Management Memo | Wildfire

EFFECTS OF WILDFIRE ON BENTHIC MACROINVERTEBRATE ASSEMBLAGES IN SOUTHERN CALIFORNIA STREAMS AND IMPLICATIONS FOR BIOASSESSMENT MONITORING PROGRAMS

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SWAMP
Surface Water Ambient Monitoring Program

OBJECTIVE

The objective of this memo is to inform management about the effects of wildfire on biological communities in streams and to propose several recommendations for research, monitoring and management needs of these ecosystems.

Background

Wildfires are common in arid regions of southern California, sometimes burning as much as half a million acres in a season. These fires often cause dramatic impacts to the vegetation and soils of regional watersheds and, consequently, to the streams that drain them. Water quality programs that monitor and regulate these systems have to account for the influence of these factors upon water quality measurements when making monitoring and regulatory decisions. This is true for traditional water quality measures (nutrients, metals, contaminants, etc.), but is especially important for integrative ecological condition indicators like bioassessment, the use of resident biological communities to infer water quality condition.

Since the mid 1990s, the San Diego Regional Water Quality Control Board (San Diego Water Board) has helped lead the development of bioassessment tools for wadeable streams in California. Throughout the Region, bioassessment is now used as a primary

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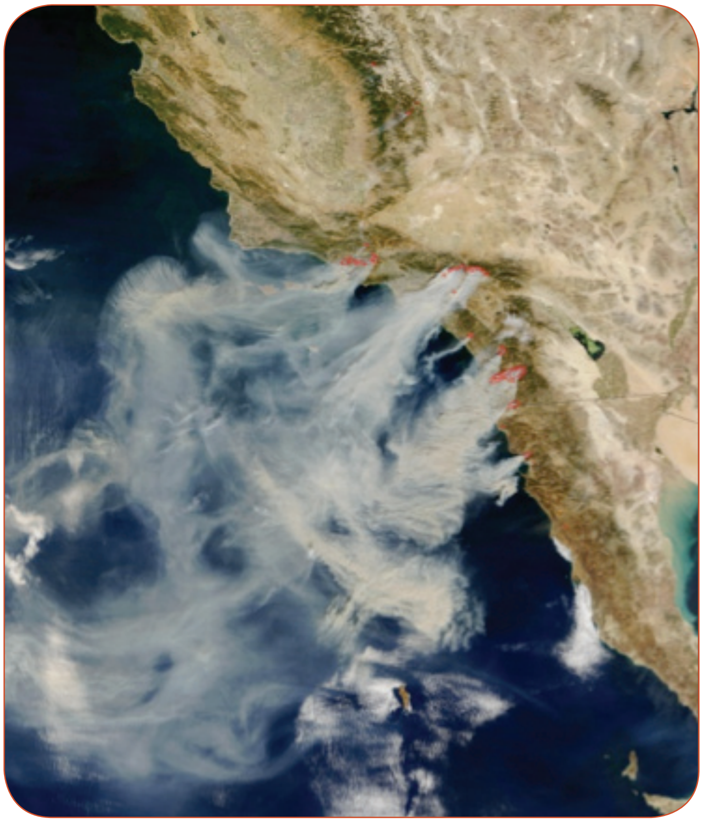

Figure 1. NASA satellite imagery of southern California taken in October 2003.

