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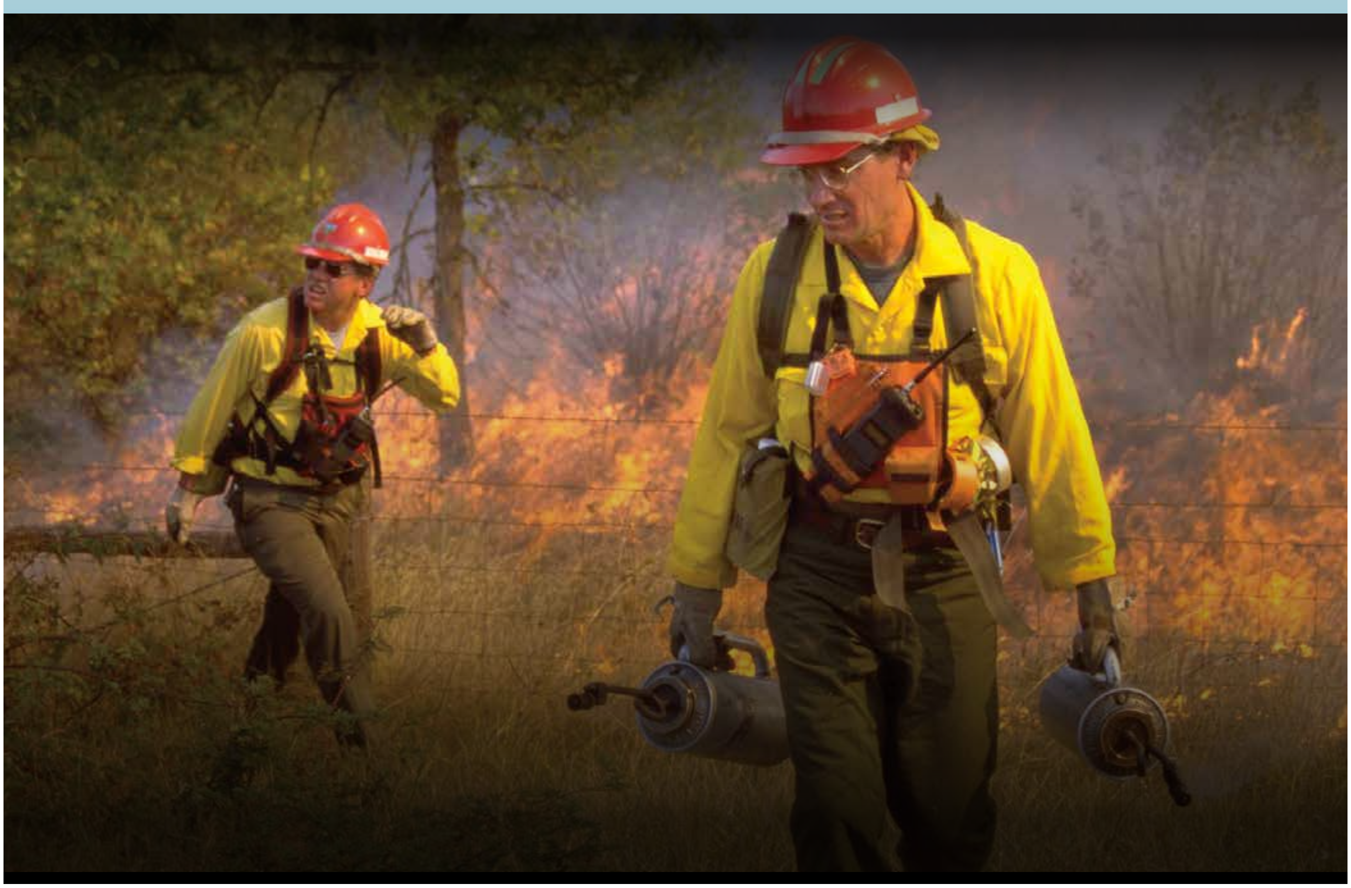
Fire, Fuels, and Streams: The Effects and Effectiveness of Riparian Treatments

Fire is an important disturbance in riparian systems—consuming vegetation; increasing light; creating snags and debris flows; altering habitat structure; and affecting stream conditions, erosion, and hydrology. For many years, land managers have worked to keep fire out of riparian systems through the use of buffers. A number of projects funded by the Joint Fire Science Program are shedding light on the dynamics of fire in riparian systems. Recent research and field practice have shown that (1) riparian treatments can be beneficial and are not as risky as previously thought; and (2) riparian treatments need the "Goldilocks" prescribed fire—not too hot and not too cold—to be beneficial.



