Effects of Wildfire on Growth and Demographics of Coastal Cutthroat Trout in Headwater Streams

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Introduction

In dynamic environments such as streams, fishes must persist under a range of environmental conditions. When factors in the stream environment suddenly change following a disturbance, a new environmental state is realized. Fishes generally respond at both the individual and population level, and those systems with the capacity to survive under the new environmental conditions persist. These biological responses to the changed environment provide insights about the relative state of the ecosystem.

For example, in headwater streams, isolated populations of coastal cutthroat trout (*Oncorhynchus clarkii clarkii*) reflect conditions in their environment. Growth of individuals and population demographics are two characteristics that can shift in response to environmental change. Growth of an individual fish is determined by the difference between the amount of energy consumed in food resources and the amount of energy expended through metabolism and gamete production, all of which are influenced by a suite of abiotic variables. Demographics also reflect the relative state of the ecosystem following exogenously driven changes in the age structure, abundance, and distribution of a population.

Wildfire, a largely terrestrial perturbation, is broadly recognized as an agent of disturbance and ecological change in forested biomes. Links to subsequent changes in aquatic, biotic systems have been less well-documented. Wildfire can cause a number of changes in stream environments including increased solar radiation, increased water temperatures, change in water chemistry, increased erosion and sedimentation, and increased water yields. At the basin scale, the influence of wildfire is theoretically most profound in headwater streams because of the tight linkage between aquatic and terrestrial eco-systems. These abiotic changes resulting from wildfire will elicit biological responses, many of which are poorly understood.

Current wildfire management plans are often based solely on theories, models, and extrapolation of forest management data. In fact, there is little empirical information about responses of stream fishes to wildfire. The majority of past studies have focused on direct mortality, extirpation, recolonization, and change in relative abundance. Information concerning the effects of post-fire conditions on ecological responses of stream fishes is lacking, although hypothetically the two are strongly connected. These gaps in understanding impede our ability to formulate comprehensive management plans. By observing growth and demographics of coastal cutthroat trout, we are attempting to understand how post-fire conditions influence fish in headwater streams at the basin scale. Specific objectives of this study are to:

- Investigate the relationships between wildfire severity, abiotic stream characteristics, and relative growth rates of coastal cutthroat trout at the landscape scale
- Investigate annual trends in the distribution, relative abundance, and population age structure of coastal cutthroat trout following wildfire

METHODS

Four small basins in the headwaters of the North Umpqua River basin of western Oregon were selected for this study. During the summer of 2002, wildfire in three of the basins resulted in a mosaic of burn severities. A fourth basin was selected as a control. Sampling was conducted upstream of migration barriers to anadromous fishes (i.e., waterfalls) where coastal cutthroat trout are the only species of salmonid present. The drainage area above the migration barriers ranges from 804 hectares to 1,489 hectares. Fish sampling and stream habitat inventories were completed during the summers of 2003, 2004, and 2005.

Stream habitat inventories were conducted during summer low-flow periods using methods developed by Gresswell and Bateman (see CFER Annual Report 1999). Stream habitat has been hierarchically classified into geomorphic segments, reaches, and habitat units. Severity of wildfire was quantified for the riparian areas adjacent to each of the study streams using visual estimates of vegetation. In addition, water temperature was continuously monitored in each stream.

All fish-bearing streams within these basins have been surveyed using a single-pass electrofishing method (see Bateman et al., CFER Annual Report 2002). In each geomorphic stream segment, scales from a minimum of 10 fish (when possible) per 10-mm size group were collected annually. In one of the burned streams, which consists of a single segment, scales from 30 fish per 10-mm size group were collected annually.

