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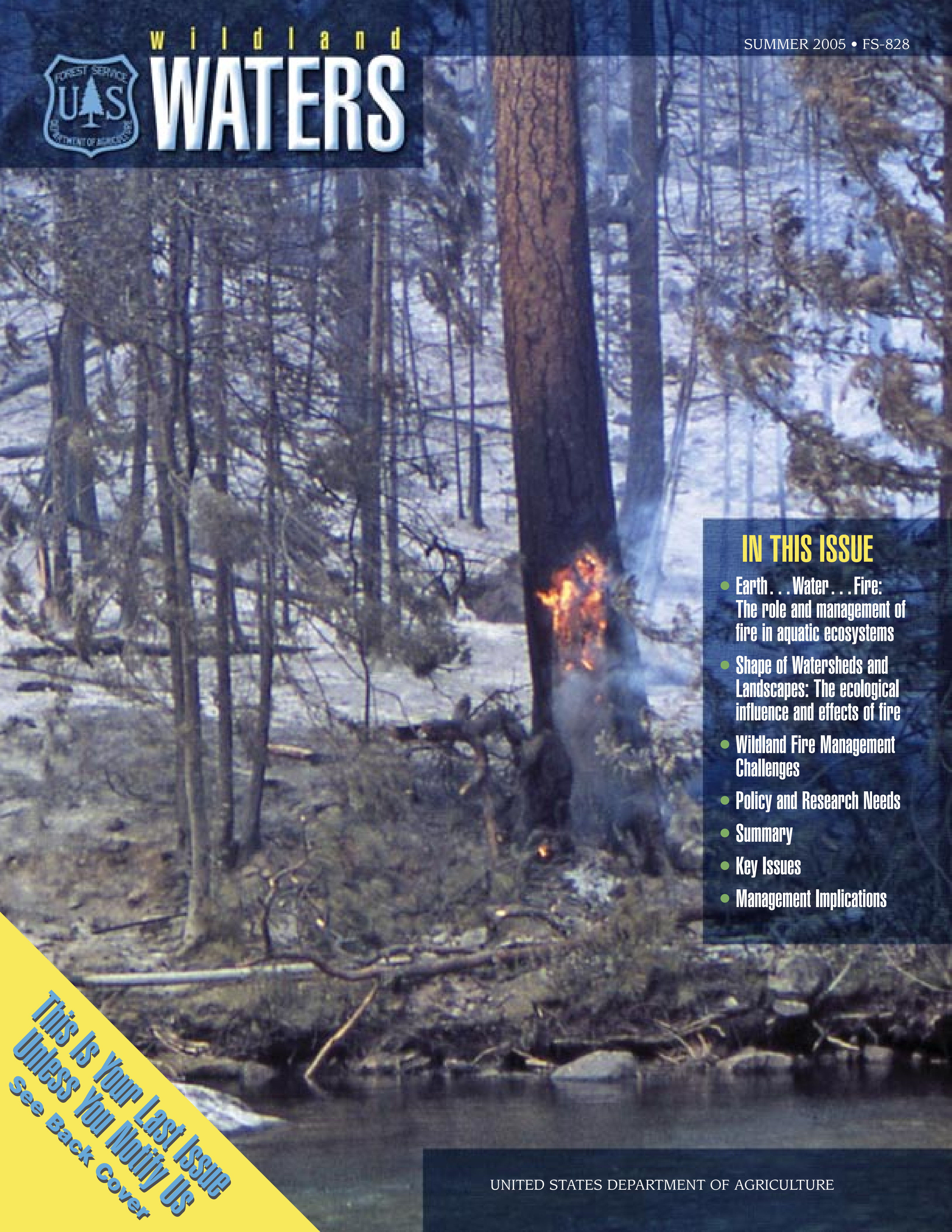

IN THIS ISSUE

This Is Your Last Issue Unless You Notify Us

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UNITED STATES DEPARTMENT OF AGRICULTURE

Earth . . . Water . . . Fire:

The role and management of fire in aquatic ecosystems

"Now every one of these Elements has two specific qualities: . . . For Fire is hot and dry; Earth dry and cold; Water cold and moist; and Aire moist and hot. And so after this manner the Elements, according to two contrary qualities, are contrary one to the other; as Fire to Water, and Earth to Aire."

—Heinrich Cornelius Agrippa (1486-1535)

http://www.esotericarchives.com/agrippa/agrippa1.htm

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For the past century or two, we have considered the sight of smoke and fire in our wildlands contrary to the health of forests and aquatic ecosystems. Although fire can be a real threat, for millennia, fire also has been a shaper and keeper of many natural communities whose origins, evolution, and survival may be closely linked to and even depend on the ecological force of fire.

The presence of wildland fire across the country has changed dramatically in recent decades, as have the ecosystems in which fire occurs. Large fires in the West and rising concerns about forest health have ignited efforts to recover ecosystem patterns and processes and to reduce the risk of "catastrophic" fires through active forest and fire management.

At the same time, we have increased our attention to the conservation and restoration of the Nation's fish and aquatic species and their habitats—efforts whose goals may sometimes seem to conflict with forest restoration and fire management goals.

Are fire and water as "contrary" and incompatible as the tarot of ancient elements suggests? Is fire always a threat to fish and other aquatic species, or can fire actually benefit aquatic communities? What kind of management is appropriate to address wildland fire, and when might the management of fuels and suppression of fire be worse for aquatic ecosystems than fire itself?

