Beyond the Flames

The Ripple Effects of Wildfire on Riparian Habitats

by Dr. Richy J. Harrod and Brian Clark

Among natural disturbances, wildland fires are one of the most difficult to understand. Wildfires result from complicated amalgamations of factors that make predicting severity and extent very challenging. They burn in just about every biome on earth, each with unique combinations of vegetation and seasonal variations in weather conditions.

Narrowing the impacts of wildfire on a particular natural resource is even more difficult. Much has been studied and written about wildfire impacts on vegetation, watersheds, and wildlife habitat, including in this magazine – check back to the Fall 2024 edition of *On The Fly Magazine* for an article about the recovery of grouse in a particular valley during the decades after a severe fire.

Far less has been written about the impact of wildland fires on riparian areas, but just as hunters are interested in how bird habitat recovers from fire, anglers are likewise keen to understand impacts to aquatic ecosystems, fish habitat, and fishes. This article attempts to address that gap.

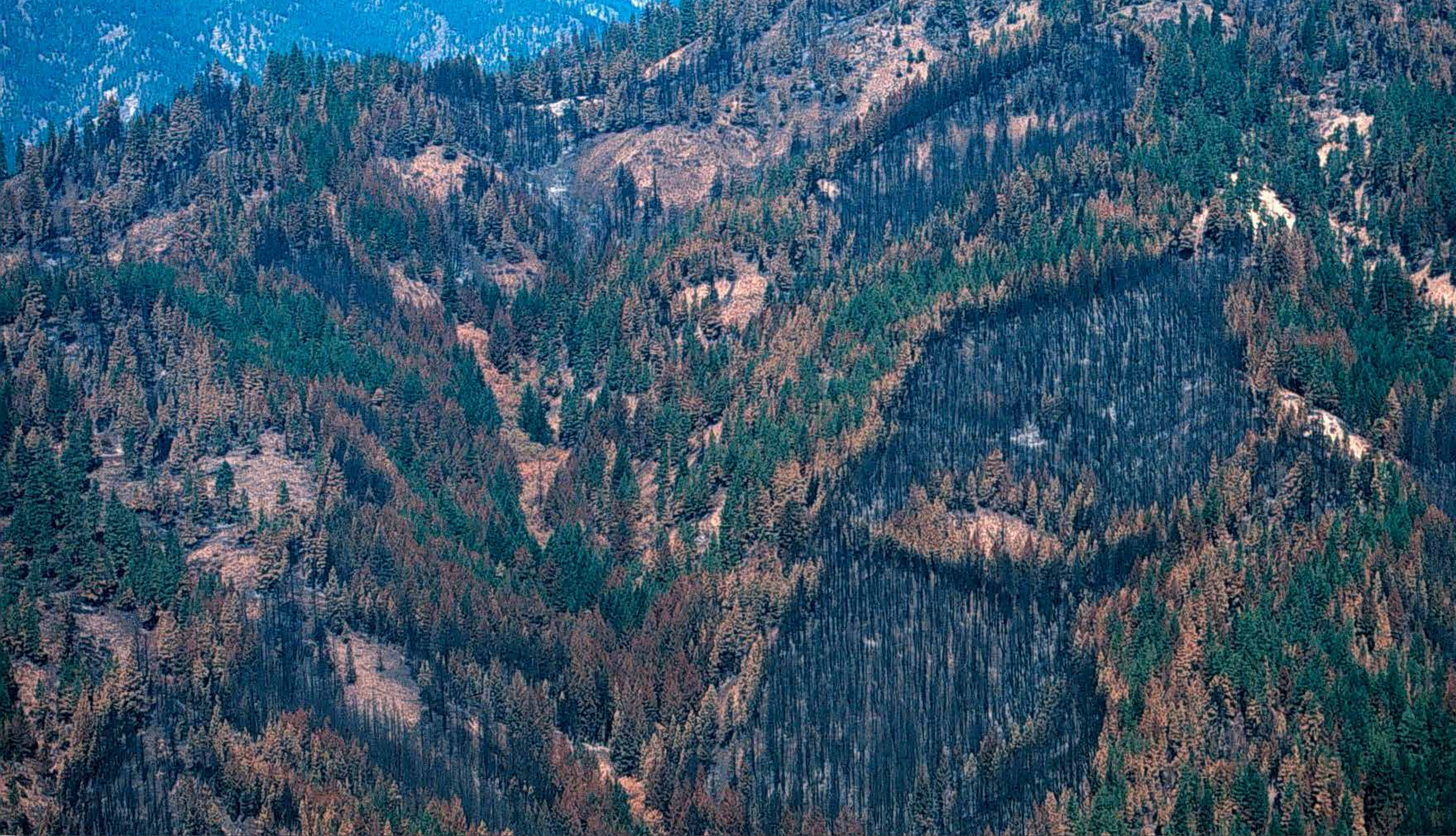
"Riparian" describes the transition areas between waterways and uplands. The Latin root of the word riparian literally means "riverbank". Vegetation along streams and rivers is distinct from the uplands and is important for the ecological health of aquatic ecosystems. Riparian vegetation helps prevent sedimentation, provides shade keeping water cool, and deposits nutrients into streams important for the entire spectrum of aquatic life. Riparian areas are dynamic, constantly changing due to episodic flooding and drought. Some post-fire conditions can create significant short- and long-term changes to stream and river dynamics.

