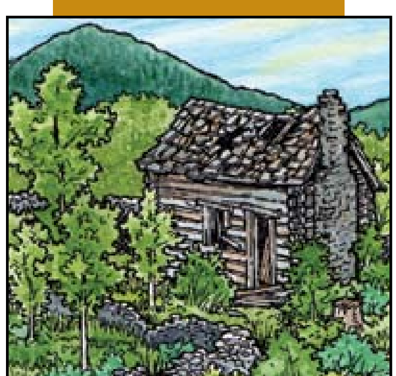


Native Americans deliberately burned pine barrens in the spring and fall to clear fields for planting, improve game habitat, drive game and assist hunting, reduce reptiles and insects, increase berries and seeds, or remove cover for protection from their enemies.

Massachusetts pine barrens (Map, page 7) were often cleared for farmland. European settlers pushed forests back to the hillsides, swamps, and dry sand plains. Settlement initially increased fire frequency, due to land clearing or escaped fires, but fire suppression became more prevalent when settlements were established.



The New Jersey pine barrens (Map, page 7) and the northern barrens of New Hampshire were actively logged but rarely plowed (discussed on next page). Pitch pine was used for firewood, fuel, fence posts, railroad ties, barrels and boxes, and early shipbuilding.



After 1850 the lure of more productive lands in the Midwest, the development of railroads, and the industrial revolution in the cities resulted in the abandonment of pine barren farms and their subsequent natural regeneration to forest.

What are the Effects of Clearing the Pine Barrens?

Plow layers in soils persist for centuries after sites are reforested. The physical effects of plowing had direct and lasting effects on understory and groundcover vegetation in the Montague pine barrens of the Connecticut River Valley (Map, page 7). Wintergreen *(Gaultheria procumbens)* is a plant restricted to areas of the barrens that had never been plowed. However, seeding experiments indicate that it can be sown and will grow in plowed areas.

Research indicates that wintergreen is absent on sites that were plowed and present only on sites that were never plowed. While it can be sown artificially, its natural rate of spread by seed and its slow growth rate kept it from colonizing plowed sites. At its present rate of expansion, it will take thousands of years for wintergreen to recolonize its former range.


Erv Evans, NC State University

In the Montague pine barrens, historical plowing and land use also affected overstory tree species. Research indicates that 97% of stands dominated by pitch pine were on formerly plowed areas, whereas 89% of sites dominated by scrub oak existed on unplowed areas. In plowed areas, scrub oak recolonized only as scattered understory individuals, in contrast to the dense thickets found in unplowed areas today. Because abandoned fields provided an excellent litter-free seedbed, nearly all pitch pine trees in plowed areas today belong to the post-abandonment cohort. (A forest cohort is a stand of trees that are approximately the same age.) Knowing that pitch pine can be reestablished by plowing is important for restoring pine barrens (described below).

What are the Effects of Changing the Fire Regime?

Since the 1940s, large fires have been excluded from many forests that formerly burned. As a result, pine barrens have changed so much that ecological threats are now appearing. Most northeast barrens are declining as a result of fire suppression.

In the Ossipee Pine Barrens of New Hampshire (Map, page 7), shade-tolerant, fire-intolerant hardwoods and white pine have increased over the last 50 years. Pitch pine declined from more than 60% to less than 40% between 1952 and 2002, even though a seed source was present. This is evidence that pitch pine seed can't penetrate the litter layer of scrub oak without soil surface disturbance.

On the Delmarva Peninsula before 1937, fire had returned every 10-40 years, supporting a landscape of oak-pine or pine woodland (50%) or open savanna (50%). Between 1937 and 1993, 25% of the barrens converted to hardwood forest, with 50% converting to closed canopy oak-pine or pine, at the expense of 50% of the savanna area.

What are the Effects on Pine Barrens Biodiversity?

Both regionally and globally rare plants and animals are dependent on these habitats. The Long Island pine barrens support 54 rare plants and 19 rare animals. Lepidoptera (butterflies and moths) are especially dependent on barrens. Scrub oak is the principal larval host for 16 (29%) of the 56 Lepidoptera of conservation concern in New England and New York. Frost pockets – small depressions where frost is likely to form – found in pitch-pine/scrub-oak barrens provide an important habitat for these rare or endangered Lepidoptera. This may have to do with the time of appearance of oak leaves. Young, tender leaves are more nutritious than older leaves because they have more nitrogen and water content. Spring leaf development is delayed in frost pockets, providing highly nutritious food on warm sunny days, resulting in rapid growth of butterfly larvae.


Gary Boyd

The Karner blue butterfly *(Lycacides melissa samuelis)* is a federally protected endangered butterfly species.

HOW CAN KNOWLEDGE OF PINE BARRENS HISTORY BE USED TO RESTORE BIODIVERSITY?

Why Restore Pine Barrens?

Restoration is important because:

- ▲ A number of rare plants and animals are dependent on these habitats.
- ▲ Pine barrens contain important bogs and marshes that contribute to biodiversity.

What's Their Current Status?

Most are old pitch-pine stands, either invaded by or being replaced by less fire-tolerant species like white pine, oak, red maple, or other hardwoods. Fifty years of fire exclusion and fragmentation have prevented the fires that regenerated these stands in pre-settlement times. Pitch-pine regeneration is minimal due to dense forest-floor leaf litter.

Important Points about Pine Barrens

Pine barrens:

- ▲ require periodic fire, so long-term management must include some kind of burning or equivalent management practice (described on next page)
- ▲ are threatened by development and fragmentation. These forests exist on outwash plains that provide flat, well-drained land suitable for housing developments, roads, shopping malls, and airports. State and private organizations are working to protect the remaining large, undeveloped sand plains.

There is no blanket approach to pine barrens management. Geographically isolated pine barrens have their own history, and restoration plans should be developed on a site-by-site basis.

Overcoming Difficulties of Pine Barrens Restoration

Historical stand-replacing fires that occured after droughts and usually in the summer, regenerated pine barrens prior to European settlement. Today, such fires are dangerous and difficult to control. Managers also face additional complications resulting from multiple ownerships and parcelization along boundaries between urban areas and large undeveloped pine barrens. The Nature Conservancy is attempting a solution in its Ossipee Pine Barrens *(see photo caption below).*

In the New Hampshire Ossipee Pine Barrens, mature pine forests originated from 1885, 1920, and 1957 fires. Fuel models that predict surface flame lengths and rates of speed indicate that catastrophic crown fires would result with wind speeds of only 15-20 mph. Burning could be hazardous to suburban property unless defensible space is maintained between dwellings and the forest edge. Fire management areas would have to be enclosed with firebreaks to prevent uncontrolled spreading.

This buffer created by mechanical harvesting during the late winter of 2005 in Madison, New Hampshire, does two things. First, it protects homes adjacent to the Ossipee Pine Barrens Preserve from wildfire. Second, it mimics the effects of fire and restores the pine barrens ecosystem by removing white pine and hardwoods and adding openings in the forest.

Joseph Klemenitovich

Effects of Prescribed Fire in Pine Barrens

Prescribed fire can be useful in restoring pine barrens. It's been used in New Jersey since the 1950s to control fuel loads and reduce catastrophic wildfires. However, its effectiveness varies with the time of year and the intensity of the burn. *(See box)*

Prescribed fires may be restricted near residential areas. For example, only spring burns are allowed in the Connecticut Valley of Massachusetts. Unfortunately, low intensity spring burns have little effect *(see box)*, so a three-part approach to restoration is recommended:

Results of Low Intensity Spring Burns

These burns:

- typically are hot enough to char bark on large trees
- have little effect on roots of hardwood and shrub species that compete with pitch pine
- don't eliminate the litter layer that prevents pitch pine establishment.

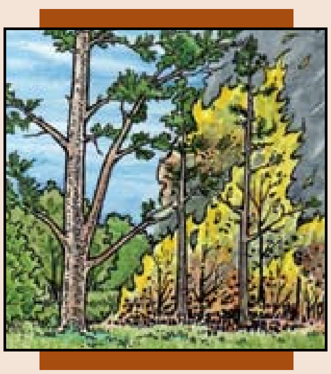
Stands are likely to succeed to mixed pine-hardwoods or red maple because these fires don't damage the root systems or sprouting ability of red maple or oak.

Results of High Intensity Spring Burns

These burns:

- can consume the litter layer
- should be planned with a heavy pitch-pine seedfall, or a harvest that opens the canopy, followed by burning slash piles to reduce fuel loads.

They are recommended for successfully regenerating pitch pine.



Results of Repeated Light Summer Burns

Burns repeated annually as many as three times:

- reduce fuel loads
- reduce red maple and grey birch by killing their rootstocks
- don't reduce scrub oak density.

Unfortunately, pitch pine does not regenerate in light burns.

Results of High Intensity Summer Burns

These burns:

- successfully regenerate pitch pine stands
- may be controlled if done during wet weather.

However, they're probably impractical due to control problems.

1. cut unwanted hardwoods in the growing season
2. scarify the soil to promote pitch pine regeneration from seed (historically effective when plowed fields were abandoned)
3. use follow-up controlled burns to maintain vegetation.

Burning doesn't always restore plant composition to historic levels, and it's not always possible to get rid of introduced species, but some kind of burning is important to perpetuate pine barrens. Where summer burns are impractical, annually repeated small-scale burns might slowly eliminate hardwood competition. Controlled growing-season burns during wet weather and/or mechanical treatments have been recommended in Massachusetts, New Hampshire, and New York to reduce fuel loads adjacent to residential development.

Is It Possible to Practice Sustainable Forestry in Pine Barrens?

If the goal is to grow white pine for harvest along with pitch pine, here's a possible scenario:

- ▲ Delay burning until white pine is large enough to withstand heat (it's intolerant of fire when young).
- ▲ Once white pine is large enough, burning each year for 3-5 years may be needed to control hardwoods.
- ▲ Continued burning at pre-settlement return intervals (10-40 years) is necessary to prevent hardwoods from growing back.
- ▲ Cutting or girdling large hardwood trees that survive prescribed burns may be necessary to remove their seed source.
- ▲ Pitch pine isn't as commercially valuable as white pine, but conversion to white pine should be avoided because pitch pine is the primary species of this ecosystem. Attempts to convert to white pine in the Ossipee Pine Barrens failed due to white pine weevil.
- ▲ Some white pine grown under the protection of pitch pine may be more weevil resistant, because it typically attacks and deforms white pine monocultures.
- ▲ Eventually, a clearcut or seed-tree harvest can be used to simulate natural disturbance.
- ▲ Soil scarification (shallow plowing) will allow pitch pine regeneration by seed from adjacent areas.

This management scenario would create even-aged pitch-pine stands similar to those that result from stand-replacing fires. It would provide structural diversity, ecological sustainability, and fuel management. It would end the history of fire suppression, which threatens today's pine barrens with replacement by fire-intolerant species. Implementing this scenario will be costly. However, it may be possible over the long term to pay management costs with profit from harvests and manage these disappearing ecosystems for their benefit to biodiversity.

INTRODUCTION TO TRANSITION HARDWOODS
(Map, page 7)

Location

- A band of transition hardwoods extends from the coast of Maine and New Hampshire through Massachusetts and northern Connecticut into southern New York and central Pennsylvania. Transition hardwoods grow in some of the most populated parts of the Northeast and are some of the most heavily disturbed and modified forests in the region.

Tree Species

Hardwoods include:

- American beech *(Fagus grandifolia)*
- sweet birch *(Betula lenta)*
- yellow birch *(Betula alleghaniensis)*
- sugar maple *(Acer saccharum)*
- red maple *(Acer rubrum)*
- northern red oak *(Quercus rubra)*
- black oak *(Quercus velutina)*
- white oak *(Quercus alba)*
- shagbark hickory *(Carya ovata)*
- mocknut hickory *(Carya tomentosa)*
- pignut hickory *(Carya glabra)*
- white ash *(Fraxinus americana)*

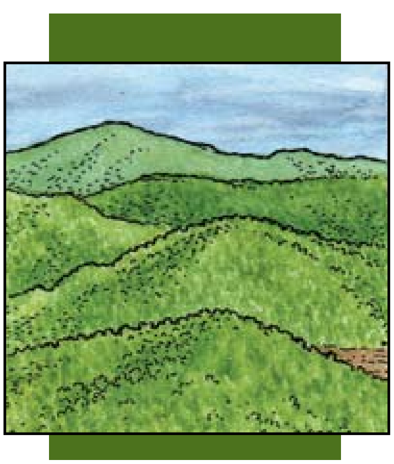
Conifers include:

- white pine *(Pinus strobus)*
- eastern hemlock *(Tsuga canadensis)*

WHAT DO WE KNOW ABOUT THE NATURAL AND LAND-USE HISTORY OF THE TRANSITION HARDWOODS AND THEIR EFFECT ON BIODIVERSITY?

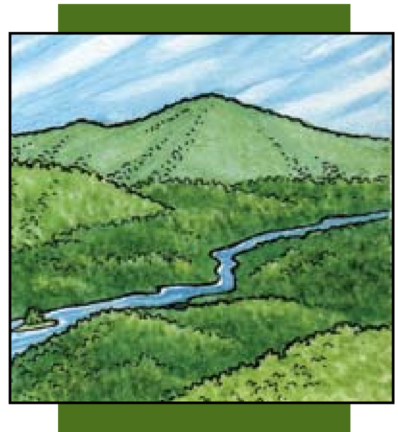
Lake sediment cores show that pre-settlement species composition varied between uplands and lowlands.

IN THE UPLANDS

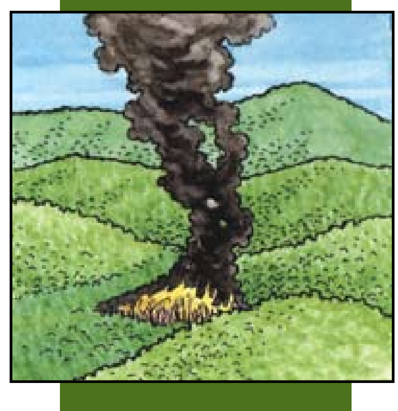


- The central uplands in Massachusetts included hemlock, sugar maple, yellow birch, beech and other shade tolerant, mature forest species.
- Hemlock and chestnut were dominant in the Berkshire-Taconic plateau of northwestern Connecticut and western Massachusetts.
- Oak and chestnut were important in other upland sites in central Massachusetts.
- Around 1450, during the "Little Ice Age" of extreme winters and cool summers, beech, sugar maple, and hemlock began to decline while oaks increased.

IN THE LOWLANDS

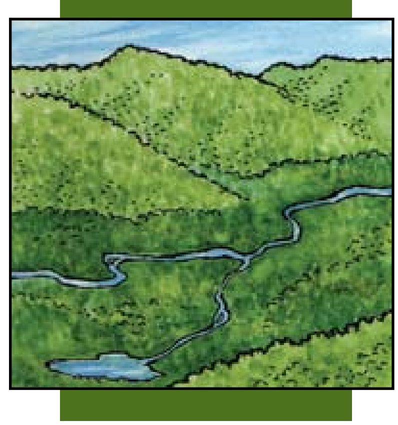


- Oak, chestnut, and hickory, along with some pine (white and pitch) dominated the lowlands and major river valleys in Massachusetts, along with lesser amounts of hemlock, beech, and sugar maple.



Charcoal in sediment cores indicates that periodic fires contributed to long-term maintenance of oak forests. Fire was most frequent in the valleys, where Native American populations were highest.

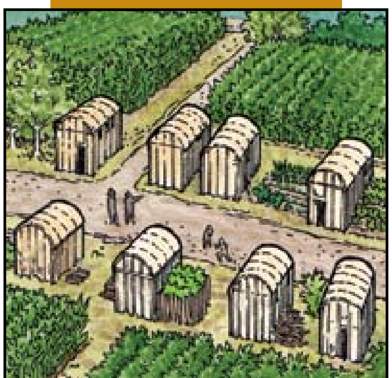
Along the eastern seaboard, hurricanes are a major stand-replacing disturbance with a return interval of from 85-150 years. The great hurricane of 1938 felled 3 billion board feet of timber on 240,000 ha (600,000 a), including half of all the white pine in the region.



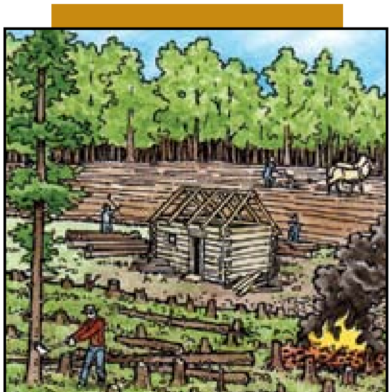
In north-central Pennsylvania, the following differences in species composition were influenced by landform, elevation and geography:

- Upper elevations were dryer, favoring oak, chestnut, and fire- and drought-tolerant pitch pine.
- Lower elevations had a higher proportion of species that require a moderate amount of water, such as white pine and hemlock, mixed in with the oaks.
- Red maple crossed all landforms and was more abundant than anywhere else in the transition hardwoods zone.

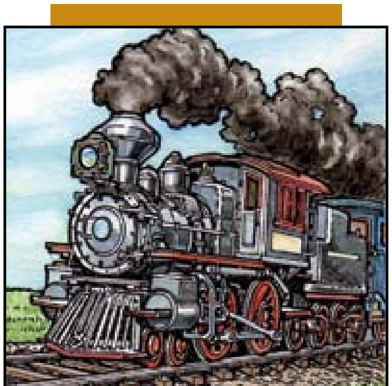
Land Use History



Native Americans in the transition hardwoods had well-developed agricultural societies. However, European diseases that arrived ahead of the colonists drastically reduced native populations. The Mayflower pilgrims, landing at Plymouth, found abandoned Indian settlements, not an unbroken wilderness, an indication of Native American impact on forested landscapes.

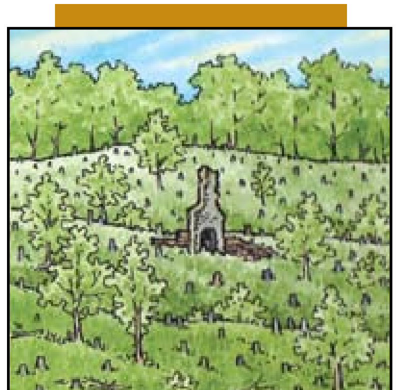


European colonies were established in the early 1600s in coastal New York, Massachusetts, and New Hampshire, and spread inland. Settlement brought extensive clearing of forests for agriculture. In Massachusetts, between 1830 and 1885, 50-60% of the land was in agriculture, sheep and cattle numbers exceeded 650,000, and forests were confined to poor quality lands, mountains, and swamps and were harvested for timber and fuel.



Both population and land use peaked around 1850 when westward railroad expansion allowed a mass exodus to more fertile Midwest farmland, leaving abandoned acreages. Forests increased and agricultural land use decreased. Only 7% of Massachusetts is in agriculture today.

Agricultural abandonment led to even-aged stands of white pine. Hemlock-hardwood understories eventually developed beneath the pine and included beech, red oak, yellow birch, red maple, sugar maple and other species. These stands were common from New England to western Pennsylvania until logged or damaged by the 1938 hurricane. Regeneration following the hurricane was in the form of advanced hardwood growth beneath the white pine. In general, hardwoods benefited from the hurricane.



Around 1900, growth of white pine stands on old agricultural land resulted in a new round of timber harvesting. Pine forests were either clearcut or selectively logged and replaced by even-aged hardwoods that had established under the pines and now became the dominant species and are still dominant today.

What are the Effects of Clearing Transition Hardwoods?

Today's stands of transition hardwoods still reflect 19th-century land-use practices in many ways:

- The age structures are often similar, the result of old-field abandonment or clearing.
- Most are stratified mixed-species stands, with complex diameter distributions and vertical structure.
- Those not cleared for agriculture were cut repeatedly for firewood, producing even-age stands and multi-stemmed trees that remain today.
- They lack large trees, large down logs, tip-up mounds and pits (resulting from wind damage), and large snags.
- Less than 1% of northeastern forests are true old-growth. Old-growth stands, defined on the basis of structure (i.e. old large trees, uneven-aged and shade-tolerant species) are extremely rare because of widespread clearing for agriculture and clearcutting from the time of settlement.
- Many understory plants haven't recolonized, and understory diversity is below pre-settlement levels. Species without adaptations for long distance seed dispersal are rare. Bedrock outcrops served as refugia (locations that support organisms limited to small parts of their previous geographic range) throughout the agricultural period for species that are poor dispersers and assisted with recovery in nearby areas.

What are the Effects of Changing the Fire Regime?

Before European settlement, frequent but light understory fire appears to have been important in transition hardwoods.

- By the late 1700s, fires decreased as the area of forest declined and most land was converted to agriculture.
- With old-field reforestation after agricultural abandonment in the late 1800s, fire returned.
- Fire incidence increased with logging, reaching a maximum around 1900, before fire control policies were established.
- Since World War II, forests that historically burned have been protected from fire. Major fires in the 20th century only occurred when drought conditions favored them.
- Fire suppression in transition hardwoods, especially in Pennsylvania, has led to a decrease in oak and hickory and an increase in red maple. The oaks will continue to decline if fire is not reintroduced.

What are the Effects on Animal Biodiversity?

Animal populations responded to forest change after farmland abandonment. Today, mid-succession stands dominate the region, and some animal species are becoming more abundant as tree sizes increase. For example, pileated woodpeckers have responded to the increased availability of larger diameter trees for nesting and foraging. However, few species are dependent upon the mid-succession stands that now dominate the region.

More than 260 vertebrates use forest habitats in the Northeast, with the majority finding food and cover in early- and late-succession forests. As a result, wildlife communities are handicapped by the lack of young forests and old-growth stands. Populations that depend on young, regenerating forests are declining conspicuously. They include bird species (golden-winged warblers), mammals (cottontail rabbits), reptiles (black racers) and various butterflies and moths.

Great Lakes Ecological Assessment

Pileated woodpeckers

- Present-day populations of cottontails *(Sylvilagus transitionalis)* depend on large patches of regenerating habitat close to each other for long-term survival.
- Golden-winged warblers *(Vermivora chrysoptera)* don't nest in patches less than 10 ha (24.7 a).
- Large-bodied snakes like the black racer (Coluber constrictor) seem limited to patches greater than 10 ha (24.7 a) of regenerating forests in human-dominated landscapes.

In contrast, white-tailed deer populations have increased in response to landscape modifications and elimination of large predators. Removal of wolves and cougars has had a lasting impact since the early 1800s. In some areas, deer density is greater than in pre-settlement times. One 50-year study at an old-growth stand in Pennsylvania showed deer populations increasing with early-succession habitat following farm abandonment and clearcutting between 1890 and 1920. Overbrowsing of tree seedlings and saplings by deer created an age/size gap for several species and also encouraged hay-scented fern (Dennstaedia pinctilobula) to dominate in the understory (see photo caption on next page).

Erv Evans, NC State University

Hay-scented fern

- **Deer feed heavily on Allegheny blackberry *(Rubus allegheniensis)*, a plant that colonizes forest openings. Blackberry seedlings in turn promote the establishment of tree seedlings. When blackberry is removed by over-browsing, hay-scented fern *(Dennstaedia pinctilobula)* replaces it. Deer avoid this fern, which then becomes very abundant and inhibits the growth of tree seedlings and small herbs. Once established, hay-scented fern may persist for decades.**

Overbrowsing deer:

- affect herbs, which represent most plant diversity in temperate forests, because they never grow tall enough to escape browsing
- may eliminate herbs that naturally occur at low densities from some locations
- can reduce vertical complexity of forest understories, reducing the abundance and diversity of shrub-nesting songbirds.

From these examples it's clear that the history of transition hardwoods has affected biodiversity. The loss of large predators has altered animal communities, resulting in an abundance of habitat generalists that can affect plant communities and modify local species abundance.

Introduced Insects and Diseases in Transition Hardwoods

Non-native invasive species have reduced populations or eliminated some native species (Chapter 2). Two important examples are:

- Chestnut blight, a fungus imported from China, completely eliminated large chestnut from its historical dominance.
- Hemlock wooly adelgid insect is a current serious concern.

This subject is discussed in more detail in Chapter 2, page 58.

HOW CAN KNOWLEDGE OF TRANSITION HARDWOOD HISTORY BE USED TO RESTORE BIODIVERSITY?

Why Restore Transition Hardwoods?

Land use, changed fire regimes, distorted animal populations, and invasive species have altered the structure and composition of these forests.

What's Their Current Status?

Transition hardwood forests are characterized by:

- a decrease in oak and hickory and an increase in red maple resulting from fire suppression, especially in Pennsylvania, trends that will continue if fire is not reintroduced
- mid-succession stands that dominate the landscape with serious consequences for biodiversity
- declining populations of animals dependent on early-succession.

They're some of the most densely human-populated and most heavily disturbed and modified forests in the Northeast, both historically and currently.

Important Points About Transition Hardwoods

There is concern about the future of sustainable forestry in this region for several reasons:

- There are a lot of small, non-industrial forest ownerships with parcel sizes ranging from ten to a few hundred hectares.
- There are only a few large industrial or even large non-industrial forest holdings, which complicates the reintroduction of fire (discussed below).
- In addition to parcelization, there's widespread fragmentation from roads, residential clearing, and commercial development along main travel corridors.

Difficulties in Restoring Transition Hardwoods

Many scientists contend that silviculture that reflects pre-settlement or natural disturbance patterns will conserve ecosystem functions and biodiversity. They point to evidence that pre-settlement forests experienced frequent large-scale stand-replacing disturbances, including hurricanes, together with understory and occasional catastrophic fire. This raises three major questions:

1. Can fire be reintroduced into this landscape?
2. What silvicultural management system is most suitable in these areas, which are dominated by the most recent post-hurricane cohort?
3. How can a mid-succession forest landscape be managed to create large live trees, large snags, and large down logs?

The Question of Reintroduced Fire

Pre-settlement fire favored the dominance of oak and pine over shade-tolerant species, but reintroducing it may not be easy for three reasons:

- Compared to pre-settlement fires, low-intensity prescribed fires fail to regenerate oak populations because the fire probably won't control the shade-tolerant hardwoods, that are otherwise fire-intolerant, due to their relatively large size.
- The infrastructure required for a safe prescribed fire effort is probably beyond the capability (and interest) of most non-industrial private forest owners, who control the majority of forestland.
- The air-quality impacts of prescribed fire would likely be a problem and create legal and policy challenges.

The Question of Silviculture in Post-Hurricane Areas

Studies of the silviculture of post-hurricane, single-cohort stands (Glossary) have produced a reasonably good understanding of the regeneration of major species. We know that:

- oaks are strongly dependent on either stump sprouts or well-established advance regeneration for dominance in the next cohort
- the stems of young eastern white pine can be protected from white pine weevil damage by leaving a canopy of partial shade until the pines have reached a predetermined height
- both of these factors argue strongly for single-cohort silviculture using a shelterwood system to establish new stands under the protection of a partial canopy of trees.

Unfortunately, the silvicultural science behind intermediate treatments such as thinning isn't well developed for transition hardwoods. Instead, many foresters rely on Midwestern oak density-management guidelines. However, considering the financial value and importance of tree grade, there is a critical need for research to develop individual crop-tree approaches to thinning.

Creating Structural Legacy in Transition Hardwoods

Legacies are conditions that link past and future systems. Mid-succession forests often lack structural legacies such as large live trees, large snags, and large down logs (see discussion of their value, page 44). One approach to developing structural legacy in single-cohort stands is to practice green-tree retention when harvesting (retain some large trees into the next rotation, described in more detail on page 45). Unfortunately, foresters lack scientific guidance for selecting retention trees or predicting their impact in the next cohort. This approach would be difficult given the importance of tree grade to the value of hardwoods and the tendency of oaks, along with sugar maples, to develop crooks following partial shade or suppression.

Another approach to structural legacy might be group selection or group shelterwood, including a variety of irregular shelterwood techniques. But there are challenges to group selection in the single-cohort structure of today's transition hardwoods. For example, relatively large openings (greater than 0.12 ha/.29 a) are required to maintain tree species diversity, and trees in lower strata would need to be eliminated. And there's another complication: the continued prevalence of the unsustainable practice of high-grading oaks and pines (taking the best trees and leaving the rest) from private forests, especially in Massachusetts. Rather than producing an uneven-aged stand, this practice simplifies stand structure, speeding the dominance of shade-intolerants like beech, red maple and hemlock in lower canopy strata.

It may be impossible to reconstruct pre-settlement forests in the transition hardwoods region, which has been substantially modified by several centuries of human activity. Instead, those who recognize this limitation recommend providing a range of forest habitats that support viable populations of native species. Ultimately, this may be more realistic than attempting to simulate natural disturbances.

INTRODUCTION TO NORTHERN HARDWOODS
(Map, page 7)

Location

- Northern hardwoods lie between the transition hardwoods of southern New England and central Pennsylvania and spruce-fir forests at high elevations and latitudes in the Northeast. They cover parts of northern Pennsylvania, New York, Vermont, New Hampshire, northwestern Massachusetts, western Maine, and extreme northeastern Maine.

Tree Species

Hardwoods include:

- American beech *(Fagus grandifolia)*
- sugar maple *(Acer saccharum)*
- yellow birch *(Betula alleghaniensis)*

Less shade-tolerant hardwood species include:

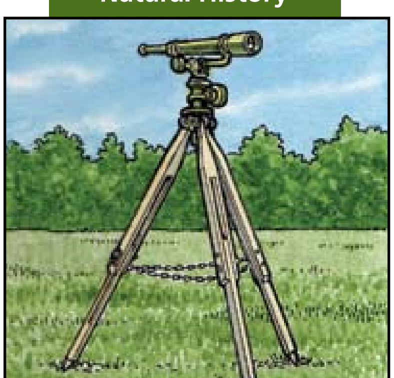
- paper birch *(Betula papyrifera)*
- gray birch *(Betula populifolia)*
- mountain paper birch *(Betula papyrifera var. cordifolia)*
- pin cherry *(Prunus pensylvanica)*
- white ash *(Fraximus americana)*
- striped maple *(Acer pensylvanicum)*
- red maple *(Acer rubrum)*

Conifers dominate lowland and riparian forests and include:

- white pine *(Pinus strobus)*
- eastern hemlock *(Tsuga canadensis)*
- balsam fir *(Abies balsamea)*
- red spruce *(Picea rubens)*

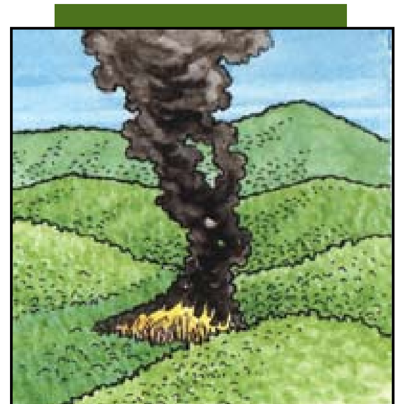
WHAT DO WE KNOW ABOUT NATURAL AND LAND-USE HISTORY OF NORTHERN HARDWOODS AND THEIR EFFECT ON BIODIVERSITY?

Natural History

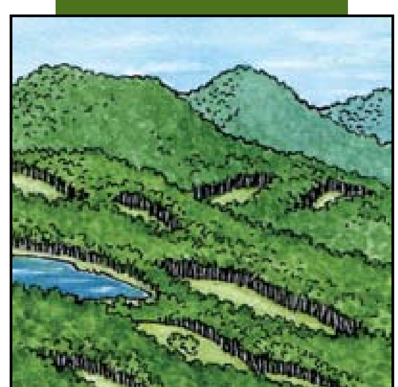


Pre-settlement forest composition and structure of northern hardwoods have been analyzed using records of "witness trees" blazed by land surveyors to mark the locations of section corners. Results include:

- **In northern New England and New York, 49 tree species were identified. 79% were beech, spruces, maples, hemlock, and birches.**
- **In Maine, New Hampshire, and Vermont, beech averaged 24%, maples 11.8%, and birches 9.7% of all witness trees. Other species were oaks, pines, hemlock, and spruces.**
- **In the Catskill Mountains of southern New York, northern hardwoods existed at middle elevations (305-914 m/1000-3000 ft), bounded by transition hardwoods at lower elevations and spruce-fir at higher elevations. In the Adirondacks, the upper limit of northern hardwoods was 980 m (3200 ft).**
- **Forest composition in north-central Pennsylvania (1765-1798) also followed elevation. Forests on the Allegheny High Plateau resembled northern hardwoods, but oaks of the central hardwoods dominated warmer and drier elevations of the Allegheny Front. High Plateau forests included beech and hemlock. Other northern hardwood associates such as maple and birch were not as common.**



Fire was rare in the northern hardwoods, with a return interval of approximately 1000 years. The reasons: cooler climate, ample rains, high soil moisture, and deciduous vegetation. The northern limit of fire probably set the boundary between transition hardwoods and northern hardwoods.

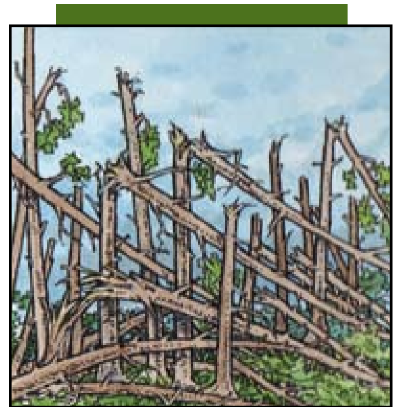


Here's an interesting question: Since fire was rare, how did shade-intolerant birches survive for 1000 years between stand-replacing disturbances?

Answer: Birches survived in canopy gaps (openings caused by the death of one or more adjacent trees). Old age, insects and fungi, physical damage, and windthrow are natural causes of gaps. More explanation is in the box on the next page: Tree Regeneration Strategies in Gaps.

Natural History

Ice storms are intermediate intensity disturbances. They create gaps by taking down trees and accelerating deterioration of injured trees. Higher elevations and/or latitudes make northern hardwoods prone to ice storms. Older trees incur more damage than younger trees because larger crowns catch more freezing rain.



The effect of windstorm disturbances.

- **Northern hardwoods closer to coastal areas were disturbed more frequently by hurricanes, which occur on average more than 380 years apart.**
- **The great hurricane of 1938 devastated the White Mountains. Post-hurricane stands were dominated by pin cherry, a pattern that also follows clearcut harvesting. Within 50 years, pin cherry was overtopped and eliminated (dynamic stratification). The result was that beech, sugar maple, and yellow birch became dominant.**

(See box below: Tree Regeneration Strategies in Gaps)

Tree Regeneration Strategies in Gaps

Different northern hardwood species respond differently to sunlight in gaps. Trees already established in the understory at the time the gap is created are called advanced regeneration. They are shade-tolerant enough to persist in the understory for many years. Examples include beech, sugar maple, hemlock, and red spruce. Each species in this group has a different strategy for securing sunlight and resources.

Beech can survive approximately 11 years (maximum 30 years) in a suppressed state. It responds only modestly to increased light in gaps. However, its capacity to root sucker allows it to dominate stands with low gap size and frequency.

Sugar maple may survive an average of 2 years in the understory, but it can alter its leaf to intercept more light in gaps. It can out-compete beech following gap formation because of its faster growth rate.

Striped maple is a gap specialist. It uses the temporary increase in light to grow quickly and produce seeds, then dies back when the gap closes.

Birch can survive for 1000-year periods between stand-replacing disturbances by arriving in a gap as seed, then germinating and outgrowing the established shade-tolerant species. Their success is controlled by gap size, because smaller gaps favor more shade-tolerant species and larger gaps favor shade-intolerant regeneration. In other words, for intolerant trees (such as birches) to be "gap fugitives" and survive between infrequent stand-replacement events, large gaps had to be a frequent characteristic of many stands. The small windblown seeds of yellow birch survive on the bare mineral soil of tip-up mounds or on rotting logs or stumps, all of which are present in gaps. Because it requires soil disturbance, heavy leaf litter or inadequate soil disturbance interferes with its regeneration.

Pin cherry stores seeds in the soil until a light gap is created, triggering germination and growth. It's shade-intolerant, but its rapid growth makes it successful in larger gaps and after stand-clearing disturbances such as fire or clearcutting. But pin cherry is a transient, and it's eventually overtopped by slower growing species that began growing at the same time. It's an example of "dynamic stratification," the reversal of stratum layers during stand development, where one layer follows the elimination of a less-tolerant stratum.

Various size gaps create a patchwork of developmental stages, with the main part of the forest being shade-tolerant species. In the White Mountains of New Hampshire, smaller, older gaps were associated with hemlock, while larger, newer gaps were associated with paper birch, striped maple, pin cherry, and red maple. Yellow birch, red maple, and striped maple were less abundant in the old-growth parts of the forest than in gaps, while hemlock, beech and sugar maple showed the opposite trend. Gap age, gap size, and location within the gap all explained variation in species abundance and community structure, with gap age being the most influential. For pin cherry and paper birch, gap size was important because both need larger gaps to regenerate. For shade-intolerant species, location within a gap was important because regeneration success increased toward the center. Finally, gap age is a strong predictive indicator of species composition and dominance as gaps are reclaimed. Knowledge of gaps is important for successful restoration.

The pattern in northern hardwoods was similar to transition hardwoods, but with interesting differences.

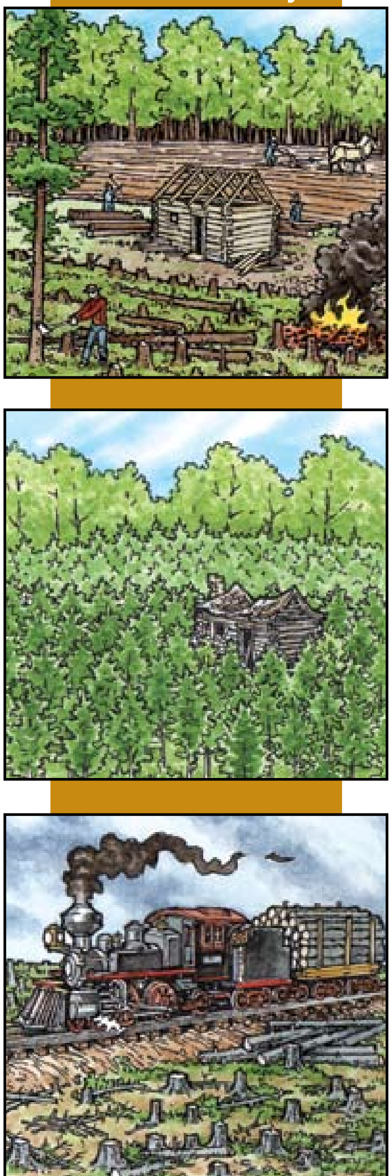
Northern hardwoods were less settled by Native Americans than transition hardwoods. Their inland location made them less accessible to European settlers, but land was cleared for agriculture when colonization occurred by the late 1700s.

Like the pine barrens and transition hardwoods, farmed acreages were abandoned in the 1850s. Here, abandoned land reverted to old-field white pine, birch, and maple. And 150 years later, these forests still show effects of those historical land uses (see Effects of Clearing Northern Hardwoods below).

From the late 1800s to the early 1900s, nearly all the northern hardwood forest was logged with a combination of clearcutting and/or partial cutting that high-graded the biggest and best trees. Custom-built logging railroads made large-scale harvesting possible from the White Mountains to the Alleghenies of Pennsylvania. The steam-powered locomotives started slash fires that raged across recently logged landscapes and shaped the character of many forests today. This devastation of forests and watersheds led to national legislation (Weeks Act of 1911) and establishment of national forests in the east.

Virgin red spruce, sugar maple, yellow birch and white pine were cut for furniture. Beech was seldom harvested but was used for wood-burning locomotives. Hemlock was cut for its bark and used in the leather tanning industry.

Land Use History



What are the Effects of Clearing the Northern Hardwoods?

Historic clearcutting and burning left current landscapes dominated by mid-succession stands with the following characteristics:

- They're often stratified single-cohort mixtures, lacking the horizontal gaps (canopy openings) that are common in advanced developmental stages. They lack tip-up mounds and pits, the result of large tree blowdown in natural forests, which provide regeneration habitats for paper and yellow birch (see box: Tree Regeneration Strategies in Gaps, page 18).
- High-grading has left forests that lack large old trees, large dead snags, and large down logs, elements which provide habitat for diversity, including insects, fungi and lichens.
- Subsequent natural disturbances – hurricanes, fires, and major windstorms – have not been enough to undo human impacts on northern hardwood forest ecosystems.

What are the Effects of Northern Hardwoods History on Biodiversity?

Long-lived, late-succession species such as beech, sugar maple, hemlock, and yellow birch have declined compared to pre-settlement populations. Shorter-lived, early- to mid-succession species such as red maple, poplars, cherries, white pine, and white ash have increased. This landscape-scale age structure favors animal species that need/prefer mid-succession habitat. Just as in the transition hardwoods region (page 14), animal species that need/prefer early- and late-succession habitats are low in the northern hardwoods, and many are declining.

What's Important About Early- and Late-succession Habitats?

Early-succession habitats offer herbaceous ground cover and fruit-bearing shrubs. The length of time some vertebrates use early-succession habitat varies, and it may be extremely short for some species. For example, the decline in the population of olive-sided flycatchers is of great conservation concern (see photo captions on next page).


Tom Munson


Tom Munson

Olive-sided flycatcher (above) eastern bluebird (below)

Olive-sided flycatchers *(Contopus cooperi)* and eastern bluebirds *(Sialia sialis)* may colonize a site a year or two after a disturbance but abandon it after only two or three breeding seasons. In addition to this short period of suitability, both species rely on large canopy gaps that may be associated with beaver dams or other disturbances that kill many trees. They do not make use of openings created by individual or small group-selection harvests.

Mammals occupy a greater diversity of habitats than breeding birds. More than 85% of the 60 species endemic to the region use various combinations of forest types and developmental stages. However, nearly all mammals in this region use early-succession habitats, and about 20 have shown a preference for such habitats. Several species are tightly associated with young forests, and their abundance is directly dependent on the dense understory vegetation found in regenerating stands (see Snowshoe hare/ Lynx caption).

Vertebrate species richness in mature stands, over-mature stands, and stands with all age classes is greater than in early-succession stands. One important feature of mature stands is decay in standing and fallen trees.


Tom and Pat Leeson/Photo Researchers

In northern hardwood forests, 41 species of birds and mammals nest, den, roost, or forage for insects in trees with stem cavities. Most nest in relatively large trees (greater than 45 cm/18 in DBH) with suitable decay.

Unfortunately, little is known about northern hardwood forest development and other organisms like insects and fungi. Organisms requiring large living trees or large down logs may be more abundant and diverse in older stands, for example:

- Some groups of beetles such as the Pselaphidae and Leiodidae appear to be more abundant in old-growth forests compared to younger managed forests. At least one Leiodid beetle has been cited as a possible indicator of old-growth northern hardwoods, and the species richness of beetles that feed on fungi under bark was higher in an old-growth stand than in a 40-year-old managed stand.
- The species richness of Calicioid lichens and fungi, which often grow on the bark of large, slow-growing trees, increases over time, with older stands supporting more rare species.
- Maintaining species richness in these insect and fungal groups may depend on protecting some old-growth northern hardwoods and managing some older stands to allow for a sufficient number of large legacy structures.

Introduced Insects and Diseases in Northern Hardwoods

As in the transition hardwoods, invasives have reduced populations of some native species. This subject is discussed in more detail in the invasives chapter, but two are of serious concern:

- Beech bark disease, a 20th-century invasive (Chapter 2, page 59), has had the largest impact of any non-native pathogen, because beech was the most abundant forest species in pre-settlement times and is also the most shade-tolerant. Eastern hemlock is the primary beneficiary, filling the openings left by dead and dying beech trees.
- Hemlock woolly adelgid is a serious invasive as it is in the transition hardwoods (Chapter 2, page 58).

Lynx hunting snowshoe hare

Lagomorphs (rabbits, hares, and pikas) are dependent upon young forests. They're major prey for a number of carnivores. Changes in lagomorph abundance affect predator number. Snowshoe hares *(Lepus americanus)* are the only lagomorph present in northern hardwoods. The lynx is a threatened species in the Northeast. Because its abundance is closely associated with the abundance of hares, attention is being directed toward maintaining adequate hare habitat to assure lynx viability.

HOW CAN KNOWLEDGE OF NORTHERN HARDWOOD HISTORY BE USED TO RESTORE BIODIVERSITY?

Why Restore Northern Hardwoods?

One reason is that current forests don't mirror the distribution of pre-settlement forests. Research based on historical records and the few existing old-growth stands indicates that those forests were more diverse:

- 30% were in early-succession stages, best produced by even-aged or single-cohort silvicultural systems.
- 40% were in later-succession stages, best produced by uneven-aged multi-cohort systems with gap sizes ranging from small groups to small patches.
- 30% were in transitional stages between the two.

Today's mid-succession forest landscape has left a shortage of early- and late-succession stands and a lack of legacy structures.

A mix of silvicultural systems would be necessary to maintain a forest landscape with the pre-settlement proportions described above. Redeveloping legacy structures will require modifying both even- and uneven-aged management approaches. To achieve that goal, some scientists advocate converting from even-aged stands to uneven-aged stands over time.

What's Their Current Status?

Today's forests are much younger than pre-settlement forests, even though the tree species are largely the same. Forests growing on abandoned agricultural fields are approximately 150 years old. The oldest second-growth forests are about 100 years old. Third-growth forests, logged and regenerated in the 20th century, are even younger. Characteristics include:

- even-aged stands with complex vertical structure but no horizontal structure (natural openings or gaps)
- some snags and down logs, but few large standing trees, large snags and large down logs (Table 1.1, page 23). Some fungi, lichens, and insects are dependent on these structures, and they tend to be more abundant and diverse in the few existing old-growth stands
- lower percentages of later-succession beech and sugar maple, and higher densities of low- to mid-tolerant red maple, paper birch, and white ash than pre-settlement forests.

Important Points about Northern Hardwoods

Even with a history of conversion and heavy harvest, these forests are not as fragmented, parcelized, or close to large human population centers as the transition hardwoods. So in theory, more management options are possible.

While the quality (grade) of trees is not the same, the forest has recovered to merchantable size, with 58% of stands in the sawtimber size class. A range of management techniques, from even-aged to uneven-aged, is available to meet management objectives.

Difficulties in Restoring Northern Hardwoods

As with transition hardwoods, many forest scientists contend that silviculture that reflects pre-settlement natural disturbance may be the most effective way to protect plants, animals, and natural ecosystem processes while maintaining a forest-supported economy. They encourage foresters to avoid even-aged management that doesn't mirror natural processes.

Local experts counter by saying that a natural-disturbance silvicultural system has not been adopted because there are no specific quantitative guidelines for designing and manipulating natural patterns.

A key question is: can modern forest management maintain forest functions (productivity, nutrient and water cycling, etc.), along with the array of native organisms present in pre-settlement forests, and at the same time deal with the loss of landscape-scale diversity in age and stand structure produced by 300 years of prior land use?

Two major issues in the restoration of northern hardwoods are:

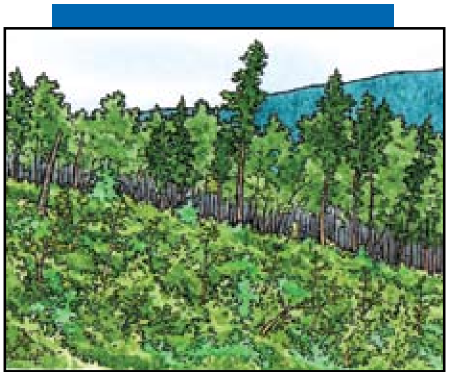
1. Is a pre-settlement model of management that calls for a shift from even-aged to uneven-aged management valid, would it achieve ecological and social objectives, and is it feasible?
2. How can the goals of creating large living trees and large down logs be achieved?

The Pro and Con of Even-Aged Management

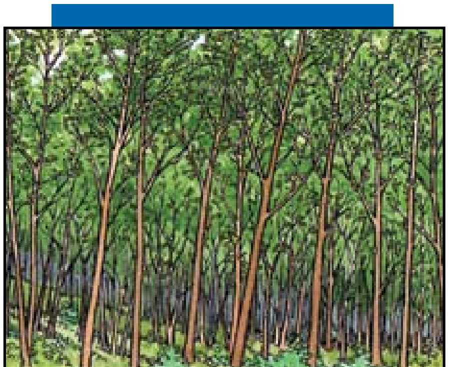
Even-aged management, practiced in many regions of the United States, is a repeatable cycle of regeneration, tending, and harvesting stands dominated by a single cohort. Its major benefit is economic because:

- Harvesting is less expensive.
- Administration and supervision are less complex.
- More wood can be harvested at one time.
- Roads and landings require less upkeep.

In the northeast, both clearcutting and shelterwood techniques are used, each having a different effect on which species will dominate after harvest. Clearcutting favors shade-intolerant birch and is highlighted in the illustrated sequence below. Open shelterwood (leaving 30-50% crown cover) favors mid-tolerant yellow birch and red maple. Dense shelterwood (leaving 80% crown cover) favors shade-intolerant sugar maple and beech.

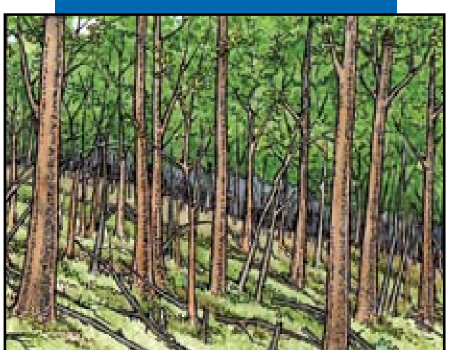


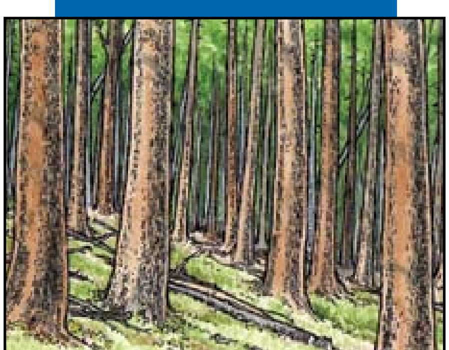
One year after clearcutting an even-aged cohort of shade-intolerant regeneration has begun. The successful species is influenced by soil. On fine till, early dominants include yellow birch, pin cherry, and paper birch, while red maple, paper birch, pin cherry, and yellow birch dominate on sandy till.



The tree canopy closes 10-15 years after logging. Herbaceous forage declines due to shading.

At 20 years, the height to live canopy is 3-4 meters (10-13 ft). At this stage, changes in canopy composition are based on elimination of short-lived and shade-intolerant species. Those early dominants decrease over time as shade-tolerant species from lower strata increase and eventually dominate.





At age 70, with trees 50-60 cm (20-24 in) in diameter, the stand is ready to harvest.

Even-aged management is not popular with the public because of its appearance. Large clearcuts are supposed to simulate large catastrophic disturbances, but the frequency of such events in any northern hardwood stand was at most once every several centuries (more about this below). Today's even-aged management uses a 50-100 year rotation.

The Pro and Con of Uneven-aged Management

Supporters of uneven-aged management contend that it is most similar to pre-settlement disturbance regimes. They refer to science-based calculations indicating that a stand-replacing disturbance affecting 20 ha (50 a) of contiguous forest would occur in the same spot every 347 years. They point out that current even-aged systems, with a 50-100 year rotation, allow more frequent clearcuts on that same area of forest. Supporters also say that a regulatory approach that regenerates 0.7-1.3% of the landscape per year would better approximate natural canopy turnover, resulting in a maximum tree age within managed stands of 70-140 years, a longer rotation than even-aged silviculture. Obviously, this approach would be more expensive. On private land, where trees are seen as a capital investment, holding stands beyond a certain age would reduce the rate of return.

General opinion is that while the concept of uneven-aged management is biologically sustainable, it's unlikely to become a viable practice because most landowners would see it as having financial disadvantages. Other challenges to successful uneven-aged management include:

- Beech bark disease has lowered beech value by killing most of the larger trees. Mortality leads to root sprouting, resulting in high understory beech densities that compete with more valuable species such as sugar maple.
- Where sprouting beech densities are high, site preparation with herbicides may be necessary to control them.
- To provide a sustainable yield, an uneven-aged stand must produce not only the same volume of wood over time, but also a consistent species and grade mix. Species composition can be regulated to some degree by gap size. For example, a group selection harvest, with patches up to 0.81 ha (2 a) would favor birch regeneration, while single tree and small group selection would favor sugar maple and beech regeneration.
- The forest must have enough pole-size trees to grow into sawtimber size, but not be so dense that growth is slowed.

Can There be a Shift From Even- to Uneven-aged Management?

Converting from even- to uneven-aged stands would take many decades and involve speeding up canopy break-up rather than waiting for trees in even-aged stands to die naturally. The result would be a structure similar to pre-settlement forests, but the maximum diameter and basal area would be smaller.

While moving from even- to uneven-aged forests, it would be important to:

- control the cut so that some older trees remain
- create gaps large enough for new cohorts to become established at regular intervals
- maintain species diversity (especially shade-intolerant species)
- assure the health and vigor of the old trees that remain
- sustain seed production until younger cohorts mature
- regulate the number and mix of trees in each cohort as multi-aged stands develop over as much as a century. Once they are established, a selection system could be sustainable.

Two methods for conversion have been suggested:

1. regularly scheduled uniform partial cuts, similar to heavy thinning or light shelterwood to establish new seedlings – for eventual single tree selection
2. periodic patch cutting (1-2 tree heights in diameter) with thinning to establish clusters of seedlings, eventually supporting group selection.

The first would favor shade-tolerant species, and the second would allow regeneration of shade-intolerant species. A mix of the two would increase heterogeneous stands, an important characteristic of natural uneven-aged forests.

Successful conversion would depend on:

- sustaining the regeneration of seedlings and saplings over many decades by growing trees free from intense animal browsing, free from interference from undesirable woody or herbaceous plants, and protected from fire and drought
- because overstory trees must produce seeds at appropriate thinning intervals, the eventual forest should have three to four age classes with consistent intervals between them, each occupying a similar amount of space.

How to Develop Large Trees, Snags, and Large Down Logs

Land-use history left very few old-growth stands with large live trees, and there's no quick fix. Table 1.1 compares the basal area of snags and the volume of large down logs in the few remaining old-growth stands with managed stands.

	Old-growth Stands	Managed Stands
Snag basal area	4-8 m^2/ha (30-60 ft^2/a)	0.3-4 m^2/ha (2.25-30 ft^2/a)
Volume of large down logs	60-160 m^3/ha (1240-3300 ft^3/a)	15-65 m^3/ha (310-1340 ft^3/a)

TABLE 1.1
A Comparison of Legacy Structures in Northwest Forests

It would take several decades for managed stands to reach the volume of large down logs in old-growth stands, even if no harvesting occurred. Thinning might accelerate the development of large-diameter trees and snags, but it would still take decades. There are three ways to achieve these goals more quickly:

- the passive approach
- the long-rotation approach
- the active retention approach.

The passive approach simply recognizes the value of large live trees, snags, large down logs, and other legacies with old-growth character. However, protecting entire stands would involve some economic cost, and there's no guarantee against a major disturbance. This approach is relatively inexpensive but probably won't achieve the targets in Table 1.1. There may be improvement as some landowners see its value, but structural legacies will be a feature in only a few stands, not a common feature in most stands.

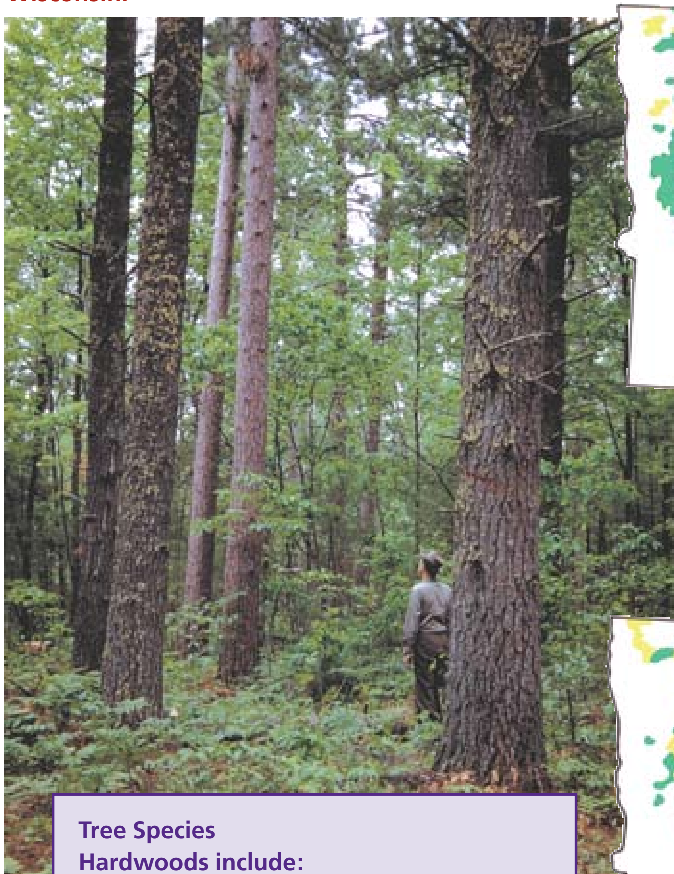
The long-rotation approach requires rotation ages of 120-200 years in even-age systems and even longer in uneven-aged systems. Unfortunately, there has been no research on this approach, and it requires economic sacrifice that might be unacceptable except for public ownerships.

The active retention approach uses green-tree retention (see page 45) to increase snags and large down logs in stands managed on shorter rotations. This idea is appealing, but there's not much field data to support recommendations on green-tree retention in northern hardwoods. In addition, there's no information about the susceptibility of retention trees to windthrow disturbance.

While it's true that biodiversity has been impacted by land-use history in the northern hardwoods, the successful development of legacy structures associated with older stands and landscapes will require modifying both even- and uneven-aged silviculture in this region. Unfortunately, a lack of older stands provides few opportunities for research. Redevelopment of the northern hardwood landscape will be a long-term proposition, not a quick and easy fix. Tools and strategies to sustain public and political commitment to this goal over multiple generations will be required.

INTRODUCTION TO LAKE STATES FORESTS

Mature red and white pine, Menominee Reservation, Wisconsin.

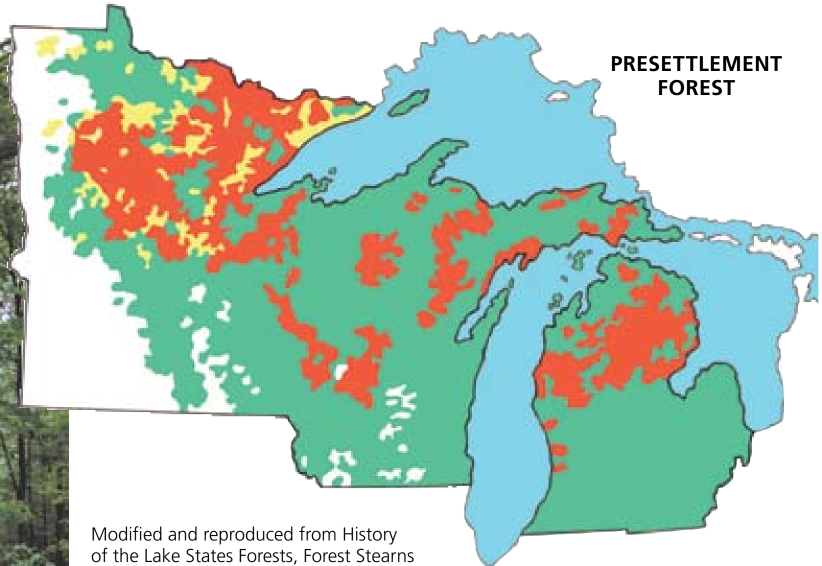


L. Wilson, Great Lakes Ecological Assessment

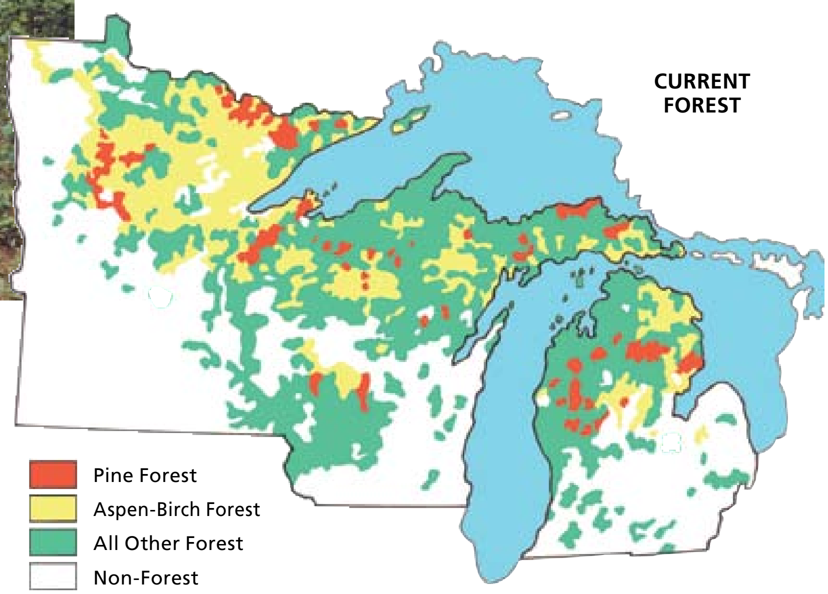
Tree Species
Hardwoods include:
- quaking aspen *(Populus tremuloides)*
- bigtooth aspen *(Populus grandidentata)*
- paper birch *(Betula papyrifera)*
- sugar maple *(Acer saccharum)*
- red maple *(Acer rubrum)*
- basswood *(Tilia americana)*
- white ash *(Fraxinus americana)*
- Ameican elm *(Ulmus americana)*
- northern red oak *(Quercus rubra)*
- shagbark hickory *(Carya ovata)*
- butternut hickory *(Carya cordiformis)*

Conifers include:
- eastern white pine *(Pinus strobus)*
- red pine *(Pinus resinosa)*
- jack pine *(Pinus banksiana)*
- northern white cedar *(Thuja occidentalis)*
- white spruce *(Picea glauca)*
- black spruce *(Picea mariana)*
- tamarack *(Larix laricina)*
- eastern hemlock *(Tsuga canadensis)*
- balsam fir *(Abies balsamea)*

WHAT DO WE KNOW ABOUT NATURAL AND LAND-USE HISTORY OF WHITE PINE FORESTS OF THE LAKE STATES AND THEIR EFFECT ON BIODIVERSITY?



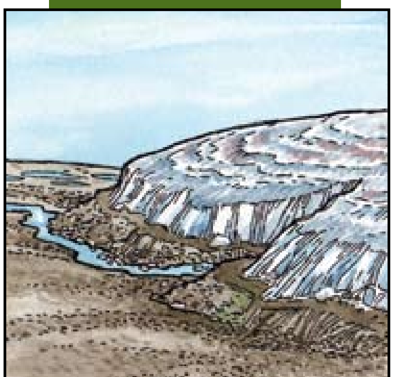
Modified and reproduced from History of the Lake States Forests, Forest Stearns



Lake States forest cover has declined from 32.7 million ha (81 million a) at the time of European settlement, to 20 million ha (49 million a) today. White pine forests have seen a drastic loss, from 1.4 million ha (3.4 million a) to 0.2 million ha (.49 million a) currently.

Natural History

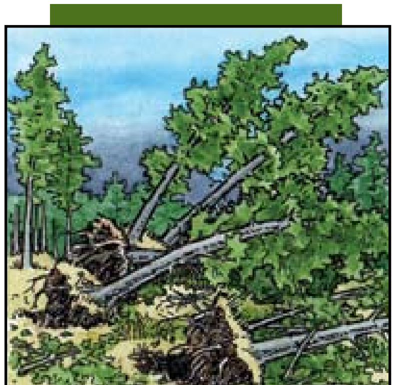
Glacial landforms, the result of the Wisconsin Glacial Epoch which ended 10,000 years ago, are a dominant part of Lake States forests and determine soils, topography, and potential natural vegetation.



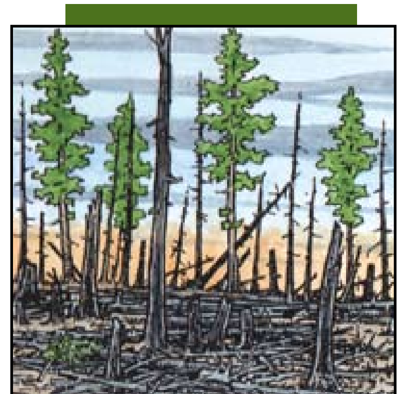
Pre-settlement forests were diverse and included:

- pine on sandy soils
- hardwood and mixed hardwood conifers on more fertile soils (till plains and moraines)
- cedar, spruce, and larch in swamp forests
- young stands of aspen/birch, pine or maple
- older stands of pine, hemlock, or northern hardwoods ranging in age from 250-400 years.

Natural disturbances that influenced forest structure and composition included wind (particularly catastrophic wind), fire, disease, insect infestations, and fluctuations in climate.



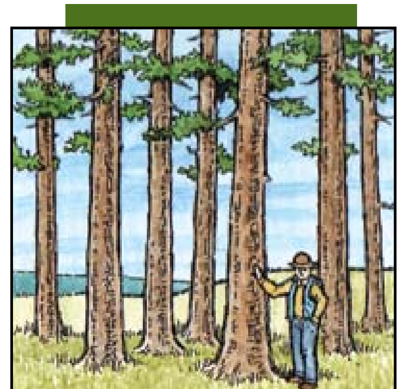
Forests located on dry, sandy soils are extremely flammable. Fire eliminated competing hardwoods, created a mineral seedbed for pine, and allowed residual trees to restock the land. White pine occurred most frequently with red pine and most often followed jack pine.



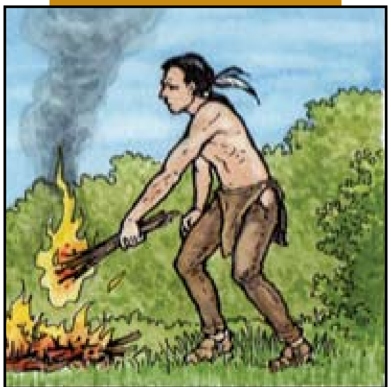
- White pine was maintained by a repeating sequence of catastrophic fires every 150 to 300 years, with light surface fires at shorter intervals.
- Fire intervals of 100-150 years tended to favor red pine.
- Intervals greater than 300 years resulted in northern hardwoods.

White pine is a mid-succession species.

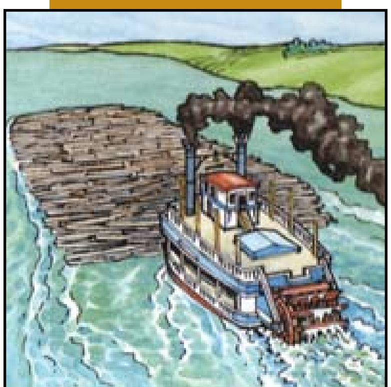
- Its seed regenerates successfully in mineral soil and full sunlight after fires.
- It is relatively slow growing during establishment, which allows faster growing pioneer species to dominate post-fire stands.
- It persists because it has a long life span (up to 450 years), has the ability to survive surface fires, and is moderately shade tolerant.



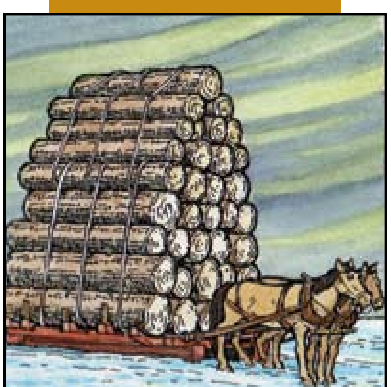
Land Use History



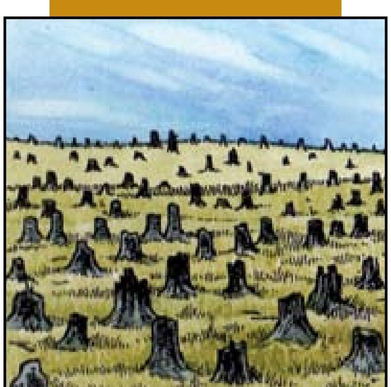
Humans have reshaped the forest landscape of the Lake States region. Native Americans intentionally burned forests for hunting and agriculture.



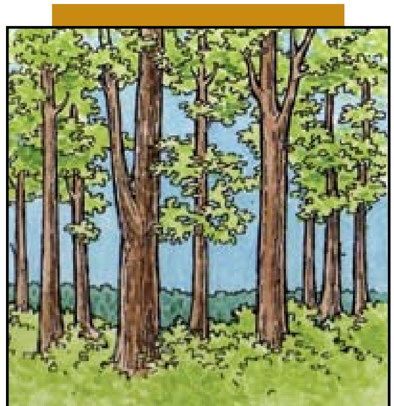
Following the clearing of northeastern forests by the 1850s, many eastern lumber companies relocated to the Lake States where there was virgin white pine and water transportation. Logging intensified from the 1870s through the 1890s.



