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Ecological Role of Fire

NCSR Fire Ecology and Management Series

Northwest Center for Sustainable Resources (NCSR)
Chemeketa Community College, Salem, Oregon
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opinions expressed are those of the authors and not
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Fire Ecology and Management Series

This six-module series is designed to address both the general role of fire in ecosystems as well as specific wildfire management issues in forest ecosystems. The series includes the following modules:

- Ecological Role of Fire
- Historical Fire Regimes and their Application to Forest Management
- Anatomy of a Wildfire - the B&B Complex Fires
- Pre-Fire Intervention - Thinning and Prescribed Burning
- Post-Wildfire (Salvage) Logging – the Controversy
- An Evaluation of Media Coverage of Wildfire Issues

The *Ecological Role of Fire* introduces the role of wildfire to students in a broad range of disciplines. This introductory module forms the foundation for the next four modules in the series, each of which addresses a different aspect of wildfire management. *An Evaluation of Media Coverage of Wildfire Issues* is an adaptation of a previous NCSR module designed to provide students with the skills to objectively evaluate articles about wildfire-related issues. It can be used as a stand-alone module in a variety of natural resource offerings.

Please feel free to comment or provide input.

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NCSR curriculum modules are designed as comprehensive instructions for students and supporting materials for faculty. The student instructions are designed to facilitate adaptation in a variety of settings. In addition to the instructional materials for students, the modules contain separate supporting information in the "Notes to Instructors" section. The modules also contain other sections which contain additional supporting information such as a “Glossary” and “Suggested Resources.”

Acknowledgements

We thank Rick O’Hara of Chemeketa Community College in Salem, Oregon, Tom Robertson of Portland Community College in Portland, Oregon, and Michelle Fulton of Feather River College in Quincy, California for their thoughtful reviews. Their comments and suggestions greatly improved the quality of this module.

Table of Contents

Ecological Role of Fire – Module Description

This lecture-based module is designed to introduce the ecological role of wildfire to students in a broad range of disciplines. It is intended for use in courses such as *Environmental Science*, *General Biology* and *Introduction to Natural Resources* and presents the current understanding of the role of wildfire. Although forest ecosystems are emphasized, most of the major points generalize to other ecosystems such as chaparral and prairies. The module is presented as a series of *PowerPoint* slides paired with a textual outline of the major points. The *PowerPoint* presentation describes the role of wildfire in reducing the probability of catastrophic fire, nutrient input into soils, control of insect pests and tree pathogens and maintaining species diversity. Supplementary lecture notes for use by the instructor are included in the notes section for each slide. Additional resources, including video presentations, are cited to assist faculty in adapting the module to their specific course needs.

Introduction

Since the dawn of humankind, wildfire has been feared as an agent of Nature that could inflict untold harm. Hunting grounds could be altered, herds of important game animals chased away, agricultural crops destroyed and human structures leveled. It is no wonder then, that even today wildfire is largely perceived as a destructive force that must be avoided or controlled. Recent news accounts of wildfire understandably focus on the destructive nature of fire and further promote this perception.

Despite this perception, recent studies of wildfire and the environments in which they occur have expanded our understanding of the important role that fires play in many terrestrial ecosystems. We have learned that despite our best intentions, excluding fire from these ecosystems has had profound implications. Fire-adapted plants, for example, have declined in abundance and overstocked forests are now more prone to catastrophic fire due to the build up of woody fuels.

In this lecture-based module, students are presented with our current understanding of the role of wildfire in ecosystems. Although forest ecosystems are emphasized, most of the major points generalize to other ecosystems such as chaparral and prairies. The module is presented as a series of *PowerPoint* slides paired with a textual outline of the major points. Supplementary lecture notes for use by the instructor are included in the notes section for each slide. Citations of relevant print and web-based resources are also provided for the instructor as background and for additional research.

The module is intended as an introduction to the topic for courses such as *Environmental Science*, *Introduction to Forestry*, *General Biology* and *Introduction to Natural Resources*.

Objectives

Upon completion of this module students should be able to:

1. Describe the various ecological roles of wildfire.
2. Provide examples that illustrate the ecological roles of wildfire.

Procedure

The ecological role of fire is a topic that probably is covered in any curriculum that addresses fire. For example, the topic may be addressed in the context of ecological succession, forest ecology or forest management.

The accompanying *PowerPoint* presentation should be delivered to students at an appropriate time in the course. In its current form the presentation will take approximately two 50-minute lecture sessions. Alternatively, the presentation could be made available to students on-line, where they could review the material on their own.

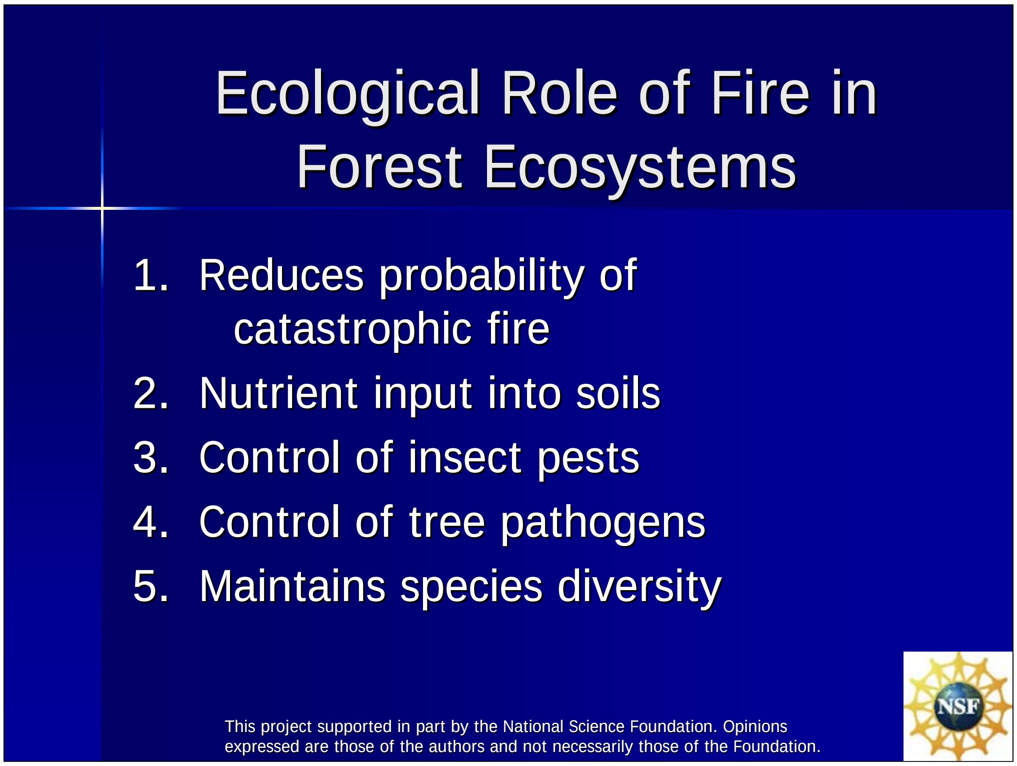
Additional text or titles may be added to the *PowerPoint* slides to match your particular instructional style.

Assessment

Student learning of the material in this module is probably best assessed with an essay question on an exam. I suggest the following:

Although the human costs of wildfires are well-known, recent research has expanded our understanding of some of the ecological <u>*benefits*</u> *of wildfire. Describe our current understanding of the ecological roles of wildfire and provide some examples that illustrate these roles.*