Vigorous current debate over such questions reflects the complexity of fire and the systems affected by it. In this issue, we explore the role of fire in aquatic ecosystems, with an emphasis on forested watersheds in the Western United States. We look at the ecological influence and impacts of fire on water, watersheds, and aquatic species; examine some management challenges and the debates in which they are enmeshed; and sample research and policy needs for effectively addressing fire, forest, water, and fish-related issues in the future.

Shaper of watersheds and landscapes: the ecological influence and effects of fire

How do we know?

Evidence abounds to tell us about fire's presence on the landscape over time. Buried layers of charcoal in the soil and even-aged stands of trees, such as western larch that require mineral soils for germination, testify to prehistoric fires. Historical writings mention fires witnessed by humans. Read through scar tissue, tree trunks in forested areas contain stories of past fires.

Streamside or riparian vegetation may survive or revive quickly after fire in adjacent uplands. September 2000.
Photo by Charles Luce.

A variable presence

Ecosystems shaped by fire are found throughout the country—pine barrens in the East and South, coastal prairies and marshes of the Southeast, northern hardwood forests of New England and the Great Lakes, Midwestern grasslands, Southwestern shrublands and chapparal, and the broad expanses of coniferous forests in the West.

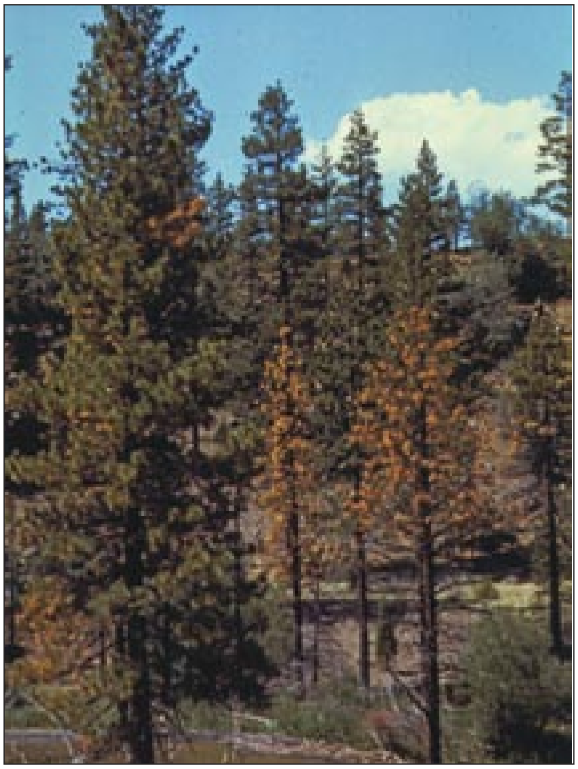
Fire's presence on these diverse landscapes varies in response to the differing vegetation, topography, and climate, which themselves change over time. The pattern of fire that occurs in different places is called the fire regime, described by the expected severity, size, intensity, location, and frequency of fires in these different places. Fire regimes also respond to human influence—whether from Native Americans and early settlers who used fire to shape their forest and grassland landscapes, or from contemporary land uses and management practices.

As if life depended on it: adaptations to living with fire

In places where fire has been a fundamental feature over time, many plants and animals are adapted to and can even depend on fire's effects.

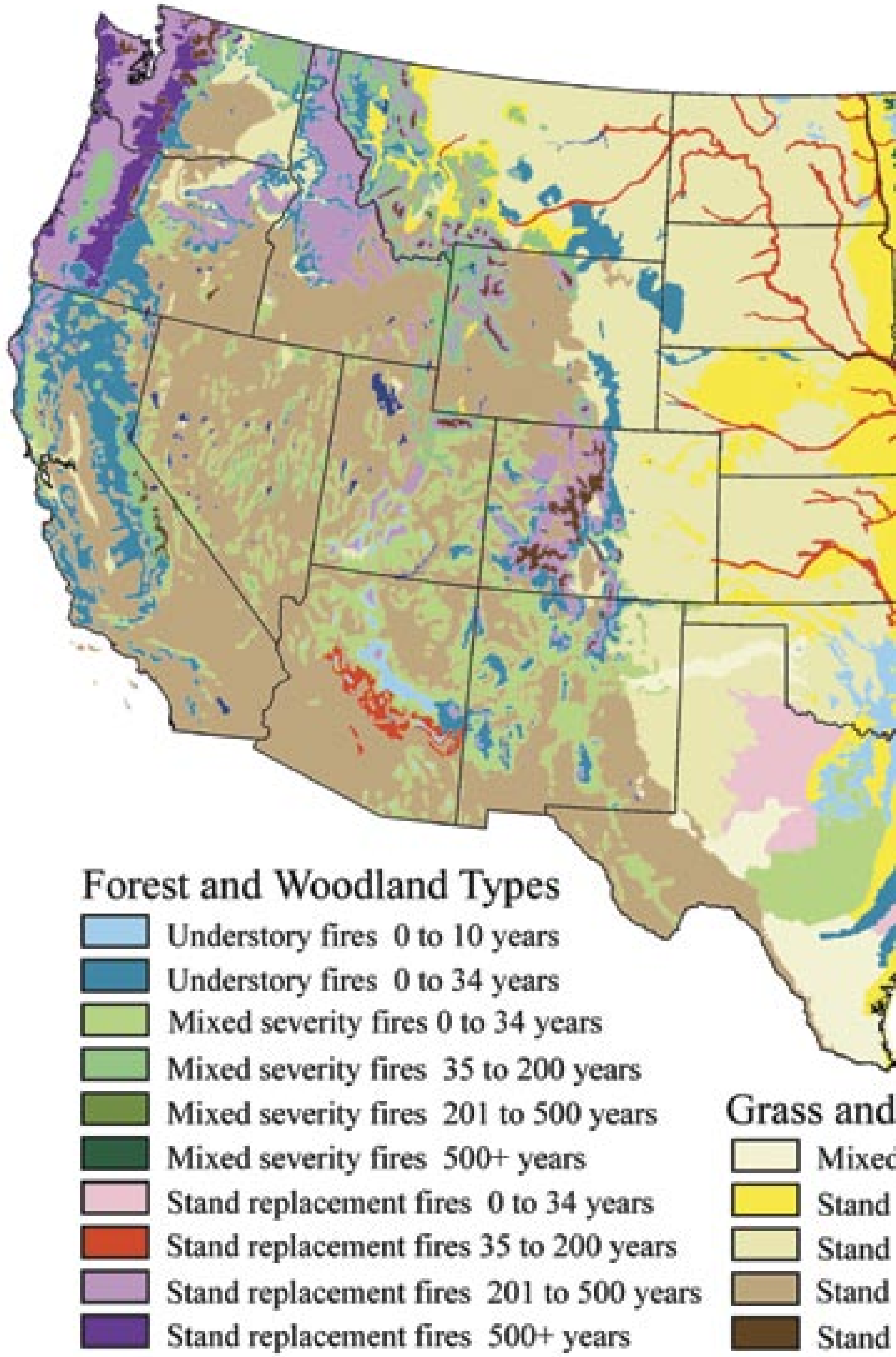
Some riparian plants, for example, have seeds or growth forms that can survive or come back quickly after fire. Some trees such as lodgepole pine have seeds that actually require the heat of a fire to open and disperse.