After field collection, up to 10 scales in each 10-mm size group were analyzed to determine the age of fish in each stream. A random sample determined which scales were to be read in each size group. Relative growth rates were derived from scales by back-calculation of length at age. Since there was evidence of size-selected mortality (Lee's phenomenon), only the last complete year of growth was used to calculate relative growth rates. Statistical analyses will focus on the effects of severity of wildfire, stream of origin, habitat, and water temperature on mean relative growth rates of coastal cutthroat trout. To detect changes in population age structure, age-length keys were constructed for each stream and sample period. Population-scale changes in the relative abundance and distribution of coastal cutthroat trout were monitored on an annual basis. Relative growth rates of coastal cutthroat trout from this study will be compared to relative growth rates of coastal cutthroat trout from 40 similar basins in western Oregon (see Rehe and Gresswell, CFER Annual Report 2005).

RESEARCH RESULTS AND MANAGEMENT IMPLICATIONS

Preliminary results from this study suggest that wildfire has influenced aquatic ecosystems in these headwater streams of western Oregon. Riparian vegetation was reduced following wildfire in the two moderately burned streams and was completely eliminated in the severely burned

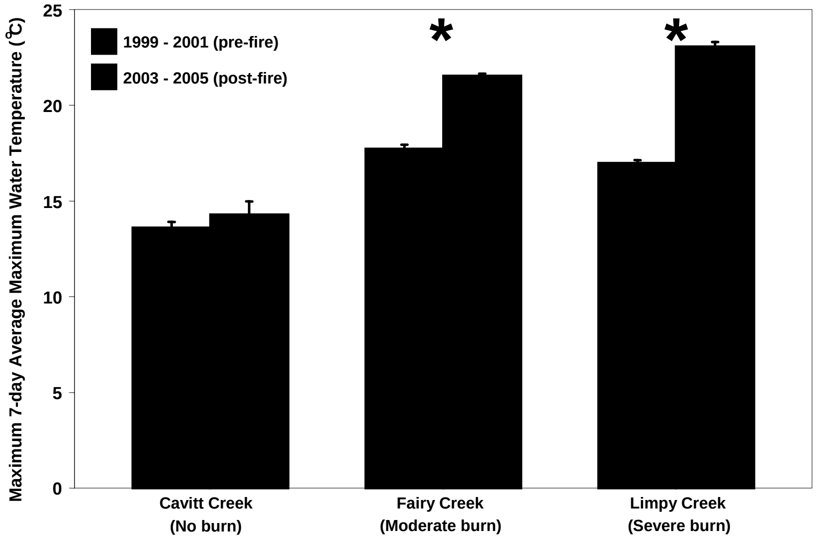

Figure 1. Comparison between pre- and post-fire water temperatures in three headwater streams. Each bar represents a three-year average of the maximum seven-day moving average of the daily maximum water temperature (MWMT). Each error bar corresponds to the standard error of each three year sample. Water temperature during 2002 (the year of the fire) was not available and was therefore excluded from the analysis. Within each stream, significant change in water temperature following the wildfire was tested for using two-sample t-tests. To minimize chances of making a type 1 error, a conservative Bonferroni adjustment was employed and the alpha for each test was lowered to 0.0166. Streams with a significant change in water temperature are labeled with an asterisk.

stream. This loss of shading greatly increased solar radiation contacting the stream. Consequently, the severely burned stream saw a 36% increase in water temperature relative to its pre-fire temperatures and one of the moderately burned streams saw a 21% increase (Figure 1). Both of these changes in water temperatures were highly significant (*p* = 0.000016 and 0.000056 respectively). In contrast, the unburned stream only saw 5% increase over the same time period which was not statistically significant (*p* = 0.206).

These abiotic changes in the stream ecosystem have appeared to illicit responses from coastal cutthroat trout. During the three years sampled, mean length of coastal cutthroat trout at the end of each growing year was consistently greater in the three burned streams as compared to the unburned stream (Figure 2). In fact, there appears to be a positive relationship between burn severity and length at age. This relationship is marred however by the fact that during the year of the fire (2002), fish growth followed the same pattern. Since the fire occurred in the middle of the growth year, we cannot differentiate between pre- and post-fire growth that year. Consequently the 2002 fish data appears to be of little value to us. While we can conclude that growth patterns of coastal cutthroat trout were greater in the two years following the wildfire, we cannot definitively say that they saw an *increase* relative to pre-fire growth patterns.