Rethinking the "Hands-Off" Approach

Riparian systems encompass relatively small proportions of landscapes but are vitally important for a range of ecosystem services, including water quality and storage and habitat for aquatic and terrestrial wildlife and plants. In fact, many species listed under the Endangered Species Act rely on riparian areas. Due to the sensitivity of water resources and threatened and endangered species to land management actions, managers have often taken a hands-off approach in riparian systems.

"Active management was difficult to get through under the ESA [Endangered Species Act]," says Caty Clifton, regional water program manager for the U.S. Forest Service Pacific Northwest Region (and former forest hydrologist at the Umatilla National Forest). "The easy path was to just avoid these areas when planning treatments."

However, fire is an important disturbance in western riparian systems—snag falls, debris flows, and erosion (resulting from fire) create pools and provide habitat for fish and other aquatic organisms. Mosaic burn patterns create habitat for terrestrial species that thrive in the cooler, moist microclimates that can exist in riparian areas.

Yet, fire only plays a beneficial role in riparian systems when it is within its historical range of frequency and severity. When a high-severity fire sweeps through a landscape that is adapted to low-intensity surface fire, the effects on riparian areas can be dramatic. Research by David Pilliod, research ecologist with the U.S. Geological Survey, has shown that the loss of riparian vegetation can lead to higher water temperatures, increased erosion, and sedimentation that negatively affect aquatic insect and amphibian larvae in streams for several years after high-severity fire (JFSP Project No. 01-1-3-12). In some cases, it may take decades for the stream and associated riparian corridor to recover.

The importance of fire in western riparian systems has caused many land managers to rethink the hands-off approach and begin the task of reducing overstocked fuels in riparian areas, both from natural fuel accumulation and from the spread of invasive species, such as tamarisk (Dwire, Rhoades, and Young 2010). "We have recognized that some riparian areas could benefit from fuel treatments," says Clifton. "Due to suppression and the 'hands-off' approach, many of these areas are a few fire cycles behind."

Definitions of Riparian

The term "riparian areas" refers to areas adjacent to streams, rivers, and springs, with boundaries ranging out to the limits of flooding. In contrast to terrestrial upland areas, riparian areas include a unique set of hydrological processes as well as ecological characteristics in terms of plant succession and aquatic ecosystems.

A number of terms and definitions have been used to guide and regulate management in riparian areas, including streamside management zones, riparian buffers, and riparian management zones. These are usually delineated using features such as soil moisture or plant community composition. Some may even employ somewhat arbitrary boundaries, drawn using fixed distances from the stream channel.

In many national forests, management activities in riparian areas are guided by special standards and guidelines in the forest plan, which commonly sets best management practices (BMPs). BMPs are generally considered to have minimal impact on streams, riparian functions, and other ecosystem services. They generally are designed to protect riparian areas from the effects of timber harvesting, road construction, grazing, recreation, and other land uses. BMPs also typically set up some sort of riparian buffer. These can vary from a few feet from the stream channel to as much as 300 feet on each side of the waterway, depending on the size of the stream and management concerns. For example, streams that are used directly for domestic water supplies are typically granted larger buffers.

It is important to realize that riparian areas are not easily delineated, consisting of a wide range of plant communities, landforms, and microenvironments, each varying in size and distance from the stream channel. In addition, riparian areas typically possess transitional upland fringes, which serve as a transitional zone or edge between the riparian area and the surrounding uplands. These are important to consider when planning fuels management treatments because of the connections and feedback between the stream, riparian areas, and uplands.

Source: Dwire, Rhoades, and Young 2010

Across the West, managers are expanding the use of mechanical treatments and prescribed fire in riparian systems, and researchers and land managers alike are recognizing that: (1) riparian treatments can be beneficial and are not as risky as previously thought; and (2) riparian treatments need the "Goldilocks" prescribed fire—not too hot and not too cold—to be beneficial.