Modern wildfires often burn whole watersheds, but it wasn't always this way. Historically, wildfires burned much more frequently in dry western forests than they do today, but individual fires tended to be much lower in terms of intensity, severity, and extent. Each fire brought about a reduction of surface fuels and overall forest density, which in turn limited the severity of following fires while maintaining a diverse range of species.

Effective fire exclusion over the past century has, unsurprisingly, resulted in greater forest density. Unfortunately, this policy has also triggered several unintended consequences. Not only do more trees growing in a given area mean a greater overall volume of wildland fuels with potential to burn, but increased density means that it's easier for fire to travel from one tree to the next, often across the canopy where winds have the greatest potential to spread a fire. In addition, the lack of regular small, low-intensity fires in dry forests has allowed surface fuels to accumulate and caused forest floors to become denser, often with fire intolerant species, creating ladder fuels which can move fire into the canopy. As a result, when wildland fires do get started, they can travel very quickly and burn with high intensity and travel very quickly. That dangerous combination can dramatically increase the size and severity of each individual wildfire, sometimes engulfing entire watersheds.

Left: *as yet unburned riparian zone of the Red River in Idaho during the 2022 Williams Creek Fire; photo by Terina Hill, courtesy of the Bureau of Land Management (BLM)*

Previous pages, title spread: *post-fire debris flow from the 2021 Dixie Fire in Northern California as of late August, 2024; photo courtesy of the Pacific Coastal and Marine Science Center*