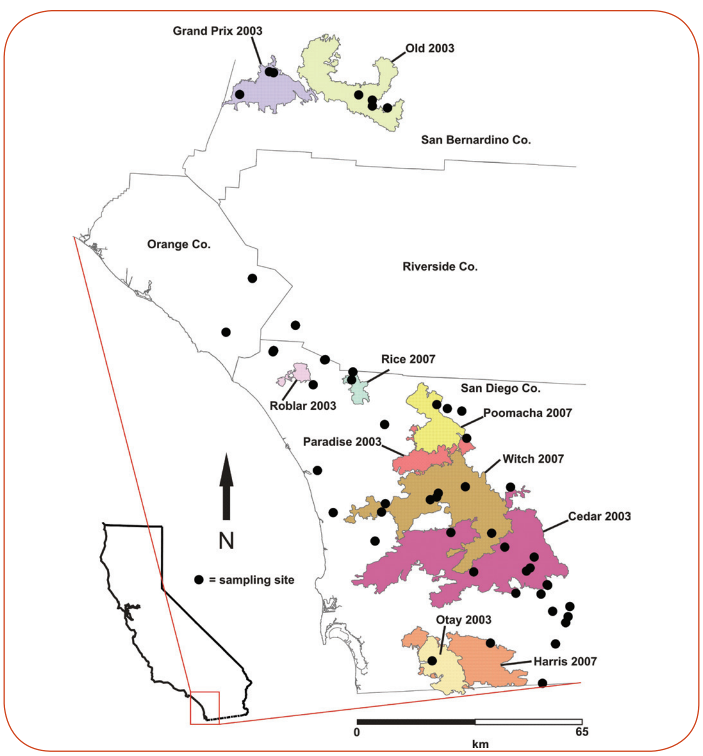

Figure 2. Map of fire perimeters for 2003 and 2007 wildfires in southern California and sampling locations where pre- and post-fire data were collected.

measure of water quality conditions, helping allocate monitoring resources, assess the effects of permitted activities, prioritize remediation efforts and measure the success of remediation.

Regional Water Quality managers need to understand the impacts of fires on bioassessment scoring tools in order to effectively direct regulatory action, permitting, and routine monitoring. Although this problem is widespread in arid regions, the implications of wildfires for biological monitoring programs are not well studied. To help fill this need the San Diego Board commissioned the Department of Fish and Game's Aquatic Bioassessment Lab (ABL) to conduct an investigation that began in 2004, encompassing significant fire seasons in 2003 and 2007.

The ABL's investigation was focused on 4 questions:

1. To what extent do wildfires affect biological condition scores at sampling sites?
2. How long does it take for biological condition scores to recover after a fire?
3. Does recovery time differ in developed and undeveloped watersheds?
4. What are the primary mechanisms by which wildfires affect biological condition scores?

This summary is extracted from ABL's technical report to the San Diego Water Board (Rehn et al. 2011).

Project History

Severe wildfires burned large portions of San Diego and southwestern San Bernardino counties in October 2003 and 2007 (Figure 1). Because of prior sampling investments by the San Diego Water Board and federal agencies (USFS and EPA), many of these fires burned watersheds where various state and federal agencies had previously established stream bioassessment monitoring sites. Since this set of sites consisted of both developed and undeveloped sites (i.e., reference sites), this situation presented a natural experiment to assess the impacts of wildfire on bioassessment data.

Methods

The ABL sampled benthic macroinvertebrates from 50 sites between 2004 and 2009 (i.e., post-fire), nearly all of which had also been sampled between 2000 and 2002 (i.e., pre-fire) (Figure 2). The biological data were supplemented with a suite of quantitative physical habitat measures of instream and riparian conditions. At the time of the study, two widely used bioassessment scoring tools were available for scoring biological condition in southern California streams, the SoCal Index of Biotic Integrity (SCIBI, Ode et al. 2005) and an Observed/ Expected (O/E) Index of taxonomic completeness (C. R. Hawkins, unpublished). Both tools measure the ecological condition of a stream based on the composition of the benthic invertebrates present at a sampling site.

For these analyses, sites were assigned to one of four categories: 1) burned, non-reference, 2) burned, reference, 3) not burned, non-reference and 4) not burned, reference. Non-reference sites were included to evaluate whether burn effects varied depending on site quality. The numbers of sites in each group varied each year.

Major Findings

Question 1: To what extent do wildfires affect biological condition scores at sampling sites?

- Biological condition scores were 30-50% lower at burned reference sites for two years following the 2003 fires and for one year following the 2007 fires (Figure 3b, 3d), suggesting that ecological condition was impaired for up to 2 years following fires at these sites.

- Some condition scores (O/E) were lower at burned non-reference sites for two years following the 2003 and 2007 fires (except for 2004). However, IBI scores at non-reference sites did not decrease following the two fire years, suggesting that O/E may be more sensitive at detecting additional impacts at stressed sites.

- Indicator species analysis of raw taxonomic data showed that burned reference and non-reference sites had greatly reduced taxonomic diversity and were characterized by rapid colonizing, pollution- tolerant taxa (such as black flies and minnow mayflies) in the first two post-fire years.

Question 2: How long does it take for biological condition scores to recover after a fire?

- In most cases, both IBI and O/E scores recovered by the third year following the 2003 and 2007 fires.

- The rapid post-fire recovery of BMI assemblages observed in this study (within 3 years) is congruent with BMI responses to wildfire reported in other recent studies and reviews.

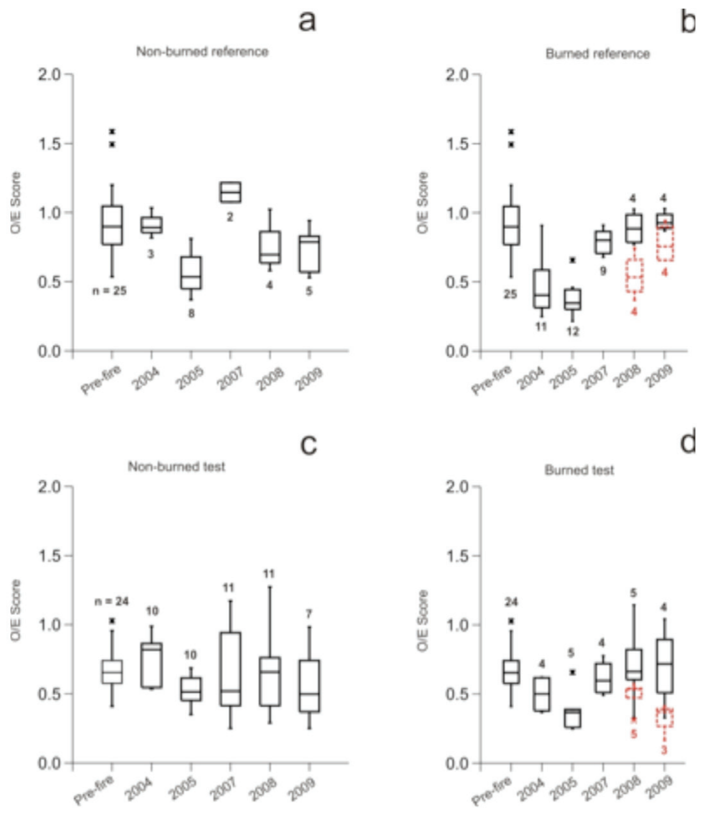

Figure 3. Box-and-whisker plots of pre- and post-fire distributions of O/E scores per year at (a) non-burned reference sites, (b) burned reference sites, (c) non-burned test sites, and (d) burned non-reference sites (test sites = non-reference sites). The box plots of burned reference and test distributions from 2008 and 2009 shown in dashed red are from sites that did not burn until 2007. Sample sizes per year are shown either above or below each plot.

Question 3: Does recovery time differ in developed and undeveloped watersheds?

- Some biological condition scores (O/E, but not IBI) decreased following burns, then recovered to pre-burn levels in the same three year time frame observed at reference sites.

Question 4: What are the primary mechanisms by which wildfires affect biological condition scores?

- Streambed alteration caused by catastrophic sediment erosion during the winter rainy season (Figures 4, 6, 7) appears to be a primary mechanism leading to decreased biological integrity scores in the year after a fire. However, even in cases of extreme physical change, IBI and O/E scores had recovered (i.e., were not significantly lower than pre-fire scores) by spring 2007.