Recognizing the Benefits

Clifton says that research in collaboration with Steve Wondzell (JFSP Project No. 01-3-3-18) helped point the way to more active riparian management on the Umatilla National Forest. They conducted a series of measurements following prescribed burn experiments looking at impacts of erosion in riparian areas. The fires were started in the uplands and allowed into the riparian areas. They found no significant increases in erosion and sediment delivery associated with the burns. "One of the biggest concerns was the effect of erosion resulting from prescribed fire, and our work showed that we could allow fire into riparian areas under low severity and not have significant negative effects," Clifton says.

… the long-term risks of not taking any action are even greater than potential short-term negatives of treating riparian systems.

Caty Clifton

Example of a sediment fence used to measure postburn hillslope erosion.

According to Clifton, the Umatilla National Forest started with a few small fuel treatment projects to "get their toe in the water." Since then, they have expanded the scope of treatments as the resource specialists have grown more comfortable. "Once we started discussing objectives of treatments, it really helped us do a better job of interdisciplinary communication," says Clifton. "Aquatic, veg, and fire people each look at a landscape differently and see different functions, benefits, and risks from any treatment. There were lots of discussions of balancing risk of short-term negatives from treatments versus the much larger negatives of having high-severity fires sweep through these areas."

That is the crux of fuels management in riparian areas—balancing short-term effects versus long-term benefits. However, there is growing recognition that the long-term risks of not taking any action are even greater than potential short-term negatives of treating riparian systems. The rapidly changing climate and the associated increase in fire frequency, size, and severity that comes with a warmer and dryer climate could significantly increase the risk of fires that are devastating for riparian ecosystems (Luce et al. 2012). Riparian management is complex, and the tradeoffs and risks are not clear cut; however, research and field experience are starting to illuminate the path forward.

Testing the Effects of Fire and Fuels Treatments on Streams and Riparian Ecosystems

Compared to studies in uplands, relatively little research has been done on fire in riparian areas. However, a number of projects funded by the Joint Fire Science Program are beginning to shed light on the dynamics of fire in these critical areas. For one, we know that higher soil moistures, cooler temperatures, and greater productivity typically characterize riparian areas. In general, this means that under wetter conditions, fire intensities should drop in riparian areas and result in patchy, mosaic-type burns. However, under drier conditions, the larger amounts of fuels in riparian areas can generate higher burn intensities and even allow fires to "wick" up or down drainages and contribute to fire spread.

In the Klamath Mountains of southwestern Oregon, John Alexander with the Klamath Bird Observatory and Jennifer Smith with the Bureau of Land Management studied the ecological effects and effectiveness of fuels treatments (thinning, pile burning, and underburning) in reducing severity in riparian buffers (JFSP Project No. 05-2-1-19). They were specifically interested in three questions: (1) Does reducing fuel loads in riparian areas reduce the threat of wildfire across the landscape? (2) Do treatments compromise important riparian functions, measured in terms of changes in vegetation and hydrological indicators? (3) Is biodiversity impacted, positively or negatively, by fuels treatments?

… riparian area fuels treatments appeared to decrease the predicted intensity of wildfires …

The researchers compared outcomes in four paired watersheds over the course of 3 years. In each pair, one of the riparian areas was buffered, meaning only the uplands were treated. In the other paired basins, both the uplands and riparian areas were treated. Researchers examined the effects of treatments on fire behavior, hydrology, aquatic macroinvertebrates, birds, amphibians, and vegetation composition.

Using fire behavior modeling, researchers found that riparian area fuels treatments appeared to decrease the predicted intensity of wildfires moving through both riparian and upland areas. This reduction in intensity would likely translate into low burn severity and minimal impacts. The researchers further proposed that, following treatments, wildfires would be less likely to "wick" into uplands or be carried into the canopy.

Fuels treatments in the unbuffered riparian sites did result in a reduction of vegetation cover and richness, especially immediately after burning. However, cover and richness increased over time. Meanwhile, there was a continual decline in species richness in buffered areas, which the researchers attributed to increased competition for water in drought years.