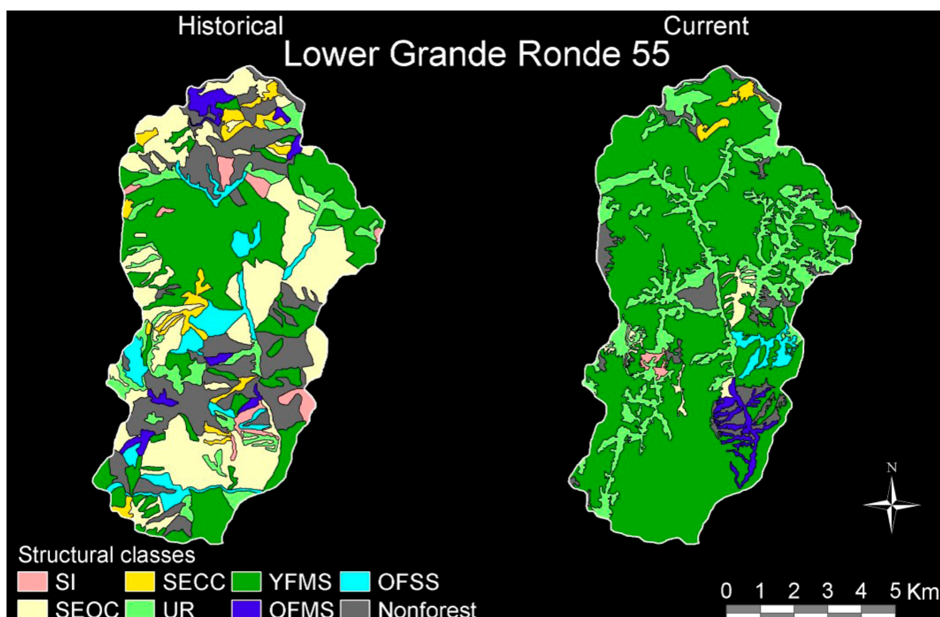
There's yet another undesirable by-product of increased forest density, one that's less obvious to the average outdoorsy layperson: homogeneity in terms of forest structure and fuels. Historically, landscapes of the interior West were naturally variable. This variability was due to changes in forest and rangeland community types over elevation (rangelands at the lowest elevations and dense cold forests at the highest elevations) and the interaction of these vegetation types with disturbances, such as fire. Frequent (every 10-20 years) fires in rangelands maintained grass-dominated vegetation and relatively open, pine-dominated dry forests. Riparian areas tended to exist as green belts in landscapes frequented by wildfires. Infrequent (every 80 or more years) fires at high elevations tended to kill all trees in large patches. Forests at mid-elevations were burned at variable intervals creating a patchwork of lightly, moderately, or severely burned forests. As watersheds traversed elevation changes, they reflected a diverse array of forest structure types from open forests, recently burned patches, and older recovering forests in patches of variable size.

Wildfires burning in historically diverse landscapes were self-limiting because they would often encounter recently burned patches or young forests (with little burnable fuel), both of which could stop a fire's spread. Because it stalled the self-diversifying process of natural forest succession, fire exclusion essentially erased the variability of forest structure across entire watersheds throughout the west. Forests have become more homogeneous, allowing fires to burn widely with no natural barriers as in the past. Even relatively wet riparian areas are no match for these severe fires.

***Above:** a mountainous region in central Washington with relatively sparse tree cover and diverse species which burned with mixed severity during the 1994 Rat Creek Fire; photo by Dr. Richy Harrod*

***Right:** a eroding downslope completely denuded by the 2017 Thomas Fire in Southern California; photo by Jason Kean, courtesy of the USGS*

***Below:** the Grande Ronde River meets the Snake River in eastern Washington; this map of the watershed contrasts historical forest structure types with current status, revealing a dramatic shift toward homogenization; used with permission from Paul Hessburg, PhD*



The more intense and severe a given wildfire, the longer the recovery time for its watersheds and stream corridors. There is a wide variation of post-fire vegetation succession depending on the vegetation type, time since the last fire, interaction with other disturbances (particularly insect and diseases), and impacts to soils.

Because wildfires burn many years apart, the impacts to watersheds, streams, and riparian areas are considered "pulse disturbances" where the effects are initially severe but dissipate with time. Fire is often the initial catalyst for a series of subsequent disturbances; although a wide variety of fire effects are described in scientific literature, here are the four variables most important for fish and fish habitat: sedimentation, water temperature, nutrient influxes, and large woody debris. We'll discuss each in turn, and it's important to note that not all impacts turn out to be negative in the long run. Over time, the cascade of impacts from fire can perform services for the ecosystem such as improving water quality, dissipating stream energy, and creating habitat features important for fish.

Sedimentation

Sediment is material broken down by processes of weathering and erosion from rocks, minerals, or organic matter from plants. It is subsequently transported by gravity or from the action of wind, water, or ice. Sedimentation is the ecological process where sediment is transported and deposited away from its source. As related to watersheds post-fire, sedimentation occurs both as vertical migrations from hillslopes to streams, and as linear movements downslope in those waterways.

In the immediate aftermath of a severe fire (one to three years post-fire), sedimentation (and related geomorphological changes like landslides and debris flows which also transport woody debris) is one of the most obvious and significant impacts to stream networks. This rapid erosion is a direct result of the sudden lack of established vegetation on the upslopes surrounding the waterways.

High concentrations of sediment suspended in stream water irritates the gills of fish and can cause death. Sediment can destroy the protective mucous covering the eyes and scales of fish, leading to infection and disease.

