H091

Chapter 6

Fish and Old-Growth Forests

GORDON H. REEVES AND PETER A. BISSON

To the public, resource managers, and many scientists, good fish habitat and strong and diverse wild salmon populations are synonymous with *old-growth forests* in the Pacific Northwest, defined here as forests dominated by trees more than 200 years old. There is little argument that large wood produced by old-growth forests is an important habitat component in all stream sizes, from the steepest headwater channels to the largest floodplain rivers. However, old-growth forests represent a limited set of the overall range of conditions observed in pristine landscapes, and relying on streams in old-growth forests to provide the best habitat for fish (fig. 6.1) may not produce expected conservation benefits.

Nonetheless, selected attributes of streams (e.g., number of pools or pieces of large wood) running through old-growth forests are used to develop reference "standards" by which the condition of streams in watersheds with management activities is assessed. These standards may also be used to establish habitat goals for restoration efforts or to provide a framework for evaluating habitat quality. Streams in old-growth forests have often been used as "controls" in studies that examine the effect of land management activities on fish and fish habitat, such as changes in the number of landslides or in peak flows.

In a similar vein, conservation plans for fish and other aquatic

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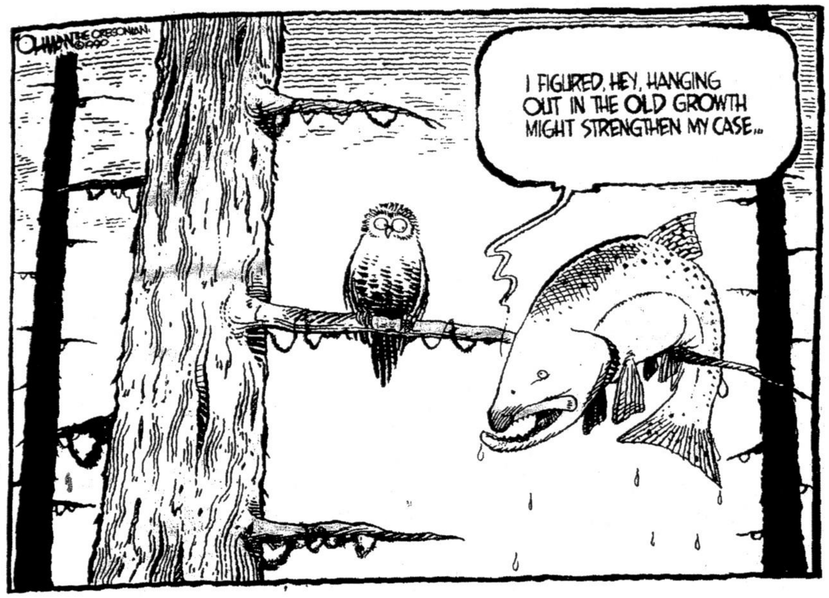


FIGURE 6.1. Editorial cartoon by Jack Ohmann. (© 2006, *The Oregonian*. All rights reserved. Reprinted with permission.)

organisms in the Pacific Northwest tend to focus on watersheds with larger intact areas of old-growth forests to anchor population recovery. As part of the Aquatic Conservation Strategy of the Northwest Forest Plan in 1993, abundance of old-growth forest was a primary factor in identifying "key" watersheds to protect high-quality habitat and to prioritize restoration of degraded streams possessing at-risk salmon and trout. Watersheds where maintaining fish populations and their habitat received special emphasis under a revised land management plan for the Tongass National Forest in southeast Alaska also contained abundant old growth (fig. 6.2).