Land Managers and Riparian Treatments

In 2010, a research team conducted an online survey with federal land managers (fire managers, hydrologists, fisheries biologists, wildlife biologists, ecologists, and cultural resource specialists) to gauge the scope of completed and proposed fuels treatments in riparian areas and wetlands on federally managed lands of the Interior West (JFSP Project No. 09-2-01-20). From the survey, the research team came to the following conclusions:

- Most riparian treatments were part of predominantly upland projects that focused on larger scale, fuel-reduction efforts across portions of managed landscapes.
- Prescribed fire was the primary tool for fuels treatments used by all agencies in riparian and wetland areas. It was clear, though, that most projects combined treatment methods; more than two-thirds of the completed projects used multiple treatments. Combinations of treatments, such as hand thinning and pile burning, were common and often supplemented with prescribed burning.
- The most significant constraint for all agencies was the potential presence of threatened, endangered, or sensitive species in the project area. While this is also a major concern for upland fuels projects, inclusion of aquatic and riparian obligate species increases the number of species of concern.
- Cultural resources were also an issue in planning fuels projects in riparian areas, particularly in the Great Basin region, where archaeological sites are concentrated along stream-riparian corridors.
- Approximately 19 percent of the respondents recorded potential litigation as a constraint to riparian fuels projects. Limited support from line officers was the least common constraint noted (3 percent of survey respondents).
- Budgets generally do not target vegetation treatments in riparian areas as a priority, so managers interested in treating riparian fuels include streamside area treatments as part of larger projects.
- Managers are concerned about riparian fuel loads and perceive them to be high along many streams in the Interior West.

Source: Meyer et al. 2012

David Pilliod

Pioneer Creek, part of the Frank Church-River of No Return Wilderness in Idaho, burned in 2000 during the Diamond Peak Fire.

David Pilliod

Cliff Creek, part of the Frank Church-River of No Return Wilderness in Idaho, burned in 2000 during the Diamond Peak Fire.

For all the other factors studied, researchers found minimal effect of fuels treatment in buffered and unbuffered riparian areas. Summer stream flow, water quality, and recruitment of large woody debris for habitat were not significantly affected by treatments in riparian areas. Similarly, macroinvertebrate communities were not affected by treatments. And, little difference was found in bird richness or nesting success in riparian sites.

Overall, the researchers concluded that riparian fuels treatments can support ecological functions on the landscape while also accomplishing fuel reduction objectives of decreasing the risk of high-severity wildfires. "Treatments in the riparian area led to more mixed-severity fire, as predicted by posttreatment fire behavior modeling," says Alexander. "In other words, the treatments were more effective when the riparian buffer was removed."

The Goldilocks Fire—Not Too Hot, Not Too Cold

While the finding that prescribed fire in riparian areas could be beneficial opened the door to expanded riparian treatments, another important lesson is that fire has to be the right type in order to gain the benefits (nitrogen availability, hazardous fuels reduction, and increased productivity), while not suffering the negative impacts (reduced canopy cover, increased stream temperatures, increased erosion, and changes in habitat structure) of a prescribed fire that burns too hot. In other words, prescribed fire that is too low in severity may not provide any benefits to riparian areas, while high-severity prescribed fire may result in detrimental effects.

David Pilliod (JFSP Project No. 01-1-3-12) led a team looking at the effect of prescribed fire on stream conditions. Pilliod and his team looked at the effects of low-severity prescribed fire in the spring versus low-severity wildfire. The team found that low-severity wildfire had lasting detrimental effects on stream conditions, including higher temperatures and increased sedimentation. Spring prescribed burns, which were conducted under cooler and wetter conditions, had very little effect, if any.

"We found that there was not really much impact on stream conditions [due to the spring prescribed fire]—macroinvertebrates, frogs, fish, and sediment pulses," says Pilliod. "Even low-severity wildfire had

Fire and Fish

Wildfire has direct effects on fish and aquatic ecosystems during and immediately after a fire has burned near or through a stream. Wildfire also has indirect effects on riparian ecosystems that subsequently influence hydrology, stream channels, fish populations, and other aquatic and terrestrial plants and wildlife.

Direct Effects

- If a severe fire burns near or across a stream, water temperature can increase substantially, leading to fish mortality.
- Fire can raise pH and toxicity levels in the water through dissolution of smoke, ash, and volatile compounds.
- Fire retardant used during suppression efforts has components that can be toxic to fish and other aquatic organisms.