Despite not knowing what the growth patterns of coastal cutthroat trout were prior to the wildfire, it is well documented in the literature that fish growth is strongly related to water temperature. Since we have established that the water temperature has increased as a result of the fire, we can speculate that fish growth has also increased. Therefore we conclude that despite considerable changes to the physical stream environment following the wildfire, in-stream ecological responses (as measured by growth of coastal cutthroat trout) appeared to be neutral at worst with evidence to suggest ecological benefit from the wildfire.

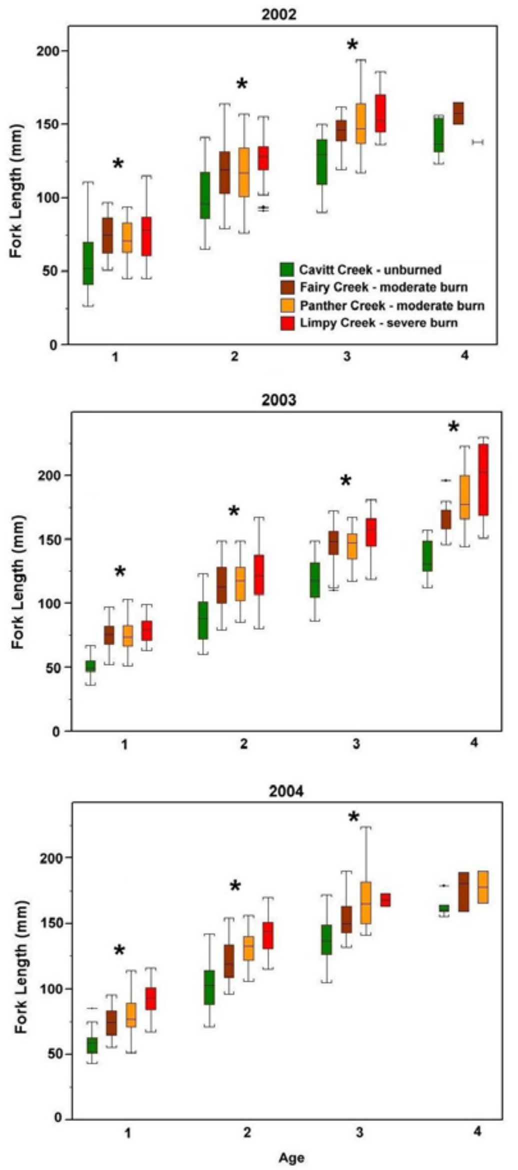

Figure 2. Mean back-calculated length at age of for coastal cutthroat trout captured in four headwater streams over three years. Each individual box-and-whisker plot contains the distribution of fish lengths at the end of their last complete year of growth. For example, Age 2 fish in Cavitt Creek ranged between 65 and 141mm by the end of their 2002 growth year. Data from the 2003 and 2004 growth years is also shown. Significant differences within each age group were tested for using analysis of variance (ANOVA). Age groups with significant differences (p < 0.05) are labeled with an asterisk.

STUDY TIMELINE

Fish sampling and stream habitat inventories have been completed. Age and growth analysis of scale samples have also been completed. A paper titled "Trout in headwater streams show increased growth following wildfire: Evidence to challenge a common perception" was presented at the North American Benthological Society's annual meeting in June 2006. In addition, a paper titled "Change isn't always bad: trout in headwater streams show increased growth following wildfire" was presented at the Ecological Society of America's annual meeting in August 2006. Data analysis will continue through December 2006, and a final report and manuscript for publication will be submitted in March 2007.

The Cooperative Forest Ecosystem Research (CFER) program was developed to facilitate sound management of forest ecosystems, with emphasis on meeting priority research information needs of the Bureau of Land Management (BLM) and the Oregon Department of Forestry (ODF) in Western Oregon.

The information contained in this document is preliminary in nature and has not been peer-reviewed. The data are not guaranteed to be correct or complete. Users are cautioned to consider carefully the provisional nature of the information.

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Program cooperators include: