18 Effects of Fire on Fish and Wildlife

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Executive Summary

Fire has the potential to accentuate impacts to fish and wildlife associated with timber harvesting, roadbuilding, and other forest management practices. For fish, the primary concerns relative to fire are increases in water temperature and sediment and the long-term loss of woody debris from stream channels. The most long-lasting and severe effects on fish habitat from fire—whether prescribed or wild—occur when it is associated with the loss of the streamside forest.

The major impacts of fire on wildlife center on its influence on vegetation structure and composition, down and dead woody material, and snags. In particular, the loss of down and dead woody material and snags during a prescribed burn removes essential structural habitat components for a variety of wildlife and reduces species diversity.

Use of cool burns in spring when the ground is moist, providing an unburned buffer along stream channels, maintaining integrity of the soil surface, and leaving and protecting snags during burning, should help prevent or limit undesirable impacts to fish and wildlife. Staggering prescribed fires over time, and spacing of burns across the landscape will minimize impacts on small wildlife that occupy areas of prescribed burn size or smaller. For larger wildlife species, such placement could maximize potential benefits by providing a relatively continuous (through space and time) distribution of forage areas. Of concern are the effects of burning in or near headwater channels which facilitate the transport of sediment and logging slash downslope into fish-bearing streams when stream networks expand during periods of high runoff. More detailed monitoring studies are needed to fully evaluate the effectiveness of burning prescriptions to limit impacts to fish and wildlife.

Introduction

Consideration of potential impacts to fish and wildlife from prescribed fire is an important factor in decisions of when and how to burn. Forests of the Pacific Northwest are home to 66 freshwater fish and 460 wildlife species (Brown and Curtis 1985, Everest et al. 1985), a number of which have considerable commercial and recreational value. Legislation and public opinion over the past 20 years also have increasingly recognized the "nonconsumptive" or amenity values of fish and wildlife as integral components of Pacific Northwest forest ecosystems.

Fire can directly affect fish and wildlife populations by causing mortality or avoidance of an area during and after burning (Chandler et al. 1983). Of greater importance, though, are the long-term consequences of fire on fish and wildlife habitats. Fire may impact the abundance and diversity of fish habitat and populations in streams by affecting the composition and structure of riparian vegetation and influencing water quality and quantity in a stream. For wildlife, important habitat alterations from fire include changes in the structure and composition of forest vegetation in the understory and overstory, and microclimate within and adjacent to burned areas (Bendell 1974, Martin and Dell 1978). These habitat changes in turn determine wildlife species composition and abundance (Chapter 6).

Despite a large number of studies conducted throughout the Pacific Northwest on the potential impacts to fish and wildlife habitats associated with timber harvesting and reforestation (e.g., Salo and Cundy 1987, Raedeke 1988), relatively little information is available on the direct and indirect effects of fire. As discussed in previous chapters, the effects of prescribed burning on fish and wildlife are often difficult to identify, since it typically precedes or follows other forest management practices and is subject to site-specific variation (Lyon et al. 1978).

As a result, a combination of approaches was used to assess the impacts of prescribed fire on fish and wildlife. In addition to synthesizing what is known, potential impacts were inferred by linking data on the effects of fire on particular watershed functions or characteristics as summarized in previous chapters[1] with information from other, non-fire-related studies that showed relationships between these particular watershed or vegetative processes and fish and wildlife populations or communities (e.g., effects of sedimentation on fish; effects of stand composition on wildlife abundance and diversity). Since use of prescribed fire has changed over the past 10 years, resource managers in the region were also consulted to document the observations of practicing professionals and to describe and evaluate practices currently used to minimize undesirable impacts. Where possible, responses of fish and wildlife to prescribed fire were compared to those from wildfires.

Fish and wildlife exist in significantly different environments, so their responses to prescribed fire will be treated separately. Mortality directly resulting from fire, habitat relationships as they are affected by burning, resultant fish and wildlife responses, management implications and ways to minimize undesirable impacts, and research needed to fill information voids will be addressed in this chapter.

Effects of Fire on Fish

In the forested regions of the Pacific Northwest, the term "fish" is generally equated with salmon and trout (salmonids). Twelve native and four nonnative salmonid species occur throughout the region, many of which support highly prized sport and commercial fisheries (Everest et al. 1985). In this section, we will focus on the effects of fire on this group of fishes. Although differing in their habitat preferences and residence time in freshwater, salmonids share a number of common requirements: cool, flowing waters; clean gravel substrate for reproduction; invertebrates for food; low turbidity (necessary for sight feeding); instream cover; and, if anadromous, free migratory access to and from the sea (Reiser and Bjornn 1979, McMahon 1983, Everest et al. 1985).

Fire can modify the quantity, quality, and use of salmonid habitat by altering water temperatures, sedimentation rates, riparian vegetation, nutrient availability and food resources, and woody debris in forest streams. The potential of fire to harm production of salmonids is perhaps greatest for those species (e.g., coho and chinook salmon; cutthroat and steelhead trout) that spawn or rear in small-to-medium-size streams draining forested lands. Because of the narrow valley floors, steep hillslopes, and abundant rainfall common to this region, the terrestrial and aquatic components of these watersheds are closely linked. Hence, riparian zones and fish populations are strongly influenced by fire and associated forest management activities occurring upslope as well as along the stream (Swanson et al., in press).

