

Implications of Changing Fire Regimes for Aquatic Systems

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INTRODUCTION

Climate change and past management, including fire suppression, have been linked to changing patterns of fire in the last century. It is widely believed that many forested areas have moved from a regime of low and mixed severity fire to more frequent and more continuous high severity fire (Hessburg and Agee 2003). There is growing concern among ecologists and natural resource managers that changing fire regimes could disrupt the function of whole ecosystems (USDA 2000). In the context of aquatic communities and native fishes, fire has an important influence on the structure and condition of habitats and can dramatically influence the dynamics of individual populations. Changing fire regimes and the potential for larger more disruptive fires may threaten the loss of aquatic habitat diversity and lead to accelerated extinction of some vulnerable populations. A simple focus on managing fuels, however, may not address the role of fire or the primary threats to the persistence of many species. An approach that aims to restore resiliency to fire related disturbances in both terrestrial and aquatic ecosystems is needed.

DISCUSSION

Wildfire can have a profound influence on watersheds and streams and associated aquatic organisms. In the short-term, fires and post fire flooding and debris flows may have ecologically catastrophic effects. It appears, however, that many species, like the fishes found in the mountain streams of the west, are actually adapted to and even dependent on disturbances like fire to maintain a diversity of habitats necessary to sustain spatially diverse and productive populations.

The immediate effects of severe fires that burn through riparian areas and across small streams may include high mortality or emigration of fishes and other organisms caused

by direct heating and changes in water chemistry (Minshall et al. 1997; Rieman and Clayton 1997, Spencer et al. 2003). Subsequent effects associated with the loss of vegetation and infiltration capacity of soils may include increased erosion, changes in the timing and amount of runoff, elevated stream temperatures and changes in the structure of stream channels (Swanson 1981, Benda et al. 2003; Wondzell and King 2003). The nature of these changes depends on the extent, continuity and severity of the fire, and on lithology, landform, and local climate (Swanson et al. 1988; Rieman and Clayton 1997; Luce in press). A severe fire burning through dense fuels can produce extensive areas of hydrophobic soils (DeBano 1981). If a large storm follows in steep, highly dissected terrain the result can be massive erosion and debris or hyper-concentrated flows that completely reorganize entire segments of mountain streams and deposit large volumes of sediment in lower gradient reaches.

For local populations of invertebrates, amphibians, and fishes these extreme events can have a dramatic effect. In our own work following the 1992 and 1994 fires in the Boise River basin, we found whole segments of stream apparently devoid of both fish and other organisms (Rieman and Clayton 1997). High mortality and even local extinctions of some fishes have been linked to similar events in other systems (Propst et al. 1992; Rinne 1996).

Whether fire is viewed as ecologically catastrophic, however, is a matter of context and scale. Following the Boise fires most populations rebounded quickly, in part through dispersal from unburned stream refugia (Rieman and Clayton 1997). Roughly 10 years post disturbance there is little evidence that the distribution and abundance of fishes in these streams are fundamentally different from similar-sized unburned streams (AR unpublished data). Beneficial effects of fire, such as increased primary productivity and invertebrate abundances may offer mechanisms for individual fish to cope with potentially stressful conditions (e.g., high temperatures) within disturbed streams. Further, on times scales of decades to millennia large disturbances have been common in these landscapes (e.g. Meyer and Pierce 2003). Fishes and other species probably evolved mechanisms such as dispersal and plasticity in life history that allow them to recover (Thorpe 1994; Dunham et al. 2003).

Other work has shown that fire and subsequent hydrologic events can contribute wood and coarse sediment that are necessary to create and maintain productive in-stream habitats (Reeves et al. 1995; Bisson et al. 2003). Benda et al. (2003), for example, have shown how mass erosion and deposition at tributary junctions can produce important heterogeneity in channel structure. Natural disturbances interacting with complex terrain has been linked to a changing mosaic of habitat conditions in both terrestrial and aquatic systems (Reeves et al. 1995; Naiman et al. 2000; Bisson et al. 2003; Miller et al. 2003). This variation of conditions in space and time may be key to evolution and maintenance of biological diversity, and ultimately, the resilience and productivity of many aquatic populations and communities (Poff and Ward 1990; Bisson et al. 2003; Dunham et al. 2003).

The interplay of fire, hydrologic disturbance, and ecological responses has played out in mountain streams for millennia, but the future may well be different than the past. Species have evolved in the face of climate variation and natural disturbances that might dwarf more recent changes in fire regimes associated with human influence. Native species have persisted and even prospered in the face of disturbances like those expected with changing

fire regimes, but humans have changed the structure and condition of forests and the nature of fire (Hessburg and Agee 2003). We may well be responsible for unprecedented changes in climate (Whitlock et al. 2003) and in the lost resilience of native aquatic ecosystems (Rieman et al. 2003).

Habitat loss, simplification, and fragmentation in aquatic systems associated with human development have been pervasive throughout the west (Rieman et al. 2003). Combined with the introduction and expansion of exotic species, these changes are responsible for contraction of native populations, local extinctions, and a growing list of sensitive, threatened and endangered species. Smaller, more isolated, and less diverse populations may be more vulnerable to disturbance because the primary mechanisms of fish recovery to disturbance (dispersal and life-history variation) are highly dependent on a well-connected, diverse environment (Rieman and Dunham 2000; Dunham et al. 2003). At the same time, greater continuity of fuels portend larger, more frequent, severe fires that will reduce the heterogeneity of terrestrial habitats (McKenzie et al. 2004) and conceivably aquatic habitats as well. If the continuity and frequency of fire related disturbance increase as populations become more restricted, diversity may be lost and the frequency and extent of local extinctions may grow. In recent work we examined the characteristic scale of past disturbance and the spatial structure of bull trout populations in the Boise River basin (CL unpublished data). Our results show that bull trout probably were able to persist in the face of dramatic disturbances because many habitat networks were larger than typical channel disturbances. However, that balance could change if available habitat continues to shrink due to climate change and other human disruption, or if disturbances increase in size because of more extreme weather or larger expanses of fire.

Even with mitigation of fuels, large disturbances are inevitable; all that can be changed is frequency and magnitude of individual events (Istanbulluoglu et al. 2004). Changing climate may result in massive reorganization of vegetation with fire as a likely catalyst (Whitlock et al. 2003). Severe fires increase the likelihood of massive floods and erosion, but in the right terrain these disturbances can be triggered by large storms even without a fire. The implication is that large disturbances will continue, regardless of what we do with fuels. Fuel management alone, then, will not solve the issues associated with changing climate and the disruption of whole ecosystem resilience from past management and development. In other words, managing fuels and restoring more natural fire regimes will not remove the underlying threat of habitat loss and fragmentation to the persistence of many aquatic species. In fact, additional management could further disrupt habitat if not done mindfully, for example by introducing chronic road derived sediments and setting up barriers to fish migration.

To insure the resilience of terrestrial and aquatic ecosystems, it is probably necessary to consider the restoration of terrestrial and aquatic ecosystems simultaneously. A challenge for research will be to integrate the emerging understanding of changing vegetation and fire with that of watershed and aquatic ecological processes to understand the full implications of the changes we are observing. A challenge for management will be to restore ecological processes that support *both* resilient terrestrial and resilient aquatic communities.

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