2005 Annual Report

CFER

December

USGS
science for a changing world
USGS Forest and Rangeland Ecosystem Science Center

Oregon Department of Forestry

Bureau of Land Management

Oregon State University
College of Agricultural Sciences and College of Forestry

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.

Mission

The CFER program will work closely with resource managers, researchers, and decision-makers to develop and convey information needed to successfully implement ecosystem-based management at forest stand and watershed scales, especially on lands dominated by young forests and fragmented by multiple ownership.

Goals

- To provide forest managers with new information to evaluate current and proposed strategies and practices associated with management of forest ecosystems
- To facilitate development of sustainable forest practices through team-oriented, integrated research

Objectives

- To further the understanding of ecological relationships in forest ecosystems with special emphasis on biodiversity and its management in young forest stands and riparian zones
- To deliver information to cooperators, forest managers, and the general public in a timely and responsive manner

Cooperators

The CFER program cooperators provide financial support, faculty and staff to conduct research and information exchange, study sites, assistance with project installations, and in-kind support as needed.

Program cooperators include:

Bureau of Land Management

Oregon Department of Forestry

Oregon State University — College of Agricultural Sciences and College of Forestry

USGS Forest and Rangeland Ecosystem Science Center

The Cooperative Forest Ecosystem Research Program

Annual Report 2005

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December 2005
Corvallis, OR

Chronology and Highlights of Program (1995–2005)

1995 • Initial cooperative agreement signed with the BLM, OSU, and USGS FRESC

1996 • Scoping meetings conducted with the BLM to determine information needs

1997 • CFER Problem Analysis completed

• Initial CFER research team established

1998 • ODF joined as a program cooperator

• Pilot studies and preliminary field work conducted

1999 • Initial research themes developed

• Integrated projects and field work underway

2000 • Research conducted on the initial research themes

• Meetings held with focus groups and district contacts on future research directions

2001 • New research initiative developed examining the influences of riparian vegetative community composition on animal community response

2002 • Report published on managing for biodiversity in young Douglas-fir forests

• Workshop held to convey results of the Tillamook Thinning Project

2003 • Scope of CFER information exchange program expanded to include the BLM Density Management Study

• Landscape Scenario Analysis Project initiated to evaluate alternative forest management scenarios

• Five-year review of the CFER program conducted

2004 • Density Management Study Workshop and Field Tour organized and hosted for the BLM

• Final report completed for the Landscape Scenario Analysis Project

2005 • Workshops conducted with BLM and ODF cooperators to identify research needs and priorities to help guide development of CFER's new Strategic Plan

• New aquatic ecologist, Jason Dunham, joined the CFER research team

My first year of leadership of the CFER program has coincided with a number of changes within and around CFER. For the old friends of Bob Gresswell, I can report that he is well and doing fine in Montana. We do still claim a little of his time to finish up some work, so you will be hearing of him for a couple of years to come.

A new aquatic ecologist, Jason Dunham, has been hired by the USGS Forest and Rangeland Ecosystem Science Center (FRESC). Jason will have a role in new CFER stream-related projects. While his work in Idaho for the Forest Service was focused on fish population biology, his current research looks more broadly at landscape ecology and conservation biology of stream fishes and habitats.

Christian Torgersen started work with CFER as a post-doc with Bob Gresswell in 2002, but he quickly moved into the role of team landscape ecologist. Sadly, Christian has moved to the Seattle FRESC office. Christian has been an energetic contributor to the success of CFER, and we will miss him. We will do our best to keep him involved with CFER.

We have been engaged this year in a review of both our research priorities and our decision process. Our original research priorities came from the 1996 CFER Problem Analysis. This year, we held a series of discussions with Bureau of Land Management (BLM) and Oregon Department of Forestry (ODF) cooperators to identify important information needs. Out of these have come a new set of research theme areas: 1) stand structure and biotic responses, 2) landscape dynamics and cumulative effects, 3) riparian processes and functions, 4) ecological monitoring and long-term research, and 5) fire ecology and management. The stand structure research theme continues ongoing work and adds a young stand dimension. The landscape theme is new and addresses the many processes that interact across complex landscapes. The riparian theme is focused on lateral and longitudinal processes of riparian systems and includes the existing riparian food chain project. The monitoring theme seeks to improve the systems of ecological monitoring and the understanding of the results of monitoring. The fire program looks at the effects of pre- and post-fire management on ecosystem processes and components. Two of these theme areas, landscape and fire, are not only of great importance to the region but have the weakest scientific underpinnings needed to aid management decision making.

Our new decision process seeks to improve the input and participation of cooperators at many levels. First, we have already begun to involve the research liaison/management representatives of the BLM, ODF and FRESC in all meetings of the CFER research team to improve communication among organizations. Second, we are exploring ways to keep the Steering Committee well informed so that CFER can better utilize their expertise in the setting of research priorities and agendas.

Enjoy the 2005 CFER Annual Report. We welcome your comments and suggestions. Much of the work reported here is continuing or recently completed work, including several final reports. There are three new projects to draw your attention to. The two dealing with fire are supported with a large dose of Joint Fire Science Program funds. John Hayes is leading a study of post-fire salvage effects on wildlife populations (page 10). Jeff Shatford is leading a study of the factors that contribute to successful post-fire natural regeneration of trees (page 29). Finally, Steve Perakis is leading a study of nitrogen dynamics in forest gaps to better understand how gaps contribute to forest diversity (page 43).

David E. Hibbs
Professor of Forest Science
CFER Program Coordinator

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Preface

This publication is a compilation of research activities occurring during the year under report. The information is preliminary in nature and has not been peer-reviewed. The study summaries are provided with the understanding that the data are not guaranteed to be correct or complete. Users are cautioned to consider carefully the provisional nature of the information.

Current Research

Research Direction

The Northwest Forest Plan and state forest management plans provide approaches for regional-scale management of forest ecosystems that attempt to accommodate human resource needs, sustain critical ecosystem functions, and maintain native biodiversity. Additional research is needed to assess the efficacy of the management approaches and to refine specific management directions.

Information needs of resource managers are inherently complex and integrative, and many of the issues extend over many years and a broad geographic area. Accordingly, CFER has designed its research to answer questions at different scales of time and space.

Research Themes

Currently, there are four research themes that focus CFER research activities.

- ❑ Stand Structure and Biotic Responses to Changes in Structure of Young Forests of Western Oregon (*Stand Structure*)
- ❑ Large Woody Debris in the Terrestrial and Aquatic Riparian Zone: Production, Recruitment, Retention, and Function (*Riparian Wood*)
- ❑ Influence of Landscape Pattern and Composition on Species in Forested Ecosystems of Western Oregon (*Landscape Pattern*)
- ❑ Influences of Riparian Vegetative Community Composition on Animal Community Response (*Riparian Linkages*)

Integration

The CFER program is designed to be integrated at various levels to produce a body of knowledge that will address complex scientific and management information needs that span multiple disciplines, spatial scales, and geographic regions in western Oregon. It is our hope that the significance of the results will be enhanced through the integrated nature of our studies. Integration is planned to occur during multiple stages of research: planning, data collection, interpretation, and presentation and synthesis of results.

Planning

During the research planning process, efforts are made to define a broad, interrelated, and integrated set of questions pertaining to a particular research theme. As a result of this planning process, a series of individual studies are identified. Each study is designed to address a key element of the larger set of questions and to address multiple objectives. For example, information on the development of understory vegetation and stand structure is collected at several sites along with terrestrial vertebrate responses. These data sets will allow development of models that simultaneously predict the response of several plant and animal species and communities to management of young forest stands.

Data collection

Whenever possible, data sets for multiple studies are collected at the same sites using multidisciplinary crews. This allows for efficient use of programmatic resources, but more importantly facilitates integration. Multidisciplinary crews help ensure that data collected for different components of a research theme will be interpreted in the context of the broader set of questions being posed.

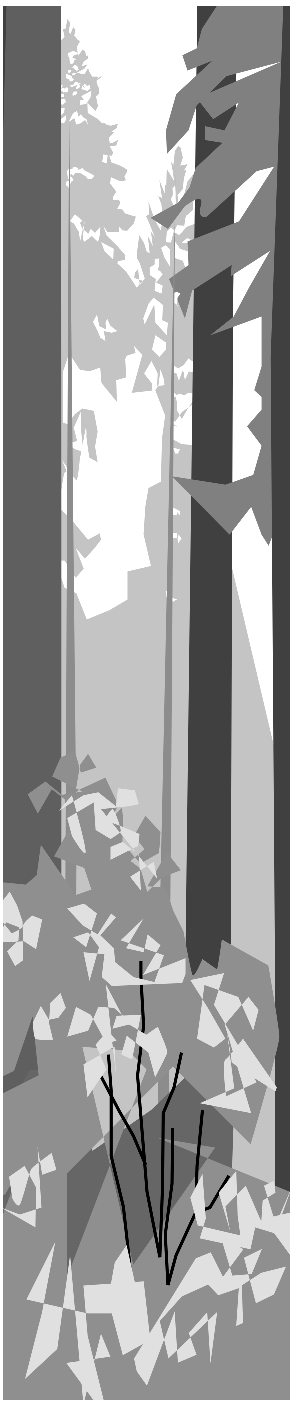
Interpretation

Following collection and analysis of data from individual studies, CFER team members will discuss results during regularly scheduled meetings and through periodic programmatic review of written materials. When possible, attempts will be made to broaden these discussions to include additional scientists in other pertinent disciplines. This will help ensure that interpretation of results from an individual study will be made in the broader context of the questions being addressed by a research theme and the CFER program as a whole.

Presentation and synthesis

Presentation and synthesis is probably the most important aspect of the plan for integration. During this step, results from each individual study and each major research theme will be synthesized to provide answers to questions concerning multidisciplinary resource management questions. Although the most appropriate mechanisms for transmitting this information are still being formulated, it is anticipated that this will involve production of white papers, review articles, and summary documents, as well as participatory events, such as field tours, symposia, and roundtable discussions. CFER's principal investigators will meet regularly to provide a programmatic forum to further develop these mechanisms for integration.

Stand Structure and Biotic Responses to Changes in Structure of Young Forests of Western Oregon



Understanding the relationships among stand structure, management activities, and ecological responses is central to wise management of forest systems. Among the primary management activities in young forest stands are density management and fuels management. Changes in forest structure resulting from these activities can affect plant and animal communities. Although some of the general relationships of structural features to stand density are well established, significant gaps in our understanding remain in some areas. In addition, the responses of plant and animal species to structural changes in young forests are poorly understood. This research examines some of these relationships for plant and animal species that are of concern to forest managers.

Goals

The two interrelated goals of this research theme are:

- to understand changes in stand structure that result from management and
- to understand some of the more important biotic responses to changes in forest structure.

2005 Highlights

- CFER-affiliated graduate student David Waldien completed his Ph.D. dissertation titled "Population and Behavioral Responses of Small Mammals to Silviculture and Downed Wood Treatments in the Oregon Coast Range." A summary of these findings is being published as a USGS/CFER fact sheet.
- The BLM Density Management and Riparian Buffer Study Establishment Report and Study Plan is being published in the USGS series *Scientific Investigations Reports*.
- CFER-affiliated graduate student Tom Giesen defended his Master's thesis titled "Four Centuries of Soil Carbon and Nitrogen Change After Severe Fire in a Western Cascades Forest Landscape."

Continuing studies during the year under report are summarized in the following section.

Influences of Post-fire Salvage Logging on Wildlife Populations: The Timbered Rock Study Becomes the Davis Lake Salvage Study

John P. Hayes and Tom Manning

Recent fires throughout the western states have heightened interest in the influences of post-fire management activities on a variety of ecological processes, social goods and services, and forest attributes, including: forest health, ecosystem integrity, future management options, and wildlife habitat. Post-fire salvage harvest of dead and damaged trees has been of particular interest because of an array of potential benefits, including commodity production and economic gain; decreased fuel loads, reducing risk of future fires; and reduction in future insect infestation. Post-fire salvage, however, may also carry significant environmental risks to soil, water, and biodiversity. Key concerns related to biodiversity center on wildlife response, especially related to species associated with dead wood, both standing dead wood (such as bats and cavity-nesting birds) and fallen (such as several species of small mammals).

As a consequence of the potential societal benefits and possible environmental impacts, post-fire salvage is becoming an increasingly contentious issue. Social conflict surrounding the issue is high, as evidenced by the interest and concern expressed by environmental organizations and by litigation surrounding proposed salvage activities. Despite considerable interest and concern, however, relatively little work has investigated environmental effects of post-fire logging. McIver and Starr (2001, *Western Journal of Applied Forestry* 16:159–168) conducted an extensive review of all studies published through February 2000 evaluating the environmental effects of post-fire logging. They found only nine studies worldwide that included unlogged controls and evaluated the ecological impacts of post-fire salvage logging. Of these, seven evaluated influences on wildlife populations (five studies of birds, two of mammals). Only four were replicated field studies, and only three of these (all studying bird response) were conducted in the United States. We are aware of one additional study on the influences of post-fire logging on birds in the Canadian boreal forest (Morissette et al. 2002, *Canadian Journal of Forest Research* 32:2169–2183) published since the completion of McIver and Starr's assessment.

Lack of information will undoubtedly fuel the social controversy surrounding this issue. Until adequate information is available to allow evaluation of actual consequences of post-fire salvage logging, anecdotal and philosophical perspectives uninformed by scientific evidence will largely drive the debate over this issue.

To help elucidate the influences of salvage operations on wildlife habitat quality, we began sampling bird and small mammal communities in the area burned by the Timbered Rock Fire in Jackson County. Pretreatment sampling took place between April and July of 2004, with the expectation that salvage would occur immediately thereafter, to be followed by 2 years of post-treatment sampling. Legal actions brought by opponents of salvage logging prevented any harvest activity. A federal court decision against the salvage in November of 2004 put an end to the study at Timbered Rock, and we started looking for alternative places to conduct this research.

After considering several recent fires with plans for salvage, we selected the Davis Lake Fire on the Deschutes

National Forest to continue our research on effects of post-fire salvage. Key considerations in our decision were the size and number of the cutting units, the homogeneity of the mixed conifer forest and similarity to counterparts on the west side of the Cascades, provision of two levels of snag retention, and the strong interest and enthusiasm for cooperation exhibited by Forest Service personnel in the area. Another important factor was that salvage at Davis Lake was already occurring, and thus the accomplishment of the study was fairly certain. Two disadvantages arise from initiating our study on areas already salvaged: we were unable to randomly assign treatments to sites, and we have no pre-treatment wildlife data to confirm that study units were equivalent before salvage.

The basic study design remains the same as at Timbered Rock. Four blocks of replicated treatments (representing uncut controls and two intensities of salvage) will be compared with respect to small mammal abundance and diversity, breeding songbird densities, and bat activity. Our work at Davis Lake will thus provide information on the influences of salvage and salvage intensity on habitat quality and abundance of wildlife species.

Studies of wildlife response to fire suggest that habitat conditions during the first few years following fire are especially important for a number of species (Hutto 1995, *Conservation Biology* 9:1041–1058). As a consequence, understanding the short-term effects of salvage, such as those that will be revealed in this study, can provide important information for management of forest stands. In addition, this study will provide an important foundation for future work on this topic, and we anticipate follow-up studies on the same sites.

Methods

Study sites and design

Potential study sites within the Davis Lake Fire were identified in collaboration with staff of the Crescent Ranger District of the Deschutes National Forest. Sites meeting the following criteria were considered to be potential sites for study: 1) the site had burned with a high fire intensity; 2) the site was at least 12 (preferably at least 16) ha in size and was not exceptionally sinuous in shape or did not include elongate extensions; 3) the site consisted of a good stocking of conifers ≥100 cm diameter at breast height (DBH); and 4) the site could accommodate at least three nonoverlapping bird survey circles (80-m radius).

Before the fire, forest stands were dominated by Douglas-fir (*Pseudotsuga menziesii*), white fir (*Abies concolor*) and ponderosa pine (*Pinus ponderosa*). Understory vegetation was predominantly snowbrush (*Ceanothus velutinus*) and manzanita (*Arctostaphylos patula* and *A. nevadensis*). Soils are primarily pumice derived from the prehistoric explosion of Mt. Mazama.

The design includes four replications of three treatments:

1) Control: No salvage activity
2) Moderate salvage: 30 snags/ha, >35 cm DBH to be retained throughout the treatment unit
3) Heavy salvage: 6 snags/ha, >35 cm DBH to be retained throughout the treatment unit

Salvage harvest of all stands was completed by early July 2005.

Bird sampling

During spring of 2005, we established three bird-sampling points in each of the 12 experimental stands. Sampling points were chosen so that the distance between points was at least 160 m and arranged so as to maximize distance between sampling points and stand boundaries. Sampling began 16 May and continued through 1 July. Each point was visited a minimum of four times. Bird sampling was conducted for 8 min at each point between 0.5 hour before and 3 hours after sunrise. Distance from the observer to each bird was estimated. This protocol will be duplicated as closely as possible in 2006. We plan to analyze bird data using both distance techniques and double-observer approaches.

We also observed foraging behavior of Hairy Woodpeckers (*Picoides villosus*) and Black-backed Woodpeckers (*P. arcticus*) within the burned areas to determine characteristics of trees used by the birds and differences associated with salvage treatments. These observations were conducted between 31 May and 8 July. We measured or estimated diameter, height, percent loose and percent tight bark, percent burned, decay class, and amount of bark beetle activity at all trees visited by individual birds during an observation session.

Small mammal sampling

Trapping was conducted with two sizes of live traps to maximize the diversity of animals captured. In each of the 12 research units, we established a 10 x 10 grid of Sherman live traps with 10 m between trap stations. Separate grids (with 25-m spacing) of Tomahawk 201 cage traps were established in each unit. All traps were baited with a mixture of peanut butter and rolled oats. Each trap was covered with a small waterproof shelter, and cotton fiber was provided inside the traps for nesting insulation. Trapping in 2005 began 25 May and finished on 7 September. During each trapping session, traps were open for 7 consecutive nights. Captured animals were identified to species, individually marked, weighed, sexed, and assessed for reproductive status. Dead animals will be necropsied during the fall/winter of 2005 to confirm field data and then sent to a qualified systematics collection to serve as voucher specimens. This protocol will be duplicated as closely as possible during 2006. We will use the program MARK to analyze mark-recapture data and to estimate abundance of small mammal populations.

Bat sampling

We recorded echolocation calls of bats using Anabat II Detectors from 21 June through 26 September. To account for spatial variation within experimental stands, we positioned one detector at each of the three bird point-count stations within a given stand. We sampled three of the 12 stands at a time (total of nine detectors working simultaneously) for 7 consecutive nights. Order of sampling corresponded to the stands being sampled for rodents during a given week. During each sampling session, each detector's microphone was placed on a 1-m pole within 1 m of the plot center. Each unit was housed in a waterproof box and fitted with a 2-m extension cable that connected the microphone with the detector. Units were programmed to record from 45 min before dusk until 45 min after dawn. During each 7-night sampling period, batteries and data cards were changed at least once to ensure adequate electrical power and data storage. We will use SONOBAT software and available call libraries to identify bat calls to the lowest possible taxonomic group. Number of bat passes recorded per stand will be the measure of bat activity used for statistical analyses.

Vegetation sampling

We gathered data to characterize the immediate post-salvage plant community structure. We recorded data at four points around each bird point-count station within each of the 12 experimental stands. These measurements included physical characteristics of the sites (aspect and slope) and visual estimates of percent cover of vegetation and other habitat elements (e.g., stone, slash, leaf litter, stumps). We also measured or estimated the diameter, percent tight and percent loose bark, percent burned and charred surface, decay class, and an index of bark beetle activity on all snags ≥10 cm diameter within a 400-m^2 circle surrounding each sampling point. Also, measurements were made to estimate the volume of coarse woody debris present at each sampling point.

Data analysis

We will use an information-theoretic approach (Burnham and Anderson 2002, *Model Selection and Multi-Model Inference: a Practical Information-Theoretic Approach*. Springer-Verlag. 488 pp.) to evaluate influences of salvage harvest on wildlife, following a general strategy used by Hayes et al. (2003, *Ecological Applications* 13:1222–1232) to evaluate influences of thinning on bird populations.

We will evaluate four *a priori* hypotheses of response to treatments: 1) population parameters (abundances for birds and small mammals or amount of activity for bats) in controls, moderate salvage, and heavy salvage stands are the same (the null model); 2) population parameters in moderate salvage and heavy salvage stands are the same, but differ from the controls (the salvage effect hypothesis); 3) population parameters in the controls and moderately salvaged stands are the same, but differ from the heavily salvaged stands (the high intensity impact hypothesis); or 4) population parameters differ in all three treatments (the salvage intensity hypothesis). We will also consider temporal trends in the responses of species during the first 2 years following salvage and evaluate differences in trends among treatment types.

The combination of treatment effects and temporal trends results in nine *a priori* models that will be evaluated (Table 1). We will then construct a set of quantitative models representing each of the nine conceptual models. Each quantitative model will include a term for the categorical effect of year; as sampling for rodent abundance and bat activity will follow a randomized block design, we will also include a term for the categorical effect of block for models of those responses. We will evaluate the likelihood of each *a priori* model given the data that we collect, using an information-theoretic approach. We will calculate AIC_c for models for species or taxa that follow a lognormal or Poisson distribution and $QAIC_c$ for those that follow an overdispersed Poisson distribution. Our evaluation of models will be based on ΔAIC_c or $\Delta QAIC_c$ and generalized Akaike weights (w_i) of each model. For taxa demonstrating a response to the treatments, size of effect of the treatments will be evaluated based on model-averaged parameter estimates.

Table 1. Models to be evaluated. C = Control stand; M = Moderate salvage; H = Heavy salvage.

Model	Treatment Effect	Temporal Effect
1	C = M = H	C = M = H
2	C ≠ (M = H)	C = M = H
3	C ≠ (M = H)	C ≠ (M = H)
4	(C = M) ≠ H	C = M = H
5	(C = M) ≠ H	(C = M) ≠ H
6	C ≠ M ≠ H	C = M = H
7	C ≠ M ≠ H	C ≠ (M = H)
8	C ≠ M ≠ H	(C = M) ≠ H
9	C ≠ M ≠ H	C ≠ M ≠ H

Preliminary Research Results

We recorded 1041 detections of breeding birds, representing 31 species (Table 2), and captured 941 individual rodents representing 7 species a total of 2966 times

Table 2: Bird species detected at sampling points at Davis Lake Fire, spring 2005.

Species	Detections
Mountain Bluebird	154
Dark-eyed Junco	149
Yellow-rumped Warbler	139
Hairy Woodpecker	81
Dusky Flycatcher	57
Violet-green Swallow	49
Red-breasted Nuthatch	46
White-breasted Nuthatch	37
House Wren	36
Chipping Sparrow	34
Fox Sparrow	34
Black-backed Woodpecker	30
Brown Creeper	26
American Robin	22
Rock Wren	20
Mountain Chickadee	19
Townsend's Solitaire	13
Unknown bluebird	13
Western Tanager	12
Western Wood Peewee	12
Northern Flicker	8
Clark's Nutcracker	7
Olive-sided Flycatcher	7
White-headed Woodpecker	7
Brown-headed Cowbird	6
Common Nighthawk	5
Western Bluebird	5
Unknown woodpecker	4
Vaux's Swift	3
Unknown	2
American Crow	1
Lazuli Bunting	1
Sharp-shinned Hawk	1
Steller's Jay	1
Total	1041

(Table 3). A large quantity of bat echolocation data awaits analysis during the winter of 2005–2006. We also completed the vegetation sampling, as well as supplemental vegetation sampling in two stands where bird point-count stations did not correspond closely to the rodent trapping grids.

Table 3: Rodents captured at Davis Lake Fire, summer 2005.

Species	Common Name	Total Captures	Total Individuals
Tamias siskiyou	Siskiyou chipmunk	944	247
Peromyscus maniculatus	Deer mouse	790	247
Spermophilus lateralis	Golden-mantled ground squirrel	746	227
Tamias amoenus	Yellow-pine chipmunk	435	192
Neotoma cinerea	Bushy-tailed woodrat	4	4
Phenacomys intermedius	Heather vole	2	2
Glaucomys sabrinus	Northern flying squirrel	4	1
Unidentified vole	Unidentified vole	24	16
Unidentified chipmunk	Unidentified chipmunk	17	5
Total		2966	941

Study Timeline

As of this writing (September 2005), field work and analysis for the 2005 season are still underway. Necropsies of rodent specimens will be carried out during October 2005 to confirm vole species and to validate reproductive assessments of live animals in the field. During fall 2005 and winter of 2006, rodent capture data will be subjected to intensive error-checking, metadata will be compiled, and preliminary estimates of rodent populations in each treatment unit will be produced. Bat echolocation data will also be analyzed over the winter to determine the total numbers of calls recorded in each stand, as an index of bat activity. We will analyze bird data to compute preliminary densities (by species for all species with adequate numbers of detections) by both the distance technique and a double-observer approach and will compare the efficacy and statistical properties of the two techniques. Vegetation data will be summarized and stand-level means computed, including estimates of coarse woody debris volume computed from the down wood measurements.

Data collection for 2006 will begin in May and finish by the end of September. We expect to complete a final report to the USDA Forest Service no later than March 2007 and submit manuscripts for publication soon thereafter.

Response of Birds to Fire Mosaics

Michelle Cannon and John P. Hayes

Habitat Selection in Breeding Birds

Habitat selection is the disproportionate use of certain habitats that has adaptive significance for individuals (Jones 2001, *Auk* 118:557–562). For breeding birds, suitable habitat is comprised of sufficient food resources and adequate shelter from predators for adults and their offspring (Cody 1985, *Habitat Selection in Birds*, Academic Press, Orlando FL). In particular, vegetation structure appears to be an important cue for breeding birds to provide foraging and nesting substrates and cover from predators. Food resources within breeding habitat are limiting on several aspects of avian reproductive ecology, including if and when a bird breeds, its clutch size, and reproductive success (Martin 1987, *Annual Review of Ecology and Systematics* 18:453–487). However, even with abundant food, breeding bird populations are limited by other factors, in particular, securing nest sites that maximize the probability of fledging offspring (Martin 1988, *Ecology* 69:74–84).

Breeding Birds in Post-fire Landscapes in the Western U.S.

Wildfire is one of the most important natural disturbances in forests of the western United States. Fires alter forest developmental trajectories and change the plant and animal communities in the affected areas. In the first few years after a fire, the flush of new vegetation can increase the abundance and diversity of wildlife, particularly those species associated with early succession habitats.

Environmental, topographic, and anthropogenic factors cause wildfires to burn across landscapes with differing intensities, creating a mosaic of severely burned, partially burned, and unburned patches (Lyon et al. 2000, *General Technical Report RMRS-GTR-42*, vol. 1, USDA Forest Service, Ogden UT). The relationship of avian species to the mosaic of burned and unburned forest patches remains poorly understood (Kotlier et al. 2002, *Studies in Avian Biology* 25:49–64). The response of the avian communities to post-fire landscapes is determined in part by the characteristics of the fire (e.g., size, severity, interspersion of burned and unburned forest, and composition and density of regenerating understory vegetation) and the life-history traits of bird species (e.g., food taken, foraging strategies, and attributes of nests).

Bird species appear to respond positively or negatively to fire, depending primarily on their foraging strategies. Studies of bird populations in fire-altered forests generally show a shift in the composition of the avian community from foliage- and bark-gleaners to shrub-foragers, tree-drillers, and cavity-nesters (Kotlier et al. 2002, *Studies in Avian Biology* 25:49–64). Approximately 78% of bird species that frequent burns are insectivores (Hutto 1995, *Conservation Biology* 9:1041–1058). Some granivores also take advantage of the seed crops provided by annual and perennial grasses. The many snags created by severe fires also benefit cavity-nesting species. Populations of many species of woodpeckers typically increase after fires because of the enhanced foraging, roosting, and nesting opportunities in the dead and dying trees resulting from fire. Aerial and shrub insectivores also tend to increase following stand-replacing fires because of flushes in volant insects and increases in herbs and shrubs.

Rigorous evaluation of alternative post-fire management activities, including salvage logging, requires an understanding of the ecological responses to fire. Although studies in other regions have led to an understanding of general patterns of bird population response to fire, region-specific information for southwestern Oregon is lacking. Moreover, the spatial context of bird response to fire is poorly understood, and the influences of the mosaic of burned and unburned patches and distance from unburned forest on bird populations are unknown.

During the summer of 2002, wildfires burned hundreds of thousands of hectares in southwestern Oregon. The largest of these fires, the Biscuit Fire, was located in and around the Siskiyou National Forest. It is estimated that this fire covered nearly 200,000 ha, nearly 40% of which was classified as having been moderately or severely burned. A large-scale mosaic of severely burned patches interspersed with underburned and unburned patches was created. Because of the size and severity of this fire, this site offers an excellent opportunity for investigating how bird communities respond to the juxtaposition of burned and unburned patches of forest.

Here we report on progress to date on the third year of a 3-year field study investigating how birds are distributed in large, severely burned patches relative to remnant, unburned, or low-intensity burned forest. Specifically, we are examining potential relationships between the richness and composition of bird communities within severely burned patches and proximity to green forests. In addition, we are examining the distribution and abundance of individual breeding bird species that are associated with burned forest. Our initial predictions were 1) that species that are associated with burns, but rely on forest habitat for nesting or cover, will be more likely to be associated with the edge of green forest and 2) that species associated with open and burned forest will show no relationship with proximity to unburned forest.

Methods

Study sites

Our study sites are located on the east-central edge of the Kalmiopsis Wilderness in the Siskiyou National Forest, southwestern Oregon, within the burn perimeter of the Biscuit Fire. The elevations of the sites range from 300 to 1350 m. The dominant overstory trees are Douglas-fir (*Pseudotsuga menziesii*), sugar pine (*Pinus lambertiana*), and ponderosa pine (*Pinus ponderosa*). The mid-canopy and understory are composed of conifers such as incense-cedar (*Calocedrus decurrens*), white fir (*Abies concolor*), and grand fir (*Abies grandis*), along with hardwoods such as black oak (*Quercus kelloggii*), Pacific madrone (*Arbutus menziesii*), tanoak (*Lithocarpus densiflorus*), and canyon live oak (*Quercus chrysolepis*). We targeted study sites within the Biscuit Fire boundary that were dominated by mature conifer forest types. We located study sites in severely burned forest (≥75% canopy death) and low to moderately under-burned forest patches (≤25% canopy death). We randomly chose sites (point-count centers) within these areas stratified by distance from forest-severe burn edges. We placed points from 50 to several hundred meters from the severe-burn forest interface. In 2003, we placed 45 points in severely burned patches and added seven more in 2004. In 2005, several sites were salvage logged, resulting in the loss of five sites. We added 18 new burned sites for a total of 53 sites. In addition, we surveyed 26–28 forest sites within the unburned/underburned forest patches between 50 m and >200 m from the burn edge each year. All points were at least 250 m from all others and will be treated as independent in analyses.

Point-count surveys

We conducted point counts for birds at each point, using a variable-radius counting method during point counts. A single observer spent 8 min at each point and recorded species, sex, and activity (when possible) of all birds seen or heard and estimated their distances from the observer. In 2003 and 2004, we surveyed each point three times during the peak nesting period in June and early July. Because of logistical constraints, a few points were surveyed only twice in 2005. All surveys were conducted between 0530 and 1100 hours. Two observers sampled 68 points in 2003 and four observers sampled 78 points in 2004 and 81 points in 2005. Observers were rotated among points when possible to minimize observer bias.

Nest searching

In addition to point-count sampling, we searched for nests on 35 burn plots in 2004 and 49 plots in 2005. Plots were 4 ha in size and were centered on point-count sites. To facilitate searching, plots were divided into 16 50-m^2 subplots with flagging and/or wooden stakes (Figure 1). Two observers surveyed each 4-ha plot twice per season, spending between 2 and 5 hours during each survey period (approximately 30 min–1 hour per 50-m^2 subplot).

Observers recorded birds encountered in plots and recorded their positions on the map. Species, sex, age, and activity were recorded whenever possible. We observed adult males for 10 min or until the bird went to a nest or was lost from view. We observed adult females encountered on the plots until they either went to a nest or were lost from view. Observers searched for nests by scanning substrates and by observing adult bird behavior for parental cues, including carrying food, nesting material, or fecal sacs, and antagonistic behavior towards conspecifics or other species, including alarm calls and chases. Bird observations and nests were recorded on a grid for later analysis of patterns of bird use and nest placement in burned stands.

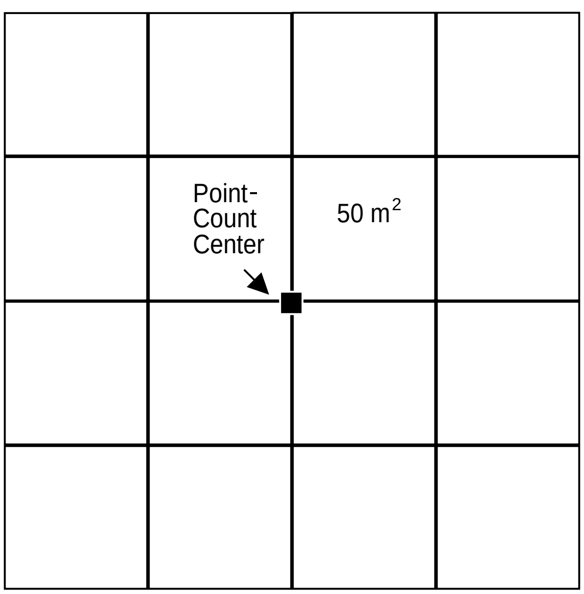


Figure 1. Four-ha nest searching plots were established at 35 point-count sites in burned stands. To facilitate searching and recording of nests and birds within plots, plots were further divided into sixteen 50-m^2 subplots.

Vegetation sampling

Vegetation and stand structure were sampled at the point-count centers by using modified BBIRD protocols (Martin et al. 1997, *BBIRD Field Protocol*, Montana Cooperative Wildlife Research Unit, University of Montana, Missoula, Montana, USA). We resampled points established in 2003 in subsequent years. In addition, we measured vegetation characteristics at nests. At each nest site we described the nest substrate(s), recorded species, diameter at breast height (DBH), and decay class of all snags and live trees >8 cm DBH located within 11.3 m of the nest. Within 5 m of nests, we estimated percent cover of shrubs, herbaceous vegetation, and bare ground; counted all live stems ≥0.5 m high; and recorded all live trees >8 cm DBH. Live foliage associated with resprouting hardwood trees was included in the percent shrub cover estimate in sampling plots.

Preliminary Research Results

Excluding birds flying over stands during surveys, we detected 2,893 individuals of 65 bird species on 81 sites in 2005. Thirty-five percent of individuals were detected within 50 m and 53% of birds were detected within 75 m of observers. Unidentified birds comprised approximately 2% of the total. Adult males comprised 66% of all detections.

Bird abundance and distribution patterns are currently being analyzed. On 49 burned sites where nest searching was conducted in 2005, we found approximately 260 nests of 31 species (Table 1). Full results from nest searching efforts in 2005 are being tabulated. On 35 nest searching plots in 2004, we detected 219 breeding pairs of 36 species with nests or fledglings (Figure 2). Of the 39 species for which we found nests over two seasons, 15 (37%) use cavities and 25 (63%) build open-cup nests.

Table 1. Breeding groups and nests detected on 4-ha plots in burned stands. Thirty-five and 49 plots were searched in 2004 and 2005, respectively. Each plot was visited twice per season and searched by two observers. The number of plots represents the total plots searched each year where at least one nest or fledgling of a particular bird species was detected. Trends in breeding activity between years cannot be discerned from these preliminary numbers.

Avian Family	Species	No. Plots Nests/ Fledglings Detected		No. Nests		Primary Nesting Substrates
		2004	2005	2004	2005	
Picidae	Hairy Woodpecker	25	28	6	23	Conifer/Hardwood snags
	Northern Flicker	8	9	6	13	Conifer/Hardwood snags
	White-headed Woodpecker	1	0	1	0	Large conifer snag
	Red-breasted Sapsucker	1	0	1	0	Hardwood snag
	Downy Woodpecker	2	4	0	3	Conifer/Hardwood snags
	Pileated Woodpecker	0	2	0	1	Large Conifer snag
Columbidae	Mourning Dove	1	0	1	0	Conifer snag
Accipitridae	Red-tailed Hawk	1	0	1	0	Large conifer snag
	Cooper's Hawk	1	0	1	0	Nest off-plot in live conifer
Falconidae	American Kestrel	2	1	2	1	Large conifer snags
Tyrannidae	Dusky Flycatcher	2	2	2	2	Branches of Douglas-fir snags
	Pacific-slope Flycatcher	2	0	2	0	Log/cutbank
	Olive-sided Flycatcher	1	1	1	1	Live Douglas-fir/Douglas-fir snag
	Western Wood Pewee	2	3	1	4	Branch of Douglas-fir snag
Corvidae	Steller's Jay	2	3	0	3	Live trees/shrubs
Muscicapidae	Townsend's Solitaire	7	8	2	8	Ground
	Western Bluebird	11	18	15	24	Conifer/Hardwood snags
	Mountain Bluebird	1	2	1	2	Conifer snags
	American Robin	9	13	11	15	Conifer/Hardwood snags
Vireonidae	Cassin's Vireo	0	4	0	5	Hardwood snags
Paridae	Chestnut-backed Chickadee	0	1	0	1	Hardwood snag
Sittidae	Red-breasted Nuthatch	7	11	5	5	Large conifer snags
Certhiidae	Brown Creeper	4	8	2	6	Large conifer snags
Troglodytidae	House Wren	10	25	7	40	Conifer/Hardwood snags
Aegithalidae	Bushtit	1	0	1	0	Hardwood (live)
Hirundinidae	Tree Swallow	1	4	1	6	Large conifer snag
Fringillidae	Black-headed Grosbeak	12	15	8	27	Hardwood resprout/branches dead hardwoods
	American Goldfinch	2	0	2	0	Hardwood resprouts
	Pine Siskin	2	0	0	0	N/A
	Purple Finch	1	1	0	0	N/A
Parulidae	Yellow-rumped Warbler	15	9	5	10	Conifer snags (87%)
	Black-throated Gray Warbler	2	0	1	0	Live oak (live)
	Nashville Warbler	1	0	1	0	Ground under live shrub/cover
	MacGillivray's Warbler	2	3	0	2	Hardwood resprouts
Emberizidae	Dark-eyed Junco	29	24	11	16	Ground under live shrub/cover
	Lazuli Bunting	15	17	21	24	Hardwood resprouts (86%)
	Western Tanager	4	10	1	10	Live conifers; Hardwood resprout
	Rufus-sided (Spotted) Towhee	3	2	0	2	Ground under live shrub/cover
	Song Sparrow	1	3	0	2	Shrubs/grass
	White-crowned Sparrow	1	2	0	1	Grass
	Chipping Sparrow	0	1	0	2	Live conifers
	Totals			120	259	

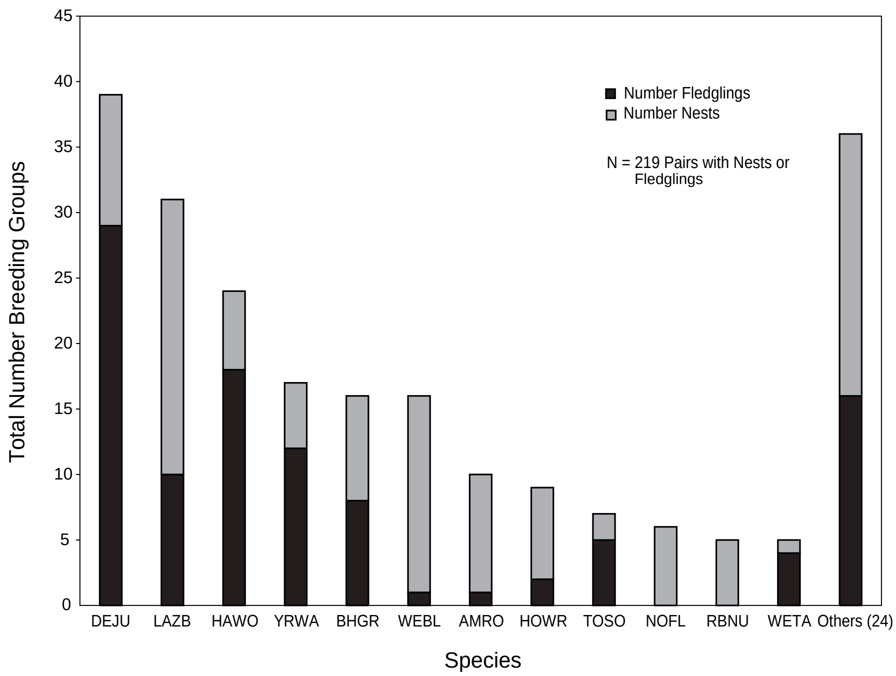


Figure 2. The number of nests or fledglings detected per species on 35 nest searching plots in 2004. Fledgling counts represent the number of pairs that produced one or more fledglings. For breeding pairs in which we detected nests and fledglings, only nests were counted. Species like the Dark-eyed Junco and Hairy Woodpecker produced the earliest fledglings on our plots, which is reflected in the relatively few nests detected for these species. For 24 species, we found fewer than five nests or fledglings present on the plots. Species abbreviations are as follows: DEJU = Dark-eyed Junco, LAZB = Lazuli Bunting, HAWO = Hairy Woodpecker, YRWA = Yellow-rumped Warbler, BHGR = Black-headed Grosbeak, WEBL = Western Bluebird, AMRO = American Robin, HOWR = House Wren, TOSO = Townsend's Solitaire, NOFL = Northern Flicker, RBNU = Red-breasted Nuthatch, WETA = Western Tanager.

Open-cup Nesting Species

Species that build cup nests used snags, residual live trees, resprouting hardwoods, and other ground vegetation and downed wood in burned forest. American Robins and Yellow-rumped Warblers are generally identified as mid-story/canopy nesters, but we found nests in conifer and hardwood snags on burned sites. The Western Tanager is a foliage-gleaning canopy nesting species that we often encountered foraging on snags in burned forest. However, 10 of the 11 tanager nests we found were in live conifers at the edge of burned stands or in resprouting hardwoods. Other open-cup nesting species using snags included Cassin's Vireo, Western-wood Pewee, Olive-sided and Dusky flycatchers, and Red-tailed Hawk.

The resprouting hardwood species (tanoak, Pacific madrone, and black oak) provided important nesting substrates for several shrub-nesting species. Lazuli Buntings and Black-headed Grosbeaks, in particular, tended to be concentrated in areas with high densities of large resprouting hardwoods. We detected three times as many grosbeak nests in 2005 than in 2004. This was due in part to increased effort but was also likely due to continued vegetation regrowth over the three seasons. This also may explain why we encountered some species in 2005 that were not detected on burned plots in previous years. For example, we did not detect Cassin's Vireo on burned sites in 2003 or 2004. In 2005, we detected vireos on several sites and found five nests in hardwood snags. We also found Orange-crowned Warblers on burned plots for the first time in 2005. Additionally, we detected Dark-eyed Juncos, Townsend's Solitaires, Rufus-sided Towhees, Pacific-slope Flycatchers, and Orange-crowned and Nashville warblers nesting on the ground under shrubs or associated with downed wood.