- IBI and O/E were weakly correlated with physical habitat variables across burned reference and non-reference sites over time. At reference sites, both indices were more strongly correlated with mid-channel canopy density and riparian canopy cover than any other physical habitat variable. At non-reference sites, O/E was most strongly correlated with riparian canopy cover, but IBI was most strongly correlated with percent fast-water (e.g., riffle) habitat (Figure 5).

Other Factors Influencing Study Interpretation

- The conclusions of this study were complicated by low O/E and IBI scores at several non-burned reference sites (Figure 3a). This unexpected result may be due a combination of factors including non-perenniality of several sites in 2004, record rainfall in 2005, un-representative stream types and low sample sizes. Only three flowing reference sites were sampled in 2004 (Black Mountain, French and Troy Creeks). Of those, 2 have had chronically low IBI scores (Black Mountain and French Creeks).

- In 2005, we added four reference sites that were dry the previous year (Devil Canyon, San Mateo Creek, Fry Creek, Arroyo Trabuco). In addition, 2005 sampling followed a wet winter with record flows that may have affected spring sampling conditions. All benthic samples from non-burned reference sites in 2004 or 2005 had low sample counts (< 500 organisms). Extreme flashiness and associated difficulty in collecting representative samples in 2004-2005 may have impaired our ability to observe fire effects against the backdrop of variation in natural flows, but we did not have adequate data to evaluate this possible explanation.

- Site-specific variation is strong and impairs our ability to generalize response to fire stress.

Figure 4. Post fire stream bed alteration at West Fork City Creek in 2004

Additional Research Needs

Need to Learn More About Impact Mechanisms

There was considerable variability among sites in responsiveness to post-fire impacts, particularly with respect to intensity of streambed alteration and flow variability. Future studies should include direct measurements of more variables (e.g., chemistry, toxicity) to better increase our understanding of ameliorating and exacerbating factors.

Confounding Effects of Perenniality

The sensitivity of stream biota to post-fire disturbances appears to be confounded by inter-annual variation in winter flow intensity and stream perenniality. New research in this area should incorporate the relationships between these factors and fire susceptibility.

Need for Greater Sample Density

Interpretation of pre- and post- fire dataset was limited by small sample sizes and data gaps caused by inconsistent sampling of sites over time. Future studies should strive for consistent data collection from all sites over a consistent post-fire time frame.