White pine was considered the only species worth logging because it was light, strong, and easy to transport. Harvesting began in the 1830s. The following 50 years saw rapid exploitation of the forest. It reached a peak around 1890 when all merchantable pine had been cut or destroyed by fire.



With the white pine supply exhausted, blister rust fungus infected many of the remaining white pines, and landowners were discouraged from replanting the tree. Timber companies moved on to hemlock and hardwood species, including maple, birch, ash, basswood, elm, cedar, and fir. Hemlock bark was used for tannin in the leather industry. After a forest was clearcut, fires were started in the slash to create "stump pastures" that were used for farming. But agriculture was not sustainable on the sandy, unproductive soils.



By the 1920s the merchantable pine, hemlock, and smaller hardwoods were gone. Logging had permanently changed the species composition of pine, hemlock and hardwood forests.

- Soils were exposed to excessive drying, eliminating seedlings and saplings of sensitive species like hemlock.
- Logging favored more aggressive, sprouting, and wind-dispersed sugar maple. The less mobile, animal-dispersed beech was at a disadvantage.
- Old-growth forests of hemlock, beech, and sugar maple were converted to second-growth sugar maple forests.
- The extensive fires that followed logging favored sprouting oak and maple. Seed producers like white pine were at a disadvantage.
- Fires helped maintain fire-dependent jack pine and pioneer species like aspen, white birch and cherry.
- In other areas, pinelands were converted to large expanses of sweet fern and open stands of aspen suckers, scrubby oak, and red maple.

The Weeks Act of 1911 and the Clark/McNary Act of 1924 funded cooperative state/federal forest fire protection and reforestation and authorized private land purchases east of the Great Plains for national forests. Both acts emphasized forest protection rather than exploitation. The incidence of fires decreased and reforestation expanded dramatically.

The Great Depression brought the Works Progress Administration (WPA) and the Civilian Conservation Corps (CCC). These agencies built forest nurseries and began reforestation.

Fire-suppression policy has left many 40-60 year old stands. Since the 1950s aspen and jack pine have become valuable as pulpwood for paper, fiberboard and waferboard. They are managed on 30-60 year clearcut rotation cycles. The low fire frequency in jack pine and aspen forests has raised concern about the maintenance of these short-lived, shade-intolerant species. Without the reintroduction of fire, major unnatural changes in the ecosystem could occur. Continuing fire control may allow spruce and fir to replace broadleaf species in the area.

What are some of the Effects of Lake States Forest History on Biodiversity?

There's been a drastic loss of white pine and red pine in Minnesota over the last 100 years. Efforts are underway to restore white pine, but there are five main impediments:

1. There's a landscape-wide reduction of viable seed trees due to the region-wide reduction of white pine and red pine forests noted above.
2. In the absence of fire, more shade-tolerant deciduous species dominate pine sites, including sugar maple, aspen, paper birch, basswood, northern red oak, and woody brush species like hazel *(Corylus cornuta).*
3. With the absence of large predators, whitetail deer *(Odocoileus virginianus)* populations in Minnesota are vastly larger than in pre-settlement forests. Deer prefer white pine buds to other conifer species due to the lower resin content.
4. Exotic white pine blister rust *(Cronartium ribicola),* a fungus disease, was introduced in 1916. North-central Minnesota has one of the highest hazard ratings for white pine blister rust in the Lake State region. (Chapter 2, page 58).
5. The white pine tip weevil *(Pissodes strobi)* kills terminal leaders of white pine saplings at least 1.5 meters tall growing in open conditions. The result is growth loss, poor form, and reduced value of individual trees.

HOW CAN KNOWLEDGE OF LAKE STATES HISTORY BE USED TO RESTORE BIODIVERSITY?

Why Restore Lake States Forests?

One reason is that the landscape of northern Minnesota and the upper Lake States is generally second-growth forests shaped by human disturbance. Timber harvesting started with white pine, moved on to other species, involved large-scale slash-fueled wildfires, and concluded with almost complete fire exclusion. The result has been a transition in forest composition from northern hardwood and conifer types to early-succession species, such as aspen, and a shift toward younger stand age.

What's Their Current Status?

- ▲ Forest cover has declined significantly from pre-settlement forest (Map, page 24).
- ▲ Old-growth forests were 68%; they now make up 5.2% for all forest types.
- ▲ Primary forests (areas that remained in forest throughout European settlement, which may or may not be old-growth) are about 1% of what they were in pre-settlement times.
- ▲ Secondary forests (cleared for farmland and/or pasture, and logged or disturbed by humans but not cleared for farmland), consisting of oak-hickory, aspen-birch, red-white pine, jack pine, swamp conifers and northern hardwoods, are the most extensive forest types.

Why Restore Eastern White Pine in Minnesota?

The challenge of white pine restoration in the northern Minnesota landscape seems insurmountable given the problems noted in 1-5 above. In spite of the difficulties, and at great cost, there has been success. The key has been to recognize the role of natural disturbance and the need for silvicultural systems that provide conditions similar to those generated by natural disturbance, particularly fire.

The Rajala Approach to White Pine Restoration

Rajala Company, a fourth-generation, family-owned group of sawmills and forest products manufacturing plants that manages about 12,000 ha (29,500 a), has worked for 25 years to restore eastern white pine and associated tree species in north-central Minnesota.

The company's silvicultural fieldwork focuses on white pine but includes red pine. Red pine is easier and cheaper to grow, but white pine is more desirable. It grows across a range of site conditions, is moderately shade tolerant, and the physical and mechanical properties of the wood make it easier to mill than red pine.

Rajala's approach differs from conventional pine management in the region. Rajala practices retention harvesting, a system best described as modified irregular shelterwood. It includes the following elements:

- ▲ Live mature trees are left during harvest, either scattered across the harvest area (in a dispersed pattern) or in clumps (aggregate pattern).
- ▲ Snags and downed logs are intentionally kept, and a mineral seedbed is developed.


Brian Palik

Overstory retention of large pine after harvest.

- White pine stands are managed on 100 to 200 year rotations with several commercial thinnings.
- White pine is underplanted following retention harvests or variable density thinnings (described in Pacific Coastal forests, page 45).
- Live mature trees, left after harvesting, act as nurse trees, but are also retained as crop trees that continue to add value as future veneer and eventual high-grade lumber products.
- White pine is the species of choice for retention, but preference is given to other commercially valuable species including red oak, paper birch, basswood, and balsam fir. If no crop trees are present, then less merchantable trees are retained as nurse trees.
- Nurse trees lessen the impact of frost pockets by retaining heat and reducing condensation from rising pockets of air. Since moisture is a key in the infection of white pine needles by blister rust, controlling moisture decreases the probability of infection. Overstory shade helps reduce tip weevil infestation by keeping white pine terminal leaders below a threshold size.

Rajala Company loggers are trained to understand the ecological requirements of white-pine regeneration. Their goal is to minimize damage to residual nurse trees, even non-commercial-crop trees, because of their importance to underplanted white pine. White pine sites range from 1-24 ha (2.5-60 a). The management cycle includes the following six steps:

1. Study stands and develop plans for regeneration.
2. Design harvest plans for white pine underplanting and mark trees to leave.
3. After harvest, prepare the site by mechanical scarification (raking) and herbicide application.
4. Plant the site.
5. Apply intermediate treatments including protection, pruning, and commercial thinning,
6. Schedule a retention harvest (described in greater detail on pages 45-46).

How the Rajala Program was Developed

The Rajala program started as an experiment using white pine on a variety of sites under different harvesting and site preparation treatments. Restoration sites were selected by soil characteristics. Yearly evaluations identified the most successful and cost-effective treatment combinations. With experience came greater site selectivity, with attention to competing vegetation and deer populations.

Retention harvest levels are determined using crown closure management instead of basal area, guided by the architectural characteristics of the tree species and the predicted crown response to thinning. For example, sugar maple crowns respond aggressively (within 2-5 years) to thinning. So in stands with abundant sugar maple the post-harvest crown closure range is 20-30%. In contrast, the crown closure target is 40-60% in stands dominated by species with much narrower and thinner crowns, such as trembling and bigtooth aspen, paper birch, balsam fir, or red pine.

Retention harvests are followed by intense site preparation and intermediate silvicultural treatments designed to optimize conditions for establishing white pine. Early attempts at underplanting prepared the site with either herbicides alone or mechanical scarification alone. Both were generally unsuccessful. Success came when site preparation combined an exposed mineral seedbed from mechanical scarification with herbicides to reduce woody brush and herbaceous vegetation for 3-5 years. Mineral soil exposure and reduction of competition in the understory imitate periodic natural surface fires in Lake States pine ecosystems. Without natural disturbance, these substitutes are important for successful white pine regeneration.

Conventional forest herbicide combinations were found to damage residual canopy trees. Current herbicide combinations are designed to reduce herbaceous and woody competition while remaining on the site for the shortest time possible (half-life of 6 days). They include low concentrations of glyphosate (Accord) and sulfometuron (Oust).

Protection treatments include manual release of white pine from woody competition and protection from deer browsing. Chemical release is less expensive than manual release, but white pine is less resistant to chemical damage than most pine species. After testing tubes and commercial deer repellents, the most cost-effective deer protection was found to be budcaps on terminal leaders, applied every fall before browsing begins. Other intermediate protective treatments include pruning to remove blister rust and prevent future infections.

Rajala Company used their understanding of local natural history to develop silvicultural techniques that meet their economic goals and at the same time conserve an important native tree species.

Brian Palik

After retention harvesting the structural complexity and compositional diversity of this red pine stand are still in place. Underplanted and budcapped (bud protection device) white pine seedlings are in the foreground.

CHAPTER 1

FOREST HISTORY AND BIODIVERSITY

Coastal Plain Forests of the Southeast

INTRODUCTION TO COASTAL PLAIN FORESTS OF THE SOUTHEAST

Beth Young

Bottomland hardwoods along the Altamaha River, Georgia.

Tree Species

Hardwoods include:

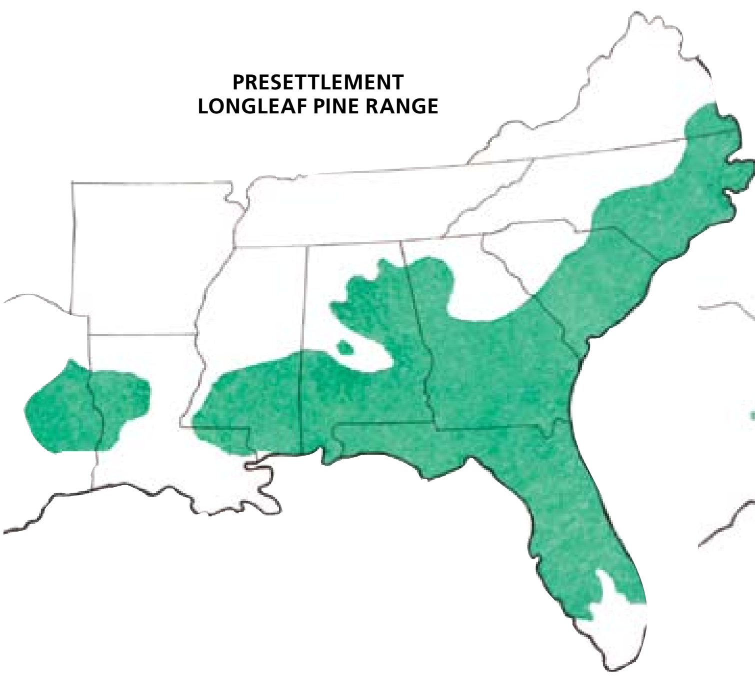
- red maple *(Acer rubrum)*
- white oak *(Quercus alba)*
- black oak *(Quercus velutina)*
- chestnut oak *(Quercus prinus)*
- scarlet oak *(Quercus coccinea)*
- American beech *(Fragus grandifolia)*
- shagbark hickory *(Carya ovata)*
- shellbark hickory *(Carya laciniosa)*
- mocknut hickory *(Carya tomentosa)*
- pignut hickory *(Carya glabra)*

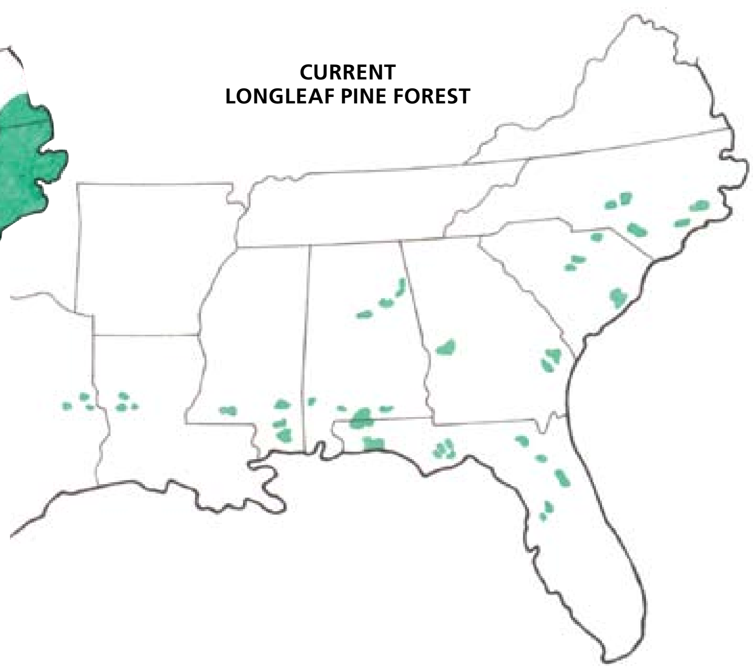
Conifers include:

- longleaf pine *(Pinus palustris)*
- loblolly pine *(Pinus taeda)*
- slash pine *(Pinus elliottii)*
- shortleaf pine *(Pinus echinata)*
- Virginia pine *(Pinus virginiana)*
- sand pine *(Pinus clausa)*
- bald cypress *(Taxodium distichum)*

WHAT DO WE KNOW ABOUT NATURAL AND LAND-USE HISTORY OF THE COASTAL PLAIN FORESTS OF THE SOUTHEAST AND THEIR EFFECT ON BIODIVERSITY?

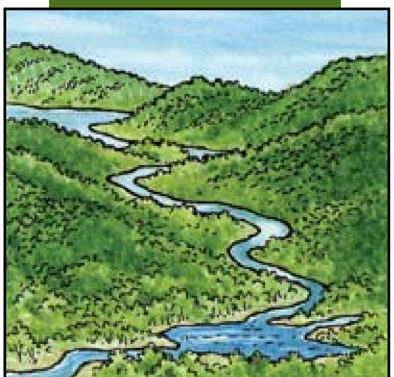
Originally, longleaf pine extended from southern Virginia to central Florida and west to Texas. At the time of European settlement its estimated coverage was 60% of the upland forest area in the coastal plains. Today, 2% of its historical coverage remains. In Virginia, Louisiana, and Texas, the decline of longleaf forests is almost complete.

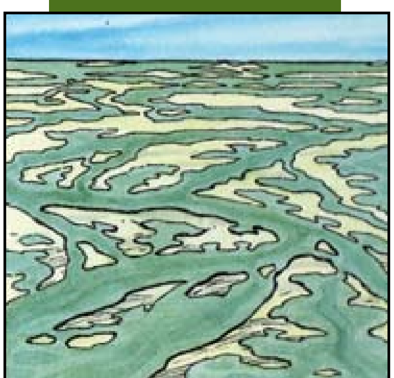




Jason McGee

Natural History





With the retreat of continental glaciers 12,000 years ago, the climate of the southeast became warmer and drier. Species that inhabit sites that are neither very wet nor very dry, such as sugar maple, beech, and red maple, retreated to bottomlands and protected coves. Oak, hickory, and herbaceous species dominated the uplands.

Approximately 5,000 years ago, the climate became cooler and moister and marshes and bogs formed along the Atlantic Coastal Plain. Southern pine and oak species migrated north, invading prairies and open forests. Swamps and floodplains covered 15% of the total area. Their changing water levels resulted in a diverse array of environments.

Disturbance regimes included tornadoes and hurricanes, southern pine beetle outbreaks, and fire. Landscape-level fires shaped longleaf and slash pine forests. Fires, usually started by Native Americans, were more local in oak forests. Fires were infrequent in floodplains, but catastrophic fires occured during major droughts.

Coastal Plain Forest Structure and Composition

- High humidity and lack of very cold winters are characteristic.
- Soils are older, strongly leached with low nutrients.
- The seven major pine species include shortleaf, loblolly, Virginia, longleaf, slash and sand pine. Longleaf, loblolly and slash pine dominate coastal areas.
- Inland areas have deciduous forest species, especially oak.
- Prescribed fire is needed to control succession of oak species because they are more shade tolerant than pine.

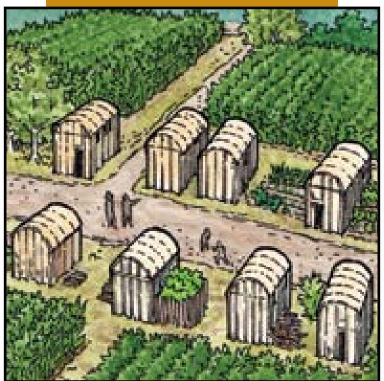
Jack Kenner

Bottomland hardwoods within the Coastal Plain:

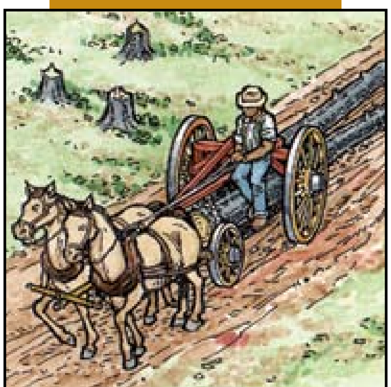
- occur primarily on flood plains next to rivers and streams
- are economically and ecologically important
- mitigate the effects of uplands by filtering nutrients and sediment
- include a large number of species.

Many of these forests have been converted to farmland.

Land Use History

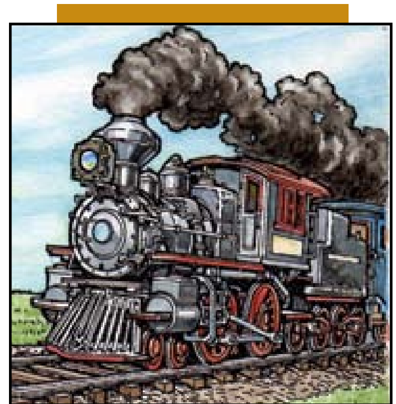


Long before European settlement, Native Americans practiced agriculture consisting of cut, burn, plant, and abandon. Late Mississippian culture (1400 to the time of European contact) decentralized into smaller agricultural villages. These settlements were more permanent and cleared 8-80 ha (20-200 a) patches of forest for agriculture.



European settlement began along the Atlantic coastline and gradually moved inland. Human disturbances included deforestation for agriculture, timber harvesting, fire suppression, and changes in floodplain hydrology. Early logging was confined to the coastline and larger rivers for easier log transport. Forests dominated by longleaf, shortleaf, loblolly, and slash pine were harvested first.

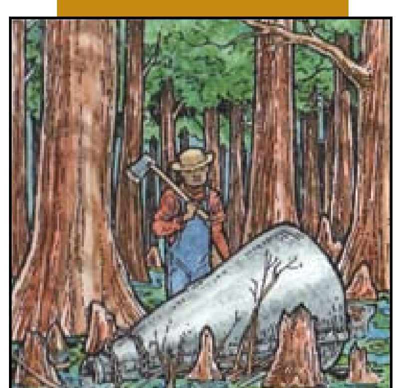
After the Civil War, forestry was the fastest growing trade in the South. Other industries that depended on the forest were turpentine, tanning, shipbuilding, shingles, charcoal for the iron industry, and whiskey. In 1870, the extent of Southern States pine was estimated to be three times that of the Lake States. Supplies were predicted to last 300 years in Arkansas alone. Exploitation increased as northeastern and Great Lakes forests were depleted. Northern timber companies purchased so-called Gulf "swampland" for 25 cents per acre.



From 1880 to 1920, an estimated 36 million ha (90 million a) of longleaf, shortleaf, loblolly, and slash pine were harvested. Only one-third was replanted, leaving extensive scrub woods and barrens. By 1910 nearly 39,000 miles of railroad in the 13 southern states helped move timber to markets. By 1914, predicted timber supplies dropped below a 30-year supply.

As concern over timber supply grew, forests became more valuable. Fire was seen as a negative factor, consuming or damaging valuable timber, especially in deciduous forests. In 1920, fire suppression policy was aimed at keeping fire out of forests.

Agricultural and logging practices prior to the 1930s Dust Bowl drought caused extensive erosion and sedimentation of streams. It's been estimated that the Piedmont has lost 25% or more of its topsoil in the last century.



From the 1920s to 1950s, forest clearing for logging and agriculture moved from uplands to floodplains and swamplands. Flood-control levees made it possible to harvest virgin timber. Bottomland was put into soybean and cotton production. Swamps were drained to grow trees and crops. Timber harvesting benefited because bald cypress could be cut out of deep swamps. Early logging used pullboat cones, attached to the end of logs, that prevented snagging on debris. By the 1950s bald cypress swamps were nearly gone.

What are the Effects of Changed Fire Regimes on Coastal Plain Forests?

In the decades following the establishment of the fire suppression policy of the 1920s, two large-scale changes in vegetation pattern began to emerge:

1. Pines, being shade intolerant and unable to regenerate under their own canopy, succeed to oak without periodic fire disturbance.
2. Most oaks, while more shade tolerant than pines, also have difficulty regenerating under a closed canopy.

What are the Effects of Coastal Plain Forest History on Biodiversity?

Slash, loblolly, longleaf pine, and shortleaf pine more than 100 years old provide rare habitat that's becoming rarer as older trees and stands disappear (Restoration section below).

- Historical forests were more open, with widely spaced trees and more understory plants. Periodic fires and large herbivores, now extinct, maintained this landscape.
- Longleaf pine ecosystems have declined steadily throughout the 20th century and are considered threatened in North America. These forests are centers of biodiversity containing upwards of 40 species of vascular plants/square meter. Their conversion to loblolly and slash pine (short-rotation plantation forestry) has dramatically increased their loss.

Gary Boyd

Today, prescribed fire is used to maintain oak forests and savanna-like pine forests such as longleaf pine.

HOW CAN KNOWLEDGE OF COASTAL PLAIN FOREST HISTORY BE USED TO RESTORE LONGLEAF PINE BIODIVERSITY

Why Restore Longleaf Pine?

Renewed interest in longleaf pine began in the 1990s, primarily due to its resistance to disease and insects and lack of vulnerability to market volatility. Declines in the pulp market have spurred landowners to look for alternative models of forest management.

What's The Current Status of Longleaf Pine Forests?

- Only 2% of their historical coverage remains.
- They are home to rare and threatened native flora and fauna.
- The long-term viability of at least 187 plants associated with Coastal Plain grassland ecosystems is of concern at state, national, or global scales. The red-cockaded woodpecker, Bachman's sparrow, flatwood salamander, gopher tortoise, and gopher frogs are very rare. Habitat for these species exists in the Red Hills (described below).

What's the Role of Fire in Longleaf Pine Savannas?

Historically, fire was the dominant disturbance that influenced structure and regulated function in longleaf pine grasslands. Pre-settlement forests were vast savannas dominated by a mix of open canopy, multi-aged longleaf pine with even-aged cohorts of regeneration in the larger openings. Most regeneration patches were relatively small (0.1 ha/. 25 a), but hurricanes and tornadoes created some larger patches. Fire frequency was most often 1-3 years, with return intervals of 3-5 years where topography protected areas from burning. Longleaf pine was co-dominant with other southern pines and/or hardwoods.

Today, these fire-maintained upland forests help conserve regional biodiversity by vectoring fire into neighboring wetlands, maintaining habitat for plants and animals, particularly amphibians and reptiles (described below).

Natural regeneration of longleaf pine depends on fire. Lightning opens canopy gaps; fire regulates competing ground vegetation and maintains open canopy conditions. Wiregrass *(Aristida stricta)*, a dominant ground-cover species, is a fine fuel for fire.

The federally endangered red-cockaded woodpecker (RCW) is dependent on tree cavities found in mature longleaf pine forests, and their frequent fire regime maintains open foraging stands.

Julius Ariail

Bunchgrass crowns catch the long needles of longleaf pine, leaving many needles elevated above the forest floor. The result is a loosely packed, fully exposed fuel that dries quickly after rain and ignites easily.

Fire is a cost-effective way to reduce hardwoods. Reintroducing fire and favorable conditions for burning is critical to restoring native biodiversity. The key is a ground cover of wiregrass that's been frequently burned in the past. Management should maintain native ground cover by:

- burning frequently
- avoiding soil disturbances that disrupt ground-cover root systems
- avoiding a dense, closed-canopy overstory
- using herbicides sparingly, if ever
- continually producing pine needles for fuel by maintaining the overstory.

Where the ground cover or forest has been disturbed, compromising fuel production by grasses, invading woody shrubs are much more difficult to control (more details below).

Restoration of Longleaf Pine in the Red Hills: A Case Study

The Red Hills region of southern Georgia and northern Florida comprises a remnant longleaf pine forest that includes a group of large, privately owned properties managed for game birds and timber. The owners of these properties recognize the importance of old tree retention, frequent fire, and complex biological communities.

The management philosophy of the Red Hills property owners contrasts with the plantation management approach that dominates industrial and other private forests. Those commercial forests are heavily stocked, even-aged plantations of slash and loblolly pine, grown on 25-30 year rotations to reduce costs. Their closed canopy structure and intensive site preparation can reduce the diversity of native understory plants. They have fewer age classes and less dead wood, and they don't provide some unique habitats that are found in native forests (more detail below). While some native plants and animals, such as young loblolly pine, slash pine, and early succession pioneer plants, deer, and turkey, thrive in this type of forest, many other important elements of biodiversity are reduced.

The Red Hills management philosophy evolved under the guidance of forestry consultants Herbert L. Stoddard, Sr., and Leon Neel, who started working with hunting estate owners in the early 1950s. Stoddard and Neel valued aesthetics and wildlife, especially the habitat needs of primary game species such as the northern bobwhite *(Colinus virginiana)*, as well as the economic value of timber. They recognized the importance of retaining old canopy trees, applying fire frequently, and maintaining complex biological communities. They developed an approach based on selective cutting and long rotations.

The Stoddard/Neel approach conserves biodiversity by applying sustainable forestry principles that include:

- maintaining a perpetual forest with all its components while harvesting timber
- allowing timber to grow to a threshold before removing part of the growth
- accepting time as an important ecological feature of land
- recognizing that forests aren't just about wood or game but are ecosystems sustained by disturbances that provide structural complexity and heterogeneity.

While disturbance takes many forms in these forests, the most important is frequently applied and controlled fire that regulates the structure and controls ecosystem function.

Julius Ariail

Frequent fire is the most important disturbance in longleaf pine-wiregrass ecosystems. It maintains the open canopy structure, sustains understory regeneration, encourages diversity of plant life, regulates the flow of energy and materials through the ecosystem, and maintains fine fuels.

How does the Stoddard/Neel Approach (SNA) Maintain Diversity?

The goal in upland landscapes is to:

- discourage hardwood vegetation that invades in the absence of fire
- keep hardwoods small by sustaining a pine overstory through time.

On more extreme longleaf pine growing sites such as dry sandhill sites and wet drainages/depressions, the overstory becomes even more important in maintaining fires.

Dry sandhills tend to be the least productive sites. Harvesting reduces pine fuels, which makes burning patchier and allows oaks to establish and grow to more fire-tolerant sizes. As oaks grow, their litter is less flammable than grass or pine needles, allowing them to persist in fire-dominated ecosystems. Fire on these sites regulates but does not eliminate scrub oak.

Wet drainages and depressions protect hardwoods, allowing them to assume dominant and co-dominant crown positions. Higher soil nutrients allow production of large amounts of litter. This reduces the frequency of fire and increases survival of hardwoods, which gradually move toward the uplands.

There is no demarcation between drainages that support hardwoods and upland, fire-dominated savannas. If this zone is well managed, it is dynamic, moving in response to prescribed fire and time since burning. It is rich in species, so managing it and neighboring wetlands is important to conserving biodiversity. The SNA recognizes the importance of the pine canopy in maintaining fire in this ecologically sensitive part of the landscape.

SNA timber harvest guidelines are designed to enhance the ecosystem by:

- increasing the age structure of pine
- converting from other pine species to longleaf on upland sites
- removing hardwoods and encouraging grass and pine fuels that sustain frequent controlled burns.

Harvesting sustains the ecosystem by:

- removing low-vigor trees
- removing trees with economically valuable defect (detail below)
- evaluating each tree individually for removal – there are no simple rules or equations, but principles that guide tree selection.

Harvest guidelines in upland sites call for:

- giving preference to longleaf pine because it lives longest of the southern pines, is preferred habitat for RCW, and provides the best fuels for burning
- using retention criteria that are adjusted as site moisture increases to include slash pine, a species commonly found with longleaf
- favoring older live trees over younger trees for retention because of their heartwood. They tend to be less susceptible to decay and fire and are a source of standing and fallen woody debris. Decay from red heart disease occurs only in older pines and provides habitat for cavity nesters in live trees.
- removing trees with sparse crowns and yellowing needles, but not all at once
- harvesting defective trees (forked, crooked, or diseased with cankers) but leaving some defect – for example, witch's brooms are kept to supply habitat to some animals
- harvesting some old dead trees, even though they have ecological value, because they're not producing needles for fuel.


Julius Ariail

After a forest reaches the desired condition, it is maintained. It changes at smaller spatial scales, with trees regenerating and growing, but remains stable over larger spatial scales.

Tree selection is also based on spatial distribution within the stand, with the goal ranging from nearly closed canopy to widely scattered trees. Trees are cut to release seedlings or create openings to encourage new regeneration, but opening size and total area are restricted to maintain canopy cover for needle production. Longleaf seedlings develop in gaps as small as 0.1 ha (.25 a). To encourage regeneration, cutting generally shouldn't exceed 0.25 ha (.6 a). Cutting single trees may start regeneration that continues through several cutting cycles, gradually enlarging openings and releasing seedlings.

How to Convert Stands to Longleaf Pine

One way to convert is to clearcut loblolly, slash, or shortleaf pine and plant longleaf in even-aged stands. But this approach can encourage hardwoods, which then have to be controlled mechanically or with herbicides to permit the use of fire.

It's better to convert incrementally by maintaining pine forests over time, even species that are less desirable than longleaf. The pine canopy provides fuel for hardwood control with fire. This approach reduces costs and maintains the herbaceous ground cover. It can be done in the following stages:

1. Use cutting practices that favor any overstory longleaf pine that is present.
2. Start a fire regime that encourages longleaf pine regeneration while suppressing other tree regeneration.
3. Plant or seed longleaf pine in gaps created by harvesting off-site pine according to the SNA approach described above.

How to Reintroduce Fire in Fire Suppressed Longleaf Pine

Some trees die in longleaf pine stands that have been burned after periods of fire suppression. The cause may be root damage from fire, stem girdling, leaf scorch, or insect or pathogen injury after fire. Mortality can be reduced by:

- Raking litter away from trees to avoid damage to valuable trees with red-cockaded woodpecker cavities. This is expensive and impractical on a large scale.
- Burning in the winter when litter is nearly too moist to burn. Only a little surface litter will be removed; smoldering embers should be extinguished to avoid pine damage.
- Continuing to burn in the cool season to remove layer after layer of duff. This encourages grass establishment for fuel and slowly expands the area of forest that is burned.
- After initial fuel reduction, burning during lower humidity and fuel moisture will increase fire intensity and hardwood control.

Repeated upland fire will help delineate between uplands and drainages that require infrequent but intense fire to keep them at bay. Periodically pushing burns into drainages helps bottomland forests and areas between the hardwood drainages and the uplands to be dynamic and defined by fire.

Biodiversity Spin-offs of SNA

Todd Engstrom/CLO

Other birds and small mammals use the cavities of red-cockaded woodpeckers. They include chickadees, bluebirds, titmice and other woodpeckers (downy, hairy, and red-bellied woodpecker). Larger woodpeckers like the pileated may enlarge the hole and take over the cavity, and screech owls and wood ducks are often next in line.

The red-cockaded woodpecker (RCW) appears to prefer longleaf pine but will use other species of upland pine (loblolly, shortleaf, slash). Patches of old-growth longleaf pine in the Red Hills support a high density of RCWs. SNA has benefited them in several ways:

- Cavity trees, a critical resource for the RCW, are noted during timber inventories and protected from harvest, in contrast to the regional trend of harvesting them.
- Potential cavity trees are identified and protected.
- SNA advocates high stocking levels for mature trees, and many old trees (more than 100 years) are kept for aesthetic reasons, providing quality foraging habitat for RCW.

Gopher tortoises excavate a burrow up to 30 feet long with a den at the end. They browse on low growing vegetation including wiregrass, broadleaf grasses and legumes.

Gary Boyd

The gopher tortoise *(Gopherus polyphemus)*, a species of concern in the southeastern United States, digs burrows in open-canopy forests with abundant ground cover for forage. SNA has benefited habitat for the gopher tortoise and the Florida gopher frog *(Rana capito)*, which lives in tortoise burrows. Here's how:

- Short-rotation forests with intensive site preparation can eliminate herbaceous tortoise food. Their high tree densities and closed canopy cause the tortoises to abandon their burrows and migrate to forest edges and roadsides. This also happens in fire-suppressed longleaf pine forests where oak encroachment results in a closed canopy.
- Gopher tortoise burrows are used by more than 60 vertebrate and 300 invertebrate species, providing shelter from high temperatures and predators. The Florida gopher frog spends most of its life in and around tortoise burrows, leaving only to breed in wetlands during winter months. It requires an open-canopy pine forest and access to wetlands. Fire suppression or changes in the water regime can make wetlands unsuitable for successful breeding.
- Invasion of oaks in the absence of fire can alter pond regimes and impact frog larvae development. Oak thickets support large numbers of predators that feed on migrating frogs.

SNA has benefited native plants because:

- Native plants are adapted to re-sprouting after fire. Some species are vulnerable to fire suppression and decline in the absence of fire. The protection of existing ground cover or reintroduction of fine fuels along with pine canopy provides the necessary fuel to sustain the plant diversity.
- Forest management that maintains a perpetual forest structure over time is key to floral diversity in the longleaf pine ecosystem.

INTRODUCTION TO PACIFIC COASTAL FORESTS

Tree Species

Conifers include:

- Douglas-fir *(Pseudosuga menzizii)*
- white fir *(Abies concolor)*
- grand fir *(Abies grandis)*
- sugar pine *(Pinus lambertiana)*
- Sitka spruce *(Picea sitchensis)*
- western white pine *(Pinus monticola)*
- western hemlock *(Tsuga heterophylla)*
- western redcedar *(Thuja plicata)*
- Alaska yellow-cedar *(Chamaecyparis nootkatensis)*

Hardwoods include:

- black cottonwood *(Populus trichocarpa)*
- red alder *(Alnus rubra)*
- Oregon white oak *(Quercus garryana)*
- big leaf maple *(Acer macrophyllum)*
- Pacific madrone *(Arbutus menziesii)*
- Oregon ash *(Fraxinus latifolia)*

Natural History

Ocean maritime influence keeps temperatures mild throughout the year. Annual precipitation is high but seasonal (127-381 cm/50-150 in), with little rainfall during the summer growing season (June through September). Dry warm summers have important wildfire implications.

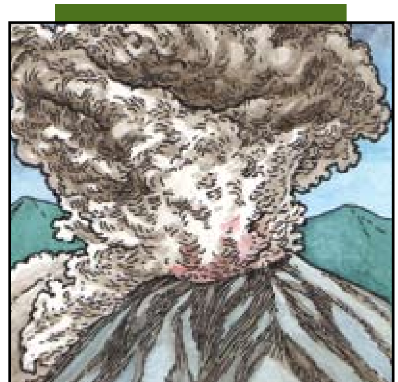
Winter storms with high winds are common. Occasional extreme wind events occur at intervals of several decades in coastal areas. The Columbus Day Windstorm of 1962 affected several million hectares in western Washington and Oregon.

Windstorms and pathogens helped shape forest development, but fire has been the primary natural disturbance.

Fire disturbance consisted of intense, very large-scale stand-replacement fires. Large fuel accumulations, coupled with weather patterns of hot, dry air from continental regions, led to these fire events. Fire return intervals decrease from north to south. For example:

- up to 750 years in the moist coastal forest of the northern Oregon Coast Range and the Olympics
- <50 years along the crest of the Coast Range in southern Oregon and coast redwood stands of northern California.

Due to ocean proximity, coastal Sitka spruce-western hemlock forests have much lower fire probabilities.



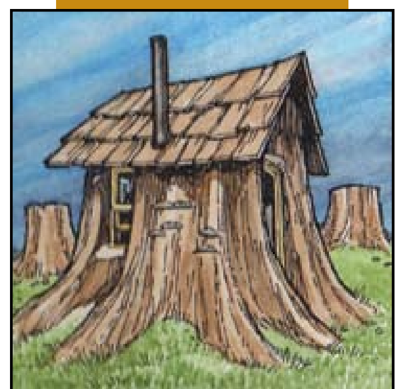
Volcanic events such as the 1980 eruption of Mount St. Helens are another kind of disturbance phenomenon. This stand-replacement event affected over 50,000 ha (123,500 a) of forest.

Al Levno, USFS PNW-OSU Forest Science Data Bank

Pacific Coast Forest Structure and Composition

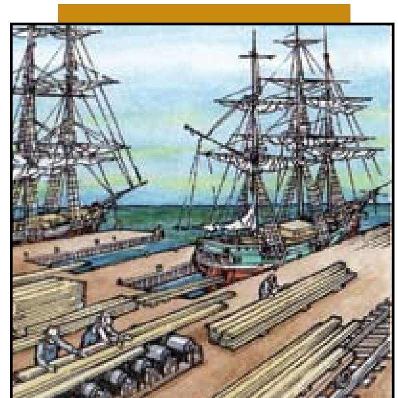
- Massive conifer forests dominated the region prior to European settlement. The major tree species have long life spans and can grow for centuries to large sizes.
- Douglas-fir dominates much of the low to middle elevations. These forests are the result of long fire intervals separated by catastrophic fires, although periodic, low-intensity surface fires were also common in places.
- The Klamath Mountains in the south, with lower precipitation and complex geological and ecological history, support a mixture of drought-resistant conifers and hardwoods.
- Southwestern Oregon and northwestern California include evergreen hardwoods, such as tanoak, Pacific madrone, canyon live oak, and California laurel.
- Coast redwood is an important and distinctive species in northwestern California and extreme southwestern Oregon.
- Oak woodlands, grasslands, wetlands, and riparian forests with black cottonwood, red alder and big leaf maple replace conifers in lowland river valleys. Oaks include Oregon white oak and California black oak.

Land Use History

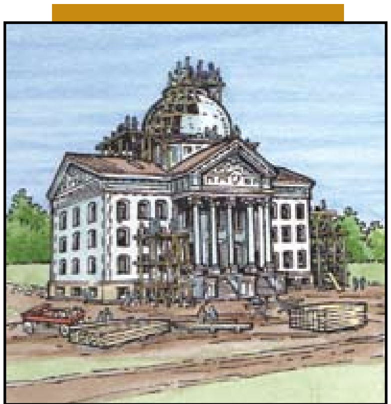


European settlement began in the early 1800s. At that time, approximately two-thirds of the coastal forest cover was more than 200 years old. These old-growth forests were the result of extensive stand-replacement fires.

Except for a few areas, such as Oregon's Willamette Valley grasslands, these forests were a challenge to early settlers who cleared them for agriculture and settlements. Compared to the Northeast, the Lake States, or the Southeast, not much forestland was cleared for agriculture because most land was unsuitable for cultivation.



Difficulties with transportation and access limited harvesting to lowland areas near harbors like Puget Sound. By the 1850s the first sawmill was operating at Fort Vancouver. By 1890, with the Lake States forests depleted, timber cutting and exporting were becoming a major industry. Pacific Coast logging expanded dramatically in the early 1900s, and by the 1920s it rivaled the Southeast.



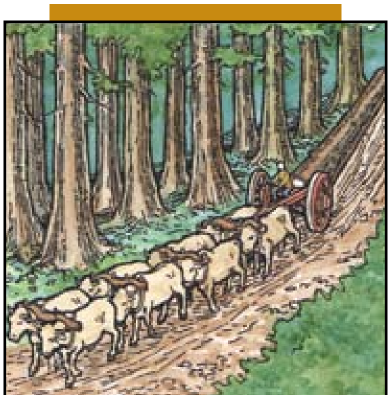
Land ownership patterns were well established by 1900, with forests divided among private, state, and federal ownership. The Homestead and Timber and Stone Acts transferred large tracts of forestland. Other land grants subsidized construction of railroads and wagon roads.

Highly productive forests with merchantable timber at low elevation with easy access were in private ownership.

State governments received trust lands that provided income for schools, universities, roads, and other public services. They also received "in lieu" lands, substitute lands in place of sections that were already in private hands. Additional lands came to the states from unpaid taxes during the Great Depression and from large wildfires like the Tillamook and Yacholt Burns.

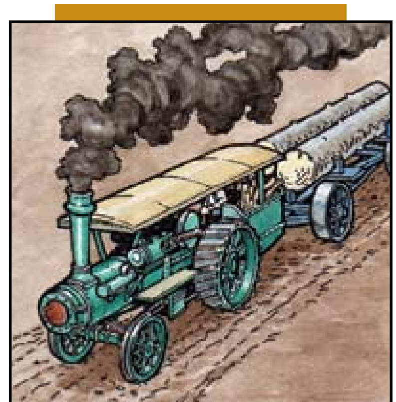
The Federal government held large blocks of national forests.

Early Logging (1880-1940)



Teams of oxen or horses moved huge logs to streams and rivers for transport to mills. Over time, railroads and steam-powered cable-yarding systems improved efficiency.

Old-growth Douglas-firs were considered the most valuable trees in the forest, and the main job was clearing these trees. Large acreages of logging slash were left behind, often resulting in devastating wildfires on and adjacent to logged areas.



By the 1920s, tractors and trucks replaced railroads.

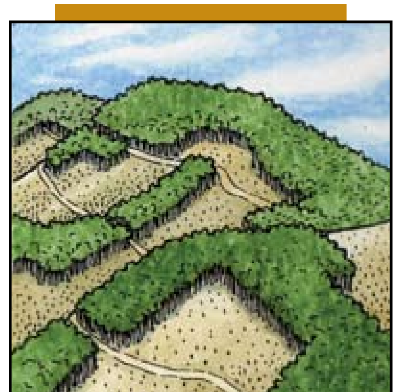
Major wildfires were a recurring problem up to the 1930s. The 1902 Yacholt Burn consumed nearly 100,000 ha (247,000 a), and the Tillamook Burns covered 111,000 ha (274,000 a).

Private landowners were unwilling to apply silvicultural principles until effective fire suppression programs were in place. By 1940, the tree-farm movement signaled the beginning of credible fire suppression programs.

Before World War II, most harvesting was on private lands because the industry lobbied to keep federal timber off the market during the Depression.

After the war, demand for wood products expanded. The Forest Service brought national forests under intensive management, and harvests increased.

Intensive management that included clearcutting and even-aged management was the norm on both private and public lands.



Clearcutting was justified because shade-intolerant Douglas-fir needed large, sunny openings to successfully regenerate and grow. Clearcuts were considered the ecological equivalent of stand-replacement wildfires.

Clearcut size depended on the ownership. Large clearcuts hundreds of hectares in size were typical of private lands. Dispersed, small clearcuts 2.5-5.5 ha (6-13 a) in size were typical of federal lands.

National forests and state trust lands followed the corporate high-yield forestry model. Planting was favored over natural regeneration, and greater log utilization left little organic material after harvest.

For a time, the Forest Service required gathering and piling of cull logs and unmerchantable wood on all clearcuts.

Slash and large down logs were even removed from streams and riparian areas in the 1960s. Stream wood was thought to block fish passage.

"What's good for wood production is good for the forest" seemed to be the motto of forest managers.

Little thought was given to the consequences of intensive management on forest biodiversity and ecosystem function.

Interest in wildlife was confined to game species that were thought to flourish in edge habitat created by clearcutting.

Scientists studied ecosystem functions such as nutrient cycling and stream flow regimes, but they received little attention from land managers.

By the 1960s, scientists were expressing concern about the effects of intensive management and forest roads on ecosystem functions such as soil stability, sedimentation, and stream water temperatures.

Public concern focused on the aesthetics of intensive management and concern for the environment in general.

Environmental laws of the 1960s and 70s made it possible to legally challenge federal land management. Litigation forced changes in management.

Current harvest patterns in the Pacific Coast region use the staggered setting or checkerboard model, with clearcut units 15 ha (37 a) or more dispersed throughout the landscape to produce a mosaic of even-aged, structurally-uniform stands.

Logging slash is typically burned to reduce fuel loading and control competition from surviving understory plants. Other management activities include herbicide and fertilizer applications that further alter the natural rates and patterns of stand development (see page 43).

Before the 1950s, reforestation was often left to reseeding from adjacent stands, but since the 1960s replanting has been practiced, often with only one (Douglas-fir) or a few species.

What are the Effects of Pacific Coastal Forest History on Biodiversity?

Most private Pacific Coast forests were converted from complex ecosystems to simpler plantations that favor wood production. The most significant effects involved changes in fire regime and loss of forest habitat:

- ▲ Within less than a century, the natural disturbance regime of wildfire and windstorms was largely replaced by short-rotation, even-aged management using clearcuts and prescribed burning, disturbances that are more frequent and less variable in size and intensity.
- ▲ The Pacific Coastal region contains some of the largest and oldest trees in the United States and harbors many endemic species. There is evidence that habitat change and loss of structural diversity in forest plantations favors some species but results in a lower diversity of others.
- ▲ The area of old-growth forests on all land ownerships in Washington, Oregon, and California has declined by greater than 50% since the 1930s and 1940s. Scientists estimate that only about 17% of the old-growth Douglas-fir forests that existed in the early 1800s remained in 1988 and that 96% of the original coastal rain forests of Oregon and 75% in Washington had been logged by 1988 (Condition and Extent of Pacific Coast Old-growth, page 102).

HOW CAN KNOWLEDGE OF PACIFIC COASTAL FOREST HISTORY BE USED TO RESTORE BIODIVERSITY?

Why Restore Pacific Coastal Forests?

- ▲ Landscapes have been limited in their ability to provide for native biodiversity related to late-succession forests. The northern spotted owl, marbled murrelet, bull trout and some salmon populations are threatened or endangered.
- ▲ The consequences of forest fragmentation continue to be an issue. Today's national forests are composed primarily of patches of older stands, with much larger trees intermixed with stands of small trees less than 50 years old.

What's Their Current Status?

- ▲ Society is concerned about biological diversity and ecosystem functions such as stream protection and water quality.
- ▲ Federal land managers attempt to maintain biodiversity and ecosystems even at the expense of reduced timber harvest and increased fire risk.
- ▲ Private and state trust lands use Best Management Practices to protect aquatic biodiversity and produce high wood yields.
- ▲ Efforts are aimed at restoration of upland and riparian forests to ensure biodiversity and functioning ecosystems. Achieving these goals requires forest management that will sustain biodiversity.

Important Points about Pacific Coastal Forests

Two major challenges to managing these forests for biodiversity are how to:

- ▲ maintain biodiversity and ecosystem function in natural stands that continue to be harvested and
- ▲ restore biodiversity and ecosystem function in young developing stands and landscapes where they have been lost due to past management.

Silvicultural systems that satisfy these challenges require three essential ingredients:

- ▲ Include biological legacies in harvesting prescriptions. (Described below in the section: What is Variable Retention Harvesting? Page 45)
- ▲ Include principles of natural stand development, including small-scale disturbance processes, in silvicultural treatments of young developing stands. (Described below in the section: Restoring Structure and Biodiversity to Young Developing Stands using Variable Density Thinning, Page 47)
- ▲ Allow for appropriate recovery periods between regeneration harvests. (Described below in the section: The Economics of Restoration, Page 48)

Pacific Coastal Forest Restoration

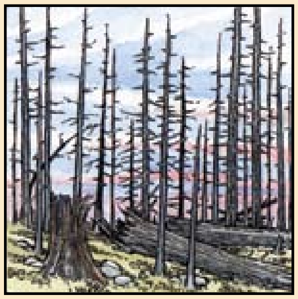
Forest restoration is already underway in coastal forests. Variable retention harvesting is used to maintain biodiversity in natural stands that continue to be harvested. Variable-density thinning is used to restore biodiversity and ecosystem function in forest stands and landscapes where they have been lost due to past management. These two restoration techniques (described below) are based on the natural disturbance regimes (described above), and stand development patterns that have been studied over the last 30 years (see box: Development of Pacific Coast Douglas-fir Forests). The following points are important:

- ▲ Different ownerships vary in their efforts to maintain and restore biodiversity, but all ownerships are involved in these practices to some degree.
- ▲ Restoration efforts include terrestrial and aquatic ecosystems, since riparian forests and stream systems have been impacted by 100 years of timber harvest and other activities.
- ▲ Reserve lands (Late-Successional Reserves on federal forests within the range of the northern spotted owl), have been established and removed from timber harvesting as part of the effort to maintain and restore biodiversity and ecosystem function.

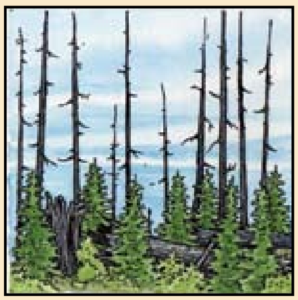
Development of Pacific Coast Douglas-fir Forests

We understand how these stands change in composition and structure. Although stand development is complex and diverse, and not all stands go through all stages, there is a general pattern across a wide range of forest types and locations. It includes eight stages.

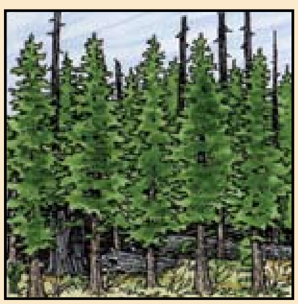
1 Disturbance and Legacy Creation. **Historically, after wildfire disturbance in an old-growth Douglas-fir stand, legacy structure was carried over in the form of large standing trees and large down logs.**



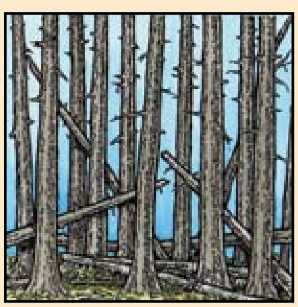
2 Cohort Establishment. **After the disturbance, a new cohort of trees and other organisms develops. Initial dominance is often by Douglas-fir, a shade-intolerant species.**

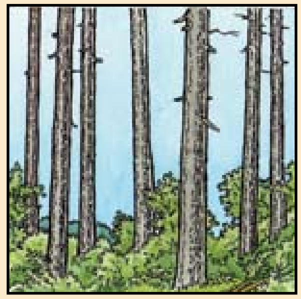


3 Canopy Closure. **As the tree canopy develops, lack of sunlight causes shade-intolerant herbaceous and shrub species to disappear along with lower tree branches.**

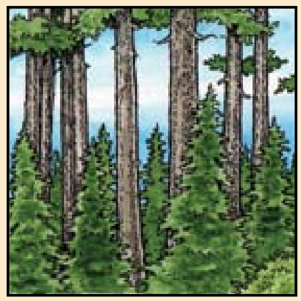


4 Competitive Exclusion. **In this stage, mortality occurs in the tree layer as trees compete for light and water. Natural pruning of lower branches occurs and understory plants and tree vegetation is sparse.**



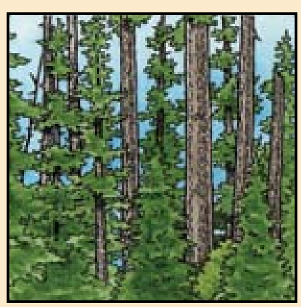


5 Maturation. **At the age of approximately 150 years, the Douglas-fir stand has achieved maximum height and crown spread. A shrub and herb layer reappears, the result of understory redevelopment.**



6 Vertical Diversification. **Canopy growth continues with the development of multiple layers. Lower branch systems develop on dominant trees. Shade-tolerant trees (western hemlock and western red cedar) may gradually become established and grow into the upper canopy, replacing Douglas-fir, a process that can take several centuries.**

7 Horizontal Diversification. **Trees develop multiple tops, stem and top rots, cavities, and brooms. Large-diameter branches form and lichens and fungi move in.**



8 Pioneer Cohort Loss. **Individual canopy trees or groups of trees begin to die, forming gaps of various sizes and shapes. New trees establish in the understory, and trees already in lower and mid-canopy positions grow taller. This phase requires hundreds of years and is uncommon in landscapes where logging and natural disturbances occur frequently.**

There are exceptions to this general development pattern. For example:

- ▲ Shade-tolerant species can be part of the initial stand-replacement disturbance.
- ▲ Douglas-fir occasionally reproduces and grows successfully in established stands.
- ▲ Stand-replacement disturbances typically return before pioneer cohort loss because Douglas-fir can survive for 800 to 1500 years.

This stand-development pattern can be generalized to forest types other than those dominated by Douglas-fir or stand-replacement fires. The descriptions of each stage are useful when planning stand treatments to be used in forest restoration.

What's so Important about Biological Legacies?

Biological legacies help conserve biological diversity in significantly disturbed forest ecosystems. Pictured here are biological legacies left behind by three different natural disturbances.

Jerry Franklin

Understory plants, large quantities of tree seedling, snags, and down logs were legacies at some locations after the Mount St. Helens eruption in Washington, May 1980.

- Biological legacies are responsible for the survival of plant species, either immature or mature individuals or reproductive structures such as seeds, spores, or sprouting vegetative parts.
- They affect other plant and animal life by creating refugia that provide a lifeboating function.
- They provide structural habitat needed by re-colonizing organisms.

Jerry Franklin

- They improve connections across the landscape for some organisms by providing protective cover.
- Their role is most important where a stand replacement disturbance has taken place. The lifeboating function is provided by the large live trees, snags, and down logs that persist. These structures sustain organisms by providing habitat (nesting sites and hiding cover) and energy, especially immediately after the disturbance.
- Live green plants that survive a stand-replacement disturbance sustain energy flows to belowground organisms and food webs, as well as to aboveground herbivores.
- Legacy structures modify microclimate conditions, allowing organisms to survive, that might otherwise be eliminated from the post-disturbance environment.

Jerry Franklin

Above: Six years after a stand-replacement fire in Yosemite National Park, California, snags and down log legacies remain to serve important functional and habitat roles.

Left: After a windstorm in the Bull Run River drainage on the Mount Hood National Forest, Oregon, understory plants, tree seedlings and saplings and down logs were left.

Jerry Franklin

Retention harvesting on national forest lands. In this case different tree species and sizes, along with large old trees, snags, and down logs, have been left (about 25% of the original stand).

What is Variable Retention Harvesting?

It includes harvesting practices that retain biological legacies and riparian buffers along streams and rivers and around other aquatic areas.

Why was it developed? Variable retention harvesting was developed to mitigate the negative impacts of clearcutting and even-aged management and mimic the biological legacies of natural disturbance regimes.

Is it new? Not entirely. Shelterwood and group selection harvesting techniques have been applied on federal lands since the 1970s. They provided experience in retaining overstory trees. When the concept of biological legacies became apparent from ecological studies of Mount St. Helens in the early 1980s, it merged with the practical experience of structural retention in shelterwood and group selection harvests. Today, it is being used on both public and private ownerships in Pacific Coastal forests.

How it differs from shelterwood? There are two major differences. First, what's left after the harvest is intended to stay into the next rotation, rather than being harvested after trees become established. Second, as shown in the photo above, the retained trees are either left in blocks or scattered across the cutting unit (lower left quadrant of photo).

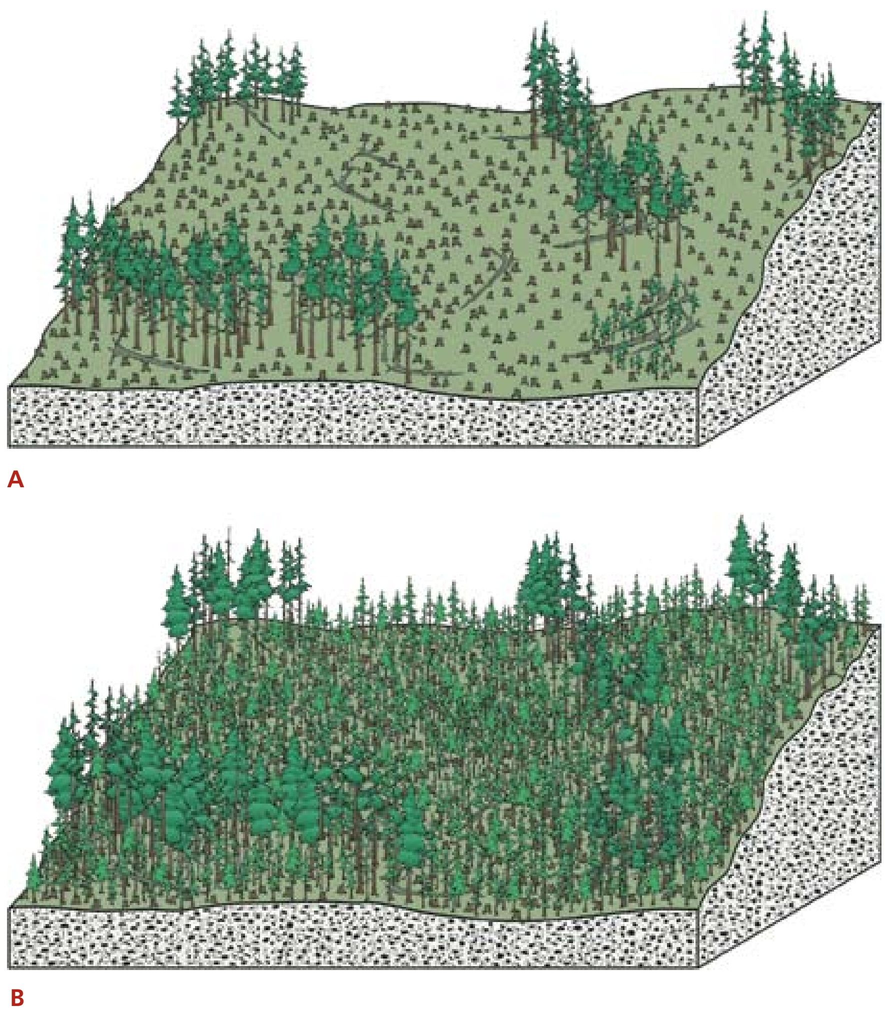
What does it look like on public forests? All federal forest land within the range of the northern spotted owl now requires regeneration harvests that retain a minimum of 15% of the previous stand, effectively eliminating the practice of clearcutting (see photo). Retained structures include some of the largest and oldest trees, large snags, and large down logs. The Washington Department of Natural Resources also has adopted this practice on its trust lands within the Pacific Coastal region.

What's its effect on biological diversity? Variable retention harvesting is thought by some to be more effective than clearcutting at sustaining biological diversity. It provides both a lifeboating effect for organisms in the near term and a means of recolonizing the harvested site by displaced species as the next forest develops (see box: What's so Important about Biological Legacies?).

Robert Logan

Cougar Ramp retention harvest unit on Plum Creek property in Washington, five years after harvest (1989).

What does it look like on private forests? When Plum Creek Timber Company started using variable retention harvesting in its Pacific Coastal forests in 1989, it was the first timber corporation in the United States to adopt and apply this approach. The goal was to reduce impacts on potentially threatened and endangered species and minimize harvesting costs and safety issues while maximizing the effectiveness of retention from the standpoint of biodiversity and aesthetics.



This illustration sequence shows the Plum Creek retention harvest in the first year (A) and what it will look like in 25 years (B). At year 1 the retention unit includes carry-over biological legacy structures from the original forest (snags for cavity nesters, old live trees, and habitat for lichens, fungi, birds, and small mammals). The result 25 years later is a complex forest, enriched with structural features that would be absent from a clearcut.

How to Restore Structure and Biodiversity to Young Developing Stands Using Variable Density Thinning

By using intermediate treatments that model processes found in natural stand development (box, page 43), simplified young stands can be managed to accelerate structural complexity and biodiversity.

What's the difference between traditional thinning and variable density thinning? Traditional thinning is done to accelerate timber production and create spatial homogeneity in the stand. It can include:

- removal of suppressed smaller trees
- development of dominant trees
- elimination of non-commercial tree species.

Variable density thinning, sometimes described as "skips and gaps," creates spatial heterogeneity in the stand. It includes:

- accelerating development of large diameter trees
- maintaining greater diversity of plants and animals and ecosystem processes
- forming "gaps" by removing dominant trees to maintain and enhance growth of shade-tolerant conifers and hardwood species and islands of understory vegetation
- leaving "skips" that maintain habitat for species and processes dependent on heavy shade.

Variable density thinning is new. There are disagreements and questions among scientists about its effectiveness in restoring late-successional structures and organisms.

- Some favor very heavy thinning, believing that it replicates the wide spacing thought to exist in the development of old-growth stands.
- Others think heavy thinning will result in two-tiered stands with a low density of overstory trees and a dense understory of either shrub species or western hemlock, neither of which is structurally diverse.

Despite differences of opinion and unknowns, there is consensus about the benefits of variable density thinning in accelerating development of late-successional forests. However, the practice and its effects are quite limited at present.

Where is This Approach Being Used?

- On federal lands where young stands are located within late successional reserves (LSRs).
- In simplified forests on municipal watersheds, such as Seattle's Cedar River Watershed.
- On trust lands administered by the Washington Department of Natural Resources where Dispersal and Nesting-Roosting-Foraging (NRF) habitat for northern spotted owls is required.

On Federal Lands

The Northwest Forest Plan, developed in 1995, is a strategy to sustain old-growth forest ecosystems and related organisms by creating LSRs that contain well-developed old-growth forests fragmented by harvesting that occurred between 1950 and 1990. The result is significant areas of young forest, less than 50 years old, mixed with old-growth.

The goal for these LSRs is to restore contiguous late-successional forest cover. This could be achieved by letting natural stand development processes take place, but that would take considerable time. To speed the process, variable density thinning can be used in young stands to create snags and large down logs, stimulate development of decadence, accelerate development of large diameter trees, and re-introduce missing plant and animal species.

On the Cedar River Watershed in Seattle

The City of Seattle watershed has a habitat conservation plan (HCP) that calls for restorating late-successional forest conditions throughout the drainage. There is some old-growth in remote and inaccessible parts of the watershed, but most is 10-80 year old stands. The city is using variable density thinning on very young stands. Thinning of older stands will begin soon, and much of the wood will be left in the forest to provide large down logs on the forest floor.

On Washington State Trust Lands

As part of its HCP with US Fish and Wildlife Service, the Washington Department of Natural Resources (WADNR) is required to create and maintain Dispersal and Nesting-Roosting-Foraging (NRF) habitat for the northern spotted owl. This requires forest stands with highly complex structure. For now, WADNR can accommodate the objective of their HCP by maintaining existing older stands, but they can't harvest those older stands until replacement stands are available for owl habitat. The department needs to develop suitable Dispersal and NRF habitat as rapidly as possible. They are currently using variable density thinning to create snags, large down logs, and other old and decaying wood.

The Economics of Restoration

It's one thing to invest in restoring and maintaining biological diversity, but in the long run forest managers have to consider economic returns along with ecological benefits. Research scientists have developed a silvicultural system called "biodiversity pathways" that integrates economic and ecological goals. It was developed for WADNR as an alternative to traditional forest practices on trust lands. Stand simulations have shown that this system can integrate ecological goals with positive economic returns. As much as 82% of the net present value generated by traditional timber management systems can result from a biodiversity management strategy that uses:

- variable density thinning
- alternating rotations of 70 and 130 years
- structural retention at the time of regeneration harvest.

Biodiversity pathways focuses on intermediate stand treatments of established stands that integrate economic and ecological goals.

Jerry Franklin

Structures retained on a harvest unit on public lands include large, decaying live trees, large snags, and large down logs. All of these structures are impossible to re-create in stands managed under even moderate (e.g., 100-year) rotations.

Summary of Pacific Coast Forest Restoration

Silvicultural practices being designed and used to restore and maintain native biodiversity and ecosystem processes include:

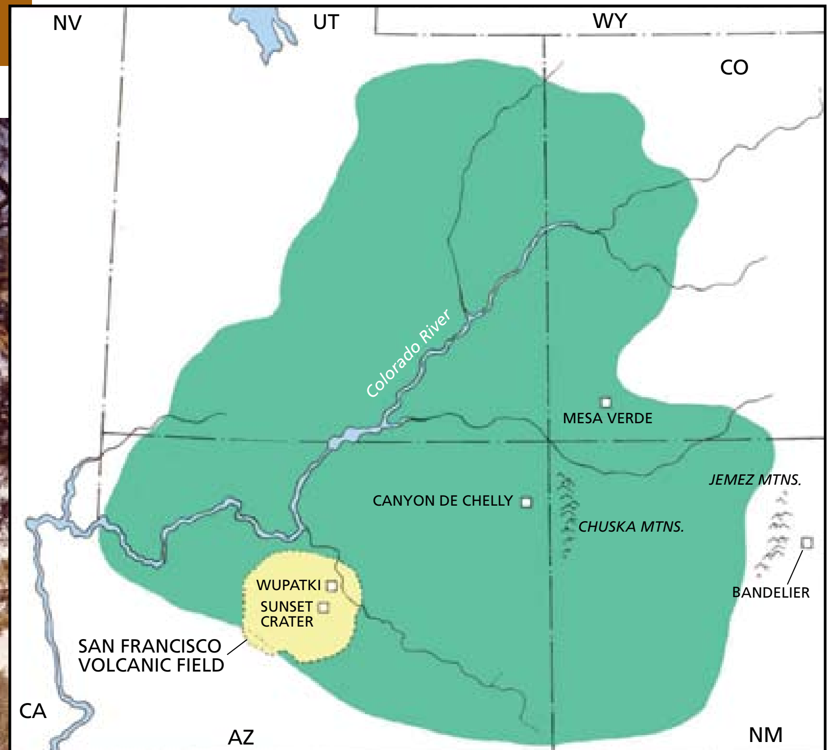
- regeneration harvests (variable retention rather than clearcutting) that mimic natural disturbance regimes, especially biological legacies
- managing young stands (variable density thinning) to restore and maintain structural complexity and compositional diversity by simulating natural development processes.

INTRODUCTION TO COLORADO PLATEAU FORESTS OF THE SOUTHWEST

Ponderosa pine forest, Colorado Plateau

Josef Muench, NAU Cline Library, Special Collections and Archives

Modified and reproduced from Woodlands in Crisis by Nabhan, Coder and Smith.



Forests of the Colorado Plateau sprawl across southeastern Utah, northern Arizona, western Colorado, and northwestern New Mexico. Noted are the four case studies referred to in the text.

Tree Species

Conifers include:

- corkbark fir *(Abies lasiocarpa var. arizonica)*
- alpine fir *(Abies lasiocarpa)*
- white fir *(Abies concolor)*
- Douglas-fir *(Pseudotsuga menziesii)*
- blue spruce *(Picea pungens)*
- Engelmann spruce *(Picea engelmanni)*
- limber pine *(Pinus flexilis)*
- bristlecone pine *(Pinus aristata)*
- ponderosa pine *(Pinus ponderosa)*
- lodgepole pine *(Pinus contorta)*
- pinyon-pine juniper *(Pinus edulis)*
- Rocky Mountain juniper *(Juniperus scopulorum)*
- Southwestern white pine *(Pinus strobiformis)*
- western juniper *(Juniperus occidentalis)*

Hardwoods include:

- quaking aspen *(Populus tremuloides)*
- Gambel oak *(Quercus gambellii)*

WHAT DO WE KNOW ABOUT NATURAL AND LAND-USE HISTORY OF THE COLORADO PLATEAU FORESTS OF THE SOUTHWEST AND THEIR EFFECT ON BIODIVERSITY?

Three Major Forest Types

The Colorado Plateau of the Southwest, also called the “Four Corners” region, includes three major forest types:

▲ Mixed conifer forests, dominated by ponderosa pine and Douglas-fir along with white fir and blue spruce, occur at high elevations. Ponderosa pine, once co-dominant in many stands, has been replaced by a dense understory of Douglas-fir and white fir, the result of fire suppression.

▲ Ponderosa pine forests grade into mixed conifer forests at higher elevations and into pinyon-juniper woodlands or grasslands or sage scrub below. Widespread surface fires occurring at 4-36 year intervals kept many of these forests open and diverse until the 1880s and early 1900s. Since then, thickets of ponderosa saplings have increased in density as old overstory trees declined or died. Ponderosa forests are shrinking as fire-intolerant fir in the mixed conifer moves downslope and pinyon in the lower elevation woodlands moves upslope.

