The Effects of Wildfire and Ecological Context on Aquatic Biological Diversity

Study Plan for 2002-2003

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Summary

In 2002, the Boise Aquatic Sciences Laboratory initiated a multi-year study of the effects of wildfire and ecological context on aquatic biological diversity. Products from this work will assist management by providing new tools for monitoring stream-living aquatic vertebrate (fish and amphibian) responses to fire, predicting the effects of wildfire on nonnative species invasions, and predicting the effects of wildfire on native species and assemblages. This work plan provides background and details on completed and planned research for 2002-2003. This research is part of a larger collection of projects representing collaborations within the Forest Service and with external cooperators, including the University of Idaho and U.S. Geological Survey. Through these collaborations, our research will provide an integrated view of both biological and physical responses of headwater streams to wildfire.

Introduction

Concern over the potential risks posed by wildfire and wildfire management in the western United States has become increasingly focused on aquatic ecosystems. In particular, wildfire management is strongly influenced by regulations that protect the growing number of threatened and endangered species, and species of special concern. Among these species, fish and amphibians are an important focus. Unfortunately, available information on the effects of wildfire on these species is limited to case studies and conceptual guidance from landscape ecology. Consequently there is a great need to develop more useful information for evaluating the effects of wildfire on aquatic vertebrates (fish and amphibians), with a special emphasis on questions that are directly relevant to management issues. Common questions often posed by managers evaluating the effects of wildfire on aquatic vertebrates include:

"How can wildfire affect aquatic vertebrates?"
"What scales are relevant?"
"When and where does wildfire or wildfire management pose a threat?"
"Do wildfires facilitate invasions of nonnative species?"
"What management alternatives are most likely to benefit aquatic vertebrates?"

Simple, useful answers to these questions are challenging, because aquatic ecosystems and the effects of wildfire may be very complex. Models that provide guidance to complement existing tools used in Forest Planning and analysis could be particularly useful for integrating concerns over aquatic vertebrates into prioritizing fuels treatments.

Overall, our objectives are as follows:

1. Develop new tools for monitoring aquatic vertebrate population responses to fire
2. Understand responses of key habitat variables to fire (channel structure, dynamics, and stream temperature)
3. Develop models to:
    a. Predict responses of native aquatic vertebrates to fire and related influences (Figure 1)
    b. Predict responses of nonnative aquatic vertebrates to fire and related influences (Figure 1)
    c. Construct hypotheses about cause-and-effect relationships between aquatic vertebrates, fire, and related influences
4. Work with managers to develop applications of these results in prioritization of fire management alternatives to benefit native aquatic vertebrates and to deal effectively with nonnative fish invasions.

Embedded within each of these general objectives are a number of important details and complexities that provide many challenges to understanding linkages between aquatic vertebrates and fire. Below, we provide a summary of what we believe to be the key issues, and how we intend to address them in this series of studies.

Background

Within a single study, we can only address a limited number of questions regarding the effects of wildfire on aquatic vertebrates, so we are beginning with a very basic hypothesis. We hypothesize that wildfire will pose risks to aquatic vertebrate populations under a limited range of conditions. Specifically, we *predict* that wildfire will pose the greatest risks to native vertebrates when habitats are small and isolated (e.g., highly fragmented), and disturbed by human influences (e.g., land use impacts, harvest, nonnative species). Dunham et al. (in press) develop the background for this hypothesis in more detail.

Our general view of how wildfire and related influences may affect aquatic vertebrate populations is described in Figure 1. The major effect of wildfire on aquatic vertebrate populations is believed to result from disturbances to stream channels following a burn. For example, reorganization of channels and disturbance caused by landslides, floods, and debris flows. Aquatic vertebrate populations could be directly affected during these events, or by changes in stream channels following these events. Channel disturbance, coupled with loss of vegetation caused by wildfires, may result in increased stream temperatures following a fire. This could result in losses of thermal habitat and reduced distribution for species that require cold water (indirect effects) or have direct effects on individuals exposed to hot summer temperatures resulting from increased stream heating (e.g., growth, mortality, behavior, population size).

Human disturbance may also be associated with stream heating. By itself, human disturbance may affect aquatic vertebrate population responses, or interact with wildfire to render aquatic vertebrate populations more vulnerable to fire effects. Both wildfire and human disturbance can affect landscape structure, which in turn could affect aquatic vertebrate populations. For example, fragmentation of habitats for salmonid fishes is related to the amount and distribution of cold water on the landscape, and fish passage barriers, such as culverts and dams.