Pulses of heavy runoff after wildfires can lead to still more erosion and delivery of even greater volumes of sediment and ash to streams, an effect which stacks: each landslide or debris flow can trigger even more episodes of additional sedimentation. Even where riparian vegetation was not burned in the wildfire, as might be the case downstream from a burn area, flooding and debris torrents can still remove vegetation from stream banks, which leads to yet more erosion. This sedimentation cycle can have massive short-term impacts on stream morphology (the shape of river channels and changes in direction over time), water quality, fish habitat, and live fish.

Where the sediment goes and its impacts once it enters a stream depend on the stream gradient and channel confinement. High gradient streams have more confined stream banks because they are situated in narrow stream corridors with steep adjacent hillslopes. Here, surface soil erosion and debris flow from hillslopes enter streams following rapid snowmelt or downpours. Low gradient

Above: *accumulations of sediment in the Whiskey Creek section of Whiskeytown Lake resulting from erosion after the 2018 Carr Fire in northern California; photo by Amy East, courtesy of the Pacific Coastal and Marine Science Center*

Below: *another view of serious post-fire sedimentation, this one in a downstream area in Central Washington which wasn't directly affected by the 2012 Table Mountain but still suffered from erosion which occurred upstream; photo by Dr. Richy Harrod*

Right: *coarse woody debris brought down by wildfire; in this case, large white fir trees in a sequoia forest in Yosemite National Park in California; photo by Alex Demas, courtesy of the USGS*

streams with unconfined streambanks are dominated more by fluvial processes (sediment is deposited in flatter portions of the stream) which are less likely to impact stream morphology. Most streams have a combination of low-, mid-, and high-gradient sections corresponding to the distance from the headwaters (high-gradient) to the floodplain (low-gradient).

Sediment can have significant short-term impacts on fishes. It can fill the pore spaces between cobbles where fish lay their eggs or suffocate eggs already laid. Sediment can clog or wear away the surface of gills, especially on juvenile fish. Recovery of fishes and fish habitats will depend on the presence of unburned areas either upstream or downstream of the wildfire impact. When entire watersheds are severely burned, recovery times for fish can significantly increase – yet another reason why the intensity and severity of modern wildfires can be more problematic than the more heterogeneous fires of the past.

Water Temperature and Nutrients

Riparian vegetation performs many ecological functions in stream ecosystems, but its influence on water temperature and nutrient input are important to fish and fish habitat. The shifting habitat mosaic due to annual runoff naturally creates diverse vegetation communities, patches of recently disturbed vegetation, and older, more stable communities. Mature vegetation along streams or rivers and in the uplands provides shade, maintaining cool water temperatures for fish and other aquatic organisms.

Temperature can influence water's ability to hold dissolved oxygen (DO), the form of oxygen which allows fish and other aquatic organisms to breathe. The higher the water temperature, the lower the water's capacity for dissolved oxygen. Many fish species, including trout, can only tolerate a limited temperature range.

Wildfires often kill vegetation along streams and rivers, thereby increasing water temperatures in the short-term due to the lack of shade. Many deciduous shrubs, however, can re-sprout quickly and grow rapidly within a couple of years following fire. Severe fires that remove large conifers along streams and rivers will have diminished ability to provide shade for decades. The response of fish to increased water temperatures varies greatly depending on species and location, but in general, fish persist through the post-fire stream conditions. It helps that they're usually able to migrate to healthier water up or downstream.

Nutrient Inputs

The introduction of organic debris (leaves, pine needles, and woody detritus, mostly) into streams and rivers provides nutrient inputs important for aquatic species. Microbes break down organic material and nutrients important for plankton and algae, which are food for fish. Various insect species feed on decaying leaf, needles, or woody material, and these insects in turn also provide forage for fish.

Nutrients in streams and rivers dramatically increase immediately after wildfire. Nitrogen, phosphorous, and potassium increase up to 60-fold after fire, largely from ash and smoke. This influx of nutrients can lead to algae blooms which decrease light penetration. When these blooms die and decompose, the amount of dissolved action decreases, which can negatively impact fish. Fortunately for aquatic life, these impacts tend to be short-lived, and pre-fire levels usually return within weeks.