- Pinyon-juniper woodlands are more heterogeneous than the other two. Some of the highest levels of species richness in the western United States have been found in landscapes dominated by pinyon-juniper woodlands. The fire history of this forest type is not well known, but recent evidence suggests that infrequent, high-severity fires were more common in the historic record than spreading, low-severity surface fires.

Four Colorado Plateau Case Studies

The Colorado Plateau is ranked in the top four of 109 ecoregions in North America for species richness in several taxonomic groups and first for unique or endemic plants and animals. The following information is based on four case studies that demonstrate the heterogeneity of today's Colorado Plateau landscape and the variability in historic land uses and other ecological changes that have shaped the current conditions. The case studies include:

- The Jemez Mountains/Bandelier National Park, New Mexico
- Mesa Verde National Park, Colorado, is known for its stone cliff dwellings that served the prehistoric Anasazi people for more than 200 years and are some of the best-preserved Indian sites in the nation.
- The Chuska Mountain Complex (Canyon de Chelly National Monument), Arizona, one of the longest continuously inhabited areas in North America, is located on Navajo tribal land, and today's Navajos play a role in preserving its integrity.
- San Francisco Volcanic Field/Wupatki and Sunset Crater National Monuments, Arizona.

How Do We Know the Natural and Land-use History of Colorado Plateau Forests?

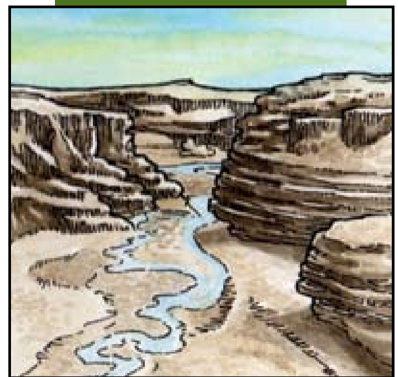
Researchers have developed detailed information about the history of this landscape based on:

- palynology (the study of pollen and spores)
- dendrochronology (tree growth rings)
- fire scars
- packrat middens (dung piles)
- archaeology
- written and oral histories and repeat photography.

Packrat middens left in caves and crevices by packrats contain fossil plants that formerly grew nearby. Rock formations can shelter and preserve these middens from the elements for thousands of years. They can be used to compare historical and modern vegetation.

Natural History

Past and current climate variability has shaped the Colorado Plateau woodlands and forests. After reviewing all climatic records of the four study areas, researchers found examples of flood, drought, or temperature variation that were more extreme in the past than any modern climate event, although the current global warming trend appears to be becoming an extreme event.

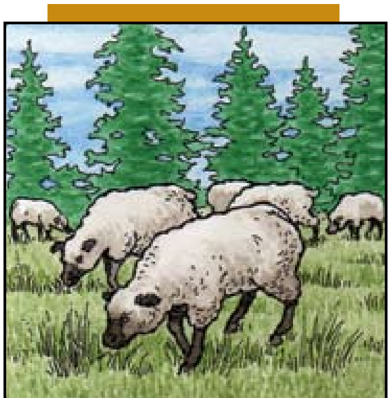


Fire history varied greatly among the four study sites, with periods of fire cessation occurring centuries earlier in some landscapes than in others. Interestingly, wildfire regimes at the four study sites were permanently and dramatically reduced by 1880. That is well before national fire exclusion and suppression policies were initiated.

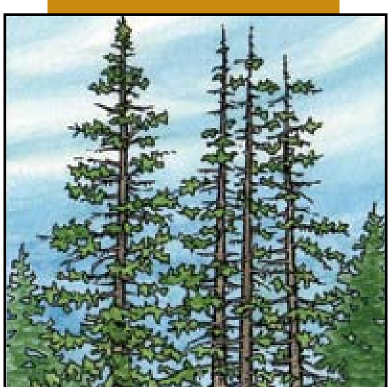
Insect infestations may have influenced prehistoric wooded landscapes across the Colorado Plateau.

Land Use History

The Southwest has a complex history of human occupation and abandonment over the last 12,000 years. That history has affected substrates, bedrock, geology, precipitation and microclimate, and the dominant forest vegetation types. Native inhabitants influenced these landscapes by many activities, including farming, grazing, and logging. In some cases, the most intensive land use occurred centuries before Anglo-American settlement.



Anglo-American settlement brought added impacts to the landscape including sheep overgrazing and logging. Historical evidence of native bunch grasses indicates that these habitats evolved with low levels of soil surface disturbance by ungulates.



Insect infestations across the Colorado Plateau have had dramatic impacts on forests and woodlands in recent years, with 750 million acres of dead or dying trees documented in Arizona and New Mexico in 2002.

Some important natural processes in pre-settlement landscapes are now difficult to maintain, such as frequent low-intensity fires, the role of missing predators, and depletion of surface and ground water through human overuse. The missing predators are the grizzly bear and Mexican gray wolf (recently reintroduced in the region).

Modern influences on this landscape include pollution, exotic species invasions, habitat loss or fragmentation, and climate change. One notable invasive plant is cheatgrass *(Bromus tectorum)*. (See Invasives, page 59)

What are the Effects of Colorado Plateau History on Biodiversity?

The land-use, climate change, and fire history of the Colorado Plateau have changed forest composition, structure, and ecological processes. Here are some examples:

- Ponderosa pine forests and pinyon-juniper woodlands have had dramatic increases in stand density, decreases in the number and variety of species in the understory, reduced native biodiversity, and loss of cool-season grasses and non-timber forest products (NTFPs).
- Higher elevation mixed-conifer forests show an increase in stand density and shade-tolerant trees.
- Intensive harvesting and fires in some locations have resulted in a loss of old-growth ponderosa pine.
- Trees and shrubs have expanded into grasslands.
- Overgrazing has affected ecological processes such as hydrologic regimes and fire frequency.
- The loss of understory vegetation has reduced surface water infiltration, which in turn has altered streamflows.
- Habitat loss and fragmentation from urban and rural population growth are threats in three (Jemez, Chuskas, and SF Volcanic Field) of the four areas studied.
- Invasive exotic plant species are a threat in three of four areas studied. For example, 10-17% of the plants are introduced species at Mesa Verde, the Jemez Mountains, and in the Canyon de Chelly/Chuska Mountain area.

HOW CAN KNOWLEDGE OF THE COLORADO PLATEAU FOREST HISTORY BE USED TO RESTORE BIODIVERSITY?

Why Restore Colorado Plateau Forests?

In the last century, forest and woodland management has resulted in increasingly homogeneous habitats that are more prone to high-severity stand-replacing fires and are less diverse in understory NTFPs. These trends have regional ecologic, economic, and cultural consequences. Their causes include interactions among land-use history, climate, physical characteristics of the landscapes, and relationships among predators, prey, protected livestock, and forage species.

What's Their Current Status?

Unprecedented wildfires in recent years prompted passage of the Healthy Forests Restoration Act in 2003. This national legislation authorizes money for preventative forest thinning. Opinions differ about whether thinning can really restore forests and about the historical conditions to which forests should be restored. Some say pre-settlement conditions should be the goal. Others say pre-settlement conditions are too general and may not apply to specific locations.

Ecological restoration to more natural conditions is urgently needed. But scientists differ about whether the changes in vegetation are the result of fire exclusion, livestock grazing, climatic fluctuations, bark beetle infestations, or other factors. Ponderosa pine forests near the San Francisco Peaks in northern Arizona have been the model for forest restoration in the Southwest. But the Colorado Plateau case studies demonstrate that the San Francisco Peaks model does not describe the historic conditions found in other ponderosa pine forests in the region, let alone mixed conifer forests or pinyon-juniper woodlands.

The Healthy Forests Restoration Act passed in 2003 has focused the debate. The question is: How can the funds provided by this legislation be used not just to reduce property-damaging fires, but also to restore the health and diversity of forests in the future? There is scientific uncertainty about how to achieve this goal in ponderosa pine forests. The conclusion, after looking at forest history in the Colorado Plateau, is that there is no single pre-settlement target for restoration.

Important Points about Colorado Plateau Forests

The four case studies demonstrate that each site has unique characteristics that must be recognized when developing management or restoration plans, and each landscape has unique needs. However, there are some general patterns.

- Species richness of native plants and birds has declined and exotic invasive plants have increased over the past 150 years at all sites.
- There have been reductions in fire frequencies induced by historic grazing that predated government fire suppression mandates.
- Most important is the reduced heterogeneity of cultural management strategies for forests and woodlands. Bureau of Indian Affairs managers have replaced Native American practices with one-size-fits-all U.S. Forest Service and National Park Service policies. Reducing Native American and Hispanic traditional use has helped to homogenize the landscape. Practices have been lost that formerly maintained a mosaic of habitats through the use of fire and small-scale farming and gathering. These policies have focused management on timber or grazing resources to the detriment of NTFPs, which contribute to biodiversity and ecosystem health.
- Geology has played a key role in the adaptation of many of the endemic plants that are influenced by particular soil conditions. This geographic heterogeneity and its influence on endemic, rare, threatened, and endangered species underscore the need for land managers to base their restoration and management on site-specific characteristics.

Two locations highlight the range of variability on the Colorado Plateau and the need for site-specific restoration.

Susan J. Smith

Pinyon-juniper forest, Jemez Mountains, near Bandelier National Monument:

- **Geology: volcanic**
- **Precipitation: moderately dry**
- **Forest: co-dominated by ponderosa pine and pinyon-juniper**
- **Almost continuously occupied by Pueblo, Hispanic and Anglo cultures**
- **Grazed by sheep since the 1600s, then cattle up to the 1930s**

Northern Arizona University, Cline Library

Mesa Verde National Park:

- **Geology: sedimentary**
- **Precipitation: more moist**
- **Forest: dominated by pinyon-juniper**
- **Intense prehistoric agriculture (900 and 1300) then abandoned until 1500 when occupied by very light presence of Utes and Anglo cultures**
- **Short grazing history by cattle (1880 to 1935)**

Differing Ideas About Restoration in the Colorado Plateau

Land managers and scientists generally agree that restoration of Colorado Plateau forests and woodlands is urgently needed. Disagreement comes in how to carry out that restoration. In response to unprecedented stand-replacing wildfires in the West, the government has invested money in preventative forest thinning to restore forests. This has prompted debate about thinning, controlled burns, and other restoration activities.

Most land managers and scientists agree that:

- ▲ the evidence indicates more frequent, intense, and large wildfires, along with increasing costs of fire suppression and rehabilitation in the ponderosa pine forests over the last decade
- ▲ these changes in fire dynamics have been related to historic changes in the density and age structure of ponderosa pine forests.

Craig D. Allen

The Cerro Grande Fire, burned into the town of Los Alamos, New Mexico in May, 2000. This is the area in April, 2006, showing the burned area adjoining the west perimeter of the townsite. Stand-replacing crown fire like this are evidence of more frequent, intense and large wildfires occurring in the Southwest, along with increasing fire suppression and rehabilitation costs.

They disagree about:

- whether the structural changes in vegetation are explained by fire exclusion and suppression policies, livestock overgrazing, climatic fluctuations, bark beetle infestations, or other factors
- the degree to which thinning or controlled burning can restore wooded habitats, and what the reference point should be.

One group of scientists advocates using pre-settlement conditions to understand what forest stand structure was like before European settlement. They conclude that thinning would restore stand structure, which in turn will restore ecosystem processes, such as frequent low-intensity fires.

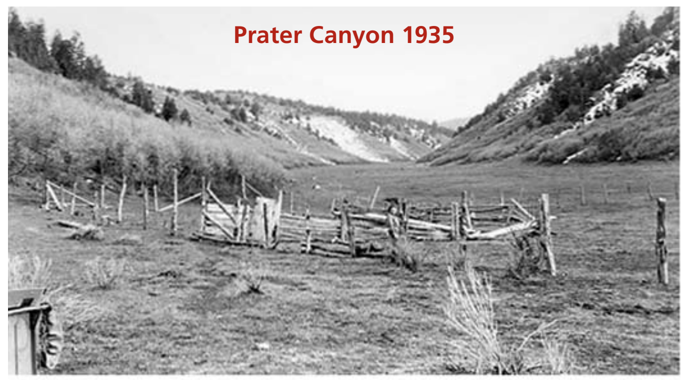
Another group of scientists fears that using structure alone, or in combination with fire frequency, to predict ecosystem function will miss other pieces of the ecosystem. Those pieces include biodiversity and understory composition, the effects of the understory on hydrology, changes in nutrient cycling, the role of predators, birds, and other wildlife, and the importance of NTFPs. They point out that using past conditions as a model to restore modern forests also underestimates new influences such as pollution, fragmentation, invasives, and climate change. They claim that a restoration model developed around Flagstaff, Arizona, is not transferable to other pine-dominated landscapes in the west and that what works in the ponderosa pine forest around Flagstaff may actually cause damage in other forests and woodlands on the Plateau.

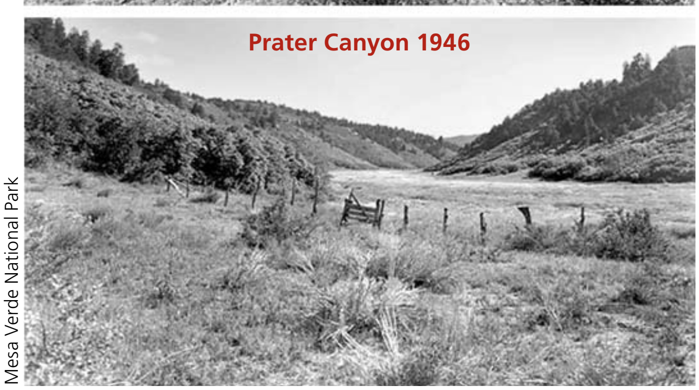
Forest Restoration Ideas for the Colorado Plateau

How have these landscapes responded to restoration treatments in the past?

- Within 3 to 50 years, grazing exclosures have shown increases in native biodiversity, increases in native cool-season grasses, and more well developed biological soils crusts (see photos).
- Mesa Verde research showed a 17-foot rise in the water table after grazing was excluded for 11 years.

After exclusion of cattle and sheep from Mesa Verde National Park, repeat photography demonstrates a change from nearly 100% bare ground to nearly 100% cover (mostly clover) within 8 years, and native herbs within 11 years. Recovery of the water table was also dramatic.





Mesa Verde National Park

- In general, fire recovery studies show changes in species composition and increases in native biodiversity following fire.
- Invasives are a concern in burned habitats.
- Preliminary results show significant changes in grass species composition and cover in response to thinning and mulching treatments in the Jemez Mountains.
- The health and richness of understory species was enhanced by the harvest of NTFPs. These species tend to increase landscape heterogeneity because they prefer certain substrates or growing conditions, and their harvest is an important way to encourage stewardship of native biodiversity in these wildlands.

Additional Thoughts on Colorado Plateau Restoration

Scientists who conducted the four case studies advocate a stronger focus on restoring ecological processes rather than exclusively focusing on forest structure or composition. They believe that historic and contemporary uses of NTFPs have been undervalued relative to timber and livestock production. They want to restore understory species and wildlife, not just conifers and grass. With these concerns in mind, they make the following recommendations.

- Manage adaptively for the uncertainty of drought or climate change rather than for timber, livestock, or fire management. Direct research toward restoring forest and woodland ecological processes, given current and predicted climatic regimes, rather than reconstructing past vegetation structure or composition.
- Management plans for ponderosa pine forests and pinyon-juniper woodlands should be based on site-specific information rather than regional generalizations. There is no single pre-settlement target for restoration.
- Since invasive plants are a significant threat over much of the Colorado Plateau, forest thinning methods that increase the dispersal, recruitment, and establishment of invasive exotic weeds should be avoided. Because most landscapes on the Colorado Plateau have evolved with low levels of soil surface disturbance, and are dependent on the biological crusts that have developed, management and restoration efforts should minimize disturbance of soil crusts in thinning and burning activities, and in recreational use, logging, mining, livestock management, and other activities that would disturb the soil's biological crusts.
- Ecological restoration must be presented to the public in a broader context than just structural thinning and controlled burns. The focus should be on managing forests as ecosystems, with cultural and economic ties to the local population. It may be difficult to promote practices that focus on overall health of forest ecosystems when the public fears wildfire. However, managers can increase a sense of stewardship through education and a stronger focus on other uses of the forest, such as the harvest of NTFPs, traditional uses, hunting, and wildlife observation and photography.

SUMMARY

The forest history of the five major regions described in this chapter is a starting place, an explanation of how and why we arrived at where we are today. It's also a step toward restoration and preparation for conserving biodiversity in the forests of the future. In Chapter 2 we will look at the role of non-native invasives, a factor that has influenced biodiversity in the past and one that will have even more profound impact in the future.

To Learn More About This Topic, See Appendix, page 167.

WHY ARE NON-NATIVE INVASIVES IMPORTANT?

A **non-native invasive species** is a species whose introduction threatens or harms natural ecosystems, human health, economic values, or all three. Throughout this chapter we'll use the term invasives as shorthand for non-native invasive species.

Forest ecosystems are adapted to the slow, natural movement of species and to natural disturbances like wildfires, floods, and droughts. In the last 200 years, however, people have been able to travel between continents faster and easier than ever before, and they have carried plants, animals, and pathogens (microscopic organisms that cause disease) to places they might never have reached by natural dispersal. Once there, away from parasites and other ecological controls that limited their environmental and socioeconomic impacts on their home continents, some of these non-native species become invasive.

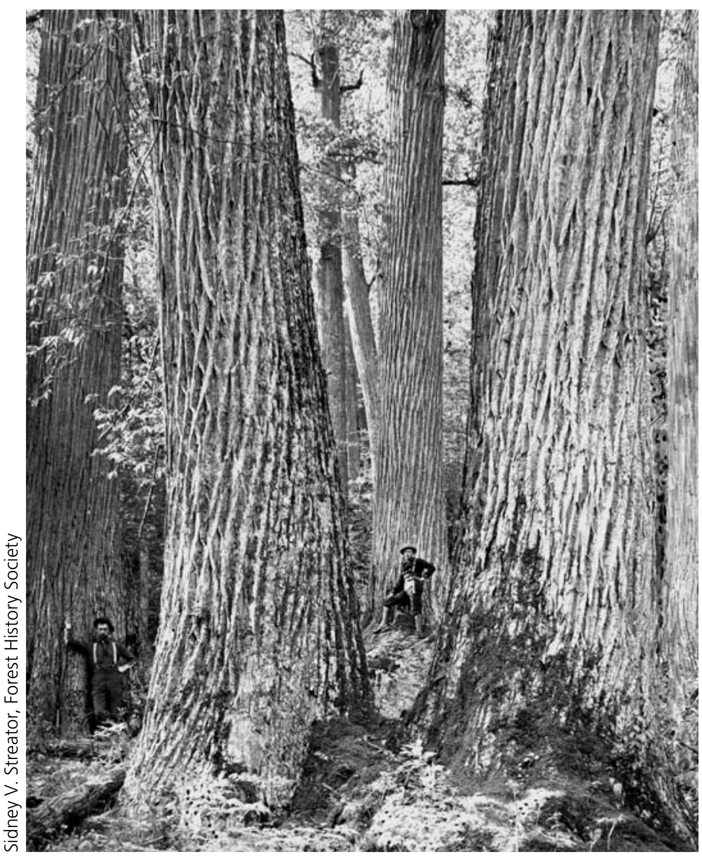
Invasive species are a major threat to sustainable forestry. Over the past century, invasives in the United States have impacted all of the forest ecosystem values that sustainable forestry seeks to ensure. They affect biological diversity, forest health and productivity, water and soil quality, and socioeconomic values. The loss, just in terms of forest products, is more than $2 billion annually. In spite of these serious impacts, we have failed to deal effectively with forest invasives in the United States and worldwide.

We have inventoried and calculated invasives, but we haven't answered the question of what we're going to do about them. To help answer that question, NCSSF sponsored a research project to describe how research can help eradicate, contain, or suggest new ways to control forest invasives. This chapter explains the findings of the scientists who conducted that project. It reviews some major invasive species that affect forest ecosystems, briefly describes the organizations involved in their control, and lays out a strategy to reduce their threat more effectively.

WHAT DO WE KNOW ABOUT THE THREAT FROM INVASIVES?

Some invasives have a long history of impact on our forests (chestnut blight), others have appeared more recently (emerald ash borer and sudden oak death), and still others such as the nun moth (pages 58-59) represent future threats.

United States forests have yet to experience many possible invasions or even the full effects of some already established non-native species. Despite defensive efforts, such as seed purity requirements and sanitation regulations for imported wood packing materials, entry pathways remain open or only partially regulated, and forest invaders continue to spread. Movement of invasives across the globe is on the rise because of increasing international and interstate commerce. At the same time, increasing human access to forests, forest fragmentation (Chapter 3), and forest disturbance all create opportunities for invaders to penetrate and become established. When climate change is added to the list, there's potential for the threat to grow in response to altered disturbance regimes and geographic ranges of forest species. We're facing future invasions that are likely to have enormous social, economic, and ecological consequences.



Sidney V. Streator, Forest History Society

Chestnut blight, one of the most devastating invasives in recorded history, reduced the most important tree in Eastern forests to insignificance. This photo, taken in Graham County, NC, first appeared in *American Lumberman* in 1910. (From left to right, B. King, Timber Warden and D.W. Swan, Timber Agent)

Before examining the impacts, let's briefly review some basics. First, invasives fall into one of four categories:

1. Invasive pathogens are microscopic organisms capable of causing disease. Sudden oak death (SOD) is an invasive pathogen that can affect many different plants and cause a variety of symptoms. Early detection is challenging because of the size of pathogens.

Joseph O'Brien, USDA Forest Service, www.forestryimages.org

Death of this oak canopy is caused by the sudden oak death pathogen *(Phytophthora ramorum)*.

2. Invasive insects, along with pathogens, have damaged and killed dominant tree species and caused changes in the ecology, function, and value of forest ecosystems. An example is the European gypsy moth, which defoliates millions of acres each year.

Mark Robinson, USDA Forest Service, www.forestryimages.org

Extensive summer defoliation due to the European gypsy moth *(Lymantria dispar)*.

John M. Randall/The Nature Conservancy

Japanese honeysuckle *(Lonicera japonica)* is found in 37 states. It invades forest edges and disturbed areas, suppressing native plants, bringing down trees and altering songbird populations by changing forest structure. Cutting stems at ground level or burning makes the registered herbicide treatment more effective.

3. Invasive plants, including trees, modify forest ecosystems by altering fire and water regimes and food webs, preventing the growth of groundcover, wildflowers, and dominant tree species. One example is Japanese honeysuckle (others are described on pages 58-59). Sometimes invasive plants are weeds, helped by forest management activities, such as prescribed fire, road building, soil disturbance, harvesting, and use of non-native plants in forest revegetation projects (i.e., following wildfire).

Gary Boyd

Adult bullfrog (*Rana catesbeiana* Shaw, 1802). Control: catch and remove frogs.

4. Invasive aquatic species and wildlife often spread from one region to another with unintended help from landowners and others who are not fully informed about how invasive species can affect the forest or about control strategies. Examples include the movement of bullfrogs, brook trout, and rainbow trout (from eastern to western United States). The fact that these invasives are viewed as desirable for recreation contributes to their spread.

What do we know about the threat from invasives?

Here's a sample of U.S. forest invaders and their impacts, arranged according to the date of their detection. Starting at the top right are two possible future invaders, followed by some of the most recent, and finally some established invaders that go back to the 1850s. The impacts noted here are not exhaustive, but they do indicate that inventory data are limited and cost estimates of impacts are rudimentary. These are just two shortcomings that hinder the war on invasive forest species. There's more about these and other limitations in the discussion of efforts needed to reduce the threat of invasives.

Hannes Lemme, www.forestryimages.org

Female Nun moth on Scotch pine in Germany.

- ● Not yet detected
- ▼ Unknown
- ■ Nun moth *(Lymantria monacha)*
- ▲ Could cause cumulative 30-year tree losses as high as $2.5 billion if established in three cities. Most damaging forest pest in Europe.
- ◆ Early eradication with registered insecticide

John M. Randall/ The Nature Conservancy

Balsam woolly adelgid killed these Fraser fir.

- ● 1908
- ▼ Europe
- ■ Balsam woolly adelgid *(Adelges piceae)*
- ▲ Attacks most North American true fir species. Caused dramatic declines in Fraser fir in Great Smoky Mountains National Park, resulting in understory and wildlife changes.
- ◆ Use registered systemic insecticide in spring

John M. Randall/ The Nature Conservancy

Hemlock woolly adelgid disguises itself inside a cottony ball.

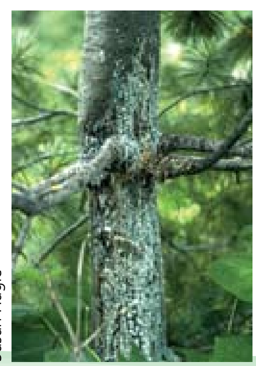
- ● 1920s
- ▼ Asia
- ■ Hemlock woolly adelgid *(Adelges tsugae)*
- ▲ Currently in more than 16 states. Contributing to the decline of eastern and Carolina hemlock. Alters bird communities and riparian ecosystems where it kills eastern and Carolina hemlock.
- ◆ Use registered systemic insecticide in spring; release predatory beetles

USDA FS archives, www.forestryimages.org

Damage to American chestnut from Chestnut blight, 1943.

- ● 1904
- ▼ Asia
- ■ Chestnut blight *(Cryphonectria parasitica)*
- ▲ Eliminated American chestnut from eastern deciduous forests. Estimated value of chestnut timber in three states in 1912 was $82.5 million. Caused decline in chestnut-dependent wildlife.
- ◆ Plant resistant chestnut

Susan Hagle



White pine blister rust on eastern white pine.

- ● Late 1800s-early 1900s
- ▼ Asia
- ■ White pine blister rust *(Cronartium ribicola)*
- ▲ Throughout the range of eastern white pine and in six western states. Killing whitebark and limber pines in western high elevation ecosystems, eliminating wildlife forage; affecting soil stability, snowmelt regulation and succession.
- ◆ Developing genetic resistance

John M. Randall

Giant reed matches its name.

- ● 1850s
- ▼ Mediterranean
- ■ Giant reed *(Arundo donax)*
- ▲ Riparian invader in nine states, including national forests in California and Arizona. Chokes waterways, generates flammable material, displaces native vegetation and wildlife like the federally endangered least Bell's vireo.
- ◆ Use integrated approach (biological, cultural, silvicultural, physical); avoid burning

KEY

- ● When First Detected in U.S.
- ▼ Origin
- ■ Invasive Species
- ▲ Ongoing and Possible Impacts
- ◆ Control Treatments


Stanislaw Kinelski, www.forestryimages.org

Adult female sirex woodwasp on Scotch pine in Poland.

- ● Not yet detected
- ▼ Eurasia
- ■ Sirex woodwasp *(Sirex noctilio)*
- ▲ Could cause cumulative 30-year tree losses of $760 million if established in three cities.
- ◆ Remove and destroy infested trees


David Cappaert, forestryimages.org

Emerald ash borer

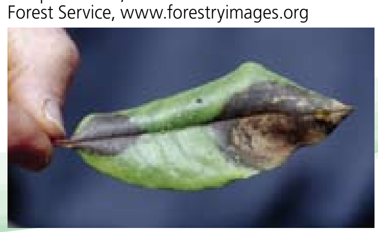
- ● 2002
- ▼ Asia
- ■ Emerald ash borer *(Agrilus planipennis)*
- ▲ Currently in Michigan, Ohio, and Indiana. Could eliminate ash as a street, shade, and forest tree nationwide.
- ◆ Remove and destroy infested trees; apply registered pesticides


Robert L. Anderson, USDA FS, www.forestpests.org

Symptoms of Dutch elm disease on American elm.

- ● 1927
- ▼ Asia
- ■ Dutch elm disease *(Ophiostoma ulmi)*
- ▲ Occurs in most states. Has killed more than 60% of elms in urban settings where the elm was a valued ornamental and shade tree.
- ◆ Plant resistant elm

Joseph O'Brien, USDA Forest Service, www.forestryimages.org

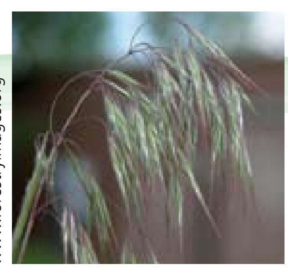

Symptoms of sudden oak death on azalea/rhododendron.

- ● 1994
- ▼ Unknown
- ■ Sudden oak death *(Phytophthora ramorum)*
- ▲ Currently in California and Oregon and spreading rapidly. Has been detected in diseased nursery stock shipped from California to 22 states. Could eliminate oak forests nationwide.
- ◆ Remove and destroy hosts; quarantine to restrict spread


Linda Haugen, USDA FS, www.forestryimages.org

Cankered stem of beech after attack of beech scale and infection.

- ● 1890 (Nova Scotia)
- ▼ Europe
- ■ Beech scale insect *(Cryptococcus fagisuga)*
- ▲ Currently from Maine to North Carolina and west to Michigan. Expected to spread throughout the range of American beech. Carrier of beech bark disease, which kills more than 75% of large trees, leaving dense beech sprouts with reduced wildlife and economic value.
- ◆ Use registered systemic insecticides


Tom Heutte, USDA FS, www.forestryimages.org

Cheatgrass

- ● Late 1800s
- ▼ Asia and South America respectively
- ■ Cheatgrass *(Bromus tectorum)* and Lehman lovegrass *(Eragrostis lehmanniana)*
- ▲ Displaces native bunchgrasses and dies early in the summer, reducing forage quality and increasing the spread and severity of fires when adjacent to forests. Particular hazard to dense western forests that are susceptible to catastrophic wildfire.
- ◆ Use integrated approach (biological, cultural, silvicultural, physical)


Hannes Lemme

European gypsy moth

- ● 1869
- ▼ Europe
- ■ European gypsy moth *(Lymantria dispar)*
- ▲ In 19 states, spot infests 12 more. Annually defoliates millions of northeastern and Midwestern forested acres; suppression costs tens of millions. Record losses in 1981: 13 million acres defoliated, $3.9 billion (1998 dollars) in losses.
- ◆ Use registered biological controls

WHO'S RESPONSIBLE FOR THE WAR ON INVASIVES?

We are all responsible for fighting invasives, but some organizations are equipped with authority, regulations, and resources to meet that responsibility. Individuals and organizations make decisions every day that determine the impacts of invasive species on U.S. forests. Table 2.1 lists their major activities and influence. Their objectives are varied and sometimes conflicting.

Some agencies have responsibility both for encouraging global trade and minimizing entrance of exotics. Obviously, this can limit their effectiveness in the war on invasives. Prevention, detection and management of invasives require multiple agency coordination, but the roles and responsibilities of agencies are not always well defined because the statutes/laws that define their responsibilities are not clear. Non-governmental organizations, like the Nature Conservancy, are joining coordination efforts at all the activity levels identified in Table 2.1.

The bottom line is that even with organizations, laws, protocols, etc., the threat of invasives is increasing. The task is complicated, and it's important to note that there always will be some uncertainties about invasives, so prevention is never 100% effective. Effective action against invasives requires flexible approaches in which forest practitioners, managers, and public agencies share a common understanding of the threat and have access to information so they can respond to the unexpected. The next page describes three strategies that can make the war on invasives more effective.

TABLE 2.1 **Groups, organizations, and government entities responsible for invasive species.**

Organization, Group, Law, etc.	Major Activity				
	International	National	Regional	State	Local
International Plant Protection Convention	T	-	-	-	-
North American Plant Protection Organization	T	-	-	-	-
Montreal Process	S	S	-	-	-
Forest Certification Programs	S	S	S	S	S
Timber and Paper Industries	S, M, C	S, M, C	S, M, C	S, M, C	S, M, C
Horticultural Industry	C	C	C	C	C
Industries involved in international trade using wood packaging materials	C	-	-	-	-
USDA Forest Service	S, M	S, M, P	S, M, P	S, M, P	S, M, P
USDA Animal & Plant Health Inspection Service	T, P	P, Q	P, Q	P, Q	-
State Agencies (forestry, natural resources, agriculture)	-	-	-	M, P, Q	M, P, Q
Private Forest Landowners	-	-	-	M	M
Local Governments	-	-	-	-	M, P

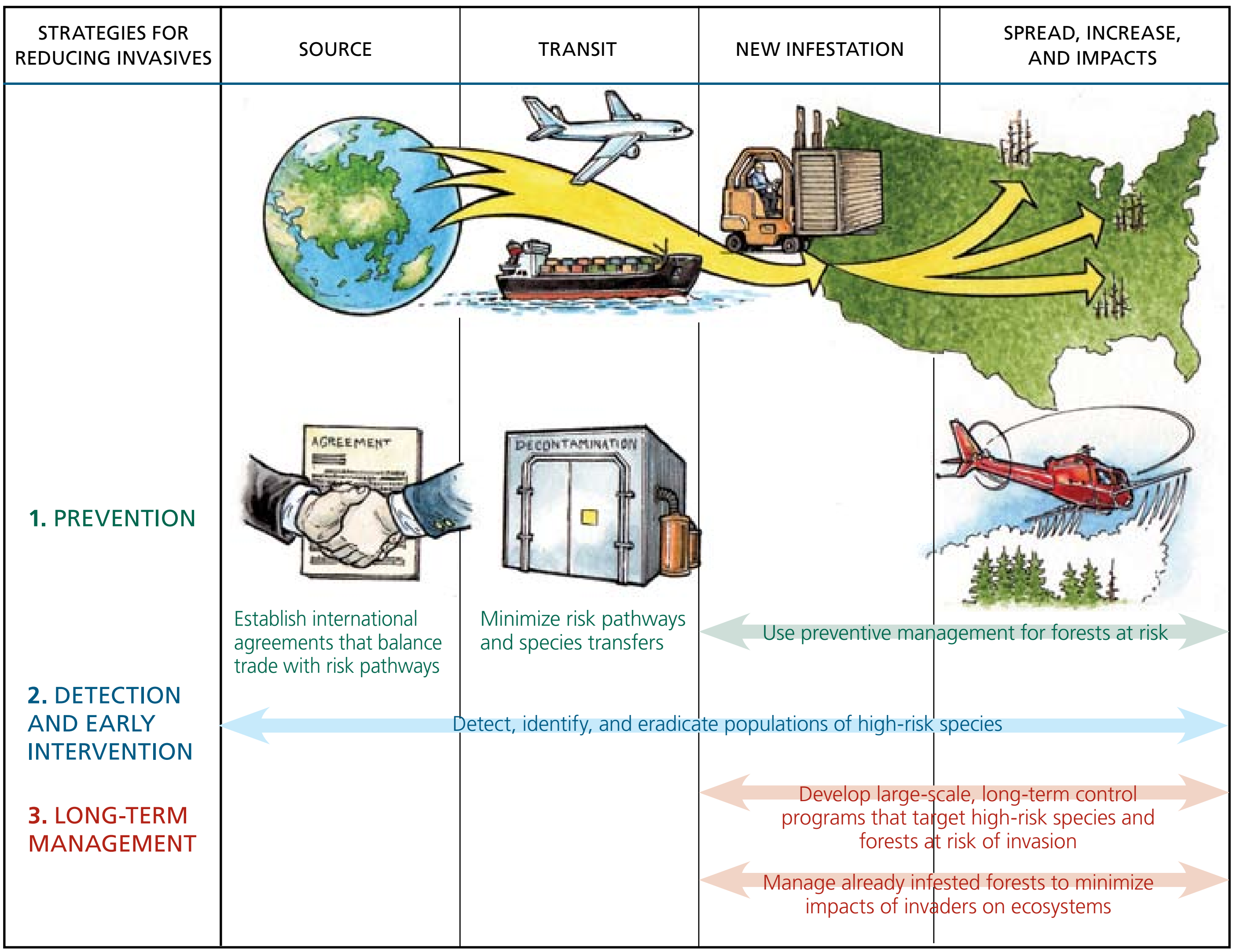
LEGEND:
- **C** responsible for commercial shipments of wood products, wood packing materials or plants that might be or become contaminated by invasive pests
- **M** responsible for forest management
- **P** responsible for implementing large-scale control programs for invasive species
- **Q** responsible for interstate regulation and quarantines of forest pests
- **S** responsible for developing sustainable forestry principles, criteria, indicators, objectives, and performance measures
- **T** responsible for international trade agreements, protocols, regulations, and quarantines
- **USDA** United States Department of Agriculture

There are three strategies to counter invasive species (Fig. 2.1).

1 identify and block pathways for introduction and spread of new invasives **(Prevention)**
2 detect and eradicate invaders that escape prevention **(Detection and Early Intervention)**
3 develop **Long-term Management** strategies for well-established invasive species.

Figure 2.1 illustrates how each strategy is linked to the source of the invasive species, their means of transportation to the United States, the location of initial infestation, and how invasives spread and impact sustainable forestry. Each strategy works to minimize not only future invasions but also the spread and impact of well-established invaders. All three strategies may be needed to control a single pest. Efforts against the European gypsy moth, for example, involve preventing introduction of the moth's Asian counterpart into the United States, detection and early eradication of spot outbreaks in new states, and long-term management aimed at containing and managing current infested areas.

FIGURE 2.1 Three strategies for reducing impacts of invasives are identified in the left column. All three are designed to minimize future invasions and the impacts and extent of already-established invaders.



WHAT CAN WE DO ABOUT INVASIVES?

The key to success against invasives is prevention, early detection and rapid response/eradication at all levels. The Weed Bounty Hunter program is a local example (see box). Effective early detection depends on better information accessible to practitioners, managers and policymakers. Knowing that, what can be done to:

- improve the link between invasive species and sustainable forestry
- provide better information resources for practitioners, forest managers, and policymakers
- provide new scientific tools
- provide better cost estimates to inform policy and management decisions
- improve prevention and management at different landscape scales (from local sites to states, regions and continents)?

How to Link Invasives with Sustainable Forestry

The Montreal Process and Forest Certification are tools being used to evaluate and document sustainable forest practices, yet they are nearly silent on the role that invasives play in affecting the outcome of forest management. For example, more than a decade ago, 12 nations, including the United States, agreed to the Montreal Process. Surprisingly, none of its indicators measure the threat to sustainable forestry posed by invasive species. In its recent report on how the Montreal Process is being implemented in the United States (National Report on Sustainable Forests – USDA FS 2004), the USDA Forest Service included no data about the economic or ecological impacts of invasive species on U.S. forests. Nor was there information comparing invasive species to other sustainable forestry threats, or any evaluation of the effectiveness of policy and management actions on invasives.

Forest certification programs, like SFI (Sustainable Forestry Initiative) and FSC (Forest Stewardship Council) can and do have influential effects on policy and management of forestland by government agencies, timber companies, and other forest owners, but they haven't addressed the subject of invasives any better than the Montreal Process. For example, measurements of invasive species in SFI or FSC assess only the extent to which participants minimize the risk of exotic tree planting and monitor and manage forests to prevent and minimize outbreaks of pests, diseases, and invasive plants and animals. Granted, this is a start, but these measurements don't reflect the magnitude of the threat of invasives on sustainable forestry.

What can be done to improve the Montreal Process and forest certification programs with respect to invasives and their threat to sustainable forestry?

First we must determine whether the correct metrics for assessing the threat of invasive species have been identified and whether they adequately measure the participants' implementation of the three strategies (described in Fig 2.1).

This should be done through the internal review process of the Montreal Process and certification programs. It should include scientists and technical experts.

The ultimate goal should be to track whether participants:

- eliminate pathways that spread invasive species
- manage forests in ways that reduce new invasions including minimizing ground disturbance that opens new areas to invasion
- monitor to detect new invasions and implement rapid response measures
- suppress established invaders by participating in large scale monitoring and management efforts
- consider how eradication strategies will affect other aspects of forest ecosystems and sustainability.

At a minimum, reporting should track the social, economic, and ecological impacts of invasive species.

How to Build Better Information Resources

Table 2.1 identifies the people and organizations involved in decisions about invasive species in the United States. Unfortunately, there's no information infrastructure to enable policymakers to make consistently informed choices. Yes, there are online databases and information sources, but the invasives information system is incomplete and fragmented, and access to and analyses of the data are weak. Global invasive-species databases are no better. Most databases are not widely used by the private landowners and local governments that own more than half of U.S. forestlands. Detailed information on the distribution and impacts of some of the most devastating forest invaders is

Weed Bounty Hunters – Warring Against Invasives at the Local Level – An Example

Where: Lower Grande Ronde River, Wallowa County, Oregon

Who: Wallowa Resources, formed in 1996, is a non-profit organization designed to bring people together and blend the ecological needs of the land with the economic needs of the community. (www.wallowaresources.org)

What: The Lower Grande Ronde River Watershed is at a high risk of degradation from noxious weeds partly due to its mixed ownership pattern (Bureau of Land Management, United States Forest Service, Private Ranches) and the fact that it is divided between two states, four counties, and two national forests. Three major target weeds include: Meadow Hawkweed, Rush Skeletonweed and Leafy Spurge.

Short-term priorities:

- ▲ coordinate and implement integrated weed management treatment projects across jurisdictional boundaries for high priority weeds along the river corridor
- ▲ inventory and map target weeds across the watershed
- ▲ private landowners along the river corridor are invited to participate but must pay for part of the costs of control efforts.

Long-term priorities:

- ▲ coordinate weed treatment across all properties in the watershed and provide "seamless treatment" of noxious weeds
- ▲ all stakeholders participating in design and treatment, contributing to costs with either financial contributions or in-kind service.

Invasive weed treatments include:

- ▲ physical, chemical, biological and cultural methods of control as well revegetation of treated areas
- ▲ exploring new techniques.

Bounty Hunter Program:

Anyone finding a "new" invasive weed site within the watershed can win $200. Maps are provided on the website to help hunters find areas that need searching. Access to private land requires permission. Tips are provided for identification, best time of year to search and how to handle noxious weeds safely.

Program Expansion:

The Wallowa Canyon Lands Partnership has been formed and addresses noxious weed issues in both the Grande Ronde and the Imnaha River Watersheds.

Mark Porter

FIGURE 2.2 **Bounty hunters located this Scotch thistle *(Onopordum acanthium L.)* infestation and Oregon Youth Conservation Corps members disposed of it. Native to Europe and eastern Asia, this aggressive plant can form dense stands, impenetrable to livestock.**

not readily available. There are no anticipatory systems for preventive action that would routinely identify emerging pathways, probable new invaders, or ecosystems vulnerable to future invasions. What's needed is baseline information about what exotics are in our forests, where they are, their rate of spread, and the size of their population.

What's available?

- The USDA Forest Service Forest Inventory and Analysis (FIA) database is a grid of inventory plots across all the forests of a state. It reports on habitat and how invasive species host trees are distributed across the landscape. This database would be more useful for identifying areas at risk of invasion if it included more information on alternative hosts (e.g., understory plants) and better links to sites with climate, soils, and high-risk locations (e.g., where host plants are sold in nurseries or bought by timber companies).
- The USDA Port Interception Network (PIN) identifies port interceptions. At present, PIN includes only pests of "quarantine significance" rather than all intercepted species, and access to PIN is restricted. It could be used to identify high-risk pathways by comparing the initial occurrence of a known forest pest with variables that affect pathways, such as the volume of trade, type of commodity, or shipping and packing materials.
- Both the National Agricultural Pest Information System (NAPIS) and the Exotic Forest Pest Information System for North America (EXFOR), report on established invasive species.
- Other databases and links to policy and management tools include web sites maintained by the National Invasive Species Council, the National Biological Information Infrastructure, the Plant Conservation Alliance, the Nature Conservancy, the USDA Natural Resources Conservation Service, the Environmental Law Institute, and the Global Invasive Species Program.

Even with the growth of online information sources, this information still needs to be translated into actionable knowledge. What's missing is a coordinated reporting system that could speed public and private responses to growing invasive threats. A solution is a national clearinghouse that allows state agencies, tree-care companies, forest managers, landowners, and others to voluntarily report verified sightings of invasives.

New Scientific Tools and Concepts

Unfortunately, it's not always easy to identify an invasive species. Physical characteristics can be subtle and difficult for non-specialists to distinguish. Taxonomy information is not always complete for pathogens and insects. Pathogen identification is more difficult if the pathogen causes different symptoms on various hosts or mimics symptoms identical to those caused by other pathogens (i.e., SOD). Identification of invasive insects and plants often depends on catching larvae or collecting seeds and spores that don't have the distinguishing features of later life stages.

Scientific tools from molecular biology, biotechnology, and digital imaging that hold promise for new and easier ways to detect and identify invasive species include:

- DNA/RNA technologies that can detect plant pathogens in nursery stock could be used to assay for known pathogens of particular hosts at ports of entry during pre-shipment certification.
- A microchip that can screen samples for the presence of 250 potato pathogens is being tested in the United Kingdom.
- DNA microprobes have potential to identify insect larval stages and eggs found within cargo and packing materials.
- Expert systems that automate risk identification at ports of entry could improve import screening. Such a system could integrate data on imports (e.g., product records, receiving ports, containerized freight destinations) with United States habitat distribution (e.g., climate, soils, forest types), and pest distributions in originating countries. This could automatically target inspections toward commodities or other vectors known to harbor high-risk species or those that come from countries that previously were sources of contaminated cargo.

Tracking the advance or retreat of invasives across large areas is another difficult problem. The information must be comprehensive yet sensitive, and it must be collected frequently enough to encounter small populations of invaders when they're easier to eradicate. It's possible that remote sensing, which includes techniques from aerial photography to satellite imagery, could be used to identify the distribution or impacts of invasive pathogens, insects and plants. For example, the pattern of defoliation, crown dieback, and tree mortality, as detected by remote sensing, can help monitor certain invasive species. This kind of analysis can pinpoint high-risk locations that can be confirmed by ground surveys. Digital "sketch mapping" techniques are being tested that provide aerial survey results within days after aerial flights rather than waiting for weeks.

Invasive species can alter ecosystem processes, so they must be better integrated into the concept of ecosystem management. We know that spatial patterns of physical and biological processes across forests can impede or promote species invasions and could be managed to reduce invasion risks. Here are some examples:

- ▲ Roads, railways, vehicles, and foot traffic provide pathways for the spread of pests.
- ▲ Contiguous populations of host plants and alternative hosts can enhance the spread of invasive pathogens and insects.
- ▲ Adjacent land uses, the size of habitat fragments, and the edge-to-interior ratio of forests all affect invasions (described in Chapter 3).
- ▲ Disturbances can open up habitat for invaders or disrupt their dispersal.
- ▲ Fire suppression can intensify pathogen outbreaks by altering stand dynamics.
- ▲ Severe wildfires after years of fire suppression can help spread invasive plants.
- ▲ Silvicultural practices affect vulnerability to and recovery from pathogens and insects, as well as the relative abundance of non-native understory plants.
- ▲ Some invasive species alter fire frequency, hydrology, and other ecosystem processes in ways that may favor further invasions by the same species or others.

We need to take what we know about how landscape structure and ecosystem condition affect invasions and use it in management prescriptions. They can be tested and improved through adaptive management (a process where research results are continually brought forward and management practices are continually reassessed as new information becomes available, see Chapter 8). The objective should be to eliminate invasion pathways and minimize impacts where invasives are established. We should examine forest management practices such as patterns of timber harvest and thinning, fire suppression and burn frequency, revegetation after disturbance, road building, and hunting and recreational uses, as well as natural disturbance regimes. Possible mitigation approaches should be identified. For example, we need to know whether closing logging roads after harvest reduces invasion risks or whether interplanting different species or establishing buffers can slow the spread of host-specific invaders.

How to Improve Invasive Cost Estimates

Although existing information about past and projected costs generated by species invasions in U.S. forests is inadequate, we know that such information has affected policy when it was available. For example, it was used to justify the Animal and Health Inspection Service's rules for treatment of solid wood packing materials.

We need better cost-benefit or cost-effectiveness analyses of past and projected costs of species invasions. That would strengthen decisions by legislators and agencies and help weigh alternative policy and management actions. But quantitative information should go beyond timber losses and pest suppression expenses. It should include non-market environmental and social values that may be degraded by invasives, such as watershed protection, biodiversity, aesthetic, and other amenity values. This won't be easy. Even with good information on environmental impacts, economic techniques that assign dollar values to non-market goods and services are costly and controversial. It's easier to estimate values for human health and aesthetic protection than for carbon sequestration or climate regulation. And it's also tough to justify expenditures today for invasive species, when the benefits may not accrue until some future time. The fact is that the benefits from avoiding harm by preventing or controlling invasives often come decades later.

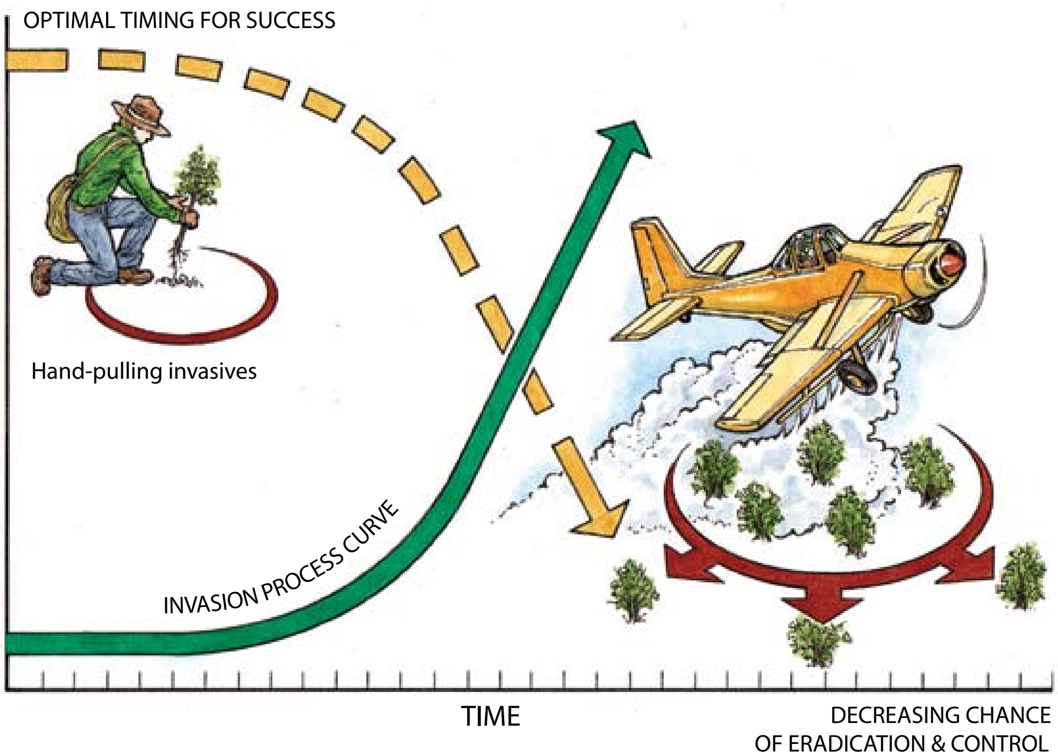


FIGURE 2.3 **As an infestation becomes larger and the invasion curve begins to peak, more aggressive treatment techniques are needed. Most invasives persist at low densities before their rapid expansion. Those small, dispersed populations are difficult to detect. Often their economic and environmental impact is uncertain. Government agencies are unable to step in and regulate their movement, and forest managers may be unwilling to implement eradication programs. But this is the most effective time for quarantines, eradication, and control.**

Better cost and benefit estimates would also improve pest suppression programs. The speed with which decisions are made and management actions are taken during a biological invasion greatly influence effectiveness; yet invasive species can confuse timely decisions as shown in Figure 2.3.

Rapid-response decision rules could help resolve the dilemma illustrated in Figure 2.3 by providing standard procedures for agencies to follow in times of emergency. At present, agencies develop assessment methods for each new situation, and that takes time. Decision rules would provide a clear rationale for efforts to fund rapid responses. Such rules would assess the risks of a new species invasion, the potential costs and benefits of responding at different points along the invasion process curve (Figure 2.3), and the best time to switch from eradication to suppression. Scenario analysis is one approach to making decisions even when uncertainty is great. It examines the cost-effectiveness of early eradication under various risk scenarios and sets a threshold risk level that triggers rapid action.

How to Prevent and Manage Invasives at Various Landscape Scales

Spatial computer models offer another approach for understanding how landscape structure affects invasions. Time-series scenarios of the spread of gypsy moths under various management strategies now guide multistate gypsy moth suppression and could be applied to other large-scale invasives programs. If we integrate better cost estimates with spatial population models, we could optimize control strategies by distributing resources where and when a species is most invasive and harmful, the treatment costs are lowest, or the chances of success are highest.

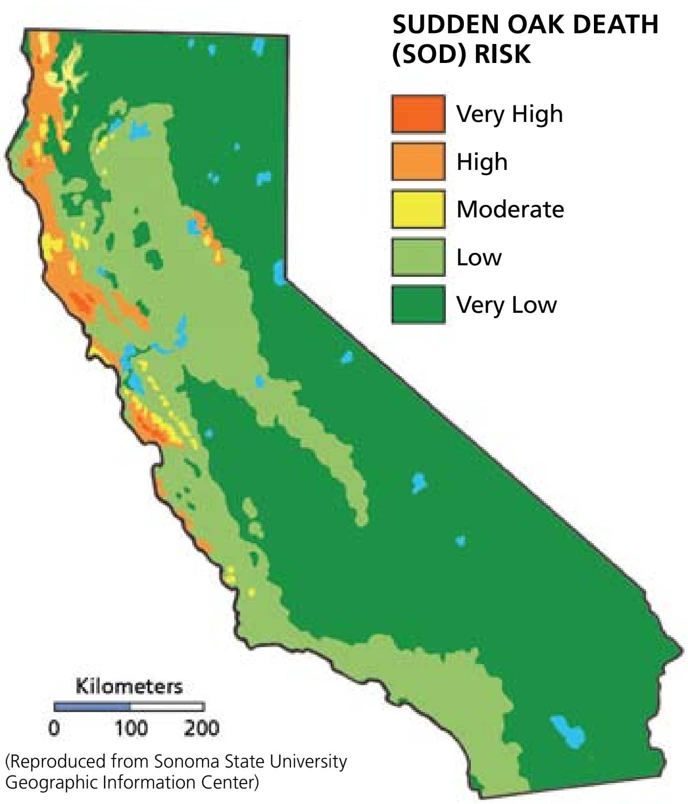


FIGURE 2.4 **SOD risk of establishment and spread in California based on climate variables and distribution of host plant species.**

Ultimately, effective management of invasive species across large forested areas will require participation by landowners and managers with different goals, cultures, and reasons for their actions. The more we know about this variation, the more it could help develop processes, incentives, or policies that encourage cooperation and accept and adopt necessary control technologies. Techniques like GIS predictive mapping could help landowners understand the susceptibility of their property to invasive species. The map of sudden oak death (SOD) in California is an example (Figure 2.4). It predicts the risk of establishment and spread of the SOD pathogen and raises awareness about risks in currently non-infested areas.

SUMMARY

In the long run, invasives are one of the biggest threats to the integrity of forest ecosystems. In a world where non-native invasive species are jumping bio-geographic barriers, we need new approaches to identifying and blocking invasion pathways and to detecting emerging invasive populations early and eradicating them rapidly. We need greater ability to intervene and manage over the long-term. We have identified better tools for tackling invasive species at large spatial scales, and we need to use them aggressively. We need to translate online information sources into actionable knowledge. Action that responds to the priorities identified in this chapter should benefit sustainable forestry and reduce harmful impacts of invasive species.

To Learn More About This Topic, See Appendix, page 167.

CHAPTER 3

FRAGMENTATION AND BIODIVERSITY

Why is this subject important?

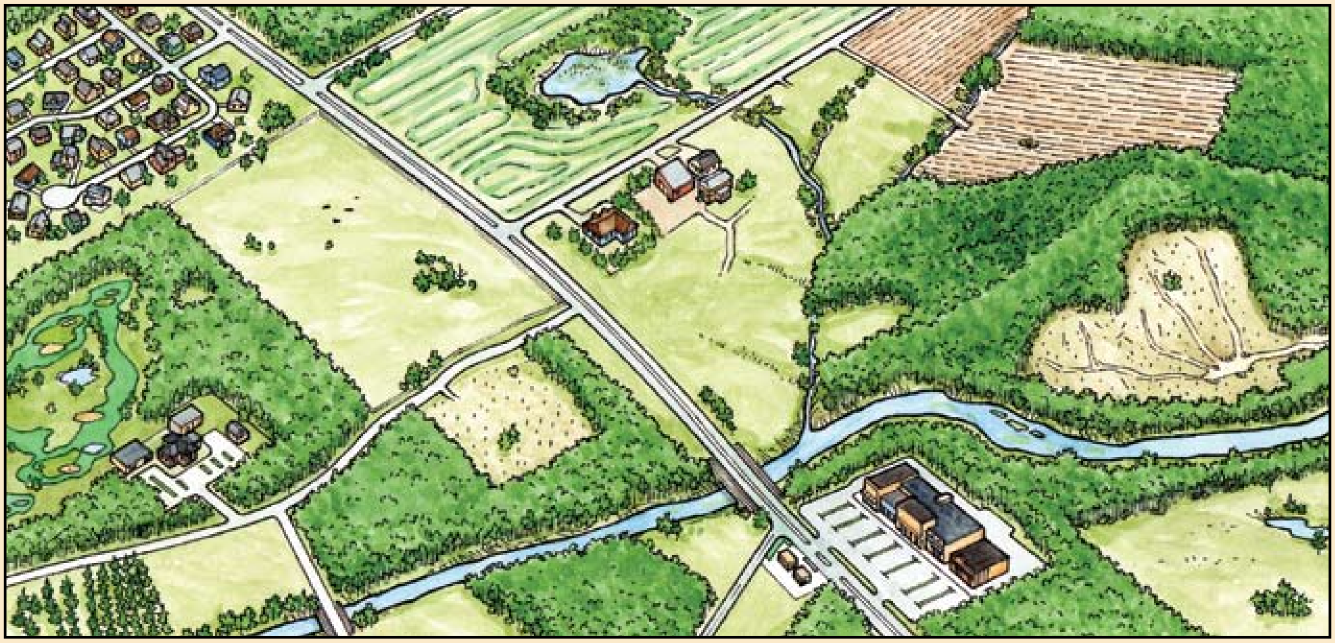


FIGURE 3.1 **From a landscape view, the fragmented pattern is a mix of forest patches and matrix. The matrix might be recently logged areas, early-succession habitats, aquatic and riparian habitats, corridors and other land uses such as agriculture, highways and development.**

WHY IS THIS SUBJECT IS IMPORTANT?

While most of us see the forest from ground level or watch it go by from the seat of a vehicle, it might be easier for us to understand forest fragmentation if our everyday view was from above, because fragmentation is a landscape phenomenon. It changes large contiguous areas of relatively homogenous forest into a mosaic of undisturbed forest "patches" and a "matrix" of disturbed lands. With a bird's-eye view of the landscape, we'd see a pattern of patches and matrix (Figure 3.1), a landscape of older forests next to younger forests next to no forest at all. Fragmentation science is all about the size and spatial arrangement of habitat patches, characteristics of the disturbed matrix lands, and the effects of that change on biodiversity and ecological processes and functions.

Simply stated, forest fragmentation is the conversion of a continuously forested landscape into isolated patches of forest. Two things are clear from this definition. First, fragmentation is about landscapes on large spatial scales, and second, the visible results of fragmentation are changes in the pattern of forests across a landscape. We'll define and describe these elements in more detail below, but it's important to recognize that while fragmentation is the result of both historical and contemporary land use, it's not just a phenomenon influenced by humans. Avalanches, fires, hurricanes, and other natural disturbances (described in Chapter 1) also contribute to forest fragmentation. However, there's a difference between human- and naturally-caused fragmentation. Human actions often are more frequent, less random, and more permanent than natural disturbances.

Today, land-use conversion or "forest loss" contributes to increasingly fragmented forest landscapes, leaving patches adjacent to or surrounded by houses, highways, parking lots, and shopping malls. This points to a distinction between fragmentation associated with forest loss and fragmentation associated with forest harvest and regeneration. Forest loss often leaves remaining habitats indefinitely degraded within a matrix that has little value to forest species. On the other hand, forest harvesting may result in a temporary reduction in habitat for species that rely on mature forests while creating new habitat for species that rely on young, early-succession forests. Differences between harvested matrix lands and undisturbed patches gradually become less pronounced over time through the processes of regeneration, growth, and succession.

Forest fragmentation is an important environmental issue. It was identified in the Montreal Process as an indicator of biodiversity (Chapter 5, page 115). The developers of the Montreal Process recognized the importance of fragmentation and separated it from other biological diversity measurements such as forest extent and protected status. They saw a relationship between biodiversity, fragmentation, and ecological processes. National assessment reports *(The 2000 RPA Assessment* *of Forest and Range Lands, The State of the Nation's Ecosystems, and The United States Roundtable on Sustainable Forests)* all cite the relationship between biological diversity and landscape structure in fragmented forests. All of these assessments support the notion that the composition, extent, and layout of land cover have the potential to affect forest ecosystem goods and services.

Given the international and national recognition of fragmentation, it was surprising when an NCSSF survey revealed that forest owners don't share these views. Survey respondents never mentioned fragmentation when describing their use of biodiversity indicators (Chapter 5, Page 116). We can only speculate about why it wasn't mentioned, but one reason might be perspective – we're not accustomed to a fly-over view of forest landscapes. However, that limitation is quickly becoming a thing of the past with remote sensing and geographic information systems (GIS), tools that help us see patterns of fragmentation and better understand its effects. As we'll learn in this chapter, another reason may be that fragmentation science has limitations. It's based on theory, established long-standing theory, but theory nevertheless. It's also based on spatial models (e.g., GIS, paper maps, relationships described in mathematical equations, and diagrams) that sometimes make it difficult to see practical implications. True, there is scientific field evidence, but because designing fragmentation experiments is complicated, the results of those experiments have had limited application to on-the-ground situations.

For these reasons, the Commission sponsored a comprehensive review of fragmentation science and what is known and not known about its effect on biodiversity. The review described current efforts to assess the effects of fragmentation, identified information gaps, and provided some practical implications for its use in forest management. But there is a caution. As you will see in this chapter, the impact of fragmentation on biodiversity depends on what particular plant or animal species we are concerned about, how it moves across the landscape, and the degree to which the landscape is fragmented. Despite our understanding of its process, theoretical underpinnings, and effects, we still don't know the thresholds at which landscape-scale movements of plants and animals become inhibited by fragmentation. However, what we do know should encourage all practitioners, landowners, managers, and policymakers to be aware of its effects.

WHAT DO WE KNOW ABOUT FOREST FRAGMENTATION AND BIODIVERSITY?

This is merely an introduction. Even the NCSSF report that provides the basis of this chapter is just a start. We briefly review the process of fragmentation, the underlying theories, and its effects on landscape pattern, biodiversity, and ecological processes. Because fragmentation science is the study of habitat alteration (either through forest loss or harvest/regeneration) and the isolation of forest patches, it asks these kinds of questions:

- What are the effects of fragmentation on plant and animal species?
- Can plants and animals survive fragmentation?
- What are the effects of fragmentation on other forest functions and ecosystem services?

Before describing those effects, let's look briefly at the origins of this science and its process, because both provide insight into how our understanding of fragmentation has developed over time.

As early as the 1950s, scientists were raising concerns about how human actions were altering landscape patterns and leading to species extirpations and extinctions. A study in 1956 drew attention to the spatial aspects of fragmentation by showing changes in forest cover in Cadiz Township in southern Wisconsin from 1831-1950, roughly corresponding to the time of European settlement (Figure 3.2). The study documented the **process** of fragmentation, which begins with **dissection** and **perforation** of forest cover (1882 map), proceeds to **fragmentation** of forest patches (1902 map), and finally results in **attrition**, where remaining patches shrink in size and become more isolated (1950 map). This process of shrinking size and changes in the spatial relationship of forest patches to one another (distance between patches) is described next.

What do we know about forest fragmentation and biodiversity?

FIGURE 3.2 **A 1956 study by Curtis of Cadiz Township, Wisconsin, is a classic but not unique example of deforestation and forest loss to agriculture and development. In 1831, essentially the entire township (23,040 acres/9324 ha) was forested. By 1882, many forest patches were still intact (half the township). By 1902 there were fewer, smaller, and more widely separated patches. By 1950, only 55 small, scattered patches of forest remained.**

We'll use the Cadiz Township study to describe the stages in the process.

Dissection is a beginning stage. Early forest management activities, agricultural development, or human settlement can contribute. Dissection can start with building a road, trail, or power transmission line into a landscape. Fragmentation science is interested in the extent to which these activities block the movement of plant and animal species. For example, consider a highway with a high concrete curb or lane dividers. They may stop less mobile animals like turtles and amphibians, while other animals such as small mammals and ground beetles are able to cross the highway, but may be unwilling or are subject to high mortality. Dissection usually acts as a filter, meaning that some individuals cannot or will not cross, but others do. A road might stop a mature turkey from leaving its home range, but at the same time be no problem for a young turkey intent on dispersing into new territory (more about barriers, filters, and dispersal below).

Perforation is the next stage. It usually includes converting part of the landscape into agricultural lands and/or settlements (essentially forest loss as shown in the 1882 map of Cadiz township). These openings may not be large enough to act as barriers to species movement, because most species can migrate around them if they can't cross them directly. The most significant effect of perforation is the creation of edges (areas where ecosystems come together). We'll pick up on the subject of edges below, and we'll see that they can have an effect on things like bird nesting success and increased predation of reptiles and small mammals.

Fragmentation follows. As perforations and dissections grow larger and extend further, they coalesce, leaving forest patches isolated from one another. At this stage the definition of fragmentation becomes a reality (1902 map). A fragmented landscape can restrict animal migration, especially non-flying animals. Problems begin to appear in the smaller isolated populations of plants and animals left in the remaining patches (discussed in more detail in the metapopulation section below).

Attrition picks up where fragmentation leaves off. In this stage, more patches are disturbed, and the remaining patches become smaller and more distant from one another (1950 map). At this point in the process, connections (corridors) between patches are cut off with increasing effects on the viability of plant and animal populations. Attrition is most likely to occur with very extensive agriculture and urban-suburban development. Plant and animal populations occupying the small, isolated patches are more likely to become extinct, and it's difficult for them to emigrate and recolonize other patches due to distance.

From this brief look at the stages of fragmentation, two major effects of the process are clear. There's a reduction in the total area of forest (referred to as sample and area effects and described below) and increased isolation and distance between the remaining forest patches (referred to as isolation and edge effects and described below).

As ecological concerns about the effects of fragmentation grew during the mid- to late-twentieth century, scientists explained its effects by borrowing from the theories of island biogeography, metapopulations, and source-sink dynamics. These theories became the basis for establishing nature reserves designed to maximize species diversity and protect critical habitat for endangered species. Next we'll review these theories and their contribution to the science of fragmentation.

What is Island Biogeography Theory?

This theory says that the number of species living on an oceanic island is a function of island size and isolation. Large islands near the mainland maintain the greatest number of species due to their size and proximity to colonization (immigration) sources. There's less chance of extinction and greater chance the habitat is heterogeneous (variable over space and time). In contrast, small, isolated islands have the fewest species due to their distance from other islands. Here there's greater chance of extinction and less chance of arrival of potential immigrant species.

Scientists applied island theory to terrestrial landscapes and drew parallels between islands and fragmented terrestrial forest patches. The idea that species richness (the number of species present in an area) varied with the amount of area was already a well-established scientific principle. However, the importance of patch isolation and especially the quantification of connectivity to a potential colonizing source population was a new concept. As mentioned, island biogeography principles were used in designing nature reserves to protect critical habitat for endangered species. The goal was to maximize species diversity, and the thought was that biodiversity would be highest in larger, less isolated reserves.

The application of island biogeography theory to terrestrial habitats requires stepping back from the idea of discrete habitat islands surrounded by unsuitable matrix (like an island surrounded by water) and recognizing that matrix lands can take on a variety of forms, contain a range of habitat qualities, and change over time through plant succession and changing land uses. However, the basic tenets of island theory remained relevant while attention turned more toward the role of matrix lands (as we'll see below). Fragmentation science began to focus more on habitat quality, not only in patches, but also in surrounding matrix ecosystems. Spatial structure in matrix lands was recognized as having a critical part in the movement of genes, individuals, populations, and communities. Theories associated with metapopulations and source-sink dynamics (described next) and models of population dynamics and the role of corridors for connecting fragmented landscapes have all grown directly out of the concept of isolation that was central to island biogeography theory. Another consequence has been interest in landscape metrics – measurements that capture not only area effects but also isolation effects in fragmented landscapes (described later).