Site characteristics are related to influences of landscape processes, and may have important influences on aquatic vertebrate at small scales. Factors such as local habitat size, occurrence of particular species (e.g., predators or competitors), and localized channel features may be important.

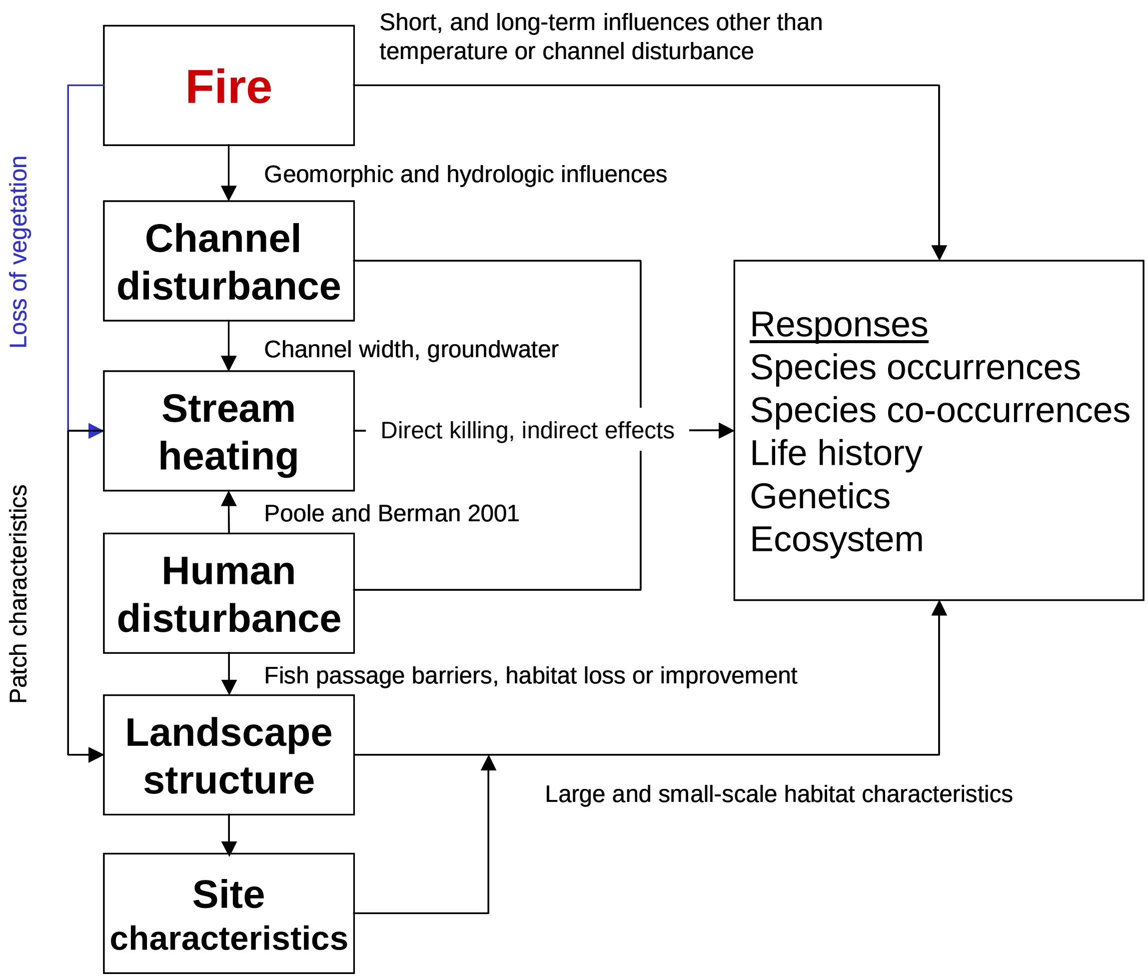


Figure 1. A simplified diagram showing potential pathways through which fire and related factors may affect aquatic vertebrate populations. A number of potential aquatic vertebrate population responses are indicated on the right side of the diagram.