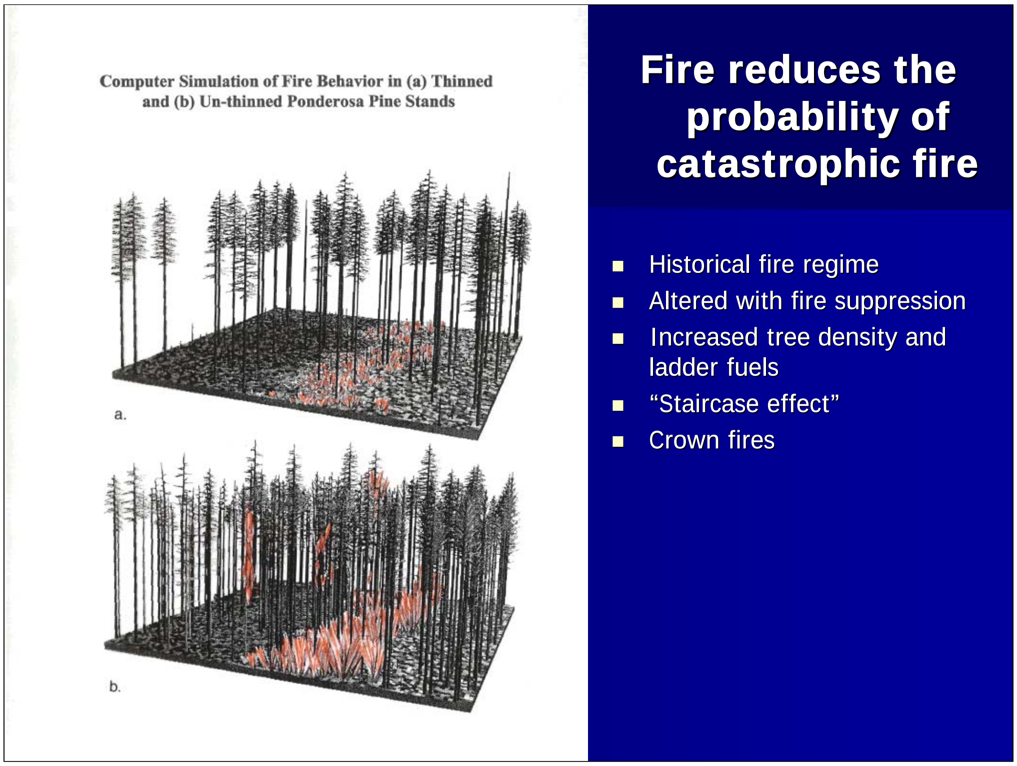
POWERPOINT SLIDES WITH INSTRUCTOR'S NOTES



Beginning in the 1960's, the perception of fire as universally "bad" as well as the long-term value of fire suppression ("Smokey the Bear") policy began to be questioned by scientists. Nearly 50 years later, we still have an incomplete understanding of the role of fire in ecosystems. However, we have learned that fire has both direct and indirect effects on all aspects of forest ecosystems. These effects are the focus of this discussion.

Role of Fire in Forest Ecosystems

1. reduces probability of catastrophic fire
2. nutrient input into soils
3. control of insect pests
4. control of tree pathogens
5. maintain species diversity



In many forest types, the **fire regime** (the historical frequency and intensity of natural fires) reduces fuels such that fires burn frequently and at low to moderate intensity. With fire suppression, tree density increases along with the abundance of **ladder fuels**, resulting in an increased probability of **crown fires** due to the **"staircase effect."**

These crown fires are more likely to result in a **stand replacement** fire in which the majority of dominant trees are killed by the fire.

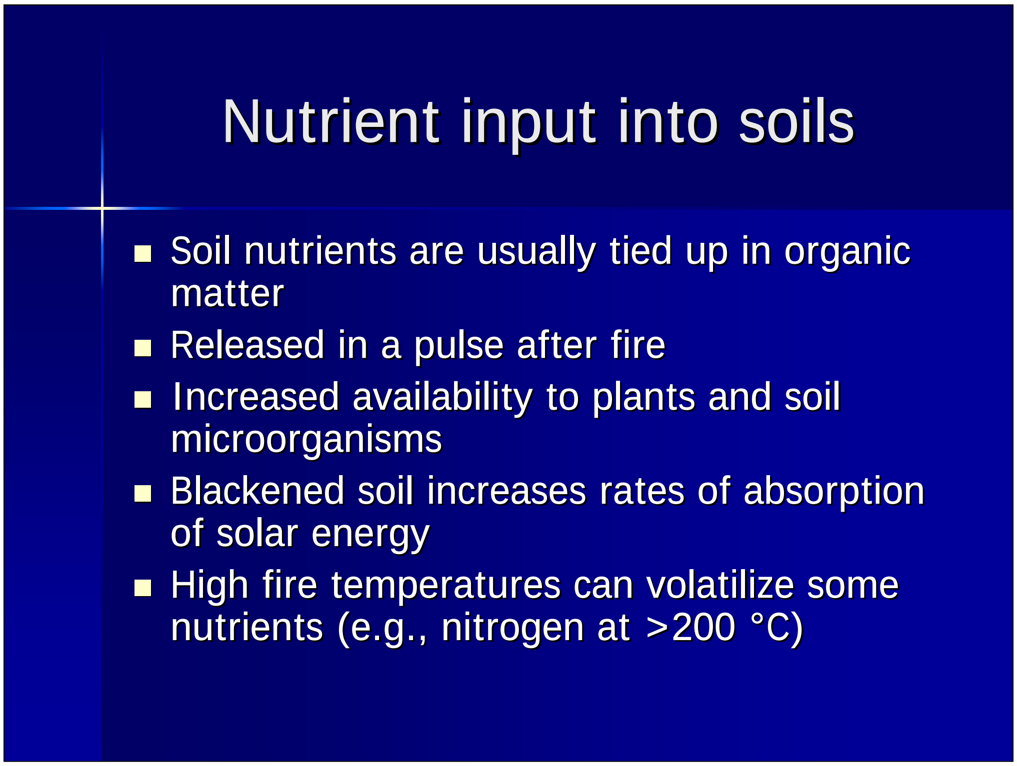
Fire impacts physical, chemical, and biological components of soil in both beneficial and detrimental ways that can affect long-term site productivity (a common sustainable management goal). Soil chemistry is particularly complex after a fire.

Soil nutrients such as N, P, K and Ca are usually tied up in organic matter (forested soils tend to be low N systems).

All are released in a pulse at the burn site and leached into the soil, which increases availability to plants and soil microorganisms (bacteria, fungi and protists).

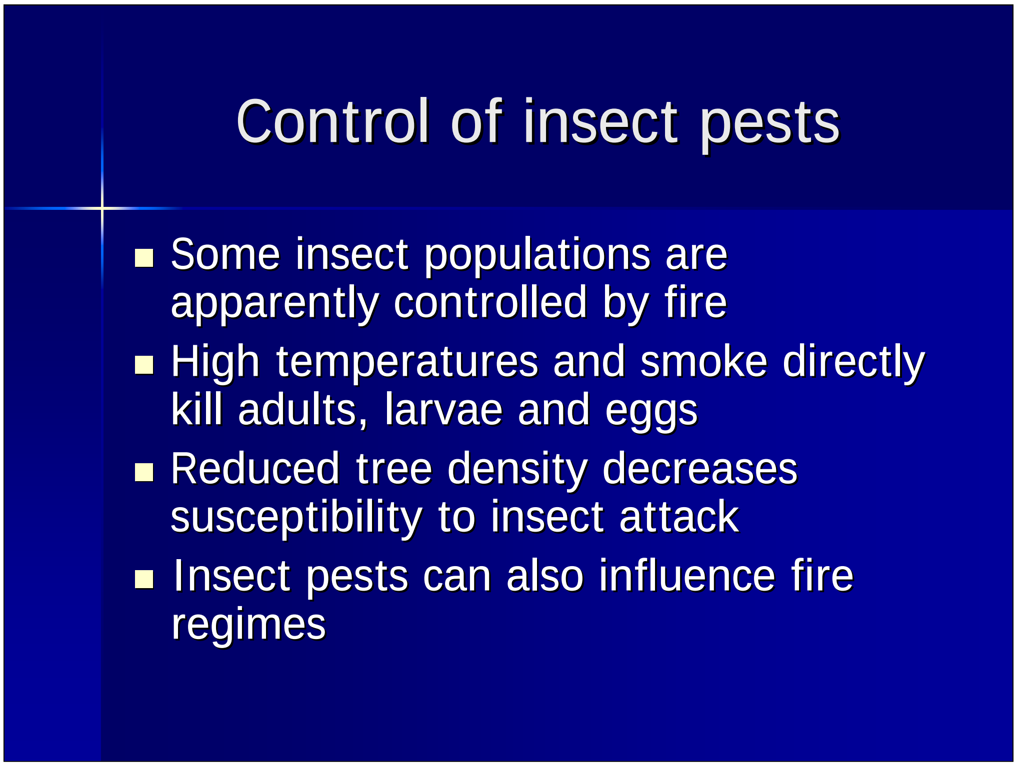
Warmer temperatures created by greater heat absorption by blackened soil increases rates of absorption.

For nearby aquatic ecosystems, erosion from uplands may increase sediment input into streams. Nutrients that runoff into these systems increase algae growth which support higher trophic levels in food webs.



High fire temperatures can **volatilize** some nutrients, which are then lost to the system. Significant amounts of nitrogen, for example, can be lost at temperatures above 200 °C . Potassium, in contrast, is lost only at temperatures above 550 °C and calcium is rarely lost since temperatures above 750 °C are required (wildfire temperatures rarely exceed 700 °C).

Spruce budworm (inset) and a Douglas-fir forest affected by this defoliating insect are shown here. Some insect pests of trees (especially conifers) are apparently controlled by fire. This control may be indirect or direct.



Direct:

High temperatures and smoke directly kill adults, larvae and eggs. There is some evidence, for example, that the lack of fire (due to fire suppression efforts) may be linked to spruce budworm outbreaks.