Temperature

Temperature is a major factor affecting fish survival, distribution, production, and community composition in forest streams of the Pacific Northwest (Beschta et al. 1987). One of the most direct effects of fire along streams is the potential to elevate water temperatures above upper thermal tolerance limits of salmonids during burning. Yet, only two studies have measured water temperatures during prescribed burns or wildfires, and only one

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[1] For example, effects of fire on accelerated hillslope erosion and sedimentation in streams—Chapters 14 and 17; effects of fire on forest succession and wildlife forage—Chapters 4 and 7.

study has monitored fish mortality (Hall and Lantz 1969). Feller (1981) noted an immediate rise in temperature from 55° to 61°F within 6 hours after slash burning along a small stream in southwest British Columbia; temperatures returned to near prefire levels 13 hours later. During a hot slash burn in the Needle Branch watershed, Oregon, temperatures in the upper reaches of this small stream rose rapidly from 55° to 82°F, causing high mortalities of juvenile coho salmon, cutthroat trout, and sculpins (Hall and Lantz 1969). By contrast, in the lower, less constrained portion of the watershed, the fire was less intense, and no fish mortality was observed. In the nearby patch-cut Deer Creek watershed, where the slash burn was separated from the stream by a buffer strip of vegetation, there was no increase in temperature during burning.

As noted in Chapter 17, the large increases in stream temperature associated with streamside timber harvest are further accentuated when followed by additional removal of streambank vegetation by slash burning (Levno and Rothacher 1969, Feller 1981, Holtby and Newcombe 1982). Depending on location, aspect, and stream size, temperature increases may persist for a few years to several decades until shading returns to prelogging levels (Fig. 17-2; Moring 1975, Andrus and Froehlich 1988).

Though water temperatures are rarely elevated sufficiently by fire to cause direct mortality, significant indirect and longer lasting effects on fish populations may occur (Beschta et al. 1987). Numerous studies have documented increased summer production of salmonids following streamside logging and slash burning from the combination of increased light and higher temperatures (leading to higher primary and secondary production) (Beschta et al. 1987, Gregory et al. 1987). However, the small (1.8°-3.6°F) attendant increases in winter and spring temperatures which also occur (Feller 1981, Holtby and Newcombe 1982) may largely offset any positive effects of elevated summer temperatures by altering the timing of critical life history events such as emergence of fry from spawning beds and smolt migration (Ringler and Hall 1975, Holtby 1988a). Persistent, sublethal temperature increases following logging and slash burning may also result in shifts in fish species composition. For example, Reeves et al. (1987a) found evidence that steelhead trout in western Oregon streams are less aggressive, more susceptible to disease, and commonly replaced by their more tolerant competitor, the redside shiner, in stream sections with elevated summer temperatures. Similarly, Barton et al. (1985) suggested that sublethal temperature increases (maximum summer temperature greater than 71.6°F) following streamside clearing were one possible cause of the observed shifts from cold water salmonids to warm water fishes in Ontario streams over several decades. Since warmed stream waters lose little of their heat as they move downstream unless diluted by cooler water sources, elevated water temperatures from the upper parts of a watershed can affect salmonid populations in lower reaches (Beschta et al. 1987). Hence, cumulative and basin-scale perspectives are needed to fully evaluate the impacts of temperature alterations due to fire and logging (Beschta and Taylor 1988).

One potential impact of slash burning that has perhaps been overlooked is its effect on groundwater temperatures. Groundwater inflows from springs into streams can greatly moderate stream temperature alterations associated with logging (Swift and Messer 1971). Such inflows also serve as important sites for salmonid spawning and as summer and winter thermal refugia for juveniles and for adult steelhead trout and chinook salmon returning upstream to spawn (Bilby 1984a, Cunjak and Power 1986, Shepherd et al. 1986). Following slash burning, increased solar heating of blackened soils and wood debris could lead to increases in soil water temperatures in clearcuts (Chandler et al. 1983). Some researchers have speculated that increases in soil and groundwater temperatures following logging and slash burning may in turn lead to stream temperature increases (Hewlett and Fortson 1982, Hartman et al. 1984). However, such effects may be small and/or short-lived, particularly in coastal areas of the Pacific Northwest where revegetation commonly occurs within 1-2 years after logging and slash burning. Further research is needed to better define the extent and magnitude of this possible influence.

Nutrients and food resources

In Northwest forest streams, the type and quantity of the food base for fish is governed by the combined interaction of light, nutrients, substrate, and organic matter inputs (leaves, needles, twigs) from the surrounding riparian vegetation (Sedell and Swanson 1984, Gregory et al. 1987). Few studies have examined in detail the response of fish populations or fish food resources to the increases in nutrients that commonly occur in streams following wildfires or logging and slash burning (Chapter 17). However, because nutrient increases are usually small or of short duration (Chapter 17; Brown et al. 1973, Scrivener 1982), their effects on food resources and fish populations are probably negligible in most cases. Commonly, nutrient spikes following fires are most pronounced during storm events in the autumn, after the summer period of maximum algal production and fish growth (Scrivener 1982). Also, studies of the response of stream biota to wildfire in forests in Alaska (Lotspeich et al. 1970), California (Hoffman and Ferreira 1976), and Washington (Wood 1977) did not detect significant changes in either algal production or aquatic insects.

Pacific Northwest streams are generally light- rather than nutrient-limited. The higher primary and secondary production that is observed in streams for about 10 years following streamside logging and slash burning is primarily attributed to the changes in type and quantity of available food associated with canopy removal over the stream rather than to increased nutrient concentrations (Sedell and Swanson 1984, Wilzbach et al. 1986, Gregory et al. 1987). Similarly, in a comparison of burned and unburned watersheds in Yellowstone National Park, Albin (1978) found similar nutrient levels but lower stream shading, higher (by 2.7°F) summer stream temperatures, and greater abundance of aquatic insects in the stream draining the watershed burned previously by wildfire. Some instances where nutrients or ash from fires exceeded federal water pollution standards (Fredriksen 1971) or caused fish kills (Leopold 1923) have been reported, but nutrient levels generally do not reach toxic or very high levels unless hot, severe burns occur either directly within the stream channel or are immediately followed by a heavy rainfall (Fredriksen 1971).