Study Approaches

Year 1

Activities and studies in Year 1 will form the foundations for future work. Our first objective is to develop models of sampling efficiency for all commonly observed species within the habitats we intend to study (small headwater streams). Research on bull trout suggests sampling efficiency is strongly related to environmental conditions. Consequently, it is necessary to understand the relationship between sampling efficiency and environmental conditions *before* making inferences about how environmental conditions affect aquatic vertebrate per-se. Our second objective is to better understand key environmental gradients and how they are distributed across the landscape. We have developed GIS-based coverages of streams that include documented fire histories, channel disturbance (in limited areas interpreted from aerial photography), and basic stream and watershed characteristics (e.g., catchment area, channel slope, elevation). Additional information on known patterns of aquatic vertebrate occurrence, land use, passage barriers, and other relevant features will be mapped and added to the GIS database in the future. For this year's field work, we are measuring temperatures along longitudinal gradients in a variety of streams draining burned and unburned watersheds to develop elevation-based models of stream temperature that incorporate the influence of fire history (e.g., timing of fire, severity, and extent). These models will allow us to predict and possibly map stream temperatures on the landscape, and understand spatial and temporal changes in availability of suitable thermal habitat (e.g., cold water) resulting from the effects of wildfire. Additional temperature data will be collected from existing sources and incorporated into modeling and mapping efforts. Understanding the distribution of cold water on the landscape is key to understanding fish populations. Finally, we will use our preliminary information on aquatic vertebrate populations in unburned and burned watersheds to refine and develop hypotheses about responses to fire.

Year 2

Year 2 is the beginning of the first of several years of research to define the effects of fire and related influences (Figure 1) on aquatic vertebrate. The foundation provided in Year 1 will significantly affect details of how the project is implemented, but some general facets of the project can be described for now.

Rationale

Our approach in this work is to identify relationships between aquatic vertebrate population responses and general types of site and landscape characteristics that are believed to have controlling influences. This includes both direct and indirect effects of fire, as indicated by pathways in Figure 1. The details of all of the possible mechanisms through which fire can affect aquatic vertebrate populations are unknown and likely too numerous and complex to cover in this study. However, it is possible to produce useful *predictive* models (as opposed to mechanistic models) that are based on simplified mechanistic pathways, as described in Figure 1. Such models can be immediately useful for prioritizing landscapes for conservation and restoration, identifying specific factors that may be important to aquatic vertebrate, and framing hypotheses to be tested through more detailed investigations in the future. Whenever possible, we will model probabilistic responses that can easily be integrated with decision support models. Our approach also allows for a large sample size, and does not depend on imposition of treatments or manipulations, or before-after data. We will make use of new information collected with our standardized protocols and sampling designs, but also utilize existing data to the full extent possible. Existing data can be useful for delineating sampling frames and study planning, and also serve as datasets for model testing and application. We do not expect our models to produce precise predictions. This does not mean the models are of limited utility. It is just as important to understand model parameters as well as the uncertainty in model predictions. We are wary of so-called "*highly precise wrong answers*."

Our work will focus on small (e.g., 1^{st} to 3^{rd} order) headwater streams: systems where we believe responses to fire are most likely. This will include streams within the Salmon River subbasin and Payette-Boise River subbasins. The Salmon River is unique in that it supports cutthroat trout, and many localities also support populations of anadromous salmon and steelhead. In the Salmon subbasin, we are currently focused on Panther Creek, which has widespread cutthroat trout, but very limited populations of anadromous salmonids. We will be working throughout the Boise River subbasin, and focusing on the Middle-South Fork Payette River systems within the Payette subbasin. By working in a number of different areas, we will have a better understanding of spatial variability in the response of aquatic vertebrates to fire.

Our goal is to collect a large number of samples to cover a wide range of conditions and variables for modeling aquatic vertebrate responses to fire. Our most basic unit of study will be a "site" or small length of stream that is sampled for aquatic vertebrate population and habitat features. The length of sites to sample will depend on results of Year 1 studies. Sites will be located within streams, which in turn will be nested within each subbasin. Thus, there are at least three spatial scales at which results of this work can be considered: sites, streams, and subbasins. Work this winter (2003) will be focused on developing a sampling frame from which we can select study locations at each of these scales.

In addition to a range of spatial scales, we will also consider a range of different variables to relate to aquatic vertebrate population responses. The following discussion is organized to follow general descriptions of influences of different environmental variables on aquatic vertebrate shown in Figure 1.

Site characteristics

Site characteristics affect both sampling efficiency and aquatic vertebrate population responses. Site characteristics related to sampling efficiency will be determined through analysis of Year 1 data. Site characteristics that may be important to aquatic vertebrate include channel structure (e.g., width, depth, and slope), temperature, instream cover (e.g., wood, undercut banks), occurrence of other species (e.g., potential predators or competitors), substrate composition, and water chemistry (e.g., dissolved solids).

Landscape structure

The amount and distribution of suitable habitats within a landscape has been shown to be a consistent predictor of aquatic vertebrate occurrence. For example, fish populations are more likely to occur in larger, interconnected habitats. The structure of landscapes is a function of natural processes, including the effects of fire, and human disturbance, including habitat loss and isolation by passage barriers.