Indirect:

When trees are overly dense, individual trees compete for limited sunlight, moisture, and nutrients and become susceptible to insect outbreaks due to a weakened state (e.g., bark beetles in the Rogue Valley in Southern Oregon attack Douglas-fir, Ponderosa pine and sugar pine).

Fires that under historical conditions would have thinned these stands, have been suppressed creating high tree density.

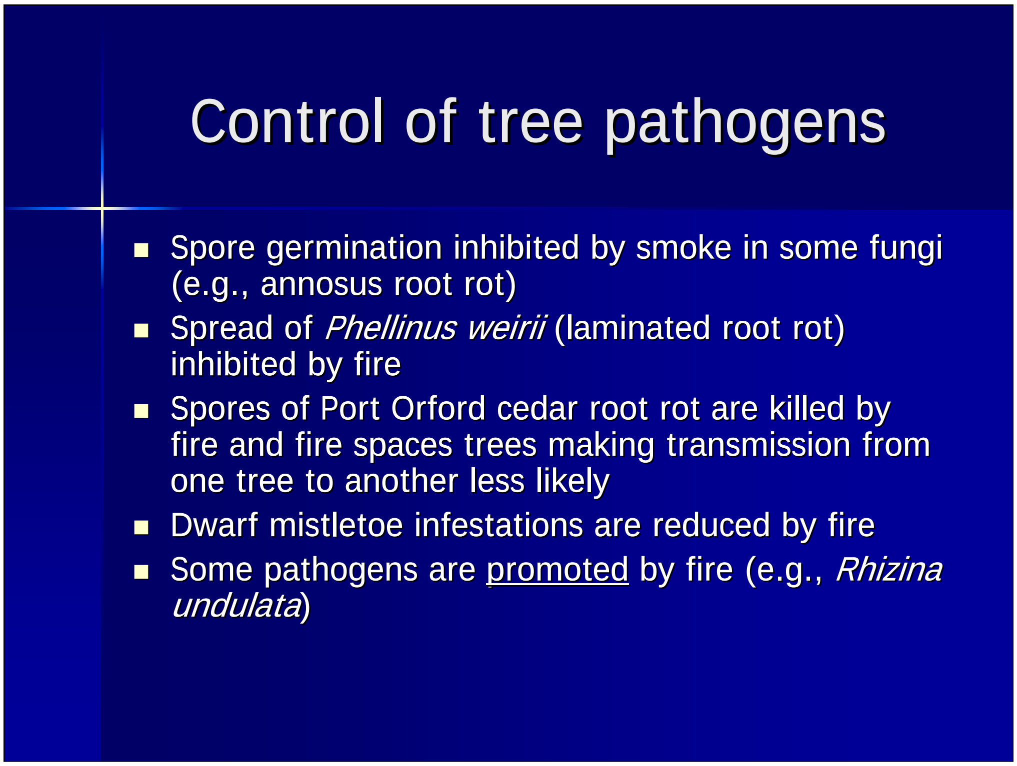
Forest management practices have also contributed by planting high value species (e.g., Douglas-fir) in areas that are more suitable for pines (due to exposure or elevation).

It is important to note that while fire influences insect and pathogen levels, the reverse is also true. Outbreaks of Douglas-fir tussock moth and spruce budworm create greater amounts of dead trees which set the stage for more intense wildfire.

Control of fungal pathogens is a mixed bag and, at this point, we have a minimal understanding of the relationships between fire and fungi.

Beneficial fungi such as mycorrhizae have been shown to be eliminated or significantly reduced following severe forest fires. Since the vast majority of forest plants benefit from mycorrhizal relationships, the recovery of forests following a wildfire may be hampered. Recent research suggests that innoculation of severly burned soils with mycorrhizal spores may enhance rehabilitation efforts (see www.mycorrhizae.com).

Mycorrhizae are the symbiotic association between specific soil fungi and plant roots. Benefits of this relationship include increased capture and uptake of nutrients, protection against pathogens and reduced water stress.



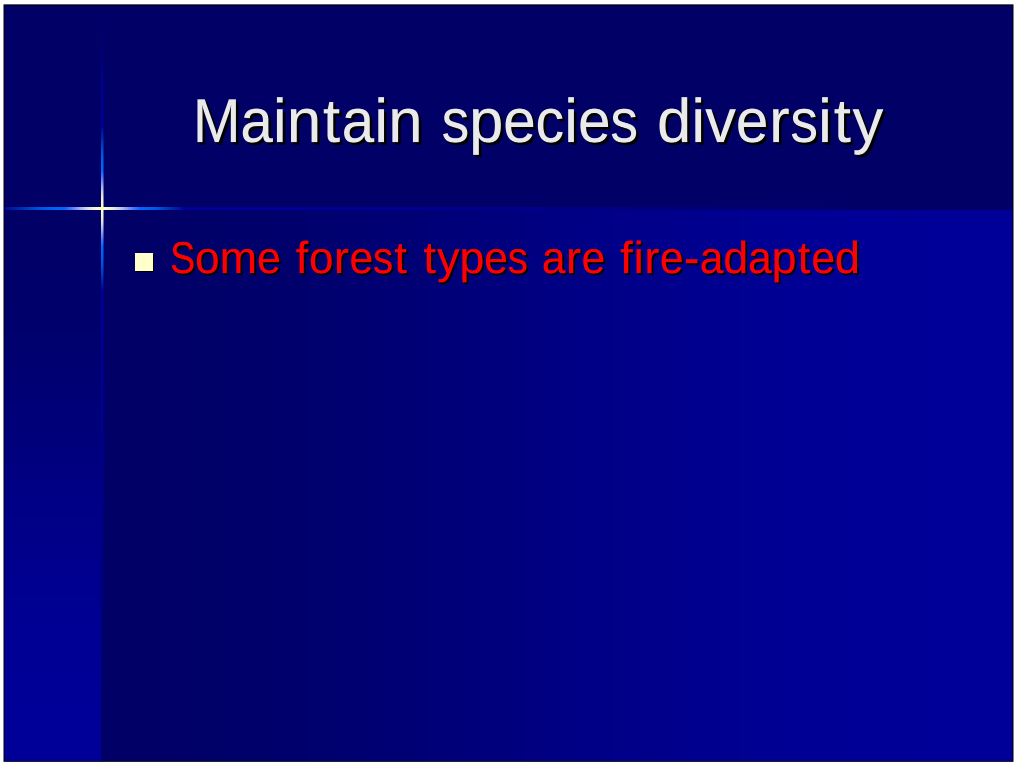
Spore germination in at least one species (the fungus that causes annosus root rot) has been shown to be inhibited by smoke.

The spread of *Phellinus weirii* (laminated root rot) appears to be inhibited on the east side of the Cascades by fire as a result of removal of stumps and roots that get burned up in fires. On the west side of the Cascades, however, the pathogen does not appear to be affected.

Port Orford cedar root rot spores are killed by fire, and fire spaces trees further apart making transmission from one tree to another less likely.

Some pathogens are promoted by fire. The fungus *Rhizina undulata*, for example, affects Douglas-fir seedlings on sites that burn at high temperatures.

Dwarf mistletoe (a parasitic plant on Douglas-fir that creates large “brooms” that can promote fire) is knocked back by fire.



The role of fire in maintaining species diversity is probably the most recent development in our understanding of these ecosystems.

Western forests, in particular, are well-adapted to fire and are the products of countless fires over thousands of years. Some tree and shrub species are fire dependent and decline in the absence of fire. Other plants and animals are adapted to tolerate periodic fire.

Wildfire also increases diversity at the community level due to the mosaic nature of fire. A variety of forest types in the landscape increase biological diversity by having forests in different stages of ecological succession.

A number of forest types are “fire-adapted”. SE pine forests (loblolly, slash, yellow, longleaf pines), Lodgepole pine, Ponderosa pine, chaparral, and sequoia are examples. These forest types decline in the absence of fire due to competition from other species and insect outbreaks.

Some species are remarkably resilient to fire. The photo pair here shows Palmetto during and five months after fire on Nature Conservancy property in the Caribbean.