Insects can quickly colonize a burned area—attracted by heat, smoke, and dead and dying trees—and lay their eggs in scorched trees. Woodpeckers and cavity-nesting birds, such as bluebirds, may find those same dead and dying trees—and those insects—important for shelter and food.



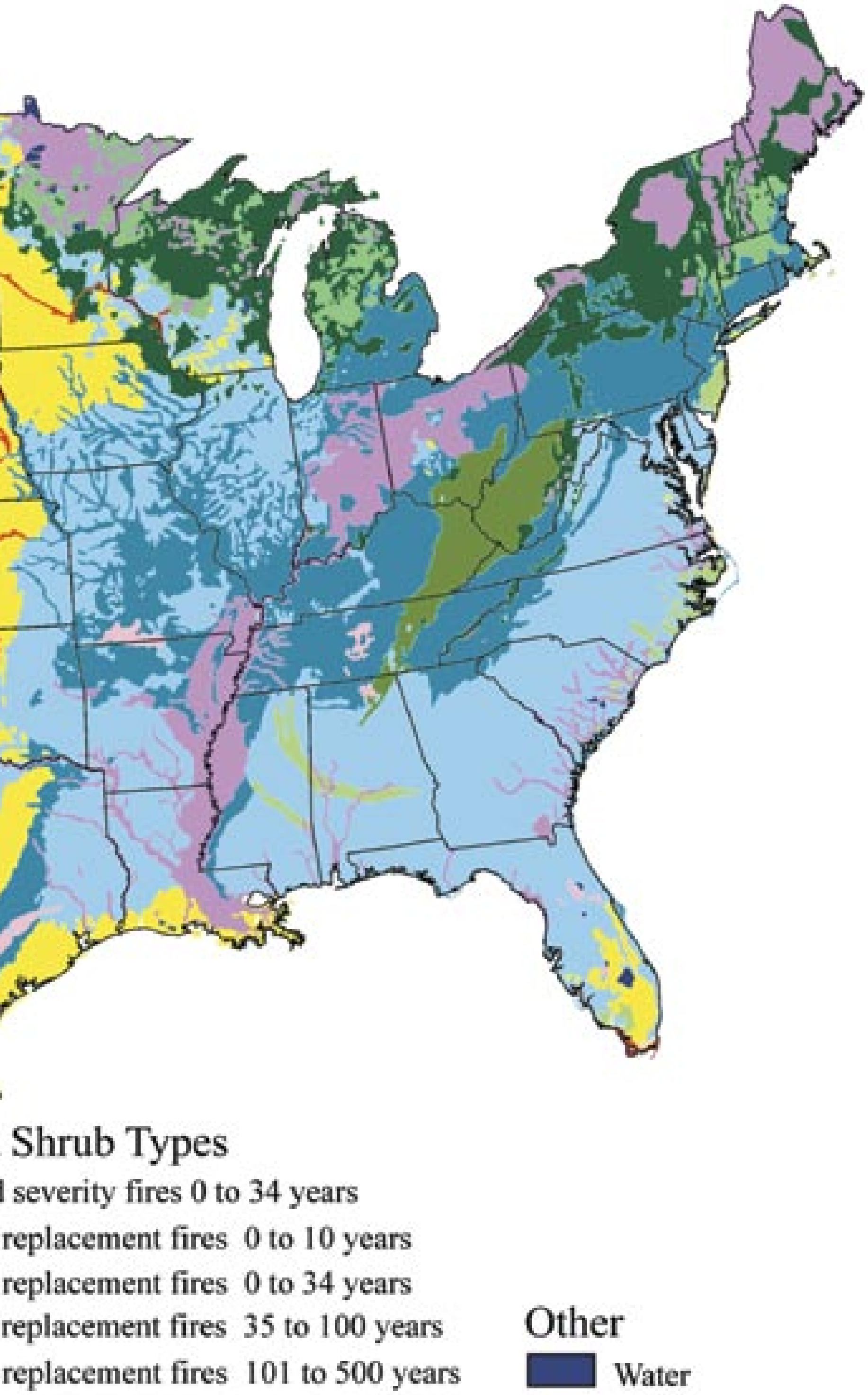
Fire might frequent a lodgepole pine forest in southwest Oregon every 80 to100 years.