Human disturbance

Human disturbance is widely believed to have a pervasive influence on aquatic vertebrate populations, but tying a specific kind of disturbance to aquatic vertebrate can be difficult. For example, forest roads can have impacts on aquatic vertebrates through a variety of mechanisms, including increased angling pressure due to improved access, sedimentation from roads, diversion of flows and channel erosion, passage barriers at road crossings, and increased risk of pollution. In spite of the potential complexities associated with the effects of roads, decreased road densities have been consistently associated with healthier aquatic vertebrate populations. For example, simple measures of human disturbance on landscapes, including road densities, patterns of land use, and development can provide useful models for understanding fish responses.

Stream heating

Most aquatic vertebrates inhabiting headwater streams are sensitive to temperature, and dependent on cold, clean water for survival, growth, and reproduction. Stream temperatures can be considered in terms of both the spatial and temporal distribution of conditions among seasons (within a year), and across years (e.g., climate cycles, climate change). Patterns of stream temperature and heating are the product of natural physical processes, and influences of human disturbances. Both the temperature of a particular location and conditions in the surrounding landscape (e.g., amount of thermally suitable habitat) can be important for fish populations.

Channel disturbance

Channel disturbance, in the form of debris flows, floods, and landslides, can have important effects on stream environments and fish and amphibian populations. The effects of disturbance may be conditioned on the timing, magnitude, and nature of how key environmental conditions are affected.

Fire

Many of the factors described above are related to fire, or have effects that are modified by fire. Fire can have many other effects that may not be related to the variables above, however. For example, short-term physiochemical changes could be important in some situations. To account for these kinds of effects, we will model aquatic vertebrate population responses in relation to the fire history of a watershed. For example, the area and severity of fire, time since fire, location, and vegetation type that was burned.

Study Implementation

This section describes the details of implementing the study outlined generally above. A time frame for major study activities is shown in Table 1.
Table 1. Time frames for major study activities for 2002-2003.

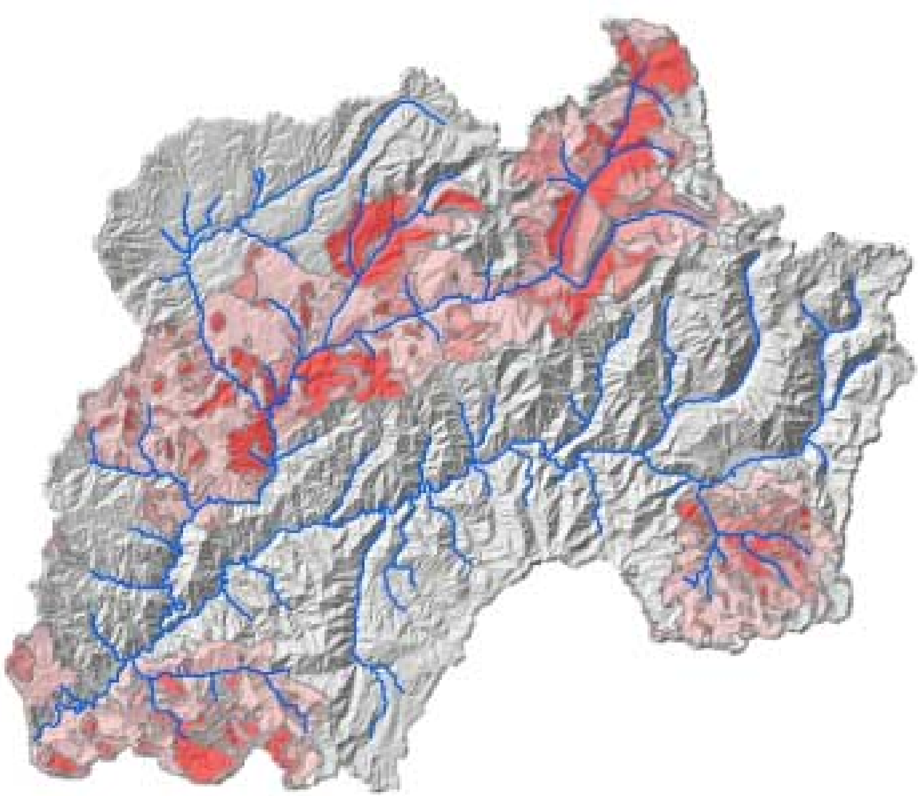
Project Year	Activity	Time frame
FY 2002	Complete field operations for 2002	October 2002
	Begin data summary and analysis	October 2002
	Complete data analysis and submit papers from FY 2002 work for publication	October 2002 - March 2003
FY 2003	Develop preliminary list of major variables to include in future study	October 2002
	Work with list of variables to develop sets of candidate models for predicting different responses of aquatic vertebrates to fire	April - May 2003
	Summarize existing information for all potential study sites to develop a "sampling frame" for fieldwork in 2003	March 2003
	Use sampling frame to develop and evaluate alternatives for sample site selection	April 2003
	Plan field logistics, interagency coordination, permits, reporting, etc.	December 2002-May 2003
	Develop final sampling plan for 2003	May 2003
	Initiate hiring of field crews for 2003	February 2003
	Hiring and training of field crews	June 2003
	Initiate field work	July 2003
	Complete field work	October 2003
	Data summary and analysis	October 2003-April 2004