Cavity-Nesting Species

We found nests of 15 primary or secondary cavity-nesting species in our burned plots, including six woodpecker species (Table 1). Nesting substrates ranged from <10 in. (<25 cm) hardwoods to >30 in. (>76 cm) conifer snags. Hairy Woodpecker was the most common cavity-nesting species we encountered on our plots, and the nest holes they constructed were used by Western and Mountain bluebirds, House Wrens and Tree Swallows. The majority of Western Bluebird nests we found appeared to be Hairy Woodpecker nests, some having been used earlier in the same season by woodpeckers before being occupied by bluebirds.

Patterns of foraging and nesting activities in burned areas relative to stand structure and vegetation characteristics will be analyzed. Preliminary results from 2004 suggest that some species, such as the Red-breasted Nuthatch and Western Tanager, tend to concentrate activities in burned forest within 100 m of green forest patches, whereas other species, such as the American Robin and Lazuli Bunting, appear to be associated with understory vegetation. We also will compare point-count detections and presence of breeding individuals in sites where both were conducted to examine how well point-count sampling, which is biased towards singing males, reflects the presence of breeding females and nesting efforts.

Study Timeline

We completed the vegetation sampling for the 81 point-count sites in August. Final analysis on breeding bird distribution and abundance and vegetation patterns will occur in fall and winter of 2005/2006. Preparation of publications describing the research and its results is anticipated in the summer of 2006.

Acknowledgements

Brian Cannon, Kendra Brewer, Jacob Cowan, Jim DeStaebler, Elizabeth Donadio, and Joseph Smith provided invaluable assistance in the field. Additionally, we would like to thank the U.S. Forest Service for assistance and permission to work in the Siskiyou National Forest.

Tree Species Controls on Nutrient Cycling in the Oregon Coast Range

Alison Cross and Steven Perakis

Plants, generally and as individual species, are an important control on nutrient cycling in terrestrial ecosystems. Trees may influence soil nutrient cycling via various mechanisms, including nutrient uptake, alteration of precipitation chemistry, root turnover, and litter inputs. Leaf litter is a substantial nutrient input to surface soils and, because leaf litter chemistry varies with tree species, may be an important mechanism of tree species control on soil nutrient cycling.

In this region, compositional shifts through succession toward forests dominated by western hemlock (*Tsuga heterophylla*) may result in altered soil nutrient dynamics, with implications for ecosystem management. Additionally, fire suppression in coastal Pacific Northwest forests is predicted to increase western hemlock dominance in late-successional reserves (LSRs) that are managed for old-growth structural characteristics. Such ecosystem simplification is of particular concern where important species differences in nutrient cycling would be eliminated.

An understanding of the effects of plant species on nutrient cycling should improve our ability to predict ecosystem response to perturbations such as climate change or invasion by exotic species. Such knowledge may also aid in guiding ecosystem management and restoration of late-successional forest composition, function, and structural characteristics. Most information on effects of tree species on soils, however, is derived from highly controlled garden studies or field studies where land-use history, air pollution, or other human perturbation may confound ecological response. Old-growth forests of the Pacific Northwest provide a unique opportunity to examine tree species effects on soils in a wide range of ecosystems that developed with minimal anthropogenic disturbance. Information on species effects on soils should be useful in managing both LSRs and young stands.

The overall objective of this research is to explore the relationship of forest ecosystem structure and composition with function. In particular, this project addresses the following questions:

- How do individual tree species differ in their influence on soils of mixed old-growth forests of the Oregon Coast Range?
- How do tree species effects observed at a single field site (*local scale*) compare to those observed at multiple sites across a broad geographic area (*regional scale*)?
- What are some potential mechanisms by which tree species influence soil properties and nutrient cycles?

In an observational study, soil and foliar properties are being quantified and compared among tree species within and across mixed old-growth stands. A manipulative study tests the leaf-litter leachate mechanism of tree species influence on soils in the laboratory.

Methods

Eight old-growth forest sites in the Oregon Coast Range were chosen for having four common tree species, Douglas-fir (*Pseudotsuga menziesii*), western hemlock, western redcedar (*Thuja plicata*), and bigleaf maple (*Acer macrophyllum*), well represented in the canopy (Figure 1). Four of the sites have soils derived from sedimentary rocks, primarily sandstone and siltstone, and the remain-

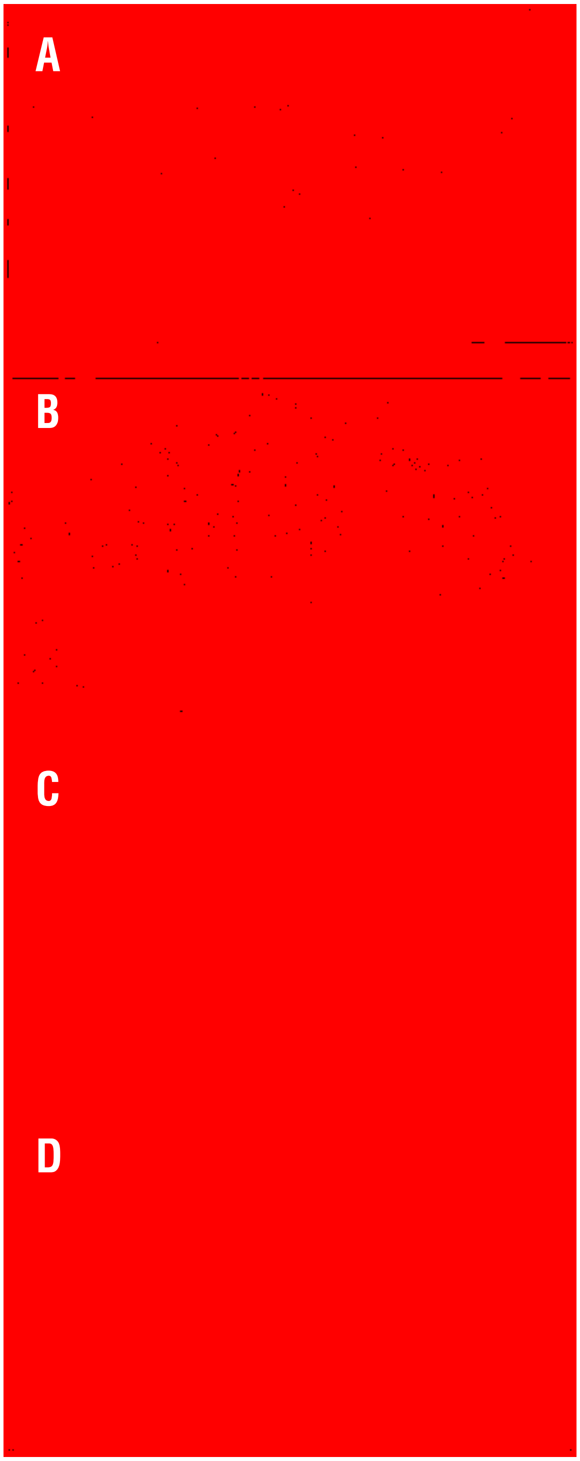


Figure 1. Foliage of A) Douglas-fir, B) western hemlock, C) western redcedar, and D) bigleaf maple. Photos courtesy of the Bureau of Land Management.

ing four have soils derived from mixed sedimentary and volcanic rocks. The Bureau of Land Management manages seven of the eight sites (Figure 2).

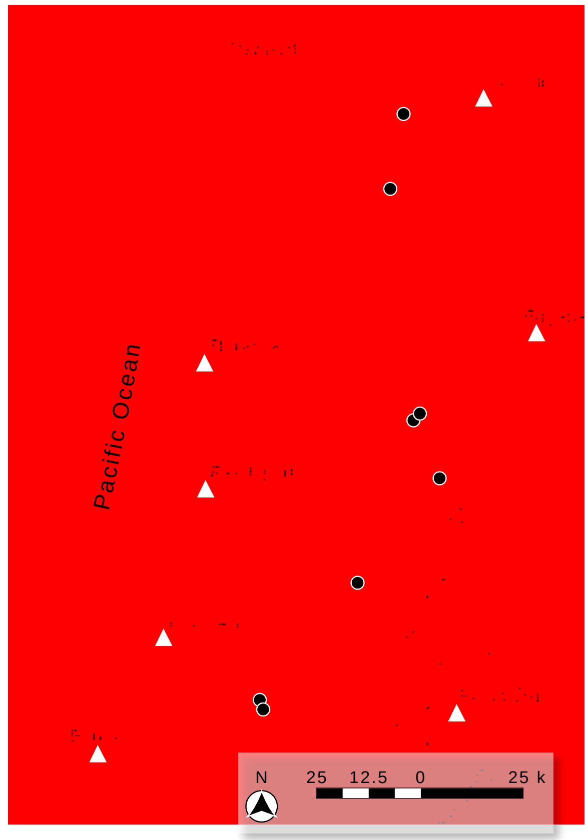


Figure 2. Map of field survey sample locations in the Oregon Coast Range (courtesy of George Lienkaemper, USGS-FRESC).

Field survey

During summer 2003, we selected six replicate trees of each of the four species at each site for sampling. Selected individuals were large canopy trees in upland areas away from stand edges, large gaps, and draws. Immediate neighbor trees were not sampled. Aspect was recorded and diameter at breast height was measured from the upslope side of each tree. Within a 30- x 30-cm template placed beneath each tree, recently fallen (Oi) and decomposing (Oe + Oa) forest floor layers were measured for depth, removed, ovendried, and weighed. Underlying soils were collected at depths 0–10 cm and

10–20 cm and sieved through 2-mm mesh. Subsamples of the <2-mm soil fractions were analyzed for pH in a 2:1 water:soil solution. Soils were analyzed for potassium sulfate-extractable nitrogen (N) and carbon (C) and Bray-extractable phosphorus (P). Separate subsamples were fumigated with chloroform before extraction to determine microbial pools of C, N, and P. Soils were also analyzed for exchangeable base cations (calcium [Ca^{2+}], magnesium [Mg^{2+}], potassium [K^{+}], and sodium [Na^{+}]). These nutrient pools are readily available to plants and microbes. Additional subsamples were analyzed by dry combustion to determine total pools of N and C.

We returned to the sites in July 2004 to collect foliage from six trees of each species. Foliage samples were retrieved from the canopy using a 0.12-gauge shotgun loaded with steel turkey shot. Samples were then frozen and later sorted, ovendried, and ground before analysis for C and N by dry combustion and for P and base cations by acid digest.

A total of 384 samples were analyzed in each soil assay; each foliar assay included 192 samples. Effects of site, species, depth, and any interactions were assessed with linear mixed effects models (Type III sums of squares). The regional-scale model used the full dataset. For each site, a local-scale analysis was conducted that included only the data for that site. Effects were considered significant at $\alpha = 0.05$.