Forests are fire-dependent because many species are fire-adapted:

Ponderosa pine – thick, fire-resistant bark, lateral branches start high up on trunk, produces abundant pitch, which allows them to seal off fire wounds

Lodgeple pine – produces both open and serotinous cones which release seeds in response to fire

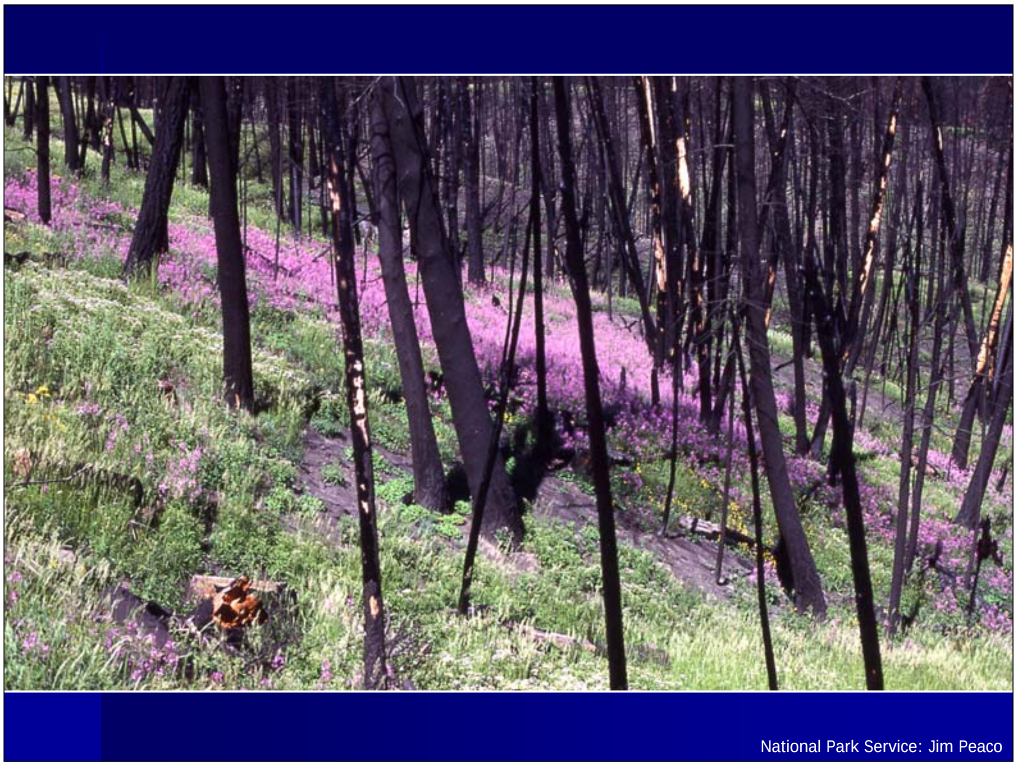
Knobcone pine – produces only serotinous cones

Western larch, Douglas-fir, redwood and sequoia – thick bark, which protects cambium layer from lethal temperatures during a fire

Quaking aspen and redwood – regenerate rapidly from roots after fire

Pitch pine - (in eastern U.S.) can resprout directly from the trunk, enabling trees to re-grow after fire has killed the crown

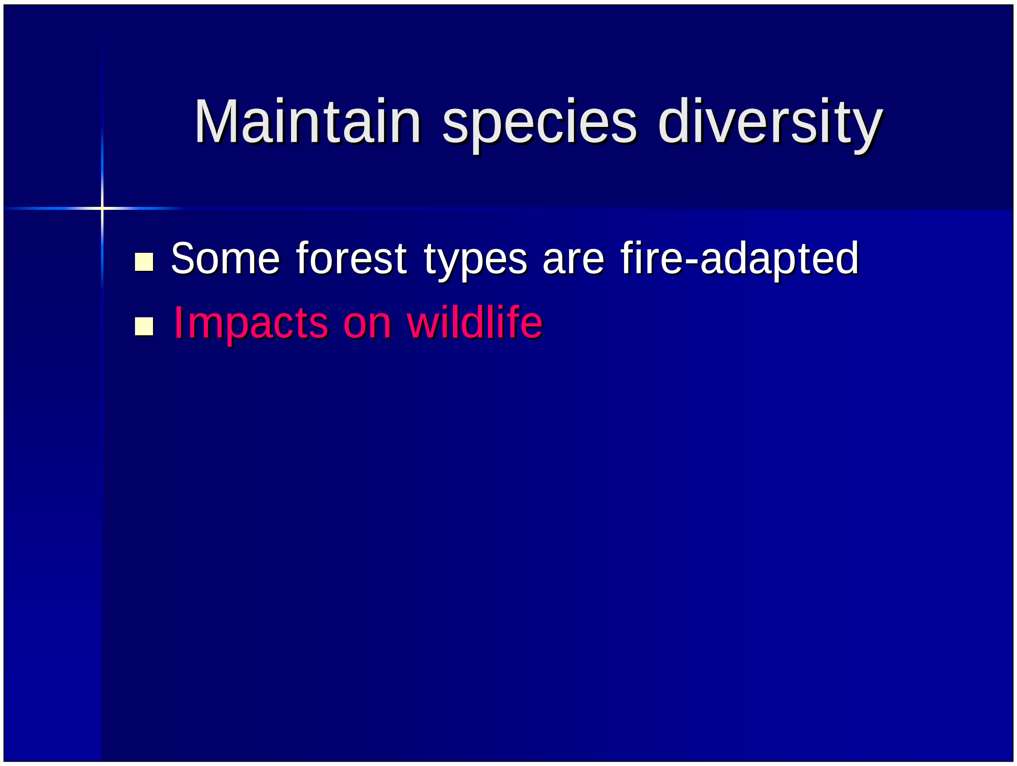
Lodgepole pine with serotinous cones after fire.



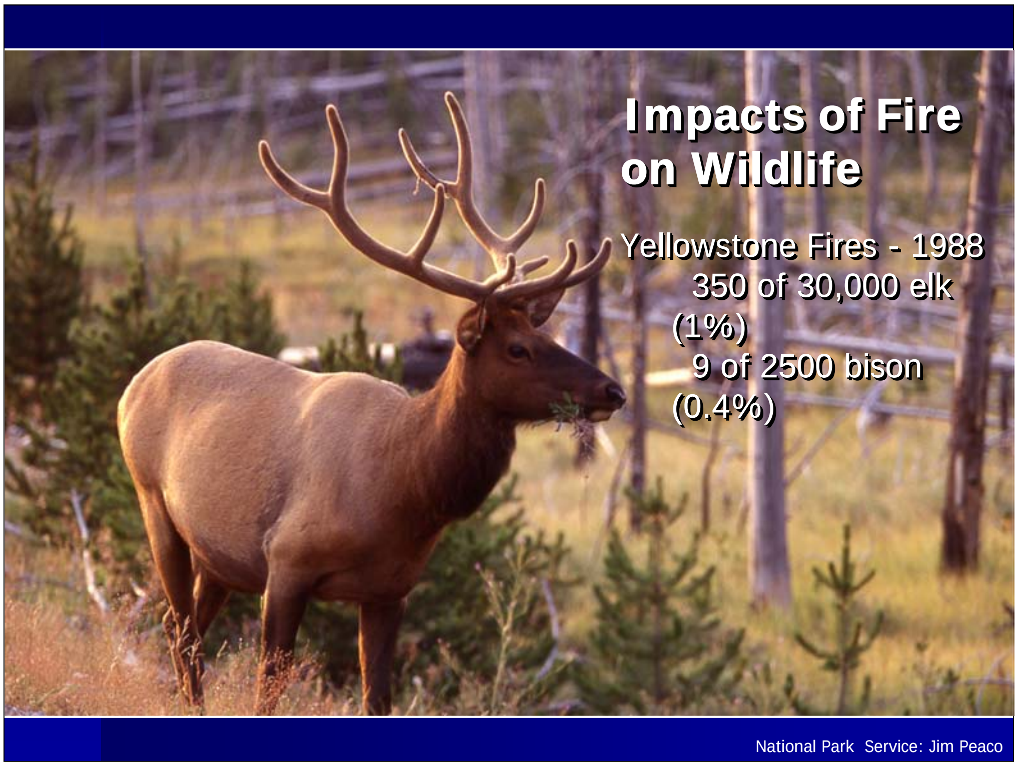
Some species are adapted to rapidly colonizing areas after fire (e.g., *Epilobium* fireweed).

Some of these rapid colonizers are nitrogen-fixing legumes (like this lupine). These species play an important role in maintaining soil fertility as the ecosystem recovers. Inset shows root nodule containing nitrogen-fixing bacteria associated with a legume.

Thus – what is seen as devastating in the short-term, actually has benefits to some species in the long-term and some species are actually inhibited by lack of fire.



The Walt Disney movie, *Bambi,* created the perception that wildfire has a devastating impact on wildlife. Public opinion today probably remains informed by that movie (much as public perception of sharks is informed by *JAWS* and similar portrayals in the popular media). In reality, fire is <u>not</u> detrimental to many species; however, it is not always beneficial either (and benefits are unevenly spread across species).