In low-elevation ponderosa pine and dry Douglas fir forests, average fire intervals have historically ranged from 5 to 20 years with low to medium fire intensity.



Fire varies in its frequency, season, size, and immediate effects but general patterns occur over long periods. These patterns describe fire regimes.

- Understory fire regime (applies to forests and woodlands) — Fires are generally nonlethal to the dominant vegetation and do not substantially change the structure of the dominant vegetation. Approximately 80 percent or more of the aboveground dominant vegetation survives fires.
- Stand-replacement fire regime (applies to forests, woodlands, shrublands, and grasslands) — Fires kill aboveground parts of the dominant vegeta-



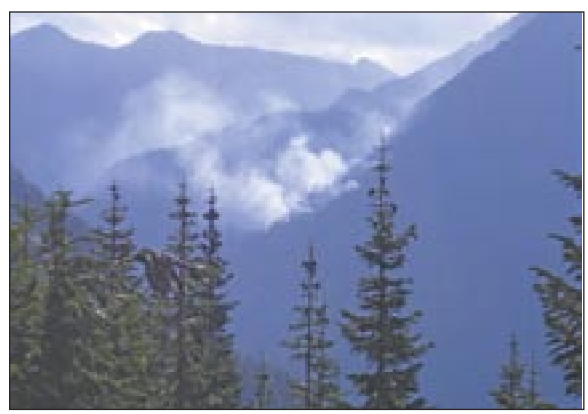
tion, changing the aboveground structure substantially. Approximately 80 percent or more of the aboveground dominant vegetation is either consumed or dies as a result of fires.

- Mixed-severity fire regime (applies to forests and woodlands) — Severity of fire either causes selective mortality in dominant vegetation, depending on different tree species' susceptibility to fire, or varies between understory and stand-replacement.

Source: Brown and Smith (2000)

High-elevation western forests, situated in wetter and colder environments than the dry forests, typically burn infrequently, though often at a much higher intensity than do dry forests. Fire intervals range from 50 to 300 years.

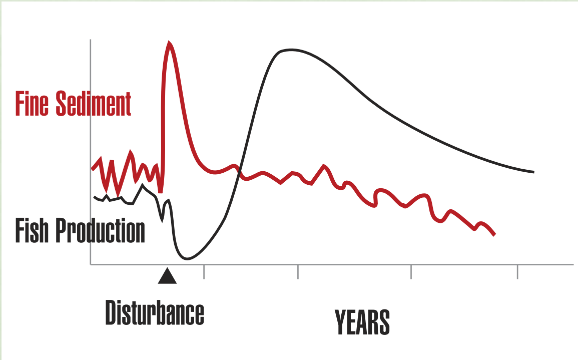
Even Wetlands, such as cypress groves, can have small patches that burn to the waterline every few years, killing vegetation that would otherwise compete with native sawgrasses.



Within a region or forest, a small, steep valley may have a different fire frequency than a nearby wider and moister valley.

Photo by Barbara Webster

Some animals with the option to flee, such as deer and migratory life stages of salmonids, might escape and avoid a fire. Less mobile animals—such as snakes and soil organisms—may be able to survive mild or moderately intense fire by hiding in moist hollows and underground burrows.



Hypothetical trends in an aquatic ecosystem over time in response to fire. Immediate increases in fine sediments may result in a short-term decline of fish survival and production. In the long term, populations may rebound because of the influx of materials such as large wood debris that contribute to the quality of the habitats.

Aquatic organisms, like fish and amphibians, also have complicated life history strategies, habitat needs, and flexibility to adapt to fire-changed conditions; some may even depend on fire to create the habitat diversity they require for long-term population stability.

An agent of disturbance

Researchers have acknowledged that wherever disturbance occurs—whether caused by fire, wind, or other agents—ecological conditions are changed. Depending on the nature and scale of the disturbance, a patch of habitat may undergo shifts in nutrients, energy cycles, and other conditions that may favor one species or community over another (Pickett and White 1985, Reeves et al. 1995). Fire's influence over habitats and species evolution comes in part from the way fire disturbs the status quo.

In shallow wetlands and riparian areas, for example, fire can keep shrubs and trees from becoming established, creating opportunities for species of amphibians that need sunny areas or open water (Pilliod 2004). Fire can also result in a mix of forest conditions and canopy shapes and sizes that can help maintain the complexity of forest habitats over time, providing conditions favorable to a variety of species (Franklin and VanPelt 2004).

Because disturbance patterns are dynamic, with the "mosaic" of habitats changing in time, species that are adapted to varied and changing environments can thrive. Aquatic ecosystems used by anadromous salmon, for example, periodically experience disturbances such as landslides, floods, and fires, according to U.S. Department of Agriculture Forest Service researcher Gordon Reeves and others (1995). Over decades and centuries of recovery, an ever-changing patchwork of habitat conditions maintains the variable life-histories exhibited by salmon populations. Disturbance may also help maintain the very adaptations that make salmon more resilient to a changing environment.

Who lives in your neighborhood?