Coarse Woody Debris

Large woody debris is important in stream and river ecosystems as it influences hydraulics, sediment routing, and channel morphology. Wood dissipates the energy of flowing water, creating pools and eddies where fish can rest and feed, plus shade and hiding places. It has been shown that pools with in-stream wood are likely to provide quality rearing habitat for salmon. Wildfires can have significant impacts on large woody debris recruitment.

Wood in streams is recruited from dead standing trees in proximity to flowing water. Wildfires can create initial pulses of wood from post-fire debris flows or fire-killed trees falling into the stream. This excess wood will often form log jams with high water flows. These wood jams help dissipate stream energy, thereby reducing erosion by trapping sediment in pools – at least in the short-term. Eventually, coarse woody debris will move through the system with subsequent floods or high-water flows, and its departure can again impact stream morphology.

New wood recruitment is yet another area where severe fires do long-term damage to watersheds. If fires have killed all the trees in the riparian area and in the uplands of a given watershed, and the erosion and debris movements addressed above have pushed most of the coarse woody debris downslope and downstream, large wood may not be recruited into streams and rivers for many decades. Trees, especially conifers, grow slowly; stands of trees may remain alive for 80 or more years before realizing any mortality. This extended gap between a sudden incursion of fire-recruited wood and natural recruitment from recovered stands of trees may lead to degraded fish habitat. Deciduous shrubs and trees grow much more rapidly than conifers, and their inputs into the streams and rivers are important, but they lack the large diameter wood important for altering stream flows.

Wildfires that only burn portions of watersheds or burn with low to mixed severity may be beneficial to providing wood to stream ecosystems. Post-fire tree mortality can be delayed in the years following wildfire, thereby leading to continuous coarse woody debris recruitment.

Disturbances, particularly wildfire, have been and will continue to be important natural ecological processes for aquatic ecosystems. The variation in post-fire effects to streams and rivers is large, difficult to generalize, and further complicated by the significant influences of a century of attempting to exclude fire from the landscape. Stream and river ecosystems are inextricably linked with the terrestrial uplands where the impacts of fire exclusion are most prominent.