Preliminary Research Results and Management Implications

Preliminary results from the field survey suggest that tree species differentially affect soil pH and nutrient concentrations in surface (0–10 cm) soils, where biological activity is highest. Any species-based differences were reduced or absent in deeper (10–20 cm) soils, where weathering is likely to be more important. Figure 3 depicts regional-scale soil chemistry "profiles" for each species. Douglas-fir soils had pH values near the mean of all species, while western hemlock soil pH was 0.25 ± 0.05 (mean ± SE) units lower than average. In addition to low pH, western hemlock soils also had relatively low concentrations of P, Ca^{2+}, Mg^{2+}, and K^{+}. In contrast, bigleaf maple soils had relatively high pH and P, Ca^{2+}, Mg^{2+}, and K^{+} concentrations. Western redcedar soils had somewhat high pH but considerably (29 ± 5%) less P than average. While Na^{+} appeared quite variable among species, overall Na^{+} concentrations are low (less than 0.25 $cmol_c\ kg^{-1}$ dry soil). For all properties measured, western hemlock soils had neutral or low values relative to the average of all species, while values for bigleaf maple soils were high. Western hemlock and bigleaf maple seem to represent the extremes of tree species effects on soils in these forests. These trends may

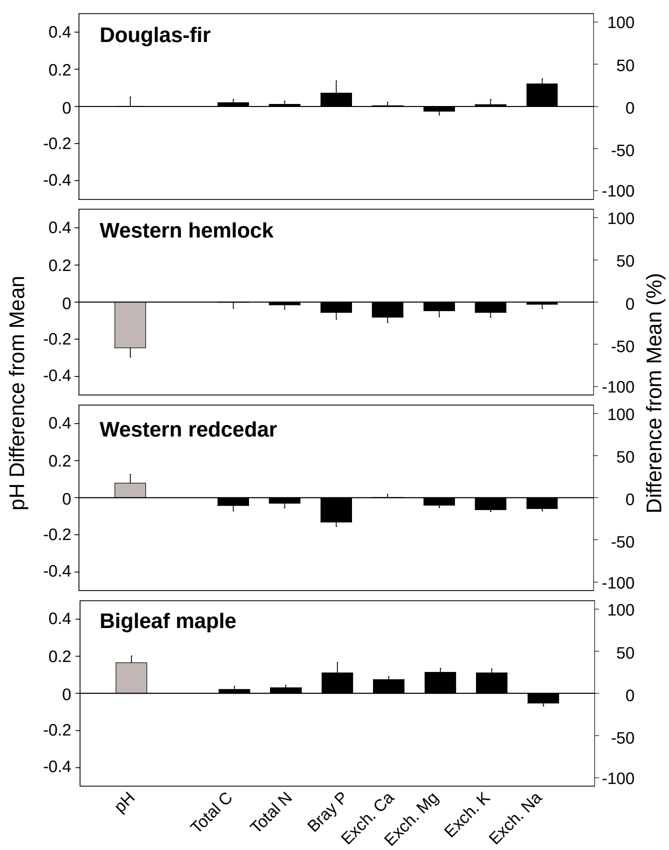


Figure 3. Regional scale "species profiles" of soil pH and nutrients for 0–10 cm soils. The species means for each soil property relative to the mean for all four species is plotted on the Y axes. Differences in pH (regional mean ± SE) are given on the left Y axes. Percent differences in nutrient concentrations (regional mean ± SE) are given on the right Y axes.

have important implications for activity of litter- and soil-dwelling organisms that are sensitive to variations in pH and soil nutrients.

For each soil property except total soil C, local species-based differences were significant at one or more sites across the region. Despite considerable variation in soil response from site to site, these results suggest three possible patterns of tree species effects on soils. In the case of N (Figure 4a), P, and, to some degree, C, interspecific differences in soil nutrient concentration may emerge as the site's overall concentration of that nutrient increases. Alternatively, the pattern observed for Ca^{2+} (Figure 4b) suggests that high nutrient availability at a site may allow for greater intraspecific variability in effects on soils, potentially reducing or masking any interspecific differences. Finally, species-based differences in soil nutrients may appear across the range of concentrations, as observed for Mg^{2+} (Figure 4c), K^{+}, and Na^{+}.

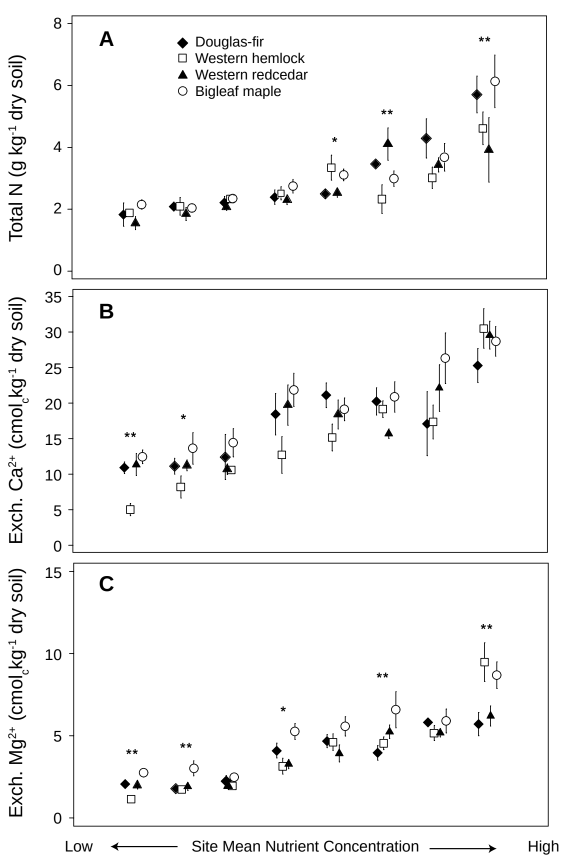


*Figure 4. Local scale species means (local mean ± SE) of 0–10 cm soil concentrations of A) total nitrogen, B) exchangeable calcium, and C) exchangeable magnesium. Species effects in local scale linear mixed-effects models: **p<0.05, *p<0.10.*

Overall, for the species we studied, we conclude that locally observed tree species-soil relationships are not necessarily indicative of general patterns across stands or at larger regional scales. Qualitatively significant variations in underlying site characteristics (e.g., soil parent material, fire history) across our study sites may contribute to differences in species-soils relationships that exist at the regional scale. Tree species-level variations in soil properties of current late-successional forests in the Oregon Coast Range may contribute to local biodiversity in soil- and litter-dwelling organisms by creating heterogeneous biochemical habitats at scales of one to several square meters, the projected zones of influence of individual trees. Such variations may decrease in the future, however, as continued fire suppression promotes dominance by shade-tolerant western hemlock in LSRs.

Study Timeline

Soils were sampled during summer 2003 and foliage was collected in summer 2004. Laboratory work and data analysis concluded in fall 2005. Preparation of publications describing the research and its results will continue through winter 2005/2006.

Fire Severity and Post-Fire Vegetation Recovery in Riparian Areas of the Biscuit Fire in Southwestern Oregon

Jessica Halofsky and David E. Hibbs

Riparian zones have great ecological importance relative to the area they occupy in the landscape. Although natural disturbances, such as fire and landslides, are integral in the dynamics of riparian systems, very little is known about the role of fire in riparian areas. Riparian zones have unique physical characteristics, as well as unique vegetation structure and composition, which have the potential to influence fire behavior in riparian zones. Upland fire behavior has been well studied, but there is no consensus on how fire behaves in riparian areas compared to uplands; some researchers have found that fire is less severe in riparian areas than in uplands, whereas others have found that fire is more severe in riparian areas. There is also very little information on vegetation recovery patterns in riparian areas following fire.

The present study was initiated in two watersheds of the 2002 Biscuit Fire in the Siskiyou National Forest of southwestern Oregon. Two objectives of the study are to determine 1) how the severity of fire in riparian areas compares to that in uplands and 2) what factors influence the severity of fire in riparian areas. Meeting objectives 1 and 2 will allow land managers to predict fire severity in riparian areas and establish what properties of riparian areas could be altered by silvicultural and fuels treatments to modify fire effects. Fire severity of uplands, forest basal area, species composition, pre-fire stand age, valley floor width, stream bank-full width, and topographic variables were measured factors. Forest productivity also is a potential organizing principle explaining the discrepancies in theories on how fire behaves in riparian areas compared with uplands, because differences in fuel composition, structure, and configuration in systems of varied productivity may affect how fires burn in riparian versus adjacent upland areas. Thus, Watersheds 1 and 2 investigated in this study represent relatively low and high productivity levels, respectively. A third objective of this study is determining what factors affect post-fire recovery patterns in riparian zones. Meeting objective 3 will provide managers with information for a predictive model for the type and rate of riparian vegetation recovery after fire. Meeting objective 3 will also provide managers with guidance in deciding on the type and locations of post-fire rehabilitation that may be necessary in riparian areas and guidance in determining whether prescribed burning would influence riparian vegetation in a desirable way. To meet this objective, we measured fire severity, abundance of resprouting hardwoods and shrubs, and width of floodplains/terraces, among other factors.

Information on the behavior of fire in riparian systems will lead to a greater understanding of the role of fire as a disturbance process in riparian areas of southwestern Oregon and will aid in the understanding of how environmental factors related to riparian zones can affect fire regimes at local and landscape scales in this region. Information gained in this study will also aid in setting pre- and post-fire management goals for riparian areas of southwestern Oregon.

Methods

Study sites

Two watersheds in the Biscuit Fire area were selected for study. The first watershed (Watershed 1, Figure 1), on the east side of the fire, is characterized by relatively low forest productivity. Watershed 1 is approximately 6000 ha in size. Dominant overstory species include Douglas-fir (*Pseudotsuga menziesii*), white fir (*Abies concolor*), sugar pine (*Pinus lambertiana*), Port-Orford-cedar (*Chamaecyparis lawsoniana*), and western hemlock (*Tsuga heterophylla*). Common midcanopy species include tanoak (*Lithocarpus densiflorus*), canyon live oak (*Quercus chrysolepis*), and golden chinquapin (*Chrysolepis chrysophylla*), and the understory is characterized by Pacific rhododendron (*Rhododendron macrophyllum*), salal (*Gaultheria shallon*), dwarf Oregon-grape (*Mahonia nervosa*), Sadler oak (*Quercus sadleriana*), and wild blackberry (*Rubus ursinus*). The second watershed (Watershed 2, Figure 2), on the west side of the fire, is characterized by relatively high forest productivity. Watershed 2 is approximately 10,000 ha in size. Dominant overstory species include Douglas-fir, sugar pine, western hemlock, and Port-Orford-cedar. Common midcanopy species include California laurel (*Umbellularia californica*), tanoak, golden chinquapin, and canyon live oak. The understory is characterized by evergreen huckleberry (*Vaccinium ovatum*), Pacific rhododendron, salal, wild blackberry, and dwarf Oregon-grape.

Sites were selected in each watershed to incorporate a range of broad fire severity classes, stand ages, and stream sizes. Within a geographic information system (GIS), a fire severity map created by the U.S. Forest Service was used to separate each watershed into three broad fire severity categories (low, moderate, and high severity). For a given severity class, first-, second-, and third-class stream segments were identified. Once stream segments were selected in each fire severity class, points were randomly selected in a GIS to incorporate a range of forest stand ages (early-, mid-, and late-seral stage). Approximately 25 points were sampled in each watershed.