Mature Douglas-fir forests in the Pacific Northwest create too much shade for their own sun-loving seedlings to grow well. Fire disturbances often create sunny openings that give Douglas-fir seedlings an advantage over shade-lovers, like hemlock. Fire thus creates conditions that help keep a Douglas-fir forest from becoming a different type of forest.

Life history adaptations of salmon—such as adult migration to and from the sea at different ages and times of the year—allow populations of anadromous salmon to persist in a dynamic environment created by disturbance.

An agent of change: effects of fire in aquatic ecosystems

The diverse and complex effects of fire hinge on a variety of factors (Dunham et al. 2004):

- **The fire**—timing, location, extent, severity and intensity, patchiness.
- **The ecosystem**—prefire condition of terrestrial and aquatic ecosystems, including the presence of invasive species and fragmented habitats.
- **Species**—characteristics and adaptations of the affected species.
- **Relationships**—numerous indirect physical and ecological linkages.
- **History**—prior management and changes to habitats and populations.

Direct effects

Effects of fire in aquatic ecosystems can be direct and immediate, often related to short-term biological and physical changes. For example, fire may—

- Cause small streams to experience short-term increases in temperature.
- Change pH or acidity levels or cause increases in nutrients, such as ammonium from dissolved smoke or ash.
- Kill many individual amphibians, fish, plants, and other wildlife.
- Elevate levels of certain nitrogen compounds that some amphibian species may be sensitive to.

Indirect effects

Some effects on aquatic and terrestrial ecosystems may show up only later. For example, fire may cause—

- Increased amounts of sediment in a stream channel or floodplain, depending on how soon intense precipitation falls after a fire, how much water repellency exists in soils, and how much forest canopy has been lost.

Erosion at Lake Creek, a tributary of the Boise River, ID, following fire. August 2004.

Photo by Charlie Luce.

- Sediment carrying nitrates and chemical contaminants to end up in reservoirs, including those for municipal drinking water.
- Hydrologic and sediment changes, modifying the shape and function of stream channels, pools, or substrates.
- Vegetation changes, altering plant evapotranspiration, soil water-holding capacity, and snow melt rates, leading to changes in the timing and amounts of streamflow.
- Increased numbers of invasive species of plants that out-compete native plant populations.
- Dramatic immediate increases in standing dead wood, leading to increases in volumes of downed wood on soils and in streams and providing terrestrial, riparian, and aquatic habitats.
- Stream warming over years or even decades, reducing habitat quality for some species while improving it for others.
- New areas of accessibility to off-highway vehicles (OHVs) due to the loss of brush and understory. Unmanaged use of OHVs can lead to erosion, invasive weed introduction, and disturbance to sensitive fish and wildlife species.
- Erosion, which buries logs and incorporates them more fully into the soil.
- Debris flows removing woody debris from smaller channels and depositing it in larger fish-bearing channels.

Some effects on aquatic and terrestrial ecosystems and organisms may show up only as indirect results of some other fire effects. Examples of indirect results include—

- Adverse effects on amphibians because of increased ultraviolet radiation resulting from loss of shade, pH or soil changes, or increased sedimentation.
- Changes in water chemistry, temperature, and quantity.
- Destruction of habitat.
- Loss of access to fish spawning and rearing sites.
- Changes in food resources, causing some fish populations to decline and other fish populations to increase.

Large woody debris resulting from fire provides new habitats in Trapper Creek, ID. Note standing dead wood in background, which eventually will fall into the creek. June 2000.

Photo by Charlie Luce.

The power of connections

In the early 1990s, fires burned through several tributary streams to the Boise River, ID. In one stream, a local population of bull trout disappeared but rebounded within a year when fish that had been outside the area returned to spawn. Another stream saw resident rainbow trout decline after the fire but come back quickly when fish simply moved back in from unburned sections of the stream. The migratory bull trout survived because of connectivity to the outside; the resident rainbows survived because of local or internal refuges that remained intact.

The effects of the fire on fish populations may depend on what else is happening in time and space across the landscape: How much of the habitat was already degraded? How much of the available habitat was affected by the fire? How much connection remains to unaffected habitats and populations? What time horizon is being considered? Can the fish species live in the changed environment?

Where fish habitats are isolated and small, fire and any resultant floods can destroy a fish population because individuals cannot move in to recolonize. If, however, local and regional habitat connections remain intact, fire can help support populations through creation of complex habitats.

Implications of change

Although fire regimes are highly variable, knowledge of an area's fire regimes "presents some expectation for the nature of fire events that might occur in an area," observed Forest Service hydrologist Charles Luce.

Those expectations are becoming harder to match to reality because accelerating climate change and human activities—including fire suppression, road building, grazing, mining, and timber harvest—have altered the patterns and processes of fire compared to our recent past.

In some areas, fires that once burned often but relatively "cool" now burn infrequently but intensely hot. In others, fires are now more numerous where they once were scarce, or they are absent altogether where they once played a key role. Such uncharacteristic fires, combined with other land use changes, can result in altered types and patterns of vegetation, affecting the ability of systems and species to respond to fire.

"Aquatic systems that have already been fragmented, isolated, and otherwise disrupted may be more vulnerable to the effects of fire and disturbance than in the past," noted Luce.