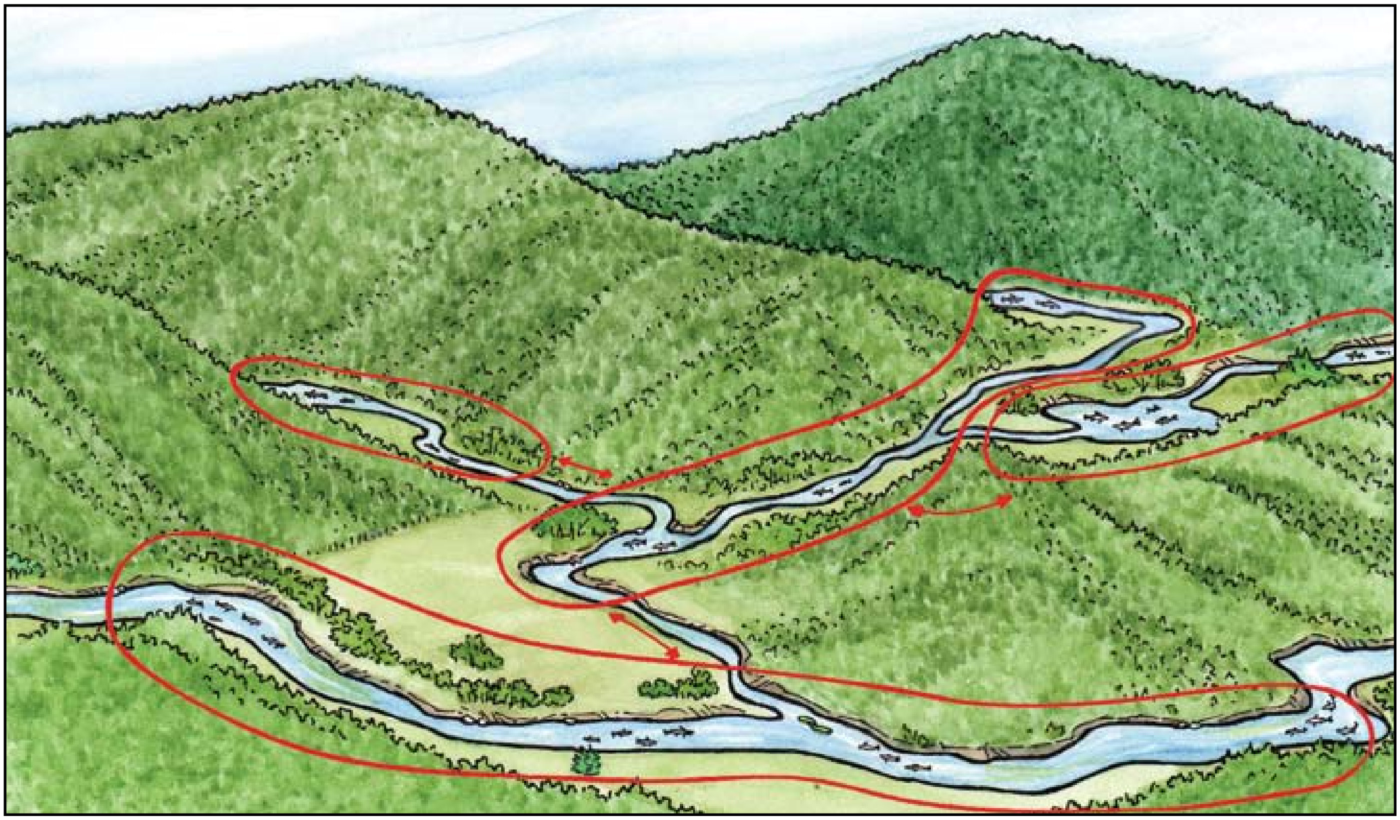


FIGURE 3.3 PART 1 Part 1 is an unfragmented landscape with four subpopulations of fish outlined.

What are Metapopulations and Source-sink Dynamics?

Metapopulation theory helps us understand the effects of fragmentation on plant and animal populations. The concept has to do with interactions among populations; for example the movement of plants and animals within and between forest patches and across the matrix. Figure 3.3 depicts a metapopulation of freshwater fish. Part 1 shows an unfragmented landscape and Part 2 a fragmented landscape.

In the unfragmented landscape (Part 1), four subpopulations of the same fish species are outlined. Taken together, these four subpopulations make up a metapopulation (a population of populations) that exists at a larger spatial scale. So a metapopulation consists of subpopulations of a species, linked to one another by migration.

In Part 2, altered by land uses (dams, roads, logging, bridges and culverts), the subpopulations have become more or less isolated from one another and interbreeding is more restricted. Some subpopulations are more restricted than others in their ability to disperse and migrate into other areas. Under these circumstances there's a possibility that one or more of the isolated subpopulations could become extinct over time due to the loss of genetic variation, demographic change, or environmental fluctuations, all of which become more important as subpopulation size decreases. From this theory, it's apparent that there is a relationship between fragmentation, habitat loss, and the potential for population extinction.

Now let's add the concept of source-sink dynamics to Figure 3.3. Consider the subpopulation in the upper left corner of Part 1. It's possible that this is poor quality habitat and the population cannot be maintained without immigration from nearby populations. If a dam prevents immigration, this subpopulation may disappear. The potential for recolonization is based on the size and suitability of neighboring subpopulations, as well as the distance (isolation) from potential emigrating subpopulations. In the theory of source-sink dynamics, a **source** is a population in which births exceed deaths and emigration exceeds immigration. A source area is a net exporter of individuals. Individuals emigrate from a source to neighboring areas with no or lower populations and more resources. Conversely, **sinks** are habitats in which deaths exceed births and immigration exceeds emigration. Habitat quality in a sink area is so poor that its population will become extinct if it does not receive new individuals from outside the area. Source populations serve as a rescue effect to sink populations, and in the absence of immigration, sink populations disappear. In Part 2, a land-use barrier (a dam) isolates that upper left subpopulation, creating a sink area without a source, where subpopulations can become extinct. Part 2 also illustrates other fragmentation examples with the potential to impact the overall metapopulation.

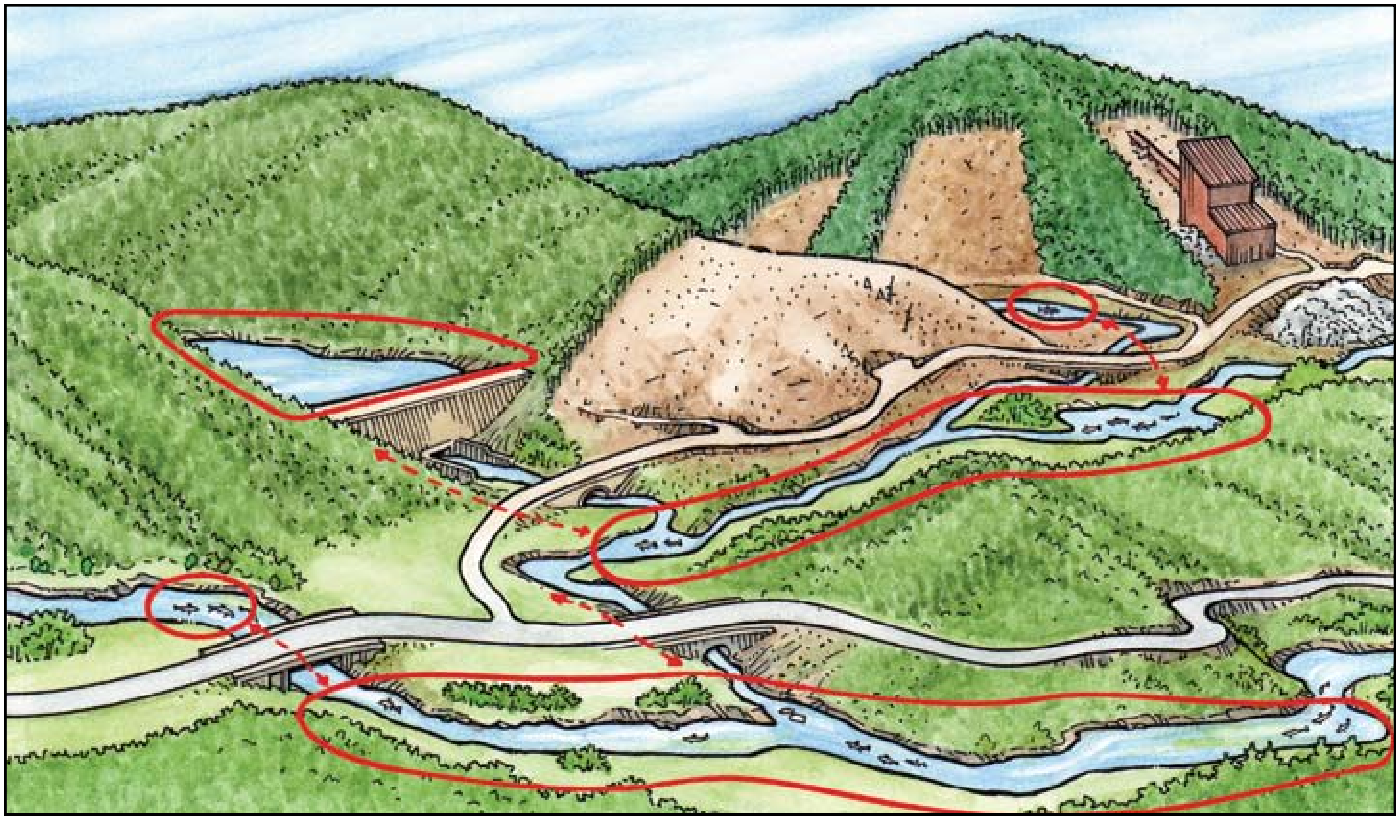


FIGURE 3.3 PART 2 **Part 2 shows the same subpopulations, isolated by various land uses.**

From this example we see that fragmentation can result in small, isolated populations that may be more vulnerable to random natural events that can reduce their viability over time. There are dispersal mechanisms that encourage the movement of individuals into new areas. If connections are maintained among subpopulations, and individuals are able to disperse between them, the probability that metapopulations remain intact over time increases. One way to help the dispersal of less mobile species in a landscape is to ensure a network of suitable areas and corridors (more about this below).

There are two important points about metapopulation theory and source-sink dynamics. The first is that the definition of an area as a source or sink is both temporally and spatially scale dependent. Second, just like island biogeography, source-sink dynamics and metapopulation theory in general fails to fully consider differences in matrix habitat. There is a difference between suitable matrix habitat that provides some, but not all the needs, unsuitable matrix habitat that may simply slow plant and animal movement, and matrix habitat that acts as a complete barrier – essentially non-habitat. While early ecological research focused on species in patches, later evidence has shown that more focus is needed on processes in the intervening matrix (more about this below).

What are the Primary Effects of Fragmentation on Biodiversity?

Based on the principles of island biogeography, metapopulation models, and source-sink dynamics, scientists have identified four major effects of forest fragmentation on the loss of biodiversity. We will describe them within the context of forest management activities in contrast to other land uses that result in forest loss. The effects are associated with landscape patterns and are referred to as sample effects, area effects, isolation effects and edge effects.

Sample effects

When a forest is cut (Figure 3.4), most of the individual plants in the cut area are lost and the animal habitat is changed. The plant and animal populations in the uncut patches are only a "sample" of the original populations. They may not represent the pre-cut populations in numbers, genetic diversity, density, age, or distribution of structure. The sample populations may also lack interactions such as predation, competition, and mutualism (when two or more species benefit in growth rate and population size by their association).

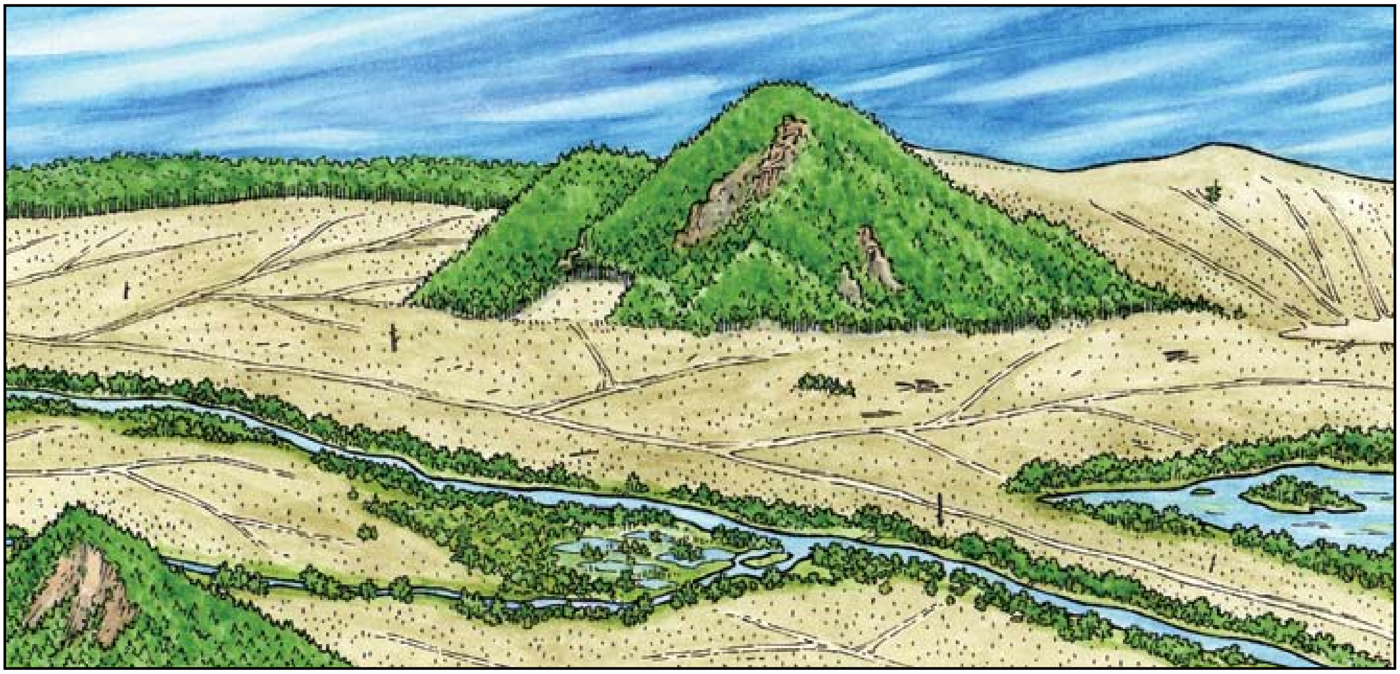


FIGURE 3.4 **The sample effects of fragmentation. After a timber harvest, a "sample" of the original populations remains, often in steep inaccessible areas, riparian areas and wetlands.**

Area effects

The area of patches affects population size, variety of habitat, natural disturbances, and species interactions in the following ways:

- A reduction in habitat area leads to smaller populations, which may be vulnerable to extinction. According to island biogeography theory, species extinction rates are higher on small islands (Figure 3.5).
- A reduction in the variety of patch habitat results in fewer species. According to island biogeography and metapopulation theory, the area of a patch affects its recolonization because recolonizing species can locate larger patches more easily (right patch versus left in Figure 3.5). Patch size may also affect the presence of large mammals and some birds, which may require larger patches for grazing, nesting, and mating. If the patch size cannot support their needs, it may not serve as a vector to other patches.
- Patch size and shape may also affect wind disturbances; smaller patches with certain orientations will have less drag on wind that may more easily loft seeds above and away, increasing dispersal.
- The patch area can affect the type, extent, frequency, and even intensity of natural disturbances. For example, small areas may be more subject to wind destruction or altered disturbance regimes that affect the biodiversity of species. Small fragments may be more likely to completely burn if fires occur. They may lack predators to control herbivore outbreaks, and they tend to be less productive.
- Reductions in forest area affect species interactions, especially trophic (food chain position) effects. For example, species at higher trophic levels, such as top carnivores, tend to require more area. A large carnivore must cover a larger fragmented territory to capture its prey. If the sample effect (described above) leaves top carnivores on small patches, they are likely to become locally extinct if those patches are too isolated to allow for inter-patch movement. Competition is also affected. For example, some species may be released from natural competition by the local extinctions of other species.

Isolation effects

The isolation of forest patches has several important effects:

- Animals can be more vulnerable as they move among patches. As a habitat becomes fragmented, patches can become separated by relatively inhospitable terrain. Wildlife attempting to cross between patches becomes vulnerable to predators, harsh environmental conditions, or starvation.
- The immigration rate (rate at which plants or animals move) will be lower to an isolated patch than to an equal patch of the same size that is surrounded by contiguous similar habitat.
- The degree of isolation of a patch depends on the distance to nearby patches and how seriously the matrix habitat restricts movement. Some species in a patch surrounded by homogenous habitat must be maintained by continual immigration. More isolated patches will have less immigration and their populations may have a greater risk of extinction.

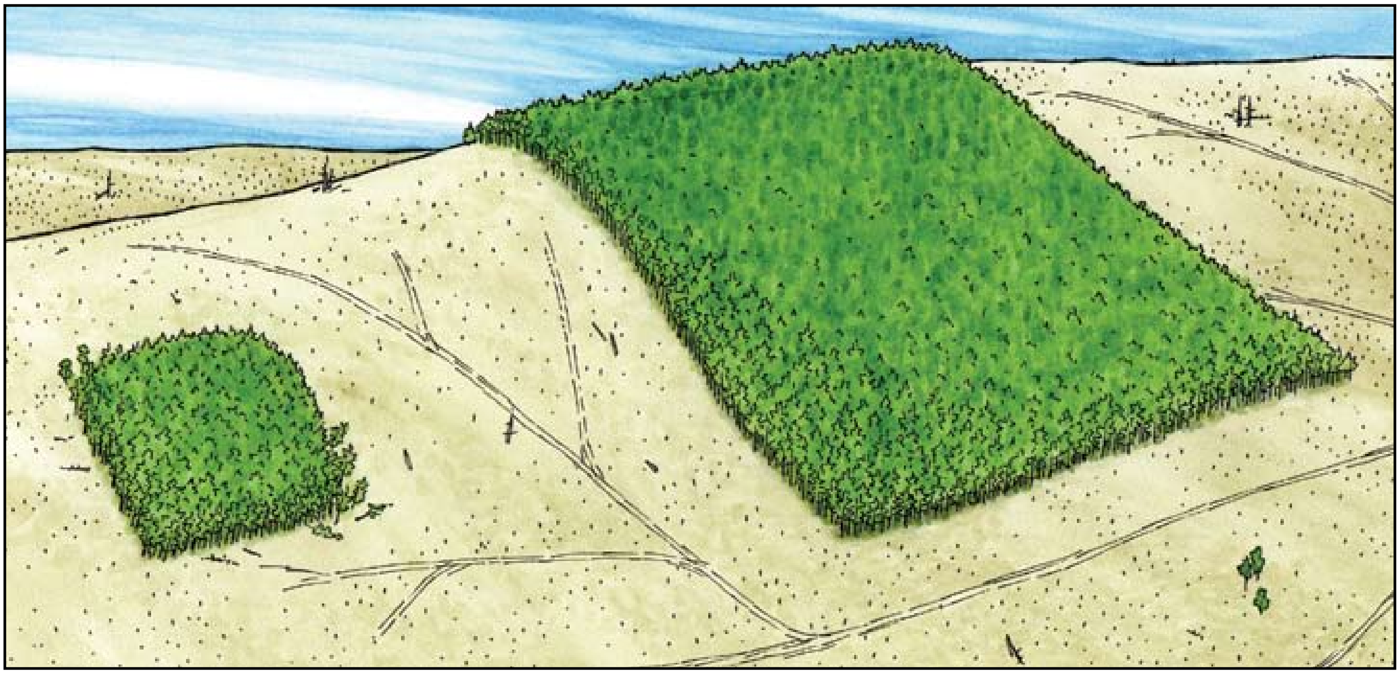


FIGURE 3.5 **The area effects of fragmentation. Two patches remain, one large the other small.**

- Corridors (connections between patches, such as the riparian areas in Figure 3.4) are thought to be beneficial for reducing isolation and maintaining biodiversity (more on corridors below).
- Isolation also affects disturbance regimes. For example, isolation from fire or pests can protect a patch population and lower the disturbance frequency by reducing the number of times a disturbance that begins in another area spreads to the isolated remnant. Isolation can also affect recovery after a disturbance by limiting the recolonization of a patch.
- Isolation effects may alter interaction among species. For example, species that could interact because they were previously in a contiguous area may no longer be able to do so because of isolation. Individuals may be in a patch without a primary predator or competitor. The extent to which these changes in interaction occur may result in some local extinctions.

The photo captions at right describe examples of isolation effects.

Edge effects

Fragmentation creates edge habitats along the margins of patches. Patches are affected both by edges and the effect of edges on patch interiors in the following ways.

- Edges create changes in microclimate (the climate of small areas). Depending on latitude, age, and the direction the edge faces, more light reaches the understory in an edge than under a canopy. More light creates higher temperatures, providing a source of energy for certain plant species that can use full sunlight.

Robert J. Erwin/Photo Researchers

FIGURE 3.6 **Red-backed vole. Red-backed voles *(Southern Clethrionomys gapperi)* in Pacific Coastal forests are habitat specialists that do not cross large areas of non-forest habitat. Research has shown that their genetic diversity is greatest in an intact landscape, least in a landscape of isolated forest fragments, and intermediate in a fragmented landscape with corridors. The implication is that corridors can moderate the effects of fragmentation (more about corridors on pages 81-83).**

Phil Meyers, Animal Diversity Web

FIGURE 3.7 **Deer mouse. In contrast to red-backed voles, the genetic variation of deer mice, a habitat generalist in coastal forests, is unaffected by fragmentation. The difference between the two species is attributed to the response of generalist and specialist species to the matrix.**

- Wind speed is higher in an edge understory than in the patch interior understory, so the potential evapotranspiration (the conversion of water into water vapor by evaporation or plant transpiration) at an edge is higher than in the interior, and conditions for plant growth may be drier. Since trees slow wind, the lack of trees in edge environments results in higher wind speeds in the edge understory than in the patch interior understory.

What do we know about forest fragmentation and biodiversity?

- Early-succession plant species are often adapted to edge microclimates. For this reason, the overall diversity of a patch may actually increase as these species are added to its edge.
- Interior patch species respond in various ways to edge conditions. Some are unable to survive.
- Non-native invasive species may be helped by edge habitats. Many invasive plants are abundant seed producers that thrive in higher light conditions and have widely dispersed seeds. These traits make them more likely to establish and thrive in edges than patch interiors.
- Edges are more susceptible to human disturbance, but their effect declines from the edge to the patch interior. Human pressures include light, noise, pets, hunting, and other activities, and depend on the nature of the matrix (described below).
- Edge effects change species interactions by increasing interaction among edge and interior species. For example, as noted in the perforation stage of fragmentation, many forest-nesting birds avoid edges because of the increased risk of predation, nest parasitism, inhospitable temperature and moisture conditions, or insufficient food *(see box)*. Note: Most research has focused on forest/agriculture edges. More research is needed in the edges of perforated forest landscapes, because initial studies have not shown predation/edge effects to be very serious.

The Nest Parasite

Interior forest birds that are forced to nest near edges can become victims of the brown-headed cowbird. This bird never builds its own nest. Instead, the female lays her eggs in the nests of other birds, as many as 40-50 eggs in one breeding season. Since cowbird eggs often hatch first, and young cowbirds grow faster, they often push other eggs or young out of the nest, and are raised by the adoptive parents who raise no young of their own (Figures 3.8, 3.9, 3.10).

Johann Schumacher/CLO

FIGURE 3.8 **The brown-headed cowbird thrives with more edge (male pictured).**

Tom Ulrich

FIGURE 3.9 **A cowbird egg with chipping sparrow egg and baby sparrow.**

Brenda Oviatt

FIGURE 3.10 **A young cowbird has emptied the nest of all competition.**

Edge-adapted birds like the yellow warbler (Figure 3.11) can deal with the cowbird. Too small to push a cowbird egg out of her nest, the warbler buries the cowbird egg under a newly constructed nest, sometimes at the expense of her own eggs. Then she tries again. One warbler was observed building a six-story nest.

Tom Ulrich

FIGURE 3.11 **The yellow warbler is adapted to life in edges.**

The cowbird is a classic example of nest parasitism in edges, and its negative effects have been documented in forest fragments in eastern forests. Cowbirds typically feed in grasslands or agricultural areas and venture into forests to parasitize the broods of other birds. In eastern forests, matrix habitats often differ markedly from forested patch habitats, but in western coastal forests matrix habitats are less open and less favorable to cowbirds making cowbird parasitism less of an issue in western forests.

- Smaller patches have proportionately high amounts of edge habitat. Long, narrow patches have little or no interior habitat.
- The amount of edge habitat increases at the expense of interior habitat. Species dependent on interior habitat suffer, while edge-dependent species, including invasive species and predators, thrive. Highly fragmented forests cannot provide the food, cover, or reproduction needs of interior forest species. Predators such as crows and raccoons and nest parasites like the brown-headed cowbird may find target nests more easily in edge habitats.
- Most of the species found in edges are common in the landscape, have generalist habitat preferences, and tolerate frequent disturbances. Edges often have high species diversity. In fact, wildlife managers advocated increased development of edges as early as the 1930s, because many game herbivores are found at higher densities in edges than in patch interiors.

Many questions remain about edges. The answers are complicated and depend on the individual species of interest, because edge effects are notoriously species-specific. Continued research is needed. These questions include:

- How far do edge effects reach into the patch?
- Do edges block the movement of animals and plants?
- Do corridors enhance population movement or make edge effects worse for species within the patch?
- Do edges encourage non-native invasives?

We can't finish our discussion of fragmentation effects without mentioning scale, because much of our understanding of forest fragmentation depends on scale (whether we're describing a watershed or a region). Sample, area, isolation, and edge effects all have scale-related aspects. As a forest becomes fragmented, there is a range of habitat destruction. Initially, there may be no noticeable effects in the patches except for some local edge effects. However, the effects increase as the fragmentation process continues, and their rate of increase seems to be linear, increasing in direct proportion to the increase in fragmentation. However, at some point nonlinear responses (large drops in biodiversity and/or function) occur with small increases in fragmentation, and these responses are difficult to predict.

The Importance of the Matrix

Up to this point we've focused on patches. Now we'll describe the function and diversity of the matrix, the area around the patch. The matrix can influence the effects of fragmentation in many ways, so it's important to understand matrix concepts. The effect of the matrix on patches and the whole landscape depends on its similarity to patches and how well it supports connections between patches.

One function of the matrix is habitat. The ability of forest species to live in and use the matrix as alternative habitat will affect their populations and the way in which the landscape functions. In terms of the rate of movement of animals, plants and energy between the matrix and patch, the matrix can act as:

- a **conduit** that allows the movement of species
- a **filter** that allows some selective movement of species
- a **source** for individuals that immigrate into patches
- a **sink** that imports more individuals than it exports
- a **barrier** that blocks all movement.

The following discussion builds on fragmentation theory and the four fragmentation effects – sample, area, isolation, and edge. We'll see that the matrix can modify them because the matrix can affect:

- resource availability (food, structure, etc.)
- population subdivision
- disturbance regimes
- microclimates
- invasives
- human pressure on patches.

This brief discussion is offered with the understanding that the extent of these effects on patches depends on processes in the matrix itself.

Effect on resources

Differences between the matrix and the patch may alter the available resources for different species, depending on whether they're habitat specialists (red-backed voles and flying squirrels) or generalists (mice or deer). Some species experience little difference between patch and matrix (deer mice), even if they differ in structure, while others (red-backed voles) respond to even minor differences.

Effect on population subdivision

Isolation effects on population subdivision depend on the area and sample effects. We learned that metapopulation division into smaller subpopulations leads to more local extinctions of species that often cannot be rescued if isolation is high. This isolation effect on population subdivision will be reduced if the matrix isn't a barrier. For example, some plant populations may be able to persist in small areas within the matrix. Seeds may be carried by wind in multiple steps across a matrix into a patch sink.

Effect on disturbance regimes

As noted above, the effects on area and isolation in turn affect the size, frequency, and intensity of disturbances such as windstorms and wildfire. If isolation is low, patches tend to function as a whole. However, the matrix can alter disturbance regimes by modifying the degree of isolation. Whether or not a matrix operates as a barrier, filter, or conduit will vary with the type of disturbance. In addition, the matrix can have completely new disturbances that were not a part of the pre-fragmentation landscape but can significantly affect patches in the fragmented landscape.

Effect on microclimate

The degree to which the matrix differs from the patch in structure and evapotranspiration will modify the microclimate and the plants that grow in edges. The matrix can reduce the effect of small size and edge on microclimate if the matrix's albedo (reflectivity) and structure are similar to those of the remnant forest.

Effect on invasives

The matrix can serve as a habitat, conduit, barrier, or filter for invasive species just as it does for native species. In fact, the edge itself may be a better habitat and/or conduit for invasive species than a contiguous forest. The matrix may have the greatest effect on the degree to which edges are suitable and accessible for invasives.

Effect on human pressure

Where clearing is done for forestry or agriculture or roads, increased human pressures may come from hunting. Unless the patches are small, the edges will have more human activity than the interior. Where forests are cleared for housing, human pressures (light, noise, pets, and local recreation) will depend on the distance to patches. If the matrix allows humans to live close to the patches, it may serve as a conduit through which they can easily approach patches. With greater distance, the matrix can act as a filter that impedes movement or even as a barrier to the impacts of human pressure.

Measuring Fragmentation (Landscape Metrics)

Fragmentation is a spatial process, and it's important that we try to quantify it. Efforts to quantify fragmentation use remote sensing and GIS, tools that have become very sophisticated over the past twenty years. Spatial and landscape-level data on land use and land cover have also improved. These tools and data allow scientists to document fragmentation patterns at scales ranging from watersheds to regions, nations, and the globe. Various ways of measuring fragmentation have been developed. Commercially available GIS and remote sensing software can calculate basic landscape measures such as patch area and perimeter. More specialized software provides metrics for landscape quantification and fragmentation.

Most metrics fall into three groups, according to what aspects of landscape structure and pattern are being measured. These aspects include:

- the composition of the landscape (the amount of different cover types found in the landscape)
- the configuration of the landscape (how patches of the same or different cover types are arranged in the landscape in relationship to each other)
- the shapes of patches and characteristics of edges in the landscape.

There also are more detailed fragmentation metrics, including isolation and proximity of cover types, diversity and evenness of patterns, connectivity, and contrast. Within each of these, there are metrics that can be grouped according to the spatial scale of interest, from patch-level metrics (calculated for each individual patch in the landscape), to class-level metrics (average values calculated for each cover type in the landscape), and finally to landscape-level metrics (calculated for the landscape as a whole). Also available are metrics that focus on specific variables of interest. For example, measures of road density and distance of forested areas from the nearest road have been used as indicators of fragmentation and road effects.

National Databases for Assessing Fragmentation

Interest has grown in developing national and international measurements and methods that can both map and monitor forest habitat loss and fragmentation. In the past decade, national and global maps from satellite imagery have made it possible to assess land cover at national and international scales and conduct preliminary assessments of forest loss and fragmentation. Here is a listing of the databases available for the United States.

- The National Land Cover Database (NLCD) is a 21-class land cover database available on a state-by-state basis.
- Global Land Cover Characteristics Database (GLCC) is a broader spatial scale database released in 1997. It provides continent-by-continent land cover data. It was developed by the U.S. Geological Survey's Earth Resources Observation System (EROS) data center.
- Global Land Cover Facility (GLCF) Databases at the University of Maryland is funded by NASA and develops and distributes remotely sensed satellite data and products.
- The National Gap Analysis Program is designed to identify the degree to which native animal species and natural communities are represented in our current mix of conservation lands. Species and communities not adequately represented are considered conservation "gaps." The program provides geographic information on the status of species.
- Topologically Integrated Geographic Encoding and Referencing (TIGER) is a database of road networks produced by the US Census Bureau.

One thing to be aware of is that land-cover maps indicate only the location and types of forest. Further data processing is needed to quantify and map forest fragmentation. In an effort to do that, several studies have used the data sources listed above to document patterns of fragmentation across the United States. They include:

- The Forest Intactness Database
- The Heinz Center's *"State of the Nation's Ecosystems"*
- Forest and Rangeland Renewable Resources Planning Act
- Riiters' Fragmentation Index
- How Far to the Nearest Road?

More information about these databases and fragmentation studies can be found in the appendix (page 167).

All of these assessments reinforce the national concern over forest fragmentation. They confirm that it is possible to use high-resolution maps to assess forest fragmentation, even if the results are preliminary and contingent on the quality of the data. The studies vary in their incorporation of roads versus land use, spatial data resolution, scale of analysis, and landscape structure. Another weakness is that there is little analysis of change over time, due mostly to the lack of long-term data. However, these studies provide needed impetus for making improvements in the next round of national assessments. Support is growing for more thorough measures of fragmentation and landscape pattern.

What's Still Needed in Fragmentation Metrics?

Some major issues that still need to be addressed are:

- the fact that landscape-scale metrics of fragmentation such as edge density and inter-patch distance have value as general indicators of disturbance rates but are often poor predictors of species richness and other measures of biodiversity in forest patches
- the need to clarify the way fragmentation interacts with habitat loss to affect biodiversity and ecological processes
- the need for a better understanding of nonlinear relationships between landscape structure, fragmentation effects, and landscape metrics
- the need for ways of dealing with the species-specific nature of fragmentation effects and using fragmentation metrics in the development of forest management and monitoring plans
- the need to develop additional metrics that recognize that most fragmented landscapes are dynamic mosaics, composed of habitats that vary in quality rather than discrete patches of habitat and non-habitat
- the need to recognize that the interpretation of fragmentation metrics with respect to effects on biodiversity and ecological pattern and process remains open-ended.

What We Know About Fragmentation

We understand the general forces and impacts of forest fragmentation. However, there have been relatively few experimental tests of fragmentation theory and models. This is because experiments at the landscape scale are difficult to perform and different species respond differently to fragmentation. As a result, the application of our knowledge to particular cases is limited. For conservation purposes, here's what we do know:

- As forest declines in extent and quality, impacts accumulate nonlinearly. Nonlinear responses are often seen as thresholds, and our ability to identify those thresholds in term of management decisions is still unknown.

- Conservation efforts need to take into account the matrix and its characteristics. The degree to which the matrix can serve as habitat or partial habitat or as a conduit between patches is variable and still unpredictable.
- There are various degrees of fragmentation, and what is suitable for some species may be inhospitable for others.
- Forests can be temporarily fragmented into smaller units by harvesting that changes the age classes and species composition of the next forest.
- Larger patches generally support more species than smaller patches of the same forest type.
- Populations in smaller patches are at greater risk of extinction due to variability in environmental conditions and population levels.
- As patches become smaller and more isolated, adverse impacts of fragmentation increase and are likely to be greatest for species that are limited in their ability to disperse. However, short-lived patches in a dynamic landscape that is continuously forested but with different age classes moving spatially over time do not function in the same way as forest adjacent to agriculture or urban development.
- Even isolated forest patches have biodiversity values that would disappear if they were converted to non-forest uses.

What More We Need to Know About Fragmentation

- Local populations in patches are strongly affected by the characteristics of the surrounding matrix. It is important to understand how fragmentation alters flows of energy, matter, and species – including dispersal and spread of non-native invasive species and diseases – across the matrix and thus affects forest succession, sediment movement, nutrient cycling, carbon sequestration, and other key community and ecosystem processes.
- Determining thresholds is an important area for fragmentation research. Models and theory demonstrate that habitat destruction has little effect on plant and animal movement until a threshold or critical point is reached or when a gap wide enough to interrupt dispersal is created. If such thresholds can be identified, managers can begin to plan their activities accordingly.

SOME PRACTICAL IMPLICATIONS OF FRAGMENTATION SCIENCE

Making use of what we know about fragmentation in forest management activities is not easy because the effects of fragmentation:

- are specific to certain groups of plants and animals, spatial scales, and ecological processes
- vary according to the type of landscape and the structure of that landscape
- can be difficult to distinguish from effects of historical land use and habitat loss per se.

Nevertheless, as we manage forests and harvest timber, we need to balance those activities with other functions that forested habitats provide. We should try to incorporate the concepts of fragmentation to sustain forest resources and protect susceptible species and ecosystems.

It's also important to remember that a forest fragmented by agriculture or urban development may be different from a forest with mature and regenerating stands that result from timber harvesting. The first situation represents a habitat that may be modified indefinitely with a matrix that has little or no habitat value for forest species, while the latter can be viewed as a shifting mosaic in which amounts and spatial patterns of forest habitat types are changing constantly in response to management activities and natural processes. The techniques described next may alter the effects of fragmentation.

Logging Systems That Might Alter the Effects of Fragmentation

New silvicultural systems need to be designed and implemented for managers who want to increase the habitat value of matrix lands. Current harvest systems, whether based on clearcutting, shelterwood, or selection cuts, create different forest patterns across the landscape and have different fragmentation effects. Logging systems that reduce the impact of one fragmentation effect may increase the effect of another. For example, selection cutting may result in reduced area effects but may increase isolation effects by creating a more extensive transportation network.

Recently, there's been interest in the use of structural retention harvesting (Chapter 1, page 45), a technique that maintains structures from the original stand. Structural retention may contribute to biodiversity conservation by:

- maintaining plants and animals on a harvested site by keeping essential habitat elements such as snags, large down logs, and small patches
- adding structural heterogeneity to the harvested stand and allowing organisms to return more quickly
- modifying the microclimate after the harvest to make it more suitable for certain species
- making it easier for species to move through harvested areas

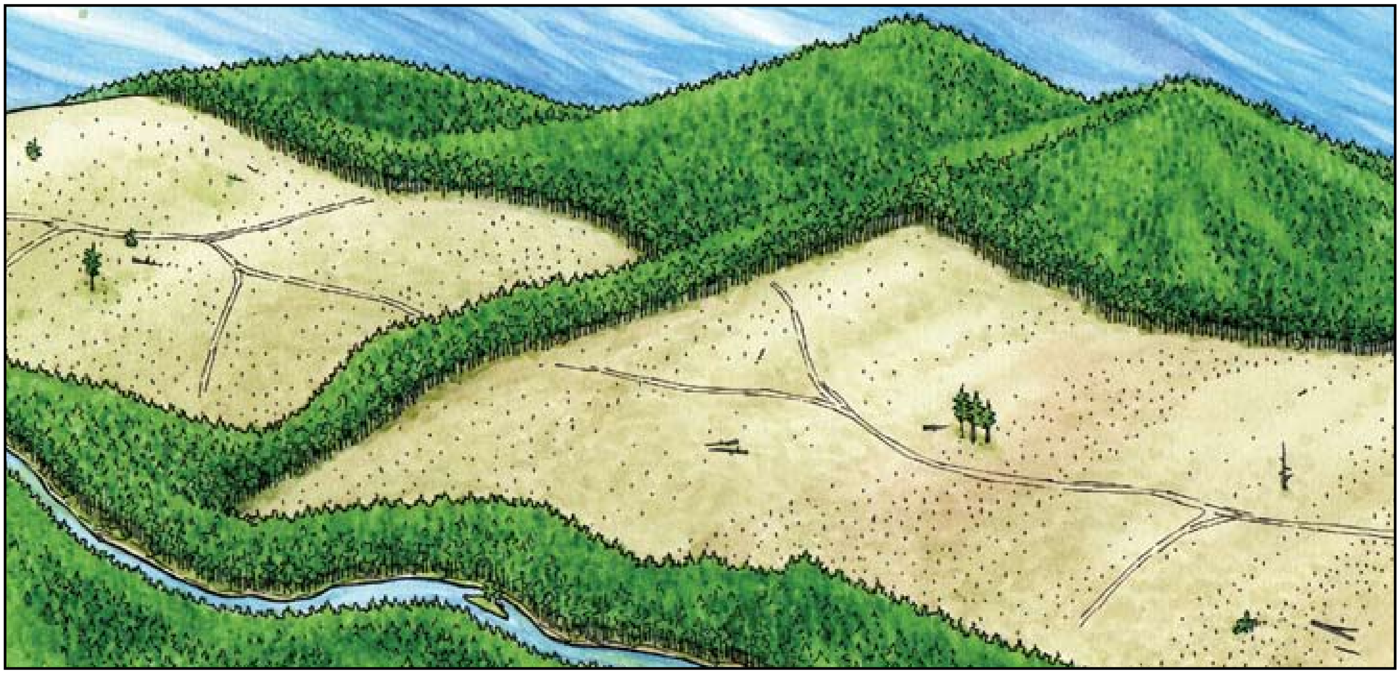


FIGURE 3.12 **Corridors can connect a streamside riparian area and a ridgeline.**

- complementing protected zones such as riparian areas within the matrix.

Within the context of forest fragmentation, retention harvesting may:

- reduce the area effect by increasing the habitat quality of the matrix
- reduce the isolation effect by facilitating movement through the matrix
- potentially reduce the edge effect by limiting the number of abrupt edges in a landscape.

However, the extent to which these elements are enhanced depends on the structures that are retained, the amount that is retained, and their spatial pattern, and the influence of each of these factors is not well understood. Research on the economics of retention harvesting is also at an early stage. Some public agencies acknowledge that they are using retention harvesting because it is considered socially acceptable and that they are still in early stages of gathering data on the benefits and costs of changing their silvicultural regimes.

All of this points to the fact that the effects of fragmentation on new and traditional silvicultural strategies are not well understood. Better information is needed about quantitative relationships between structural features of stands and the requirements of forest-dependent plants and animals. There is also a need for research on costs and benefits of alternative conservation strategies such as variable retention, use of mini-reserves in intensively managed areas, corridors, adjacency constraints, and restrictions on harvest unit sizes.

The Demonstration of Ecosystem Management Options (DEMO) Study, a large-scale, long-term experiment on structural retention harvests in the Pacific Northwest, is investigating some of these questions. It is designed to examine the responses of diverse groups of plants, animals, and processes to various amounts and/or patterns of live trees retained in harvests. There is information about this experiment in the appendix.

Using Corridors and Stepping-stones to Alter the Effects of Fragmentation

One important way to promote connectivity between isolated patches is to create corridors of land that connect patches but differ from the surrounding matrix (Figure 3.12). One example of maintaining connectivity across highways is shown in the box on the next page. Some of the potential advantages of corridors are:

- They may increase the movement of animals among habitat patches, promote genetic exchange, and help to recolonize suitable habitat patches.
- They may reduce mortality by assisting species in their movement between patches. Species that seem to benefit most from corridors are those that avoid open matrix habitat and species that require a suitable kind of habitat for dispersal.
- They can provide additional habitat area, increase the foraging area for species that require large areas, and serve as refuges (Chapter 1, page 44) from large disturbances.

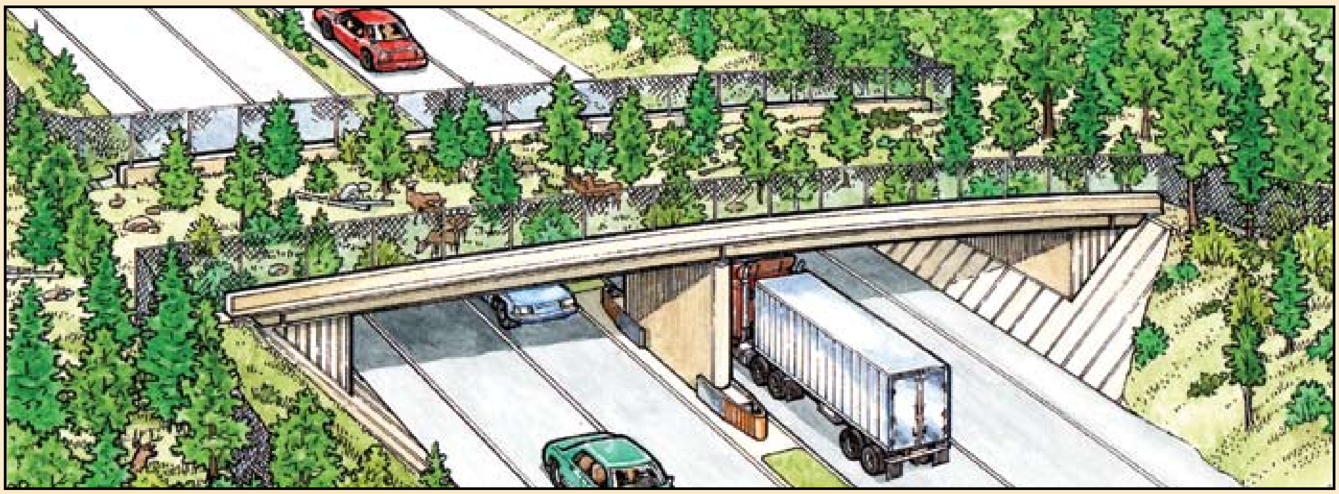


Figure 3.13 **The two examples above show how habitats can be separated that otherwise would be available for wildlife movement. Wildlife crossing structures are being planned in locations with high-quality habitat and little human access off the roadway. The goal is to design structures that benefit the widest range of wildlife species. Some may be oversize culverts for movement of small species like rodents and amphibians, while others may be tunnels or vegetation-covered bridges.**

Connecting Habitat Across Major Highways

The metapopulation model described earlier indicates that subpopulations are generally located in areas of suitable habitat, and that it's important that animals can move across landscapes between subpopulations to sustain their viability and alleviate isolation. We know that landscapes are not uniform, but instead consist of habitat patches often interspersed with various barriers. The term "landscape permeability" indicates the amount of resistance that animals perceive when moving across barriers from one habitat to the next. For example, natural barriers like rivers and steep topography are no barrier to river otters and mountain goats respectively. Land-use barriers act in a similar way. A deer may cross a subdivision, but for a wolverine that subdivision becomes a permanent obstacle. Major highways can act as barriers too, affecting landscape permeability. Researchers are designing ways to increase their permeability, making them a conduit or filter and improving animal movement.

Researchers in the Pacific Northwest who are studying highway permeability for grizzly bears, wolverines, grey wolves, and lynx point out that roads can:

- block movement and dispersal of animal populations
- isolate and fragment populations
- provide human access and development into wildlife habitat
- contribute to vehicle-animal collisions.

Using GIS and other techniques, researchers can identify areas along highways with the best wildlife habitat and locate linkages between them. They find where animals are most likely to cross highways and design wildlife crossing structures that improve highway permeability and minimize the problem listed above. The primary challenge is finding the correct structure for each species (Figure 3.13).

Figure 3.14 **Kincaid's lupine patches *(Lupinus sulphureus ssp. kincaidii)*, a threatened plant, located at proper intervals, can act as stepping-stones, for the Fenders' blue butterfly *(Icaricia icarioides fenderi)*, an endangered insect listed under the federal Endangered Species Act. Lupine is the primary larval food for the butterfly.**

There is debate about corridors. Although they are in use, there are questions about their ability to increase connectivity for many species and their effectiveness for conserving biodiversity. The benefits of corridors are species-specific, making it difficult to provide general guidelines for their use. Whether corridors are effective depends on a range of factors specific to individual cases, including:

- the length and width of corridors
- the suitability of habitat within the corridor and the adjacent matrix
- the demography of the patches
- characteristics of the species being helped, including their method of dispersal.

Studies are needed to document not only whether corridors assist the movement of species across the landscape, but how their movement differs from the way they move without corridors, recognizing that matrix characteristics are important. Studies are also needed that address the willingness of species to use corridors, cross-gaps, and cross-matrix structures. It may be that the best strategy to enhance connectivity for some species is to manage for or improve structural conditions in the matrix rather than investing in corridors.

Another kind of dispersal technique being investigated is the use of **stepping-stones**, patches that allow species to "hop" from one patch to another. The movement of **Fenders' blue butterfly** in the Willamette Valley of Oregon is an example of the stepping-stone technique (Figure 3.14). Historically, lupine patches, which served as suitable "source" habitat for this butterfly, were less than 0.5 km apart. This distance was easily within the 2 km dispersal potential of Fenders' blue butterfly across non-lupine "sink" habitat. However, fragmentation has left lupine patches that are isolated by 3 to 30 km, dividing metapopulations into non-interacting subpopulations. Scientists have suggested developing stepping-stone lupine patches to reconnect the populations, rather than corridors, because stepping-stones are more like the historical landscape structure. Continued research is needed on other species that might benefit from this technique.

Developing Management Plans that Recognize the Effects of Fragmentation

Here are three suggested principles to use in forest management plans that recognize the effects of fragmentation on biodiversity.

Principle 1: Promote connectivity

Connectivity can be improved by not only creating or reserving habitat corridors, but also by using stepping-stones that help the movement of species across a landscape. Other ideas include retention harvesting, mini-reserves in intensively-managed areas, adjacency constraints, and restrictions on harvest unit sizes. It may also be possible to manage the matrix to increase its suitability as habitat and increase its permeability. Where the matrix consists of agriculture or residential development, parks, land-use planning that conserves open space and greenways, and passageways across major highways may reduce the effects of fragmentation.

Principle 2: Maintain structural complexity

Structural complexity includes:

- the variety of stand structures present in natural forests along with stand ages and size classes
- snags and large down logs
- variation in canopy gaps and canopy layers.

Principle 3. Spread the risk of doing the wrong thing

Because it is difficult to identify how changes in forest extent or connectivity associated with fragmentation affect even a single species, the adoption of multiple strategies at multiple scales increases the probability of providing suitable habitat, connectivity and stand complexity in at least some parts of the landscape. For example, if the corridor strategy is ineffective, then another strategy, such as stepping-stones or structural retention, will be in place to protect elements of the landscape. This approach reduces reliance on a single strategy and spreads the risk while research continues to clarify the science of fragmentation.

To Learn More About This Topic, See Appendix, page 167.

WHY IS THIS SUBJECT IMPORTANT?

This chapter revisits the five regions described in Chapter 1, focusing on old-growth (OG) forests. Each region's OG story is different, influenced by its natural and land use history. We will learn that in some regions OG is nearly nonexistent, while in others it's rare and disappearing. In regions where OG is more abundant, it's susceptible to catastrophic disturbances, but management can help sustain OG across the landscape.

Regardless of the region, science confirms one prominent message – OG is an important stage in the dynamic development of any forest (Figure 4.1). That doesn't mean that OG is more important than other stages of development, but it does recognize that its complexity is vital to biodiversity and that it's the rarest stage of forest development in every region. Research confirms the need to conserve existing OG in all regions and develop strategies to grow more.

The term OG refers to forests in the late stages of stand development. It occurs after a forest has grown for long periods of time, often centuries, with low to moderate levels of disturbance. OG includes the mature stage, where trees reach their maximum height and crown diameter although they still lack some of the structure and composition of OG (Figure 4.1). The mature stage is included in OG because it may become the OG of the future. Recently, researchers have used the term "older forest" when referring to the mature and OG stages, and that term will be used in this chapter.

In the eastern United States OG is rare and its future is questionable. In the Northeast for example, less than 1 percent of the forest is OG, while mature forests are slightly more abundant but rapidly disappearing (details below). In the Southeast, what's left of the remaining OG amounts to approximately 0.5 percent of the total forest area. In the Lake States, the supply is even shorter. Given these conditions, NCSSF-sponsored researchers in these regions offer conservation strategies aimed at growing more OG. In the west, where old growth is more abundant, forest policy has focused on protecting existing OG forest reserves in the Pacific Northwest and deciding how to manage them. In the Southwest the focus is on how to manage OG in frequent-fire landscapes. Long-term strategies are being developed in all regions to ensure OG has a place in the landscape, whether that landscape is subject to wildfire, fire suppression, invasive species, pathogens, or other disturbances.

OG is known by various names: old forests, heritage forests, ancient forests, virgin forests, pristine forests, and late-succession forests. Whatever the name, this forest stage provides habitat for many organisms, some of which show a preference for OG conditions. Some OG supports endangered species: the spotted owl in the Pacific Northwest, the red-cockaded woodpecker in the longleaf pine forest, and the rediscovered ivory-billed woodpecker in bottomland hardwoods of the southeastern coastal plains. Other regions may lack charismatic species but still have species that are dependent on OG remnants that often are rapidly disappearing. Old forests themselves are an important element of biodiversity. Their size, structure, and spatial characteristics make them a fascinating part of the earth's biota, and one worth preserving in its own right for both scientific and aesthetic reasons.

This chapter highlights regional differences in OG; describes its extent, condition, and major threats; addresses the question of how much is enough; and offers strategies to enhance OG. It explains environmental, social, and economic issues in each region, focusing on the following general points:

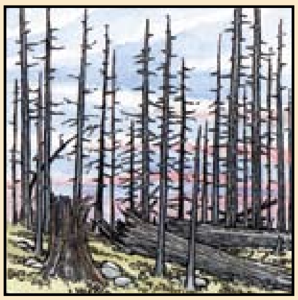
- Old forests are more than just old trees.
- There's a connection between biodiversity and the need to retain and grow more old forests.
- Threats to OG go beyond logging and include development, invasive species, and unnatural disturbances resulting from fire suppression.
- If we want more OG, we must do more than simply preserve what we have; it will require managing and restoring younger forests.

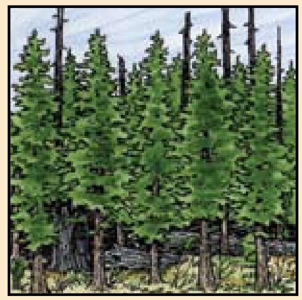
Older forests provide functions and processes that are vital to forest biodiversity. Their functions include providing large living trees, large standing snags, and large down logs (biological legacies, Chapter 1, page 44), all of which young forests need after stand-replacement disturbances. Their processes include the ecological forces leading to their development and maintenance, such as gap formation, regeneration, nitrogen fixation, low-severity fire, productivity, and decomposition. These functions and processes, along with the variety of organisms that OG forests protect, all contribute to biodiversity.

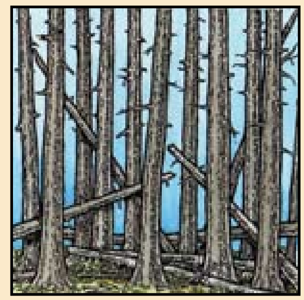
Why is this subject important?

Because OG is a natural part of many forests, practitioners, landowners, managers and policymakers need to accommodate them in their forest management activities. While public lands should bear most of the burden of supplying OG, private landowners should be encouraged to grow older forests too, especially in regions that have little public land. The NCSSF-sponsored research featured in this chapter offers management strategies that can accommodate the social and economic goals of private landowners and the public. It offers creative ideas for conserving old forests that are tailored for each region.

FIGURE 4.1 **Pacific Northwest Douglas-fir is shown as an example of forest development. The start of OG begins in the mature stage (5) and progresses through structural and composition stages (6, 7, & 8), each with characteristics that serve a role in conserving biodiversity (details in Chapter 1, page 43).**







Stage 1. **A stand-replacement disturbance that leaves legacy structures**

Stage 2. **Early cohort establishment**

Stage 3. **Canopy closure**

Stage 4. **Competitive exclusion**

Stage 5. **Maturity, the start of OG (80-120 years of age)**

Stage 6. **Vertical diversification typically occurs at 150-250 years of age. OG trees are more than 39 inches in diameter, with lower and midstory shade-tolerant trees and large dead trees.**

Stage 7. **Horizontal diversification typically occurs at 150-250 years of age. Large down logs, a variety of foliage heights, the patchy distribution of canopy gaps and understory vegetation all characterize OG forests.**

Stage 8. **Pioneer cohort loss (final stage of OG)**

WHAT DO WE KNOW ABOUT OG IN THE NORTHEAST?

Overall, the Northeast is more forested today than it was 150 years ago (Chapter 1, pages 8-23), but today's forest cover has not reached the OG stage because most of the northeastern forest was converted to agriculture and pasture (except for the far northern states). At the same time that forests are becoming more mature, the Northeast is generally losing forest cover to development in the southern tier of states. In the far northern tier of states, which were never deforested and converted to farmland, the forests have more old forest qualities, but because of the emphasis in the last 30 years on managing timber more efficiently, most of the remaining mature forest is rapidly being removed from the landscape (more about this below).

Jerry and Marcy Monkman

FIGURE 4.2 OG Red Pine in Maine.

John Hagan

FIGURE 4.3 Big Reed OG Reserve in Northcentral Maine.

John Hagan

FIGURE 4.4 A tip-up mound in OG northern hardwood forest, Maine.

John Hagan

FIGURE 4.5 Researcher John Hagan and OG Ash in Big Reed OG Reserve.

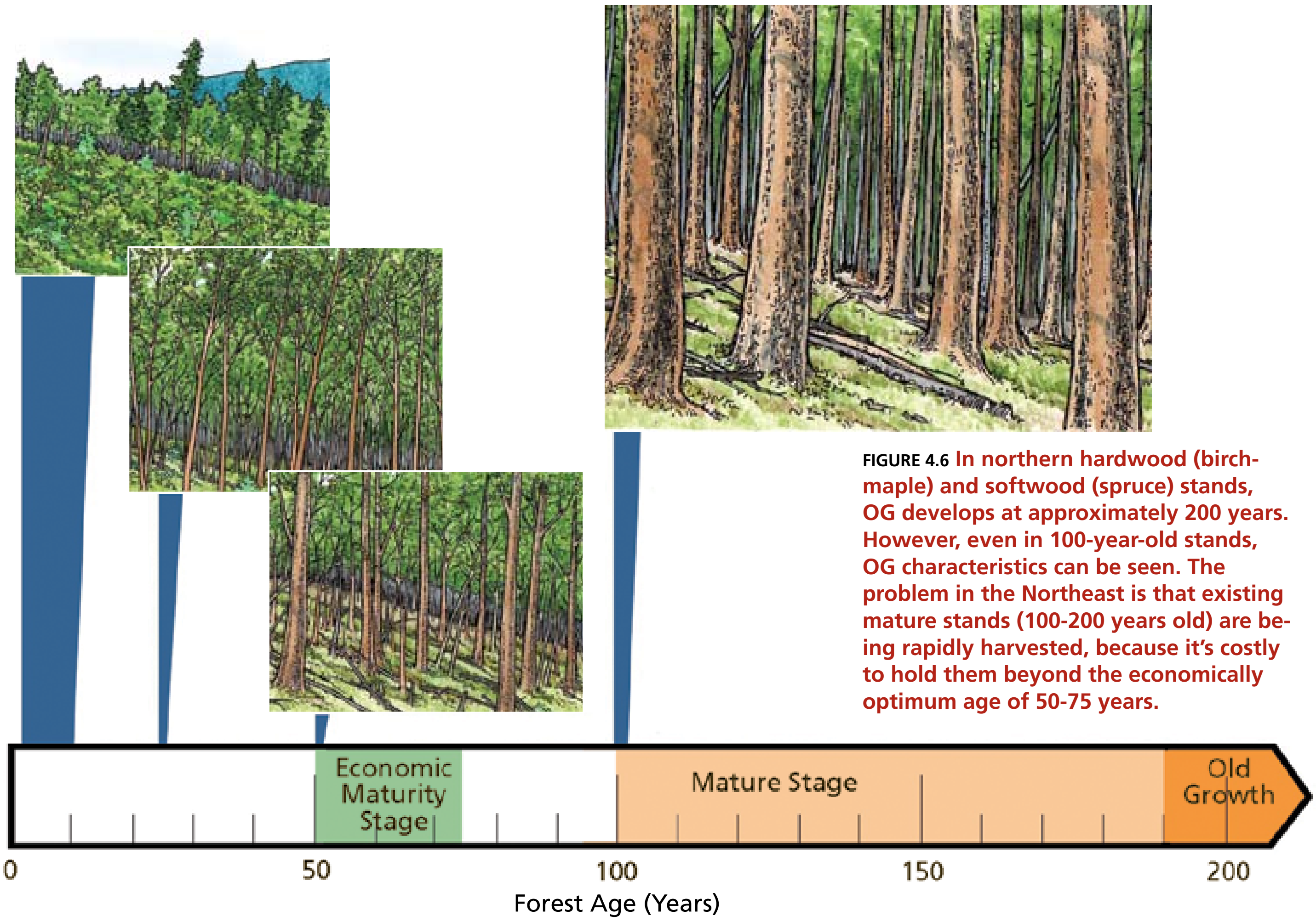


FIGURE 4.6 **In northern hardwood (birch-maple) and softwood (spruce) stands, OG develops at approximately 200 years. However, even in 100-year-old stands, OG characteristics can be seen. The problem in the Northeast is that existing mature stands (100-200 years old) are being rapidly harvested, because it's costly to hold them beyond the economically optimum age of 50-75 years.**

FIGURE 4.7 **Based on field reconnaissance in Maine, NCSSF-sponsored researchers have found stands that contain trees in the 100-200 year age class, but they are rapidly disappearing.**

Victor Brunelle

Forest ownership is critical to any discussion of OG in the Northeast, because most forests are private (Figure 4.10). The vast majority of private forestland is in the hands of family forest owners, but there are large private ownerships as well. The opportunity to retain existing OG in the Northeast lies primarily on public lands, and public ownership of forestland varies between 5 and 15 percent across the Northeast states. With such a small portion of the forest in public ownership, it's necessary to encourage private owners to grow OG. They will be key to any OG conservation strategy in the Northeast (more about this below).

What's the Current Condition and Extent?

There's no clear point at which Northeast forests become OG, but as the forest development diagram in Figure 4.6 shows, stands 100-200+ years old are considered older forest.

An inventory of OG in the Northeast is needed but has not been done; this is what is known. Less than 0.1 percent of any Northeastern state is OG older than 200 years. What little remains is primarily on public lands and has been protected because it is so rare. Individual states estimate the following amounts of OG:

- Maine – 0.17 percent
- New Hampshire – 0.41 percent
- Vermont – 0.05 percent
- New York – 0.70 percent
- Pennsylvania – 0.06 percent
- Connecticut – 0.01 percent.

In contrast, mature forest 100 to 200 years old is more abundant but is being harvested because of the cost of holding it (more about this in "threats to OG" section below). Mature forest is estimated to occupy less than 5 percent of the forested landscape. In northern Vermont, New Hampshire, and Maine, where forests were not cleared for agriculture but were managed for timber for more than 150 years, remnants of mature forests remain, but they are disappearing with concentrated harvesting. In the state of Maine for example, there was a net loss of mature forest between 1982 and 2003. The amount of mature northern hardwoods declined from 3.93 to 1.1 million acres (1,587,720 to 445,154 hectares) (Figure 4.7).

John Hagan

FIGURE 4.8 This 150-year-old sugar maple is covered with old forest mosses and lichens. Due to its harvest history, the stand is not OG, but it contains OG trees with OG dependent species.

John Hagan

FIGURE 4.9A
This OG moss *(Neckera pennata)*, tightly associated with older sugar maple trees, is evidence of the need to retain mature hardwood stands.

John Hagan

FIGURE 4.9B
The epiphyte (lichen) *Lobaria quercizans* is another species dependent on older forests in Maine.

In the southern tier of states, where European settlers cleared the landscape for farming and grazing, mature forests are returning. In Pennsylvania today, approximately 20 percent of forest cover on state-owned lands is in the mature stage (100+ years). Forests have also recovered in Massachusetts, but forestland is now being lost to development, and the prospects for retaining mature forests are uncertain (strategies are being proposed and are described below).

Are There Old-growth Adapted Species?

In contrast to other forest regions, such as the Pacific Northwest and Southeast, The Northeast has no charismatic wildlife species that depend on OG. However, some mosses, lichens, and fungi are dependent on older forests (Figure 4.8 and 4.9A and 4.9B).

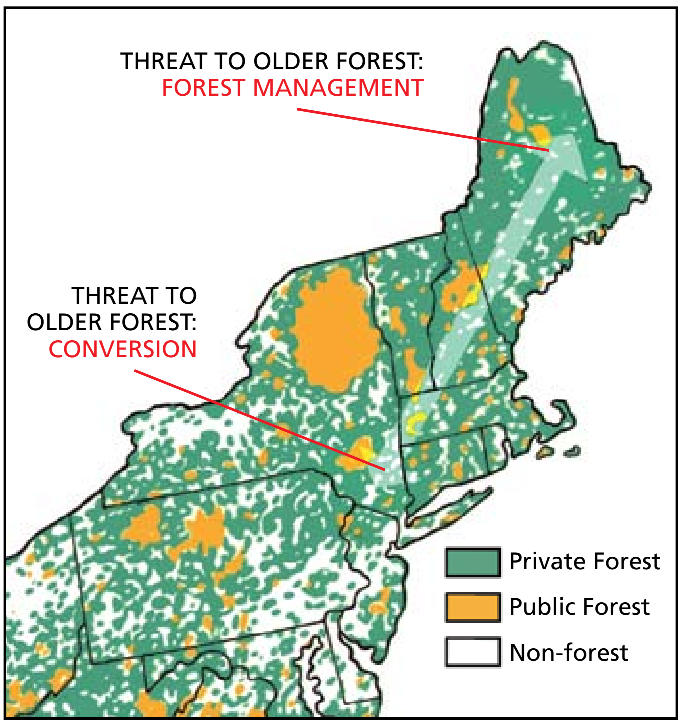


FIGURE 4.10 **Northeastern states vary between 5 and 15 percent public ownership. Timber harvesting on large, private commercial forestland threatens much of the remaining mature forest in northern Vermont, New Hampshire and Maine, due to financial considerations. It's just too costly to hold these stands to ecological maturity. At the opposite end of the Northeast region, the primary threat is development and the conversion of forest to non-forest uses.**

What are the Major Threats to OG in the Northeast?

While the small amount of OG that exists in the Northeast is protected, threats to mature forests are different for various locations in the region. In the north, mature forest will steadily decline due to harvesting. In the south, development is the threat (Figure 4.10).

Other threats to older forests in the Northeast come from acid rain, invasive species, and an overabundance of deer. While there has been some reduction in acid rain in recent years, the chronic leaching of calcium from the soil continues to stress some tree species, especially shade-tolerant, long-lived sugar maple. Invasive species include chestnut blight that eliminated American chestnut, beech bark disease, and hemlock wooly adelgid (Chapter 2, pages 58-59). Overabundant deer prevent regeneration in older forests in New York and Pennsylvania and interfere with the maintenance of existing mature forests.

How Much OG is Needed to Maintain Biodiversity?

NCSSF-sponsored researchers say there's not enough time or money to answer this question because most remaining mature stands are scheduled for harvest in the next 1 to 5 years. It's estimated that 4 to 6 percent of the total forest in Maine might qualify ecologically as mature forest, but there is no information on how much mature forest remains in all of the Northeast. Field observations suggest that it would not take large set-aside areas to maintain the sensitive species found in mature forests. Rather, it's possible that setting aside many small, very high-quality areas might be the best strategy to maintain well-distributed populations of mature forest species. Just how that might be done is described below.

How Does Society View OG in the Northeast?

Surveys indicate that the general public values old forest and wilderness areas and wants them maintained in the region. What's unclear is how much is wanted and how it should be distributed. Unfortunately, the public is not currently involved. There's been no public discussion about older forests in the Northeast – the public is more concerned about forest conversion to development than about old forests. However, researchers are exploring ways to involve the public in dialogue about old forest.

HOW CAN KNOWLEDGE OF OG BE USED IN MANAGEMENT STRATEGIES ON PUBLIC AND PRIVATE FORESTLANDS?

While there is little Northeast-based scientific information to explain what species or processes will be lost with the disappearance of older forests, researchers assume that many species, especially mosses, lichens, fungi, and insects, will be threatened. Current efforts to conserve older forest are deadlocked between those who call for immediate conservation strategies and those who think more science is needed before taking action. Researchers suggest four strategies (the "Four Rs") to conserve and manage old forests:

- **reserves** – no-harvest areas used to maintain and grow OG
- structural **retention** – leaving old trees after harvest to maintain OG characteristics
- **restoration** – accelerating development of old forest characteristics in younger stands
- longer **rotation** – grow trees longer before harvest.

The state of Pennsylvania has developed an OG reserve policy. Overall, its forests are mostly in the 80- to 100-year-old age class, so older forest acreage will come from state-owned land where 20 to 25 percent will be designated as OG. That goal will be met through the use of reserves, long rotations, and retention strategies. Efforts to encourage OG on private lands will be voluntary.

In Massachusetts, a proposal called "Wildlands and Woodlands" would use reserves and easements to protect forest cover, including old forests. The goal is to establish 2.25 million acres (909,000 hectares) (45 percent of the state) as "woodlands" and 0.25 million acres (100,000 hectares) (5 percent of the state) as "wildlands." Woodlands will be managed for timber, and development will not be permitted. Wildlands will be off-limits to timber harvesting and development. "No-development" easements will be used to accomplish the woodland goal. The wildland goal will be accomplished by designating existing public lands.

In Maine, researchers are proposing a combination of strategies to conserve older forests, depending on landowner goals (family forest, public forest, or commercial forest). They acknowledge that extending rotation length conflicts with economic reality, but they believe a new management strategy that balances economics and OG conservation could accommodate landowner goals. With a growing interest in conservation among family forest owners, they suggest buying rotation length. The objective would be to purchase rotation length using a new type of easement that compensates landowners for the cost of continuing to grow stands beyond the financially optimum rotation length (50 to 70 years) into the mature and OG stage. The cost of added rotation length can be calculated and would be paid for through easements, the same way owners are currently compensated for development rights.