Indirect Effects

- Peak flows and erosion can increase substantially after a fire and can persist in a watershed for years postfire.
- Loss of riparian vegetation and the shading it provides can result in higher water temperatures.
- Woody debris is important for creating habitat in streams, as well as trapping sediment. Fires can either result in more accumulation of wood or even a complete removal of wood from the vicinity of the stream depending on preexisting forest and fire severity.

Even in cases where fires cause extensive mortality (or even local extinction) of fish populations, studies show that rapid recolonization and population rebound is the norm. In fact, fires and subsequent debris flows can open up new habitat by removing migration barriers (e.g., impassable road culverts). Fish are most vulnerable to wildfire impacts when populations are restricted to isolated stream sections or small networks where a severe fire can potentially burn a large proportion of the headwaters and riparian ecosystem. Where populations are large and have access to diverse, well-connected habitat, vulnerability is reduced. Managers can support the conservation of native fish by building resilience via connection of remnant habitats through the removal of migration barriers and by reducing the risk of high-severity fire in riparian ecosystems.

Source: Luce et al. 2012

an effect on many of these indicators, but [the low-intensity] prescribed fire did not mimic the ecological effects of wildfire.” Pilliod says that if the goal of riparian treatments is to create a natural fire regime and reduce fuel loads, then fire should be introduced gradually, and riparian areas should be prepared to receive wildfire in ways that reduce severity or that produce mixed-severity burns.

Principal investigator Kathleen Kavanagh (JFSP Project No. 04-2-1-97) found that wildfires and prescribed fires have very different effects on nitrogen dynamics in riparian areas. Working in higher elevation headwater streams in central Idaho, Kavanagh was interested in how fires affect soil chemistry, specifically nitrate and ammonium levels in the soil, as well as the movement of nitrogen into the surrounding watershed. In many higher elevation ecosystems, plant growth is directly linked to nitrogen availability.

“Managers usually worry about sedimentation in streams postfire, but they need to consider the benefits of nutrients that result from fire, especially in upper elevation headwater systems,” says Kavanagh. “At lower elevations, nutrients are considered pollutants, but we are taking lower elevation thinking and applying it to upper elevation systems. In upper elevation forests in central Idaho, you will rarely find nitrogen in soil samples. It is in such high demand that it is quickly taken up as soon as it is released—like $100 bills dropped on the ground.”

Wildfires, especially high-intensity wildfires, can free up the nitrogen that is locked away in plants and allow it to permeate into stream waters. The result is that primary production increases, and nutrient spiraling through terrestrial and aquatic food webs increases.

Kavanagh was interested in finding out if land managers could use prescribed fires to stimulate stream productivity. What she and the team learned was that wildfires created much higher levels of nitrogen in the soil and vegetation of riparian forests than low-intensity spring prescribed burns. In fact, the smaller nitrogen pulses from prescribed burns were completely taken up by riparian vegetation and were not evident in the adjacent streams. Wildfires, by contrast, created nitrogen pulses that did reach the streams and persisted for several years. “If increasing stream productivity is the goal of a treatment, you might not get the same effect from a prescribed burn as a wildfire, unless the prescribed fire is intense enough to consume the overstory—ground or surface fires aren't likely to have an effect," says Kavanagh.

Confronting Invasives in the Southwest

While research in the Pacific Northwest and northern Rockies is showing that fuels treatments are much less risky than previously thought, the story in the Southwest is much different. In the Southwest, the story is complicated by the presence of threatened and endangered species and invasives that are completely transforming riparian systems.

> ***In the Southwest, the story is complicated by the presence of threatened and endangered species and invasives …***

Riparian cottonwoods and the ecosystem that depends on them have been in decline for over a century along the length of the Rio Grande in New Mexico. Farming, river-control projects, and urban development have dramatically decreased the water supply and disrupted annual flood cycles. These changes have driven transformations in the entire riparian forest and ecosystem. Deprived of the floods that spread their seeds, cottonwood trees cannot regenerate naturally. As older cottonwoods die, holes are left in the canopy, and invasives, such as tamarisk/salt cedar (*Tamarix ramosissima*) and Russian olive (*Elaeagnus angustifolia*), have moved in to fill them, crowding out the willows and other natives that historically made up the riparian understory.