Vegetation sampling

At each randomly selected point, four plots were established: two 5- x 25-m plots were placed directly adjacent to the stream, and one 10- x 25-m upland plot was placed 25 m above the riparian area on each side of the stream. In each plot, fire severity was assessed. Fire severity measures taken in each plot included scorch height and percent crown scorch of the three tallest trees in each plot. These measurements were done with a hypsometer. Percent exposed mineral soil and percent oxidized soil were visually assessed in each plot. Basal area mortality and live basal area were approximated in each plot by measuring the diameter at breast height (DBH) of all trees >5 cm DBH and recording by species whether the individual trees were living or dead. All individual trees <5 cm DBH were counted by species. Dead shrub stems were also counted by species, and the percent cover of all live shrub species was visually assessed to approximate former shrub cover by species. Aspect and elevation were recorded for each plot.

In addition to the above methods, further measurements were taken in riparian plots. These measurements included stream gradient within the plots, percent slope to each of the upland plots, bank-full width, and valley floor width. For the purposes of assessing recovery of riparian vegetation, all live and dead trees in the plot measured within 2 m of the stream were recorded separately. In addition, all regeneration of trees and shrubs was recorded in the 2-m band. It was noted whether regeneration was by seed

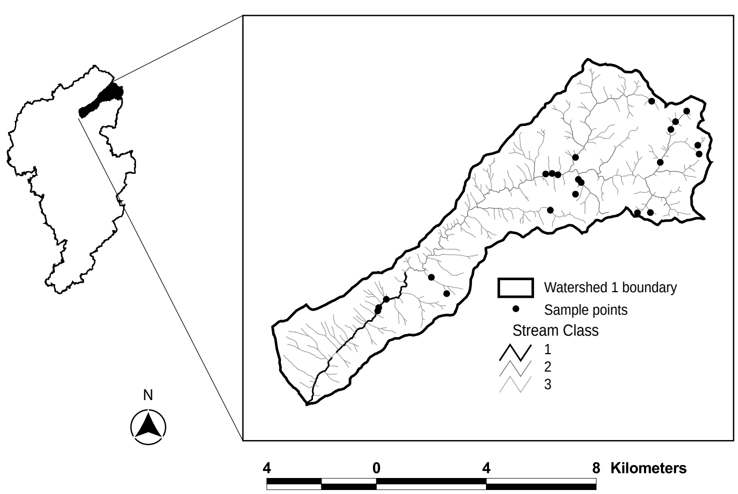


Figure 1. Watershed 1 (low-productivity watershed) location in the Biscuit Fire.

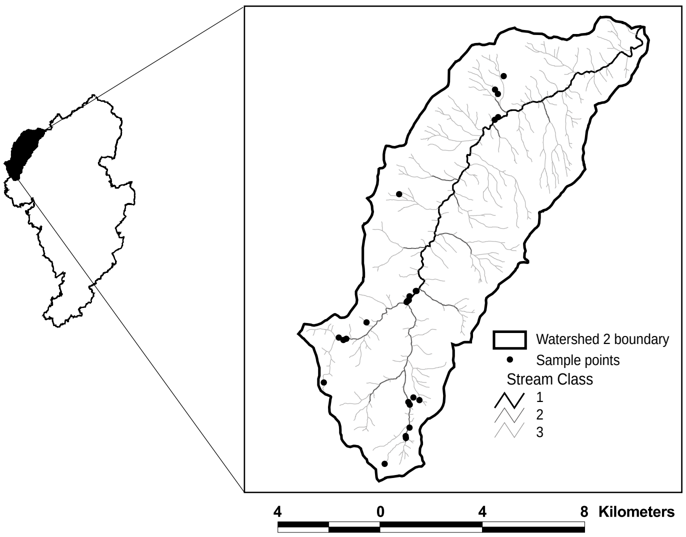


Figure 2. Watershed 2 (high-productivity watershed) location in the Biscuit Fire.

or sprouting. All riparian plot centers were permanently marked with rebar, and GPS coordinates of the markers were taken for future measurement purposes.

Analysis

T-tests were used to determine whether fire severity measures differed significantly between riparian areas and adjacent uplands. Model selection based on Akaike's Information Criteria (AIC) was used to identify environmental and topographic variables that influenced riparian fire severity. *A priori* hypotheses were generated and used to develop a set of approximately 50 biologically reasonable one-, two-, and three-factor regression models for each fire severity response variable, including percent exposed mineral soil, percent crown scorch, percent basal area mortality, and scorch height. Explanatory variables included in the models were stream gradient, valley floor width, bank-full width, upland total basal area, riparian total basal area, upland conifer basal area, riparian conifer basal area, riparian alder basal area, and upland fire severity. The models developed for each fire severity response variable were compared using AIC, and the set of models with the lowest AIC values were considered to be the models with the most explanatory power.

Nonmetric multidimensional scaling (NMS) ordination was used to examine species composition of regenerating vegetation in riparian zones. Stem count data of all regenerating species were used in the analysis. Environmental variables included in the analysis were watershed, stream class, seral stage, stream slope, valley floor width, bank-full width, scorch height, crown scorch, percent exposed mineral soil, basal area mortality, conifer basal area, and alder basal area. Multi-response permutation procedure (MRPP) was also used to test for differences between regenerating plant communities in plots along different stream classes and in different watersheds.

Preliminary Research Results and Management Implications

Upland versus Riparian Fire Severity

Both percent exposed mineral soil and scorch height on trees were significantly lower in riparian areas than in the adjacent uplands. Percent crown scorch and dead basal area proportion, however, did not differ significantly in the riparian and adjacent upland plots. These results indicate that the intensity of fires (scorch height) in riparian areas is generally lower than that of uplands. Despite lower fire intensity in riparian areas, fire damage in riparian areas (crown scorch and mortality) was not significantly different from that in the uplands. The level of damage in riparian areas may be explained by the shorter stature and greater sensitivity to fire of many species, particularly the hardwoods, found in riparian areas. The level of tree mortality caused by fire in riparian areas of the Biscuit Fire indicates that fire plays a major role in riparian vegetation dynamics in southwestern Oregon, similar to that in the uplands.

Factors that Influenced Riparian Fire Severity

Upland fire severity, stream gradient, riparian alder basal area, and bank-full width (or stream size) were found to be strongly associated with riparian fire severity (regardless of which fire severity measure was used in the model). Both upland fire severity and stream gradient were positively related to riparian fire severity, which suggests that when fire is severe in the uplands, it will also be severe in riparian areas, but when fire is of moderate or low severity in the uplands, the fire will be of moderate or low severity in the riparian zone. It also indicates that streams with high gradients burn more severely than those with lower gradients. Higher gradient streams could burn more severely because fire tends to burn uphill with increased slope steepness resulting in increased flame length and surface fire rate of spread. In addition, in the landscape of the Siskiyou Mountains where the Biscuit Fire occurred, smaller streams generally have higher stream gradients than the larger streams. Thus, it is possible that streams with higher gradients burned more severely because they are generally smaller and have less influence on fire behavior than larger streams.

Riparian alder basal area and bank-full width were negatively related to riparian fire severity, suggesting that riparian fire severity was lower with greater riparian alder basal area and bank-full width, or stream size. Alder serves as a microsite indicator in that its presence indicates generally wet conditions. The wet conditions in which alder grow would lead to lower riparian fire severity. In addition, larger streams may have more influence on fire severity than smaller streams because they have higher flow, thus serving as a larger fuel break, and also have a greater effect on adjacent vegetation, which can influence fire behavior. Larger streams also have lower gradients than smaller streams, thus resulting in decreased fire severity along larger streams. These results suggest that fire may play less of a role in riparian zones with relatively high alder basal area and in riparian zones adjacent to relatively large streams.

Overall, results indicate that fire severity is highest in riparian zones with relatively high stream gradient or slope, little alder presence, small stream size, and high upland fire severity. This information could be useful in targeting locations in the landscape for pre-fire fuels reductions and post-fire rehabilitation.

Riparian Recovery

Post-fire regenerating plant community composition in riparian zones depended on fire severity and stream size (bank-full width and stream class). Regeneration communities were significantly different among stream classes (MRPP yielded $P < 0.0001$ and $A = 0.06$), but there were only small differences between watersheds (MRPP yielded $P = 0.0014$ and $A = 0.02$). Greater regeneration of riparian associates, such as red alder (*Alnus rubra*), ocean spray (*Holodiscus discolor*), willow species (*Salix* spp.), and Saskatoon serviceberry (*Amelanchier alnifolia*), occurred along larger streams and in locations that had lower fire severity. Lower fire severity and greater water availability appear to combine to result in greater regeneration of riparian associates along larger streams after fire. Regeneration of riparian species such as bigleaf maple (*Acer macrophyllum*), vine maple (*Acer circinatum*), western raspberry (*Rubus leucodermis*), and stink currant (*Ribes bracteosum*) was positively associated with pre-fire basal area of red alder, although oddly, regeneration of red alder (mostly sprouts) was not associated with pre-fire red alder basal area. Greater red alder basal area is associated with greater regeneration of riparian species, but not with red alder, possibly because red alder sprouts only in areas of relatively low fire severity, not in areas of high fire severity, where most alder are killed.

Information on the factors that influence post-fire riparian vegetation recovery can again help managers predict locations where riparian areas may be most in need of post-fire rehabilitation treatments. Results suggest that post-fire rehabilitation should be concentrated on small streams where fire severity is relatively high and regeneration of riparian associates is low compared with large streams.

Study Timeline

Data collection in the Biscuit Fire was completed in September 2004. Similar data was collected in the B&B Complex Fire in the Deschutes National Forest in the summer of 2005. Riparian recovery will be remeasured in the Biscuit Fire plots in the summer of 2006.

Predicting Post-fire Regeneration Needs: Spatial and Temporal Variation in Natural Regeneration in Southwestern Oregon and Northern California

Jeff Shatford and David E. Hibbs

Forest management for the last 50 years has emphasized artificial regeneration following fire, whereas research on natural regeneration following wildfire has received less and less attention on public lands. This is due partly to a focus on timber production, which penalizes delays in reaching full stocking, and the emergence and success of planting technology. The result has been a substantial gap in our understanding of natural regeneration patterns under current climate and disturbance regimes. Despite the increasing dependence on natural regeneration, information that can justify efforts and prioritize management decisions is lacking. This, along with growing budgetary constraints, has made post-fire reforestation planning an ever more frequent but difficult task for forest managers.

Recent decades have seen an increase in the frequency and extent of wildfires in the Klamath-Siskiyou region of southwestern Oregon and northern California. We are undertaking a two-stage research program to investigate natural regeneration on forest lands in this region. We surveyed sites subject to high-severity forest fire across a productivity gradient from moist to dry plant series in the region. We quantified sapling density and stocking levels 1–2 decades after wildfire. We will model sapling abundance as a response to aspect and distance to seed source over time and compare the patterns among forest types across the productivity gradient. A regional analysis of data sets available from existing survey and monitoring plots will be used to expand our scope of reference and build a knowledge base to guide management of forest types across the region. By improving predictions of natural regeneration patterns in time and space, this study will be highly informative to forest managers trying to prioritize management actions after wildfire.