Along with these conservation strategies, researchers have developed new tools to help foresters manage for OG. One is an index that screens stands for OG content. The Late-Successional (LS) Index is a field tool that can be used in northern hardwood and upland spruce-fir stands. It recognizes OG by measuring certain characteristics and scoring the results. It's based on large-tree density and the density of trees with one or two lichen species. Tree size is closely related to stand age, and the identity of certain lichens helps to assess the ecological history/age of the stand. Together, these two characteristics can identify OG. The index score helps foresters recognize an older forest when they see it. It can screen stands prior to harvest, after a harvest to determine how much OG was retained, or to build an inventory of OG stands by using the stand score in a GIS database.

Given the complicated and rapidly changing character of northeastern forest ownership, and the economic pressure to harvest stands that are beyond financially optimum age, each of these strategies (reserves, retention, restoration, and rotation length) will be needed to conserve older forests and their biodiversity.

WHAT DO WE KNOW ABOUT OG IN THE LAKE STATES?

Forests in the northern Lake States (Minnesota, Wisconsin, and Michigan) are very different from the region's historic forests (Chapter 1, pages 24-29). Today's forests are still recovering from the cutover of the late 19th and early 20th centuries (Figure 4.11).

So little OG remained after the cutover era that the challenges facing this region are recovery and restoration rather than preservation of OG. It's estimated that less than 1 percent of the pre-cutover era OG remains, and far less hemlock, yellow birch and white pine remains (details below). There's a serious need to restore ecological complexity to the regional landscape, and older forests are one important component. What's needed is a full spectrum of forest stages across the landscape. Older forests deserve immediate attention, not because they're more important but because they have a complexity that is most threatened by current land management activities. They cannot simply be protected in reserves while the majority of forest is managed on short rotations for biomass.

FIGURE 4.11 **By 1890 the supply of white pine in the lake states was exhausted. Timber companies moved on to hemlock and hardwood species including maple, birch, ash, basswood, elm, cedar and fir. After harvesting, widespread fires created "stump pastures," an unsuccessful attempt at agriculture on the sandy, unproductive soils.**

Wisconsin Historical Society, Image ID #3991

Craig Lorimer

FIGURE 4.12 **Old-growth hemlock-hardwood, Porcupine Mountains Wilderness State Park, Michigan.**

Craig Lorimer

FIGURE 4.13 **Old-growth eastern white pine and yellow birch, Sylvania Wilderness Area, Michigan.**

Craig Lorimer

FIGURE 4.14 **Managed uneven-aged northern hardwood forest, Wildcat Creek, Nicolet National Forest, Wisconsin.**

NCSSF-sponsored researchers brought together a group of experts to develop an OG conservation framework for the region. It's briefly described here with more detail in the answers to the questions below. Its ideas, principles, agreements and rules are an outline that can be filled out in the future. What's most important is that the framework be able to cross regional boundaries, allowing states to work in partnership.

1 There must be consistent definitions and reliable inventories of existing older forests.

2 There must be targets and goals for protecting existing older forest remnants. Many existing OG stands have no protection and must be located and measured.

3 The goal of forest management must be a more ecologically complex forest landscape, and OG must be part of restoring ecological complexity.

4 Monitoring must be tied to adaptive management (Chapter 8). Without monitoring it's impossible to know how regional forests are responding to pests, pathogens and invasive species. Adaptive management allows for response to changing conditions identified by monitoring results.

5 There must be cross-border cooperative strategies that:
- encourage active management on private lands to keep land in forest cover
- include working forests to maintain the wood products industry
- reform state forest laws
- encourage forest restoration on private lands.

What's the Current Condition and Extent?

No inventory exists of older forests in the Lake States. What's needed is an inventory and assessment of older forests on both public and private lands. In the meantime, here are best estimates.

- Less than 1 percent of the pre-cutover era OG remains
- Less than 0.2 percent of hemlock/hardwood remains
- Less than 0.5 percent of white pine/red pine remains

Assessments should include mature forests, not just forests currently in OG condition, because future OG requires identifying, protecting and restoring mature stands.

Are There Old-growth Adapted Species?

There are no OG-dependent vertebrate species in the region. However species groupings and parts of the forest landscape that are being lost are needed to maintain forest resilience in the face of rapid future change.

What are the Major Threats to OG in the Lake States?

Major threats include the following social and ecological changes:

- fragmentation and parcelization from development, especially second-home development
- changes in large-scale disturbances, particularly due to fire exclusion
- increasing demand on watershed services
- invasive species and their probable impact on some forest types in the region. Current control efforts are aimed at the wrong invasives, such as the gypsy moth rather than the hemlock woolly adelgid (Chapter 2).
- climate change and new diseases and epidemics that are likely to occur.

How Much OG is Needed to Maintain Biodiversity?

The question of how much of the landscape should be OG (1 percent, 10 percent or 25 percent) is not simply a scientific decision, but something that should be answered through public discussion and agreement. Whatever the target amount, the region is nowhere near it. It's important to get started. Lack of inventories and targets is being used as an excuse for inaction while existing OG is converted to development or replaced by aspen.

The question of how much OG has been answered in Minnesota, and that model could be useful in other states. In 1991, Minnesota developed and implemented a statewide OG policy to identify and protect the highest quality remaining OG forest. There were several steps:

- inventory all lands statewide for OG
- set statewide targets for OG
- develop new forest management structures, projects, and databases for OG.

Since 1991 Minnesota has gone from 0 to 40,000 acres (16,000 hectares) of designated OG and learned the following lessons:

- establish an interdisciplinary management system with clear management authority
- set quantity targets for OG, as well as indicators, with stakeholder involvement (Chapter 5)
- develop a standardized inventory, evaluation and database system
- resolve stakeholder conflict through strong leadership.

How Does Society View OG in the Lake States?

In spite of Minnesota's public-involvement experience, Wisconsin and Michigan have not had a public conversation on OG. There is a need to educate the public about OG and foster that conversation across the region.

HOW CAN KNOWLEDGE OF OG BE USED IN MANAGEMENT STRATEGIES ON PUBLIC AND PRIVATE FORESTLANDS?

The same NCSSF-sponsored group that developed the OG conservation framework described above also developed the following strategies.

Protect Existing OG

Many existing OG stands on both public and private lands have no protection. All existing OG on public lands should be protected immediately. Those few stands with 120-year-old trees should be protected first. Mature stands nearing OG should be next. Easements, purchases, tax incentives, and exchanges should be used to protect OG on private land.


Craig Lorimer

FIGURE 4.15 **Many even-aged young stands are uniform, with closed canopies and few snags, down logs, saplings, large trees, or hemlock, yellow birch and white pine. Variable-density thinning could be used in this even-aged, 70-year old sugar maple stand (Chequamegon NF, Wis.) to mimic natural small-scale disturbances, forming gaps and introducing other species.**

Second-growth Management Strategies

Second-growth areas on public lands should be managed using extended rotations. They occur in even-aged forests and where older cohorts of trees exist in multi-aged forests. Variable density thinning (Chapter 1, page 47) and prescribed fire may speed the development of older forest characteristics in these areas. Where second- or third-growth forests on public lands are being managed for timber production, researchers recommend management that increases biodiversity and ecological complexity at all forest development stages. The goal is not to manage these areas for OG but to incorporate adequate amounts of biological legacies (large decadent trees, snags, and large down logs) and other structures (Chapter 1, page 44). Future OG can be created by using active management in younger even-aged stands or former plantations as well as uneven-aged stands with a few large trees (Figure 4.15).

Caution: heavy thinning can delay the onset of OG structure in older uneven-aged stands with numerous legacy trees. However, there are ways to decide which stands might benefit from these techniques.

Other Public Forest Management Strategies

For most second- and third-growth public forest, management practices should increase biodiversity and ecological complexity while providing timber products. Stands dedicated to timber production should incorporate some structural composition and complexity characteristic of OG stands because complexity is needed in all stages of stand development.

Monitoring and Adaptive Management

Monitoring and adaptive management are necessary to determine how forests will respond to climate change, new pests and pathogens, and invasive species. Agencies must fund monitoring, along with adaptive management (Chapter 8). Monitoring and flexibility will make it possible to respond to changing conditions that are difficult to predict. In Minnesota, for example, government agencies built adaptive management into their OG reserve policy. If monitoring indicates that the actual amount of OG is over or under the targets by 10 percent or more, stakeholders automatically re-evaluate management practices. This kind of adaptive flexibility provides safety measures and also develops trust among stakeholders.

Cross-boundary Coordination

A coordinated approach should include state foresters, the Council on Forestry Directives, and professional societies that can help move the process along. The conservation framework described above must cut across regional boundaries to allow states to work together in partnership.

Deal with Invasive Species, Pests, and Pathogens

Exotic species can impact all stages of forest development and could have significant impact on older forests in the region. If nothing is done, they could devastate older forests within the next 20 to 50 years. A multi-state approach to regulation, research, monitoring, and control is needed.

Control efforts for exotic species should focus on the most dangerous pests, but that isn't happening today. Two exotic pests – the hemlock woolly adelgid and the Asian long-horned beetle – could devastate the remaining OG hemlock-hardwood forests. The group of experts felt that more attention should be focused on these pests and less on the gypsy moth, which is a less serious threat to forests but is widely regarded as a public nuisance. The public demands that gypsy moths be controlled because they cause highly visible damage in urban neighborhoods. This demand should be changed with education that focuses on older forests that are at much greater risk from the hemlock woolly adelgid and the Asian long-horned beetle.

Deer are another major threat to OG recovery and restoration. High deer populations affect hemlock, white cedar, yellow birch, maple, and white pine regeneration (Chapter 1, pages 14 and 27). Hunting is on the decline in the Lake States, and any effort to encourage hunting access in the forest could bring more invasive plants and pests from the use of ATVs. A publicly funded bounty system might work to control deer, wild boar, and other invasive species.

Biotechnology techniques, tree breeding, or inserting resistant genes into susceptible species should be considered. Such approaches are effective with American chestnut and may be better than waiting and hoping for the best.

Reintroduce Fire

Fire is needed to maintain pine and oak forests, but there are major social and economic constraints. Social attitudes about fire need to be changed with outreach and education. There's a lack of ecological understanding about the role of fire in the region's forests. Experiments comparing the effects of fire could help resolve these concerns. Agencies need to make a commitment to personnel and resources for the job, because fire is an important tool in the effort to provide a diverse complex forest landscape across the region.

Restore Complexity

To protect OG, land managers should focus on restoring complexity to the entire forested landscape using the tools, techniques, and principles of ecological forestry such as:

- including biological legacies in harvest prescriptions (Chapter 1, page 44). For example, retain a hardwood component in a conifer-dominated stand, retain both commercial and non-commercial species, and retain species with special abilities, such as nitrogen-fixing plants. Retain some live trees across one or more rotations, allowing long-lived species to live out their natural life span. In appropriate locations, reintroduce missing or depleted species such as eastern white pine (Chapter 1, pages 27-29). Use these techniques in both even-aged harvest practices and in prescriptions for multi-cohort stands subject to tree- or gap-based disturbance regimes, such as OG northern hardwood ecosystems (Chapter 1, page 18). Use marking guidelines that include goals for maintaining old and large trees and their snags and large down logs as part of the stand.
- mimicking natural stand development processes using intermediate treatments that create, restore, and maintain structural complexity. For example, thinning can promote development of large trees, snags, and large down logs. Planting, seeding and protecting established populations of eastern white pine can introduce and conserve stand composition diversity. Prescribed fire and other site preparation or control methods can be used to establish certain species. Timber stand improvement can be used to encourage yellow birch and white pine saplings. Appropriate thinning from below can speed development of large-diameter high quality trees. Variable density thinning (Chapter 1, page 47) mimics small-scale disturbance or gap-formation, contributing to greater stand structure.
- extending rotations to allow older cohorts to develop. Commercial stands often lack legacy structures and tree species diversity because short rotations exclude shade tolerant species from establishing and growing into intermediate or co-dominant positions in the canopy. By extending rotations, these natural stand components can be integrated into commercial forests.

Provide New Silvicultural Guides

Lake States foresters currently use silvicultural guides that concentrate on timber growth and yield, but they need information focused on ecosystem sustainability. Early research results are available to help foresters understand forest dynamics, but they must be presented in a form that working foresters can use on the ground. Demonstration sites are needed to validate these strategies.

Reform State Forest Laws

To encourage OG restoration on private lands, Managed Forest Law (MFL) programs in the region should be reformed. Originally developed to increase reforestation, provide a continuous timber supply, and allow public access to forestlands, these programs do not encourage OG restoration and protection. In exchange for developing a forest management plan for their property, landowners are given a tax break that increases if the landowner allows public access for hunting. Currently, MFL allows only 20 percent of a forest to be classified as "nonproductive forest lands" – a category that includes all values other than traditional sustained-yield forestry. The percentage of forest classified as nonproductive should be changed to 50 percent to allow for restoration and protection of older trees. Extending the MFL contract length beyond 20 years would encourage ecological values and make it more difficult to back out of the programs. Requiring owners to give 10 years advance notice would discourage landowners from selling in order to cash in on a real estate boom. Other MFL changes are needed to encourage cross-boundary cooperation and allow multiple landowners to coordinate forest plans that have a landscape emphasis. A single forest plan would simplify management and encourage local landowners to collaborate on harvests and management plans.

In the Lake States, a lack of regional policy, social agreement, agency capacity, financial resources, and tested silvicultural techniques hinders the conservation of older forests. However, the strategies developed by the NCSSF-sponsored group of experts and described here offer a framework to overcome these obstacles and achieve that goal.

Julius Ariail

FIGURE 4.16 **Fire plays an important role in forests of the Southeast Coastal Plain. Longleaf pine forests occupy the upper end of the fire-frequency continuum with an understory fire frequency of approximately 1-4 years.**

WHAT DO WE KNOW ABOUT OG IN THE SOUTHEASTERN COASTAL PLAIN?

Shaped by humans for thousands of years, older forests in the Southeastern Coastal Plain have influenced the culture, economic development, and ecology of the region. NCSSF-sponsored researchers chose to focus on two OG forests at opposite ends of the fire-frequency continuum – longleaf pine and bottomland hardwoods (Figures 4.16 and 4.17).

Historically, longleaf pine dominated uplands in much of the Southeastern Coastal Plain and provided a conduit for frequent fire into neighboring forests (Chapter 1, page 35). In contrast, bottomland hardwood and cypress-tupelo forests experienced the lowest fire frequency in the Southeast. What complicates the story of these two OG forests is that both produce valuable wood products and are located in a landscape dominated by private land. Any management strategy that encourages older longleaf and bottomland hardwood forests must recognize these economic realities if these forests are to be sustained in ways that serve conservation (more about this below).

Gary Boyd

FIGURE 4.17 **Bottomland hardwoods and cypress-tupelo forests represent the low end of the fire-frequency continuum with an understory fire frequency of approximately 3-100 years.**

What's the Current Condition and Extent?

OG forest inventory data for the entire Southeast is rudimentary, but 424 sites in 10 southeastern states (Virginia, N. Carolina, S. Carolina, Georgia, Florida, Alabama, Mississippi, Louisiana, Arkansas and Texas) have been identified. They represent an estimated 274,000 hectares (677,000 acres), or approximately 0.5 percent of the total forest area in the Southeast. Much of this total is located in the Appalachian Mountains – not the Coastal Plain.

Specifically for the Coastal Plain, OG data identify 67 cypress/tupelo and bottomland hardwood sites, located primarily on public ownerships (61 percent). Their location along the major rivers of the Southeast made them susceptible to extensive harvesting in the late 19th and early 20th centuries. In Louisiana alone, 51 percent of the acreage of forested wetlands at the time of European colonization was eliminated by 1974. Almost all forested wetlands and bottomland hardwoods have been harvested at least once since the 19th century.

Data on OG longleaf pine in the Coastal Plain indicates a total of approximately 12,355 acres (5,000 hectares). This represents 0.013 percent of the original historical area of 91.9 million acres (37.2 million hectares) of longleaf and longleaf-oak forests. Longleaf pine coverage at the time of European settlement was estimated to be 60 percent of the upland forest area in the coastal plains. Today, there are only 29 well-known OG longleaf pine sites (Chapter 1, page 30). Like the bottomland hardwoods, most are in public ownership (74 percent), and only one of the tracts is more than 1,000 acres.

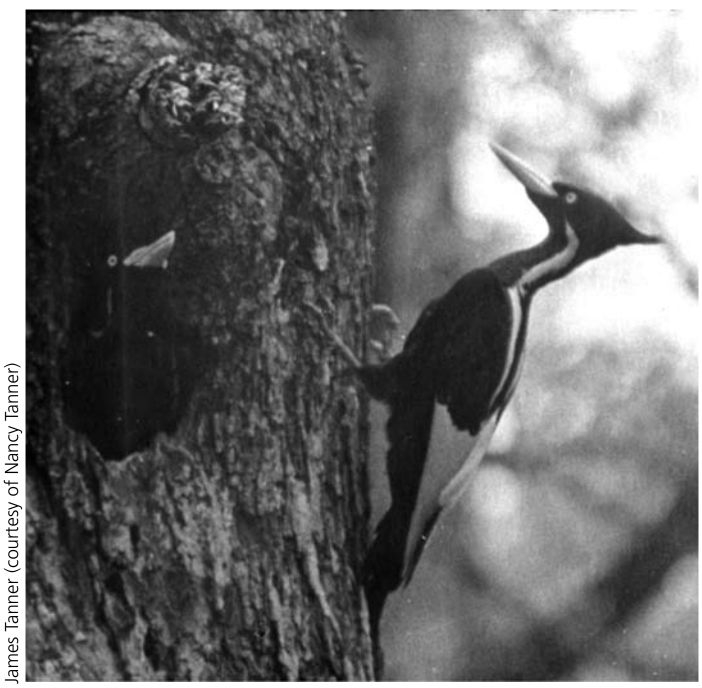
Researchers stress that even with this dramatic and nearly complete loss of older bottomland and longleaf pine forests from the landscape, these small remnant stands still support critically important components of biodiversity.

Are There Old-growth Adapted Species?

Almost two-thirds of all species of concern in the Southeast Coastal Plain (those that are in danger of extinction, threatened to become endangered, or are rare on the landscape) make their preferred home in mature longleaf pine forests that have been frequently burned for a long time. Two endangered woodpeckers – the red-cockaded woodpecker (Figure 4.18) and the recently rediscovered ivory-billed woodpecker (Figure 4.19) – have drawn attention to OG in the Coastal Plain. Other unusual plant and animal species combinations contribute overall species richness and unique biological diversity of these OG forests.

Todd Engstrom/CLO

FIGURE 4.18
The red-cockaded woodpecker *(Picoides borealis)* depends on OG longleaf pine for cavities but often forages in younger nearby forests.



James Tanner (courtesy of Nancy Tanner)

James Tanner (courtesy of Nancy Tanner)

FIGURE 4.19 (ABOVE AND LEFT)
The ivory-billed woodpecker *(Campephilus principalis)*, rediscovered in the Big Woods of Arkansas after disappearing for 70 years. These historical photos, two of the few available, were taken in 1938 in Singer Tract, Louisiana. The photo above is an adult male with a female peering out the cavity entrance. Left is a rare color photo (zoom lenses were not available in 1938). Researchers are trying to gather current photographic evidence.

What do we know about OG in the Southeastern Coastal Plain?

Even though OG longleaf pine and bottomland hardwood forests are scarce and have been fragmented – putting some plants and animals at the brink of extinction – researchers identify numerous characteristics that are valuable to their unique biodiversity.

- **Older large diameter legacy trees in the canopy.** The heartwood of pines older than 100 years provides the structure necessary for the endangered red-cockaded woodpecker (RCW). These birds excavate heartwood for nesting and roosting cavities (Figure 4.20). They prefer to forage for insects on the largest, oldest trees available. The old trees offer cavities for roosting and den sites for many other birds, mammals, reptiles, amphibians, and invertebrates. In bottomland hardwood forests, more than 50 species of old trees provide for an even greater diversity of arthropods (insects, arachnids, centipedes, and crustaceans). With age, the trees develop large dead branches and tops that provide additional wildlife habitat. The ivory-billed woodpecker appears to require large old trees for its cavities and dead trees or parts of trees for foraging.

Julius Ariail

FIGURE 4.20 Cavity in longleaf pine.

- **Dead and dying large-diameter trees.** Snags and large down logs provide cavities for foraging and escape cover for animals. Many bird species use stumpholes and down logs for protection from predators. Bird abundance depends on snags and down wood In bottomland hardwoods, dead and dying wood supplies beetle larvae for the ivory-billed woodpecker and basking habitat for many reptiles. Amphibians, reptiles, and mammals also use stumps.
- **Intact ground cover.** Undisturbed, frequently burned ground cover in longleaf pine ecosystems (Figure 4.21) supports higher species diversity than historically plowed or grazed understories. Wiregrass *(Aristida stricta)* dominated ground cover is most important.
- **A history of appropriate disturbance** (either a fire regime for uplands or flooding regime in bottomlands). Frequent fire in uplands results in more light on the forest floor and encourages understory diversity. Fire also controls the abundance of arthropods, particularly ants, the primary diet of RCW. In bottomland hardwood understories, where regular flooding and scouring make herbs sparser, there is still a variety of rare and endemic plant life.
- **Minimal forest area and fragmentation.** Depending on habitat quality, a small RCW population (20 clusters) requires approximately 800 to 2000 hectares of upland pine forest. Approximately 40 hectares of fire-maintained habitat is necessary to sustain 50 gopher tortoises (Chapter 1, page 37), a minimal viable population size based on home ranges. The home range for a single male Sherman's fox squirrel is approximately 40 hectares of mature pines or mixed pine and hardwood stands. The area necessary to support a viable population of the rediscovered ivory-billed woodpecker is open to question. Historically, individual territories were as large as 17 square miles.
- **The connection between pine uplands and hardwood wetlands.** Pine uplands provide a corridor for fire into hardwood wetlands. The Apalachicola River area in Florida and the Altamaha River and Ochlockonee River areas in Georgia are places where upland and riparian OG occur together and where large-scale conservation could be developed.

Julius Ariail

FIGURE 4.21 Native grass cover and dead wood.

James H. Miller, USDA Forest Service, Bugwood.org

FIGURE 4.22 **The non-native plant kudzu *(Pueraria Montana (Lour.) Merr.)* is a climbing vine that grows over, smothers, and kills all other vegetation including trees. Native to Asia, it was introduced in America in 1876 and planted throughout the east in an attempt to control erosion.**

What are the Major Threats to OG in the Southeast?

Major threats include:

- **Improper fire regime** is the greatest management challenge to protecting upland OG pine forests on public lands. A 50-year accumulation of fuel has created unnatural conditions that can result in mortality of large trees from smoldering fires when prescribed burns are reintroduced into OG stands. The loss of fire, if mandated by clean air regulations, poses a major challenge to the restoration and maintenance of old longleaf pine stands.
- **Changes in hydrology** from levees, dams, and other river alterations threaten OG bottomland forest. Some no longer flood as often or as long as they did historically, while others flood more frequently. The result is altered forest plant communities.
- **Non-native invasive species** in bottomland hardwoods have caused understory problems (Figure 4.22). Examples include Chinese privet *(Ligustrum sinense)*, Chinese tallow *(Sapium sebiferum)*, and chinaberry *(Melia azedarach)*. Invasive animal species include zebra mussels *(Dreissena polymorpha)*, nutria *(Myocastor coypus)*, and wild hogs *(Sus scrofa)*.
- **Development** across the Southeast interferes with the need for frequent fire in longleaf pine and demands flood control in bottomland hardwoods. Development also contributes to invasive exotic infestations.
- **Lack of a complete inventory** leaves managers of public parks, forests, and preserves unaware of the presence of OG resources.
- **Lack of knowledge** about OG has led to a failure to appreciate forests that contain OG characteristics or forests that have scattered patches of OG. OG features in younger forests should also be protected.
- **There is no mandate** to protect OG on military or national forest lands unless endangered species are present.

How Much OG is Needed to Maintain Biodiversity?

Researchers don't know the answer to this question, but they do support a large increase in the area of these forests, saying it would greatly enhance biodiversity in the region. Setting an acreage target is probably not as important as acknowledging that the current area is completely inadequate to maintain the range of potential biodiversity in the region. Any efforts to increase the acreage by organizations like the Longleaf Alliance should be supported to the greatest extent possible.

How Does Society View OG in the Southeast?

Social values derived from these forests include their role in the heritage and identity of the Southeast and their usefulness as scientific benchmarks for biodiversity. Their economic values include recreational opportunities such as hunting and ecotourism, their unique timber products (heartwood), and the clean air and water they generate.

HOW CAN KNOWLEDGE OF OG BE USED IN MANAGEMENT STRATEGIES ON PUBLIC AND PRIVATE FORESTLANDS?

Because OG remnants are so rare, small, and fragmented, an OG conservation strategy in the Southeast must first preserve and manage remaining OG stands. Any stands with OG characteristics that might not be considered OG, but that provide rare and important habitat, also need to be identified. In pine uplands these include:

- stands with intact understory plant communities, because these communities may be the oldest biological parts of the forest

- stands with a long history of frequent burning, because of their open canopy and herb communities dominated by grass, their scattered old individual trees that provide structure, and their snags and large down logs.

In bottomland forests these include:

- stands with open canopy structure and a few scattered old, large trees
- stands with differences in tree vigor, including snags and trees that can supply large down branches.

Managing OG in the southeast is especially difficult because there is so little public land. Even on large public-land parcels, OG remnants are small, isolated, and often surrounded by short-rotation forestry, incompatible recreational activities, or military testing and training facilities. In other locations, agricultural lands and suburban development may border OG. Even with these challenges and the threats described above, researchers have developed creative strategies to enhance OG. They include:

- develop a complete inventory of OG forests on public and conservation lands, while at the same time searching for the ivory-billed woodpecker
- protect OG remnants on public lands by practicing long-rotation forestry on bordering lands
- help managers recognize gradations of OG so they can prioritize restoration efforts. Especially important is helping managers recognize undisturbed OG understories
- test and practice burning prescriptions for long-unburned OG stands on public lands to avoid excessive tree mortality from inappropriate prescribed fire
- restore river hydrology wherever possible, returning channeled rivers to their original meanders and timing dam releases to mimic historical patterns
- increase education and training for public managers in the burning of OG longleaf pine stands, the practice of ecological forestry, and long-rotation timber management
- develop guidelines for land managers that promote OG conditions
- develop partnerships among agencies with OG that encourage information sharing about OG restoration and management
- inform the public and conservation communities about activities that may impact OG resources on military lands. These lands, such as Eglin Air Force Base in the Florida Panhandle, contain more than half of all remnant OG longleaf pine stands
- establish cooperation among states, federal agencies, and private organizations to acquire future OG properties as timber companies sell off land holdings.

Although OG is located mostly on public lands, there is some high quality OG on private forestlands. However, changes in the forest products industry and development pressures are causing dramatic shifts in land use and ownership patterns. These trends could severely impact forest conservation if the federal Farm Bill isn't changed. Researchers identified the following problems with the current Farm Bill.

- There are no incentive programs helping landowners retain older forests (Chapter 9, page 163).
- There is no focus on healthy forests including the use of prescribed fire and native groundcover.
- There is no transparent, consistent way to prioritize recipients of Farm Bill incentives.
- There are no priorities for protection of bottomland OG forests.
- Farm Bill programs are cumbersome and difficult to work with.

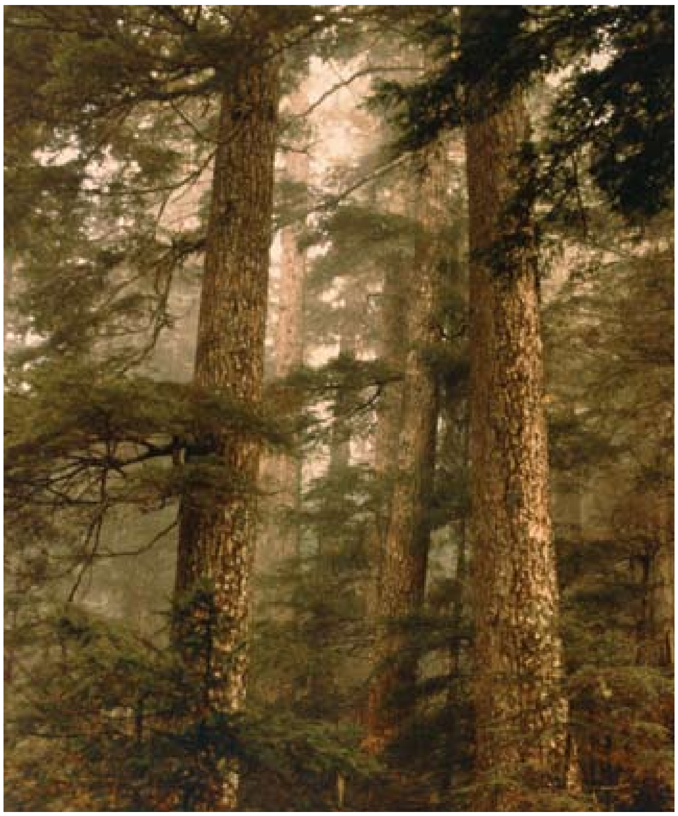
Among the suggested changes to existing Farm Bill programs are the following:

- encourage long-rotation management of longleaf pine acreage in Conservation Reserve Program (CRP) plantings by adding ground-cover restoration and long-rotation incentive payments, benefiting both regional game and non-game species
- prioritize Farm Bill dollars to parts of the landscape that provide the greatest benefit, such as buffering conservation lands and watershed protection
- develop education and outreach efforts to help identify and educate private landowners whose lands fall within priority conservation areas and help them enroll their property
- establish an upland reserve program to provide payment to private landowners who have significant forested habitat, streamside buffers, and high-quality native ecosystems.

Efforts to conserve OG in the Southeast are burdened with obstacles, some similar to those in other regions and others unique. Researchers have identified short-term strategies that require immediate attention and more long-term policies that will require public dialogue and agreement.

WHAT DO WE KNOW ABOUT OG IN THE PACIFIC NORTHWEST?

The Pacific Northwest (PNW) has more OG than any other temperate forest region in the world, and it offers an opportunity to learn how to maintain large areas of forest with high natural values in a landscape dominated by development. Compared to other regions, the PNW has a long history of OG science, policy, management, and politics. As early as the 1970s, scientists identified the biological importance of PNW OG. Policy debate began in the 1980s



Jon Martin

FIGURE 4.23 **OG western hemlock forest. In some cases, these forests can produce more water than young forests because their tall canopies capture and condense water from fog.**

R. Pabst

FIGURE 4.24 **OG Oregon white oak**

Tom Spies

FIGURE 4.25 **Open OG ponderosa pine forest (Eastern Oregon Cascade Mountains). Before fire suppression policy, the history of frequent surface fire made these forests relatively resistant to fire damage due to their tall isolated canopies and thick bark.**

Tom Spies

FIGURE 4.26 **OG Douglas-fir with hemlock (Western Oregon Cascade Mountains). OG forests can store several times more carbon than young forests.**

with the threatened northern spotted owl. The debate expanded to include additional species and the "values" of OG ecosystems. Attempts to manage OG began with the Northwest Forest Plan in 1993 (Chapter 7, page 140). The social debate over OG raged throughout the 1990s, focusing on wild versus managed forests and forests as reservoirs of nature versus resources for humans. And despite the establishment of millions of acres of OG reserves on public lands, debate continues, and efforts to preserve, manage, and/or restore OG remain controversial (more about this below). Figures 4.23, 4.24, 4.25 and 4.26, are some of the different types of OG forest in the PNW.

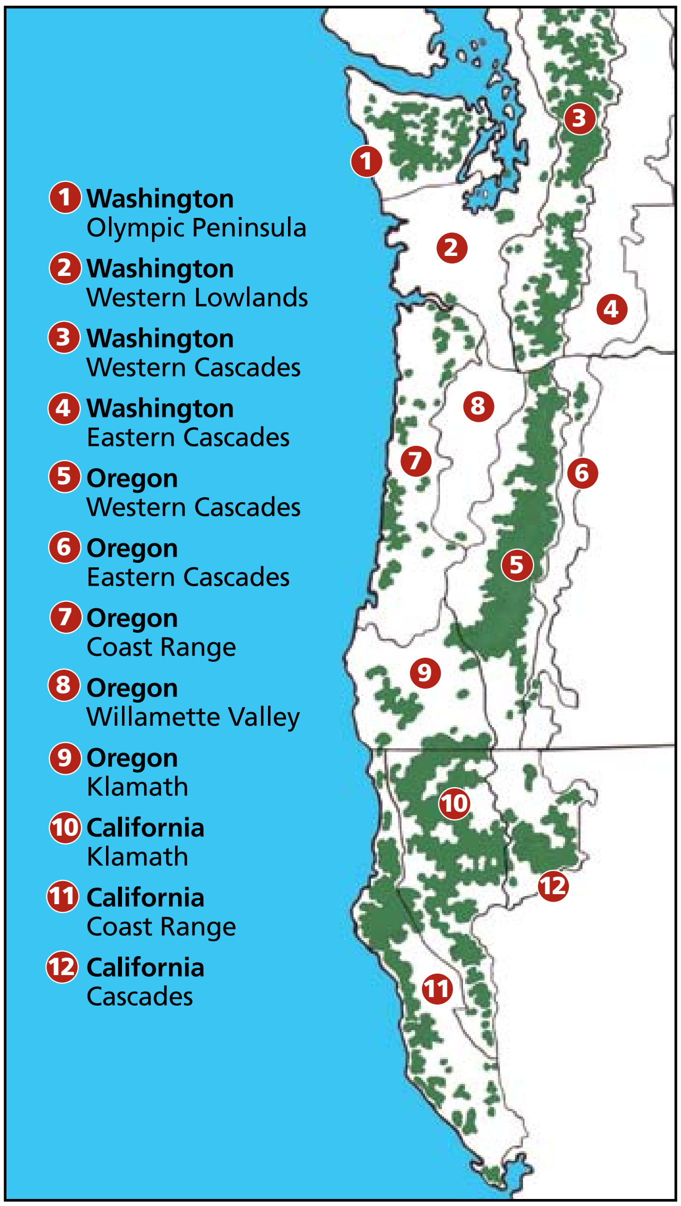


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FIGURE 4.27 Both medium and large older forest in the PNW are included in this map. The region is divided among twelve provinces, each with different ecological characteristics.

The general stages of Douglas-fir OG development illustrated at the start of this chapter (page 85) serve only as an example. Research has confirmed that forests can follow numerous pathways, and OG forests differ depending on their age, geographic location, and disturbance history. Even within the OG stage, disturbance continues to be a natural and important part of development. For example, fire suppression has resulted in a buildup of fuels in some PNW provinces (Figure 4.32), while in others fire suppression has had little or no impact on fuels because fuel loads are naturally high (more about this in Threats to PNW OG). Today's OG has developed from disturbances and climate conditions of the last thousand years. One unanswerable question when designing management strategies for PNW OG forests is whether or not their composition and structure can occur again under modern climate and disturbance regimes.

What's the Current Condition and Extent?

Figure 4.27 indicates the general locations of OG in the PNW within the range of the northern spotted owl. It's primarily concentrated west of the Cascade Mountains. **Across the region** (including western Oregon, Washington, and northern California), the area of older forest on all ownerships is estimated to be about 12.2 million acres (4.9 million hectares) out of a total area of 56.8 million acres (approximately 21 percent). Of that 12.2 million acres, an estimated 3.5 million acres (1.4 million hectares) (about 6 percent of the total) falls into the category of largest and most complex older forest (trees more than 30 inches in diameter with complex canopies). **Located on the region's federal land (24 million acres or 9.7 million hectares)** is most of the medium and large older forest (about 64 percent) and most of the largest and most complex older forest (77 percent). Of the 24 million acres of federal land, 7.87 million acres (3.2 million hectares) are older forest. Of the 7.87 million, 2.72 million acres (1.1 million hectares) are stands with trees larger than 30 inches dbh (diameter at breast height) and with complex canopies. **The remaining old forest** in the region is located on nonfederal lands, mostly state owned.

Compared to historical conditions, the amount of OG declined during the 20th century because of logging and wildfire. The decades-long practice of fire suppression also has contributed to the loss of some fire-dependent OG types (Provinces 9, 10, 4, 6, and 12). For example, historically the percentage of OG (more than 200 years old) in the Oregon Coast Range (province 7) was estimated to range between 25 and 75 percent of the area. The Coast Range was a mosaic of open area, young closed-canopy forest, and older stages; never a landscape completely covered by OG. Today, the amount of OG (forests containing 39.4 inch diameter trees and large down logs) is estimated to be approximately 1 percent of the Coast Range; the remainder is in the medium size class.

While it may be useful to know the percent range of historical OG in a province where conservation of native biodiversity is a major management goal, researchers concede that it may be impossible to reach those ranges in the future, given climate and disturbance regime change. An example is the difficulty of predicting the loss of OG to wildfire. Within just the last 10 years, the "overall loss" of older forest on federal land due to stand-replacement natural disturbances such as fire was 0.18 percent annually, versus a predicted amount of 0.25 percent. However, in the dry provinces (9 and 10), rates of loss of older forest to wildfire were much higher than the overall average (more about this under "Threats" below). This points to the ecological differences between the provinces and the need for an OG fire-management strategy (more in strategy section).

Are There Old-growth Adapted Species?

The species described in figures 4.28, 4.29, 4.30 and 4.31 are adapted to older forests in the PNW and show a preference for them. While not confined to OG, they do use OG components (large standing live and dead trees). In addition, some other species are more abundant in OG than in younger forests – for example, woodpeckers are 10 times more abundant. Some salamanders that live only in large decaying logs are much more likely to be found in old forests than young forests. So the biodiversity value of OG can be traced to both its unique structures and the long time period that it has existed.

FIGURE 4.28 **The northern spotted owl *(Strix occidentalis)* shows a preference for older forest habitats even though it uses younger natural forests and some second-growth forests at low to mid elevations in western Washington and Oregon. In younger forests, the bird is often associated with remaining older forest patches.**

Al Levno

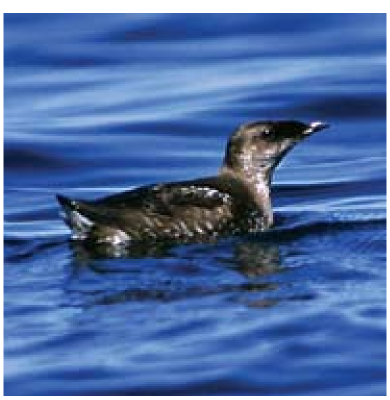

FIGURE 4.29 **The marbled murrelet *(Brachyramphus marmoratus)* nests in OG conifer forests within 30 miles of the pacific coast. It's a secretive, robin-sized bird, with sooty brown to black plumage. In winter, the bird has a white belly.**

Martin Raphael

FIGURE 4.30 **The red tree vole *(Arborimis longicaudus)* is found in dense, moist conifer forests with a sufficient number of Douglas-fir trees. It spends its entire life in the tree canopy, feeding almost exclusively on Douglas-fir needles. The vole is bright orange-red to cinnamon on top and silvery gray underneath, with a tail more than 50 percent of its body length. It's the prey of spotted and other owls.**

Eric Forsman

FIGURE 4.31 **The Johnson's hairstreak butterfly *(Callophrys johnsoni)* requires mid- to low-elevation OG forests similar to spotted owl habitat. This medium-sized butterfly has chestnut colored wings with a prominent white line following the curve of the wing about halfway out.**

Jeffrey C. Miller

More than 100 species of epiphytes (lichens, mosses) are found in OG canopies. Because they disperse, colonize, and grow slowly, they may occur in OG simply because enough time has elapsed since a major disturbance. The Lobaria lichen, an important nitrogen fixer (Chapter 7, page 142), is abundant in the canopy of older Douglas-fir forests. In one well studied older forest in Washington, 1 to 1.5 tons of lichens per acre were measured (half were nitrogen fixing lichens). This lichen/older forest interaction may be important to the centuries-long maintenance of OG.

What are the Major Threats to OG in the Pacific Northwest?

Threats differ depending on the OG province and include logging, wildfire, and insects and disease. Logging is a threat on lands outside the reserves. Wildfire and insects and disease are a threat in dry, fire-prone provinces.

The Logging Threat

Although logging of OG on federal lands has slowed in recent years, about 20 percent of the remaining OG on federal lands is open to logging. The Northwest Forest Plan allowed for logging in matrix lands, but little OG has been harvested over the first 10 years of the Plan. In addition, older forests on some state-owned lands are still eligible for harvest.

The Wildfire, Insect and Disease Threat

OG provinces reflect different disturbance regimes. For example, OG ponderosa pine (Figure 4.34) on dry sites has a relatively open understory that was maintained historically by frequent low to moderate intensity fire at intervals of less than 20 years. OG in wetter forests, such as western hemlock (Figure 4.23), has large accumulations of live and dead wood in the understory and has experienced stand-replacing fire disturbances every 100 to 400 years. Between these extremes are other OG forests that experience "mixed severity" fire regimes, where fire can range from low to high severity (Figure 4.32, left map).

The greatest threat to OG in dry provinces is fire suppression and the high severity wildfires that have resulted from that policy. In the 0-35 year frequency, low severity fire areas (Figure 4.32, right map), fire suppression has changed naturally open understories to far denser understories of small diameter conifers, making them susceptible to high severity wildfire. These fires result in the death of OG pine and Douglas-fir trees that probably survived the lower intensity fires of the past. Not only wildfire but insect and disease outbreaks that can kill old trees may be more common in these dense stands.

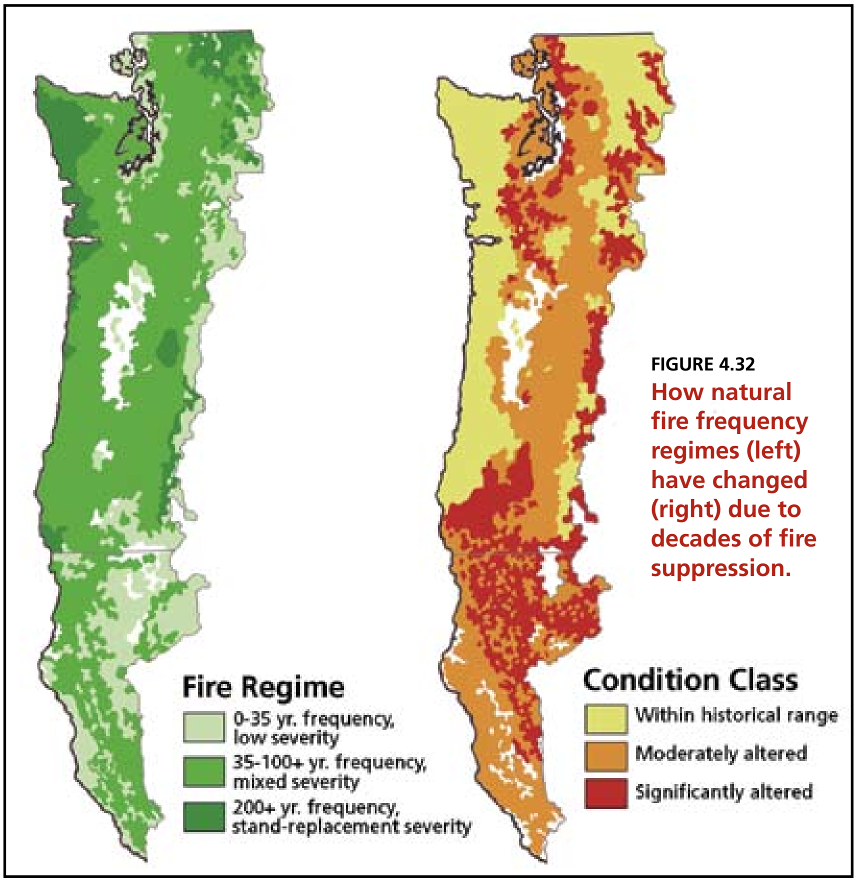

FIGURE 4.32
How natural fire frequency regimes (left) have changed (right) due to decades of fire suppression.

Modified and reproduced from USFS references

Understanding provincial variation is important for developing OG management strategies. While the management of existing OG reserves has been relatively passive since adoption of the Northwest Forest Plan, researchers recognize that active management, including fuel reduction and restoration, is needed in fire-dependent provinces to reduce OG losses to high-severity fires (Figures 4.33 and 4.34).

Where OG has been lost to wildfire in recent years, debate centers on post-wildfire management and salvage logging. For example, in the areas of the 2002 Biscuit Fire (Figures 4.35 and 4.36) in Provinces 9 and 10, the question is: what management activities are appropriate when OG burns (more about this below).

How Much OG is Needed to Maintain Biodiversity?

As with other OG regions, the answer to this question is more social than scientific. While science can inform the public-policy debate, it cannot resolve it. Science can help define OG, identify processes and stand-level practices to protect and produce more OG in the future, and clarify tradeoffs and offer alternatives for specific OG provinces. However, the "how much" question and other related ones must be answered in the social arena, for example:

- What types of OG management are socially acceptable?
- What long-term policies are appropriate?
- What are the economic implications of those policies?
- How will they be paid for?

While the region is relatively rich in OG, recent scientific assessments indicate that current amounts are much lower than desired. For example, the future target amount of older forest within the range of the northern spotted owl on federal land in Oregon and Washington is about 7.6 million acres. Currently, the amount is about 5 million acres. Estimates indicate that it will take more than 100 years to reach that desired level of old forest. However, the fact that most of the remaining OG is in large acreages on federal and state lands indicates good potential for strategies to conserve and restore OG.

How Does Society View OG in the Pacific Northwest?

OG in the PNW goes beyond technical scientific descriptions and involves other social issues including logging, recreation, the role of humans in nature, and the spiritual and aesthetic values of forests. To some, OG has become an icon that symbolizes wild, pristine, undisturbed nature, while to others it represents productive forests and timber harvesting. From the standpoint of timber value, one acre of OG could be worth $25,000, and a 50-acre clear cut worth $1.2 million (assuming 50,000 bdft/acre and $500/mbft). For those who see OG as an icon, it represents places that are unaltered by humans, where nature lives in "balance." However, this concept of balance is not really consistent with what research has learned about the role of disturbance in OG forests, especially in fire-dependent OG (more detail in fire management below).

Public opinion surveys in the PNW indicate a high recognition of the term old-growth (even if the public doesn't exactly know what it is) and a high value placed on its conservation. One study found that the public preferred that one-third of the landscape be protected to conserve OG forests. That would be a challenging goal for forest managers.

Years of debate have produced many OG interest groups in the PNW, each with different expectations and ideas. The result has been OG management paralysis, and the Northwest Forest Plan is a perfect example. It allows for a balanced approach, including the harvest of OG outside of reserves, but after more than 10 years of executing the plan, little OG has been cut. Instead, OG has been almost completely protected. The result has been more controversy, with some claiming the Plan didn't provide what was originally promised.

In recent years, "new sources" of knowledge have added to the OG debate. No longer are government land-management agencies and academic/research institutions viewed as the sole sources of information and technical expertise about OG forests. Today, non-governmental scientists with access to satellite imagery and technical information resources compete in the marketplace of public opinion. The Internet has changed the way the public gets its information and whose science they believe. Technology and knowledge aren't confined to established institutions.

K. Norman Johnson

FIGURE 4.33 **In fire-dependent forests in the eastern Cascade Mountains (Provinces 4 and 6), decades of fire suppression have created high-severity wildfire conditions. Without active management, including thinning (Figure 4.34) and prescribed fire, OG Ponderosa pine forests are subject to lethal fire.**

K. Norman Johnson

FIGURE 4.34 **After thinning, fire-dependent OG ponderosa pine forests will require frequent low-severity prescribed fire.**

Tom Spies

FIGURE 4.36 **This patchy pattern of mortality after the 2002 Biscuit Fire is typical of province 9. Satellite imagery showed approximately 45 percent of the fire area was unburned or had low vegetation mortality, 25 percent moderate and 30 percent severe mortality immediately after the fire.**

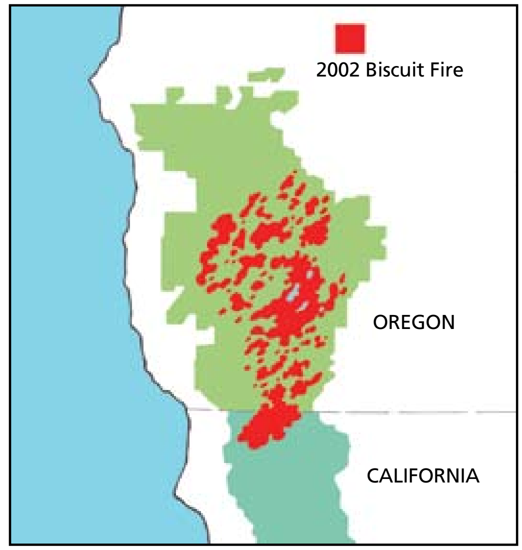

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FIGURE 4.35 **The Biscuit Fire (2002) was a stand-replacing wildfire that clearly demonstrated the fire risk in OG and focused attention on the need for an OG fire-management strategy.**

HOW CAN KNOWLEDGE OF OG BE USED IN MANAGEMENT STRATEGIES ON PUBLIC AND PRIVATE FORESTLANDS?

Despite its millions of OG acres, the region is faced with the fact that OG must be managed, because just like other stages of forest development, it is part of a dynamic system. Regardless of the notion that it's "in balance," OG is constantly in the process of changing to another stage. Today's OG may become the new young forest of the future, while mature forests today become future OG. Therefore, the region's OG management comes down to four major issues (described below):

- fire management
- developing OG characteristics in forest plantations
- landscape-scale planning and OG
- OG protection policies.

Fire Management

Designating OG reserves provides no protection against loss from high-severity fire and/or the gradual loss of ecological complexity from the suppression of patchy fires, which were important in the development of fire-dependent OG. In Provinces 9 and 10 for example, fires were more frequent and usually low to mixed severity before fire suppression policy changed them. Today, reducing the buildup of understory density and restoring frequent surface fires are crucial or this OG will be lost in the coming decades to more insect outbreaks, disease, and high-severity fires. A recent example is the 2002 Biscuit fire that burned nearly 500,000 acres (Figure 4.35 and 4.36).

Farther north in western Oregon and Washington (Provinces 3 and 5), the fire regime is a combination of surface and crown fires. OG in these areas is also at risk to wildfire, although fires were less frequent than in Province 9. Researchers believe that while the last century of fire suppression has had less impact on OG in Provinces 3 and 5, if suppression continues for another half century or more, changes will also occur in these OG forests, so active management is needed there too.

In the coastal OG of Oregon and Washington where the climate is wetter (Provinces 1, 2 and 7), fires were infrequent, occurring at 100- to 400-year intervals, but often more intense. Because these forests are more productive, a century of fire suppression has not changed fuel levels as much. However, the urban development now located close to these forests makes it impossible to allow fire back into these forests. Still, fire management is needed in the urban-wildland interface of these provinces.

The most urgent need for an OG fire-management strategy is in fire-dependent provinces 4 and 6. The most logical strategy recommended by researchers is active management, including mechanical thinning treatments and prescribed fire.

How to Develop OG Characteristics in Forest Plantations

Plantation forests, originally established on public lands for timber production, are now expected to develop into future OG. This goal is complicated by the mix of planted species and the densities of these stands. However, what's been learned about OG forest development may be useful in managing plantations. Research supports the idea that plantation forests can be put on a pathway toward complex OG ecosystems. That restoration includes techniques like variable-density thinning (Chapter 1, pages 47-48) and similar practices designed to create structural complexity. But this kind of restoration will require trained workers, adaptive management (Chapter 8), and financial resources. Plantation restoration won't happen if it's too costly or impractical.

With both plantations and OG forests dependent on fire and both requiring silvicultural techniques that either substitute for fire or include prescribed fire, managers must face the fact that this type of management may not generate economically viable products. A new way of valuing non-commodity goods and services will be needed along with new ways of investing in forests. Both short- and long-term funding will be needed. Among the new ways of generating income may be fees from recreation, carbon sequestration markets (evidence shows that OG forests store carbon more efficiently than was once thought), and use of stewardship contracts. All may be part of getting restoration work done in plantations and older forests.

Landscape-scale Planning and OG

Sustainable OG forests will require regional planning over long periods of time. With the help of landscape-scale planning (Chapter 7), managers can see what it will take to maintain the diverse forest conditions needed for all habitats and ecological functions. Landscape planning models like the Oregon CLAMS model (Chapter 7, page 140), predict that under today's federal policies, mature forests (tomorrow's future OG), will decline over the long-term. That decline, when viewed across a landscape of national forests and private timberlands, will leave two predominant age classes – old forests and young plantations. The old forests will be located primarily on federal lands with young plantations on private and federal lands. Intermediate age classes will be very scarce.

This scenario raises such issues as how much landscape diversity nature will create through fire and other disturbances and how much landscape diversity will be created by the use of silvicultural techniques where firefighting reduces the number of wildfires. The answer to questions about how to maintain future diversity in all forest development stages across the region will come from a combination of active management and natural disturbance. Just as historical fire regimes differed among OG provinces, so will decisions about the urgency to apply silvicultural management techniques differ among provinces.

OG Protection Policies

Current federal policies are focused on protecting the region's OG, but even protected OG forests will change. Natural disturbances, fire suppression, invasive species, insect and disease outbreaks, forest succession, and changing climate will all contribute to that change. Managers have to decide whether or not these changes are compatible with OG goals. Some of them may not be desirable, and managers may need to take action. Those actions will depend on the variability among provinces and the role of fire in creating complex ecosystems at stand and landscape levels.

All of this raises the question of whether or not timber harvesting is appropriate in OG after stand-replacement disturbances. Research indicates that when OG is subject to high-severity fire, 100 to 200 years may elapse before the area returns to old forest conditions. During that time, the ecological influence of OG does not end with the death of trees. OG legacies, including dead trees, surviving live trees, and associated organisms carry over into the new forest and can persist for many decades as the young forest develops. Researchers find significant amounts of dead wood in post-fire stands 100 years after fire. Of course, the amount and duration of this legacy wood varies with species, climate, and disturbance regimes, but what's important is the recognition that developmental stages are connected through the surviving and decomposing components of previous stages.

The relative abundance of OG in the PNW and the fact that it doesn't exist anywhere else in the world's temperate forests were pointed out in the opening of this section. However, as NCSSF-sponsored researchers have described, that abundance carries with it the need to maintain those large areas of forest with high natural values in a landscape dominated by development. That won't be easy.

WHAT DO WE KNOW ABOUT OG IN THE SOUTHWEST?

The Southwest has three major forest types: mixed conifer forests, ponderosa pine, and pinyon-juniper woodlands (Chapter 1, page 49-50). The OG stage of each forest is pictured (Figures 4.37, 4.38, 4.39 and 4.40), but this section will focus on the most widespread type, ponderosa pine.

While it's true that ponderosa forests have old trees, NCSSF-sponsored researchers in the Southwest point out that it's not just old trees that make an OG ponderosa pine forest. OG definitions from other regions are really not relevant to the Southwest. That's because under natural conditions (without overgrazing, logging, and fire suppression), frequent low-intensity fires create an OG landscape that is patchy, almost park-like, with a variety of openings and groups of trees that vary in size from tenths of an acre to several acres (Figure 4.38). These forests have a rich understory, depending on whether it is near clumps of big trees, in small openings between clumps, or in large meadows. In many locations, ponderosa grows with Gambel oak *(Quercus gambelii)*, the second most abundant woody shrub in the ecosystem (Figure 4.40).

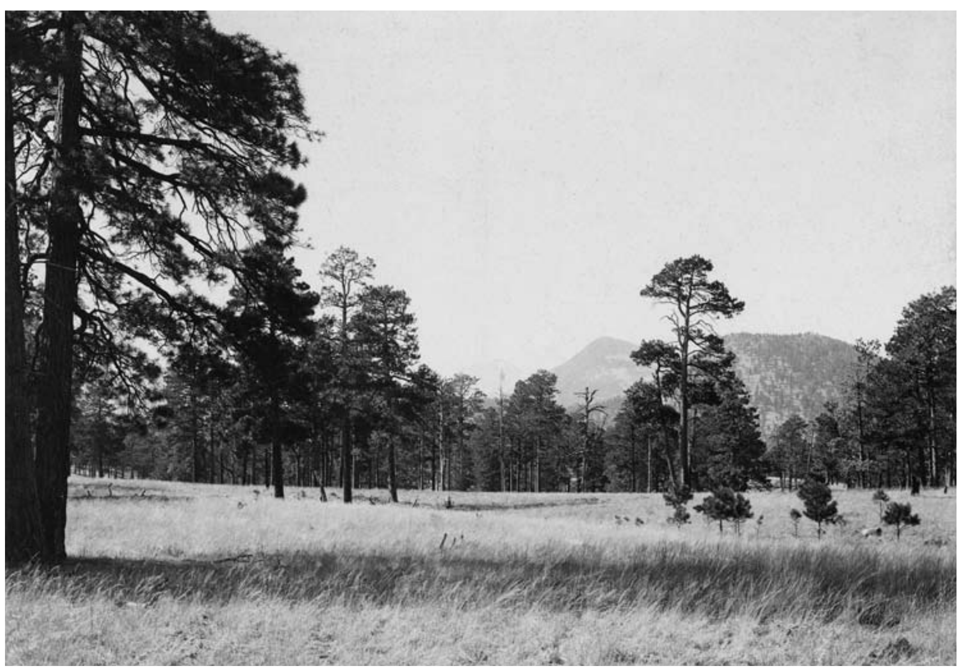
So while natural frequent-fire ponderosa pine never takes on the appearance common to OG in the PNW, after decades of fire suppression some older ponderosa pine forests do have an unnatural appearance, similar to the PNW (Figure 4.33).

The natural OG ponderosa pine forest is a plant community adapted to low-intensity frequent fire. Ponderosa pines, along with other western long-needled pines, not only tolerate this disturbance regime, they rely on it for long-term survival. The following adaptations make ponderosa pine perfectly suited:

- thick, heat-protected buds
- needle bundles that open into a loose arrangement, unfavorable to combustion
- foliage with high moisture content
- tree stems resistant to scorching
- deep roots.

Dave Egan, Northern Arizona University

FIGURE 4.37 **This OG mixed-conifer high-elevation forest includes ponderosa pine, Douglas-fir, white fir, limber pine and blue spruce. As a result of fire suppression, ponderosa, once co-dominant in many of these stands, has been replaced by the other species.**



Dave Egan, Northern Arizona University

FIGURE 4.38 **Historically, ponderosa pine OG forests were a mixed landscape of trees, some hundreds of years old, with grassy openings and maintained by frequent low-intensity fire. In some locations, depending on the soils, there were clumps of old fire-resistant trees with highly diverse understories. In other locations, trees had higher densities, but nowhere near the density of today's ponderosa pine forests (Figure 4.41).**

Dave Egan, Northern Arizona University

FIGURE 4.39 The fire history of pinyon-juniper forests is not well known, but evidence suggests that the fire regime consisted of infrequent, high-severity fires.

Dave Egan, Northern Arizona University

FIGURE 4.40 A group of older Gambel oak (right) in a mixed stand with ponderosa pine after a prescribed fire.

Along with climate and fire, other factors shape the structure and function of ponderosa pine ecosystems: variable soils, bark beetles, woodpeckers, mycorrhizal root fungi (Chapter 6, page 133), humans, mistletoe, cankers, and rust. They all interact to produce what was historically a heterogeneous landscape of grassy openings and old trees (Figure 4.38). Today, remaining OG trees are important because they have survived hundreds of years of environmental fluctuation, and their presence contributes to genetic diversity.

Historical fire suppression has been detrimental to these forests, eventually destroying the OG. But the reintroduction of fire into these degraded OG forests, along with appropriate thinning, can restore these ecosystems (more about this below).

The cumulative effects of livestock grazing, tree harvesting, fire suppression, and climate change have disrupted and reduced the health and resiliency of these forests. The changes include:

- a shift in tree density to shade-tolerant species and younger, smaller ponderosa trees
- replacement of grassy and herbaceous understories with woody and/or invasive species
- decrease in wildlife habitat along with decreased plant and animal diversity
- increased runoff, erosion, and sedimentation.

Without landscape-scale restoration efforts, researchers agree there will be more increasingly severe, stand-replacing fires, along with increased non-native invasive plants, increased tree loss to insects and pathogens, and decreased wildlife habitat.

George Sheppard, NAU Cline Library, Spepial Collections and Archives

FIGURE 4.41 **After decades of fire suppression, these forests have undergone major changes in structure, composition, fire frequency, fire intensity and severity, and landscape pattern. As a result, unnatural severe fire regimes threaten to destroy, rather than renew, the pine ecosystem (more details below).**

What's the Current Condition and Extent?

Ponderosa pine forests stretch across parts of southern Colorado and Utah, northern Arizona and New Mexico, southeastern Nevada, and western Texas. However, the best data available on ownership come from New Mexico and Arizona.

In New Mexico, the USDA Forest Service oversees 1.8 million acres or 64 percent of the ponderosa pine forest. Other public agencies manage 172,000 acres, and family forest owners (including Native American tribes) own 798,000 acres. The majority of this acreage (2.4 million acres) is in non-reserved status (available for management for wood production).

In Arizona there are approximately 3 million acres of ponderosa pine. The USDA Forest Service oversees approximately 2 million acres. Other public agencies manage 122,000 acres, and family forest owners (including Native American tribes) own 851,000 acres. In Arizona, 6 percent of the total is protected from harvesting for commercial wood production.

How much is OG? In southern Colorado and New Mexico, less than 5 percent of ponderosa pine stands are classified as OG. Estimates in the inter-mountain Southwest indicate OG ponderosa pine has declined 85 to 90 percent during the last century. The amount of OG ponderosa today is unknown, partly because there's no agreement about the definition of OG in the southwest. But however it is defined, OG is a very small percentage of the existing ponderosa pine ecosystem in the Southwest.

Tom Munson

FIGURE 4.42 **The pygmy nuthatch *(Sitta pygmaea)*, a cavity nester, relies on OG structures such as large trees.**

FIGURE 4.43 **The Abert's squirrel *(Sciurus aberti)* needs an entire patch of OG trees to move easily and find food.**
Photo: J.G. Hall, Mammal Images Library (American Society of Mammologists)

Rick Kline/CLO

FIGURE 4.44 **The northern goshawk *(Accipiter gentiles)* requires OG conditions in a landscape matrix that contains a wide variety of habitats.**

Are there Old-growth Adapted Species?

Researchers have identified 135 vertebrates that rely on frequent-fire OG ponderosa pine forests. Some species are year-round residents, others use these forests for breeding, wintering or migration (Figures 4.42, 4.43 and 4.44).

Some species that rely on OG also play a reverse role, providing a service to other species. For example, hairy woodpecker *(Picoides villosus)* populations expand after fire, right along with their food source – bark beetles. Since half of the species that nest in tree cavities in ponderosa pine forests cannot excavate their own cavities, hairy woodpeckers are important in supporting them. Without surface fires severe enough to kill or partially kill some trees, hairy woodpecker populations may be low, reducing needed habitat for other species and resulting in changes to the forest ecosystem.

OG ponderosa pine also helps to cycle soil nutrients. Studies have shown that in over-stocked, fire-suppressed ponderosa pine forests, nitrogen is mostly in above-ground tissue, relatively unavailable to soil microbes and other plants. In contrast, most of the nitrogen in more open areas was found in the top 6 inches of soil. Open grassy areas with clumps of large, old trees have more active soil communities, supporting both understory species and the large trees. Along with soil nutrients, soil water is important in ecosystem production. Open OG stands intercept less precipitation compared to dense, fire suppressed stands, allowing more moisture to reach the soil and providing for more diverse plants and animals.

As with OG in other regions, while some mature trees may have diameters and heights similar to OG trees, they do not have the structures that many wildlife species require, including large gnarly branches, nesting sites created by dwarf mistletoe (witches brooms), exposed dead wood ready-made for cavity nest building, and loose bark for bat roosts. Where OG trees grow in groups, their closed canopy can provide escape routes for squirrels and other canopy-dwelling animals.

What are the Major Threats to OG in the Southwest?

Threats to the preservation and restoration of OG ponderosa pine include:

- ▲ fire suppression that continues to alter the size and severity of fires, resulting in undesirable consequences for both existing and future OG
- ▲ fire suppression also allows shade-tolerant species to encroach on ponderosa pine ecosystems, causing the death of old trees
- ▲ continuing outbreaks of western pine beetle and dwarf mistletoe
- ▲ non-native invasive plants
- ▲ both legal challenges and the required use of diameter caps (upper size limits of trees allowed to be cut) by environmental groups. While attempting to protect OG from logging, these groups have hindered restoration efforts to thin trees in and around OG. The result is more inaction, more overstocked pine forests and eventually more catastrophic fires resulting in the loss of OG.

There are also social values that influence the OG issue. They include:

- ▲ urban development in forested ecosystems that increases the risk of fire
- ▲ conflict between scenic and recreational values and timber management activities
- ▲ public knowledge that fire has a role in frequent-fire forests but the continuing discomfort about allowing wildfires to burn
- ▲ opposition to logging OG, but no consistent public opposition to removing some larger trees during thinning operations
- ▲ support for mechanical thinning to reduce forest fuels and restore forest structure.

How Much OG is Needed to Maintain Biodiversity?

Researchers see OG restoration in the Southwest not as a singular goal, but as part of a larger effort to reduce the hazard of severe wildfire, protect the urban interface, foster biodiversity, and provide recreational and watershed values from the entire ponderosa pine forest ecosystem (details below). Rather than focusing exclusively on OG, their goal is to restore all stages of forest development. However, they do think that more OG is needed than currently exists, and they use pre-European settlement estimates as a point of reference. For example, older forest probably ranged from 17 to 25 percent at pre-settlement, with the remainder being grassy openings and younger forests. Research results clearly indicate that OG constituted a significant proportion of the Southwest's forests. For that reason, researchers call for as much OG as possible. They emphasize that it is relatively easy to enhance OG qualities by protecting old trees and thinning and burning forest stands to accelerate the development of OG characteristics. These restorative actions are consistent with the larger effort aimed at the entire system. The problem however, lies with the current limited ability to handle all the acres in need of treatment and the time it takes for OG structure and function to develop.

How Does Society View OG in the Southwest?

A brief review of southwestern forest history from the 1960s to present is useful in answering this question. During the past 50 years the public has shown increasing environmental concern and has had access to forest and wilderness areas. As a result, OG forests are regarded as representing an ideal of untouched nature, while harvested forests are seen as violated or defiled. Early in the period, USFS management moved toward multiple-use and sustained yield, but it still favored cutting OG and replacing it with second-growth forests. National legislation (the Wilderness Act, the National Environmental Policy Act, and the Endangered Species Act) along with environmental organizations such as the Sierra Club and the Wilderness Society brought an end to OG conversion. More recent policies have emphasized restoring natural forests and fire regimes. In the past 20 years timber processing has declined by over 60 percent, resulting in a waning forest industry. At the same time, catastrophic fires have raised concern about public safety, property and ecology. New federal initiatives and legislation (the National Fire Plan, the Healthy Forest Initiative, and the Healthy Forest Restoration Act) all support the restoration of frequent-fire forests along with forest research to achieve that goal.

With that historical backdrop, surveys indicate the following public views about ponderosa pine forests.

- ▲ Society prefers open, park-like forests similar to OG ponderosa pine rather than dense pole and/or sapling-sized trees. Large, mature trees are seen as an important part of scenic beauty.
- ▲ Public policy discussions do not focus on OG, but on wildlife, aesthetics, and recreation. With respect to wildlife, crown fire is seen as the major threat rather than logging.
- ▲ Attempts to use prescribed fire in restoration activities have resulted in public concern about smoke.

Researchers concede that in order to achieve the goal of healthy OG in frequent-fire forests, the public must be educated about these ecosystems and persuaded that active management, rather than preservation, is the best course of action for the future.

HOW CAN KNOWLEDGE OF OG BE USED IN MANAGEMENT STRATEGIES ON PUBLIC AND PRIVATE FORESTLANDS?

While developing OG strategies, researchers point to Native Americans, who lived in ponderosa ecosystems for centuries prior to European arrival and regularly used fire to manage the forest. Whether ignited by Native Americans or lightning, those frequent low-intensity fires occurred at intervals ranging from 2 to 35 years. Stand-replacing fires were rare or non-existent, but they did occur in dry forests in other parts of the West. The result of frequent, low-intensity fires was an open stand structure that limited the size and severity of insect outbreaks and kept dwarf mistletoe in check. Wildfire research studies indicate a dramatic decrease in low-intensity fires by the late 1800s due to exploitation of OG and overgrazing.

Given this historical setting, OG restoration strategies call for thinning to recover ecosystem structure, followed by low-intensity fire to return the ecosystem to more natural rates of decomposition, nutrient cycling and productivity, while reestablishing plant and animal communities. But OG restoration depends primarily on two things:

1. the ability to return fire to the ponderosa pine ecosystem after thinning, so its structure and function can be restored
2. the ecosystem's ability to produce OG from existing trees, once it is thinned and exposed to low-intensity fires.