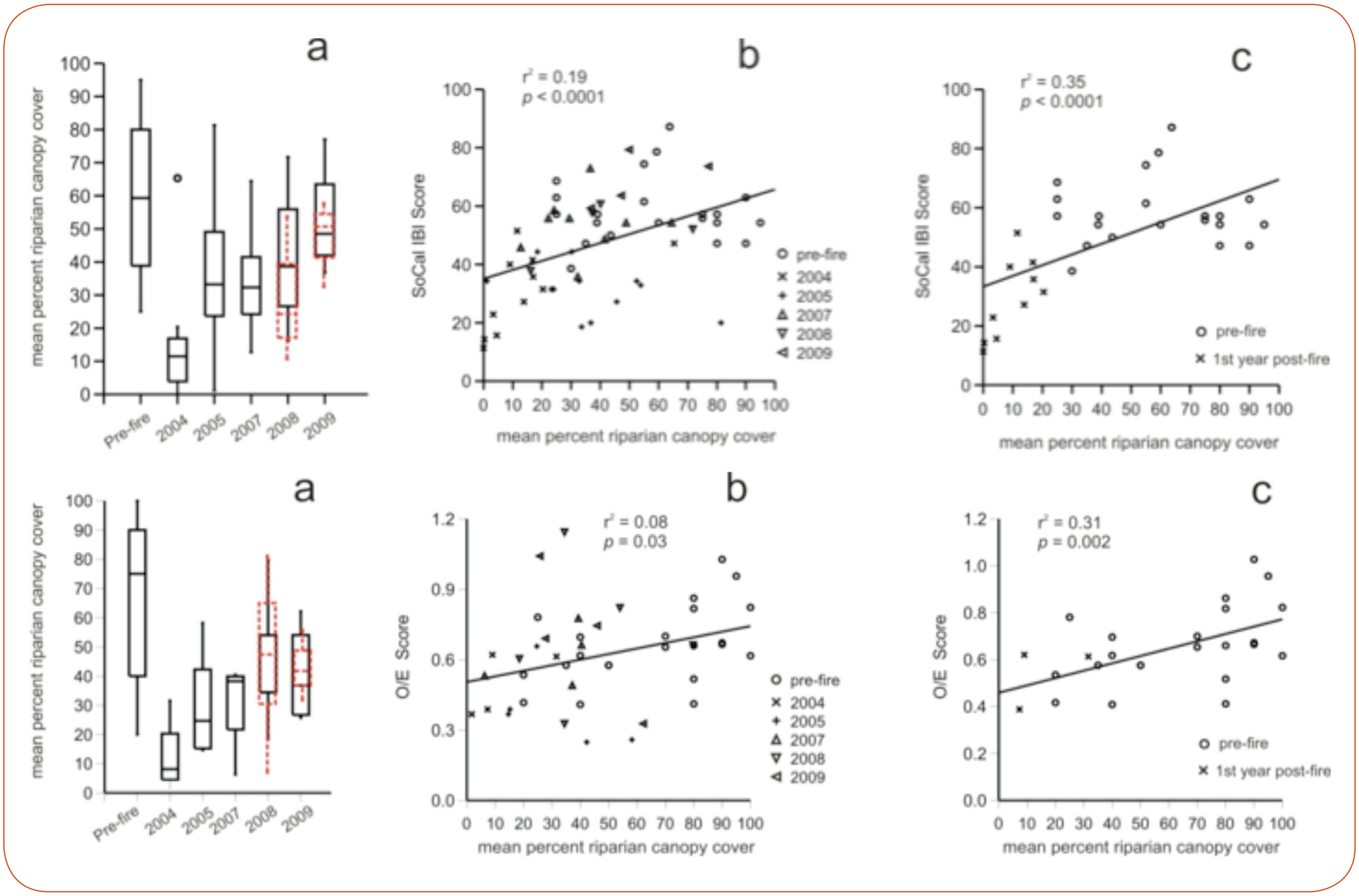

Figure 5. (a) Box-and-whisker plots of pre- and post-fire distributions of percent riparian canopy cover at burned reference sites (upper set of graphs) and burned non-reference sites (lower set of graphs). The distributions from 2008 and 2009 shown in dashed red are from sites that did not burn until 2007. (b) Scatterplots and least squares regressions of O/E on percent riparian canopy cover at burned test sites for all study years and (c) for pre-fire and 1st year post-fire (2004) only (test sites = non-reference sites).

Additional Condition Indictors

Future research should take advantage of new ecological condition indicators, particularly algal community and riparian condition indicators

Figure 6. Pre (2002) and post (2004) fire images showing extreme sediment deposition at Roblar Creek.

Recommendations for Monitoring and Management

Wait 3 Years for Reference Monitoring

Existing or candidate reference sites that have recently burned should be given 3 years to recover from post-fire effects before being used to monitor BMIs for trends in reference condition over time or to set BMI-based expectations for biological condition in indicator development.

Protect Riparian Zones

Pre- and post-fire anthropogenic disturbances in riparian corridors should be restricted or avoided because stream recovery is especially sensitive to, and dependent on, the extent to which riparian processes remain intact. This policy should extend to road construction and even fire minimization activities, such as extensive thinning and fire break construction outside of residential areas.

Develop Partnerships

Seek opportunities to partner with other regional monitoring programs (e.g., Stormwater Monitoring Coalition, permitted monitoring, see also Stein and Brown 2009 recommendations) to develop the capacity to gather more data and address the specific research needs listed above.

Integrate Fire Impact Research With Ongoing Non-Perennial Stream Research

Effective biomonitoring of non-perennial streams will require more complete understanding of fire impacts.

Figure 7. Debris flows in West Fork City Creek in winter 2003-2004 mobilized massive quantities of sediment.

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