Wildland fire management challenges

Wildland fire use ***(http://www.fs.fed.us/fire/fireuse/index.html)*** *is the management of naturally ignited wildland fires (for example, lightning strikes) to accomplish specific predetermined resource management objectives. Although most wildland fires are suppressed to meet resource and social goals, their careful use can approximate the historical role of fire and enhance long-term resource and social values. To safely reintroduce naturally ignited fires to the ecosystem, wildland fire use is limited to geographic areas specifically identified in the forest's fire management plan. The Forest Service continues to suppress man-made wildland fires and naturally ignited fires if they are not in areas covered in the fire management plan.*

Wildland fire management combines elements of prevention, suppression, and use. Decisions about fire management go hand-in-hand with resource management decisions and are based on approved fire management and land and resource management plans. At the same time, these plans provide land managers the necessary flexibility to choose from the full spectrum of fire management actions ranging from prompt suppression to use of wildland fire.

Management challenges with respect to fire and aquatic ecosystems have become increasingly complex and controversial as fire's relationship to forest and ecosystem health has come into sharper focus.

Some managers, for example, advocate aggressive fuels and fire management to help prevent uncharacteristic fires and their effects, especially in aquatic ecosystems (summarized in Bisson et al. 2003), and to help restore natural vegetation patterns and fire regimes to be more consistent with former conditions (Hessburg and Agee 2003).

Others believe that active forest restoration and fuels management goals can be in conflict with goals to restore degraded aquatic habitats, because management activities—such as road building—can also directly affect watershed processes, potentially posing a greater threat to aquatic ecosystems than the fires themselves (Rieman et al. 2000).

These management issues must be considered many times over—before, during, and immediately after a fire, and continuing over time in the form of rehabilitation, restoration, and long-term management activities. The issues on both sides of the debate are shaped by society's goals for future forests and by the relative risks, benefits, and costs of both action and inaction. Some questions that frame management decisions might include: Are human life, drinking water, property, or recreational or cultural resources at stake? Is the short-term persistence of a threatened or endangered population at risk? Are systems already degraded or threatened by fragmentation, invasive species, or the effects of prior management activity?

The issues may be framed as a "balance of harm." For example, some people see short-term "harms" as insignificant and acceptable to achieve long-term benefits, while others are not willing to accept short-term effects in exchange for unknown potential long-term payback.

In 2003, the Aspen Fire burned 85,000 acres in the Coronado National Forest—a prime recreational-use forest—in Tucson, AZ. Forest Service personnel applied emergency treatments to more than 10,000 acres of land, 6 miles of roads, and 7 miles of stream channels to reduce damage and stabilize slopes. Monitoring treatment effectiveness is part of the BAER plan (Aspen BAER 2003).

Before the fire: planning, fuels management, and aquatic restoration

"We don't wait for a fire and then react," stated Forest Service Watershed Improvement Program Manager Meredith Webster. "Response to a wildfire is determined by the forest plan and fire management plan. These plans are put in place long before any fire begins."

Forest plans and fire management plans take into consideration the desired future conditions of the landscape; the current conditions of terrestrial and aquatic ecosystems in an area; and the ecological, economic, and social values that might be at risk from uncharacteristic fires. The process involves not only scientists and managers but the public.

"Our reaction to fire is well thought out in advance, through a public process, and considers many different perspectives," explained Webster.

Local forest and fire management plans also fit into broader national-level plans, including the multi-agency National Fire Plan (NFP), developed in 2000. The NFP has five key points, one of which is active reduction of hazardous fuels—such as accumulated dry brush and trees—to prevent or reduce the risk of future catastrophic fires, considering local social, economic, and environmental factors.

By creating patterns that are more consistent with natural fire regimes, prefire vegetation and aquatic restoration activities aim to alter habitat and landscape structure to create forest and aquatic ecosystems that will be more resilient when fire does happen. For example, forest managers may use prescribed fire and thinning to restructure riparian and upland forests; make physical improvements to stream channels to reconnect them with their floodplains; or remove road culverts and other obstacles that interfere with fish migration. Such activities could be particularly important in watersheds where there is high potential for a large fire and local populations of sensitive aquatic species are isolated, very small, or otherwise vulnerable to disturbance.

National Fire Plan: key points

- *Assuring necessary firefighting resources and personnel.*
- *Conducting post fire stabilization and rehabilitation activities.*
- *Reducing risk of catastrophic fire by removal of hazardous fuels.*
- *Assisting States and communities threatened by wildland fire.*
- *Committing to a Wildland Fire Leadership Council.*

—http://www.fireplan.gov

Biscuit Fire: management dilemmas

Over 2 months in 2002, the Biscuit Fire on the California/Oregon border burned nearly a half million acres, much of which was being managed to provide habitat for species that live in complex, mature, conifer forests ***(http://www.biscuitfire.com)****. The fire burned in a "mosaic" pattern: 20 percent burned lightly, killing little vegetation, and 50 percent burned very hot, killing most of the vegetation. The area included habitats for 300 wildlife species, including the threatened northern spotted owl, as well as 460 miles of streams and rivers that contain salmon, including the federally listed coho. Management choices are complex: Will postfire action in favor of mitigating future fires and salvaging some timber conflict with goals to restore stream conditions? Will watershed restoration activities protect and enhance salmon populations? What will happen if managers simply "let nature take its course"? Society and managers must wrestle with the consequences of both action and inaction (Sessions et al. 2004).*

Responses during fire

Beginning in the 1930s, response to fire in the United States primarily focused on suppression. Although fire suppression is no longer the automatic reaction, control or suppression are frequently used, with the level of response dependent on the characteristics of the fire, landscape, resources affected, and management objectives for the watershed.