There are obstacles to this strategy. First, even though it's possible to use small-diameter trees from forest thinning for wood products and bioenergy, profit from these uses is marginal. Currently, there are no manufacturing facilities and no industry plans to rebuild mills, because the industry has no long-term confidence in USDA Forest Service policy. Second, the manpower and financial resources needed to do restoration work at an acceptable pace and scale aren't available. Third, in some locations successful restoration may require reseeding or transplanting missing plant species, raking around old trees before burning (Figure 4.45), controlling non-native invasive plants, and regulating grazing. Fourth, monitoring is needed to track the progress and modify restoration plans as needed. And finally, there are key gaps in scientific knowledge. For example:

Dave Egan, Northern Arizona University

FIGURE 4.45 **Hand-raking around OG prior to prescribed burning prevents heat damage from the long-term accumulation of needles.**

- How well will understory vegetation and animal habitat recover after thinning and/or thinning and prescribed fire, and will it be close to OG conditions?
- Will restoration techniques, tested and used in northern Arizona ponderosa pine areas, be successful in other areas of the Southwest?
- How different are dry mixed conifer forests from ponderosa pine forests, and what techniques can be used to restore them?

In the meantime, managers have to make site-specific decisions about OG restoration objectives, treatment prescriptions, and implementation strategies in frequent-fire forests. Here are some general principles recommended by researchers.

- Retain all trees that pre-date European settlement because they tend to be fire resistant, often provide wildlife habitat, and have aesthetic benefits.
- Retain some post-settlement trees to replace those that existed before European settlement but have died or been removed. Note that ponderosa pine frequently grows in small clumps. The size, density, number, and location of clumps affect wildlife habitat and the future risk of crown fire.
- Thin and remove excess trees, recognizing that some grassy openings were historically in place for very long periods of time. Re-creating these openings, lost to encroaching pines during fire suppression, provides habitat for many wildlife species and can reduce the risk of crown fires.
- Rake heavy fuels from the bases of old trees if necessary to prepare them for safe prescribed fire.
- Burn to mimic the natural disturbance regime. Fire is crucial in cycling nutrients and maintaining forest structure. Without fire, thinned forests become dense again.
- Reestablish healthy understories with native rather than exotic species. Besides offering wildlife food and cover they provide the fuel needed for frequent low-intensity fires that maintain forest structure.

SUMMARY

From this brief overview its clear that the OG resources of each major forest region are poles apart as are the strategies to restore and manage those resources. For example:

- In the Northeast, Southeast, and Lake States there are relatively small amounts of OG.
- The Northeast faces the impending loss of its OG.
- Little attention is given to OG in the Northeast, Southeast, and Lake States.
- There's a continuing loss of OG in the frequent-fire forests of the West.

Our understanding of OG forests changed during the late 20th century. It's become more than just old trees and is now recognized as a complex forest ecosystem. We must learn from existing OG and manage for future OG. The bottom line is that:

- Any effort to retain biodiversity depends on having more old forest.
- Threats to OG go beyond logging and include development, unnatural fire regimes, and non-native invasives.
- If we want more old forest we need more than preservation strategies; we need restoration and management tools.
- Maintaining and growing more OG is not just a science issue, it's a social issue.

The major forest regions can learn from one another. While the PNW was the first region faced with the OG issue, other regions have learned from that experience. The PNW has a richness and abundance of OG unique in the world's temperate forests. How it is maintained and managed in the PNW may have application to other regions. For example, PNW OG Douglas-fir forests have many similarities to OG white pine forests in the eastern United States. What's still not clear is whether there are similarities to boreal forests or the deciduous forests of the eastern United States. However, it is true that the strategy of increasing structural complexity as forests mature is applicable to all forests.

Preserving what OG remains, restoring OG in mature stands, and developing techniques that enable the growth of more OG in the future are the major messages of this chapter. No matter what the region, OG forests are part of the forest developmental process and serve a vital role in forest biodiversity.

One final word concerning OG: although it has been mentioned only briefly, climate change is another threat to OG in all regions. Scientific opinion holds that as the climate grows warmer over the next century, the climatic environment for most existing tree species will shift northward. It's assumed that most forest vertebrates will probably be able to keep up as their habitats shift northward. However, species that depend on OG, such as some lichens, mosses, fungi and invertebrates that disperse slowly may be at risk. One strategy for biodiversity conservation in the face of climate change may be a system of OG stepping stones and corridors (Chapter 3, page 83), permitting slow moving species to keep up. This is just another reason for each region to locate all existing OG and plan for the development of future OG in strategic locations.

To Learn More About This Topic, See Appendix, page 167.

WHY IS THIS SUBJECT IMPORTANT?

Forest practitioners and managers who want to maintain certain components of biodiversity in the context of sustainable forestry face some challenging questions:

- How to decide what components of forest biodiversity to maintain?
- How will we know if we're successfully sustaining forest conditions and desired values that support those components?
- How will we recognize success in sustaining the desired components of forest biodiversity, given thousands of plants and animals, the functions they perform, and the ecological processes they support?

A process of selecting indicators and then monitoring them is essential for answering such questions. Simply stated, **indicators** are a relatively few measurements of the forest system that correlate with as many other unmeasured desired elements as possible. **Monitoring** consists of repeatedly measuring change in indicators over time. So the indicators used in a monitoring program are selected to provide information about the status of the larger and more complicated forest. Using indicators is the only practical way to know if we are sustaining what we are trying to sustain. And that's important, because it's not physically or biologically possible to sustain every component of forest biodiversity on every acre all the time. Nor is it appropriate to try to sustain all components of every forest irrespective of their management policy or purpose. Who owns a forest (public versus private) and the purpose of the forest (reserve versus managed) are critical backdrops for sustaining biodiversity components that will enable us to meet overall management goals.

In 1995, the Montreal Working Group, which represented 12 countries including the United States, developed the Montreal Process. This process encouraged assessment at country or regional levels to assist governments in evaluating their forest policy goals. The working group described seven criteria or goals for conservation and sustainable management of temperate and boreal forests, starting with conservation of biological diversity. The members agreed to a framework of 67 inventory indicators so countries could share information. Of those 67, the group identified nine that could be used to measure biodiversity.

The Montreal Working Group saw the importance of indicators, and while The Process was useful at large scales (country or regional levels), it was never meant to fit the individual forest or watershed. Meaningful indicators at those scales should be developed locally, based on relevant state and federal forest and environmental policies and landowner intent.

Since then, worldwide efforts by forestry organizations to use the Montreal Process indicators to evaluate their forestry practices have created some confusion among forest managers and stakeholders (individuals and organizations that have an interest in the forest).
For example:

- Who decides what indicators to use?
- Will stakeholders or individual landowners be confident that the best indicators have been chosen?
- Who's responsible for the monitoring necessary to make indicators meaningful?

Science by itself cannot answer these questions, because there are complex and significant trade-offs in efforts to sustain forests for various values and uses that go beyond science and involve group decisions. The goal of the NCSSF-sponsored research projects that form the background for this chapter was to provide information and tools for those who are seeking answers, including a tested framework that engages the public (or in the case of family, community, tribal, or industry owned forestlands) appropriate stakeholders, in a group process to reach agreement on indicators relevant to forest goals, that can be applied at a variety of spatial scales, from a forest site to a landscape.

INDICATOR SELECTION

Indicators are like your car's instrument panel, which lets you assess the current status of major operating systems with a glance. Repeated monitoring detects changes and indicates system trends. Warning lights indicate a serious change that requires prompt attention (next page).

Forest biodiversity indicators perform similar functions. They should:

- provide a current status report
- describe trends
- indicate the origin of any problems that exist.

Forests are complicated systems, far more complicated than an automobile. There will always be a lot we don't know about them. So it's understandable that we're always in the process of designing or refining an instrument panel for our forest cruiser. Because forests in different places and under different ownerships are managed for different purposes, we will need a different instrument panel for each kind of forest. There may be one for measuring biodiversity conditions and trends in forest reserves (managed for a suite of values and uses most likely to be sustained only in reserves), another for plantation forests (managed for a suite of values and uses that is led by growing trees for wood products), and still another for multi-purpose and urban forests that typically are managed for a broader and more complex suite of values and uses than either reserves or wood production forests.

How Forest Managers Are Currently Using Indicators

Interest in indicators is growing, encouraged by:

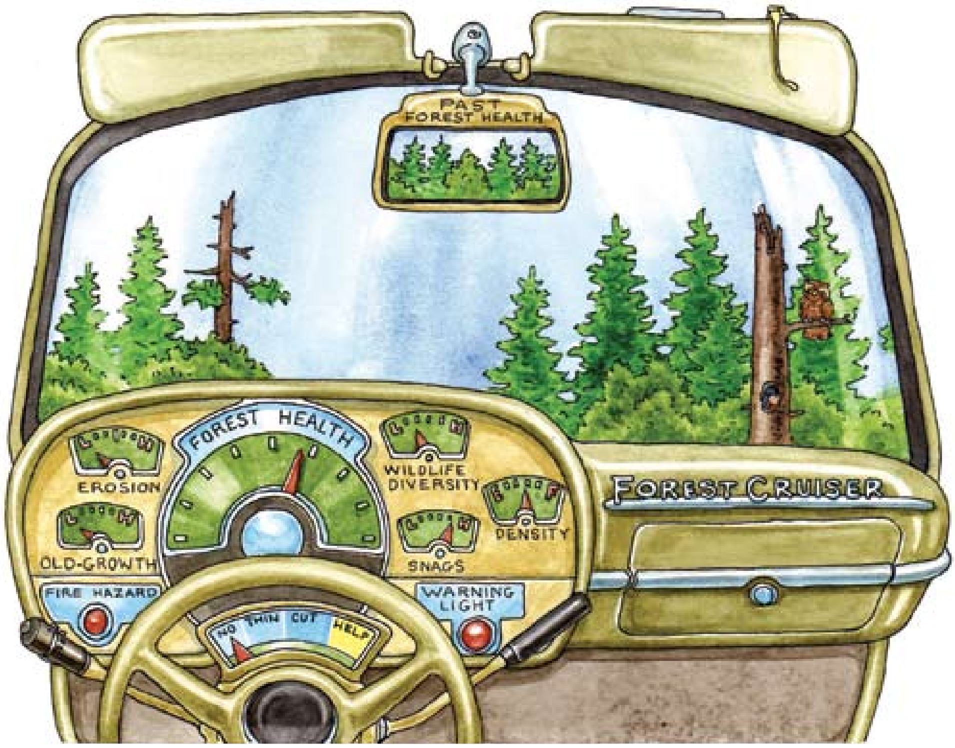
- ▲ principles, criteria, and indicators described by the 1995 Montreal Process
- ▲ forest certification standards, including those of the Sustainable Forestry Initiative (SFI) and the Forest Stewardship Council (FSC)
- ▲ social concerns about conservation, preservation, and forest restoration
- ▲ interest in maintaining and re-establishing components of biodiversity placed at risk by historic land uses.

One NCSSF project surveyed more than 1,500 forest landowners and managers nationwide about their biodiversity practices, asking what indicators they used for biodiversity conservation. All levels of forest ownership were sampled, from small private woodlands to large industrial and public forests. Survey results indicated that:

- ▲ nearly 60% of respondents felt their forest biodiversity programs were being implemented
- ▲ nearly 66% believed their forest management is successful in producing desired forest conditions, uses, and values.

Here's what survey respondents said about biodiversity indicators:

- ▲ Most of them don't use Montreal Process indicators directly, but many Montreal indicators are incorporated with different names.
- ▲ At the **stand level**, timber inventory, tree species composition, age-class distribution, and stand structure were most often considered important indicators for successful biological diversity programs.
- ▲ At the **landscape level**, hydrology and stream protection were considered the most important indicators of forest biodiversity.
- ▲ It was considered important to protect important habitats, in compliance with federal and state laws or regulations.
- ▲ Interestingly, no indicators of fragmentation (Chapter 3) were being used. Respondents apparently either don't consider fragmentation an important indicator of biological diversity or don't know how fragmentation relates to the components of biodiversity they are trying to sustain. Fragmentation is one of the nine Montreal Process indicators for use at regional or national scale.



Indicator selection is about building a biodiversity instrument panel that indicates biodiversity trends and pressure points. It requires the involvement of forest managers, scientists and stakeholders appropriate to the forest ownership or purpose.

- ▲ An implemented biodiversity plan was viewed as the most significant indicator of program success.

While the survey showed that land managers are using biological indicators, NCSSF project scientists sensed some confusion because the subject of indicators is relatively new territory for many practitioners and forest managers. That confusion seems to lie in the selection and application of indicators. Many of them just aren't useful for assessing biodiversity for the following reasons:

- ▲ An appropriate indicator at a large spatial scale (state or region) may not be appropriate at the forest management unit or stand level.
- ▲ Indicators that work for one forest type, ownership or management purpose may not be appropriate for another.
- ▲ Indicators are sometimes selected without considering the biodiversity component they are intended to indicate (more about biodiversity components below).
- ▲ Benchmarks or target levels for indicators are almost always lacking. Once the indicator is measured, it's not clear what action, if any, should be taken.
- ▲ Indicators can conflict with each other and that's why there's a need for landscape level indicators. For example, if you have an indicator for early-succession habitats and one for late-succession forest, they could conflict on the stand level, but across a landscape they wouldn't.

▲ The indicator selection process needs to be transparent. When public land managers select indicators, stakeholders can become skeptical if they cannot see that their social, economic, and environmental values are being addressed.

Selecting Biodiversity Indicators

Given the challenges identified above, NCSSF project scientists set out to develop a four-step group process for selecting sensible indicators for specific situations and locations. The steps include:

- ▲ identifying and prioritizing the desired biodiversity components to be sustained
- ▲ identifying condition, pressure, and policy response indicators for those components
- ▲ determining how to evaluate high-priority indicators
- ▲ selecting the top indicators.

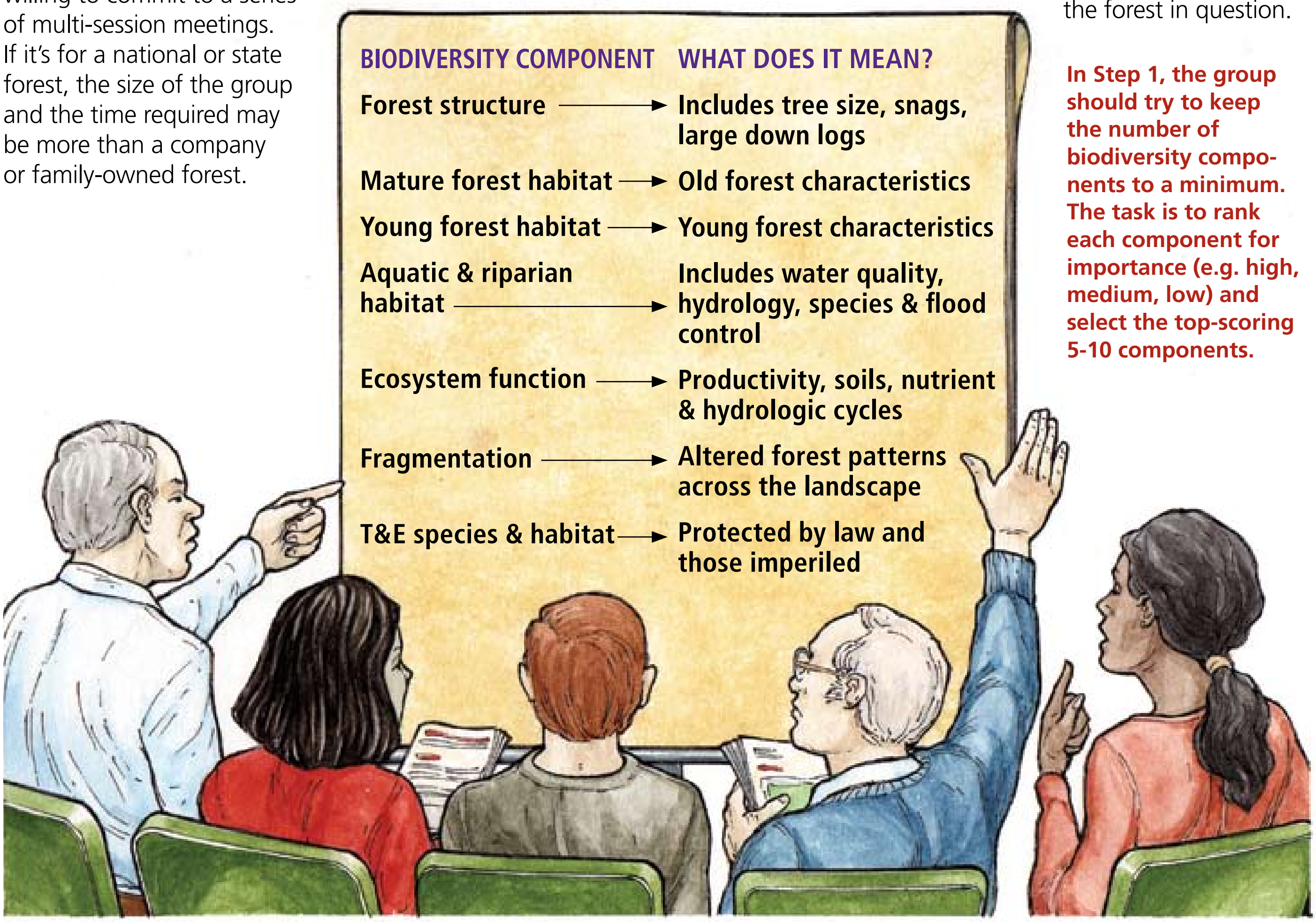
Researchers who conducted group process workshops shared their observations. The first is this: To insure transparency and success, the group should consist of stakeholders, land managers/policymakers, and scientists/technical experts appropriate to the forest ownership and willing to commit to a series of multi-session meetings. If it's for a national or state forest, the size of the group and the time required may be more than a company or family-owned forest.

Step 1: Identify and Prioritize Biodiversity Components

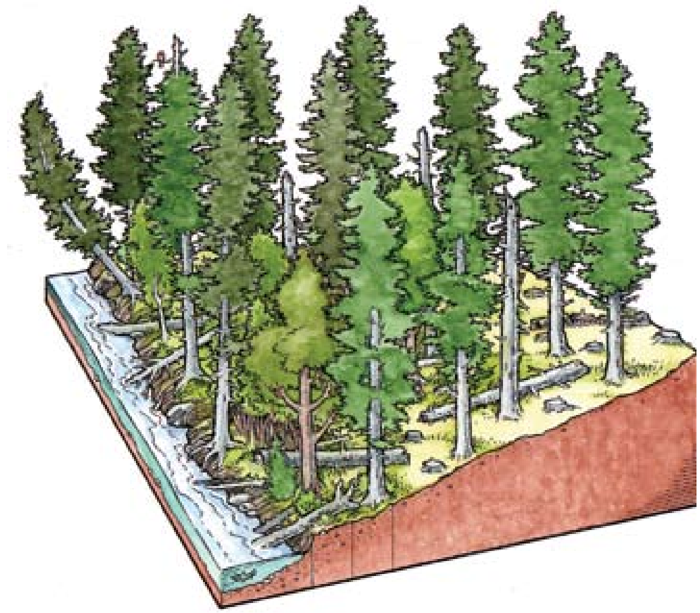
The first step is to identify, define, and organize the important biodiversity components for a particular site, forest, or landscape. Because biodiversity is such a mind-boggling concept – it's literally all the species and processes that comprise a forest ecosystem, from the biggest and showiest to the microscopic and obscure – the first task is to break down this complexity into more understandable and meaningful components. Then indicators can be selected and linked to these components.

But **what are biodiversity components?** The flipchart in the illustration (below) shows some examples and their meanings. Biodiversity components vary with forests and stakeholders, so there's no correct or universal set.

According to researchers' experience, Step 1 may require a facilitator. There's potential for disagreement in the group because this step identifies "what values are going to be sustained" in a particular site, forest, or landscape. Group participants come to the realization that biodiversity components that aren't included at the end of Step 1 may not be sustained because they may be incompatible with the designated purposes of the forest in question.



In Step 1, the group should try to keep the number of biodiversity components to a minimum. The task is to rank each component for importance (e.g. high, medium, low) and select the top-scoring 5-10 components.



We know that large-diameter snags are important for those parts of biodiversity that require snags in many forest types (Chapter 1, page 44).

Step 2: Identify Condition, Pressure, and Policy-Response Indicators

This step introduces the group to three different types of indicators used to support each of the top-scoring biodiversity components. They are:

- **Condition indicators** that measure the current status or condition of a biodiversity component.
- **Pressure indicators** that point to where a biodiversity component is headed in the future. The pressure affecting the condition of a biodiversity component can be positive or negative (such as a human action that may be degrading or improving the condition).
- **Policy response indicators** are management plans or policies designed to maintain or improve the condition of a biodiversity component.

These three types of indicators provide different information to policymakers. We'll use large-diameter snags to illustrate each one.

A **condition indicator** for large snags might measure their density in a forest or an ownership. It describes the condition of large snags using units of measure (e.g., snags greater than 20 inches dbh/ha or acre).

A **pressure indicator** for large snags could be harvest rotation length. If the rotation length is too short for them to develop, there will be fewer large snags in the future, regardless of the current density indicated by the condition indicator. The fire-management regime for a forest could also be a pressure indicator for snags.

Here's an important point: Condition indicators without pressure indicators can be misleading. If we rely solely on condition indicators, evidence of change in a biodiversity component may come too late. Pressure indicators provide a warning light on our instrument panel for a future change in condition.

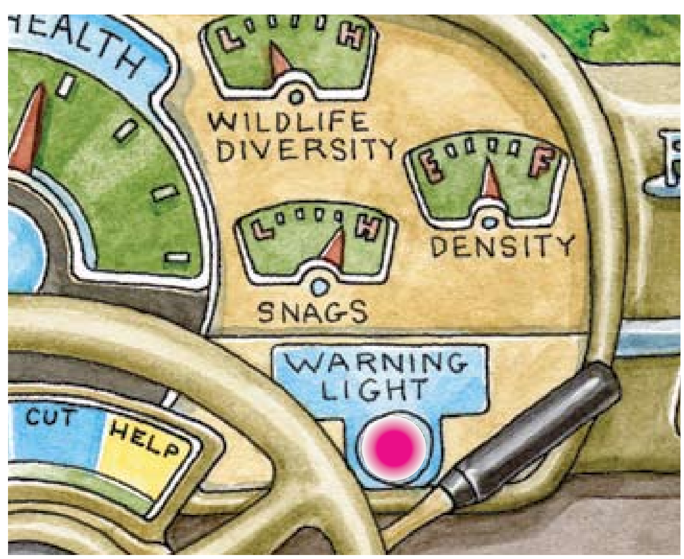
A **policy response indicator** might be a written management plan for snags. While condition and pressure indicators are expressed with units of measure (e.g., snags/acre, rotation length in years), policy response indicators often are not. They're either "yes" or "no" indicators, (i.e., the plan either describes snag protection or it doesn't).

Table 5.1 describes condition, pressure, and policy response indicators for another biodiversity component, mature forest. The boldface terms under each indicator require specific definitions, agreed to by the group, to make them useful.

It's apparent that condition, pressure, and policy response indicators each provide land managers and policy-makers with different information. Ideally, each biodiversity component identified by the group should have a condition, pressure, and policy response indicator.

How to Accomplish Step 2

Assign a small group of people to identify condition, pressure, and policy response indicators for each biodiversity component from Step 1. Be sure each small group is a mix of scientists, managers, and stakeholders appropriate to the forest ownership (public, private, large or small).



Biodiversity Component	Condition Indicator	Pressure Indicator	Policy Response Indicator
Mature forest	1. percent of area in **mature condition,** by **forest type.** 2. **large-tree** (greater than 'X' dbh) density in designated **mature forest stands,** by **forest type.** 3. percent or area in **mature forest reserves.**	1. percent of landscape with rotation length shorter than **time required to develop mature forest characteristics** (negative pressure). 2. percent of acres managed for timber with **mature forest retention practices applied** (positive pressure).	1. written policy for conservation and management of **mature forest.** 2. tax break, carbon credit, or conservation easement for timberland in a **mature forest management regime.**

TABLE 5.1
Example indicators for another biodiversity component (mature forest). Boldface terms need precise definitions.

Step 3: Evaluate High-Priority Indicators

Use the following five criteria to evaluate indicators. Although this step is seldom included in indicator selection processes, it helps stakeholders understand why one indicator was selected over another. Evaluation criteria include:

- **Scientific merit.** Is there scientific support for the indicator and the biodiversity component? For example, a commonly used indicator is the amount of area by forest type and age class (a Montreal Process indicator). Science recognizes that various species depend on different forest types and age classes, so this indicator has high scientific merit. What science still doesn't know is how much of each forest type and age class is needed to successfully maintain each component of biodiversity in any geographic area. So setting target levels for an indicator is both a social and scientific question (i.e., how much do we want?)
- **Ecological breadth.** Does the proposed indicator correlate with other biodiversity components that aren't being measured? An example is the density of large living trees. Large living trees correlate with and are good indicators of mature forest epiphytes (mosses and lichens), raptor nesting habitat, and future large snags and down logs.
- **Practicality.** An indicator is practical if it's not too expensive to measure, doesn't require special skills to measure, and doesn't require complicated analysis. If the cost of the indicator is too high, its scientific merit usually doesn't matter.
- **Utility.** Can a forest manager use the indicator to make a decision? If there are targets for a biodiversity component, the indicator has high usability if it informs the manager whether the system is above or below the target so action can be taken. Often targets aren't set in sustainable forestry because target setting is so contentious among stakeholders. Science can help set targets but is often inadequate for answering the question "how much is enough?" especially when "enough for what, and whom, and where?" hasn't been addressed.
- **Relevance.** How well does the indicator represent the stakeholders' or owner's biodiversity values? Since indicators are used to inform whether forest sustainability is being achieved relative to certain forest values and uses, they must be linked to stakeholders' or forest owner's values.

How to Accomplish Step 3

Use volunteers from the full group to create a science workgroup (scientists/technical experts) and a manager workgroup (managers/policymakers). The science group rates each indicator for scientific merit and ecological breadth. The manager group rates each indicator for practicality and utility. The workgroups should present the ratings to the full group. Then stakeholders appropriate to the ownership rate each indicator for how well it reflects their values. This ensures transparency and recognizes the strengths and weaknesses of each indicator.

Step 4: Select the Top Indicators

Finally, the group selects the top scoring indicators to be used. In this step the group sums the evaluation scores for scientific merit, ecological breadth, practicality, and utility for each indicator in Step 3. Compare the summed scores with the stakeholders' score for the indicator. Indicators that score poorly for stakeholders should be eliminated if group discussion does not lead to modification of the stakeholder score. Researchers admit that practicality usually wins out in the final set of indicators, because finances are always limited.

Cautionary Observations About the Four-Step Process

Researchers who tested the four-step process made the following cautionary observations:

- ▲ Before selecting indicators, be sure the group knows how they're going to use them once they are measured and how the data will be collected. Researchers suggest answering the following questions:
  - What resources are available to measure the indicators and analyze data?
  - Who's responsible for measuring the indicators?
  - How often will the data be reported, and to whom?
  - How will decisions be made in response to what the indicators indicate? Who will be included in policy-making?
  - What actions might be taken if indicators suggest a problem?
  - How will stakeholders participate in discussion and evaluation of results?

Unless these questions are dealt with, stakeholders can be frustrated because they don't see how indicators will be used to make forest decisions that protect their values.

- ▲ Stakeholders, forest managers/policymakers, and scientists/technical experts have discrete roles in the indicator selection process. Stakeholders identify the forest values they want sustained; scientists/technical experts identify potential indicators that best track those values; and managers/policymakers ensure the indicators will be practical and useful in policy-making. Scientists can participate as stakeholders or as technical advisors, but not both. Be sure the indicator selection process includes all three groups. Avoid giving a technical team responsibility for leading and selecting indicators and then presenting them to stakeholders after the fact.
- ▲ A trusted group of leaders is needed. Establish a stakeholder/scientist/manager leadership team to guide the larger group.
- ▲ Indicator selection can be contentious, since it reflects values that people want to sustain, and only a finite number of indicators can be measured. Participants with different values must be able to work together. It may be necessary to invest in building social capital (the ability of people to work together) before selecting indicators. If it's carefully organized and facilitated, the four-step indicator selection process can be effective at building social capacity.
- ▲ Establish targets for each biodiversity component, but not necessarily numerical targets. An example of a non-numerical target might be "to maintain representation of all natural forest types and age classes in every county or forest district." While qualitative, it's still instructive for policy-making. If a forest type or age isn't present, or is rapidly disappearing, a policymaker can act to maintain the target.
- ▲ Be clear about the spatial scale at which the indicators are to be applied (watershed, community, state, or national forest level). If they are to be used at a landscape or regional scale, be sure that owners of private property within the spatial scale are informed and engaged. They are naturally going to be concerned about the implications of the indicators for their policy-making rights.
- ▲ Be aware of other indicator efforts going on at other spatial scales. Coordinating indicators among different scales can provide insights that are otherwise not possible. However, stakeholders within each spatial scale legitimately have their own values to track with indicators, and not all indicators will be relevant at all spatial scales or even similar scales between two different landowner types (e.g., national forests vs. private commercial forest).

SUMMARY

The questions raised at the start of this chapter are being answered. NCSSF-sponsored researchers have field-tested a four-step framework for selecting biodiversity indicators for forests at different spatial scales. The tool removes much of the confusion that may have previously hampered this process. It provides a way for any landowner (public or private) to decide what indicators to use and how to use them once they're selected. It offers a deliberate, transparent group process where stakeholders can have confidence that the best indicators have been chosen and there's a way to recognize success in sustaining the desired components of forest biodiversity. In addition, specific cautionary observations are noted that can avoid potential problems. For information on biodiversity monitoring programs, check *Participatory Inventory and Monitoring* on page 169 of the Appendix.

To Learn More About This Topic, See Appendix, page 167.

WHY IS THIS SUBJECT IMPORTANT?

What are some things that I should consider if I'm interested in enhancing biodiversity in my managed forest? Many industrial and family landowners are asking this question as public recognition of the importance of forest biodiversity increases. This chapter offers some answers based on NCSSF-sponsored research that examined:

- ▲ biodiversity enhancement in forest plantations, using loblolly pine and Douglas-fir as examples
- ▲ biodiversity enhancement in family forests, based on a study of Florida owners
- ▲ pre- and post-wildfire strategies for enhancing biodiversity, based on research done on public lands in the western United States.

The ideas presented here are intended for managed forests, both naturally regenerated and artificially planted. The ways they are applied will depend on the management objectives of individual owners. As we will see, research results clearly show that biodiversity enhancement in managed forests can have significant economic costs. If the costs are more than private forest landowners are able or willing to pay, and private forests continue to be converted to other uses, society will have to decide whether government should partner with owners to provide economic incentives to enhance biodiversity. If the answer is yes, then new ways must be developed to establish and support such partnerships (Chapter 9, pages 165-166).

HOW TO ENHANCE BIODIVERSITY IN PLANTATION FORESTS

In general, planted forests do not have the same level of biodiversity as naturally regenerated forests (more details below). However, there's growing interest in developing strategies that increase biodiversity and non-timber economic values in planted forests while also growing wood products.

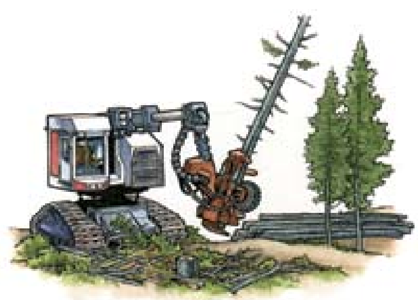
Planted forests are common in the coastal plains and piedmont of the Southeast and in the Pacific Northwest, particularly west of the Cascade Mountains. They have expanded dramatically in the Southeast. For example, in 1953 there were about 2 million acres (809,900 hectares) of planted pine in the Southeast. By 1999 there were more than 32 million acres (13 million hectares), and that number could double by 2040. The primary planted species are loblolly pine in the Southeast and Douglas-fir in the Pacific Northwest.

Despite their differences, loblolly pine and Douglas-fir plantations have some overall similarities (Figure 6.1). For example:

- ▲ They're artificially planted, often with genetically superior tree seedlings.

FIGURE 6.1 **Planting, vegetation control, and mechanical harvesting – the typical short-rotation management cycle for plantations.**

- ▲ Herbicides may be used to control competing vegetation during seedling establishment.
- ▲ Thinning and other practices are used to improve wood production.



- ▲ They usually follow a relatively short clear-cut rotation pattern.
- ▲ Despite their lack of structural diversity (details below), they provide forest cover for wildlife.
- ▲ They support greater biodiversity than agricultural lands or urban development.
- ▲ The conversion of plantation forestlands to other uses, especially in areas of urban growth, indicates that economics plays a large part in their long-term future and sustainability.

There are differences in the level of biodiversity between naturally regenerated forests and loblolly pine and Douglas-fir plantations. Chapters 1 and 4 provide greater detail, but here's a brief overview – first loblolly and then Douglas-fir.

Craig Hedman

FIGURE 6.2 **This uneven-aged longleaf pine-wiregrass stand represents the structural goal that researchers envision for loblolly pine plantations. Its open, park-like structure and herbaceous understory provides habitat for a variety of wildlife species.**

Robert Logan

FIGURE 6.3 **Mature Douglas-fir forest.**

www.forestryimages.org

FIGURE 6.4 **Overstory shade in the stem-exclusion stage of this loblolly plantation reduces biodiversity and eliminates understory forage and wildlife habitat.**

NCSSF-sponsored researchers used mature, naturally regenerated longleaf pine in the Southeast Coastal Plains (Figure 6.2) as a structural goal for loblolly pine plantations because longleaf is recognized for both high levels of biodiversity and economic values that include:

- ▲ open, park-like conditions that allow light to reach the forest floor, creating a rich, herbaceous understory
- ▲ high levels of plant and animal diversity
- ▲ frequent, low-intensity fires that prevent dense shrub layers from developing and stimulate understory vegetation.
- ▲ income from saw-timber and hunting leases.

In the Pacific Coastal region, Douglas-fir plantations also differ from mature, naturally regenerated forests (Figure 6.3), which have the following characteristics:

- ▲ vertical structural diversity (multiple canopy layers)
- ▲ horizontal diversity (large live and dead trees along with canopy gaps)
- ▲ lower stand densities that allow for larger tree diameters
- ▲ a more vigorous understory shrub and herb component.

While loblolly pine and Douglas-fir plantations generally lack the structural diversity and more mature forest components of naturally regenerated forests, there are stand-level management practices that can contribute greater biodiversity. They are described next, starting with loblolly pine.

Enhancing Biodiversity in Loblolly Pine Plantations

It's possible to increase biodiversity in loblolly pine plantations and move them toward the longleaf pine structural model described above and shown in Figure 6.2. A primary objective is to minimize the stem-exclusion stage in which shade from a closed canopy eliminates understory vegetation (Figure 6.4), and instead create a more open overstory, allowing development of a diverse understory that can provide forage and wildlife habitat. However, there are tradeoffs, as noted in the recommendations below, such as the effect on wood quality when planting at wider spacing.

While it's true that maximum production of total wood volume is achieved in dense, fully-stocked stands, here are some things that can be done to enhance biodiversity in loblolly pine plantations:

- ▲ **Plant at wider spacing** (12 feet). This delays canopy closure and maintains a more diverse tree establishment phase for a longer period. It also allows for disking or mowing between tree rows to maintain a more productive understory. The disadvantage of wide spacing is a reduction in wood quality from larger branch knots. An alternative is to plant close and follow up with early and frequent thinning. This minimizes the stem-exclusion stage, allows light to reach the forest floor and increases biodiversity.
- ▲ **Begin commercial thinning** at age 15, with subsequent thinning every five years. The disadvantage of thinning is that it allows understory hardwoods to develop a midstory, creating heavy shade and reducing understory vegetation. Thinning can also result in understory vine and shrub growth that shades out herb and grass vegetation. In general, a hardwood midstory is undesirable for most wildlife, and without hardwood control (burning or herbicide treatments described below), thinning can result in a less productive and diverse understory. On the other hand, mature hardwoods such as oaks are desirable because they provide mast – acorns, nuts, and seeds – an important food source for many wildlife species. When controlling midstory hardwoods, individual mature trees should be retained, along with occasional clumps of hardwoods, especially those growing in bottomlands and drainages, which are typical hardwood sites.
- ▲ **Use prescribed burning.** Historically, frequent low-intensity fire in naturally regenerated pine stands controlled the hardwoods and maintained an open stand structure and a diverse understory. Prescribed burning, in combination with thinning, can mimic those conditions. It is recommended at 3 to 6 year intervals once pine trees are 15 feet tall. Burning should be done in patches rather than evenly, to provide nesting cover. Avoid annual burning because it can eliminate all hardwoods and reduce biodiversity. Coordinate burning and thinning. Thin after burning because it avoids the problem of too hot a fire from thinning slash.
- ▲ **Use herbicides as an alternative** to prescribed burning for hardwood vegetation control. They are generally not directly toxic to wildlife and their effects last longer than burning or mechanical hardwood control.
- ▲ **Use less intensive site preparation** for vegetation control at the time of planting. Intensive site prep reduces the availability of fruit for wildlife. Mechanical site preparation, in contrast to herbicides provides more understory production. Burning may also be an option for site preparation vegetation control.
- ▲ **Fertilize,** but keep in mind that fertilization has a mixed effect on biodiversity in pine plantations. It can improve understory food production in thinned stands, but it can also speed canopy closure and offset wildlife benefits. Fertilization used to benefit both diameter growth and wildlife habitat is best done along with thinning.
- ▲ **Retain snags, large down trees, and mature live trees.** Streamside management zones, wetlands, and other special habitats in pine plantations can contribute to biodiversity by providing wildlife corridors (Chapter 3, pages 81-83) while at the same time protecting water quality.

- **Extend rotations.** All of the biodiversity enhancement practices noted above will be more effective if rotations are extended. Rotations of 40-100 years ensure older forest conditions and long-term wildlife forage, hardwood mast, snags, and cavities. However, longer rotations have an economic impact, depending on pulpwood and saw-timber prices, and can affect the rate of return acceptable to landowners.

Enhancing Biodiversity in Douglas-fir Plantations

There are stand-level management practices that can increase biodiversity in Douglas-fir plantations. The objective is to promote both vertical and horizontal structural diversity (multiple canopy layers, large live and dead trees, and canopy gaps). As with loblolly pine plantations, there are tradeoffs, and they are noted in the recommendations below. Here are some of those practices:

- Since Douglas-fir plantations typically are planted with 435 trees or more per acre, **thinning** is a way to increase the structural diversity in stands. As in loblolly plantations, thinning opens the stand, allowing development of herbaceous plants, understory trees, and shrubs, which provide wildlife forage and create multiple layers of vertical diversity. Thinning should be heavy and frequent because large conifers develop mature forest conditions faster with heavy thinning.
- The type of thinning is important. Instead of uniform thinning, **variable density thinning** is suggested (Chapter 1, page 47). This type of thinning leaves unthinned areas and gaps that contribute to structural diversity. Variable density thinning attempts to mimic natural processes.
- **A mix of different species,** especially naturally occurring shade-tolerant species should be maintained while thinning. Hardwoods are important habitat for wildlife, especially small mammals, and retention of some hardwoods is recommended.
- **Biological legacies** such as mature hardwood clumps, snags and down logs should be retained (Chapter 1, page 44).
- It's important to maintain and manage **streamside management zones,** wetlands and special habitats. These are areas of high diversity and can help meet legacy retention needs.
- **Underplanting,** the practice of planting or sowing seed in canopy gaps or under-thinned areas, can create multiple layers.
- **Fertilizing** individual plants or groups of plants can promote vertical diversity.
- **Early branch pruning** and thinning creates space for birds to fly inside the stand.
- Final harvest, using **variable retention** (Chapter 1, page 45) is a way to leave structural diversity for the next rotation. However, variable retention increases harvesting costs, and the retained trees can impact tree growth in the following rotation, decreasing wood production.
- **Rotations** longer than those commonly used in industrial forests are needed to improve wildlife habitat for a number of species. Even with thinning, it takes 100 years to develop old-forest characteristics, and typical Douglas-fir plantation rotations are 30 to 50 years. Longer rotations are costly because they delay harvest revenues while management costs continue to rise. However, Douglas-fir can grow and produce wood efficiently over long time periods, up to and sometimes exceeding 100 years.

Thinning in both loblolly and Douglas-fir plantations can accelerate development of mature forest structures that are complex, support a variety of species (some dependent on them), and are in short supply and difficult to replace on the landscape. However, just creating structures doesn't make plantations suitable for old-growth dependent species, such as lichens or fungi. That takes time. Thinning can create these structures and shorten the time for their use by old forest species (Chapter 4).

While these practices enhance biodiversity at the plantation stand level, they are also important at the landscape scale (Chapter 7). The size, shape, and spatial arrangement of stand structures and age classes should be spread across the landscape to ensure a range of biodiversity. This is easier to do where landowners control larger acreages than it is where landscapes are split among multiple owners. However, multiple landowners who use these practices at the stand level are also supporting increased biodiversity at the landscape level.

Ultimately, all of these biodiversity practices have a cost, and if that cost is too high they are unlikely to be used on private forest plantations. For landowners and managers who are interested in supporting greater biodiversity in their plantations, NCSSF researchers developed actual management strategies for loblolly pine plantations and analyzed their costs using computer simulations. Details concerning those costs are available in the Appendix (page 167).

In summary, plantation forest systems have been widely adopted by landowners in the Southeast and Pacific Northwest. Estimates indicate that high-intensity plantation management has increased southern timber yields as much as 65% over standard site preparation and planting and 100% over naturally regenerated forests. But, along with their increasing prevalence, there's growing interest in strategies that can increase biodiversity in these forests. There are several stand-level management practices described above that can support increased biodiversity. The key is providing structural diversity. While they are simplified management systems, plantation forests still support more biodiversity than other land uses such as development and agriculture. With the very real threat of plantation conversion to development in the Southeast and Pacific Northwest, landowner incentives are needed to counter forestland conversion and support biodiversity conservation in plantations. Chapter 9 (Policy that Encourages Biodiversity) addresses the need for incentives.

HOW TO ENHANCE BIODIVERSITY ON FAMILY FOREST OWNERSHIPS

Family forest owners, who control 58% of the timberland in the United States, have adopted intensive plantation management practices over past decades, especially in the Southeast and Pacific Northwest. But family forest owners are different from industrial owners. First, they are more diverse and more often have values other than timber production as major objectives. Second, it's much more difficult to meet the information needs of family forest owners because there are so many of them and they are so diverse.

Reduced wood production from public forestlands since the early 1990s has made these owners and their forests more important than ever. However, family forests are far more than just sources of forest products. Society depends on them for wildlife habitat, water quality protection, and other ecosystem services. In this section we consider the role that family forests play in conserving biodiversity and review the biodiversity-compatible forest practices recommended in Chapters 1 and 4. Then we look at Florida, where NCSSF-sponsored researchers identified specific practices for family forest owners in their state.

Biodiversity-compatible Forest Practices for Family-owned Forests

Figure 6.5, on the next page, identifies biodiversity-compatible forest practices that are considered important in each of the five major forest regions. More detailed scientific justification for the practices in each region can be found in Chapters 1, 2 and 4. This illustration makes it easy to see recurring recommendations that reach across all regions, such as:

- ▲ adopting the use of prescribed fire wherever appropriate
- ▲ emphasizing harvesting techniques that maintain legacy structures
- ▲ looking to streamside zones and wetlands as places to maintain legacy structures, such as large live trees, snags, and large down logs
- ▲ being aware of and controlling non-native invasives
- ▲ encouraging longer rotations.

Guidelines for Biodiversity Conservation in Pine Ecosystems in the State of Florida

NCSSF-sponsored researchers in Florida identified specific biodiversity-compatible forest practices for family forest owners in that state. Their approach can serve as an example of how other states might develop detailed guidelines for their landowners, if such guidelines aren't already available.

From the outset, researchers recognized the value of voluntary best management practices (BMPs) in Florida, but they also acknowledged that BMPs alone may or may not promote proactive management of wildlife habitat. So they developed a list of biodiversity-compatible forest practices, without regard for their cost or potential for adoption by family forest owners. Once these practices were identified, the researchers analyzed their impact on family forest owners' economic returns.

The most serious concerns that researchers found with respect to biodiversity conservation on forest ownerships in Florida were:

- ▲ conversion of longleaf pine-wiregrass ecosystems to slash or loblolly pine and its detrimental effect on wildlife (Chapter 1, page 33)
- ▲ the need to restore fire in fire dependent forests to control invasive species
- ▲ the need for uneven-aged management and longer harvest rotations in longleaf and other pine forests in the Southeast
- ▲ recognition of the role of stream and wetland riparian habitat for biodiversity.

Given these scientific concerns, the researchers, along with a team of forest and wildlife professionals, identified some practices that enhance wildlife habitat and promote biodiversity in pine ecosystems in Florida. The purpose of these practices is to ensure mature trees and dead wood, both important elements for improving wildlife habitat. They include the following:

- ▲ delay the timber harvesting age
- ▲ encourage uneven-aged management
- ▲ expand the width of streamside management zones (SMZs)
- ▲ improve ground cover management with controlled burning
- ▲ restore native understory vegetation, especially wiregrass
- ▲ control non-native invasive species
- ▲ use thinning techniques that provide an open canopy.

From the list, the team ranked the four most important practices in this order:

1. uneven-aged forest management
2. prescribed burning and invasive species control
3. increasing the rotation length
4. increasing SMZ widths.

Next, the researchers analyzed the financial effect these practices would have on landowners, by calculating the opportunity cost values foregone when these practices are adopted. During this analysis, many forest owners indicated that uneven-aged management, the highest ranked practice, would be economically unfeasible for them. As a result, researchers decided to drop this practice from further consideration. The opportunity costs of the other practices were determined as follows:

- The average land expectation value (LEV) under the typically used management scenario of a 26-year rotation is $729 per acre or $28 per acre per year.
- The cost of adopting prescribed burning and invasive species control (second-ranked), along with the practice of increased SMZ width (fourth-ranked), would be $25.32 per acre per year. The LEV under this management scenario would drop to $6 per acre per year.
- The practice of delaying harvesting, taken alone, decreases LEV by $11 per acre per year. The cost of adopting the two practices described above, plus delaying timber harvest up to 50 years (third ranked), would be $33.00 per acre per year. The LEV under this management scenario would be minus $5 per acre per year, resulting in a negative financial return for the landowner.

From this analysis it's clear that biodiversity conservation can involve significant costs to landowners. If the public wants private forestland to provide this larger suite of social values, public support will be needed to retain these lands as forest. Without public support in the form of financial incentives, a majority of family forest owners are unlikely to adopt these practices at the necessary levels to produce the desired wildlife habitat results.

The question then is: since the costs of biodiversity conservation accrue to landowners and the benefits are spread to the entire society, who should pay? Are there incentive programs for family forest owners that encourage these practices? If not, what additional steps can be taken to support the adoption of biodiversity-compatible forest practices by family forest owners? Answers to these questions are discussed in Chapter 9, where policies and incentives that encourage biodiversity are explained (pages 163-166).

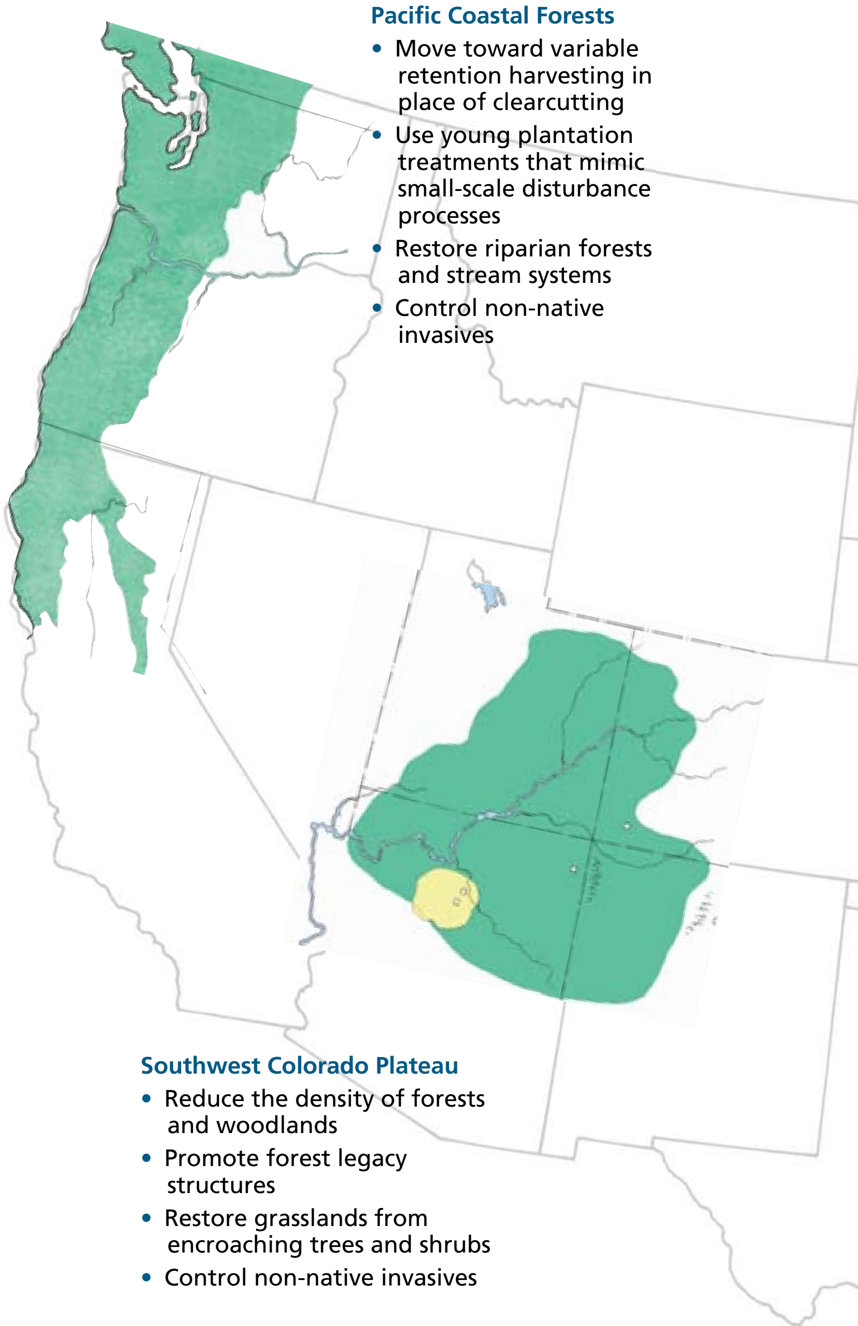


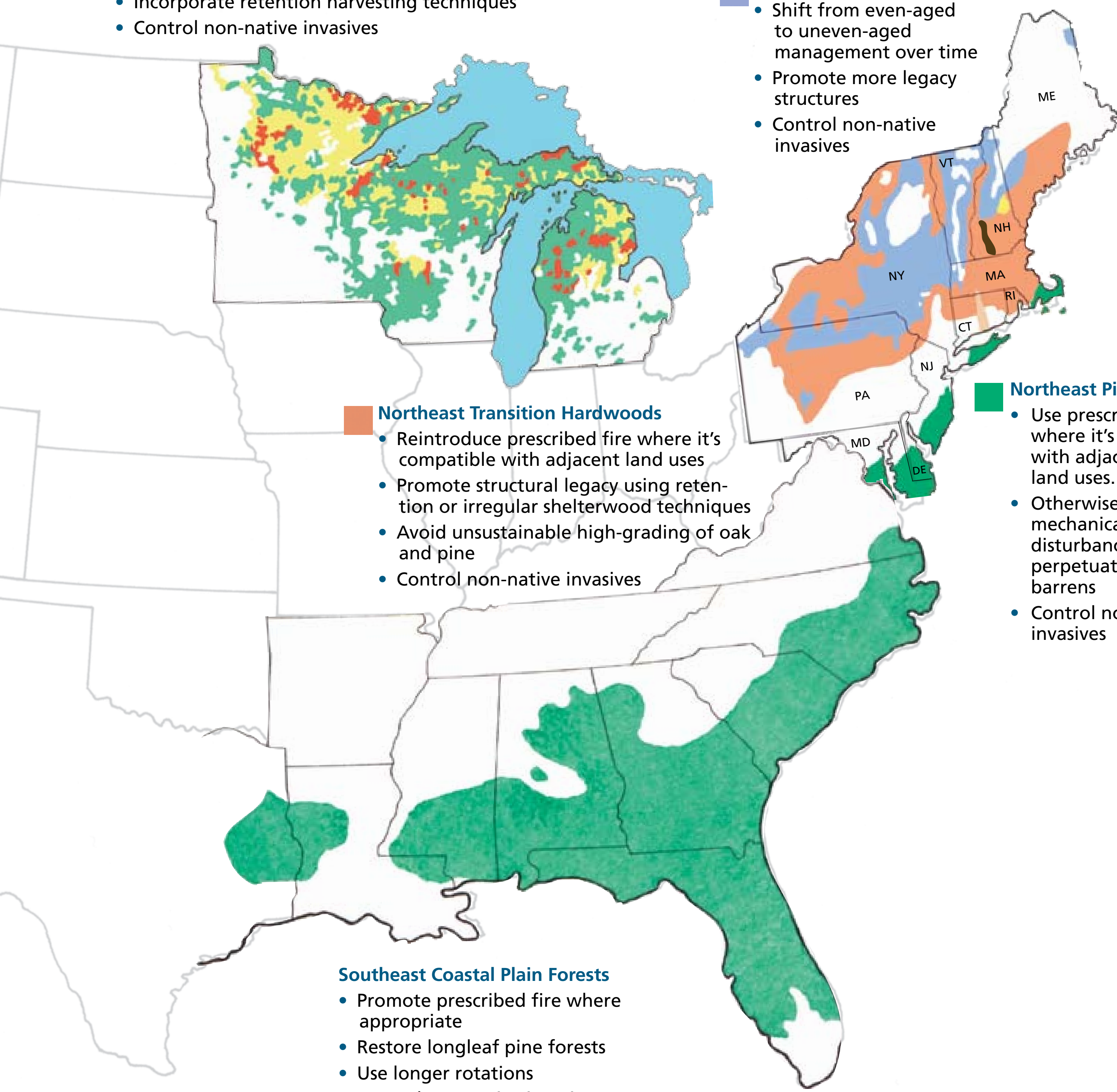
FIGURE 6.5 Biodiversity-compatible forest practices for each of the major forest regions in the United States.

Lake States Forests

- Restore white pine where appropriate
- Move from a preponderance of early-succession aspen/birch forests
- Move toward longer-rotation northern hardwood/conifer forests
- Incorporate retention harvesting techniques
- Control non-native invasives

Northeast Northern Hardwoods

- Shift from even-aged to uneven-aged management over time
- Promote more legacy structures
- Control non-native invasives



Northeast Transition Hardwoods

- Reintroduce prescribed fire where it's compatible with adjacent land uses
- Promote structural legacy using retention or irregular shelterwood techniques
- Avoid unsustainable high-grading of oak and pine
- Control non-native invasives

Northeast Pine Barrens

- Use prescribed fire where it's compatible with adjacent land uses.
- Otherwise, use mechanical disturbance to perpetuate pine barrens
- Control non-native invasives

Southeast Coastal Plain Forests

- Promote prescribed fire where appropriate
- Restore longleaf pine forests
- Use longer rotations
- Control non-native invasives

PRE- AND POST-WILDFIRE STRATEGIES FOR MANAGED FORESTS

Wildfire is an important disturbance that influences the structure, function, and productivity of many managed forest ecosystems. Three NCSSF-sponsored research projects, focused on separate major wildfires in Colorado, Oregon, and California, shed new light on pre- and post-wildfire management strategies in the western states. While the studies were done on public land, this does not imply that management practices on public lands should be applied to private land. Rather, the intent here is to uncover principles discovered on public land that are worth considering by both industrial and family forest owners.

- **The 2002 Biscuit Fire,** the largest recorded fire in Oregon, was started by lightning and resulted in 375 fires that grew to approximately 494,000 acres (200,000 hectares) on the Siskiyou National Forest and the Kalmiopsis Wilderness Area, one of the most ecologically diverse landscapes in North America.
- **The 2002 Hayman Fire** in central Colorado, the largest in the state's recorded history, encompassed 138,000 acres (55,850 hectares) of the Upper South Platte Watershed, dominated by ponderosa pine, Douglas-fir, and understory grasses, forbs, and shrubs.
- **The 2002 Williams Fire** swept through the San Dimas Experimental Forest, northeast of Los Angeles, CA. in the San Gabriel Mountains, burning 38,000 acres (15,400 hectares) of chaparral forest terrain.

The Biscuit Fire burned through several pre-fire management treatments including areas that had been salvage-logged after the 1987 Silver Fire and through 450 acres of long-term ecosystem productivity (LTEP) study plots that were established in 1992 and had not been burned since 1881. The LTEP plots included several different pre-fire treatments: thinning, thinning and underburning (controlled burning under mature forest canopies as shown in Figure 6.7), and clear-cutting followed by reforestation with Douglas-fir or a mixture of Douglas-fir and knobcone pine, and high and low levels of retained large down logs.

These pre-burn treatments gave NCSSF-sponsored researchers the opportunity to examine their effect on Biscuit fire severity and the recovery of the forest ecosystem. They learned that pre-fire management changed how the Biscuit fire burned. For example:

- The highest tree mortality was found in thinned stands that were not underburned (Figure 6.6A) and in young (6-year-old) Douglas-fir plantations.
- Fine fuel (foliage litter and small dead twigs) was the only type of fuel that correlated with crown scorch.
- Stands with mid-story hardwoods appeared to have less fire damage to overstory conifers.
- Plant biodiversity did not dramatically increase after the fires; there was a slight increase in LTEP control plots, but biodiversity decreased in severely burned areas.

Bernard Borman, USDA PNW

FIGURE 6.6A Thinning without underburning.

Bernard Borman, USDA PNW

FIGURE 6.6B Thinning with underburning.


Bernard Borman, USDA PNW FS

FIGURE 6.7 **Underburning after thinning was essential to reduce fuels.**

The findings imply the following tentative conclusions about pre-wildfire management strategies:

- Thinning alone may not adequately reduce fire damage to mature trees. Underburning in thinned stands is required to adequately reduce fuels in mature forests (Figure 6.6B and 6.7).
- Unmanaged stands subjected to fire suppression will not necessarily burn severely (Chapter 4, page 106, Figure 4.36, shows the patchy pattern of mortality after the Biscuit Fire)
- The severe fires in the study area were fueled by finer material, and large amounts of downed wood are not necessarily a predictor of fire severity. However, questions remain about future fire risk as this material decays.
- Hardwoods may actually help reduce fire damage to conifers (Figure 6.8).


Bernard Borman, USDA PNW

Bernard Borman, USDA PNW

FIGURE 6.8 **Tan oak (left) and madrone hardwoods (right), left during thinning, may reduce fire damage to conifers.**

The Hayman Fire gave NCSSF-sponsored researchers a chance to evaluate the effect of one rehabilitation treatment on the natural regeneration and growth of understory plants. The rehab treatment, called seed-and-scarify, is designed to minimize immediate post-fire erosion and surface runoff. The treatment was applied shortly after the fire to 13,200 of the 31,600 acres (5,300 of the 13,200 hectares) rehabilitated by the USDA Forest Service. Researchers wanted to answer three questions.

- What effect did the rehab treatment have on native species, many of which regenerate and re-establish after fire?
- What effect did rehab have on non-native invasives, which can displace native species, change fire regimes and alter the ecosystem?
- What effect did rehab have on other species of concern, such as blue grama (Figure 6.9) and dotted blazing star (Figure 6.10), plants important to the threatened Pawnee montane skipper butterfly (Figure 6.11).

Beckie Hemmerling

FIGURE 6.9 **Blue grama *(Bouteloua gracilis)***

Paula Fornwalt, USDA FS

FIGURE 6.10 **Dotted blazing star *(Liatris punctata)***

Paul Opler

FIGURE 6.11 **Pawnee montane skipper butterfly *(Hesperia leonardus Montana)***

High-severity wildfires can produce a water-repellent layer just below the soil surface that reduces water infiltration into the soil and can increase runoff and erosion in coniferous forests. To minimize flood and erosion damage, managers often use emergency rehabilitation treatments including seeding with native or non-native understory species, mulching with straw or other materials, breaking water-repellent soils by scarifying with rakes or machinery and trapping runoff and sediment that might move downhill by placing logs or straw wattles on hillside contours and in drainages (Fig 6.12 A, B, and C). After the Hayman fire, managers used all of these techniques. NCSSF-sponsored researchers focused on the effects of the seed-and-scarify treatment (Figure 6.13 A and B).

Here's what researchers found when they compared the response of understory plants in unburned, burned, and burned-and-rehabilitated sites.

- Eighteen months after the fire there was no visible sign of the soil scarification treatment, so the treatment effect on understory plants could not be determined.
- Of the two annual grass species seeded (70 percent barley and 30 percent triticale), only triticale germinated, providing less than 1 percent cover. While this minimal coverage was likely due to unfavorable weather conditions following the fire, it is consistent with other studies of seed-only treatments (without scarification) where coverage is often 10 percent or less.
- The researchers saw little effect of the seed-and-scarify treatment on native and non-native species richness and cover, though there were some effects of the burn in general. Total understory cover was comparable among the unburned, burned, and burned-and-rehabilitated treatments, averaging around 15 to 20 percent.
- Most of the dominant understory species common to the area (9 of 14 species) were tolerant of both the fire and the post-fire seed-and-scarify rehab treatment. Each of the species was able to survive and recolonize after the disturbance by sprouting or re-establishing from adjacent seed sources.
- The fire had no long-term effect on the food source of the Pawnee montane skipper butterfly. Blue grama's sprouting ability allowed it to reach pre-burn levels quickly, and dotted blazing star was unaffected by the burn or rehab treatment.

Two important implications of these findings for post-wildfire management strategies are:

- The Hayman Fire had some short-term effect on the understory plant community as a whole and on individual species, but the seed-and-scarify treatment had little additional effect, probably because of the low treatment intensity and also because many plants have developed adaptations to survive or successfully regenerate after wildfire disturbance.
- It's unlikely that the seed-and-scarify post-fire rehabilitation treatment met the goals of reducing soil erosion, but researchers were not willing to recommend whether or not land managers should continue to use the treatment in the future. They thought that further study should be done before using the treatment under similar conditions.

Joseph Wagenbrenner, USFS

FIGURE 6.12A Contour-felled log erosion barriers on the Hayman fire.

Peter Robichaud, USFS

FIGURE 6.12B Straw bale check dams on a small channel within the Hayman fire.

Peter Robichaud, USFS

FIGURE 6.12C Straw wattle erosion barriers (straw-filled mesh tubes staked on hillslopes where there are no burned trees available) on the 2003 Pira fire in Southern California.

A

Peter Robichaud, USFS

B

Peter Robichaud, USFS

FIGURES 6.13A, 6.13B High severity-burn areas and slopes less than 20 percent were scarified using all-terrain vehicles (ATVs) pulling chain-link harrows with 4 inch teeth to break up the water repellent soil layer and increase infiltration rates. On steeper slopes hand rakes were used. Scarification was followed by aerial or hand seeding. The seed treatment was a certified weed-free mixture of 70 percent barley and 30 percent triticale at a rate of 80 kg/ha (70 lb/ac) or 280 seeds/m^2 (26 seeds/ft^2).

The Williams Fire offered a unique opportunity for NCSSF-sponsored researchers to learn how the underground world of California chaparral responds to fire. While there is considerable knowledge about the above-ground chaparral plant response to fire, little was known about the underground world before this research. Obviously, post-fire management decisions need to benefit both above- and below-ground biotic activity.

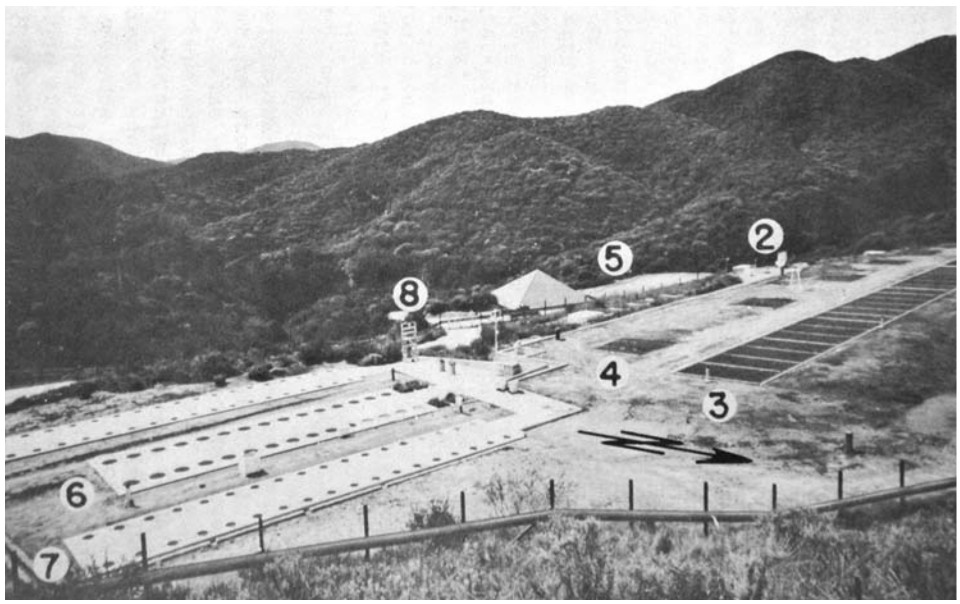
The fire swept through the San Dimas Experimental Forest, including a research study area where soil lysimeters have been used to examine forest soils since the 1930s (Figures 6.14 A and B). (Lysimeters are pits filled with native soil that are used to measure the downward percolation of water and losses of soluble materials leached from the soil by the percolating water.)

After the burn, researchers re-established lysimeter soil-testing equipment and studied how various segments of the underground world responded to the fire. They used soil microbes and macrofauna (animals large enough to see with the naked eye, such as earthworms) as indicators of biological diversity recovery following the fire. The new information, together with existing knowledge about soil microorganisms, emphasizes the role they play in nutrient cycling, decomposition, and plant growth. The activity of microbes and macrofauna, such as altering soil aeration, moisture relations, nutrient status, and penetrability, all affect the growth of plants after wildfire.

The findings have the following implications for post-wildfire management strategies.

- It's important to retain down wood and stumps as part of post-fire restoration. This material controls erosion and releases organic nutrients through decomposition by bacteria and fungi. Re-sprouting stumps are reservoirs of mycorrhizae, associations of fungi and roots that assist plants in the uptake of water and nutrients (see Mycorrhizae Primer box).

FIG 6.14A, 6.14B **The soil lysimeter study area in the 1930s (A) and shortly after the Williams fire (B). After the fire, native vegetation was planted across the lysimeter area to study the effect of plants on soil water movement and nutrient use. The intense fire left vegetation, soil organic matter, and soil organisms incinerated or carbonized. Since the fire all the pines in photo B have died and blown over. Regrowth has been good, including pine from seed, resulting in trees that are already eight feet tall. Oak and greasewood *(chamise)* resprouted along with California lilac *(ceanothus)*, which was absent from the lysimeter area for many years before the fire.**



Paul Sternberg, UC Riverside

A

Paul Sternberg, UC Riverside

B

Mycorrhizae Primer

A **mycorrhiza** is an association of a fungus with the roots of a plant. The fungus enhances the uptake of plant water and nutrients through its extensive system of mycelia (root-like filaments) and hyphae (threads that make up mycelia). There are two major types: **Ectomycorrhizae** and **Endomycorrhizae**.

Ectomycorrhizae are referred to as "ecto-" (a prefix that means "outside") because they form an external sheath of mycelium around the plant root tip. Their cells don't penetrate the root cell walls, but may go between cells in the cortex (the primary tissue of the root). There are a large number of these fungi, but only a few plant families have ectomycorrhizae, and these plants are always trees, such as birch, alder, beech, oak, eucalyptus, pine, and Douglas-fir. The fungus absorbs simple carbohydrates that the tree produces. The tree appears to produce these carbohydrates specifically for the fungus, as the tree doesn't use them. Ectomycorrhizae usually form mushrooms, puffballs, truffles, etc. on the soil surface.

Endomycorrhizae don't have an external sheath around the plant root tip plant (endo- means "inside"), but the fungus mycelia do penetrate the root cells of the host. One variety called vesicular-arbuscular mycorrhizae (VAM) is found throughout the world. The name comes from the distinct structures – rounded vesicles and branched tree-like arbuscules – inside the cells of the infected roots. The vesicles and arbuscules contain stored minerals that the plant needs; they lie in the root cells, making minerals available to the plant. VAM don't produce large fruiting bodies such as mushrooms.