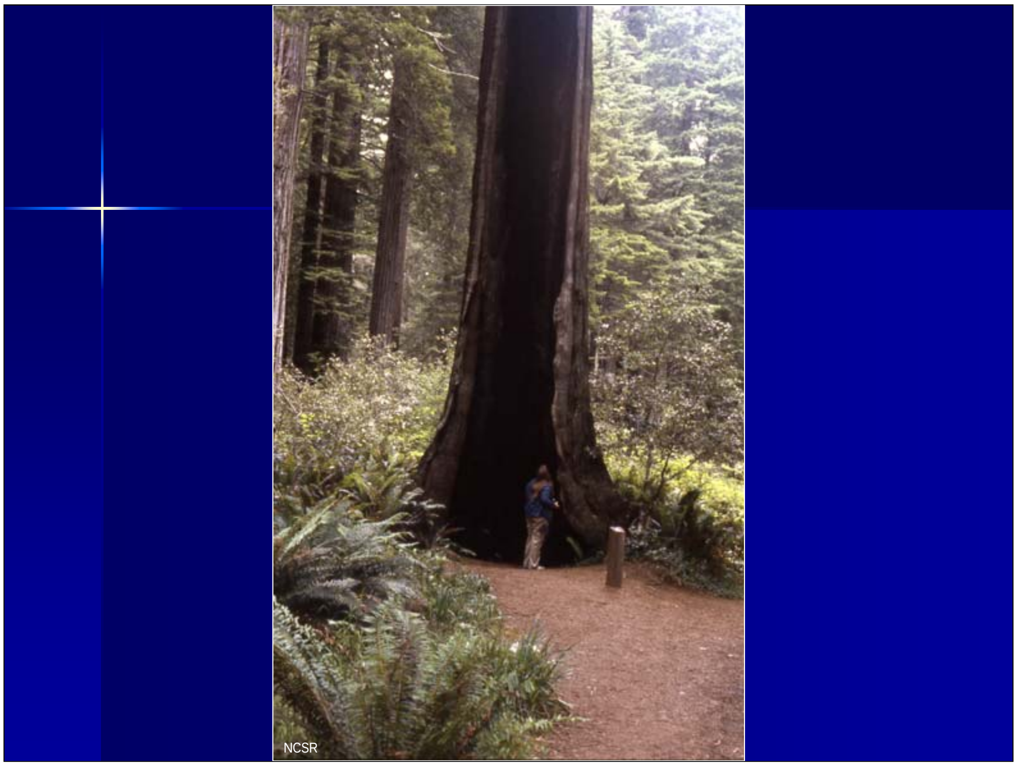
Short-term impacts on wildlife – large mammals are best studied.

Even with the intense fires in Yellowstone in 1988 (1 million acres burned) only 350/30,000 elk (1% of population) and 9/2500 (<0.4%) bison perished in the fire (most by smoke inhalation).

Predators (e.g., cougars, hawks) and scavengers are either unaffected by fire or are favored in the short-term due to increased food availability.

What are the long-term impacts on wildlife?

As with any environmental change, there are “winners” (e.g., moose, deer, elk, woodpeckers, black bear, quail) and “losers” (e.g., marten, wolverine, fisher, caribou).



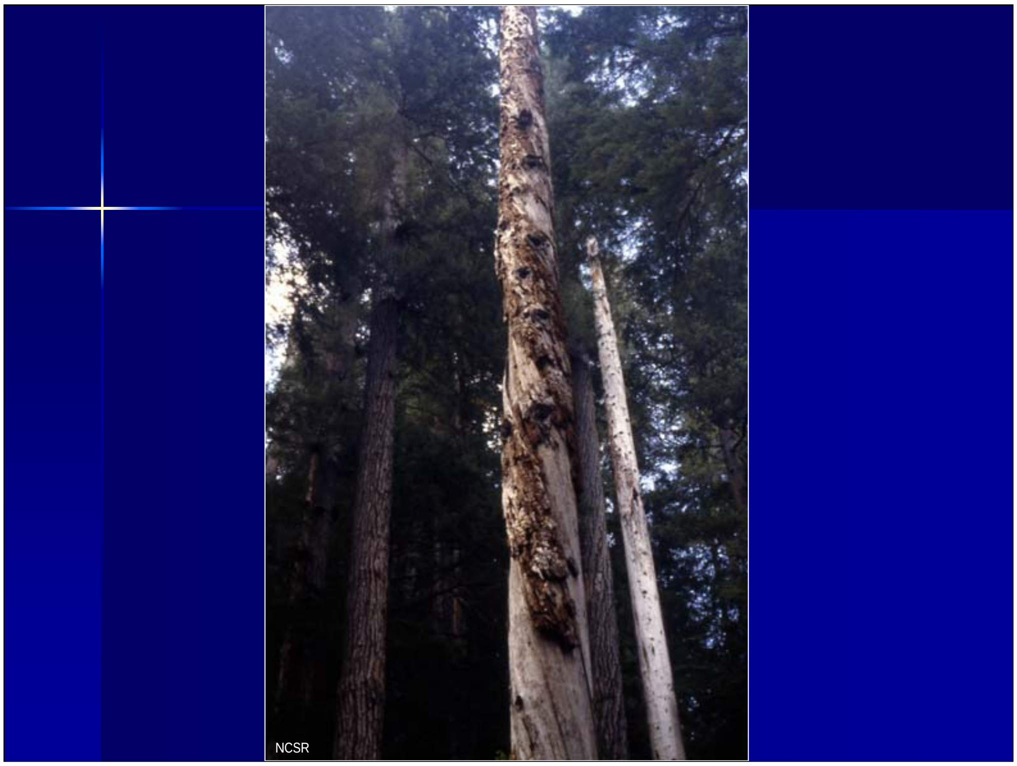
The major effects of fire are on habitat.

Cavity nesting birds (e.g., tree swallows, woodpeckers) benefit from habitat creation (snags and logs) and food availability (wood-boring insects). In Yellowstone, species that had been in decline due to the suppression of fire thrived in the aftermath of the 1988 fires (e.g., 3-toed woodpecker feeds primarily on wood boring insects and uses snags as nest sites).

Forage increases for large herbivores such as elk and deer and omnivores such as bears.

Ground-foraging birds such as quail, grouse, turkeys and pheasants have been shown to increase after fires presumably due to a reduction in forest cover or an increase in edge habitat.

Habitat components are created as a result of fire – some of these components are in short supply in young managed stands. Most of these components are "biological legacies" (habitat components that are left behind after a disturbance such as fire). These legacies are remnants from the previous ecosystem and contribute to the recovery of that system. Several current forestry practices are designed to increase the level of biological legacies in harvested stands.



Standing dead trees (snags) are an example of this biological legacy.

Dead wood in various forms (logs, snags, etc.) provide important substrate for wood boring insects, an important food source for cavity nesting birds.

Kirtland's warbler and jack pine (*Pinus banksiana*) illustrate an interesting connection between wildlife, fire-adapted trees and the consequences of fire suppression.