Tamarisk is especially troublesome for riparian ecosystems. The higher soil salinity tolerance of tamarisk gives it a competitive advantage over native riparian plant species in some areas, and tamarisk also promotes higher fire frequency in plant communities that are generally fire intolerant. Fire kills the natives, and tamarisk further expands its hold on riparian systems. Introduced in the 1800s, tamarisk now occupies around 1.5 million acres of riparian habitat in the Western U.S., much of it in dense homogenous stands.

The Bosque del Apache National Wildlife Refuge straddles the Rio Grande south of the town of Socorro, New Mexico, on the edge of the Chihuahuan Desert. The refuge contains one of the healthiest, most extensive remaining bosques, or riparian cottonwood forests, left in the Southwest. This bosque provides critical habitat for many of the birds, mammals, insects, spiders,

Yasmeen Najmi

Bosque fuels reduction study sites in Bosque, New Mexico. Nonnative trees and excess dead and down wood were removed/treated in 2003. In March 2014, a fire burned through the site. The photo on the left was taken during mop up of the fire, and the photo on the right was taken about 3 months later. The fire burned lighter through native groundcover, where most of the trees survived. Since more than 10 years had passed since treatment, the mulch probably had a chance to significantly decompose. Therefore, the fire didn't burn as hot or long.

and crustaceans of the southwestern riparian ecosystem and an important link in the route for many migratory birds such as sandhill cranes.

The refuge has been working to restore and maintain the bosque for a couple of decades now and has learned some important lessons about using prescribed fire and other fuels treatments to remove and control invasives, while also supporting native plant communities. The refuge has worked to clear invasives from 4,000 acres and has restored natives on 3,000 acres. Part of the success has been the restoration of annual flood cycles using upstream releases of water from reservoirs north of the refuge.

"Our biggest advantage is that the river still acts like a river," says refuge ecologist Gina Dello Russo. "Flooding is the disturbance that drives bosque ecology—native plants are tied to the water cycles." Dello Russo says that fire has historically moved through riparian areas and that mature, healthy, native riparian forests can tolerate low-intensity fire reasonably well. However, she seldom sees low-intensity fire in the bosque now. It is important to limit fire as a tool to small patches of dense vegetation, as occurred historically, and to areas where restoration potential is highest. The refuge has worked to reintroduce fire on a limited basis—primarily using fire for pile burns for fuel reduction and in experimental invasive removal treatments.

Deborah Finch, biologist and team leader with the U.S. Forest Service Rocky Mountain Research Station, led a team of researchers and land managers to determine the best way to remove invasives, such as tamarisk and Russian olive, from the cottonwood understory, while not damaging cottonwood and other native plant and animal species in the Rio Grande bosque (JFSP Project No. 01-1-3-19). Finch and her team set up 12 experimental sites along the Rio Grande, ranging from urban sites in Albuquerque in the north to protected sites at Bosque del Apache in the south. The team compared three types of treatments: (1) mechanical removal of dead and down wood and exotic plants; (2) partial mechanical removal of dead and down wood and exotic plants followed by light prescribed fire; and (3) mechanical removal of dead and down wood and exotic plants followed by revegetation with native plants. The team monitored water quantity; soil salinity; habitat structure; plant reproductive response; and bird, bat, and herptile populations.

Deborah Finch

Untreated bosque (riparian cottonwood forest).

Albuquerque Open Space

Treated bosque (riparian cottonwood forest).

They found that fuels treatments reduced fuel loads and created more open space in the understory, which will reduce wildfire intensity and save native trees that are not well adapted to fire. Also, mechanical treatments created deep mulch, which reduced the ability of invasive plants to regrow; however, it also suppressed natives. When wildfires occurred on the treated sites, the team found that mulch can increase smoldering around large trees, such as cottonwoods, and increase mortality. Bird, mammal, amphibian, and reptile species that prefer more open habitat benefited from treatments. Species that rely on the dense habitat that characterized pretreatment conditions declined.

This is important since an endangered species, the southwestern willow flycatcher, nests in tamarisk. "The flycatcher evolved with natives, but it has adapted to live in these homogenous stands of invasives," says Finch. "We learned that in order to restore the native system, it is best to remove the salt cedar in patches to leave habitat for the birds as they transition back to habitat comprised of native species like coyote and Goodding's willow. It is a balancing act to remove invasives and not lose your endangered species."