The implication of these management policies is that streams in old-growth forests provide something akin to perfect salmon habitat. Although we believe many attributes of old-growth forests are important for maintaining healthy fish populations, the past forty years of scientific studies have demonstrated that simply maintaining old growth, by itself, is insufficient to support the full spectrum of ecological processes needed to sustain productive aquatic ecosystems. The problem is that old-growth conditions were initially believed to be stable and relatively free from natural disturbance. Based on today's knowledge of dynamic watershed processes, however, old-growth forests that are protected from all disturbances, natural or

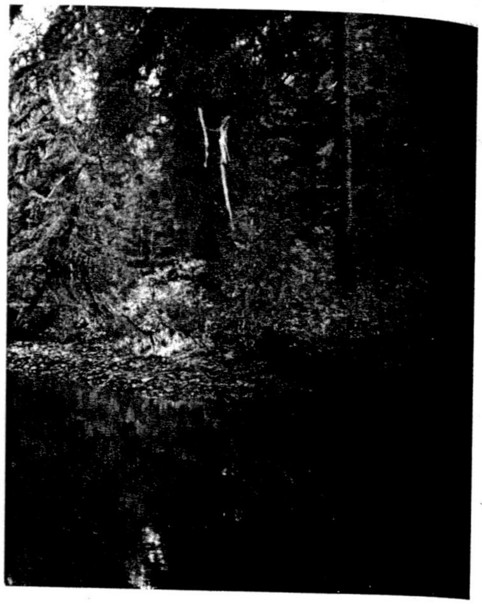
FIGURE 6.2. An old-growth forested stream in the Tongass National Forest of southeast Alaska, illustrating cold, clear water associated with a dense forest canopy. (Photo: P. Bisson)

anthropogenic, do not necessarily provide conditions that favor high levels of production of many salmon and trout species.

The purpose of this chapter is to examine relationships among fish, fish habitat, and old-growth forests. We review the history of research that led to the perception that salmon and trout require old growth and ask if this perception has remained valid in light of our developing understanding of aquatic ecosystems and watershed processes. We stress that our intent is not to diminish the need to conserve old-growth forests; rather, we believe it may be more accurate to say that old growth is necessary but not sufficient for maintaining salmonid habitat.

Early Research

For decades it was assumed, and then documented, that land management activities could result in damage to streamside (riparian) forests. However, the basis for the assumed dependency of fish on old-growth forests was less obvious. In the late 1970s and the early 1980s, numerous studies



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(Franklin et al., 1981) conducted at the H. J. Andrews Experimental Forest in Oregon's western Cascades documented the ecological properties and uniqueness of old-growth forests in the Pacific Northwest. Prior to and even during this time, old-growth forests were considered decadent forests and regarded as biological deserts by many land managers and policymakers. There were calls by federal officials to dramatically reduce the amount of old growth to establish commercial forest harvest rotations of sixty to eighty years. Research at the H. J. Andrews Forest found that old-growth forests were far from decadent and in fact contained a wealth of biological diversity. Furthermore, many of the plants and animals appeared to be strongly reliant on conditions associated with old-growth stands.

Studies on old-growth forests included aquatic as well as terrestrial ecology, and new insights into many aspects of aquatic ecology in the Pacific Northwest (Franklin et al., 1981; Sedell and Swanson, 1984) and Alaska (Murphy et al., 1984) resulted from this work. One principal finding of the studies from the aquatic perspective, and one that has had a major impact on management and policy, was documentation of the importance of large wood in streams to fish habitat. Large wood from trees of the size characteristic of old-growth forests created pools, stored and stabilized gravels, and provided cover for fish and a substrate for aquatic invertebrates, important foods for fish. The recognition that large wood was important contradicted the previously held notion that large wood (especially in log jams) often impeded fish movement and constituted a habitat problem. Previously, management agencies actively removed wood from streams throughout the western United States and Alaska to improve streams for fish. Research on the ecological importance of large wood became the impetus for the reintroduction of wood into streams as part of restoration projects and also for new policies aimed at managing riparian areas as sources of future wood for streams. Because much of the research was done in streams in old-growth forests, it was generally assumed by many managers and scientists that streams in old-growth forests held the best habitat for fish.

Is the Perceived Link Between Old Growth and Fish Habitat Valid?

The assumption that fish and old-growth forests are tightly linked persists today, but results from recent studies show that the relationship between fish and forests is much more complex and deserves continued examination.