Fishing's Fiery Future

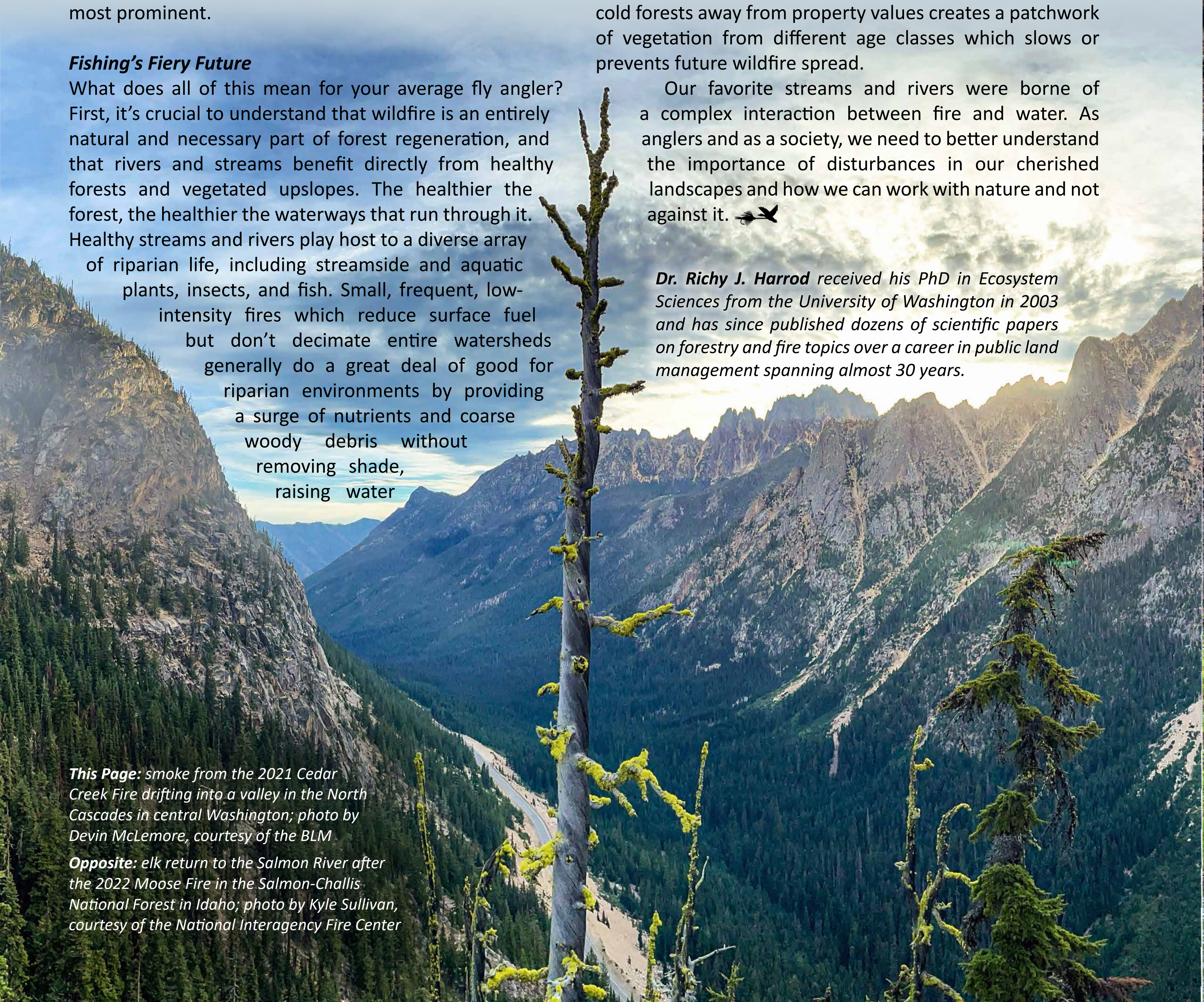
What does all of this mean for your average fly angler? First, it's crucial to understand that wildfire is an entirely natural and necessary part of forest regeneration, and that rivers and streams benefit directly from healthy forests and vegetated upslopes. The healthier the forest, the healthier the waterways that run through it. Healthy streams and rivers play host to a diverse array of riparian life, including streamside and aquatic plants, insects, and fish. Small, frequent, low-intensity fires which reduce surface fuel but don't decimate entire watersheds generally do a great deal of good for riparian environments by providing a surge of nutrients and coarse woody debris without removing shade, raising water temperatures for an extended period, or triggering massive sediment movements which can directly kill or negatively impact fish.

In sharp contrast, large, severe, high-intensity wildfires which lay waste to an entire watershed greatly impact fish and fish habitat. Erosion and sedimentation are among the most obvious immediate impacts, but the removal of shade and loss of coarse woody debris may degrade fish habitat for decades.

Not all is gloom and doom, however. Forest managers can proactively mitigate the impacts of severe wildfires. The key is to design thinning and burning treatments that return variability in forest structure so that watersheds can once again absorb the impacts of wildfires. That means doing work over large areas specific to forest type. For example, thinning and burning treatments that promote widely spaced fire-tolerant pines in dry forests will help promote low-intensity wildfires in the future. Under the right conditions, allowing some fires to naturally burn in the cold forests away from property values creates a patchwork of vegetation from different age classes which slows or prevents future wildfire spread.

Our favorite streams and rivers were borne of a complex interaction between fire and water. As anglers and as a society, we need to better understand the importance of disturbances in our cherished landscapes and how we can work with nature and not against it.

__Dr. Richy J. Harrod__ received his PhD in Ecosystem Sciences from the University of Washington in 2003 and has since published dozens of scientific papers on forestry and fire topics over a career in public land management spanning almost 30 years.



***This Page:** smoke from the 2021 Cedar Creek Fire drifting into a valley in the North Cascades in central Washington; photo by Devin McLemore, courtesy of the BLM*

***Opposite:** elk return to the Salmon River after the 2022 Moose Fire in the Salmon-Challis National Forest in Idaho; photo by Kyle Sullivan, courtesy of the National Interagency Fire Center*