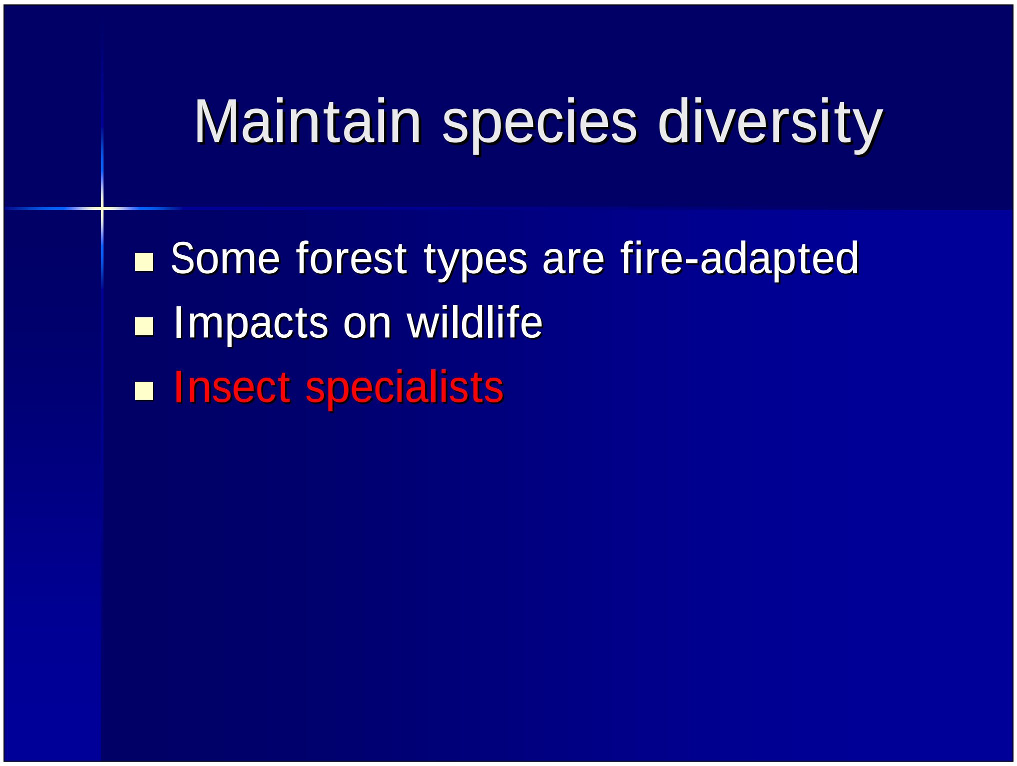
Kirtland's warbler is listed as "federally endangered" under the Endangered Species Act of 1973. It nests in a very limited area in the northern lower Michigan and only in young (5-16 feet tall), widely spaced, jack pine forests on a special type of sandy soil. The species is thought to be in danger of extinction due to its specific habitat requirements and brood parasitism by brown-headed cowbirds. Under historical conditions, suitable Kirtland warbler nesting habitat was produced over broad areas due to frequent fires. Lightning-caused fires would burn the existing forest and as the forest recovered, early stages of ecological succession were dominated by young jack pine. Fires remove competing vegetation and serotinous jack pine cones are opened by the heat generated by the fire. The seeds are released in an ash bed that is ideal for germination. Extensive logging in Michigan in the 1800s followed by widespread wildfires created vast areas of Kirtland warbler nesting habitat. However, as agriculture and more permanent settlement of the area occurred, fire suppression became the rule. As a result there were fewer fires, fewer jack pine forest and fewer warblers. Current management attempts to increase the amount of Kirtland warbler habitat by harvesting older jack pine stands and introducing fire after the harvest to stimulate the release of jack pine seeds. Seedlings may be planted if necessary. After approximately 8 years, the trees are of sufficient size to attract nesting warblers.

Photo credit:

Ron Austing, U.S. Fish and Wildlife Service
www.fws.gov/Midwest/endangered/birds/Kirtland/kiwamgmt.html

For wide-ranging, generalist species such as grizzly bears, fires may create a mosaic of habitat types in different stages of ecological succession. A landscape in which a variety of habitats is available may be more suitable for wide-ranging species than a landscape dominated by a single habitat type.

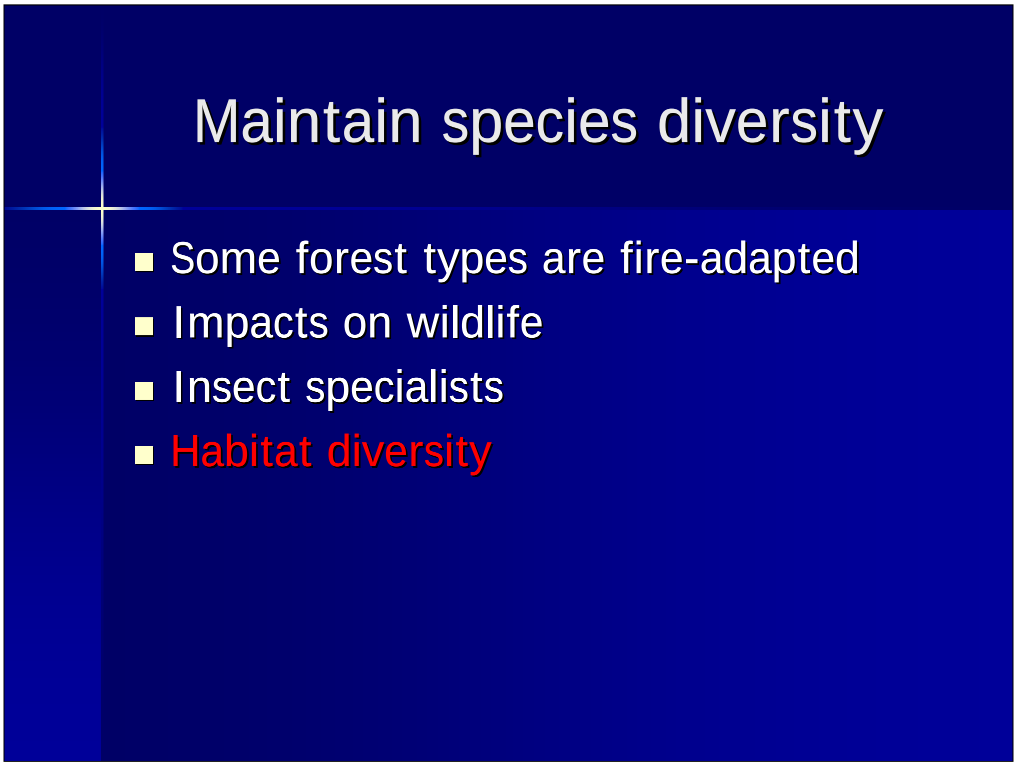
“Losers” include mostly late successional species such as spotted owl, fisher (upper right) and pine marten (lower right). Late successional stages may be set back to an earlier stage by fire.



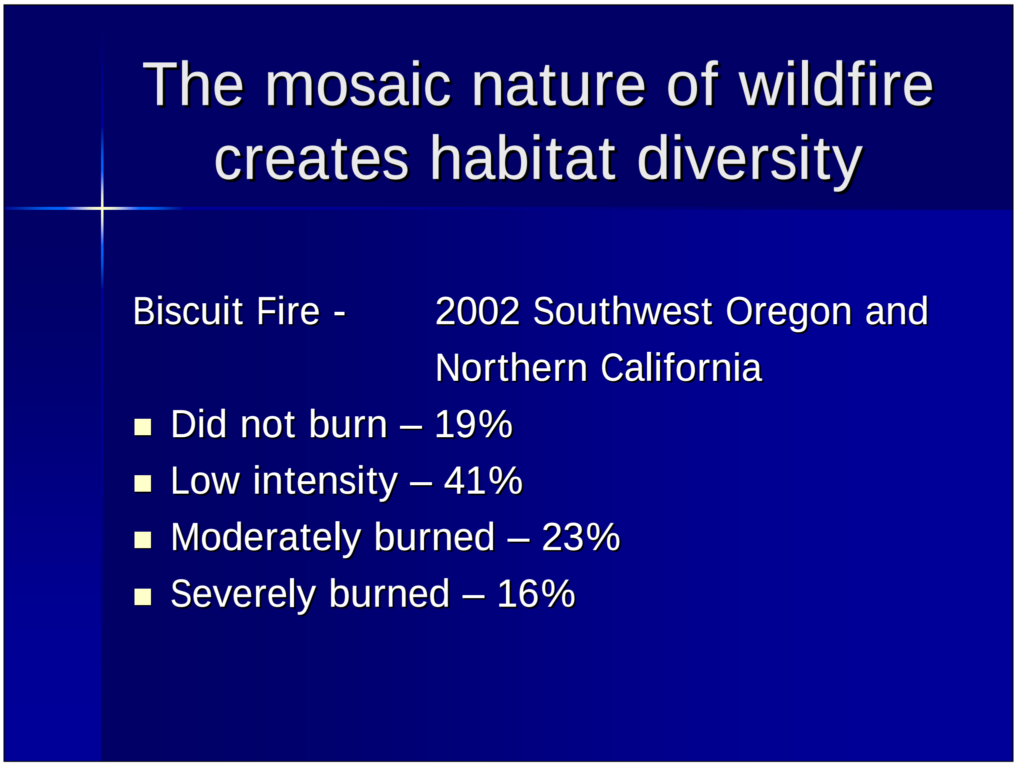
Insects and other invertebrates colonize as soon as the forest cools after a wildfire. Some species are apparently attracted by smoldering wood.

Melanophila beetle (flat-head borers) – usually breed in fire-damaged pines, eggs are deposited below the bark and larvae feed on cambium of newly killed trees. Adults are attracted by heat and smoke (adults have infrared detectors in sensory pits). Agee (1993) reports that at University of California football games in the 1940's, there were regular reports of fans being annoyed and sometimes even bitten by these beetles attracted to the 20,000 or so lit cigarettes in the stands!

Therefore, what may be seen as catastrophic to our eyes, may be a “welcoming mat” to other species.