Until recently, much of the management and research focus for fish ecology and conservation has been carried out at relatively small spatial scales, such as individual habitat types and stream reaches. Habitat requirements of individual species or local species diversity are of primary interest at these scales. But management policies and recovery plans for fish populations listed under the Endangered Species Act have been prompted by better scientific understanding of larger spatial and temporal scales (Benda et al., 1998; Reeves et al., 1995). As a result, the spatial scale of management attention has moved somewhat from the scale of individual streams to multiple watersheds.

The larger spatial extent requires that watershed processes be considered in the context of time scales of decades to centuries. Long-term changes have not previously been a major consideration when describing the productivity of aquatic ecosystems. Until very recently, streams were often assumed to be relatively stable through time and likely to recover relatively quickly if they were disturbed by natural events. Unmanaged forests, in contrast, have for some time been understood as very dynamic, with stand ages comprising a series of patches whose location varies over the landscape through time.

The life histories of many salmonids suggest that they are highly adapted to disturbance-prone environments (Reeves et al., 1995; Wondzell et al., 2007). There is a tendency for a relatively small fraction of individuals in populations of anadromous salmon and trout to stray from their stream of origin. Also, some juveniles may emigrate from their natal stream to other streams during the freshwater phase of their life cycle. In resident trout and char, some fish may undertake extensive movements throughout the drainage network, while others remain within a very limited part of a watershed. The migrants can occupy new habitats that become available following disturbances. Additionally, salmonids have a relatively large number of eggs for their size, compared to other fish that spawn in the gravel, and they may construct *redds* (spawning areas) in multiple locations during a given spawning season. The high fecundity facilitates lifecycle risk-spreading by allowing offspring to rapidly populate new areas and ensure that at least some survive.

There is an emerging understanding that streams may be very dynamic in space and time and that they can experience a wide range of conditions, just as do the terrestrial ecosystems in which they are embedded. Indeed, the association of salmon and old growth cannot be considered without taking into account extensive variation within watersheds and across regions. Several examples are used here to illustrate this important point.

Oregon Coast Range

The Oregon Coast Range experienced a history of large wildfires occurring on average every 150–350 years (Reeves et al., 1995). Landslides often followed these fires, inundating stream channels with thick layers of coarse and fine sediment. Large amounts of wood and boulders likely also entered the channels, but much of it was buried (fig. 6.3a). The primary fish habitats in the summer were pools that became isolated from each other because much of the flow passed through rather than over porous gravel. Fish numbers were relatively low, dominated primarily by coho salmon. These conditions may have persisted for as long as eighty to 100 years in heavily burned watersheds.

During the early part of the second century after a large wildfire, habitat for fish became diverse and complex. The amount of gravel decreased as it was eroded or transported downstream, exposing previously buried wood (fig. 6.3b) and sculpting pools. Additionally, as the surrounding forest recovered, wood was recruited from the adjacent riparian zone. During this phase of recovery, fish abundance (of all species) and habitat quality were high. Preliminary estimates suggest that these conditions probably existed over thirty to sixty percent of the forested landscape of the Oregon Coast Range before European settlement but shifted over time.

Habitat conditions for fish likely declined as the old-growth forest developed. A dense, shady multilayered canopy inhibited algal and invertebrate production. The amount of large wood in the channel increased with increased input from the aging forest. However, the loss of gravel exceeded the input rate of new gravel, and as a result the streambeds likely contained large expanses of bedrock (fig. 6.3c), in which pools were infrequent and of low habitat quality. Fish numbers were low, again dominated by coho salmon.