Project Details: FY 2002

The objectives for FY 2002 were to develop a foundation for future work (2003-2005). There are four specific objectives tied to this initial effort: 1) acquisition of existing information on aquatic vertebrate populations (fish and amphibians), local habitat and landscape characteristics, including information on fire history; 2) preliminary field sampling in burned and unburned streams for comparison of aquatic vertebrate distribution and diversity; 3) development of sampling methods for aquatic vertebrates; 4) empirical modeling of stream temperature gradients, with special reference to the effects of post-fire stream heating. A progress summary for each objective is listed below.

1) Acquisition of existing information. We have acquired GIS coverages, including data from the Salmon-Challis, Boise National Forests to create a base layer of digital elevation maps, streams, roads, and fire histories for the Panther Creek and Boise River basins. We have also modeled stream characteristics using models from Utah State University to describe basic characteristics of each stream segment in the basin, including elevation, contributing drainage area, and channel slope. This information played an important role in guiding fieldwork for 2002. Work on data acquisition will continue through 2003. Data available on file now can be obtained by request.

Figure 1. GIS map of the Middle and North Fork Boise Rivers upstream of Arrowrock Reservoir showing information on recent fires and fire severity (red = high severity). These data from the Boise National Forest, and DEM information are summarized to provide detailed information on fire histories and watershed characteristics.



2) Preliminary sampling of aquatic vertebrates and habitat in burned and unburned streams. Fieldwork was just completed, and data summaries are in progress. To date we have collected information on aquatic vertebrates (fish and amphibians) at sites in over 25 streams with different fire histories. Our focus is on populations in smaller, headwater streams, which are hypothesized to be most vulnerable to the effects associated with fire (Dunham et al., in press). This new data will be merged with existing information available within each study basin in future efforts. This larger database will allow further evaluation of associations between aquatic vertebrates and fire, and provide a basis for designing future sampling efforts. Methods for fieldwork conducted in 2002 are available on request (jbdunham@fs.fed.us).

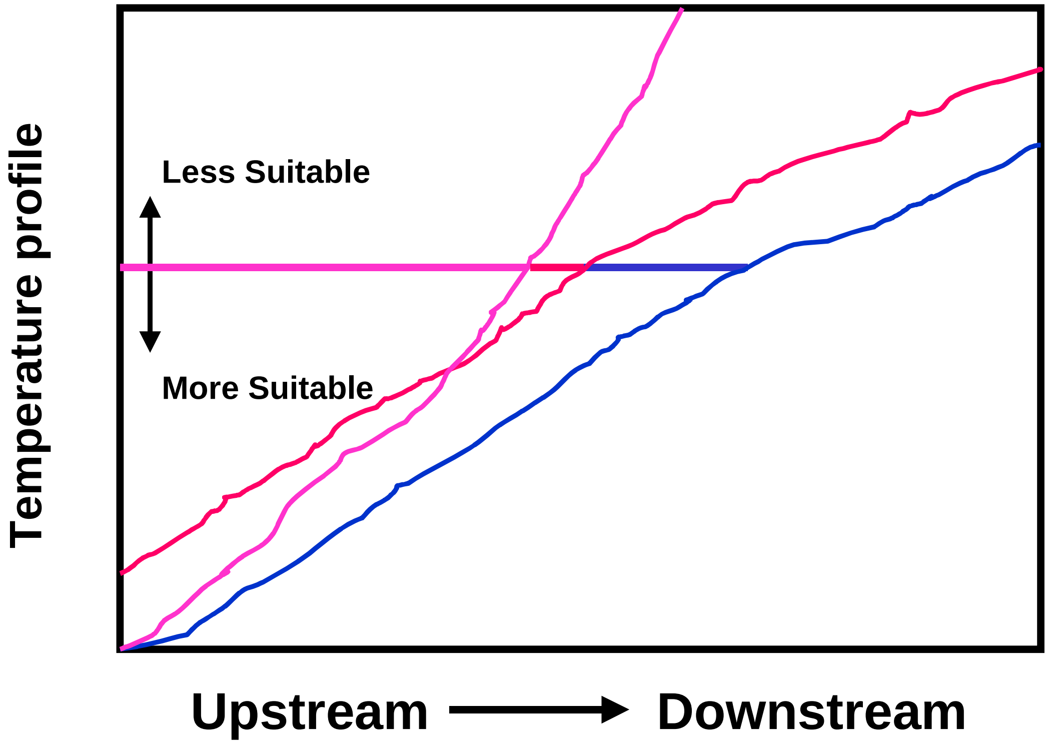
Figure 2. Shorthead sculpin from South Fork Sheep Creek, Boise basin.