Since streamside logging and burning initiate a sequence of changes in the composition, structure, and density of riparian vegetation (Agee 1988, Andrus and Froehlich 1988), how these changes affect the food base of forest streams must also be considered. Along small coastal streams, the removal of trees in riparian zones and the exposure of bare soil through yarding and slash burning tends to favor the rapid establishment of alder, salmonberry, and other deciduous vegetation which then may dominate riparian stands for at least 80 years prior to the reestablishment of conifers (Fig. 18-1; Sedell and Swanson 1984, Agee 1988, Andrus and Froehlich 1988). These vegetation changes cause a shift in the food base from the diverse mixture of deciduous and conifer litter and algae characteristic of unmanaged streamside forests to a simpler food base with algae as the chief energy source during the time period prior to canopy closure over the stream (Fig. 17-2). Later, the food base shifts to one primarily driven by deciduous litter derived from the dense corridors of alder bordering the stream (Fig. 18-1; Sedell and Swanson 1984, Gregory et al. 1987, Bilby and Bisson 1989). Higher biomass but lower diversity of aquatic invertebrates are associated with these food base shifts (Newbold et al. 1980, Murphy et al. 1981, Gregory et al. 1987). The response of fish populations to this changing food web is variable, with biomass increasing markedly during the open canopy phase (Bilby and Bisson 1989) and then declining as the alder canopy closes over the stream (Chapman and Knudsen 1980, Murphy et al. 1981, Gregory et al. 1987).

Woody debris

Potentially one of the most important and long-term impacts to fish habitat following streamside logging and burning is the loss of large woody debris. Historically, infrequent stand-replacement wildfires in Douglas-fir forests were the source of large inputs of large wood into streams and on hillslopes (Chapters 3 and 4). However, clearcut and burn rotations of 60- to 100-year intervals in western Cascades or Coast Range forests have resulted in much lower levels of woody debris compared to unmanaged forests (Spies et al. 1988). Surveys of various streams flowing through second-growth stands in western Oregon and Washington show an overall decline in large coniferous woody debris compared to unmanaged systems (Sedell et al. 1984, Grette 1985, Bisson et al. 1987, Andrus et al. 1988, Heimann 1988). Woody debris in streams plays a dominant and complex role in the physical and biological processes that affect production of salmonids (Bryant 1983, Bisson et al. 1987). Without management regulations or prescriptions for maintaining and establishing conifers in riparian zones as a source of large

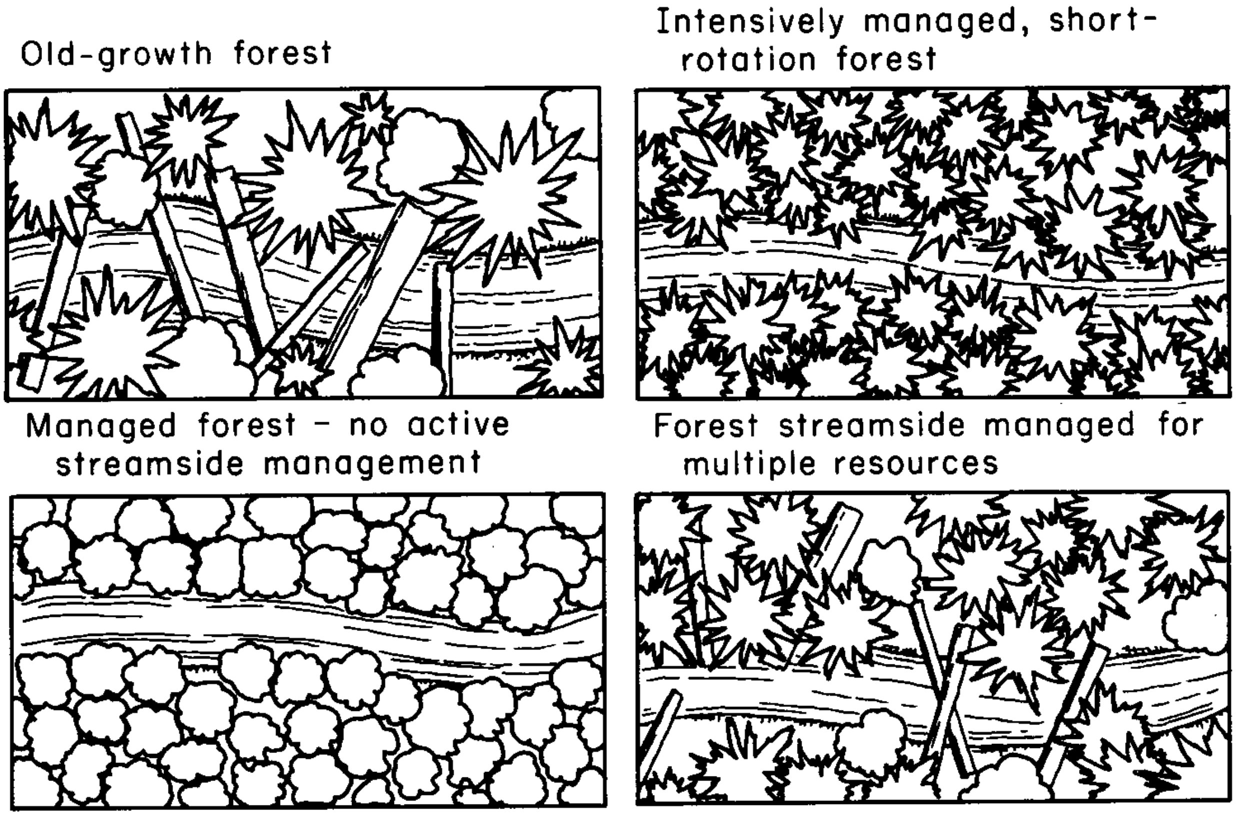

Figure 18-1. Schematic representation of changes in riparian vegetation and large woody debris in streams under different riparian management scenarios. (Adapted from Sedell and Swanson 1984)

woody debris, over time streams that flow through intensively managed (short rotation) or alder-dominated riparian zones lose much of the sediment and organic matter storage capacity and fish habitat provided by large downed conifers in the stream channel (Fig. 18-1; Bisson et al. 1987, Andrus et al. 1988). As a result, stream channels become simpler and less stable, and lose much of the habitat complexity important for providing the diversity of stream velocities and cover used as feeding and resting sites by salmonids (Sedell and Swanson 1984, Tripp and Poulin 1986a,b). Consequently, marked changes in abundance of salmonid fishes and aquatic insects have been observed following the removal or loss of debris from streams (Bryant 1983, Dolloff 1986, Elliott 1986, Murphy et al. 1986). The effects of this loss are particularly acute during winter when large woody debris provides fish refuge from high stream velocities during the frequent and at times severe freshets common to Northwest streams (Tschaplinski and Hartman 1983, McMahon and Hartman, in press); this loss of winter habitat may nullify the beneficial effects of increased fish production associated with canopy removal that has often been observed in streams after streamside logging and slash burning (Heifetz et al. 1986, Murphy et al. 1986).