The role of fire in maintaining species diversity by increasing habitat diversity is a recent development in our understanding of these ecosystems



Forest fires do not typically burn everything or burn at a uniform intensity. Patches of intensely burned areas, lightly burned areas and other areas that are either not touched or not significantly impacted are usually intermingled within the boundary of the fire. This was the case with the Summer 2002 Biscuit Fire in Southwest Oregon and Northern California resulting in a mosaic pattern of burned areas. For this 500,000-acre fire, over 50% either did not burn or burned at low intensity leaving mature trees alive and standing:

Did not burn – 19%

Low intensity (green trees standing) – 41%

Moderately burned (underbrush and > 50% of mature trees killed – 23%)

Severely burned (ash) – 16%

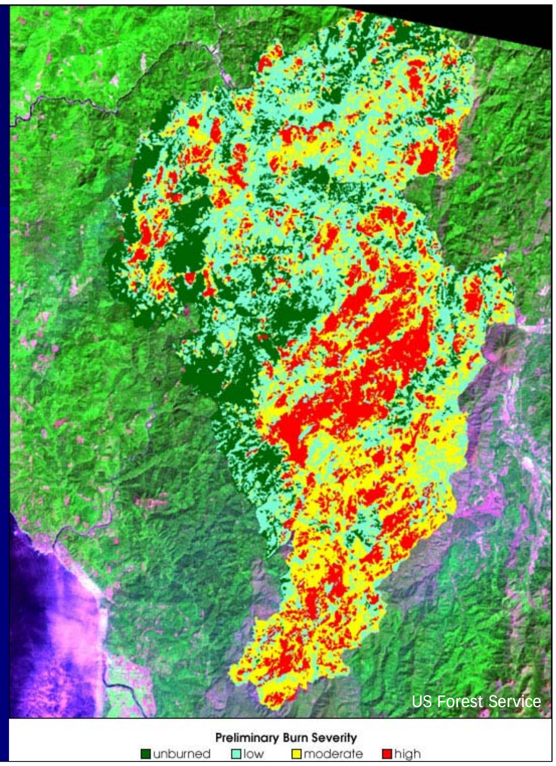
Evaluation was conducted by aerial photography after the fires were put out.

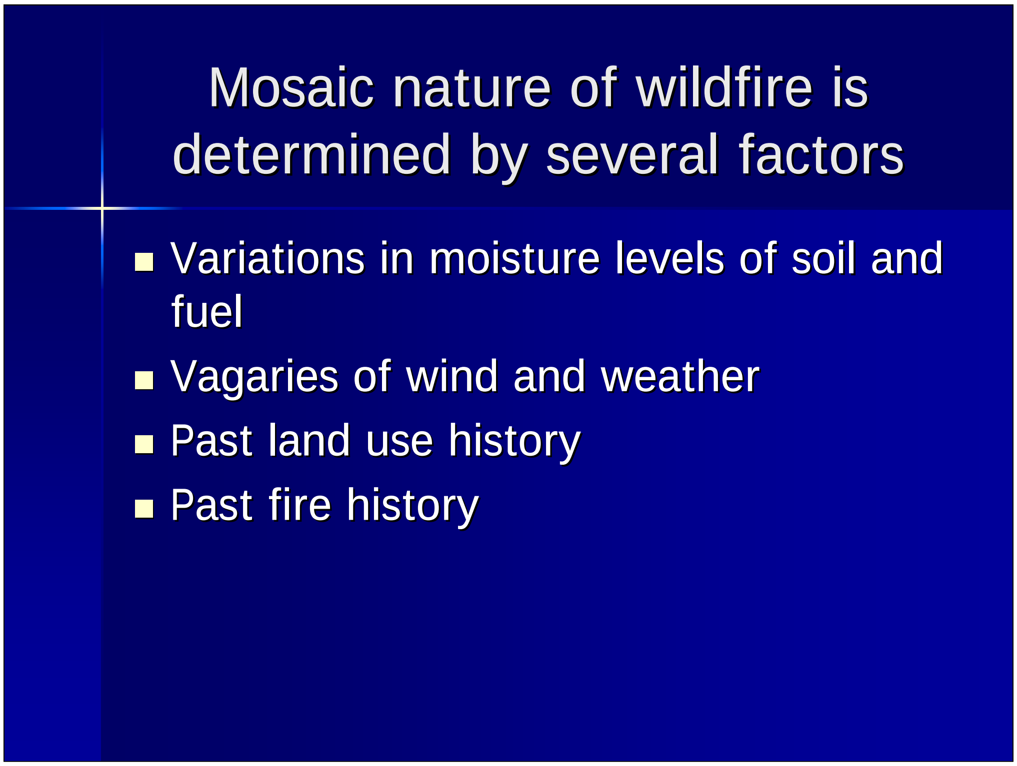
Natural fire frequency in this area is about once every 50-70 years.

Preliminary Burn Severity Assessment

Biscuit Fire

Summer 2002





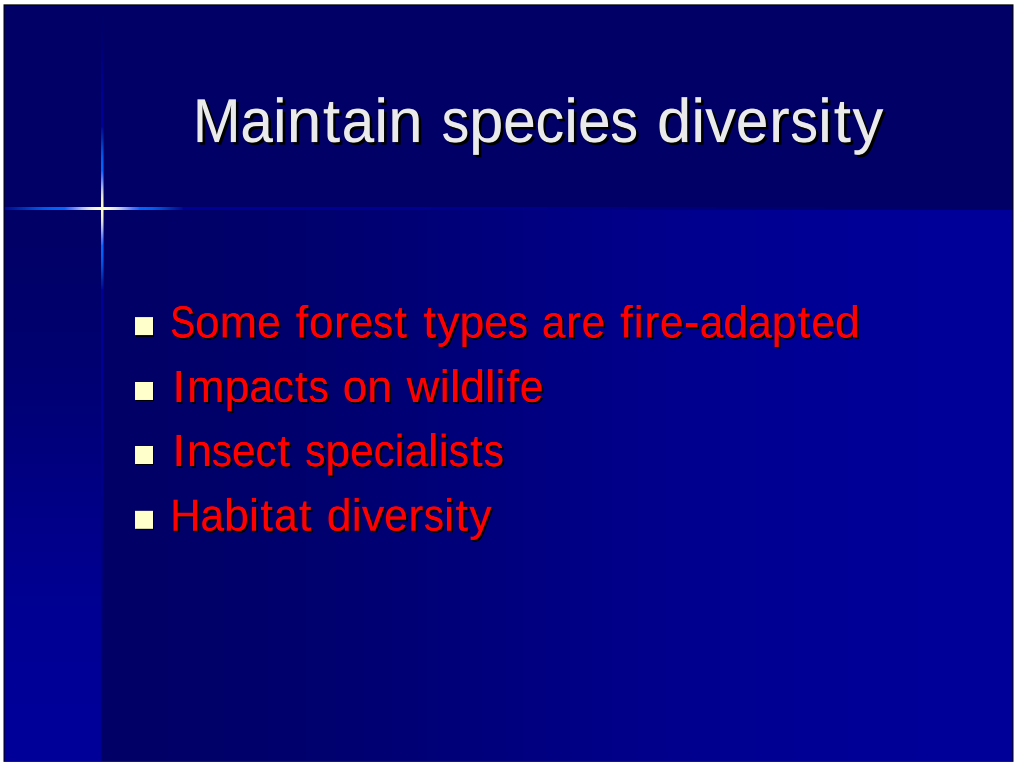
Several factors influence which areas burn and at what level of intensity.

Moisture levels for example, may be influenced by topography. Fuels and soils in depressions or natural wetlands typically have higher moisture levels than surrounding uplands, resulting in areas of less intense burns (or perhaps, no burn at all).

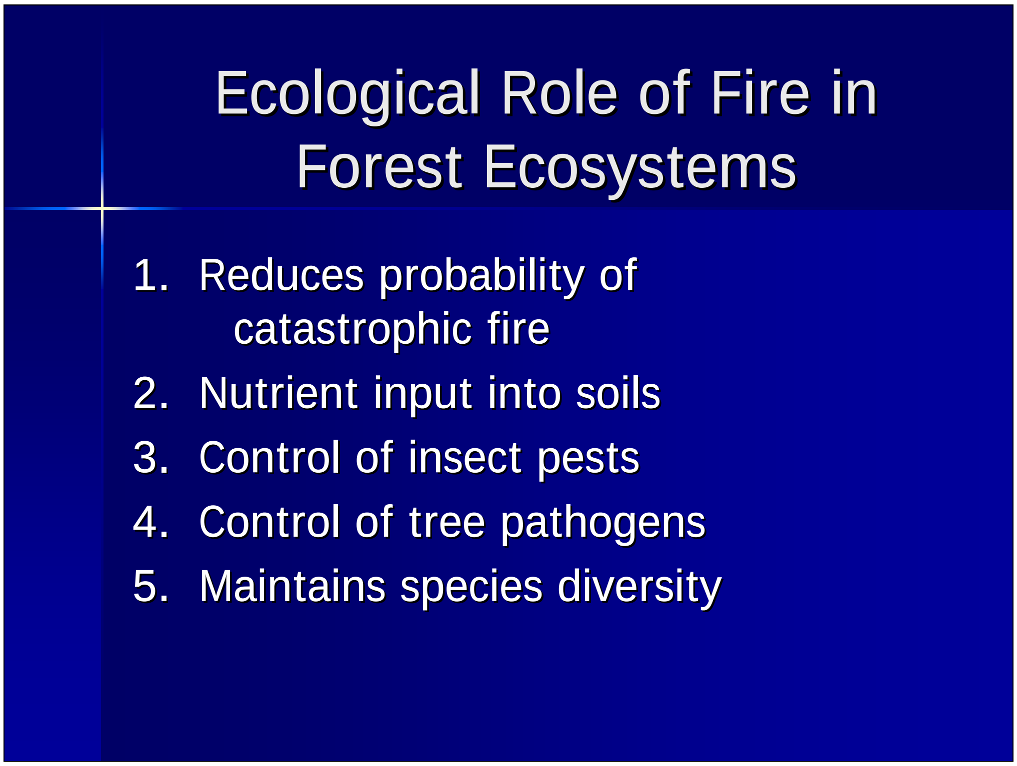
Changes in wind direction, velocity and weather obviously influence the intensity and progression of wildfires. Changing conditions during the course of the fire result in a mosaic of fire impacts.