"Because suppression can perpetuate the fuel problem, wildland fire itself is increasingly being used to meet management objectives to restore historical vegetation patterns," Forest Service hydrologist Charlie Luce pointed out. "However, fairly strict conditions must be met to allow such wildland fire use, and preplanning is important to know when and where to step up suppression efforts."

An increased understanding of the choices available to make watersheds more resilient to wildfires is also increasing available choices relative to wildfire use. Watershed values are still one of the primary constraints on allowing wildfire use. Substantial reductions in suppression costs could be realized if there were a wider recognition of the capacity of aquatic ecosystems to recover from wildfire.

The suppression response itself may have negative implications for aquatic ecosystems. Some fire retardants may contain compounds that are toxic to aquatic species, and air tankers can be only so precise. "Burnouts" used to reinforce fire lines burn slowly and deeply, often resulting in severe soil burning. Firelines constructed with bulldozers have potential erosion effects until they are rehabilitated after the fire.

Emergency stabilization and rehabilitation

Response after a fire is divided into two steps. First the burned area is stabilized to prevent further damage. The first step is called emergency stabilization. It is followed by the rehabilitation of damage caused by the fire.

Burned Area Emergency Response (BAER) teams develop emergency stabilization plans to protect people, property, and natural resources. These interagency teams of hydrologists, soil scientists, engineers, biologists, vegetation specialists, and archaeologists often begin their assessments and treatments before the wildfire has been fully contained. Treatments may include early warning systems to protect downstream residents from floods, hillslope or road stabilization to protect municipal water supplies from contamination by ash and sediment, and protection of habitat for threatened and endangered species from additional damage.

"Treatments are tailored to the unique characteristics of each fire and the area weather, landscape conditions, and values at risk. Severely burned areas and steep, fragile slopes above homes, road crossings, or drinking water supplies are of particular concern," Webster explained.

Following emergency stabilization, rehabilitation projects, such as invasive plant control, seeding, and planting, may be undertaken on those lands otherwise unlikely to recover to the desired condition described in the forest plan. Other types of rehabilitation projects include watershed improvements, trail reconstruction, roadwork, riparian enhancement, fencing, and boundary line location.

Some managers feel that better information is needed to evaluate the effectiveness and long-term effects of emergency stabilization and rehabilitation treatments. Monitoring and research activities are ongoing throughout the Western United States to evaluate the effectiveness of many of these treatments. This research and increased monitoring are providing the information needed to determine the most effective treatment application methods, as well as where and when postfire treatments might be most beneficial (Robichaud et al. 2000).

The effects of both emergency stabilization and rehabilitation activities are dependent on the site, treatment methods and operations, fire severity, and weather during the postfire recovery years. Monitoring and adaptive management are needed to measure effects and adjust the treatment to reduce the inherent uncertainty and risk in restoration treatments and natural recovery.

Removal of dead trees following a wildland fire.

Postfire logging

Postfire logging to recoup the economic value of fire-killed trees has been a common practice for the past 40 years (McIver and Starr 2001). It is sometimes a controversial practice, to be sure, and has stimulated vigorous public debate, especially when it occurs in sensitive locations, such as riparian areas.

"Clearly, postfire logging can provide economic support to local communities, and at least some people believe the practice may have ecological benefits as well," noted Jim McIver, Forest Service research ecologist. "For example, postfire logging may reduce fuel loads enough to diminish future reburn intensity should another wildfire visit the same forest."

Opponents of postfire logging argue that the practice can further damage sensitive sites and may actually make fire effects worse. Erosion can increase; logging operations can hamper natural vegetative recovery; and the large wood (living and dead) that provides ecological benefits for soils, wildlife, and future fish habitats is removed (McIver and Starr 2001). In some opinions, postfire logging can actually delay or prevent recovery (Karr et al. 2004).

The conflicting views of the benefits and problems associated with postfire logging for both aquatic and terrestrial ecosystems highlight the strong need for additional research on this topic.

Stewardship contracting—a creative approach

http://www.fs.fed.us.forestmangement/projects/stewardship/index.shtml

This new authority provides the Forest Service and Bureau of Land Management with a one-step approach to multiple ecosystem services. Stewardship contracting is an active public/private partnership tool to improve forest health while meeting local and rural community goals. Many stewardship contracting projects involve hazardous fuel reduction. Key features include:

- *Allowing a contract period of up to 10 years, contributing to the development of sustainable rural communities and providing a continuing source of local income and employment.*
- *Trading goods for services. In exchange for services such as thinning trees and brush and hauling dead wood, private companies, communities, and others may retain those forest and rangeland products.*
- *Accelerating watershed restoration and enhancement efforts by using excess receipts for important work on the ground.*

A more integrated approach

Long-term restoration of patterns and processes is an important ecosystem management goal before or following fires and other disturbances in both aquatic and terrestrial ecosystems. Traditional restoration actions often focus on site-specific projects to restore vegetation, stream channels, and fuel patterns in certain areas.

But ecosystem management encompasses larger goals and may entail an entirely different approach that reflects the strong interaction and dependency between terrestrial and aquatic ecosystems, incorporating built-in cycles of disturbance and recovery (Reeves et al. 1995).

Examples of fire management choices before, during, and after a fire

All of these are appropriate decisions depending on the situation and consistency with the forest plan. Some variables affecting the decision include effects of the fire, desired condition, and competing resources.