Interior Pacific Northwest

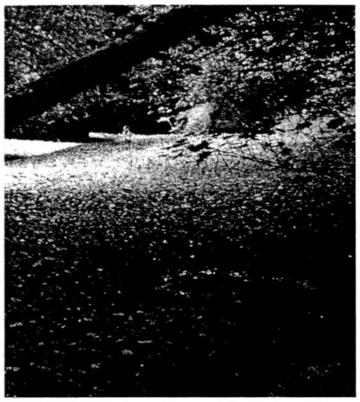
Streams in the more arid regions of the Pacific Northwest, particularly those flowing through meadows, may also pass through a range of conditions in response to periodic wildfires (Rieman and McIntyre, 1995). Following wildfires, intense thunderstorms can result in gully erosion that delivers sediment to streams in the valley. Deposition of sediment in the channel helps maintain the water table at a high level and provides the setting for

a. 80–100 years after wildfire

b. 120–140 years after wildfire

c. More than 200 years after wildfire

FIGURE 6.3. Potential range of conditions that streams in the Oregon Coast Range historically experienced. (Photos: G. H. Reeves)



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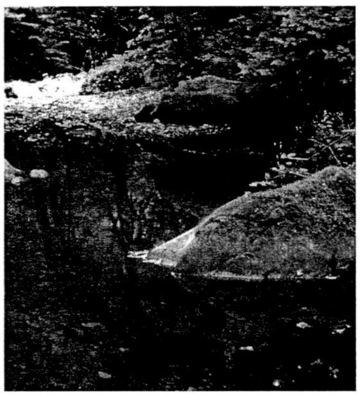

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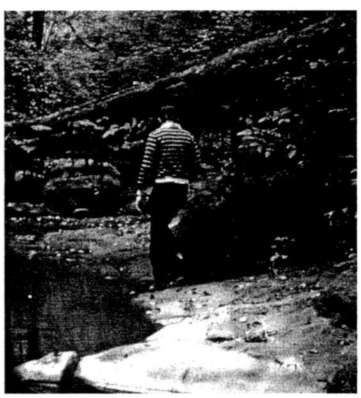

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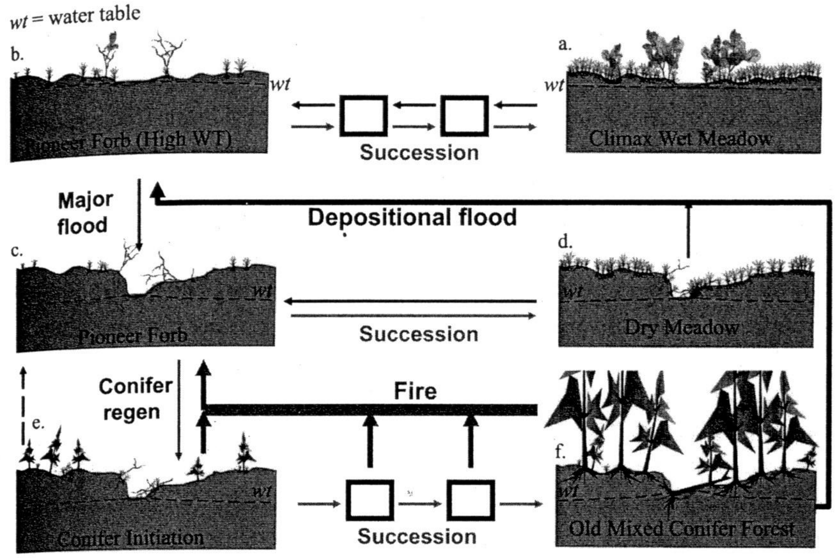

FIGURE 6.4. Potential responses of meadow streams in eastern Oregon to wildfire and old-growth ecosystems. (Wondzell et al., 2007)

the development of wet meadows (fig. 6.4). Good fish habitat tends to occur when the channel is in this condition. The water table can lower if the channel incises over time, drying the meadow and leading to a change in vegetation and a decline in habitat suitability for fish. Impacts of land use, such as grazing, may exacerbate downcutting. If the water table is lowered for an extended period, coniferous forests can invade the area that was formerly too wet for many tree species (fig. 6.4).

Development of an old-growth riparian forest reduces light levels and ultimately primary production. The stream's energy base largely shifts to the input of needles, which tend to be less nutritious than deciduous vegetation for bacteria, fungi, and invertebrates. Thus, old-growth forests along these streams may not necessarily be the most productive for fish. Several recent studies (Dunham et al., 2003; Minshall, 2003) of the effects of wildfire on fish, fish habitat, and aquatic invertebrates in interior western streams have found that there may be positive responses to wildfire in many areas.