A number of specific land management recommendations came out of the study. Land managers determined that it is best to establish a quarter-mile buffer around flycatcher nesting habitat and that it is best to use a staged approach—remove tamarisk and Russian olive and then replace them with natives. Restoration also worked best in places that allow controlled flooding, such as Bosque del Apache. "The seed bank for natives is there, but it is too dry without flooding," says Finch.

Cottonwood systems are very vulnerable to fire, but prescribed fire can still be used as a treatment tool if done carefully. Finch says that fire must never be taken all the way down to the main river or stream channel, as this can damage streambanks and increase nonpoint source pollution. Also, she recommends that debris be removed from around large trees to prevent damage from smoldering.

Yasmeen Najmi with the Middle Rio Grande Conservancy District says that a number of lessons came out of the project treatments on the urban sites of Albuquerque. For one, the district found the same problems with mulching that were discovered in Bosque del Apache. Now, the district generally only mulches small branches and gives the rest of the removed fuels away as firewood. They also leave dead and down wood and 3 to 6 snags per acre for habitat, as recommended by ecologists. Controlled flooding throughout much of the Middle Rio Grande bosque usually requires additional restoration that isn't always feasible; because of this, they focus on sites that are more suitable for removal of invasives/exotics and hazardous fuels reduction efforts, namely places with grass cover. This reduces weed regeneration and recolonization after treatment.

Najmi says that the treatments have been a success from a forest protection standpoint and in terms of improving public safety. "These riparian areas have been a significant fire risk for the past few decades. We have seen a number of large fires in the Albuquerque area that originated along the river," says Najmi. "But since the treatments, we've not had the high-intensity, catastrophic fires that have swept through in the past."

Yuma Clapper Rails Benefit from Prescribed Fire

The Yuma clapper rail (*Rallus longirostris yumanensis*) is a federally endangered species, and 90 percent of the U.S. population exists in only two wetlands along the lower Colorado River. The California black rail (*Laterallus jamaicensis coturniculus*) is another sensitive species of national management concern that lives in this region.

Historically, marsh habitats along the lower Colorado River were highly ephemeral with periodic flooding and natural fires that eliminated decadent stands of emergent vegetation. However, years of flood control and fire suppression resulted in substantial areas in which the dead stem densities crowded out live stems and decreased overall marsh productivity.

Conway, Nadeau, and Piest (JFSP Project No. 03-3-2-07) examined the effectiveness of prescribed fire as a possible management tool to restore habitat for these two species in Arizona and California. The numbers of both species increased significantly following fire in burned sites compared to control sites. Increases were apparent in the first year following fire for clapper rails and in the second year following fire for black rails. The research project led to the development of a set of field protocols for monitoring the effects of management actions on marsh birds.

Source: Conway, Nadeau, and Piest 2006

Building Resilience

As a driver of restoration and regeneration, fire is an important part of riparian ecosystems, and many species have learned to live with fire, evolving and adapting to cope with its effects. However, the ways in which fire operates on the landscape is changing—fire frequency, size, and severity are increasing in response to a general warming and drying trend across the Western United States. Fuel loading from natural accumulation and vegetation shifts from invasive species has also caused many ecosystems to transition out of natural fire regimes. The challenge for many land managers now is to combine their knowledge of fire and its effects on riparian ecosystems under normal conditions with an understanding of how land management can affect systems that are operating under the "new normal." The key is deciding the point at which benefits of human intervention in the natural disturbance cycle outweigh the risks of not taking any action.

The key is deciding the point at which benefits of human intervention in the natural disturbance cycle outweigh the risks of not taking any action.

There will always be tradeoffs in land management. Within riparian ecosystems, most treatment options, including no action, have important consequences for both the stream and the plant and animal communities associated with it (Luce et al. 2012). However, many forests are in need of treatment, but the resources to accomplish treatment are increasingly limited. Managers must prioritize and focus on the tradeoffs among the different goals that guide any decisions regarding management in riparian systems—maintaining threatened and endangered species, water quality and quantity, and other ecosystem services. While those decisions will always be complex, research is now beginning to illuminate the risks and payoffs of different alternatives.

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