3) Development of sampling methods. Sampling at the sites is intensive, involving multiple electrofishing passes and mark-recapture. This is because the objective is to establish baselines for sampling, based on a rigorous assessment of sampling efficiency. In spite of the fact that electrofishing has been used to sample fish populations for several decades, there has been no effort of this kind to understand sampling efficiency, with the exception of bull trout. Work from 2001-2002 will provide an important contribution to population monitoring associated with fire effects and in general for aquatic vertebrates.

Figure 3. Sampling fish in the North Fork Boise River basin using backpack electrofishing.

4) Empirical modeling of stream temperature gradients. Our work in other regions shows that stream temperatures can be predicted accurately using elevation-based empirical models. The relationship between elevation and stream temperature is a measure of the rate of stream heating. Our hypothesis is that fire history (e.g., time since fire, burn severity, area burned upstream) should have an influence on patterns of stream heating. We predict stream temperatures to increase following fire, due primarily to loss of vegetation and changes in channel structure. Because most aquatic vertebrates in headwater streams depend on cold water, we expect the amount and distribution of suitable habitat to change following fire. Our interest is in quantifying loss of thermal habitat, and understanding how long it takes for burned systems to return (if they do) to pre-fire conditions. Other research on aquatic vertebrates shows the amount and distribution of suitable habitat is a key factor related to population persistence. Overall, we have deployed over 220 thermographs in 22 streams in the Boise River and Panther Creek basins to measure stream heating in relation to fire history. We will complement this dataset with existing information on temperature and related variables collected by the National Forests and other agencies.

Figure 4. Possible patterns of stream heating following fire. Diagonal lines on the graph represent a general pattern of heating as streams flow from high elevation headwaters to downstream reaches. The blue diagonal line represents a hypothetical pattern of heating in an unburned stream. Streams may be warmer overall (red diagonal line), or heat faster (pink diagonal line) following a fire. The result of warmer conditions is less available habitat, as indicated by the horizontal colored lines, representing the amount (stream length) of suitable habitat associated with each pattern of stream heating. The horizontal lines correspond to an arbitrary thermal boundary between "more suitable" and "less suitable" habitat for a particular species.



Project Details: FY 2003

Details for implementing research in FY 2003 will be constantly evolving during the course of the winter and through early summer of 2003 (Table 1). Accordingly, plans described herein should be expected to change somewhat in the near future. The first and most important step is to identify the main driving variables and their potential interrelationships among themselves, and with biological responses (Figure 1). Each of the main variables (effects) in Figure 1 can be described in a variety of ways (Table 2). Variables can be described as "primary" (directly measured) or "derived" (derived from combinations of primary variables or from models).

Table 2. Major effect categories (Figure 1, left side), and potential primary and derived variables that describe each effect.

Effect	**Primary Variables**	**Derived Variables**
Fire	Location burned Extent of burned area Time of burn Severity of burn Type of vegetation burned	Fire index (combination of vegetation burned, extent, severity, and time since fire)
Channel disturbance	Location of disturbance Extent of area disturbed Time of disturbance Severity of disturbance Type of disturbance	Modeled disturbance probabilities
Stream heating	Measured temperature Amount of suitable thermal habitat	Modeled temperature Patch area (if defined by temperature)
Human disturbance	Road density Occurrence of nonnatives Passage barriers Land use/condition overlays	Modeled road effects (e.g., major sources of sediment, weighted influence functions for a particular segment/site) Isolation index (e.g., function of how much aquatic vertebrate passage is impaired) Land use impacts index (e.g., some index of cumulative human influences)
Landscape structure	Patch area Patch isolation Fire (see above) Human disturbance (see above) Geology Landform	Fragmentation indices Overall index of disturbance (e.g., some combination of human + natural and human or natural) – as determined through PCA-type analysis
Site characteristics	Variables related to sampling efficiency Standard variables depth width wood substrate conductivity or TDS temperature @ sampling	Estimated sampling efficiency /detectability Modeled temperatures (e.g., maximums, means)