The loss of large coniferous wood can have a long-term effect on the productivity of salmonid streams (Holtby 1988b). Second-growth conifer stands do not produce appreciable amounts of the large stems and rootwads necessary to form stable and complex debris accumulations for at least 50 years after harvesting (Grette 1985, Bisson et al. 1987, Heimann 1988). Although alder contributes to woody debris in streams, its value as large woody debris is much less than that of cedar, spruce, and Douglas-fir because of its relatively small stem size and rapid decomposition (Bisson et al. 1987).

Streamside logging and overzealous removal of debris from stream channels under the auspices of protecting roads, bridges, water quality, or fish passage (Bilby 1984b, House and Boehne 1987) have likely had a greater effect than slash burning on the loss of much of the present and future sources of large wood from streams. However, by creating more bare soil and a more uniform soil environment in riparian areas, slash burning along streams may reduce the establishment, growth, and future recruitment of conifers as woody debris into streams by creating an even more favorable environment for the formation of dense and uniform stands of deciduous trees and shrubs than would logging alone (Fig. 18-1; Agee 1988). Conversely, judicious use of prescribed fire in riparian zones in conjunction with thinning or conifer planting may be a useful site preparation tool for reestablishing conifers in brush-dominated riparian zones to insure a future supply of large wood and snags (Fig. 18-1; Hibbs 1987, Andrus et al. 1988).

Logging commonly creates large quantities of slash and one of the key purposes of prescribed burning is to decrease the amount of this material to meet site preparation and fire hazard reduction objectives (Chapters 6 and 8). One possible side effect of burning, particularly severe burns on steep slopes, is to decrease the stability of existing debris; burning logs and other slash rolling downhill are not an uncommon sight during a fire. Due to the effects of water and gravity, large quantities of logging slash may accumulate in streams, especially steep draws and headwater channels (Brown 1974, Bryant 1983). During large storm events, this small, floatable material can then be transported downstream in the form of debris torrents, where it builds up and causes failure of formerly stable natural debris jams (Swanson and Lienkaemper 1978, Toews and Moore 1982, Bryant 1983, Hartman et al. 1987). Large deposits of small, unstable slash and debris may also form barriers to upstream fish passage (Bisson et al. 1987). Proposed guidelines for the removal of slash that has a high likelihood of moving during storm flows while protecting the integrity of stable debris have been offered by Bryant (1983), Bilby (1984b), and Dolloff (1986).

Sediment and turbidity

Despite widespread concern over the potential effects of fire-related sedimentation on fish and aquatic habitats (Lyon et al. 1978, Chandler et al. 1983), questions about how much sediment is delivered to streams following prescribed burning and what effects this has on fish habitat are difficult to answer definitively. Relatively few studies have measured sediment or turbidity during and after fires. And, in the sediment yield studies that have been done (Chapter 17), it is difficult to clearly identify burning as the source of sediment input into streams since several other potentially sediment-producing management activities occur concurrently with the use of fire.

Salmonids in the Pacific Northwest have evolved in steep, highly erosive, sediment-rich watersheds with highly variable streamflow; but too much sediment can adversely impact salmonid habitat in a number of ways (Everest et al. 1985, 1987). Excessive sediment reduces suitable spawning and rearing habitat by increasing scouring and intrusion of fine sediments into spawning gravels. In low-gradient stream sections, where fish production is often concentrated and sediment deposition occurs (Reeves et al. 1987b), the filling of pools and the creation of wide, shallow, unstable stream channels prone to dewatering during periods of low flow in summer may also result from high sediment inputs (Swanson and Lienkaemper 1978, Tripp and Poulin 1986a,b). The net effect of these changes is a reduction in the survival of salmonid eggs and fry (Cederholm and Reid 1987, Hartman et al. 1987) and a shift in the species and age composition of the fish community from one dominated by pool-dwelling species such as coho salmon and older steelhead and cutthroat trout to one dominated by riffle-dwelling species such as young steelhead and cutthroat trout (Bisson and Sedell 1984). Even relatively small but chronic increases in suspended sediment or turbidity may negatively influence fish populations by decreasing food production, feeding rate, and growth and by increasing avoidance of the affected area (Bisson and Bilby 1982, Sigler et al. 1984, Lloyd et al. 1987). Reduced angler effort and success may be an additional side effect of high turbidity, even at relatively low levels (Chapter 17; Everest and Harr 1982).

In most instances, however, roads or soil and bank disturbances associated with timber harvesting along streams are the dominant factors contributing to increased sediment delivery to streams via increased surface soil erosion or mass wasting (Chapter 14; Brown and Krygier 1971, Swanston and Swanson 1976). A sediment budget developed for various management practices in the South Fork Salmon River, Idaho, watershed estimated that sedimentation due to fire contributed less than 1 percent of the total annual sediment to the river; 85 percent of the total yield was due to roads (Nobel and Lundeen 1971; see also Cederholm and Reid 1987). However, as indicated in Chapters 14 and 17, several-fold increases in sediment yield can be expected after clearcutting and a hot burn on steep slopes (see also Mersereau and Dyrness 1972, Rothacher and Lopushinsky 1974). These chapters also discussed several ways to minimize accelerated soil erosion and increased sedimentation of streams draining steep watersheds through well-planned and supervised logging operations and site preparation that limit the exposure of bare soils and maintain soil and root strength. These practices include avoidance of hot burns or use of alternative methods for slash removal; minimizing consumption of the organic duff layer by use of cool burns; providing an unburned buffer along stream channels; rapid revegetation of bare soil; and maintaining vegetation in small headwater channels.

Maintaining large woody debris in streams and on hillslopes is also crucial for moderating the input and adverse effects of increased stream sediment associated with burning. By dissipating stream energy and erosive power during storm events, large woody debris in streams greatly increases the capacity of a channel to deposit and store sediment, and thus reduces levels of bedload and suspended sediment and turbidity (Beschta 1979, Bisson et al. 1987). In a similar fashion, woody debris on hillslopes, terraces, and in headwater stream channels serves as erosion barriers, trapping fine sediments and small debris, and hence helping buffer downstream fish habitats against rapid pulses of sediment (Mersereau and Dyrness 1972, Wilford 1984, Bisson et al. 1987).

Other considerations

The importance of offchannel, floodplain habitats (minor tributaries, beaver ponds, ephemeral swamps, sidechannels) to the overall production of juvenile salmon (primarily coho salmon) and steelhead and cutthroat trout has become increasingly recognized (Bustard and Narver 1975, Cederholm and Scarlett 1982, Peterson 1982, Hartman and Brown 1988). Representing only a small fraction of the total stream area and in some places situated several hundred yards from the main stream channel, these protected sites nevertheless can provide overwintering habitat for a significant portion of the smolts produced in a stream basin (Cederholm and Scarlett 1982, Brown and McMahon 1988). However, these sites are small and often dry during the summer, and thus are commonly overlooked during forestry operations. Although relatively invulnerable to direct impact of fire due to their wetland-type characteristics, these areas are very susceptible to sediment and slash deposition from upslope harvesting, roads, and prescribed burning because of their position in the watershed. Ways to identify and protect the quantity, quality, and use of these sensitive and important floodplain habitats during logging and site preparation are discussed by Hartman and Brown (1988).

Wildfire versus prescribed fire

Fire has been a relatively common occurrence in Pacific Northwest forests for at least the past 10,000 years (Chapter 3). The adaptations or responses of fish and stream ecosystems to the effects of historical fires provide an important context from which to view modern-day uses and impacts of prescribed fire on fish in managed forests (Sedell and Swanson 1984).

The catastrophic stand-replacement wildfires that occurred throughout western Oregon and Washington on the average of every 100-250 years (Chapter 3) undoubtedly had large impacts on fish habitat via the introduction of large pulses of sediment and debris. The impacts of such large-scale and severe events, however, were probably ameliorated when riparian zones remained intact. Studies by Hemstrom and Franklin (1982) in Mount Rainier National Park and Teensma (1987) in the central Oregon Cascades revealed that the oldest forest stands often occur along streams, indicating that historic stand-replacement fires less commonly extended down to the moist valley floors and streamside areas.

In addition, Sedell and Swanson (1984) suggest that even where fires did burn across riparian areas the remaining structural influence of the forest from snags and large woody debris in the stream served to minimize sedimentation and hasten recovery of disturbed stream areas. In studies of streams previously burned by major wildfires in western Oregon, Swanson and Lienkaemper (1978) and Andrus et al. (1988) found that large wood in streams may persist for many decades after fires, continuing to provide the majority of the structure for fish habitat in streams until the post-fire stand begins to produce large wood.

Despite the many large and well-publicized wildfires that have occurred throughout the Pacific Northwest during the past 100 years, monitoring of fish population responses to these disturbances has been limited. The effects of the Mt. St. Helens volcanic eruption in 1980 were analogous in their impacts to stream ecosystems to a very large and severe wildfire. In the blast zone, riparian forests were buried, streams were inundated with massive amounts of ash and fine sediment, and most of the fish populations were eliminated (Martin et al. 1986). However, in stream channels where structural features provided by large quantities of wood remained both from the preblast forest and from blowdown during the blast, there was little channel widening, pools were maintained, and recovery of the channel and riparian vegetation has been rapid due to the large quantities of ash and fine sediment being either transported downstream or deposited onto the floodplain within a few years after the blast (Sedell and Dahm 1984). By contrast, in areas where downed trees and riparian forests were either buried by mudflows or removed during salvage logging, streams lacked such structural features and had wide, shallow, highly unstable channels and few pools and side channels, and carried high sediment loads of fine sand (Sedell and Dahm 1984). Due to a combination of high summer water temperatures and a lack of large wood for winter refuge, coho salmon reintroduced into streams throughout the blast area within 1-2 years after the eruption exhibited their lowest survival in stream sections exhibiting these latter characteristics (Martin et al. 1986).

Compared to historic or modern-day wildfires, prescribed burns are generally much less severe and much smaller in areal extent; hence, the impacts on fish populations can be expected to be much less severe as well. The above information on wildfires or wildfire-like events suggests that potentially the most long-lasting and severe effects of fire—whether prescribed or wild—will be when results include the loss of the streamside forest and its mediating influence on stream temperature, sediment, and woody debris.

Management implications

Table 18-1 summarizes various approaches to minimizing undesirable impacts to fish habitat during and after prescribed fire. The recent shift in the Pacific Northwest to the use of more cool burns, coupled with leaving riparian buffers along fish-bearing streams, should help alleviate many of the potential impacts of fire on fish and stream ecosystems. As noted in Chapters 14 and 17, burning when the forest floor is moist is a particularly effective way to minimize sedimentation by limiting

Table 18-1. Management prescriptions for minimizing potential impacts of fire on fish habitats.

Potential Impact	*Prescriptions*
Increased water temperature	Maintain stream shading via riparian buffer strip; promote rapid revegetation of charred hillslopes.
Nutrient increases/altered food resources	Avoid hot burns especially prior to high rainfall in the fall; maintain riparian buffer with mix of coniferous and deciduous vegetation.
Loss of large woody debris	Maintain riparian buffer strip with large conifers; prevent input of large quantities of slash into streams.
Sedimentation	Use cool or spring burns; promote rapid revegetation of burned sites; avoid stream bank disturbance; maintain or enhance sediment storage capacity by leaving large wood in streams and on hillslopes and by leaving vegetation in and along headwater channels.
	Use alternative methods for slash removal (e.g., cable yarding) on steep (>80%), unstable slopes.
Floodplain habitat damage	Maintain fish access; minimize disturbance from sediment and slash deposition; protect vegetative cover.

the exposure of bare soil and the loss of large wood pieces on hillslopes and headwater or intermittent stream channels that serve as effective sites for deposition and storage of sediment.

Riparian buffer strips, too, serve an important and multipurpose role in protecting the integrity of fish habitat during and after fire and associated management activities (Hall and Lantz 1969, Froehlich 1973, Barton et al. 1985, Beschta et al. 1987, Bisson et al. 1987, Hartman et al. 1987). Recent changes in forest practice regulations in the Pacific Northwest reflect increasing awareness of the important role of streamside vegetation in providing fish and wildlife habitat over the long term by requiring the leaving of live conifers as a future supply of large wood for snags and instream woody debris (Adams et al. 1988).

A concern during the planning and operational phases of a prescribed burn is how to protect riparian buffer strips during a fire. A recent survey of 45 buffer strips in the Siuslaw National Forest revealed that nine (20 percent) had been damaged by prescribed fires, with four of these sites moderately to severely damaged (defined as having more than 40 percent of total area affected) (Swanson and Roach 1987). Use of sprinklers, fire lines, removal of slash from buffers, burning when buffer strips are moist, and erection of sheet metal barriers to prevent rolling embers from entering buffers are some of the ways used to minimize fire damage to these sensitive areas. Prompt reseeding of fire lines constructed to protect buffers will help ensure that these areas do not act as a sediment source for nearby streams.

A continuing challenge for prescribed fire management is to minimize downstream effects from burning in or near intermittent or headwater stream channels. Commonly, buffers are not left along these channels because they usually do not support fish. Nevertheless, they represent the majority of stream miles within a basin; for example, intermittent tributaries comprise about 70 percent of the total stream miles in the Mount Hood National Forest (personal communication from D. Heller, Mount Hood National Forest). Fire severity and accumulation of small, floatable slash tend to be higher in these steep, narrow sites; hence, they can be important contributors of sediment and small debris to fish-bearing waters downstream when stream networks expand during major storm events (Chapter 14). More information is needed to evaluate to what extent and under what conditions downstream impacts on fish habitat occur due to burning in or near headwater channels, and to identify and assess prescriptions for minimizing these impacts.

Effects of Fire on Wildlife

Direct effects

Although the literature is somewhat divided on the magnitude of wildlife mortality resulting directly from fire, the consensus is that this mortality is insignificant in terms of number of animals killed and impact on affected populations (Bendell 1974, Wright and Bailey 1982). Death of small mammals with small home ranges, such as voles, deer mice, shrews, chipmunks, tree squirrels, woodrats, and rabbits, has been documented for prescribed burns (Tevis 1956, Chew et al. 1958, Cook 1959, Ahlgren 1966, Komarek 1969, Gashwiler 1970, Black and Hooven 1974, Fala 1975). Mortality of small mammals is related to uniformity, severity, size, and duration of the burn (Buech et al. 1977). Ground-dwelling mammals can avoid the intense heat of fires simply by going underground (Chandler et al. 1983); soil temperature just inches below the surface stays within normal ranges (Kahn 1960, Lawrence 1966). Komarek (1963) observed no mortality of marked cottonrats following a small prescribed burn.

Even when individual small mammals are killed during prescribed burns, the impact on the population may be ephemeral, at least for some species. Tevis (1956), Tester (1965), and Simms and Buckner (1973) noted that mice and voles colonized areas that had been prescribed burned within weeks.

There is little documentation of avian mortality resulting from fire. Chew et al. (1958) found two passerine bird carcasses following a wildfire in California chaparral. Obviously, prescribed burns conducted during nesting season will destroy ground-nesting bird nests. Doerr et al. (1970) reported failure of grouse to nest in an area following a fire; notably, no adult grouse carcasses were found.

Medium-to-large mammals usually move rapidly enough to escape fire. Members of a raccoon family left a 24-acre prescribed burn, returning afterwards to resume normal activities (Sunquist 1967). Deer and other larger mammals rarely are found in burned areas, unless the burn is of sufficient size and severity that they are trapped; such characteristics are not typical of prescribed burns. Chew et al. (1958) did find one dead black-tailed deer following a chaparral fire. Cause of death among wildlife in fires seems due mostly to asphyxiation, rather than to burning (Chew et al. 1958, Lawrence 1966).

It is reasonable to expect that by manipulating prescribed burns (size, season, location) there will be little direct wildlife mortality of consequence.

Indirect effects

Mechanism of indirect effects. Providing food and cover (for protection from environmental extremes and predators) are basic tenets of wildlife management (Dasmann 1981, Robinson and Bolen 1984). Food, cover, and water and their arrangement are essential components of wildlife habitat (Thomas 1979). Each wildlife species is adapted to a specific arrangement and amount of these habitat components, collectively called "habitat." The greater the diversity of these habitats, the greater, in turn, the diversity of wildlife species (Odum 1971). The structure (arrangement of vegetative layers—grasses and forbs, shrubs, saplings, maturing and mature trees) and composition (by species) of vegetation provide diversity of food (for herbivorous wildlife) and cover.

In addition to quantity, the quality condition of foods influences abundance and welfare of wildlife. Wildlife provided good nutrition are better able to withstand severe weather conditions and generally exhibit higher reproductive rates (Robinson and Bolen 1984). Fire is presumed to improve the quality of foods by release of such nutrients as nitrogen, calcium, and phosphorous, but other factors related to burning, such as greater exposure of plants to sunlight, and removal of litter, may also influence forage quality. Bendell (1974) noted that there is not a simple relationship among burning, release and uptake of nutrients, and use by wildlife. He noted that the level of nutrients in plants after burning may increase, decrease, or not change, depending on season, soil, weather, nature of fuel and fire, and other factors.

The size and arrangement in space and time of habitat components also influence wildlife abundance and diversity. Generally speaking, the smaller the wildlife species, the smaller the area within which it seeks its habitat needs. Mouse or vole habitat may include an area of less than 1 acre, whereas mountain lions and eagles usually include thousands of acres in their habitats. Larger wildlife species usually include more than one kind of vegetative structure/plant community in the list of habitat components they require. For these animals, the proximity (called juxtaposition) of these different, required habitat components determines animal presence and welfare; components in close proximity require less travel to get from one to the other, which results in less exposure to predation and weather extremes. If components are sufficiently far apart, they cease to be available to some animals, the animals' habitat needs are not met, and some will cease to exist.

Because of plant succession, those wildlife habitats that include seral plant communities phase in and out as determined by factors that control succession. The degree to which prescribed burning advances, retards, or maintains seral plant communities influences habitats and wildlife. Anything forest managers do that affects structure or composition of vegetation influences habitats and, in turn, wildlife species residing within those habitats. Because prescribed burning affects plant structure, composition, and succession (Chapter 4), it has the potential to alter the composition and abundance of the wildlife community existing in the vicinity of the burn.

Prescribed burning may impact none, a few, many, or all of the multitude of habitat components that determine the abundance and composition of wildlife communities in the vicinity of the burn. The impact(s) may be beneficial, detrimental, or innocuous, depending on timing, scope, severity, and placement of the burn, site characteristics (soil type and depth, slope, moisture, exposure), and on the wildlife species under consideration (Neitro et al. 1985).

Impacts of prescribed burning on groups of wildlife. Much is known of habitat requirements for such game species as deer, elk, and grouse. The management strategy for game animals usually is to optimize their abundance, and it includes management practices like burning and seeding to improve quality and quantity of foods.

Swanson (1970) noted that availability of forage for elk in western Oregon was determined by amount and distribution of slash and residual vegetation, which was reduced by prescribed burning. Bunnell and Eastman (1976) and Taber et al.

(1981) indicated that prescribed burning improves forage productivity of clearcut sites and extends the length of time preferred forages are available.

Orme and Leege (1976) noted that prescribed burning in fall resulted in successful germination, seedling growth, and survival of redstem ceanothus, an important elk winter browse food in Idaho. Spring prescribed burning was less expensive and resulted in a higher rate of sprouting of preferred winter browse species (Leege 1968). Prescribed burning reduces the height of existing browse, making it more available to elk, increases palatability of browse, and adds new browse plants via enhanced seed germination (Nelson 1976).

Prescribed burning has long been recognized as an important factor in management of bobwhite quail in the South (Stoddard 1963) for provision of nesting habitat and seed and insect foods. However, the impact of prescribed burning on upland game birds in the Pacific Northwest is unclear. Marshall (1946) stated that regeneration of preferred foods of ruffed grouse in Idaho is stimulated by fire, but Doerr et al. (1970) found little change in grouse numbers, mortality, and reproductive success before and after a wildfire in Alberta. Wright and Bailey (1982) stated that fire enhances spring, summer, and fall blue grouse habitat, but Redfield et al. (1970) stated that clearcut logging alone seemed to provide increases in blue grouse numbers.

Nongame wildlife includes such diverse groups as small rodents (mice and voles), sciurids (chipmunks and squirrels), birds of prey (hawks, owls, eagles, and vultures), and reptiles and amphibians. Until the last decade, there was little interest in nongame wildlife species unless they were categorized as threatened or endangered. Wildlife species so classified were accorded special status, including protection under federal laws from alteration of habitats which might result in reductions of their numbers or have other adverse effects upon them. Now, in addition to the protection afforded threatened and endangered species, nongame wildlife are receiving more attention, including manipulation of habitat for their benefit.

A number of reptiles, amphibians, small mammals, and birds use clearcuts and other forest openings. A required structural component within forest openings for these animals is down and dead woody material, such as logs and downed branches (Maser et al. 1979). These animals seek prey under logs, dig and nest in burrows in and under logs, store pine cones inside them and feed on fungi growing on and within logs. Some use logs as lookout posts. Larger mammals (snowshoe hares, skunks, and raccoons) use hollow logs for protection from weather extremes and predators (Maser et al. 1979).

Removing slash by prescribed burning or other methods eliminates this essential habitat component. Several years are required before chipmunks and voles colonize prescribed burned sites (Cook 1959, Ahlgren 1966, Fala 1975). These and other small mammals (ground squirrels and deer mice) have been identified as carrying spores of mycorrhizal fungi from adjacent forest lands onto clearcut sites (McIntire 1985). The fungi form a symbiotic relationship with commercially valuable conifers, enhancing uptake of soil nutrients, which is crucial on harsh, stressful sites (Chapter 13; Mikola 1970, Molina and Trappe 1982). Prescribed burning, by negatively impacting these small mammals, could conceivably have a deleterious effect on growth of conifers, especially on droughty sites. Maser et al. (1979) outlined procedures whereby prescribed burns would have least negative impacts on down and dead woody materials (e.g., burn in spring before logs dry out, or after recent precipitation has occurred; rake combustible materials away from logs prior to burning).

Some small mammals (bats, flying squirrels, and chipmunks) use cavities in snags, as do cavity-nesting birds (woodpeckers, flickers, bluebirds, swallows, sparrowhawks), for nest sites and protection from weather extremes and predators (Thomas et al. 1979, Neitro et al. 1985). Insectivorous birds like woodpeckers, nuthatches, and creepers obtain their prey primarily from snags. Other, noncavity-nesting birds nevertheless use snags as perching sites and hunting platforms.