- Mycorrhizal inoculum survives in post-fire soils under re-sprouting shrubs (below the heat of the fire).
- Instead of using mechanical techniques such as ripping that have a negative effect on soil structure, post-fire restoration efforts for soil erosion that use contour log terraces, straw wattles, or silt fences (Figures 6.12 A, B and C) may be more effective.
- Considerable research has shown that mechanical techniques that disrupt the soil surface can destabilize VAM networks (Mycorrhizae Primer box). Loss of VAM may in turn reduce glomalin-associated soil aggregation (a glue-like compound exuded by mycorrhizal hyphae that promotes soil aggregation). It has only recently been discovered that VAM release a lot of glomalin. Ectos also aggregate soils, but the high diversity of ectos and the tendency for some species to occur in deeper soil layers provides a buffer that makes the ectos as a group less sensitive to soil disturbance than VAM. Nonetheless, ecto formation on seedlings can be reduced in areas with heavy soil erosion or other forms of excessive soil disturbance such as mine spoils.
- Activities such as stump removal or excessive control of early succession shrubs should be carefully considered. They can impede the recovery of mycorrhizal fungi by removing sources of inoculum.
- Seed harvesting ants (Pogonomyrmex) also play a role in determining the structure and composition of the vegetation after wildfire. Their excavation for nest cavities in the soil may help to redistribute organic and mineral particles in the soil profile.

While in most cases, mycorrhizal inoculum is probably adequate for post-fire plant regeneration, where excessive soil disturbance (e.g. erosion) or elimination of plant reservoirs has reduced mycorrhizal inoculum, it may be useful to inoculate planted seedlings with mycorrhizal fungi.

SUMMARY

These pre- and post-wildfire projects point to a growing body of knowledge about biodiversity in the recovery of forests following wildfire disturbance. They provide insight into wildfire strategies for managed forests. For example, thinning without underburning is unlikely to reduce wildfire severity because fine fuels contribute more to severe fires than large woody debris. There is evidence that:

- leaving midstory hardwoods during thinning may actually help reduce wildfire damage to overstory conifers
- using seed-and-scarify wildfire rehabilitation treatments are questionable because of their low rate of effectiveness
- fire-adapted native plants are capable of reestablishing their role as ground cover following fire.

Rehabilitation techniques that disturb the soil surface can interfere with what's happening in the underground soil world, where re-sprouting plants and down wood contribute to the activity of mycorrhizal fungi. Post-fire soil mechanical disturbance may interrupt these fungal networks that are necessary for inoculating emerging plants, transferring soil energy, and stabilizing soil. After a fire it is important to look carefully at soil conditions, the potential to introduce invasives, and the impact of salvage logging. Whether or not to salvage log is a decision dependent on ownership management objectives and the personal time horizon and values of the owner.

To Learn More About This Topic, See Appendix, page 167.

WHY IS THIS SUBJECT IMPORTANT?

Biodiversity includes all the living organisms in the forest and the processes that support them: water and nutrient cycling, food webs, energy flows, insect outbreaks, and disturbance regimes. Forestry practitioners, landowners, and managers make decisions every day that affect biodiversity, while at the same time juggling the demands of regulations, forest policy, and changing public attitudes.

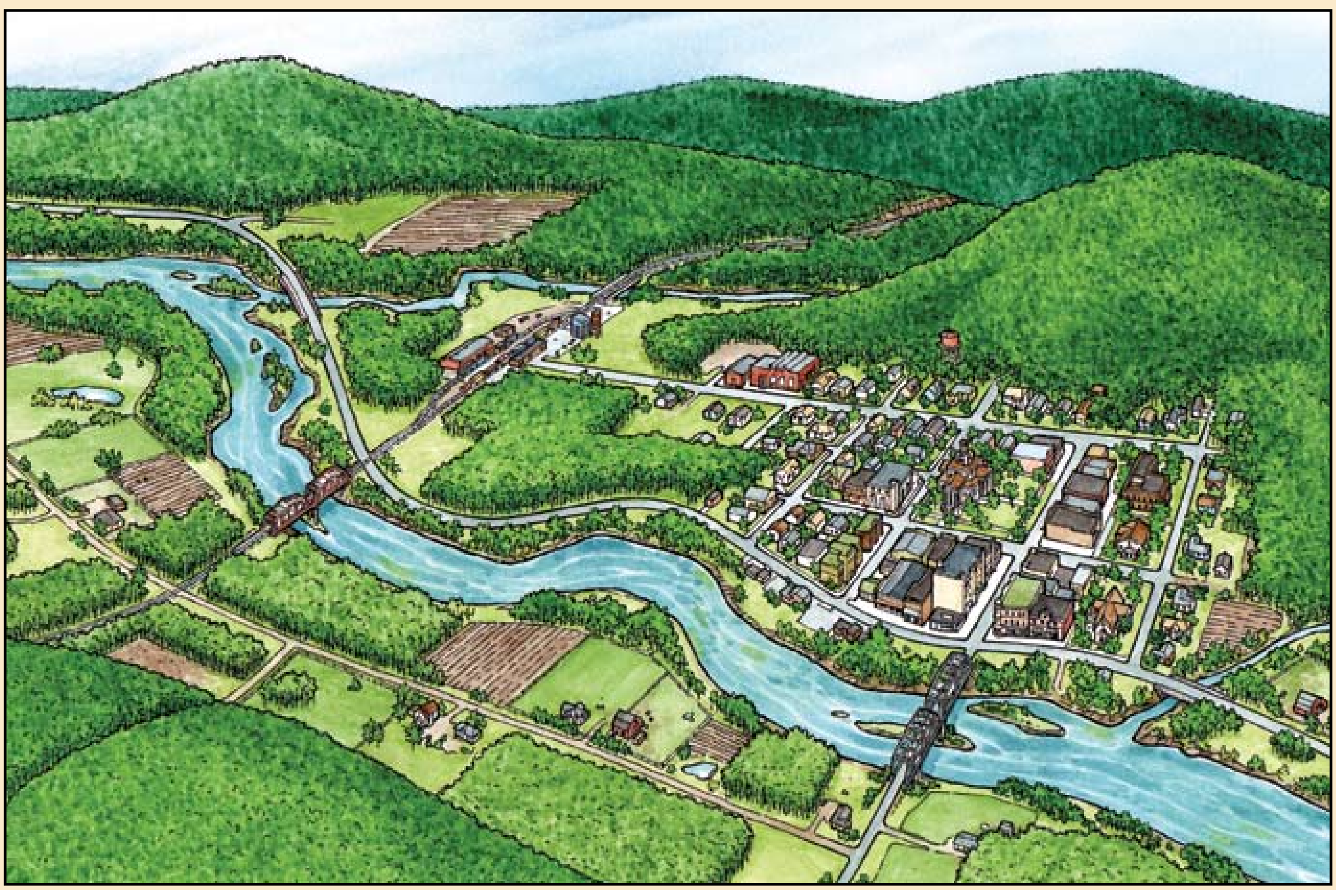
FIGURES 7.1 A & B Landscape planning has taken great strides in the past decade with the help of increasingly sophisticated computer models called Decision Support Systems (DSSs), capable of forecasting change, including land use change like the 50-year projection shown here. The ability to simulate, not just a single town, but multiple communities across a regional landscape, decades into the future, with industrial and retail expansion, roads and major highways, residential growth and forest use change; based on realistic projections and input from stakeholder groups, is a powerful tool. DSSs can help do that, while also calculating forest acreage loss and providing insight into the potential impact on certain wildlife species populations and overall biodiversity.

One NCSSF-sponsored researcher put it this way: *"From spotted owls to spotted frogs, from fishers to mushrooms and bats, we have national, state, and local commitments to keep them thriving in our woods."* The phrase "keep them thriving in our woods" poses a major challenge in terms of both space and time. It means that managers are being asked to maintain biodiversity not only at the stand level (which itself is complicated), but also at the landscape level, and do it over time (for decades in the future), and within the land's historical context.

The larger the scale and the longer the time, the easier it becomes to sustain the native biodiversity of a forest. It is impossible to accomplish this at the stand scale over short periods of time because parts of the total biodiversity of a forest occur only in early stages of stand development and other parts occur only in old-growth. Obviously, one cannot have both at the same time at the stand scale. Thus the need for landscape-scale planning and management.

Landscape is a term that involves scales from small watersheds to entire regions. Landscapes are a mix of various types of land cover resulting from natural conditions, disturbance regimes and human activities

FIGURE 7.1 A

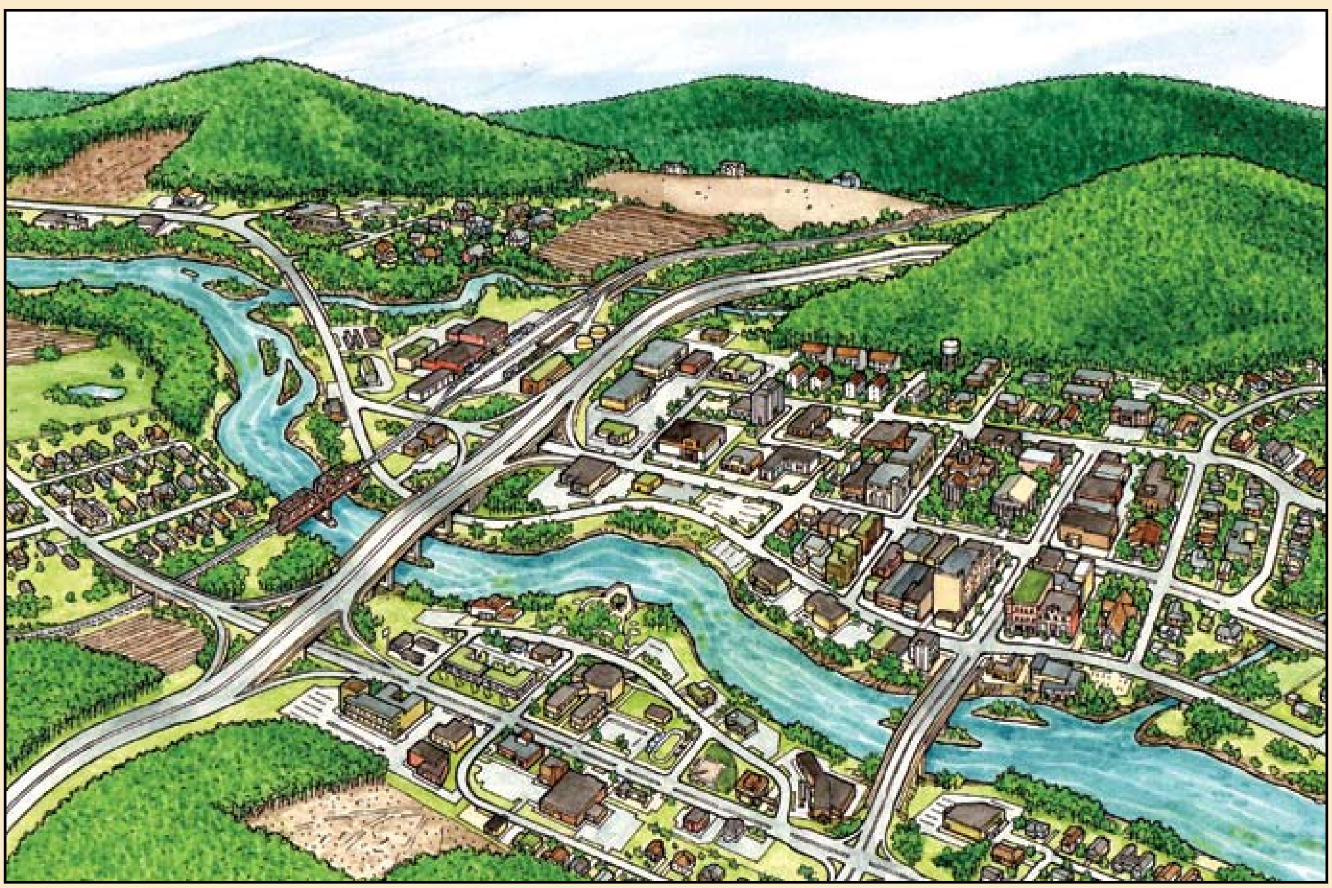


(Chapters 1, 2, and 3). Managing forests at the landscape scale often requires collaboration and coordination of activities across jurisdictions, because species and ecosystems do not follow legal boundaries. Consider for example birds that migrate each year, breeding in North America and wintering in South America, or fish that spawn in forested watersheds, migrate to oceans for part of their life, and return to the original watershed to continue their life cycle. While each forest stand determines what species can live there, some species occur only because of interactions between stand and landscape habitat patterns (more about this below). Biodiversity conservation requires both stand and landscape considerations when managing forest species and the processes that support them. All of this demands planning at the landscape level and has fostered a relatively new area of forest science that uses computer models called decision support systems (DSSs) to assess the impacts of management policies on biodiversity.

This chapter begins with a description of DSSs. It makes the important point that these analytic tools can help managers make decisions but can't make decisions for them. Instead, DDSs help us think about the consequences of alternative actions. Scattered throughout the chapter are highlight boxes describing case studies where DSSs have been applied. They demonstrate the variety of situations where landscape planning is essential. In addition, two NCSSF-sponsored projects, one from the Oregon Coast Range and the other from the Southeast Coastal Plain, are offered as examples of what decision support tools can tell us about the effects of forest policy and management strategies on biodiversity. Be advised that the results of these examples do not apply directly to other regions. You are encouraged to find regionally relevant models for your area. Some are identified in the chapter and others can be found in the appendix references for this chapter.

Landscape-scale planning is important now, and it will become even more important in the future because, although species and ecosystems are not confined by ownership boundaries, the management policies of various owners across a region set the pattern for biodiversity. If full biodiversity conservation is the goal, stakeholders must be able to examine landscapes across ownerships and assess the effects of forest management policy over both space and time (Figure 7.1 A and B).

FIGURE 7.1 B



LANDSCAPE-SCALE PLANNING AND DECISION SUPPORT SYSTEMS

The use of DSSs in landscape-scale planning allows the planners to examine policy effects on specific aspects of biodiversity and provides greater understanding of the consequences. It gives a context to forest policy – a way to see how it fits across the landscape and over time. We will look at two landscape-planning efforts that evaluate policy effects in two major timber regions, a mixed-ownership landscape in the Oregon Coast Range and an industrial ownership in the Southeast Coastal Plain. But first, here's some background information on DSSs.

What are DSSs?

The term DSS is often used to describe a type of computer software, but in more general terms it could be any system for supporting decisions, whether or not it uses computers. DSSs are tools that provide help with complex decisions that involve multiple objectives and uncertainty. Notice the word "help" – a DSS is not a tool that makes decisions, but it can provide valuable guidance for the policymaker. For example, a DSS could give you guidance regarding the identification of an invasive species problem and the management options for dealing with its control and point to other sources of information that might help. But it would still be up to you to consider all the information and make a final informed decision.

DSS Example 1:
Baltimore Reservoirs Forest Conservation Plan

Timeframe: 2000 – 2003

Spatial size: This landscape analysis covered 17,580 acres (7,113 hectares) divided into 836 stands. Fourteen forest plant communities were identified along with many forest habitat structure elements (vertical canopy structure, interior habitat, large down logs). No individual species needs were tracked and no temporal aspect was analyzed (current inventory only).

DSS Used:
NED-1 and ArcView GIS

Description: Baltimore city government wanted to analyze the risks to the long-term sustainability of their reservoir lands and develop and evaluate alternative management scenarios. Maintaining water quality was the primary goal but others included maintaining and enhancing the forest habitat to contribute to regional biodiversity.

For more information:
http://cityservices.baltimorecity.gov/dpw/waterwastewater03/watershed_fcp/cfcp2004.pdf

Christine Duce

FIGURE 7.9 **The City of Baltimore owns and manages three reservoirs that supply water to over 1.8 million people.**

DSSs can be sophisticated computer models, capable of handling millions of pieces of information. They have proven helpful in many fields, including business planning, medical diagnosis, and air traffic control systems. In forestry, they were first used to schedule timber harvests, select silvicultural treatments, and evaluate insect and disease management options. Over time, they also have been recognized for their potential to assist in sustainable management of natural resources, because they can model complex processes and integrate knowledge from diverse academic disciplines.

Why are They Called DSSs?

DSSs consist of three parts: data management, analytical computer models, and a user-friendly interface. They are called DSSs because they:

- evaluate alternative options or scenarios (decision)
- help to deal with complexity (support)
- have a clear, reproducible protocol (system).

How DSSs Can Help

Managers are asking questions about sustaining biodiversity over thousands and even millions of acres. Many of these questions reach decades into the future. It would be impossible to analyze the information needed to answer these questions without computers. They can keep track of and process vast amounts of information, but they must be carefully programmed. An advantage of using DSSs is that patterns and processes not immediately apparent to users begin to emerge from the results. If what emerges makes sense and is believable, then the user has learned something new that may be useful in the final decision.

DSSs can also help to organize and guide stakeholder group thinking. Let's face it, group decision-making can be very complicated, especially if deliberations extend over time and are difficult. A DSS can help organize the suggestions of technical experts.

A Misunderstanding About DSSs

It's a mistake to think of DSSs as computer models that take in your data and crank out answers to your biodiversity problems. Instead, they should be seen as one step in the decision process, tools that can enhance the deliberations about biodiversity problems. They are also referred to as deliberation support tools, because they can inform the debate and deliberation about a problem. They also can be used as exploratory aids to help people think through problems and as games to analyze both problems and solutions. A variety of alternative outcomes may be examined by repeatedly running a DSS model.

Focus	Function	Acronym & Full Name/ Organization
Biodiversity	Reserve selection	CAPS (Conservation Assessment and Prioritization System)
Biodiversity	Reserve selection	Sites
Biodiversity	Reserve selection	Vista (NatureServe)
Biodiversity	Population modeling	RAMAS
Forestry	Activity scheduling	Habplan
Forestry	Activity scheduling	Woodstock (Woodstock, Spatial Woodstock & Stanley)
Forestry	Forest growth and management	NED
Forestry	Forest growth and management	LANDIS
Forestry	Forest growth and management	LMS
Forestry	Forest growth and management	VDDT / TELSA
Forestry	Forest growth and management	RMLANDS
General	Evaluation and prioritization	EMDS (Ecosystem Management Decision Support)
Regional Assessment	Forest growth and management	CLAMS (Coastal Landscape Analysis and Modeling System)

TABLE 7.1 **Focus and function of some DSSs examined by NCSSF researchers**

Different Categories of DSSs and What They Mean

While conducting a survey of DSSs, NCSSF-sponsored researchers found over 100 systems and screened them down to 32 that fit one of the following categories:

- systems that focus on wildlife and biodiversity
- systems that focus on forestry
- general-purpose DSSs with application to forest biodiversity issues
- regional assessments that include forest biodiversity as a component.

Here's what the categories mean:

1. Biodiversity-focused systems are designed to address the problem of reserve selection (finding the most efficient land parcels for conserving specific aspects of biodiversity, based on a landscape in which each parcel is assigned one or more biodiversity values). Often the analysis includes potential costs such as the cost of purchasing the land. Other biodiversity DSSs focus on population modeling, estimating the size of populations over time, given various assumptions about breeding and available habitat (you will see this type of analysis in the Oregon and Coastal Plain DSS below).

2. Forest-focused DSSs fall into two types. The first involves models for scheduling activities. They are similar to reserve-selection models because they try to find efficient patterns for harvesting timber over time. That efficiency can be analyzed both in economic and ecological ways. The second type focuses on simulating tree growth and management. These DSSs can simulate either individual tree or stand growth over time and apply silvicultural treatments or natural disturbances.

3. General purpose DSSs are designed to help with evaluation and prioritization. They provide users with a framework to rate various aspects of a problem and combine the ratings into an assessment, such as the relative condition of a number of watersheds or priorities for restoration (you will see this in the Oregon example).

4. Regional assessments are customized applications designed for use in a specific region. They often involve several individual models linked together to provide an overall conceptual framework (the Oregon model is an example). While designed for a particular region, the methods and tools can potentially be transferred to another region with proper alterations.

Table 7.1 is a handy reference if the world of DSS is unfamiliar territory. It lists some of the DSS examined by NCSSF researchers, according to their focus and function.

What DSSs Do and Don't Do

As mentioned above, DSSs don't give definitive "answers" that will resolve problems once and for all, but they can provide insights that assist with negotiation.

Many DSSs specialize in predicting the impacts of silviculture, fire, and biological threats, but they generally do not include mechanisms to address the impacts of these disturbances on organisms other than trees. One exception is **NED**, which uses simple habitat-species matrices to give landowners an idea of the types of species their forest might support.

Another significant gap is that they tend to focus on types and aspects of trees that are important for timber production. There are, of course, many other forest structural components that could be included in assessing forest habitat, and some DSSs are now integrating downed wood and snags. **LANDIS** even has the capacity to model effects of climate change.

Many DSSs can address components of forest biodiversity, but no single DSS exists that is easily accessible and can provide a manager with an assessment of the probable impacts of alternative forest management options on biodiversity. Few DSS options exist for assessing the effects on biodiversity of climate, biological agents (pests, pathogens, invasives), or fire.

Regional assessment DSSs can model the effects of silviculture and land-use change, but none address the influence on biodiversity of wildfire, biological threats (pest, pathogens, invasive species), or climate change. It is expected that future regional assessment DSSs will include climate change and wildfire influences. Incorporating invasive species is more challenging because of the difficulty of predicting what species might strike and what effects they might have.

Typical Situations and Relevant DSSs

Researchers briefly described the following situations and suggested useful DSSs.

I am a wildlife biologist with an organization concerned that current or proposed forest management is not conducive to the long-term viability of a threatened or endangered species. I need to assess the population viability of the species. Is there a DSS available?

RAMAS is a widely used wildlife-modeling program for meta-populations (Chapter 3, page 72). It can be used to predict extinction risks and explore management options such as designing reserves, translocations, reintroductions and assess human impact on fragmented populations.

PATCH, an alternative, models wildlife at the level of individuals and is designed to project populations of territorial vertebrate species through time.

As a consulting forester, I work with family forest owners. They are interested in harvesting timber but often want to supply habitat for wildlife or protect special areas like wetlands. Is there a DSS available?

NED is a public domain DSS developed by USDA Forest Service. It helps resource managers develop goals, assess current and future conditions and produce management plans.

LSM (Landscape Management System) uses standard inventory information to predict changes in stands and landscapes over time.

Both NED and LSM use **FVS** (Forest Vegetation Simulator) to project stand growth and both systems are stand based. FVS simulates growth and yield for most major forest tree species, forests types, and stand conditions in the United States.

I am part of a conservation organization that is concerned about the loss of wildlife habitat in our region and wants to find areas that are highest priority for preservation. Is there a DSS?

This is a "reserve selection" problem (described above). **SITES** has been widely used and has been adopted by The Nature Conservancy for ecoregional planning. It enables users to specify spatial criteria and display map results. **Vista** (from NatureServe, page 169) is a successor to SITES and operates as an extension to the newer ArcMap GIS software.

I am part of a stakeholder group that wants to work on an ecosystem management approach to the forests in our region. We are concerned with fire and alternative mitigation strategies. Is there a DSS?

Several forestry DSSs can model the effects of fire on forests. **FVS** can simulate effects of fire and the potential fire risks for all trees in individual stands but it does not simulate the spread of fire. **VDDT** simulates fire by having the user suggest the probability of fire for different vegetation types. **TELSA** can locate the fires spatially on a landscape. **Woodstock** and **RMLANDS** can simulate fire, but are very complex computer programs.

Whether or Not to Use a DSS

NCSSF-sponsored researchers are quick to encourage potential users to carefully consider whether DSSs should be used at all. DSSs tend to make information explicit, and that can sometimes lead to highly visible errors. For example, if a stream segment that is known to be dry gets a high fish habitat score, some stakeholders may get the impression the DSS is an untrustworthy black box. All models are limited, and the limitations need to be explained to the users. It is very important that stakeholder participants are given a chance to learn about the inner workings of the DSS. Successful use of DSSs involves small groups of participants who meet repeatedly over an extended period of time.

Are Off-the-shelf DSSs Available?

Yes, many have been developed either at universities or federal laboratories. Some, like **RAMAS** and **Woodstock**, can be purchased from commercial businesses that sell the software and also offer consulting services. Some organizations develop their own in-house DSS.

LANDSCAPE PLANNING AND FOREST MANAGEMENT DECISIONS IN THE OREGON COAST RANGE

Landscape-scale planning using DSSs is a way for policy-makers, managers, scientists, and the public to explore new approaches to forest policy that conserve desired aspects of biodiversity while providing desired levels of commodity production. It enables us to look at forest sustainability across multiple ownerships (public and private forestland, agricultural lands, and urban development). It allows us to answer such questions as how existing policy strategies and new approaches will affect forest biodiversity and timber yield in the coming decades.

Until recently, such answers were limited to a single ownership (usually public forests) or a specific species (often threatened or endangered). Information was not available about policy interactions and their effects across different forest ownerships and ecosystems. Instead, most forest policy assessments focused primarily on economic implications for timber supplies (how much timber will be available?). What was lacking was a broader landscape perspective along with a view of time and geographic space. Today, forest policy strategies that require a long and large view can be matched with technology capable of handling the different perspectives. The CLAMS project (Coastal Landscape Analysis and Modeling System) allows us to see both the forest and the trees and answer questions such as:

- How will reducing the harvest from public lands affect private forestlands over the next century?
- How will today's harvest practices affect biodiversity in 40 or 100 years?
- How will various forest management strategies affect certain wildlife species?

Today's Oregon Coast Range is a mosaic of major forest ownerships, both public and private, each having different management priorities (Figure 7.2). For example, USDA Forest Service (USFS) and U.S. Bureau of Land Management (BLM) lands provide late-succession and old-growth forest. State of Oregon lands contain a range of forest ages and structures, including young forests with large legacies of down wood and higher-elevation true fir forests. Family forest ownerships contain both young forests and the greatest abundance of hardwoods. Private industrial lands include much of the Coast Range early-succession forest, most of the mixed hardwood-conifer forest, and large amounts of legacy down wood.

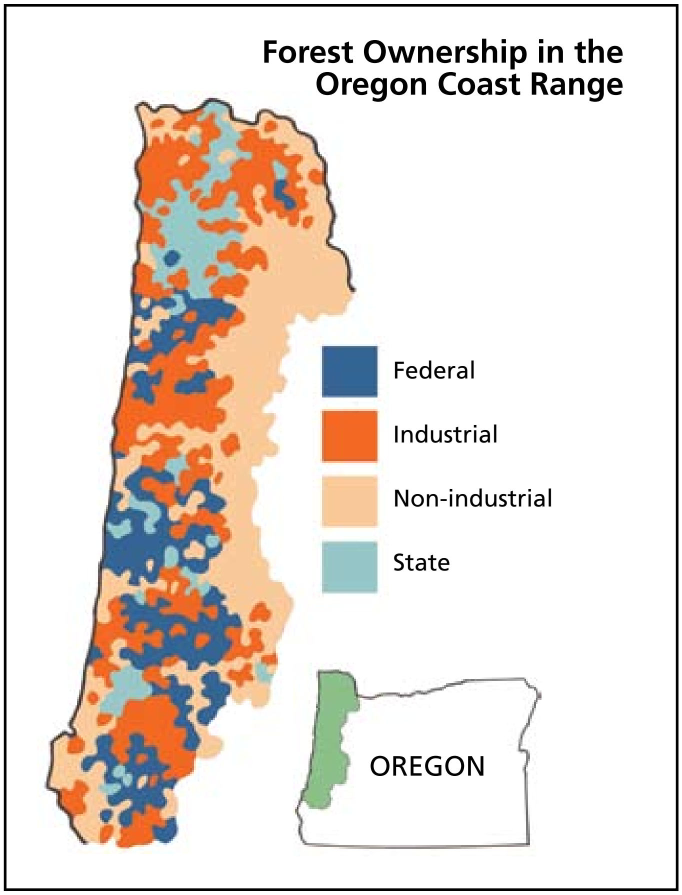


FIGURE 7.2 **Forest ownerships in the Oregon Coast Range.**

NCSSF sponsored part of the CLAMS project. It's a regional assessment DSS that focuses on forest growth and management and simulates current and alternative forest policies and how they affect biodiversity and timber production in the Oregon Coast Range. CLAMS provides a way for researchers, practitioners, policymakers, and the public to understand the potential consequences of forest practices at broad scales. One of its objectives is to determine the effect of current forest policy on biodiversity over the next 100 years (see box on next page). The forest policies include:

- the Northwest Forest Plan for USFS and BLM lands
- the State of Oregon Management Plans for state-owned lands
- the Oregon Forest Practices Act for private lands.

Today's Oregon Coast Range Forest Management Policies

In the 1990s, the **Northwest Forest Plan** brought sweeping changes to USFS and BLM management in the Pacific Northwest, reducing timber sales by almost 90%, the result of policies to protect threatened and endangered species, most notably the northern spotted owl. The Plan placed 67-90% of federal forestland in reserves of one kind or another, allowing harvests only to achieve ecological objectives such as late-succession forests. Along with the Plan, certain salmon species were also listed under the Endangered Species Act, resulting in even more management regulations on all forest ownerships.

The **State of Oregon Management Plan** covers state-owned lands in the Coast Range and assures sustainable timber and revenue while providing for sustainable forest ecosystems and healthy watersheds. It calls for achieving a variety of forest structures including older conifer forests.

Since 1971, the **Oregon Forest Practices Act** has set increasingly stringent standards for any commercial activity involving the establishment, management or harvesting of trees on Oregon's forestlands. It controls those activities on all privately owned forestland.

Given the current forest management policies (see box above), researchers set out to answer the following questions:

1 Where will the timber harvest come from in the next 100 years?
2 What will happen to ecologically important habitats?
3 How will biodiversity change under current policy?
4 Will current policies create biodiversity shortages?
5 What's the potential effect of future population growth, housing density, development, and land-use change (Figures 7.1A and B)?
6 What's the role of different ownerships (federal vs. private) in providing habitat?
7 How can landscape analysis be used to identify protected areas as future sources of large down logs for streams?

The CLAMS DSS provides answers, including social and ecological information, that places people in the landscape and encourages them to think about their role in creating the future. Here are those answers:

1 With the current forest policies (see box), what role will forest ownerships play in supplying timber in the next 100 years?

Industrial lands managed on 35-to-45 year rotations will supply most of the future timber, relying heavily on clearcut harvesting and active reforestation that can be sustained in the future under existing policies. Since two-thirds of the private forests in the Coast Range are industrial, their management will dominate the private forest landscape. Family-forest management is more difficult to predict, but on those ownerships there will probably be few acres with forests over 100 years old.

A small volume of timber will come from forest thinning on public lands (USFS or BLM). Timber harvest on federal lands will decline in the second half of the century as stands become older and are no longer eligible for thinning.

2 What will happen to ecologically important habitats?

There will be a decline in open forests. Today, these forests include hardwoods, remnant trees, and a dominant shrub cover, but hardwood acreage will decrease by 85% on all ownerships as conifers overtop hardwoods. Also contributing to this decline are the reforestation requirements of the Oregon Forest Practices Act which call for conifer trees to be "free to grow" within six years after a harvest, and supports the suppression of hardwood and other vegetation that competes with those conifers.

Open forests with remnant trees will decrease by 20%. Most of the "planned" openings will be created on industrial lands by clearcuts, and only a minimum number of remnant trees will be left, the result of requirements by the Oregon Forest Practices Act. However, openings from wildfire or windstorms, which are infrequent natural disturbances in the Coast Range, could influence this trend.

The most ecologically diverse forests will be on state-owned lands, where the highest management flexibility currently exits.

3 How will forest biodiversity change under current policy?

The CLAMS DSS results indicate that:

- ▲ Forest acreage dominated by mature and old-growth conifers and associated species will increase by nearly 300%. However, that amount is still at the lower limit of historical levels (Chapter 4, page 102).
- ▲ Habitat acreage for red-backed voles, a focal species (Chapter 3, page 75), will increase by 25%, mostly on public lands.

- Habitat acreage for low-dispersal canopy lichens (Figure 7.3) will double and be concentrated on public lands.
- Habitat for spotted owls and marbled murrelets (both federally listed as threatened species in Oregon, Figures 4.28 and 4.29) will increase dramatically over the next 100 years, but whether their populations also will increase is highly uncertain, as non-habitat factors appear to be driving population dynamics.
- Habitat for western bluebirds, a focal species, will decline slightly; they need open meadows and early succession habitats.
- Habitat for moderate-dispersal lichens, a focal species, will decline and then stabilize.
- Habitat for olive-sided flycatchers, a focal species, will decrease at first then increase later in the century.

4 Will current policies create biodiversity shortages?

The CLAMS DSS results indicate that:

- The increase in older conifer forests will be matched by a decline in area of other forest types that provide biologically diverse and unique habitat on federal lands, namely early-succession and mixed-species stands. This could be an undesirable change.
- The increasing contrast in habitats and reduced habitat diversity across and within ownerships could restrict the movement of some species.
- The decline in hardwoods will affect the species diversity associated with those forests.
- The decline in early-succession forests with openings, remnant trees, snags, and dominant shrubs will affect species associated with them.
- Middle-age forests (50-150 years) will decline and not be replaced through any planned action on federal lands.

Robert Logan

FIGURE 7.3 **The lettuce-shaped, nitrogen-fixing lichen *(Lobaria oregana)* converts atmospheric nitrogen to a form useable by both terrestrial and aquatic plants. It's more common in conifer stands that are at least 200 years old and is limited to the Pacific Northwest coastal region.**

5 What are the potential effects of future human population growth, housing density, development and land-use change?

The CLAMS DSS results indicate that:

- The majority of Coast Range forest will remain intact as long as markets exist for wood from private forests.
- An expected 60% increase in Oregon's population will mostly be felt at forest edges, particularly in the Willamette Valley and around the cities of Portland and Salem.
- There will be a projected 10% reduction in industrial forests available for timber harvesting and a 33% reduction in family forest ownerships over the next 100 years, with the most vulnerable forests near urban-growth boundaries.

These answers indicate that the CLAMS DSS goes well beyond the level of analysis previously available to land managers. It can also help to develop and evaluate alternative policies that could lead to more effective forest management

DSS Example 2:
Chesapeake Forest Plan

Timeframe: 1999 - present

Spatial size: The Chesapeake Forest is 58,000 acres (23,466 hectares) on the eastern shore of Maryland. In 1999 the state of Maryland acquired the lands along with a sustainable forestry management plan and an ongoing contract with consultants for management.

DSS Used: Tree growth simulator plus HABPLAN

Description: A DSS was used to analyze trade-offs between timber production and endangered Delmarva fox squirrel habitat, over a 50-year period. But when the process was opened to the public, access to hunting for other species became the dominant issue. The result was a process that focused on the values involved in the hunting debate.

For more information: http://www.dnr.state.md.us/forests/chesapeakeforestlands.asp

Conservation Fund/Chesapeake Forest Lands

FIGURE 7.10 **Marshyhope Creek, the Rosedale Powerline and other land uses (pictured) contributed to the complications in developing the Chesapeake Forest Plan.**

in the Coast Range. For example, what if the Oregon Forest Practices Act required private landowners to retain five large live trees per acre? Realizing that this was a way to retain wildlife habitat after a harvest, researchers wanted to know what effect it would have on certain species if it were used across the entire Coast Range landscape. Here's what they found:

- The policy would result in increased habitat for red-backed voles, western bluebirds, and moderate mobility lichens.
- It would require landowners to leave valuable trees in the forest.
- If the practice were to become policy, private landowners could experience a 5-7% reduction in harvest that would cost millions of dollars each year in reduced wood available.

Forest management restrictions to protect threatened and endangered salmon encouraged researchers to look at fish-habitat quality in the Coast Range. They found that it correlated with forest ownership. For example, stream reaches best suited for steelhead trout occur primarily on publicly owned forestlands. That's where smaller, higher gradient streams most suitable for steelhead reproduction are found. In contrast, stream reaches best suited for coho salmon occur on privately owned lands. Coho salmon occupy low-gradient, valley-bottom streams flowing mainly through private agricultural lands that were forestland, wetlands, or meadows at one time. CLAMS found that over the next century, it's likely that these lands will be subject to more intensive land management than steelhead streams, with implications for coho populations.

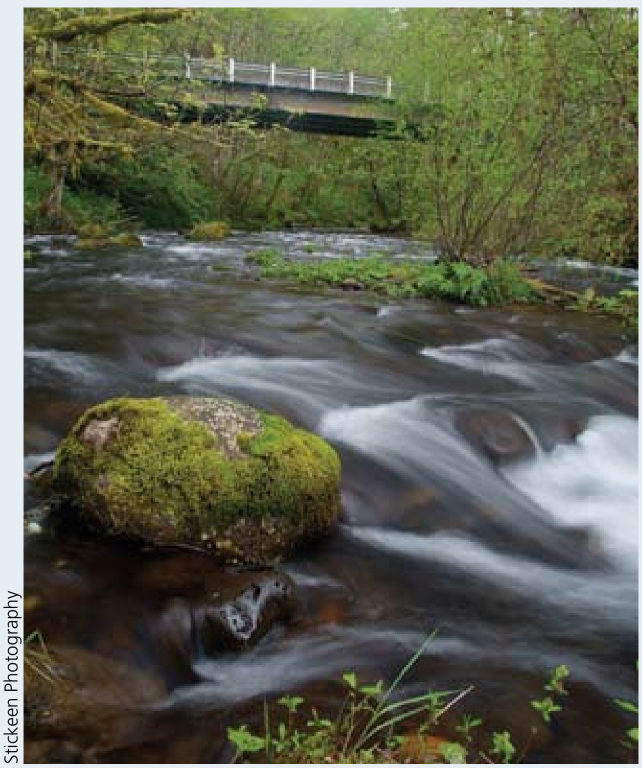
While CLAMS takes a broad look at the landscape, it can also be practical at very small scales. For example, land managers who are trying to determine where stream restoration should occur often don't have much information about where it might be most effective. CLAMS can tell them how well a landscape can support a threatened species such as salmon. In the case of coho, CLAMS can describe the potential for valley-bottom streams to produce coho habitats. CLAMS researchers also developed new riparian-protection strategies base on the potential for hillslopes and headwater streams to deliver sediment and wood to fish-bearing streams. They learned that it might be possible to develop more effective riparian policies based on providing disturbance processes that maintain fish habitat complexity. And they identified key headwater areas where the most wood could be provided to streams for the least total area in protected status.

In summary, landscape-scale planning, like that in the Coast Range using the CLAMS DSS, demonstrates that forest management policies can have a strong affect on biodiversity. It shows how policies might effect biodiversity across all ownerships and allows for evaluation of alternative policies that can lead to more effective forest management in the region.

DSS Example 3:
Sandy River Basin Anchor Habitats Project

Timeframe: 2004-2005

Spatial size: The Sandy River is a tributary of the Columbia River, draining 508 square miles. The river's mouth is within 20 miles of Portland, Oregon. Approximately 75 percent of the watershed is in public ownership and 25 percent private. The river supports several species of anadromous salmon, including spring and fall Chinook, coho and winter steelhead, all of which have experienced declines during the last century and have been listed as endangered under either state or federal Endangered Species Act.



Stickeen Photography

FIGURE 7.11 Gordon Creek, Sandy River Basin

DSS Used: EMDS

Description: The goal was to develop a basin-wide watershed restoration strategy for the Sandy River Basin by identifying anchor habitats – stream reaches that are critical for the maintenance of high quality habitat for four species of salmon and steelhead – than the greater river system. Anchor habitat stream segments were identified and can now be used to guide habitat restoration planning activities.

For more information:
http://www.oregontrout.org/images/8success/Sandy%20Habitat%20Report.pdf

LANDSCAPE PLANNING AND FOREST MANAGEMENT DECISIONS IN THE SOUTHEAST COASTAL PLAINS

Like forest practices in the Oregon Coast Range, those in the Coastal Southeast are directed by regulations and guidelines designed to protect habitat values such as:

- riparian-zone width
- regeneration and harvest methods
- retention areas
- set-asides
- harvest area size.

NCSSF-sponsored researchers in the Southeast developed DSS tools that can evaluate the tradeoffs associated with some of these forest regulations and guidelines. These tools (see Quantitative Habitat Models box) allow landowners to simulate various landscape strategies and compare tradeoffs between biodiversity protection and wood production.

This landscape-scale project consisted of two parts. **In the first part,** the researchers developed models that described the relationship between elements of biodiversity in the southeast, (communities of birds and herpetofauna such as salamanders, frogs, toads, turtles, lizards, and snakes) and major factors that potentially affect them, such as landscape patterns at various scales, forest structure, and biomass. The researchers wanted to evaluate these relationships in forested landscapes managed for commercial forest products. They gathered data on bird communities and landscape and forest structure from managed forest landscapes in Arkansas, South Carolina, and West Virginia, and collected data on herpetofaunal communities from one site in Arkansas (Figure 7.4).

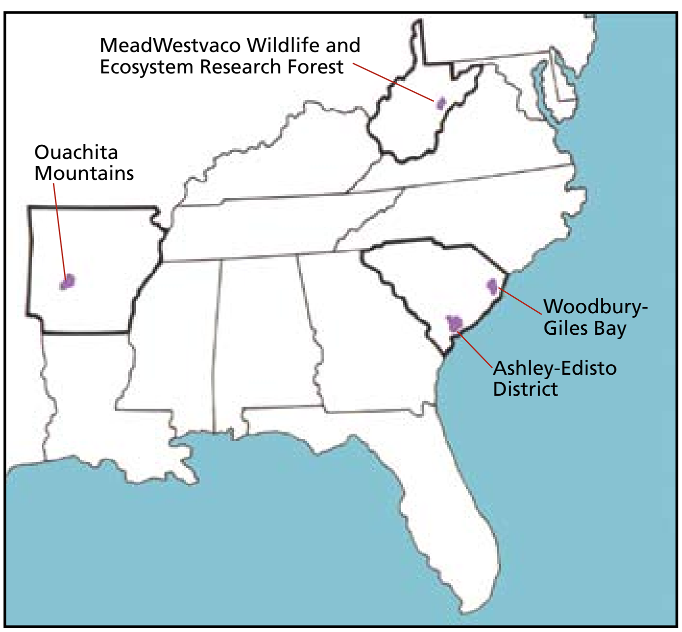


FIGURE 7.4 **Landscape planning databases came from a broad area in the Southeast, giving researchers confidence in making region-wide application of the results.**

Quantitative Habitat Models and What They Can Do

Any successful landscape-scale approach to sustaining biodiversity will depend on our understanding of the relationship between landscape patterns such as stand ages and forest types and the abundance (richness) of various species or species guilds (groups of organisms that use the same forest resource in a similar way). It's essential to quantify these relationships. For example, while it's obvious that the cavity-nesting bird guilds need trees that provide cavities, this doesn't tell us how much of this habitat is required to sustain viable populations, or how to balance the needs of this group with the needs of other bird guilds that may require different habitats. Today, researchers have quantitative habitat models that allow exploration of landscape strategies and their ecological and economic tradeoffs (see A Misunderstanding about DSSs, page 137).

Here's an important point: most studies of bird communities and their dependence on forest structure have been done at the forest plot or stand level. Unfortunately, stand-level relationships rarely extrapolate well to broader landscape scales. That's because the actual distribution of individual bird species (how they select habitats, their foraging and mating behavior, and their population dynamics) may be taking place on a much broader scale than the plots or forest stands where they were measured. For this reason, habitat models must be responsive to space if they are going to be used to simulate effects of various landscape management strategies or to test the effects of spatial regulations such as harvest area size restrictions or requirements for retention areas or set-asides. Before 1995 there were no quantitative models capable of relating species abundance to landscape patterns at various scales. Since then such models have been developed, and this NCSSF-sponsored project produced one of them.

FIGURE 7.5
Acadian flycatcher *(Empidonax virescens)* is a neotropical migrant.

Greg W. Lasley/CLO

FIGURE 7.6
Blue-gray gnatcatcher *(Polioptila caerulea)* is a neotropical migrant.

John Dunning/CLO

FIGURE 7.7
Common yellowthroat *(Geothlypis trichas)* is a neotropical migrant.

Isidor Jeklin/CLO

FIGURE 7.8
Eastern wood-pewee *(Contopus virens)* is a neotropical migrant.

Michael J. Hopiak/CLO

In the second part of the project, the bird-habitat models were combined with a harvest schedule model **(Habplan,** Table 7.1**)** to develop management scenarios for a large industrial forest (Ashley-Edisto District, Figure 7.4) in South Carolina. It's located in the Outer Coastal Plain Mixed Province, south of the town of Summerville.

The vegetation of the Ashley-Edisto District includes loblolly pine on upland sites and interior swamps of water tupelo, swamp tupelo, and bald cypress. Many of the upland forests contain isolated wetlands with hardwood and/or pine overstories. The bird-habitat models measured habitat suitability for overall bird richness and richness of selected guilds, including:

- canopy nesters
- cavity nesters
- shrub-associated birds
- neotropical migrants.

They also used models specific to vulnerable birds in the region that need conservation actions to ensure sustainable populations such as the:

- Acadian flycatcher (Figure 7.5)
- blue-gray gnatcatcher (Figure 7.6)
- common yellowthroat (Figure 7.7)
- eastern wood-pewee (Figure 7.8).

These guilds and species were selected to represent a range of habitat requirements.

The researchers simulated five forest-management scenarios that involved constraints on harvesting, including:

- **Unmanaged (no harvest, complete protection)** All stands were allowed to age over the 40-year planning period.
- **Set-aside** A do-nothing regime was assigned to all pine and hardwood stands older than 40 years at the start of the simulation. This gave about 24% of the forest area to set-asides. Most were hardwood stands that continued to age over the 40-year planning period. The intent of this scenario was to mimic guidelines that call for part of the landscape to be managed under extended rotations.
- **Harvest adjacency restrictions** Three scenarios were simulated: unrestricted, 180-acre, and 120-acre maximum harvest size.

- **Road closure** All roads were planted with pine at the start of the simulation allowing them to age over the 40-year period. This scenario removed the effect of roads from the analysis.
- **Riparian guidelines** These guidelines were tested using a 50-meter management zone on each side of the major streams. The riparian zones were unmanaged hardwoods that were allowed to age over the 40-year simulation.

Throughout the simulations, there was an even flow of harvested acres and wood volume, preventing a large harvest at the end of the 40-year period. All harvested wood was considered to be pulpwood. The total harvested wood volume was calculated for each scenario.

What was the Response of Birds to the Five Forest Management Scenarios?

The unmanaged scenario yielded the greatest improvement in overall species richness. It resulted in an increase in canopy nesters, cavity nesters, neotropical migrants, and the eastern wood-pewee. In contrast, shrub-associated birds decreased over time along with the Acadian flycatcher, common yellowthroat and blue-gray gnatcatcher. Of course, all of the increases also came at the expense of any harvested wood volume over the 40 year modeling simulation. Obviously, this is not an economically viable scenario for commercial forests.

The set-aside scenario was most striking because it benefited bird richness as a whole and many of the guilds, probably through increased landscape heterogeneity and a modest increase in the availability of older forest. In all cases it produced bird habitat benefits that were greater than the other managed scenarios (described next) and reduced harvested wood volume by 14%. Researchers speculated that smaller set-asides would likely produce a lesser, but still noticeable wildlife benefit.

The harvest adjacency restrictions scenario had a small benefit for some groups, but at considerable cost, because these restrictions prevented some larger stands from being harvested. In contrast to expectations, this scenario did not generate significant benefits. While harvest block size restrictions may meet aesthetic objectives, they don't appear to meet some biological objectives.

The road closure scenario did not have a large impact, indicating that edges caused by roads, at least in this study, did not influence diversity, nor did roads cause either a positive or negative effect overall.

The riparian buffer scenario (50-meters) had a neutral effect. It did not benefit any of the individual species or guilds, except the Acadian flycatcher (a riparian-dependent bird).

Taken together, the harvest adjacency restrictions, road closure and riparian guidelines had a negative effect on total bird richness, canopy nesters, cavity nesters, neotropical migrants, and the eastern wood-pewee. They had a neutral or positive effect on shrub-associated birds, Acadian flycatchers, common yellowthroats, and blue-gray gnatcatchers.

Research Surprises

Researchers were surprised at the high benefit/cost ratio of setting aside a small portion of the landscape or managing a small portion on an extended rotation. Even more surprising was the fact that all bird species and guilds benefited at least to some degree compared to the other management scenarios. These results support recommendations to set aside some portion of the landscape or manage it on an extended rotation and suggest that in at least some cases the cost in wood production is relatively low. Set-asides might be done at no cost when sufficient noncommercial lands, such as parks, are combined with commercial forestlands, but each case must be evaluated on its own merit. Also, set-aside costs can be reduced when these areas are managed for long-rotations and high quality wood. Riparian zones could also function as set-asides.

Another surprise was that the other management scenarios provided little benefit to breeding birds. The harvest-adjacency restrictions (requiring smaller harvest units) provided no benefit. Riparian zones benefited only the Acadian flycatcher, a bird associated with riparian areas. However, only one riparian width (50 meters) was tested, and results may vary with different zone widths, age structures, or vegetation composition. Researchers also pointed out that the Outer Coastal Plain Mixed Province landscape includes many small water bodies (ponds, swamps, etc.), which may have caused simulation confusion in classifying riparian versus upland habitat.

The researchers caution that the study looked only at birds and acknowledge that results could be different for other animals such as amphibians. They also point out that the results are limited by the strength of the bird habitat DSS models (there's always room for improvement) and the extent to which birds are representative of overall biodiversity, especially less mobile organisms. The results are specific to the area modeled. However, this kind of analysis shows the value of landscape-scale planning and the insight that DSSs provide for testing alternative management strategies.

SUMMARY

This brief look at landscape-scale planning in the Oregon Coast Range and the Coastal Southeast indicates that DSSs can help managers understand the effects of forest policy on biodiversity and sustainable forestry. In today's Coast Range, the various forest ownerships each play a role. Federal forestlands are being managed as natural forests, and over time they will provide predominantly late-succession old-growth, with relatively little early-succession habitat. In contrast, private industrial forestlands will provide most of the timber supply and will

DSS Example 4:
Summit County (Colorado) Lower Blue Subbasin Master Plan

Timeframe: 1995-2000

Spatial size: The analysis looked at 178,400 acres (72,178 hectares) and the maximum "build out" estimate under nine different development scenarios. Biodiversity consisted of four measures: rare vegetation types, habitat for species of special concern, neighborhood species richness and economically important species habitat.

DSS Used: custom GIS application (System for Conservation Planning – ScoP)

Description: Summit County, CO is home to the mountain resorts of Breckenridge, Vail and Keystone and has been one of the fastest growing in the nation. 80 percent of the county land area is The White River National Forest. Researchers at Colorado State University helped county government and stakeholders integrate biodiversity information into county-level planning and understand the impact of development regulations on biodiversity by projecting the landscape to maximum allowed development density.

For more information:
http://www.consecol.org/vol6/iss1/art5

David Theobald

FIGURE 7.12 **Lower Blue Subbasin, Summit County, CO.**

do it sustainably for at least the next 100 years if local wood markets hold.

The Southeast Coastal Plains study describes an approach to evaluating costs and benefits of forest management guidelines in commercial forest enterprises, by measuring biodiversity (multiple bird species and guilds) with spatially explicit wildlife response models.

Findings of these studies indicate that:

- Landscape planning with DSSs is relevant to forest management everywhere.
- Forest-management policies create landscape patterns that strongly influence biological diversity. It is important to assess policy effects at the landscape scale when considering biodiversity and sustainable forestry practices.
- Landscape-scale analyses are needed in other forest regions to assess the effects of forest management policies on biodiversity. Cross-ownership simulations are important. The problem of forest sustainability is that species and ecosystems do not follow legal boundaries, but policies of forest owners do set the direction for biodiversity in a region. Unless it is very big and contiguous, a single ownership doesn't provide a complete picture of the changes in a region, and policies developed ownership-by-ownership can result in loss of diversity or declines in some habitat types. However, landscape analyses within single ownerships also provide information about biodiversity and guidance for sustaining it.
- When estimating biodiversity effects of regional policies, it's important to recognize stand-level characteristics such as tree growth after thinning and the number and size of wildlife legacy trees. In some cases relatively minor changes in stand practices can have landscape and regional impacts on biodiversity.
- Spatial analysis can identify parts of the landscape that are crucial to biodiversity conservation and can reduce the cost of achieving that biodiversity (for example, salmon habitat protection and older forest set-asides for birds).

To Learn More About This Topic, See Appendix, page 168.

WHY IS THIS SUBJECT IMPORTANT?

Today more than ever, forest managers and policymakers face uncertainty. There's uncertainty about how to manage the complex and dynamic ecosystems for which they are responsible. There's uncertainty about the global markets in which they compete. There's uncertainty about the societal values they attempt to satisfy. There's uncertainty about future climate change. And there's uncertainty about the regulatory environment that dictates their actions. But even with all this uncertainty, forest managers must still make decisions based on forest capabilities, their goals, and the best available science, accepting that there are limits to our knowledge of ecosystem-based forest management.

It's in this kind of uncertain environment that adaptive management (AM) is most valuable. Forest managers and policymakers are discovering that AM is a way to learn how to deal with uncertainty by deliberately designing and practicing management actions as experiments and learning from them. AM combines research and management, making management more scientifically rigorous and research more policy-relevant. The word

AM Example 1:
Adaptive Management of Pine-Lichen Woodlands

Where: British Columbia (Canfor Corporation)

The Problem: Find silvicultural methods that maintain and enhance terrestrial lichens for woodland caribou after timber harvest.

Timeframe: Ongoing for 5 years. The slow growth rate of lichen requires several years to follow lichen response to stand-management practices.


Kevin Land

Caribou occupy forests with abundant lichens.


Kevin Land

White reindeer lichen is caribou winter food. Lichens grow slowly and mature clumps are as much as 100 years old.

Experimental design: Nine replicated treatments, approximately 100 hectares (247 acres) each, replicated 3 times. Treatments include a variety of timber harvesting systems evaluated by monitoring pre- and post-harvest lichen abundance.

Expected results: Best management practices that result in policy improvements.

More Information:
www.wildlifeinfometrics.com

adaptive implies a need to adjust or continuously improve forest practices, based on better science, the lessons of experience, and changing public expectations. In fact, AM may be essential for achieving sustainable forestry, because it can help managers adapt to changes in environmental conditions, economic markets, scientific knowledge, experience, technology, and social values.

Chapter 1 described how managers in various regions of the United States are trying silvicultural approaches modeled after natural disturbance regimes. The purpose is not to precisely mimic natural disturbance and stand development, because that's almost never possible, but rather to achieve ecological goals. However, it's a challenge to silviculturally mimic natural disturbance in order to restore ecological complexity. Managers need tools that lead to both restoration and maintenance of ecological complexity, while at the same time meeting timber-management objectives. No one can say for certain that these approaches will result in biodiversity conservation and sustainable forestry, but AM can be used to test these approaches, monitor their effects, and adapt to what we learn.

AM is valuable because it forces managers to keep asking the correct questions and to look beyond traditional science. AM encourages scientists and managers to engage with stakeholders or shareholders, those who have legitimate roles in policy-making concerning forest use and management. AM is about learning while doing. It does not postpone action until "enough" is known, but instead acknowledges that time and resources are too short to defer action, particularly action to address problems of declining biodiversity.

Despite its problem-solving potential, examples of successful AM initiatives are not common. While it's a logical and compelling approach – learn from what you do and change practices accordingly – experience shows that AM has fallen short on delivery. For that reason, NCSSF sponsored a project to explore AM and describe what it is, how it's different from traditional management, and how to use it more effectively. NCSSF wanted to know what factors make AM work successfully and what factors inhibit its success. This chapter describes the findings of that project. It starts with background information, identifies AM enabling factors, and provides insight from AM practitioners about how to use it successfully in forest management. Scattered through the chapter are boxes that highlight on-the-ground examples of AM.

WHAT DO WE KNOW ABOUT ADAPTIVE MANAGEMENT?

What is AM?

Here are some important characteristics of AM:

- It is a form of learning. It deliberately uses management actions as a source of learning to inform subsequent management policy or actions.
- It is a systematic process for continually improving management policies and practices by learning from the outcomes of operational programs.
- It is the careful combination of management, research, and monitoring to gain credible information and allow management activities to be modified by experience. It acknowledges institutional barriers that need to change and designs ways to overcome them.
- It is a rigorous approach for learning through deliberately designing and applying management actions as experiments.

AM was first formally developed in the 1970s (trial and error, its common-sense, less rigorous counterpart, has been around for a very long time) and has been applied to resource and ecosystem management problems throughout North America and elsewhere. It's been applied to attempts at salmon rehabilitation in the Columbia River Basin while producing hydroelectric power, management of acid rain in the eastern United States, and management of water in the Florida Everglades. It's also been applied to forest management issues. For example, it has been attempted mostly without success in Adaptive Management Areas in the Pacific Northwest, with better outcome in the Clayoquot Sound of British Columbia and in Alberta, where the Alberta-Pacific Forest Industries have adopted AM as the guiding principle for their operations.

As mentioned above, AM seems so logical – learn by doing. Yet, as our list of its characteristics pointed out, AM adds a deliberate and formal dimension to framing questions and problems, undertaking experimentation and testing, processing the results, and reassessing policies in light of new knowledge. As shown in Figure 8.1, AM is an approach to management that involves:

- synthesizing existing knowledge about a problem (Step 1)
- exploring alternative actions and making predictions about their outcomes (Step 2)
- selecting one or more actions to implement (Step 3)

- monitoring to see if the outcomes match those predicted (Step 4)
- comparing actual outcomes to forecasts (Step 5)
- using the results to learn and adjust future management plans and policy (Step 6).

The Six Steps in AM

Some of the steps in AM overlap. Others must be revisited over time. Some may require more detail than others. All the steps need to be planned in advance, though it may be necessary to modify them later. All six steps are essential to AM. Omission of one or more will hamper the ability to learn from management actions. In addition, documenting each step and communicating the results are crucial to building knowledge, especially for projects that extend over a long time.

Step 1, problem assessment, frames the problem by forcing the right questions. For example, in the controversy over what management strategy was appropriate for salmon recovery in the Pacific Northwest, it was crucial to identify the underlying cause of salmon decline. Fisheries managers said it was habitat loss, fishermen pointed to predators, and others said it was water pollution, hydropower dams, harvests or hatcheries. Most likely, all of these factors contribute to population conditions. The challenge in AM is to test each possible factor in a complex, dynamic, interacting ecosystem where all the other factors may be at work. Step 1 also emphasizes the social and political aspect of AM. It's a process of "working through" the problem, and is often done in a facilitated workshop. All stakeholders (or responsible parties in a private sector setting) most likely to be affected by the policies being implemented need to be involved in defining the scope of the management problem, synthesizing existing knowledge, and exploring the potential outcomes of alternative management actions. Forecasts need to be made about the potential outcomes in order to assess which actions are most likely to meet management objectives. During this exploration and forecasting process, key gaps in understanding (those that limit the ability to predict outcomes) are identified.

Step 2, design, involves designing a management plan and monitoring program that will provide reliable feedback

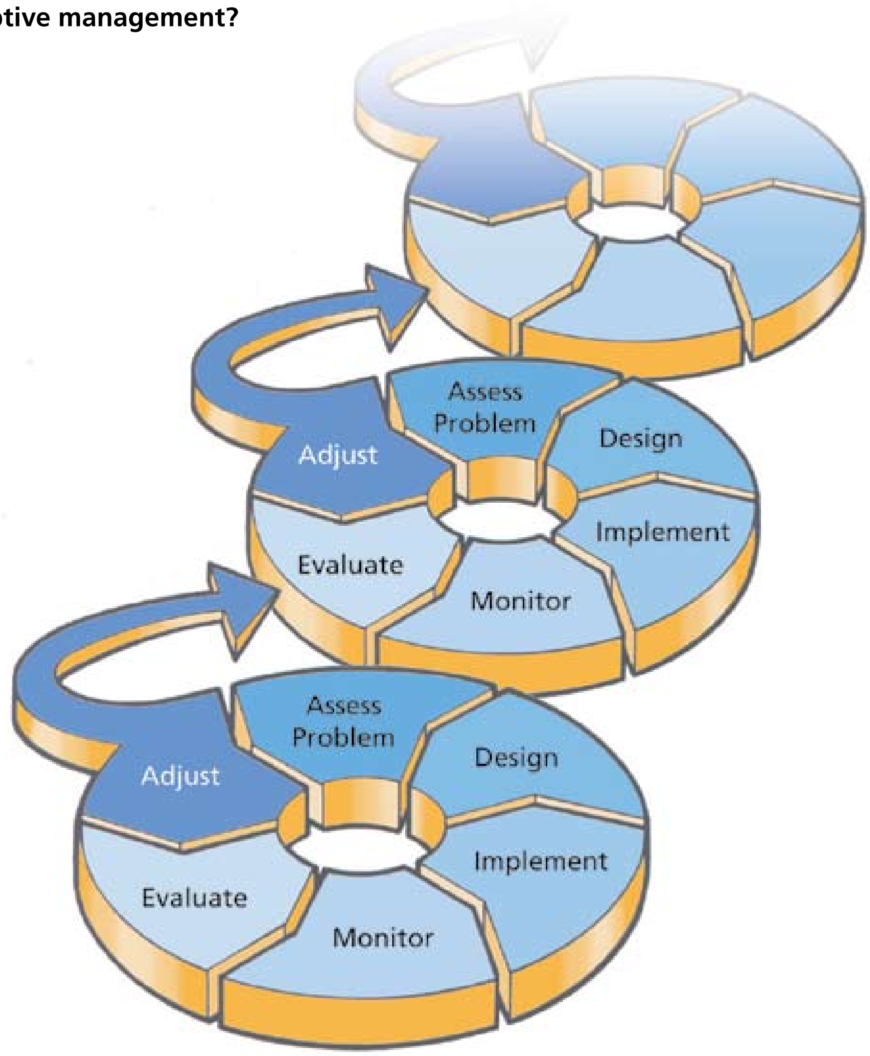


Figure 8.1 **Adaptive Management is a cycle and successful AM requires completion of all six steps. One cycle often leads to new options and continual cycles of improvement.**

about the effectiveness of the chosen actions. Ideally, the plan should yield information to fill the key gaps in understanding identified in Step 1. Proposed plans or designs should be evaluated on the basis of costs, risks, information gained, and their ability to meet management objectives.

Step 3, implementation, puts the plan into practice.

Step 4, monitoring, monitors indicators (Chapter 5) to determine how effectively actions are meeting management objectives and to test the hypothesized relationships that formed the basis for the forecasts.

Step 5, evaluation, compares the actual outcomes to forecasts and interprets the reasons underlying any differences.

Step 6, adjustment, adjusts practices, objectives, and the models used to make forecasts to reflect new understanding. Understanding gained in each of these six steps may lead to reassessment of the problem, new questions, and new options to try in a continual cycle of improvement.

How is AM Different?

It's true that natural resource management has always demonstrated an ability to build on previous actions and outcomes and change its management policies in light of past performance. It's also true that some learning takes place regardless of the management approach; even trial and error has been one way to learn and adapt by experience.

But what distinguishes AM is its purposefulness, its agreed-upon goals and objectives that are used as a baseline for measuring progress and lessons learned. AM mimics the scientific method by identifying uncertainties, specifying and evaluating hypotheses, and designing actions that test those hypotheses in field applications. It replaces trial-and-error learning with learning by careful tests. It acknowledges uncertainty about what policy or practice is "best" for the particular management issue. It encourages a thoughtful selection process of the policies or practices that should be applied. There is careful implementation of a plan of action designed to reveal knowledge that is currently lacking. There is monitoring of key response indicators. The management outcomes are analyzed considering the original objectives. And finally, the results are incorporated into future decisions.

AM is a sociopolitical approach as well as a technical-scientific undertaking. It's about changing relationships between scientists, resource managers and the public, relationships that are basic to the idea of social learning. The adaptive approach encourages learning, along with open forums that identify problems and ongoing learning and informed debate about alternatives, options, and consequences.

Figure 8.2 shows a major distinction of AM. It is juxtaposed between managers (conventional forest management) and researchers (basic scientific research). In that position, it requires dialogue and collaboration between managers and researchers because it addresses the interests and objectives of both groups. Typically these two groups have operated independently. For example, conventional forest management tends to focus on meeting objectives, with less interest in learning about cause/effect relationships between management actions and outcomes. There's little interest in systematically learning whether these actions are actually effective in achieving the desired outcomes. Basic forest research, on the other hand, tends to focus on learning objectives, but often for areas, scales, or topics that have little direct relevance to managers. AM brings the two together, focusing both on management and learning objectives.

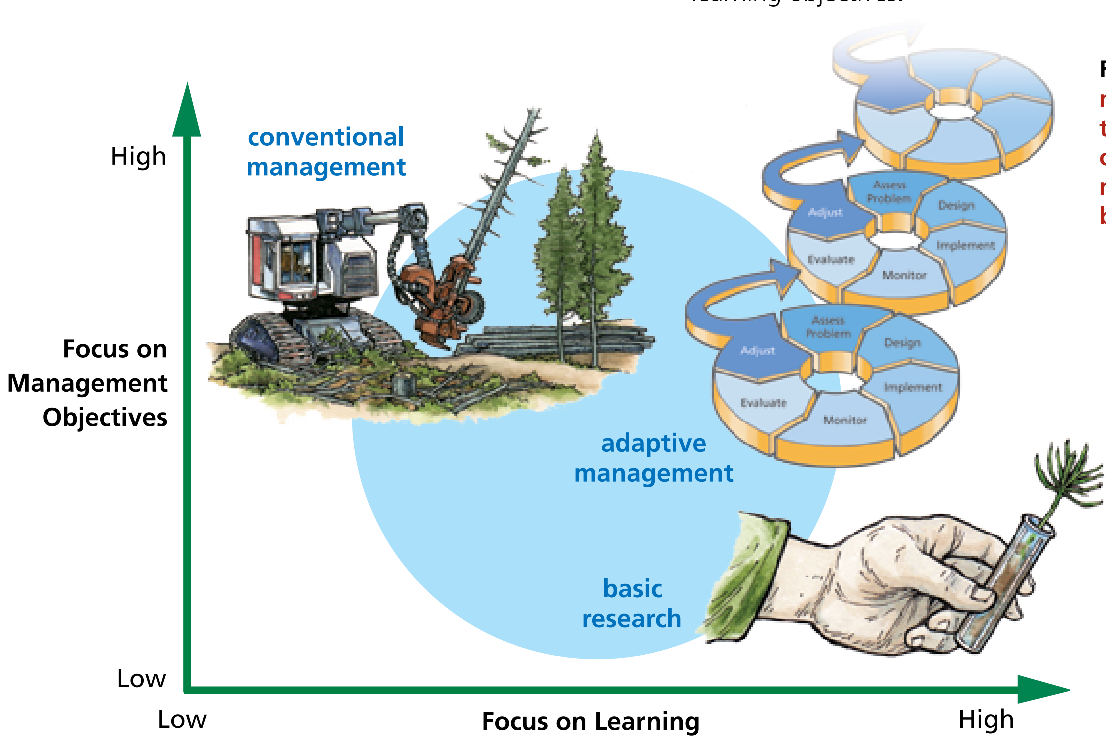


Figure 8.2 **Adaptive management brings together the strengths of conventional management and basic research.**

Bill Besse, Western Forest Products, Inc.

Group retention harvesting (Franklin River, Vancouver Island, BC) is one strategy that was adopted in this AM project while phasing-out clearcut harvesting over 5 years (see Chapter 1, page 45, Variable Retention).

AM Example 2: Coast Forest Strategy (originally the Forest Project)

Where: British Columbia (Western Forest Products Inc.) on 2.7 million acres (1.1 million hectares).

The Problem: Conflict over clear-cutting and the desire to conserve old-growth forests in coastal BC, led to a corporate decision by MacMillan Bloedel to adopt an adaptive management strategy to balance ecological, social, and economic goals in their forestland management. They set out to answer the question: How can we sustain biological diversity in managed forests?

Timeframe: From November 1997 to the present.

Goal of the project: Sustain biodiversity or native species richness and its associated values.

Results: Among many, one came from monitoring ground beetles, amphibians, and birds, and resulted in a decision to increase retention patch size from 0.6 to 1.2 acres (0.25 hectares to 0.5 hectares), along with more flexible spatial distribution of patches.

More information: http://www.forestbiodiversityinbc.ca/forest_strategy/default.htm

What Factors Enable or Inhibit AM?

NCSSF-sponsored researchers used three separate approaches to identify the factors that enable the success of AM. First they reviewed earlier studies of AM. Next, they conducted a written/telephone survey with AM practitioners who had recently carried out AM projects. And finally, they brought together some of the interviewees in a workshop designed to gather practical ideas about the relative importance of the enabling factors. Twenty AM project practitioners participated in the survey. Thirteen projects were led by public agencies, six by private forest management organizations, and one by a non-governmental organization. The projects (four are highlighted in the boxes) were distributed across nine states and two Canadian provinces. They ranged from plot to watershed scales and from a few hundred to seven million dollars in project costs. Most of the AM projects had positive outcomes. Fourteen of the twenty projects led to changes in policies or future management actions.