Large River Systems

The association of fish with old-growth forests may be stronger in larger streams and rivers low in the stream network, such as the Hoh River on the Olympic Peninsula in Washington (Sedell et al., 1984). Rivers in downstream portions of a drainage basin tend to be lower gradient and set in wide valleys. However, unlike meadow streams of the arid interior or steep headwater streams in the Cascade or Coast Ranges, sediment supplies are less variable because of regular inputs from glacially fed headwaters, and there is a very low likelihood that gravel in these streams would ever become depleted. In such settings, old-growth forests contribute to the complexity and diversity of habitat and productivity of fish by providing large amounts of wood that serve as primary fish habitat structures. The wide valley floors of alluvial rivers and the tendency of floodplain rivers to meander create many canopy openings that maintain aquatic production. As a result, the abundance of food organisms is less likely to be reduced by the dense forest canopy often associated with narrowly confined, old-growth forested headwater streams. Unfortunately, old-growth forests along lowland rivers are rare because of past and present human development.

Higher gradient rivers, in contrast, are much less likely to meander, and they usually contain cobbles and boulders that may persist for long periods of time. In these streams, the aquatic food web is strongly limited by the amount of light reaching the stream (Bisson and Bilby, 1998) and high water velocities that limit algal development. Periodic gaps in the riparian canopy of old-growth forests along these streams, rather than disturbance of large areas, may provide increased light, leading to higher aquatic productivity (Sedell and Swanson, 1984) and greater food availability within the stream for fish.

Conclusions and Challenges

The association among fish, fish habitat, and old-growth forests is not as simple and straightforward as has been assumed and appears to vary widely across the Pacific Northwest and likely across the western United States. Case studies of fish production in Pacific Northwest watersheds tend to support the hypothesis that a range of forest ages, including early and midseral stages, leads to a combination of habitat and trophic conditions that are favorable for salmon and trout within the larger drainage system. The potential to extrapolate results from the studies described above to large areas is unknown at this time. We believe that the results are applicable to the watersheds in which the studies were conducted, but it is premature to generalize them over broad areas. The properties of streams over time

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Presumed positive relationships between old-growth forests and fish productivity may hold true in large, floodplain-dominated river systems but may not hold in high-relief streams, where coarse sediment inputs are rare and controlled by very large natural disturbances, such as in the central Oregon Coast Range. Streams in old-growth forests in these settings may not be very productive because of the depletion of gravel and heavy shading, important components of fish habitat.

The association between salmonids and old-growth forests may be strongest in streams that have the capacity to recover quickly from disturbances, such as those studied in the western Cascades, which possess abundant large wood to trap coarse sediment, or in large alluvial rivers lower in the drainage network. However, even in these streams, localized disturbance of the riparian forest is a prerequisite for increased aquatic productivity by creating small openings that allow sunlight to penetrate to the stream as well as excavation and recruitment of buried wood when rivers meander. It must also be remembered that the vegetation dynamics of older forests, for example, can be different between uplands and lowlands, with more frequent and more kinds of disturbances occurring in the uplands. In arid regions, old-growth forests may not necessarily be the most productive setting for fish where factors other than large wood may limit habitat quality. The examples provided earlier suggest that gravel and larger sized material may be lacking when there has been a long interval since the last major disturbance.

We believe that it would be timely to reexamine the assumptions about fish, fish habitat, and old-growth forests by addressing research questions involving multiscale perspectives, from individual habitat units to the ocean. Old-growth forests are one part of this huge range of habitat complexity, but only one part, and we may discover that directing riparian restoration projects to the recovery of old growth is not the sole avenue for capturing the complexity of salmon habitat and life cycle needs. We suggest that landscapes containing a mixture of successional stages may be a more appropriate setting for robust salmon populations. This would require conducting studies involving a range of forest successional stages, not just old growth and clearcuts, which were the focus of many early studies.