Choosing a biological response

There are a variety of responses that aquatic vertebrates can have to the factors listed in Figure 1. A focus on species occurrence will be our priority in 2003. At the most basic level, we are interested in patterns of occurrence (presence or absence) for each species, and patterns of coexistence among different species (Table 3). Important patterns of coexistence include relationships between co-occurrence of native and nonnative species, such as nonnative brook trout and native trout, or nonnative trout and native amphibians. The relationship of species to one another may be just as important as other environmental variables. Variables can be summarized across all species, among different species, or within a different species (e.g., different size or age groups). Information on species abundance (standing crop) is also being considered as a potential response.

From results of fieldwork in FY 2002, we anticipate the most common species encountered in our study systems, in descending order of abundance, will be rainbow trout, tailed frog, bull trout, shorthead sculpin, brook trout, cutthroat trout, and western toad. Other species may be found with additional sampling, and the relative abundance of each will vary on a site-to-site basis.

Table 3. Major potential responses (Figure 1, right side) of aquatic vertebrates to effects of fire and related influences to be measured during field work in 2003. Each response variable is described in terms of units of measure, and whether or not it requires field sampling for presence, abundance, size structure (e.g., weight and/or length).

Response	**Units**	**Presence**	**Abundance**	**Size structure**
Observed presence	0, 1	+	-	+, -
Standing crop	Density (fish/m^2)	+	+	+, -
Standing crop	Biomass (g/m^2)	+	+	+, -
Species composition	Species richness, size classes	+	-	+, -
Species composition	Dominance, evenness	+	+	+, -
Species composition	Coexistence	+	-	+, -
Species composition	Size structure	+	-	+

Additional biological responses

Other biological responses that fall into the categories of life history, genetics, and ecosystem attributes may be considered (Figure 1) if funding allows. Additional funding will be needed to use modified sampling designs to measure these responses, and for additional sample processing (e.g., aging scales or conducting genetic analyses). It will be unlikely that resources will be available to study these attributes for more than one or two species. Our priority taxa for efforts to examine additional responses will be rainbow trout and bull trout. These species are potentially present throughout all study areas. In terms of habitat specificity, rainbow trout can be described as a “generalist” and bull trout as a “specialist” among the common aquatic vertebrates in headwater streams in our study basins. For example, bull trout are usually restricted to the coldest, headwater portions of streams, whereas rainbow trout are considerably more widespread in regard to temperature. Rainbow trout are easier to work on because they are not listed under the U.S. Endangered Species Act, and impacts to individuals through research are less of a concern. Thus, it is possible to collect sacrificial samples if necessary.

Life history – related variables that may be considered include size structure, and age and growth patterns. Age and growth patterns can be inferred from scales or otoliths (ear bones). Either should retain a record of annual growth increments, and size-at-age can be determined for each individual fish and compared among samples with different characteristics. Size structure and scale samples will be collected during surveys of aquatic vertebrate occurrence to allow future opportunities to investigate life history variation.

Genetic patterns may prove particularly useful in identifying population bottlenecks or founder events associated with disturbance or fire effects on population size. Research on fish population responses to fire indicates that populations can rapidly rebound following a fire. Thus, within a single to few years following a fire, it may not be possible to detect the effects of fire because fish populations have fully rebounded. However, if the population was reduced to a very small size during the fire or other disturbance, it will be possible to detect the reduction in population size by looking at patterns of genetic variation within the population. Thus, genetic markers can provide a useful signal for transient reductions in population size, even if the present population size is very large. This is a useful complement to analyzing patterns of occurrence (presence-absence). In a sense, signals of genetic bottleneck or founder events can be considered to be “early warnings” of risks to population persistence and occurrence.

Another important genetic consideration is hybridization. Some species in our study systems can and do hybridize in nature (brook-bull trout; rainbow-cutthroat trout). Patterns of hybridization in relation to environmental characteristics are only beginning to be understood. It is possible that, like other species, hybridization may be more likely to occur following environmental disturbances and reductions in population size. Thus, both patterns of genetic variation and hybridization can be important indicators of fire and other disturbances or environmental influences on aquatic vertebrates. Non-invasive tissue (fin) samples will be collected during surveys of aquatic vertebrate occurrence to allow the opportunity to study genetic patterns.