The ten factors identified as potentially enabling AM are listed in Figure 8.3. Of course, these same factors can inhibit AM success if they are not handled properly. AM practitioners attending the workshop suggested organizing the ten factors into a hierarchy, indicating that some may be more important than others, or at least need to be addressed very early on. That doesn't mean, however, that the other factors are less important, because each AM situation is unique. An AM initiative, led by either the public or private sector, will be unique in terms of agency or corporate culture or structure, relationships with other stakeholders, and the scale and focus of the initiative. The importance of each enabling factor needs to be assessed in the context of an emerging AM initiative.

The enabling factors were organized into three tiers:

- The top enabling factor is the historical and current context of the problem that is driving the need for experimental management. This factor motivates the need for AM.
- The second tier includes four factors: leadership, executive direction, problem definition, and communications/organization structure. Each is essential for enabling AM to get started, but none is sufficient alone. They represent different elements necessary to gain and maintain a broad level of support for the AM initiative and achieve clarity for its focus.
- The third tier includes community involvement, planning, funding, staff training, and the conduct of science. All are important elements needed to support AM.

Historical Context Driving the Problem

Leadership
Executive Direction
Problem Definition
Communications/ Organizational Structure

Community Involvement
Planning
Funding
Staff Training
How AM Science is Conducted

FIGURE 8.3 **The three tiers of AM enabling and/or inhibiting factors.**

ENABLING SUCCESSFUL AM IN FOREST MANAGEMENT

If you or your organization is considering using AM in your forest management operations, this section should be useful. It discusses each enabling factor in more detail, highlighting the practical suggestions and experiences of successful AM practitioners, starting with the top enabling factor.

Historical and Current Context

Both the historical and current contexts supply reasons for an AM initiative. A problem or driving force is needed to get an AM project started. For example, without the spotted owl there would not have been a Northwest Forest Plan (Chapter 7, page 141). It's also important to pay special attention to understanding the nature of relationships (research vs. management vs. stakeholders) in the place where the initiative will occur. In other words, is there community-led support or is there an existing relationship between the research community and land managers that supports the AM initiative? In contrast, is there an adversarial relationship that should be explored rather than ignored with the hope that the AM initiative will somehow overcome the situation? The important thing is to honestly appraise the social issues surrounding the place where the AM initiative will occur.

Once the need for an AM approach is recognized, leadership, executive direction, problem definition, and communications/organizational structure all play a part in the decision to proceed, and they all will help sustain the project throughout the AM cycle.

Leadership

Leadership is needed to get support to begin an AM initiative and sustain it over time. One person needs to become the project advocate, selling it throughout the organization. In a government agency that person (the forest supervisor, for example) can make all the difference in the world. In the private sector, the landowner, chief forester, or regional manager might be that person. To gain support, an AM initiative requires legitimacy in the organization and an understanding among employees about why the initiative is needed. The leadership role may change as the initiative moves through the AM cycle. An initiative proposed at an executive level (described below) may end up being led at a program or project level.

When AM projects are initiated from the top down, it is important to enable success by providing the necessary staffing and budgets to secure support at lower levels of the organization. It's also important to tie the organization's performance measurements to the initiative so it is part of each individual's performance at the field level.

Leadership is essential but not sufficient for success. A key part of leadership is effective communication that gains support throughout the organization (described below).

Executive Direction (Corporate Culture)

Current institutions are not designed to carry out AM as a formal endeavor. Therefore, a clear executive commitment is necessary for success. For example, in the development of the British Columbia Coast Forest Strategy (box on page 152), senior corporate management decided that a new approach was needed to the way forests are managed. That approach was defined as AM by managers at the project management level. Executive direction was then critical to moving the company to action. It's important to note that in a later change of ownership, new executives did not show the same support for AM, and support from other levels in the organization began to erode. As with leadership, executive direction/support can erode over time as personnel change, so incorporating the goals of the AM initiative into the organization's performance measures may be an important means to help maintain support.

Remember, it takes time to transform an established institutional culture to one that is willing to embrace the uncertainty of AM, and it's important to develop educational programs that train personnel to manage that uncertainty.

Definition of the Problem

Correctly defining the AM problem is critical because it establishes the focus of the work. Take time to get this right at the start and revisit problem definition throughout, because it is likely to change as you learn more (check example problem statements). If you don't do this you will be in trouble all the way through the cycle. Failure to clearly define the problem leads to later trouble maintaining an effective focus. It may be better not to set the focus as a "problem" at all, but to express it positively as a goal. Be sure to ask the question, "is this really the problem, or is it a manifestation of a larger problem?" If the "problem" does not capture the larger context, but only reflects a piece of it, there's a danger it will not be "durable" and the focus will be lost with a shift toward crisis management as other aspects of the real problem emerge over time. Determining the "durable" questions should be the responsibility of the organization and should not be left to scientists alone. Scientists will rarely see the whole picture that managers must face because their strength is their expertise on the parts they know best. Expressing the problem as a goal is consistent with AM because it is really a tool for helping managers achieve management goals in the face of uncertainty. Coming to grips with uncertainty is a key feature of AM and an important element in the process of problem definition. Keep in mind that recognition of uncertainty can lead to resistance to taking an AM approach by the organization, but facing it head on is the only effective way to deal with it.

When dealing with uncertainty and establishing the focus for AM, it's important to make predictions about the expected outcome. Making predictions forces you to think clearly about what is known and not known and identify hypotheses that can be explored. Be willing to admit worry about uncertainty. Recognize that we do not have all the answers and that AM is a tool to help move into an uncertain world.

Communications/Organizational Structure

Communication needs to be two-way. It's not just communicating the need for the initiative. It's also about a mutual understanding of how AM may affect the needs and interests of others in the organization. Organizational structure can either help or inhibit communication. It's important to get to the right people, but some organizational structures can make that difficult. For example, if there's not a venue to get executives, managers, and researchers together, create one by meeting in the forest. It's a neutral location that encourages effective communication. Keep in mind that:

- Academic disciplines have their own language.
- Academic disciplines may see the world differently.
- Biologists may want to work within a system.
- Engineers may want to restructure the system.
- Researchers tend to focus on what they don't know.
- Managers tend to focus on what they do know.

While cross-discipline communication can be a challenge, so can the barriers between researchers and managers. Traditionally, managers have been told they are not allowed to do research. However, AM promotes cooperative management and research in the quest to learn and adapt to new knowledge. Develop a team atmosphere among biologists, foresters, social scientists, and others by making it clear that each brings something valuable to the table.

AM Example 3:
Greater Flagstaff Forests Partnership

Where: Coconino National Forest, Arizona

The Problem: With the loss of traditional logging activity, and in an atmosphere of confrontation and public distrust, managers recognized a need to develop harvesting strategies that would put a 180,000 acre (72,800 hectare) landscape on a path representative of stand structures present prior to European settlement. Managers wanted to find an ecosystem restoration approach to forest management while protecting communities from catastrophic wildfire and harvesting small diameter timber.

Timeframe: From 1998 to present

Goal of the project: Restore the composition, structure and function of degraded ponderosa pine forests, manage wildfire fuels, protect communities and develop restoration techniques. Re-establish and maintain the historical range of stocking variability during stand restoration treatments. Emphasize ecosystem stability above fiber production and create stand structures resilient under natural fire regimes.

Preliminary Results: Treatments have been refined as lessons learned from earlier projects are incorporated into new projects.

More Information: www.gffp.org


Steve Gatewood, USFS

Complex forest structure is the goal of restoration treatments.


Steve Gatewood, USFS

Existing forest conditions contribute to catastrophic wildfire.

Effective communication must continue throughout the AM cycle, in an effort to close the loop so that useful results get integrated into policy. Remember that AM is not simply about research at a management scale – the focus has to be relevant to management decisions. Be sure you understand at the beginning what key advice policymakers need, then target their needs specifically. Regularly report the findings of AM within the organization. At the end of the AM cycle, the strategy is to get people to use the findings. Incorporate those findings into guidelines. If you get buy-in from operations people, policy recognition often will follow. Finally, here are two keys to good communication:

- Learn the concerns of the people you are trying to communicate with. Be curious about why they think the way they do. Be a good listener.
- Be aware of how people are responding to the AM process. Are they engaged? Are all sides contributing? Some people learn best in the field, others around a table, so communicate in both venues.

Next comes community involvement, planning, funding, staff training and how AM science is conducted. Each has a part in AM success.

Community Involvement

Community involvement depends on the AM initiative, and it mostly applies to AM cases on public lands. Community involvement is needed when there's a clear public investment in the issue being addressed or when laws or regulations mandate it. Local community knowledge can be valuable for scoping and designing the AM initiative. If there are interested parties who can either stop or assist an initiative, they should be involved. Interested private landowners may offer their property for participation or as a reference site. Involve the community early so they can contribute to problem definition. If the people of the community don't want to be involved, try to find out why. It may be that they don't understand the initiative or it could indicate resistance to it. If it's lack of understanding, keep the door open for later involvement.

When engaging the public, be clear about what you're inviting them to do. Some community participants will make valuable contributions about values and acceptable alternatives but may not want to be involved in the technical details. It may be useful to have two committees: a consultative committee and a technical committee. This does not mean keeping the public and technical people separated, because they need to exchange views, but it does mean keeping the focus of discussions clear – not confusing discussions of values with those of technical issues.

A small corporate AM initiative on a plot or stand scale may not need community involvement. But keep in mind that people who could be affected by the outcome, if it's incorporated into future policy or management actions, may be important to help close the loop of the AM cycle.

Planning

A distinction needs to be made between planning the AM initiative and how that initiative is carried out in the organizations existing system of forest management planning. Let's look first at AM initiative planning. Once the problem/focus of the initiative is set, planning should center on designing and implementing the management intervention and monitoring program. This also involves how you want to use the findings and how you want to incorporate them into the policy-making process. There will probably be some adjustments later, but plans for how all of this might occur will help with success.

Next is how the AM initiative will be carried out in the context of existing forest management planning systems. Be aware that where the regulatory environment is highly risk-averse, existing planning systems can interfere with taking an AM approach. This is because acting on the basis of existing knowledge is always less risky than conducting a management experiment to help resolve uncertainty. Many existing planning systems tend to be rule-based, the opposite of AM initiatives that are designed to explore the consequences of different approaches, not just to follow the rules. So be prepared to focus effort on how to conduct AM within the context of forest management planning. Note that the National Environmental Policy Act (NEPA) can work either for or against AM. Learning is part of the NEPA model, so there is no reason an AM approach cannot be taken. However, you may need to convince people who are used to working within a planning system that is counter to AM.

Funding

Some people think that AM can be done simply and cheaply, but the opposite is true. It's also true that having adequate funding to complete the AM cycle is important to success, but it won't guarantee success. It may be that having or not having the necessary funds is an indication of executive support. Even with strong executive support it's important to recognize that there are other constraints on funding cycles that may make funds available at a future time if they are not currently available. This is where support for the AM initiative from outside the organization may help to provide access to grants or other funding sources. Sometimes a lack of funding can stimulate other creative ways to get things done, but it's naive to think you can do the work without sufficient funding.

Staff Training

AM means doing things differently from the ways they've been done before. Embracing AM can require a shift in corporate culture, such as shifting from a risk averse/rule-based culture to one that acknowledges uncertainty and seeks to reduce it. That's why staff training is so relevant to AM initiatives. Initial training should be in the basic concepts of AM and the broad goals and approaches of an initiative. This is related to the discussion above about organization structures/communication. And this training isn't just for staff at lower levels in an organization; it's important for all levels of management. Subsequent training has to do with

Michael McClellan, USFS

One technique being tested to develop understory vegetation is thinning without slash treatment.

AM Example 4:
Tongas-Wide Young-Growth Studies (TWYGS)

Where: Tongas National Forest, Alaska

The Problem: Following clearcutting, western hemlock and Sitka spruce regenerate naturally. As those stands move into the stem exclusion stage (25-100 years old), they are nearly devoid of understory vegetation, with negative consequences for wildlife and fish. Is it possible to minimize the length and severity of stem exclusion by developing understory stand structure (herbs and shrubs) that supports wildlife while retaining wood production?

Timeframe: From 2001 to present.

Experimental design: Four silvicultural treatments are being tested, including artificially regenerating alder in stands less than 5 years old, precommercial thinning (15-25 year old stands), precommercial thinning and pruning (25-35 year old stands) and thinning without slash treatment (stands over 35 years old). Understory biomass, nutritional quality, a deer forage supply model, and a stand growth model are all being used to assess the usefulness of these treatments for understory forage and timber quality.

Results: Eventually the results will be used in the Tongas National Forest 10-year management plan.

More Information: Forestry Sciences Laboratory, Juneau, AK

Michael McClellan, USFS

Stem exclusion stage of Western hemlock/Sitka spruce with little or no understory vegetation.

details of the initiative itself. If the initiative covers a large area with many different people involved in the management prescription, training is essential to consistent implementation. Final training has to do with the knowledge gained through the AM initiative that will be incorporated by staff into policy and future management practice. Depending on the scale of the AM initiative, some or all of this training may be done by hands-on engagement of the staff in the initiative.

How AM Science is Conducted

Earlier, the point was made that AM is a combination of research and management in order to learn from management experience. To enable AM, both research and management have to be transformed so management becomes more scientifically rigorous and research becomes more policy-relevant. How can this be done? First, recognize that large-scale AM cannot be as scientifically rigorous as small, controlled research experiments. There is a tradeoff. There must be a reasonable balance between the rigor of the scientific method and the costs imposed by that rigor, because this issue can become an impediment to using the AM approach. Don't let science hang up the process by thinking you can only do AM when you have teams of researchers.

Here is where the distinction between passive and active AM is important. With passive AM a single "best-bet" management alternative is used together with careful monitoring to evaluate its effectiveness. With active AM more than one management alternative is used at different places and/or times, together with monitoring in an effort to learn from contrasting results. Active AM offers more rigor and more rapid learning. However, risk-averse regulatory environments, concern from groups opposed to proposed actions, and concerns about costs can make active AM more difficult than passive AM, because active AM makes all the uncertainty about management completely open.

Deciding between active and passive AM requires being clear about what is already known and what new knowledge is needed. This must happen by engaging scientists with management at the problem-definition stage. The important thing is to bring together people with the necessary expertise who can provide correct answers. It's possible that what is needed is the application of existing knowledge rather than an AM initiative. Or what might be needed is active AM at a smaller scale combined with passive AM on a larger scale. The level of rigor needed is linked to the stakes of the outcome.

An Inhibiting Factor

While each of the enabling factors, if not handled properly, could turn out to be inhibiting, AM practitioners at the NCSSF-sponsored workshop identified one additional factor that may be inhibiting – the lack of instruction in how to do AM. Because AM is not currently being taught either in academic institutions or in most public and private forest management organizations, managers and researchers have to gradually learn from experience. Given the fact that there are no governmental organizations whose current culture, policy or budget is designed to support AM, managers and scientists find themselves trying to shift corporate culture. Education is important for dealing with this situation.

SUMMARY

Despite the challenges of AM, the findings of this NCSSF project show that it can be and is successfully being applied to solve problems with various levels of complexity at different scales. There is no single formula for enabling AM, but the suggestions provide valuable insight for helping future AM initiatives. The simple act of engaging in AM may in itself be sufficient to create a shift in corporate culture that is more accepting of the need to manage in the face of uncertainty. Acceptance of AM requires acknowledging uncertainty and dealing with it. It requires people who accept the fact that forest ecosystems (including human socioeconomic systems) are constantly changing, even though regulations are often fixed. Regulatory risk aversion may make it infeasible in many forest regions to engage in active AM on large landscape scales. In such cases, it may be more feasible to use well-monitored passive AM at a landscape scale to assess effectiveness, combined with the limited application of active AM to assess cause-effect relationships at smaller, safer, and easier scales such as stands.

To Learn More About This Topic, See Appendix, page 168.

WHY IS THIS SUBJECT IMPORTANT?

How forests are treated can impact their ability to provide habitat for rare, local or sensitive animal and plant species. Poor forest management or the loss of forests to developed land uses can cause these species to become threatened, endangered or extinct. Well-informed forest management, on the other hand, can sustain critical habitat and even contribute to the recovery of threatened species.

Forest owners are often unaware of the presence of sensitive species, and those who are aware often do not know which forest management practices are or are not compatible with continued habitat protection. Technical assistance and financial incentive programs aimed at improving forest management may or may not reflect the best available science regarding biodiversity conservation. Existing policies aimed at promoting biodiversity conservation may or may not serve as an adequate basis for supporting biodiversity-compatible forest practices, particularly on private lands.

The Commission is committed to helping develop policies that encourage biodiversity conservation and this chapter focuses on that need.

The first section of this chapter offers ideas developed from Commission sponsored research over a period of six years. Some of the ideas embrace guidebook topics. Others raise concerns that reach beyond the guidebook. All are meant to stir interest in future forest policy action and establish a forum for discussion. They should be particularly useful to policymakers involved in forestry incentive programs.

The second section examines biodiversity incentive programs that are currently available for private forests. It answers the question: Do current incentive programs encourage biodiversity-compatible practices? Since private forests account for more than 70 percent of the nation's forestland, they provide important public conservation benefits that would be difficult or impossible to replace if they were lost. The Commission believes that public policy that encourages biodiversity, especially on private forests, is urgently needed.

The final section offers policy ideas to help private forest owners adopt biodiversity-compatible practices. In Chapter 6 (Biodiversity in Managed Forests), Florida researchers identified several high-priority biodiversity-compatible forest practices for the 257,000 private forest owners in their state. They calculated the opportunity costs for owners likely to adopt those practices and determined that biodiversity conservation costs can be significant (Chapter 6, page 126). Since the costs accrue to landowners and the benefits are distributed throughout society, researchers raised the question: Who should pay? The Commission believes that the answer lies in socially responsible forest policies like those described in the new social contract with rural America (see Karl Stauber reference in the Appendix).

POLICY IDEAS FROM THE COMMISSION

While identifying gaps in biodiversity science and sponsoring research to bridge those gaps, the Commission recognized a number of issues and concerns. They are listed in this first section, not in any priority order, to promote discussion and focus on needed action. As a backdrop to these ideas, it's important to review the three broad principles that governed the Commission, described in the Introduction (page 6). Those principles include the recognition of a forest continuum, the importance of public permission, and the need to keep forests as forests.

Changes in United States Forests and Forestry

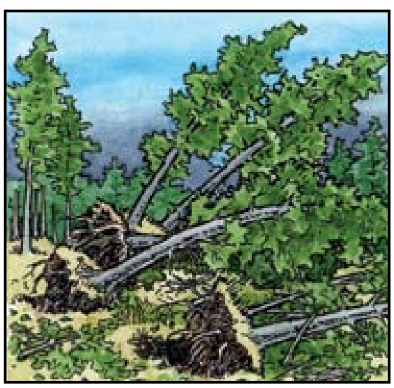
The Commission policy ideas are prefaced by the following major changes that are expected over the next several decades:

- The next 15-20 years will witness the largest intergenerational transfer of family forest ownership in the nation's history. What the next generation of woodland owners will do with these forests – and how much of it will be given over to development and other nonforest land uses – is an immense source of uncertainty over the future of more than half the nation's forests.
- The United States population is expected to increase by 100 million in the next 35 years, mostly in the South and West and mostly in urban and suburban areas.

- Along with this will come increased demand for land development, water, recreation, and green space, with an urban influence extending far beyond areas actually developed.
- Markets for traditional wood products are not projected to grow significantly, but wood consumption for renewable energy production is expected to more than double over the next two decades.
- The shift of timberland ownership in the United States, from industry to financial investors is now nearly complete and is expected to level off. Returns from timberland investments are expected to decline during the next 10 to 15 years, however. Many of these forestlands will be sold for development. Others will be transferred to new forest owners whose management goals and objectives have yet to be identified.

Forest History is Important

The historical record - both ecological and social – provides a context for today's forests. It tells us how and why our forest ecosystems came to be what they are: the result of natural disturbances (fire, wind and flood) and human uses (the treatment of forest ecosystems and what humans think about forests). Forest history is a starting place, a step toward restoration of forest processes and the preparation of forests for the future (Chapter 1). The question is whether forest history is useful in managing for biodiversity conservation in the future? While knowledge of forest history cannot be understated, climate change, human population growth, non-native invasives and fragmentation may be moving today's forests in a direction quite different than anything in the past.

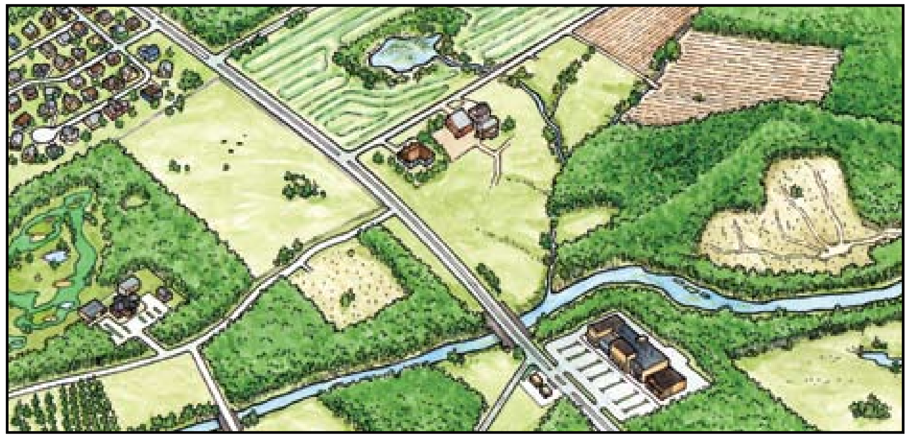


Along with forest history, what may turn out to be just as important is the social acceptability of landscape conditions and management practices. For example, modern society, for obvious reasons, is not willing to allow the full reintroduction of natural disturbances (forest fires are not allowed to burn unchecked and rivers are regulated to prevent floods). However, society does accept "let burn" policy for lightning-induced forest fires in some forests and the reintroduction of disturbance through prescribed fires or prescribed flooding (via dam releases). Society also accepts fuel reduction treatments, as demonstrated in the Southwest (Chapter 4, page 112), and historical fire regimes as guides in the timing of prescribed fire in the Southeast (Chapter 1, page 33).

In the future, what will be most important are society's objectives for the conservation of forest biodiversity in light of given land use and development changes, population growth, invasives and climate change. Forest practitioners, landowners, managers and policymakers will all be called upon to help society understand dynamic landscapes (how forests change over time), and develop management plans that achieve society's objectives.

Non-native Invasives

Introduced species of trees and other plants, insects, and diseases are a steadily increasing threat to native biodiversity in forests, but effectively addressing this issue is exceedingly difficult. Movement of non-native species is facilitated by the global mobility of people and forest products around the world. New diseases and insect pests are appearing each year that attack or out compete native species in every region of the country. This calls for greatly enhanced monitoring capabilities to prevent entry of invasive non-native species, the discovery of new invasive species promptly so that they can be contained, and combat those that are already established. More cost-effective monitoring strategies are needed at the national, state and regional scales.



Old-growth Dynamics

The role of old forests in the preservation of biological diversity is well recognized, but the dynamic nature of old forests and the role of younger forests in eventually producing biodiversity-friendly older forests are less well known. To adequately preserve and protect the habitat and functions of old forests, the entire forest life cycle must be considered and managed. The extent and role of old forests varies with land-use history and the natural environment, and their management guidelines must be region- and even locality-specific. Policymakers will remember from Chapter 4 that the proportion of remaining old-growth varies by region, and the cost of protecting more old-growth will be significant.

Indicators

Tools and processes have been developed to facilitate and enhance decisions about the objectives and appropriate systems of managing forests for biodiversity and other purposes. No single set of biodiversity indicators serves all situations and objectives, but there are processes for selecting indicators that are highly relevant and useful (Chapter 5). However, none of these tools and processes are truly functional unless they are employed in an intelligent "social conversation" that brings mutual understanding and general agreement on forest values and forest conditions that are important to maintain or avoid.

Managed Forests

Intensively managed forests, including planted forests, generally are not as biologically diverse as forests that are managed under more "natural" systems with greater variety of overstory and understory species. However, managed forests are much more diverse than typical agricultural and urban landscapes, and in the context of the total forest landscape they can add elements of biodiversity that would not otherwise be present (Chapter 6). Leaving legacy components during harvests can significantly improve long-term biodiversity in managed forests. The increased productivity of managed forests can relieve harvesting pressures on high conservation value forests, and create new opportunities for protecting landscapes where biodiversity values are the greatest. However, most private landowners depend on the economics of forest ownership to keep forestland as forest and provide biodiversity legacies. The reality is that there is a cost to providing biodiversity and currently those costs accrue to private landowners while the benefits are spread to all of society.

The Role of Fire

Many forest ecosystems are, to varying degrees, dependent upon natural disturbance from periodic fires. Understanding the role of natural fires in a given forest ecosystem is key to maintaining natural species diversity. In the West, for example, it is vital to manage understory fuel loads to maintain natural fires regimes, and minimize large catastrophic wildfires that have negative ecological effects as well as unacceptable social and economic impacts. In the South, maintaining the traditional role of fire in pine forests is increasingly challenging, with significant implications for future biodiversity. Air-quality regulations must be modified to accommodate prescribed fire if we are to sustain biodiversity values and avoid future increases in catastrophic wildfires. In those landscapes where the barriers to prescribed fire are insurmountable, alternative approaches must be found to replicate the essential ecological functions of fire.

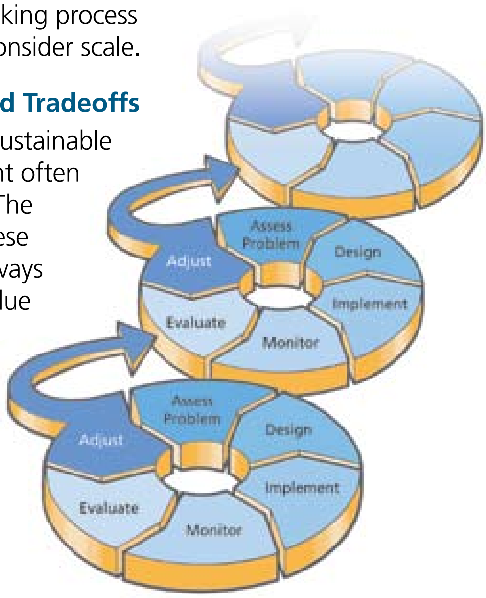
Decision Support Systems and the Concept of Scale

Policymakers faced with choices that affect forests and biodiversity need better decision support tools. At the same time, they must keep in mind that complex models are effective aids to policy-making, but they do not make decisions by themselves (Chapter 7). All decision support system models are abstractions that can, at best, only approximate the complex web of biological interrelationships that exist in the forest as a community of organisms. Decisions about the whole forest need to be made through social processes aided by models and other data sources. Properly used, decision support systems can inform the social debate about desired future conditions and help find a path to accomplish these objectives.

The degree to which biodiversity is enhanced or diminished by forest management decisions depends upon the results at both the stand and landscape scales. In the past, silviculture has tended to focus on individual stands and ecology has focused on the landscape, with the result that an integrated view of the effects of management is rare. In addition, with forests being converted to non-forest uses at scales ranging from stands to landscapes, the effects of land-use policies and patterns can often overwhelm the effects of forestry treatments. Decision support systems can help the policy-making process when managers consider scale.

Uncertainties and Tradeoffs

Decisions on sustainable forest management often involve tradeoffs. The exact nature of these tradeoffs is not always well understood, due to limitations in scientific understanding or the policymaker's level of knowledge.



Forestry and biodiversity conservation require that land managers and policymakers make choices among objectives and methods based on imperfect information. Therefore an adaptive (learning) approach to management for biological diversity values is necessary and must go beyond "trial and error" or "learning by doing." Formal learning designs need to be understood and implemented by teams of scientists and managers (Chapter 8). A critical role for science is providing reliable information about the feasibility and consequences of achieving objectives; and about the benefits and costs of alternative methods of pursuing objectives. Experience shows that scientific information is often most useful to policymakers when it is structured as an analysis of tradeoffs among competing objectives with important sources and consequences of uncertainty clearly identified.

Changes in Forest Ownership and Demand

Forests are dynamic in terms of ownership as well as biology and are subject to the goals and values of different owners. Changes in the relationship between forest management and biodiversity conservation can be expected as ownership changes, and biodiversity conservation strategies must be tailored to changing ownership patterns. Similarly, as markets for forest products change with the global economy, patterns of forest use can be expected to change markedly, and these changes must be factored into plans for biodiversity conservation. Social costs imposed on landowners can adversely affect the retention of forestland as forest unless policies are provided that offset the pressure of conversion to so-called "higher and better" use.

Forests and Energy, Climate, and Water Policies

Forests traditionally have been viewed mostly as a source of wood, and forest policies are only now being developed to address the full range of ecological, economic and cultural values that forests represent. Forests are key to the wellbeing of human populations, and should be considered when developing policies in other areas such as energy, climate change mitigation and clean water. Forests affect, and are affected by major natural systems. They are, for example, the major on-land carbon sink, sequestering, or storing, large amounts of carbon, countering the effects of carbon dioxide emissions from other sources. They are also major reservoirs of on-land biodiversity. As the world seeks to move away from its unsustainable reliance on fossil fuels,

forests can provide a variety of carbon-neutral substitutes. Traditional technologies for using wood for heat or electrical power generation are evolving quickly to become far more efficient and produce far less air pollution. Emerging technologies for producing wood-based liquid fuels such as cellulosic ethanol could become an important replacement source for petroleum-base fuels for the transportation sector. Forests are important generators of oxygen, a byproduct of photosynthesis, and forests are the nation's primary source of clean water, and water is already in short supply in many regions.

Need for an Integrated National Forest Policy

Forest laws, regulations, and incentives must be part of an integrated national policy that reflects all forest uses and values. Many forest laws, enacted 30 or more years ago, are outdated and no longer fit current conditions. American society and forests have changed immensely since a large number of our forest policies, laws, and regulations were formulated and implemented. Some are contradictory,

others address past needs but not current issues and concerns (Chapter 4, pages 95 and 100). Many regulations that apply to private forests have nearly an opposite effect from what was intended, and many "incentives" no longer motivate contemporary forest owners. Unless forest policies are relevant, even the best forest science goes unused because the conditions are lacking to implement it. An integrated policy on forests is needed. At the core of that policy should be regulations and incentives aimed at minimizing the further net loss of forests through conversion and development, and ensuring that the most biologically diverse forests are protected and sustainably managed.

DO CURRENT INCENTIVE PROGRAMS ENCOURAGE BIODIVERSITY-COMPATIBLE PRACTICES?

The Commission recognized the need for an in-depth evaluation of forest policies, laws, regulations, and programs to assess whether they will be rational in the world of forests and people that will exist in coming decades, when conditions will be very different from those that prevailed even two decades ago. It sponsored an examination of existing government incentive programs to evaluate awareness and knowledge of these programs among private forest owners and to assess how many actually participate in them.

The federal government has provided financial incentives to private forest owners since the 1940s. The initial objective was to encourage owners to become active timber managers and contribute to the nation's timber needs. Early incentives focused on tree planting and pre-commercial thinning practices. Thousands of forest owners were

Federal incentive programs that are available to private forest owners include:

- Taxation of harvest income as capital gains
- Forest Stewardship Program (FSP)
- Conservation Reserve Program (CRP)
- Environmental Quality Incentives Program (EQIP)
- Forest Land Enhancement Program (FLEP)
- Conservation Security Program (CSP)
- Forest Legacy Program (FLP)
- Landowner Incentive Program (LIP)
- Southern Pine Beetle Prevention and Restoration (SPBPR) available only in the South.
- Wetlands Reserve Program (WRP)
- Wildlife Habitat Incentives Program (WHIP).

State incentive programs that are available to private forest owners include:

- various types of preferential property tax for private forest owners in all states
- forest cost-share programs in some states to help fund timber management, wildlife enhancement, riparian area protection, and conservation easements.

Other incentives are offered by the forest industry, land trusts, and conservation organizations.

encouraged to follow intensive forest management models, with the help of financial assistance provided through incentive programs. During the 1990s, the sustainable forestry concept emerged, emphasizing water quality protection, biological diversity, and the maintenance of other public conservation values derived from public, industry, and family forests (see box). Today the question is: Have incentive programs kept pace with that concept and are they flexible enough to address these needs?

The NCSSF-sponsored research revealed that most federal and state incentive programs play only a limited role in promoting sustainable forestry practices on private forests. Although these incentives offer support for sustainable forestry, the researchers found that they are only a minor part of the decision-making process that private forest owners use in managing their land. The reasons most frequently offered are:

- Funding is inadequate, particularly for federal financial incentive programs. For example, of the $17 billion in conservation funding authorized in the 2002 Farm Bill, 99.4 percent was devoted primarily to farmers and 0.6 percent primarily to private forest owners. Yet private forest owners control about the same amount of rural land as farmers – even more in the eastern United States.
- Eligibility requirements for federal incentive programs vary among the states. In contrast, both state-funded and privately sponsored programs were rated more favorable in terms of program stability and effectiveness in encouraging land conservation and quality forest practices.
- There aren’t enough available forestry professionals with whom landowners can discuss the range of management options on site.
- Inflexible federal assistance programs don’t address regional differences in forest characteristics and owner objectives.

When researchers interviewed private forest owner groups in Pennsylvania, Minnesota, Oregon, and South Carolina about incentive programs, they learned that:

- The most widely used incentive programs were preferential property tax assessment at the state level and capital gains treatment for income from timber harvesting at the federal level.
- Private forest owners’ participation in other incentive programs was substantially lower.
- The type of incentive forest owners wanted was technical assistance (one-on-one access to a forester or other natural resource professional) that can walk the land with them. This type of incentive was preferred over financial incentives.
- The majority of forest owners acknowledged not having a written forest management plan for their forest.
- Owners expressed frustration with incentive programs that had inconsistent administration and implementation and were slow and bureaucratic.

To understand more about private forest owners, the researchers asked them to describe sustainable forestry. They learned that many owners have a long-term management perspective and see the concept of sustainable forestry as attractive. In spite of that, current practices on many private forests do not reflect the broader principles of sustainability. While many owners see it as appealing, its meaning is often misunderstood. Most owners described sustainable forestry as similar to sustained yield (the amount of wood a forest can produce indefinitely on a regular basis). Sustained yield management implies continuous production, planned to achieve a balance between the growth of trees and their harvest. In contrast, sustainable forestry specifically includes the concept of other forest values, goods, and services, including biodiversity conservation.

Four things are clear from these findings:

1. One-on-one access to a natural resource professional is a high priority among private forest owners across all regions.
2. Differences among forest regions must be recognized with respect to how incentive programs are administered and how closely they align with owner objectives because those interests strongly influence forest owners’ participation in the programs, and thus their effectiveness.
3. The benefits of incentive programs must be better promoted because existing federal and state programs play only a limited role in promoting sustainable forestry on private forest ownerships. Many landowners are unaware of these programs, and among those who are aware few actually participate in them.
4. Incentive programs should include a strong educational component that emphasizes the scientific rationale for biodiversity conservation.

WHAT POLICIES WILL ENCOURAGE PRIVATE FOREST OWNERS TO ADOPT BIODIVERSITY-COMPATIBLE PRACTICES?

Most national policy efforts aimed at private forests have been directed at family forest owners, essentially ignoring industrial forest owners. That should change. While each group may need different tools to provide biodiversity-compatible forest practices, policymakers need to listen to what owners say and provide what they want.

In the case of family forest owners, research indicates that the key is foresters and natural resource professionals who can provide necessary information when they "walk the land" with landowners and give one-on-one assistance. These professionals must be able to explain sustainable forestry and biodiversity conservation practices while still considering the economic goals of landowners.

This strongly suggests the need, particularly at the federal level, to strengthen direct landowner assistance programs that provide on-site consultation, even if this requires reallocating budget resources from financial incentive programs. Financial incentive programs are generally regarded as unstable and unreliable, in terms of both eligibility requirements and appropriated funding. Issues of distribution equity among states further cloud the reliability of these federally funded programs. Forest owners consistently expressed a need for greater access to direct consultation with a natural resource professional (public service or extension foresters rather than private consultants whose compensation typically is based on a portion of receipts from timber sales). This means that funding for public service forestry and forestry extension should be a higher public policy priority along with new or expanded financial incentive programs.

The evaluation and redesign of existing forest landowner assistance programs should take into account the following recommendations that emerged from the research:

- ▲ Programs should be designed to put forest owners in direct contact with a natural resource professional as early as possible, with the development of a forest management plan as an explicit objective.
- ▲ Participation in landowner assistance programs should be linked to accomplishing agreed-upon objectives and outcomes for biodiversity conservation and other values, rather than simply adopting a particular set of forest management practices. Priorities for participation in incentive programs should be determined on the basis of measurable environmental benefits, rather than a "first-come, first-served" basis.
- ▲ Incentive programs should be monitored and evaluated in terms of their biological effectiveness and economic efficiency. Monitoring should be aimed at answering such questions as:
    - Are incentives really achieving biodiversity conservation?
    - Are incentives keeping up with dynamic environmental and ecological problems?
    - Is there a more appropriate incentive mechanism?
- ▲ Finally, programs should be designed with a single point of contact for forest owners. These contacts, whether at a state agency or university-based extension office, should be equipped to provide information and coordination with other relevant state agencies as needed, for wildlife management, water quality, wetlands protection, biodiversity conservation, and permitting of facilities, transportation systems and other forest management-related activities. The primary contact can also serve as a source of information to forest owners who need the services of resource management specialists in one of these areas.

SUMMARY

Private forests account for nearly 70 percent of the nation's forestland, and they provide important public conservation benefits. Yet each year the United States permanently loses an estimated one million acres annually to development, and many more acres suffer from fragmentation and unsustainable forest practices.

NCSSF-sponsored research has brought into focus the shortcomings of current incentives for forestland protection and sustainable management. Private forest owners, for whom the programs are intended, identify important opportunities for improving the effectiveness of incentive programs in promoting sustainable management.

Simply putting more funding into nonfunctional programs will not help. Effective approaches should be augmented, and approaches that are failing should be reduced or eliminated. A more comprehensive review and evaluation of current landowner assistance policies and programs is needed if we are to reverse the current disturbing trends in the loss of private forestland and forest management that falls short of its potential for protecting conservation values.

No society that has destroyed its forests has survived. The Commission encourages the development of a new public consensus on how our society views and values forests. The United States has a remarkable legacy of forest recovery over the last century, but much of that is potentially jeopardized by population growth, urban development, and lack of understanding or appreciation of the true value of forests for wood, water, wildlife and biodiversity, recreation, green space, carbon sequestration, oxygen and carbon dioxide exchange, and other ecosystem functions. Forest biodiversity cannot be conserved in a vacuum where other forest attributes are not recognized. The rationale of "higher and better use" for real estate development of forestland only recognizes immediate, short-term financial values at the expense of all other explicit and implicit forest values. In reality, the highest and best use of a forest to society is its continued existence as a forest. "Keeping forests as forests" in the face of all of the pressures to convert them to other uses is becoming a new national imperative.

Responding effectively to this imperative will require:

- Engaging the public and stakeholders in new types of meaningful and collaborative social dialogue that creates a bold, new vision for U.S. forests and establishes agreed-upon management objectives, key indicators for preserving biodiversity and a shared responsibility for the concept of who pays and who benefits.
- Bringing the human dimensions (the understanding of public values, attitudes, knowledge, and behaviors) of sustainable forestry to the forefront of forest and biodiversity management and policy planning.
- Establishing public-participation strategies that build long-term trust, support, and community and national leadership on behalf of sustainable forestry.
- Recognizing the difference that words can make and the necessity of creating innovative and effective communication programs. Although the public generally supports protecting biodiversity, most people don't have a consistent or meaningful understanding of the concept and are likely to support decreases when put in the context of social and economic tradeoffs.
- Changing the focus of "educating the public" to a multi-objective approach focused on educating managers and scientists as well as the general public – an approach that recognizes the public as an equal partner in conserving biodiversity and keeping forests as forests.

To Learn More About This Topic, See Appendix, page 168.

To learn more about the chapter topics, additional research and organizations involved in forest biodiversity

To Learn More About the Chapter Topics

Beneath each chapter are the research projects and additional references. Unless noted, all of the references can be found on the NCSSF website: **www.ncssf.org**

Chapter 1

Forest History and Biodiversity

1. Project B1.1: Land Use History Impacts on Biodiversity – Implications for Management Strategies in the Northeastern U.S., including the Lake States, John Litvaitis: The University of New Hampshire.
2. Project B1.2: Land Use History Impacts on Biodiversity – Implications for Management Strategies in the Southeastern U.S., Josh McDaniel: Auburn University.
3. Project B1.3: Land Use History Impacts on Biodiversity – Implications for Management Strategies in The Western U.S., Gary Nabhan: Northern Arizona University.
4. Project A6: Evaluation of the Role of Ecosystem Restoration on Biodiversity, Robert J. Mitchell: Joseph W. Jones Ecological Research Center.
5. Project A7: Identification of Biodiversity Research Needs Related to Forest Fragmentation (Chapter 5), John A. Kupfer: University of Arizona.
6. Woodlands in Crisis: A Legacy of Lost Biodiversity on the Colorado Plateau, Nabhan, G.P., Coder M. & Smith, S.J. Bilby Research Center Occasional Papers No. 2, Northern Arizona University, 2004.
   (Not available on the NCSSF Website)

Chapter 2

Non-native Invasives and Biodiversity

1. Project A1: Synthesis of Key Science Needs to Reduce the Threat Posed by Invasive Diseases, Insects, and Weeds to Sustainable Forestry, Elizabeth Chornesky: Conservation Science and Policy.
2. Science Priorities for Reducing the Threat of Invasive Species to Sustainable Forestry, Chornesky, E.A, BioScience, April 2005, Vol.55 No. 4.
   (Not available on the NCSSF website)

Chapter 3

Fragmentation and Biodiversity

Project A7: Identification of Biodiversity Research Needs Related to Forest Fragmentation, John A. Kupfer: University of Arizona.

Chapter 4

Old Growth Forests and Biodiversity

1. Project C10.1: Northeastern Late Successional/Old Growth Workshop, John Hagan: Manomet Center for Conservation Sciences.
2. Project C10.2: Northwest Old Growth Workshop, Tom Spies: Pacific Northwest Research Station.
3. Project C10.3: Southwest Old Growth Workshop, Wally Covington: Northern Arizona University.
4. Project C10.4: Great Lakes Old Growth Workshop, Nancy Langston: University of Wisconsin.
5. Project C10.5: Southeast Old Growth Workshop, Robert Mitchell: The Jones Center.
6. Northwest Forest Plan, The First 10 Years (1994-2003), Status and Trend of Late-Successional and Old-Growth Forest. General Technical Report, Pacific Northwest Research Station. PNW-GTR-646, November 2005.
   (Not available on the NCSSF website)
7. Northwest Forest Plan, The First 10 Years (1994-2003), A Synthesis of Monitoring and Research Results. General Technical Report, Pacific Northwest Research Station. PNW-GTR-651, October 2006.
   (Not available on the NCSSF website)

Chapter 5

Selecting Indicators for Biodiversity

1. Project A3: Survey the Lessons Learned about Managing Forests for Biodiversity and Sustainability Based on Practical Experiences, Steven R. Radosevich: Oregon State University.
2. Project A8: Identification of Core Biodiversity Indicators to Apply Sustainable Forestry, John M. Hagan: Manomet Center for Conservation Sciences.
3. Biodiversity Indicators for Sustainable Forestry: Simplifying Complexity, Hagan, J. M. & Whitman, A. A., Journal of Forestry, April 2006.
   (Not available on the NCSSF website)

Chapter 6

Biodiversity in Managed Forests

1. Project C1: Templates for Forest Sustainability on Intensively Managed Private Forests, Kevin Zobrist: Rural Technology Initiative.
2. Project C1: A Literature Review of Management Practices to Support Increased Biodiversity in Intensively Managed Douglas-fir Plantations, Kevin Zobrist: Rural Technology Initiative.
3. Project C1: A Literature Review of Management Practices to Support Increased Biodiversity in Intensively Managed Loblolly Pine Plantations, Kevin Zobrist: Rural Technology Initiative.
4. Project C1: A Template for Managing Riparian Areas in Dense, Douglas-fir Plantations for Increased Biodiversity and Economics, Kevin Zobrist: Rural Technology Initiative.

5. Project C1: Management Templates for Increased Biodiversity and Economics in Intensively Managed Loblolly Pine Plantations, Kevin Zobrist: Rural Technology Initiative.
6. Project C3: Conservation Context of Forestry: Identification and Assessment of Conservation Compatible Forest Practices on Non-Industrial Private Forest, Janaki Alavalapati, University of Florida.
7. Project C4.1: Soil Ecosystem Indicators of Post-Fire Recovery in the California Chaparral, Louise Egerton-Warburton, Chicago Botanic Garden.
8. Project C4.2: Using Remote Sensing to Evaluate Biodiversity Indicators: Implications for Biscuit Post-Fire Restoration, Bernard Borman, PNW Research Station. See also the following website: www.fsl.orst.edu/ltep
9. Project C4.3: Short-term Effects of Fire and Postfire Rehabilitation on the Forest Understory: A Case Study from the Colorado Front Range, Paula Fornwalt, Rocky Mountain Research Station.
10. The Possibility of Plantations: Integrating Ecological Forestry into Plantation Systems. Report from the National Wildlife Federation, May 2006. *(Not available on the NCSSF website)*

Chapter 7
Landscape Scale Planning and Biodiversity

1. Project A5 (East): Assessment of the Scientific Basis For Standards/Practices at the Stand, Management Unit, and Landscape Levels in the Eastern United States, T. Bentley Wigley: National Council for Air and Stream Improvement, Inc.
2. Project A5 II (East): Assessment of the Scientific Basis For Standards/Practices at the Stand, Management Unit, and Landscape Levels in the Eastern United States, T. Bentley Wigley: National Council for Air and Stream Improvement, Inc.
3. Project A5 (West): Assessment of the Scientific Basis for Standards/Practices at the Stand, Management Unit and Landscape Levels in the Western United States, Thomas A. Spies: USDA Forest Service.
4. Project A5 II (West): Assessment of the Scientific Basis for Standards/Practices at the Stand, Management Unit and Landscape Levels in the Western United States, Thomas A. Spies: USDA Forest Service.
5. Project A10: Decision Support Systems for Forest Biodiversity: Evaluation of Current Systems and Future Needs, Sean Gordon, Oregon State University.
6. Project A10 II: Conserving Creatures of the Forest: A Guide to Decision Making and Decision Models for Forest Biodiversity, K. Norman Johnson, Oregon State University.

Chapter 8
Adaptive Management and Biodiversity

Project D1: Enabling Adaptive Forest Management, David R. Marmorek, ESSA Technologies Ltd.

Chapter 9
Policy that Encourages Biodiversity

1. Project C2: Existing and Potential Incentives for Practicing Sustainable Forestry on Non-industrial Private Forest Lands, John Green: USDA FS, Southern Research Station.
2. Project C5: Assess Public Knowledge, Values, and Attitudes toward Biodiversity and Sustainable Forestry, Michael Manfredo: Colorado State University.
3. Why Invest in Rural America – And How? A Critical Public Policy Question for the 21st Century, Karl N. Stauber. www.kc.frb.org/Publicat/Exploring/RC015tau.pdf
4. Incentives for Biodiversity Conservation: An Ecological and Economic Assessment. Casey, F; Vickerman, S; Hummon, C; and Taylor, B. Defenders of Wildlife, 2006.

To Learn More About Other NCSSF Research Topics Not Included in the Guidebook

Nontimber Forest Products (NTFP) and Biodiversity

NCSSF sponsored research looking at the relationship between forest management practices, non-timber forest products and biodiversity. Researchers developed an online database of over 1300 current or historically harvested species, an online bibliographic database, interviewed harvesters and surveyed US Forest Service and state forest managers. In addition, an interdisciplinary curricula was developed for forestry schools and management training programs that describes the ecological, cultural and economic importance of NTFPs and the role of NTFPs in ecosystem management.

1. Project A4: Assessment of Knowledge about Non-Timber Forest Products (NTFP) Management Impacts on Biodiversity, Rebecca McLain: Institute for Culture and Ecology.
2. Project A4 II: Non-Timber Forest Products Curriculum, Kathryn Lynch: Institute for Culture and Ecology.
3. Online NTFP species database available at www.ifcae.org/ntfp/
4. Online NTFP bibliographic database available at www.ifcae.org/ntfp/
5. The Relationship between NTFP Management and Biodiversity in the US. Submitted to NCSSF, Jones, McLain, Lynch, March 2004. (Revised August 2005). Available at www.ifcae.org/projects/ncssfl

To learn more about the chapter topics, additional research and organizations involved in forest biodiversity

Participatory Inventory and Monitoring

Efforts to conserve NTFP could be helped with inventory and monitoring programs. Inventories would indicate commercial quality and quantity. Monitoring would indicate sustainable harvest levels.

1. Project C8: Guidelines for Participatory Biodiversity Inventory and Monitoring of Sustainable Forest Management, David Pilz: Institute for Culture and Ecology
2. NTFP Inventorying and Monitoring in the US: Rationale and Recommendations for a Participatory Approach. Available at www.ifcae.org/projects/ncssfl
3. Workshop Guide and Proceedings: Harvester Involvement in Inventory and Monitoring of NTFP. Available at www.ifcae.org/projects/ncssfl

Changing Forest Ownerships and Biodiversity

Project C11: Changing Forestland Ownership Patterns in the Northern Forest and Implications for Biodiversity, John Hagan: Manomet Center for Conservation Sciences, ME.

Forest Ecosystem Rapid Assessment Scorecard

This is a ready-to-use forest monitoring system that measures forest ecosystem function. NCSSF sponsored its development to explore a monitoring system focused on measuring forest functions rather than counting species.

Project A9: Evaluation of Indicators of Ecosystem Function Applicable to Forest Management, Daniel Markewitz: University of Georgia

Carbon Trading: A Primer for Forest Landowner

Carbon trading is intended to help mitigate the increase of CO_2 in the atmosphere. Businesses (power generators or other manufacturers) that emit CO_2 to the atmosphere may want to balance their emissions through carbon sequestration (purchase carbon credits). Businesses that manage forest or agricultural lands might sell carbon credits based on their ability to accumulate carbon in trees or agricultural soils. This website, developed by NCSSF researchers at DB Warnell School Forests Resources, is designed for forest landowners who want to learn more about how to enter the carbon trading market. The URL is http://www.carbon.sref.info. It includes a carbon calculator and some of the current carbon sellers.

To Learn More About Organizations Involved in Forest Biodiversity

The Commission encourages forest practitioners, managers, landowners and policymakers to interact with others skilled in biodiversity management and innovation.

NatureServe

A non-profit scientific conservation organization that provides information and tools needed to help guide effective conservation action. NatureServe along with its network of **Natural Heritage Programs** operates in all 50 U.S. States, Canada, Latin America and the Caribbean and are a leading source of information about rare and endangered species and threatened ecosystems. They collect and manage detailed local information on plants, animals, and ecosystems. They develop information products, data management tools, and conservation services to meet local, national and global conservation needs.

NatureServe Vista is a DSS that integrates conservation information with land use patterns and policies, providing planners, resource managers and communities with tools to help manage their natural resources.

NatureServe Explorer is a web application that provides an online encyclopedia of plants, animals and ecosystems of the U.S. and Canada. Version 4.7 is available at: http://www.natureserve.org.

State Wildlife Action Plans

Supported by the State Wildlife Grants Program, created by Congress in 2000, each state has developed a Wildlife Action Plan. The plans assess an identify species of concern, gather relevant information about those species, and document problems or threats to species and habitats. Many of the plans include maps showing biologically unique landscapes and habitat quality. All of the plans were submitted to the US Fish and Wildlife Service for approval. Contact your state Wildlife Resource Agency for more information. For a Review of all the State Wildlife Action Plans, read the report prepared by the Defenders of Wildlife, http://www.defenders.org

adaptive management
the process of learning as you go, where research results are continually brought forward and management practices are continually reassessed as new information becomes available

anthropogenic
resulting directly from human activity

biodiversity
(biological diversity, natural heritage) the variety and abundance of all life forms in a place – plants, animals, and other living organisms – and the processes, functions, and structures that sustain that variety and allow it to adapt to changing circumstances. Includes the complexity of gene pools, species, communities, and ecosystems at spatial scales from local to regional to global

biomass
the total quantity (at any given time) of living organisms per unit of space (species biomass), or of all the species in a biotic community (community biomass)

biota
all living organisms in a given ecosystem, including bacteria and other microorganisms, plants and animals

buffer
land set aside to block or absorb unwanted impacts to the area beyond the buffer (set asides next to wildlife habitat to reduce an abrupt change to the habitat)

canopy
a layer of foliage in a forest stand. Often referring to the uppermost layer of foliage, but it can be used to describe lower layers in a multistoried stand

climate change
the actual or theoretical changes in global climate systems occurring in response to physical or chemical feedback, resulting from human or naturally induced changes in terrestrial, atmospheric, and aquatic ecosystems

cohort
a group of trees developing after a single disturbance, commonly consisting of trees of similar age. It can also include a range of tree ages from seedlings or sprouts to trees that predate the disturbance

conservation easement
a legal agreement between a landowner and a conservation agency that permanently restricts the property's uses in order to protect its conservation value

conservation strategy
a management plan for a species, group of species, or ecosystem that prescribes standards and guidelines that provide a high likelihood that the species, group of species, or ecosystem, will continue to exist as a viable population

corridor
usually linear strips of habitat, differing from surrounding vegetation, that connect two or more similar patches and intended to facilitate movement or dispersal of organisms between habitat patches in the hopes that metapopulation dynamics will be maintained on the landscape

cover
vegetation used by wildlife for protection from predators, or to mitigate weather condition, or to reproduce. May also refer to the protection of the soil and the shading provided to herbs and forbs by vegetation

demographic
relating to density, age and distribution of individuals in a population

disturbance
a specific event that alters ecosystem pattern and process by disrupting community structure or changing resource availability and allocation.

natural disturbances
disrupt the ecosystem and kill trees, but relatively small amounts of organic matter are consumed or removed

human disturbances
can mimic natural disturbance in terms of effects, but more often contrast sharply with natural disturbances in terms of type, intensity, frequency and size

disturbance regime
the type, the frequency and intensity of forest disturbance. Disturbance regimes can determine the composition and structure of tree and other forest communities

low-severity disturbance
small or low-intensity fires, insect and disease mortality, floods and sediment deposits where tree mortality is light to moderate.

ecological processes
processes fundamental to the functioning of a healthy and sustainable ecosystem, usually involving the transfer of energy and substances from one medium or trophic level to another. Three primary processes:

- production of sugar compounds from carbon dioxide (CO_2), water and sunlight performed by green plants
- consumption of what's produced, performed mostly by animals
- decomposition of organic materials into inorganic materials that can be used again by plants performed by fungi and bacteria.

ecoregion
a contiguous geographic area with a relatively uniform climate, possibly with several vegetation types, and used as an ecological basis for management and planning

edge
place where plant communities meet or where succession stages within plant communities come together. Conceptually, edges have environments significantly different from the interior of adjacent patches and typically differ in biomass, soil characteristics, and species composition and abundance

edge effects
the ecological changes that occur at the boundaries of ecosystems, including variations in the microclimate, influences from adjacent communities and land uses, and an altered species composition

endangered species
any species of plant or animal defined through the Endangered Species Act as being in danger of extinction throughout all or a significant portion of its range, and published in the Federal Register

endemic *(adjective)* **endemism** *(noun)*
a plant or animal native or restricted to a certain country or area

a disease or condition regularly found in a certain area

epiphytes
a moss or lichen that lives on another plant, moss or lichen. Old trees may have many epiphytes. Epiphytes obtain their nourishment from the air and rainwater

even-age silviculture
manipulation of a forest stand to achieve a condition in which trees have less than a 20-year age difference. Regeneration in a particular stand is obtained during a short period at or near the time that a stand has reached the desired age or size for harvesting. Clearcut, shelterwood, or seed-tree cutting methods result in even-aged stands

exotic species
any species growing or living outside its natural range of occurrence and purposely or accidentally introduced into countries or regions where they do not historically occur

extant
currently existing

extinct
a species that no longer exists anywhere on Earth

extirpation
species no longer existing in the wild in a certain area, but existing elsewhere

exurbanization
the migration of urban residents to rural environments

filter
coarse filter refers to management of overall ecosystems and habitats

fine filter management refers to management of specific habitats or sites for selected individual species

forest
: contiguous area of 1 acre of more where forest trees of any size or age comprise 10% or more canopy cover. Includes areas where vegetation development, either natural or human aided, will eventually lead to forest but where trees are not yet present or are present in less than 10% of canopy cover

forest structure
: the physical distribution of the components of a forest including tree density, tree heights, tree bole diameters, crown layer, shrubs and other non-woody understory plants, snags (standing dead trees), and down wood (fallen trees on the forest floor)

forest type
: a category of forest defined by its vegetation, particularly composition, and/or locality, as categorized by each country in a system suitable to its situation. The broadest general groups are:

broad-leaved (hardwoods)

coniferous (softwoods)

mixed broad-leaved and coniferous

function
: the flow of mineral nutrients, water, energy, or species

geographic information system (GIS)
: a computer system capable of storing and manipulating spatial (mapped) data

generalist
: species that can use many different environments and play many different roles

green-tree retention
: a stand management practice in which live trees as well as snags and large down logs are left as biological legacies within harvest units to provide habitat components over the next management cycle

habitat
: the place where a plant or animal species naturally lives and grows and includes characteristics of the soil, water, and biologic community (i.e., other plants and animals). Examples include: riparian areas, bottomland forests, upland forests, and wetlands

habitat diversity
: the number of different types of habitat within a given area

habitat fragmentation
: the breaking up of habitat into discrete islands through modification or conversion of habitat by management activities

heterogeneous
: exhibiting dissimilarity among members of a group

heterogeneity
: variation in the environment over space and time

spatial heterogeneity
: how stand structure (age, size class, snags, large down logs, canopy gaps and canopy layers) are arranged across a landscape

historical range of variation (HRV)
: the range of variation in forest attributes that might be expected in a landscape over time under a particular disturbance regime (for example, frequency, type, and severity). HRV can be a useful context for understanding the state of present landscapes

homogeneous
: exhibiting similarity among members of a group

homogeneity
: with respect to one or more samples or populations: the state of being identical in some or all parameters

landscape
: a general term that may imply scales from small watersheds to regions

working at a landscape scale
: integrating actions across jurisdictional boundaries, requiring community collaboration

landscape connectivity
: a threshold phenomenon, in which even small losses of habitat near the critical threshold are likely to disconnect the landscape, having serious consequences for population distributions

legacies
: biological pieces such as live and dead trees, surviving seeds, spores, and animal species inherited from the previous ecosystem on the site

matrix
: federal lands not in reserves, withdrawn areas, or managed old-growth areas

mature trees
: trees that have achieved a substantial part of their potential height growth

model
: an idealized representation of reality developed to describe, analyze, or understand the behavior of some aspect of it. A mathematical representation of the relations being studied

monitoring
: the process of collecting information to evaluate if objective and anticipated or assumed results of a management plan are being realized or if implementation is proceeding as planned

multistoried
: forest stands that contain trees of various heights and diameter classes and therefore support foliage at various heights in the vertical profile of the stand

mycorrhizae
: fungi having a beneficial relationship with plant roots (aiding water and certain nutrient uptake and sometimes offering protection against other soil-borne organisms)

nontimber forest product (NTFP)
: any forest product except timber, including resins, oils, leaves, bark, plants other than trees, fungi, and animals or animal products

nutrient cycle
: the circulation or exchange of elements and inorganic compounds, such as nitrogen and carbon dioxide, between non-living and living portions of the environment

old-growth
: forests in the later stages of stand development after a forest has grown for centuries with only low to moderate levels of disturbance. These forests contain large live and dead trees, a variety of sizes of trees, and vertical and horizontal heterogeneity

overstory
: trees that provide the uppermost layer of foliage in a forest with more than one roughly horizontal layer of foliage

parcelization
: a general shift from a few landowners with large holdings to many landowners with smaller holdings

patch or remnant
: a relatively uniform area of vegetation that differs from its surroundings

plantation
: forest stands consisting almost exclusively of planted trees of native or exotic species, and managed to generally maintain this composition at maturity

population
: a collection of individual organisms of the same species that potentially interbreed and share a common gene pool

population density
: the number of individuals of a species per unit area

population persistence
: the capacity of a population to maintain sufficient density to persist, well distributed, over time

prescribed fire
: a fire burning under specified conditions that will accomplish certain planned objectives

primary or original forest
: an original forest, usually containing large trees, that has not been significantly disturbed or influenced by human activity. May also be areas that remained in forests throughout the history of European settlement, but not necessarily old-growth

processes
: ecological dynamics that lead to development and maintenance of forests. For example, rates of succession, gap formation, low-severity fire, productivity and decomposition.

productive capacity or productivity
a potential indicator of soil health, soil microbial activity, and nutrient cycling, and carbon storage

a classification of forestland in terms of potential annual cubic-measured volume growth of trees per unit area at culmination of mean annual increment in fully stocked forest stands

range (of a species)
the area or region over which an organism occurs

refugia
locations and habitats that support populations (endemic populations) of organisms that are limited to small fragments of their previous geographic range

reserves
areas set aside from extractive and intensive uses such as mining and residential development necessary to protect some species but insufficient for full biodiversity conservation

restoration (rehabilitation)
the use of silvicultural approaches that sustain native biodiversity by integrating concepts of ecosystem response to natural disturbances

riparian area
an area containing an aquatic ecosystem and adjacent upland areas that directly affect it. It includes flood plain, woodlands, and all areas within a horizontal distance of about 100 feet from the normal line of high water of a stream channel or from the shoreline of a body of water

rotation
the planned number of years between regeneration of a forest stand and its final harvest. The age of a forest at final harvest is referred to as rotation age

secondary forest
areas that experienced a transition in land use during European settlement, including clearing for farmland or pasture. Disturbances like plowing and grazing eliminated native vegetation

senescent
very old, with little or no growth occurring, and with decreased ability to resist or repair damage

shade-tolerant species
plant species that have evolved to grow well in shade

silviculture
the science and practice of controlling the establishment, composition, and growth of the vegetation of forests stands. It includes the control or production of stand structures such as snags and down logs in addition to live vegetation

spatial
happening or existing across space

species richness
a measure of the number of species present in a community, ecosystem, landscape, region, etc

stand
distinguishable, contiguous area of trees reasonably similar in age, composition, and structure

stand composition
the mixture of tree species

stand structure
the complexity or arrangement of tree age/size classes

stand development
changes in forest stand population/ structure as forests age. May or may not be accompanied by a change in species composition

structure
the various horizontal and vertical physical elements of the forest

succession
a predictable development of an ecosystem, where one or more species replace each other as the ecosystem grows older. Generally the species that come later are more shade tolerant and are referred to as late-succession species, because they can regenerate in canopy gaps and maintain themselves within closed-canopy forests in the absence of stand-replacement disturbance.

succession stage
a characteristic of many ecosystems that experience a change in structure and/or species on a given site in relation to time since a major disturbance

seral stages
include early succession vegetation through to later succession stages. In many cases, the succession stages reflect a shift from the dominance of shade-intolerant species to that of shade-tolerant species

suppression
extinguishing or confining a fire

sustainable forestry
the suite of forest policies, plans, and practices that seek to sustain a specified array of forest benefits in a particular **place**. Not all forests can be expected to – or are capable of – sustaining the same suite of benefits at all times

place
can range from as small as a single tract of forest to an area the size of watersheds, states, regions, nations, or the world. As the defined place increases to the scale of a state or nation, the suite of forest benefits to be sustained increases to approach all possible values

forest sustainability
the capacity of forests, ranging from stands to ecoregions, to maintain their health, productivity, diversity, and overall integrity, in the long run, in the context of human activity and use

suite of benefits
may include various values, uses, products, functions, and services from forests. May include but are not limited to wood, recreation, watershed protection and water quality, native and desired non-native species of plants and animals, spiritual retreats, non-wood forest products, landscape aesthetics, carbon storage, and nature's processes of energy transfer, renewal and recycling

sustainability
a path which balances economic, social, and environmental considerations

a process and an aspiration, not a single, immutable end-point or static condition. Goals as well as the process for sustainable forestry change in response to changes in what society values and how science and technology inform management and conservation

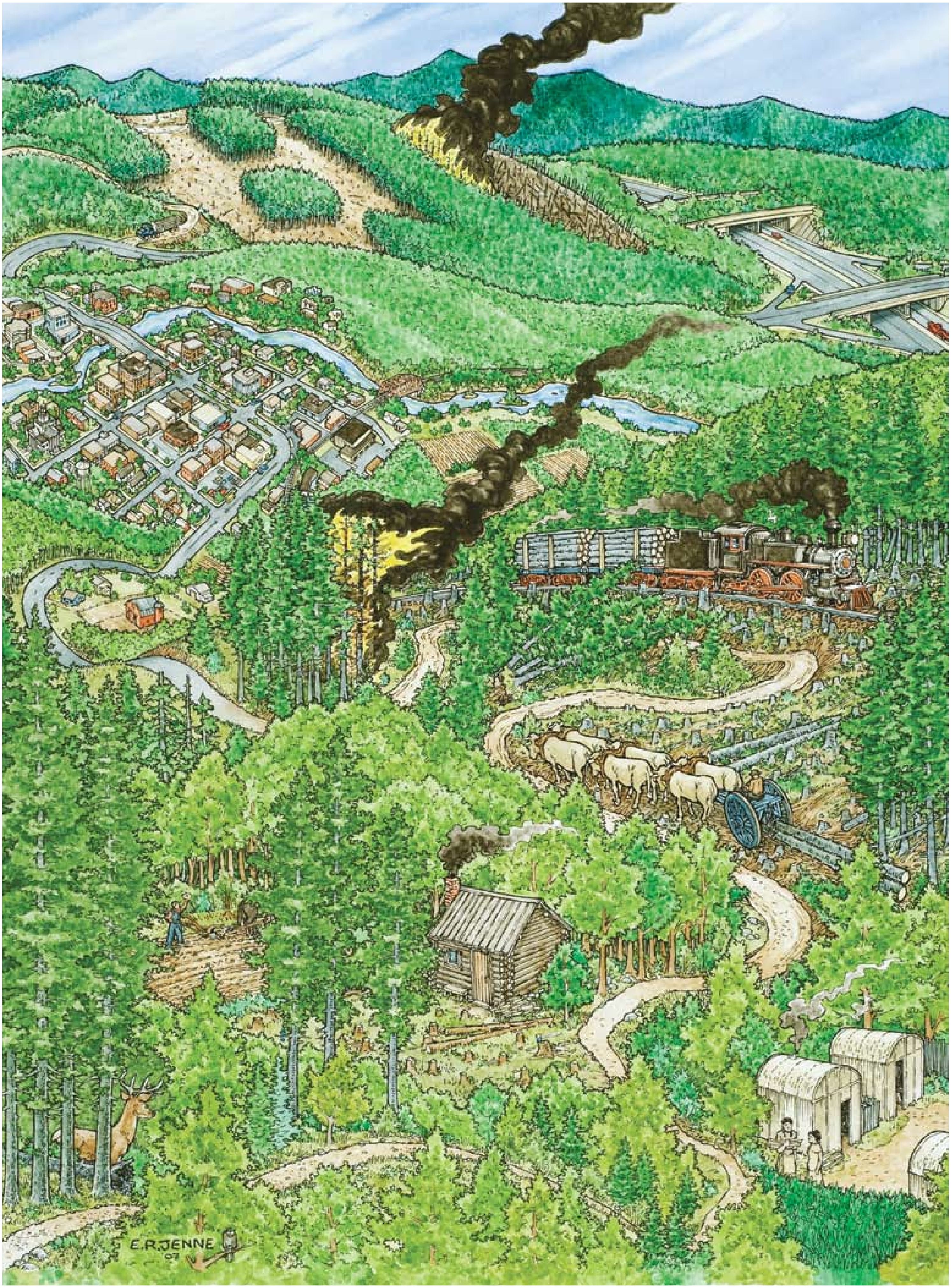
temporal
of or limited by time

viability
the ability of a wildlife or plant population to maintain sufficient size so that it persists over time in spite of normal fluctuations in numbers

variable density thinning
involves varying the thinning intensity across a stand

variable retention harvesting
a specific harvesting technique that requires retention of some portion of a stand. The retained portion is distributed such that the influence of forest or residual trees is maintained over most of the area. Creates a multi-aged stand and patchiness at a stand level

well-distributed
a geographic distribution of habitats that maintains a population throughout an area and allows for interactions of individuals through periodic interbreeding and colonization of unoccupied habitats


E.R.JENNE
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The Guidebook is dedicated
to the memory of

Phil Janik

former Commission member
and Chief Operating Officer of the
USDA Forest Service

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