In this context, and as opportunities arise, it will be important to reassess the effectiveness of habitat reserves, such as key watersheds in the Northwest Forest Plan, that were designed to make both short- and long-term contributions to the recovery of Endangered Species Act–listed and other legally protected fish populations. Many of these habitat reserves were selected because of the presence of old-growth forests. If, as we have suggested, old-growth forests may not be the most productive environments for fish in some landscape settings, then the overall effectiveness of management and recovery plans for at-risk salmonids may not live up to expectations if the goal is simply to increase the amount of late-successional/old-growth forest stands. Of course, there may be other compelling reasons to increase the amount of old growth (such as habitat for endangered wildlife), but policymakers are best served if the tradeoffs are made clear.

The major challenge to management agencies and policymakers will be to decide whether to approach old-growth forests and streams from a static or dynamic landscape perspective. Each will affect social, economic, and ecological objectives in different ways. The static approach to managing stream habitat targets only one stage of the potential range of conditions in aquatic ecosystems and relies on fixed standards that usually involve setting quantitative targets for environmental attributes—for example, pieces of large wood per unit length of stream. Thus, adopting a static landscape approach may result in two management problems: (i) the long-term depletion of old-growth forests and the benefits they provide to fish if old-growth preserves are spatially "hardened" into land use plans without provisions for their replacement in other areas and (ii) the need for expensive, often frequent, bioengineered substitutes for the large wood and other habitat features provided by old-growth forests to streams. These problems are critical, but they are not often recognized in the current debate. Although there may be some sense of accomplishment in the short term in protecting remaining old-growth forest, it may only postpone dealing with the difficult issue of replacement until the range of potential options is much smaller than what we have today.

A dynamic landscape perspective recognizes that periodic disturbances are needed to maintain ecosystem properties through time and facilitates a natural range of conditions throughout the management area. The dynamic view allows for spatial and temporal variation in environmental attributes, thereby considering their historical or natural range of variability rather than relying on rigid standards. For example, a dynamic landscape approach to managing stream habitat in old-growth forests would include allowing some features characteristic of early, mid-, and late-seral forests, because these patchy conditions result naturally from disturbances in unmanaged areas. It would also involve recognizing that wildfires rarely leave wide buffers around streams: They may burn through them. The relative abundance and size of different forest patches, and their persistence over time, will

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vary widely across a region. In some places within a watershed, including frequently disturbed floodplains, late-seral forest conditions are rarely attained, and recruitment of large wood occurs when this material is fluvially transported from headwaters during high flows. An actively managed landscape can work toward maintaining many of the desired habitat features of streams in old-growth forests, including their inherent variability, with a variety of forest conditions, both within and among watersheds, some dominated by old forest, others by young forest, and yet others by a mix. This can be done only *if* basic watershed processes are maintained and the habitat-forming legacies of natural disturbances are not disrupted.

Old-growth riparian stands may persist for a long time, often centuries, but most are eventually altered by floods, wildfires, windstorms, insects and diseases, or other natural disturbance agents. Although placing a watershed with abundant old growth into a reserve may achieve the short-term objective of maintaining a forest type that is much less abundant now than in the past, the old-growth features that are so highly desired will not persist indefinitely. Without a strategy that allows forests in other watersheds to attain old-growth properties as existing stands are gradually lost to natural disturbances, river basins will continue to experience a chronic, cumulative loss of large wood and other habitat attributes critical to productive conditions. Nevertheless, maintaining old-growth forests in watersheds may be desirable and even necessary in many drainage systems, but this will not be sufficient to ensure the suite of conditions needed for viable fish populations. In other words, old-growth forest stands, by themselves, do not represent the sole forest age or condition needed for the conservation of native salmon and trout in the Pacific Northwest.

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Old Growth in a New World

A PACIFIC NORTHWEST ICON REEXAMINED

EDITED BY

Thomas A. Spies and Sally L. Duncan

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