It is unlikely we will have the time or funding to study the ecosystem effects associated with fire, but we will pursue opportunities as they arise. Ecosystem effects include the importance of aquatic vertebrates to the structure and composition of associated fauna and flora, and fluxes of energy and nutrients through their influences as predators, prey, and sources of energy. For example, in many areas salmonids are thought to contribute massive amounts of nutrients through carcasses left behind following spawning, or by altering important parts of aquatic food webs. Thus, the effects of fire or other environmental influences listed in Figure 1, may affect other ecosystem components through initially affecting aquatic vertebrates. It is our priority to quantify the first-order effects on aquatic vertebrates before looking into "indirect" effects.

Choosing a scale to work at

The scale at which a biological investigation is conducted can have a profound effect on the results of a study, and it is becoming increasingly obvious that studies addressing multiple spatial or temporal scales are most likely to produce useful results. Our most basic unit of study in this investigation will be a "site" representing a short length of stream (100 m). By working in 100m stream segments we are ignoring "microhabitat" variables that could be important to occurrence of aquatic vertebrates on very small (<100m) scales. Patterns at small scales are important, but in general, management planning is oriented toward patterns at much larger spatial scales. Sites will be nested within streams (e.g., we will sample multiple sites within a stream), and streams will be nested within larger basins (e.g., Panther Creek versus Boise River). Thus, it will be possible to look at responses among sites within streams, among streams within basins, and between basins. Processes working at all of these scales can be important.

Choosing locations to work in

As described above, we have initiated work in the Panther Creek and Boise River basins. We are considering the opportunities to work in other adjacent areas as well (e.g., South Fork Payette River basin). Our effort to develop a "sampling frame" (Table 1) will provide the basis for choosing locations to work in for this study. Basically, the sampling frame will consist of relevant information on landform (stream catchment area, valley slope, elevation, Shreve link number), fire history (Table 2), disturbance (Table 2), and data for occurrence of aquatic vertebrates. The details of what exactly will constitute the sampling frame, in terms of exact kinds of information, are being worked out. In concept, however, we want to have a prior representation of conditions throughout the areas will be working in (Panther Creek, Boise and South Fork Payette Rivers). Within this area, we can test a variety of sampling schemes to see how representative alternative sampling approaches are of the range of conditions within the sampling frame. Because we are working within a nested spatial framework (see above), a logical approach to start with random selection of headwater streams (defined by size criteria to be determined) within each major area, with random location of sites for sampling within each selected stream. This two-stage random selection of study sites should provide an unbiased sample from which we can make inferences about the effects of fire. One important question that can be resolved is the utility of stratifying samples. For example, randomly select samples within strata defined by different fire histories, or other variables of interest. Through careful advance planning using known information, we can develop a better field sampling design to address our objectives.

Products

Products and/or tech transfer delivered in 2002:

We have two papers describing much of the rationale behind our project:

Dunham, J.B., M.K. Young, R.E. Gresswell, and B.E. Rieman. In press. Effects of fire on fish populations: landscape perspectives on persistence of native fishes and non-native fish invasions. Forest Ecology and Management.

Dunham, J.B., S.B. Adams, R.E. Schroeter, and D.C. Novinger. In review. Alien invasions in aquatic ecosystems: toward an understanding of brook trout invasions and their potential impacts on inland cutthroat trout. Reviews in Fish Biology and Fisheries

Some of the work in these publications has been presented at scientific meetings, including the Fire and Aquatic Ecosystems Workshop (http://www.fs.fed.us/rm/boise/teams/fisheries/fire/firehome.htm), and the 2002 Annual Meeting of the Society of Ichthyologists and Herpetologists.

Products anticipated in 2003:

In 2003 we will continue to be in contact with local biologists and regularly disseminating information through new publications, meetings, workshops, and personal communications.

Planned manuscripts (tentative titles and target journals)

Effects of wildfire on summer thermal habitat for aquatic vertebrates in headwater streams (Potential target journals: Canadian Journal of Fisheries and Aquatic Sciences; Transactions of the American Fisheries Society; Freshwater Biology; Ecological Applications)

Efficiency of electrofishing for four salmonid fishes in headwater streams: individual-based predictive models (Potential target journals: Canadian Journal of Fisheries and Aquatic Sciences; Transactions of the American Fisheries Society; North American Journal of Fisheries Management)

Factors affecting detectability of fishes and amphibians in headwater streams using backpack electrofishing (Potential target journals: Canadian Journal of Fisheries and Aquatic Sciences; Transactions of the American Fisheries Society; North American Journal of Fisheries Management)