Standard practice for prescribed burns has been either to: fell snags prior to the burn and burn them with other slash, or ensure that they are burned during the prescribed burn (Martin and Dell 1978). This practice eliminates nesting and roosting sites for the above-mentioned mammals and birds as well as a primary source of food. Studies have shown clearly that without snags on or near clearcut sites, the cavity-dwelling birds and mammals are lost from the wildlife community, reducing animal species diversity by about one-third (Mannan et al. 1980, Morrison and Meslow 1983, Schreiber 1987).

Several practices may be employed to protect snags during prescribed burning, including conducting the burn in early spring before snags lose much moisture, treating the base of snags and surrounding flammable material with fire-retardant material, and removing flammable material from the base of snags prior to the burn, via hand or machine piling of slash (Maser et al. 1979, Neitro et al. 1985, Schreiber 1987).

Larger mammalian predators (fishers, martens, foxes, coyotes, bobcats, mountain lions, bear) and avian predators or raptors (hawks, owls, vultures, and eagles) have such large home ranges that areas impacted by prescribed burning usually comprise but a small proportion of the total. Impact on the cover component of habitat is likely to be negligible. Predators congregate on burned areas, presumably because of the vulnerability and availability of prey species (Stoddard 1963, Komarek 1967, 1969, Bendell 1974). Thus, prescribed burning likely will increase short-term quantity of food available to predators.

Impact of prescribed burning on damage caused by wildlife to forest regeneration is slight and is discussed in Chapter 9. The use of prescribed fire to enhance wildlife habitat is discussed in Chapter 7.

Impacts of prescribed burning on wildlife communities. Like other forest perturbations, fire (at least fire contained within areas of the size representative of prescribed burns) seems to have negligible impacts on species abundance and diversity (Bendell 1974). Some species disappear from burned areas, while others appear which were absent prior to fire. Except in the case of endangered or threatened species, for which an area under consideration for burning might constitute a significant portion of the species' known distribution, prescribed burning should have a minimal effect on individual species.

As the proportion of prescribed burned lands in an area under consideration increases, the potential for impact on the wildlife community increases. Timing and placement of prescribed burned areas also influence impact. Staggering the conduct of prescribed burns over time, and distributing the burns evenly over the landscape will minimize impact on small wildlife species that occupy areas of prescribed burn size or smaller. For larger wildlife species, such placement could maximize potential benefits by providing a more even (through time and space) distribution of enhanced forage areas of the size likely to be fully utilized. (Note: Above a certain size of opening, deer and elk utilization of forage areas declines.)

If larger areas are prescribed burned, or a series of burns is conducted over a short time frame on contiguous areas, the overall effect is to create one large prescribed burn, which will result in increased negative impacts on small mammals (because they cannot escape the direct effects of fire), and reduced use by small animals (especially "edge-effect" animals) and larger animals (if the area is larger than typical foraging area). Again, however, the effects of prescribed burning must be separated from those caused by clearcutting and thinning, which may have a greater impact on wildlife use of an area than fire.

Management implications

Maximizing positive effects and minimizing negative effects of prescribed burning on wildlife requires careful comparison of its impacts on wildlife resident within the area considered for burning. Needs of, and areas inhabited by, threatened and endangered species must be evaluated in light of responses of these species to the characteristics of the proposed burn. Of even greater importance may be evaluation of the impact of practices proposed to precede (e.g., clearcutting, thinning) or follow (e.g., seeding of exotic forage plants; planting single species of conifer) the burn.

Where prescribed burning as a procedure by itself may result in negative impacts, mitigation measures may be called for, such as removing flammable material around logs or snags to prevent their consumption during the burn (Chapter 22). Careful timing and placement of the burn will avoid many potential negative effects as well as optimize potential beneficial effects. Planning for a sequence of prescribed burns during a burn season, or even over a period of years, will assure that benefits are optimized and detrimental effects are minimized.

Conclusion

For fish, the major habitat impacts associated with fire are increases in water temperature and sediment and the long-term loss of large woody debris from stream channels. Current information suggests that the use of cool burns and riparian buffers along streams should effectively prevent or limit these impacts in most cases, but more before-and-after monitoring studies of the effectiveness of these management practices are needed. This is particularly the case for fires on steep slopes and in headwater stream channels where the potential for downstream transport of sediment and slash is high. Expanded use by land management agencies of site-specific prescribed burn plans that mesh reforestation goals with soils, fish, and wildlife considerations should also help minimize stream impacts associated with prescribed fire. A future research and management challenge will be to evaluate the use of fire along selected portions of brush-dominated riparian zones as a means to reestablish conifers for snags and woody debris.

For wildlife, it seems likely that impacts from prescribed fire should not differ substantially from those of wildfire on wildlife. Indeed, because prescribed burns likely are of lesser severity, cover much smaller areas, and can be controlled concerning season, slope, moisture content of fuel, and other factors that impact wildlife, it would seem that negative impacts of fire posed by prescribed burning could be minimized, and positive impacts optimized.

In the future, for managers to make more definitive statements about the implications of prescribed fire on wildlife, there is a need, too, for monitoring studies of fire effects under various management scenarios. For example, rather than infer that wildlife welfare and abundance will automatically increase with increases in the quantity and nutritional quality of forage resulting from prescribed burning, it would be helpful if wildlife responses were monitored directly. The same could be said for inferred detrimental effects, such as the destruction of ground-dwelling bird nests, snags, and dead and down woody debris.

For both fish and wildlife, separation of the impacts of prescribed fire from those of clearcutting, thinning, and other management practices is also a valid research goal. Similarly, the response of fish and wildlife to the pattern of prescribed burns over large landscapes, such as watersheds, through time intervals spanning several to many seasons, would be valuable information for managers.

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