Past land use practices, particularly those that change the distribution and density of fuels (eg. mowing, thinning, tree harvest, tree planting), influence the intensity of wildfire on the landscape.

Past fire history also influences the distribution of fuels. Variations in the intensity, frequency and distribution of past fires across the landscape may therefore result in a mosaic pattern in the current fire.



Review of major points.



Review of major points. Particularly in ecosystems maintained by fire, modern natural resource management often attempts to reintroduce fire back into the system. See NCSR modules, *Historical Fire Regimes and their Application to Forest Management* and *Pre-fire Intervention: Thinning and Prescribed Fire* for details.

Photo Credits

- Flybrain Online http://web.neurobio.arizona.edu
- Forestry Images: Various Photographers www.forestryimages.org
- National Park Service: Various Photographers www.nps.gov
- NCSR – Wynn W. Cudmore PhD
- Ron Austing, U.S. Fish and Wildlife Service www.fws.gov
- The Nature Conservancy: Ronald L. Myers, PhD www.tncfire.org
- The White House www.whitehouse.gov
- University of Wisconsin: Jean-Michel Ane, Ph.D. www.agronomy.wisc.edu
- US Fish and Wildlife: Various Photographers www.fws.gov
- US Forest Service www.fs.fed.us
- US Geological Survey www.biology.usgs.gov
- USDA Agricultural Research Service: Scott Bauer www.ars.usda.gov
- USDA Forest Service www.na.fs.fed.us
- Virginia Tech University: College of Natural Resources www.cnr.vt.edu
- Washington Biodiversity Project www.biodiversity.wa.gov

Resources

Print and Web-based Resources

Arno, S.F. and S. Allison-Bunnell. 2002. Flames in our forest - disaster or renewal. Island Press. Washington, D.C. 227 pp.

Arno, S.F. and C.E. Fiedler. 2005. Mimicking nature's fire: Restoring fire-prone forests in the West. Island Press. Washington, D.C. 242 pp.

Agee, J.K. 1993. Fire ecology of Pacific Northwest forests. Island Press. Washington, D.C. 493 pp.

Brown, J.K. and J.K. Smith (eds.). 2000. Wildland fire in ecosystems: effects of fire on flora. Gen. Tech. Rep. RMS-GTR-42-vol 2. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 257 pp.

This comprehensive review of our state-of- knowledge on the effects of fire on ecosystems is the second in a five-part series entitled "The Rainbow Series." This volume emphasizes fire regimes, the effects of fire on plants and post-fire plant community development. Other volumes evaluate other ecosystem components such as animals, cultural resources, soil, water and air. Paper copies of these documents can be ordered from:

Fort Collins Service Center
Publications Distribution
Rocky Mountain Research Station
240 W. Prospect Rd.
Fort Collins, CO 80526-2098
970-498-1392
rschneider/rms@fs.fed.us
www.fs.fed.us/rm

The 5-part series is also available on-line at:

http://www.fs.fed.us/rm/pubs/rmrs_gtr042_1.html	Effects of Fire on Flora
http://www.fs.fed.us/rm/pubs/rmrs_gtr042_2.html	Effects of Fire on Fauna
http://www.fs.fed.us/rm/pubs/rmrs_gtr042_3.html	Effects of Fire on Cultural Resources
http://www.fs.fed.us/rm/pubs/rmrs_gtr042_4.html	Effects of Fire on Soil and Water
http://www.fs.fed.us/rm/pubs/rmrs_gtr042_5.html	Effects of Fire on Air

Carle, D. 2008. Introduction to Fire in California. University of California Press, CA. 216 pp.
www.go.ucpress.edu/natsci

Carr, M. 2005. Wildland Waters USDA Forest Service. Summer 2005 FS-828. 22 pp.

This special issue on fire provides an excellent general introduction to the fire issue. Most aspects are briefly addressed including fire regimes, fuels management, restoration, fire responses, salvage logging, and rehabilitation. Links to additional resources are provided.

Jensen, S.E. and G.R. McPherson. 2008. Living with Fire: Fire ecology and policy for the twenty-first century. University of California Press, CA. 198 pp. www.go.ucpress.edu/natsci

Noss, R.F., J.F. Franklin, et al. 2006. Managing fire-prone forests in the western United States. Front. Ecol. Environ 4(9):481-487.

This is an excellent review of the literature on the ecology and management of fire-prone forests in the western United States. The article and the references cited within should provide faculty with a comprehensive understanding of this complex issue. It has also been posted on-line by the Ecological Society of America at www.frontiersinecology.org.

Pyne, S.J. 2005. Tending fire. Island Press. Washington, D.C. 240 pp.

USDA Forest Service – Fire Effects Information System
www.fs.fed.us/database/feis

This Forest Service site summarizes and synthesizes current research about living organisms' relationships to fire. If you are looking for species-specific information (photos, distribution, ecological characteristics, fire ecology, fire effects, management considerations) for plant and animal species in the U.S., this should be your first stop. Trees, shrubs, lichens, vertebrate animals and some arthropods are included. The site is easy to use and well-referenced for further research.

Sugihara, N.G., et al. (eds.). 2006. Fire in California's ecosystems. University of California Press, CA. 612 pp. www.go.ucpress.edu/nasci

USDA Forest Service – Pacific Northwest Research Station – PNW Science Update www.fs.fed.us/pnw/publications/sci-update.shtml

PNW Science Update is published several times a year. The series examines the science behind current natural resource issues including fire. The articles are suitable to assign as student reading and several are relevant to this module.

Wuerthner, G. (ed.). 2006. Wild fire: A century of failed forest policy. Foundation for Deep Ecology, Sausalito, CA 322 pp.

Video Resources

The video productions below may be shown to students to supplement the *PowerPoint* presentation included with this module or they may be used as instructor resources.

Prescribed Natural Fire. 1998. Oregon Field Guide. Episode #904. Oregon Public Broadcasting, Portland, Oregon. 15 min.

Prescribed Natural Fire - Update. 2001. Oregon Field Guide. Episode #1209. Oregon Public Broadcasting, Portland, Oregon. 15 min.

Chetco Fire - Update. 2003. Oregon Field Guide. Episode #1408. Oregon Public Broadcasting, Portland, Oregon. 15 min.

These three "Oregon Field Guide" episodes emphasize various aspects of wildfire management including the ecological role of wildfire. They may be ordered from the Oregon Public Broadcasting web site at www.opb.org. All are useful supplements to the PowerPoint presentation included with this module.

Biscuit Fire Recovery. 2004. Oregon Field Guide. Episode #1507. Oregon Public Broadcasting, Portland, Oregon. 30 min.

This special production by Oregon Field Guide examines wildland fire issues related to the 2002 Biscuit Fire in southwest Oregon and northern California. Several perspectives are presented including those of the USDA Forest Service, the timber industry, fire ecologists and environmental groups. Although the details may differ, most of the issues associated with the Biscuit Fire also pertain to wildfires across the West.

Fighting Fire with Fire. 2005. The Nature of Things, Canadian Broadcasting Company. Distributed by:

Bullfrog Films
P.O. Box 149, Olney, PA 19547
800-543-3764
www.bullfrogfilms.com

This 45-minute production narrated by David Suzuki provides an excellent introduction to our current thinking on fire management. Although the emphasis is on fire issues in Banff National Park and Yellowstone National Park, the concepts discussed may be broadly applied across the West. The influence of past fire fighting policy, the current condition of western forests, thinning and prescribed fire, the ecological role of fire, and the implications of global climate change are all examined.