Before a fire	Restore terrestrial ecological processes to mimic natural fire regime using prescribed fire and mechanical thinning.
	Modify terrestrial landscape structure to reduce fire spread and intensity.
	Remove barriers to aquatic organism passage.
	Restore aquatic habitat condition.
	Accept the increased risk of catastrophic fire that has developed.
During the fire	Use the wildfire for management goals.
	Suppress the fire.
After the fire	Let nature take its course.
	Stabilize conditions to protect human life, property, and natural resources.
	Apply rehabilitation treatments to repair or improve lands unlikely to recover to a desired condition.
	Capture economic values of dead trees to fund postfire activities and to reduce fuel loading at that site.
Monitoring	Monitor postfire emergency stabilization, rehabilitation, and restoration to determine treatment effectiveness and long-term effects.

Source: Adapted from Dunham et al. 2004 and other sources.

This more holistic and integrated approach acknowledges that substantial disturbances associated with large fires, storms, or other causes (such as the volcanic eruption of Mt. St. Helens) will occur whether we manage fuels or not. This becomes especially apparent with the realization that climate change may cause more extreme conditions conducive to fire (Whitlock et al. 2004).

"Fuels management alone treats only the symptoms of what threatens these ecosystems, it won't cure it," stated Forest Service fish biologist Bruce Rieman. "What we need for the long term is to increase the resiliency of aquatic systems to the disturbances they encounter."

The goal is to restore not just a fixed snapshot of a habitat condition but also the physical and biological processes and patterns that create and maintain habitats and populations of species we hope to conserve.

"Context matters in managing landscapes for forests and fish," Rieman added. "We need to understand that both landscapes and aquatic systems are dynamic and strongly interconnected."

To act or not to act

Even with the best intentions, risks associated with scientific uncertainties are inherent in management choices. For example, removal of trees during postfire logging may have implications for changing patterns of snow accumulation and snow melt that are yet to be explored.

Climate change specialists caution that vegetation manipulation to restore past conditions may actually collide with future conditions that are perhaps unimagined at the moment and certainly not under management control (Whitlock et al. 2004). "These interactions have the potential to produce unexpected and undesirable consequences," they noted.

Such considerations contribute to the notion that a hands-off approach might be appropriate in certain situations.

"In some cases, maybe the best thing we can do for watershed restoration is to stay out of the way," explained Rieman. "Some watersheds and disturbances don't need rehabilitation or restoration. A strict focus on mitigating fuels conditions might actually harm the very sensitive species it is intended to protect."

"Now that we no longer stamp out all the low-intensity fires, we can let the fire do some of the heavy lifting," suggested McIver. "This may reduce the cost of managing our landscapes and reduce the future risk."

However, stepping aside and letting fire and watershed disturbances play out depends on understanding and accepting all possible outcomes—and whether we choose to act or not to act, there will be consequences, noted Forest Service natural resource specialist Richard Cook. "Whether those consequences are considered to be positive or negative often depends on personal values."

"The issue is not whether to do something or nothing," Rieman concluded, "but rather to weigh the risks associated with our actions as objectively as possible."

Policy and research needs

The formulation of forest plans that address today's debates, concerns, uncertainties, and inherent risks has become even more difficult because "forest conditions and management goals have fundamentally changed, both in terms of fire and in terms of ecology," noted Rieman. "Given the uncertainties and new priorities, how do you move forward?"

Future fire management policy is likely to address, in a more integrated way and over longer timeframes, the relationship between fire and diverse objectives for watersheds, threatened and endangered species, and other resources in both terrestrial and aquatic ecosystems. National and local forest policies, fire plans, and aquatic conservation restoration strategies will be called upon to place fire and our response to it increasingly into the context of the ecosystems, species, and conditions at hand.

Although some management decisions will, by necessity, be made with incomplete information, research can help land managers make informed decisions. Key areas for further research include:

- Effects of climate change on fire regimes and vegetation.
- Fire frequencies and the role of fire in watershed and aquatic ecological processes.
- The risks that aquatic communities and sensitive populations face from fire and fire-related management.
- Effects of postfire logging and how it influences aquatic ecosystems.
- Critical areas for aquatic conservation and effective methods for restoration.
- The restoration of ecological processes that are critical to creating and maintaining productive and resilient aquatic and terrestrial ecosystems.

Summary

Effectively addressing the effect of fire on aquatic ecosystems will hinge on broad recognition of the inherent links that connect fire, forests, watersheds, and the organisms they support. Although the nature and complexity of fire in watersheds and aquatic ecosystems will continue to stimulate healthy and heated scientific and social debate, fire management choices will ultimately be driven by both ecological and social goals and values. Those choices will be best served when made with an understanding and appreciation of the dynamic relationships among the classic elements of earth, water, and fire.

Key Issues

- Fire plays a critical role as a shaper of watersheds and landscapes. Aquatic and terrestrial ecosystems are dynamic and often adapted to fire but the resiliency of the ecosystems is affected by management decisions.
- Fire and water are not necessarily opposed to each other. Watersheds can respond in positive ways to fire and natural disturbance.
- Disturbance from fire is inescapable and often desirable. We can influence fire, both positively and negatively, but we can't stop it nor do we always want to.
- Fire patterns have changed, setting in motion a host of ecological changes.

Management Implications

- The most effective management will address whole landscapes, including aquatic and terrestrial ecosystems, over broad planning horizons to ensure resiliency and productivity and to restore important ecological patterns and processes.
- For aquatic ecosystems, active fire and fuels management might be most appropriate in watersheds where the threat of a catastrophic fire is high and local populations of sensitive species are isolated, small, or otherwise vulnerable to disturbance.
- Action and inaction have benefits and consequences both in the short term and long term.
- Research, monitoring, and adaptive management will be key to reducing uncertainties in management decisions.

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