This project will focus primarily on the regeneration of shade-intolerant conifer species within areas that have experienced high-severity wildfire. This focus is based on the assumptions that 1) reforestation efforts are most relevant to areas of high fire severity, where seed sources may have been reduced or eliminated, thereby limiting natural regeneration; 2) conifers depend more on regeneration from seed, whereas many hardwoods regenerate by basal or root sprouting, and 3) shade-intolerant conifers are, in most cases, the appropriate species in early successional habitats and, therefore, of most interest to forest managers in this region.

The two parts of our approach to modeling post-fire conifer regeneration are intended to complement one another: part 1 will investigate both temporal and spatial patterns of regeneration across the region, while part 2 will provide a spatially robust, but temporally limited, analysis of natural regeneration.

Part 1 will take a retrospective approach to assess natural regeneration on sites 10–30 years after wildfire. We will develop a model of post-fire natural regeneration from data we will collect from the field. There is a reasonable chance that fires in this period will have accurate and accessible records in agency files, including maps, records of planting areas, and aerial photographs. They represent many years of regeneration, which can be assessed in a single survey. This may be particularly important for species with high annual variation in seed productivity, because our time frame will span 3 or more high seed years. In addition, sufficient years will have passed to distinguish stands with abrupt versus protracted stand initiation.

In part 2, we will access existing surveys of natural regeneration from USDA Forest Service (USFS) and Bureau of Land Management (BLM) managers and area ecologists working in southwestern Oregon and northern California. This data set will be used to assess natural regeneration over the short term (a few years after disturbance) but across a very broad set of site conditions.

Methods

Study area

The Klamath-Siskiyou region (4 million ha) is recognized for its floristic diversity and the historic role of fire in shaping and defining its plant communities and successional patterns (Sensenig 2002, *Development, Fire History, and Current and Past Growth of Old-Growth and Young-Growth Forest Stands in the Cascade, Siskiyou, and Mid-Coast Mountains of Southwestern Oregon*. PhD Dissertation, Oregon State University, Corvallis, OR; Weisberg and Swanson 2003, *Forest Ecology and Management* 172:17–28). The resulting vegetation patterns are complex but well described in terms of the variation in geology, climate, and elevation (Atzet et al. 1992, *Vegetation in Reforestation Practices in Southwestern Oregon and Northern California*. Oregon State University, Corvallis, OR).

We focused our surveys on the most common plant associations in the area. Together, these represent a broad gradient of productivity from moist, highly productive Douglas-fir/Tanoak series on the western end to the more arid Douglas-fir and Pine-Oak series farther inland. From 1970 to 1989, 94 wildfires, totaling over 175,000 acres, occurred in southwestern Oregon; >100,000 acres burned in the Klamath region of northern California in 1987 alone.

Study Design

Part 1

To build the regression models, we will sample across the range of each of the factors of interest (plant association, elevation, slope, aspect, and distance from seed source) and the full range of each combination of variables. Candidate sites were identified from GIS data on fire occurrence between 1975 and 1996 and the locations of managed stands (indicating areas to avoid). Sample sites met the following general criteria: 1) subject to canopy replacing wildfire 15–30 years prior (>90% tree mortality); 2) not subject to post-fire salvage logging or tree planting; 3) one of the four plant series of interest present; 4) aerial photographs taken shortly after the fire (1–5 years).

The sampling unit was a rectangular plot comprised of thirty 4- x 4-m (16-m^2) cells. Each cell, roughly equivalent to 1/250 acres, provided a means to assess tree stocking (the proportion of an area occupied by trees). Plot-level measurements included plant series, aspect, slope, elevation, and distance to nearest seed source. For each cell, we tallied saplings by species and diameter at breast height (DBH) class. For saplings <1.3 m we recorded species and height. In each cell, we aged the largest (presumably oldest) shade-intolerant conifer (pine or Douglas-fir), if present, or secondarily, a shade-tolerant conifer (true fir, cedar, or hemlock). We aged saplings by cutting or coring at the base and counting annual growth rings. We aged the three smallest, and presumably youngest, shade-intolerant conifers in the plot to determine the time since cessation of seedling establishment.

Part 2

Regeneration survey data will be solicited from the BLM, USFS, and area ecologists. Data must meet the following general criteria: 1) natural regeneration on sites that had been subject to wildfire has been surveyed; 2) date of fire and survey are known; 3) location can be determined and described in terms of plant series, elevation and aspect; and 4) density and stocking levels of natural regeneration by species and/or species size classes can be determined or calculated. Regeneration survey manuals following a standard format have been in use by federal agencies since the early 1980's (BLM 5710 Manual) and earlier.

Preliminary Research Results

Part I

Over the 2005 field season, natural regenerating conifers were sampled in 38 plots within 11 historic fires in the Klamath-Siskiyous region. The sample included a broad geographic area with considerable range in forest types (Douglas-fir/Tanoak, Douglas-fir, White fir, Shasta Red-fir), elevation (260–1940 m), and aspects. Years since stand replacing wildfire ranged from the oldest at 18 years (1987) to 9 years. Three 'test' plots were sampled in the Biscuit Fire of 2002.

Canopy openings ranged from ~10 acres to >100 acres. Evidence of recent fire (3–18 years ago) included charred snags, and down wood was abundant at each site. Competing vegetation, shrubs and resprouting hardwoods, was abundant on many sites except at the youngest fire sites (Biscuit) and one xeric site. Distance from seed source to plot ranged from 0 to >200 m.

The density of natural regenerating conifers ranged over three orders of magnitude (Figure 1). Sapling density in Douglas-fir groups (including tanoak associations and mixed-conifer forests) ranged from a low of 146 trees per hectare (TPH) to a high of 8188 TPH (1878 ± 2184 [mean ± SD], *n*= 18). Sapling density on true fir sites ranged from a low of 688 TPH to a high of 16,771 TPH (9193 ± 5763 [mean ± SD], *n*=8).

A 4- x 4-m cell containing a sapling >1 year was considered occupied or stocked. Conifer stocking at Douglas-fir sites averaged 65%, and true fir sites averaged 80% stocking (Figure 2).

Although the abundance of natural regeneration was frequently high, the age and size of saplings ranged considerably (Figure. 3). Frequently, the regenerating

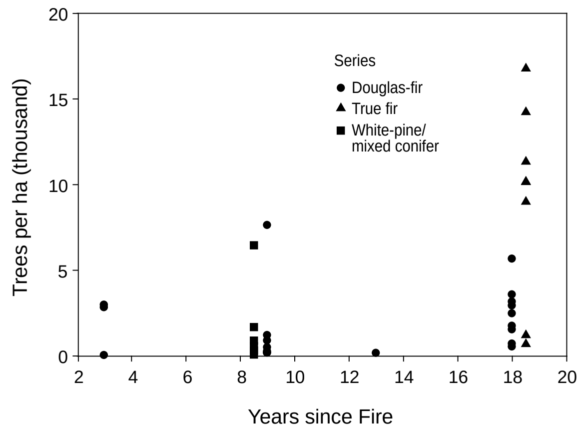


Figure 1. Conifer sapling density following canopy removing wildfire in the Klamath-Siskiyous region.

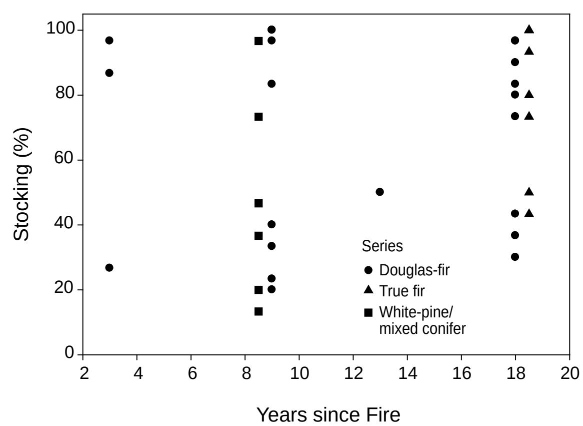


Figure 2. Percent of 0.016 ha (=1/250 acre) cells occupied by conifer saplings following canopy replacing wildfire at sites in the Klamath-Siskiyous region.

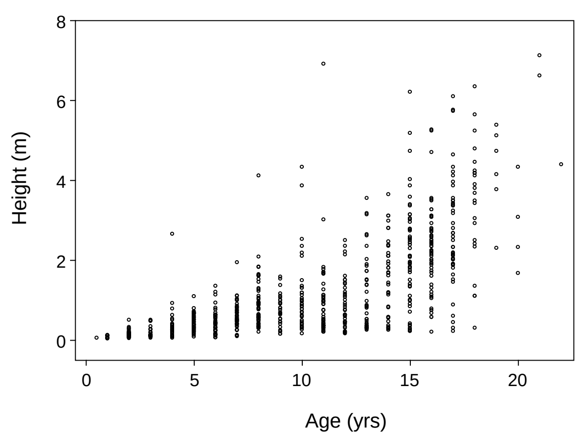


Figure 3. Age and height relationship for saplings occupying post-wildfire sites in the Klamath-Siskiyous region (all species and sites combined).

saplings were over topped by shrubs and hardwoods. There was no evidence of recent conifer sapling mortality (i.e., no dead or dying saplings) caused by competition from shrubs or self-thinning. Saplings were generally in good condition, with dominant trees having a live crown ratio of 50% or greater. Browsing by mountain beaver was evident at one location.

Part 2

At least two USFS Ranger Districts have provided data from past natural regeneration surveys in post-wildfire settings. Additional sources have been identified including Forest Inventory Analysis and Ecosystem Plots in southern Oregon.

Additional data will be required to adequately model the influence of forest type, distance to seed source, slope/aspect, etc. Field surveys will continue through the spring and summer of 2006. We have identified sites in parts of the Klamath, Rogue River-Siskiyous, and Umpqua National Forests and Crater Lake National Park that fit our criteria. We are interested in expanding our search to include additional sites in the Shasta-Trinity and Fremont-Winema National Forests and in areas managed by the BLM. We will be in contact with district managers in these areas to help broaden our search and identify suitable areas.

Study Timeline

This is a 2.5 year project. Field work for this study will continue through 2006 with analyses, report writing, and technology transfer to continue through the following year. Project completion is scheduled for November 2007.

Four Centuries of Soil Carbon and Nitrogen Change after Severe Fire in a Western Cascades Forest Landscape

Thomas Giesen and Steven Perakis

Fire changes forests both above ground (combusting vegetation) and below ground (heating soils). Severe fire effects on soils include combusting some (or all) of the forest floor, reducing soil carbon (C) and nutrient contents, and altering many soil properties. Changes in soil C and nutrients, especially nitrogen (N), may be especially important factors that influence stand recovery rates and biotic response after fire. Fire disturbances in forests have been studied most often in terms of above-ground effects, with less attention given to below-ground effects, and usually have been limited to understanding short-term effects. In contrast, studies of the long-term effects of fire on soils in temperate coniferous forest ecosystems are exceedingly rare. Consequently, theories of long-term fire effects on soils are based primarily on extrapolation from short-term observations and experiments.

Changes in soil nutrient capital and dynamics following fire result primarily from organic matter combustion and from soil heating. Severe fire effects (Figure 1) on soils result from high temperatures occurring in a given place over a period of time. Although fire effects on soils can be extremely patchy, there typically is a net loss of C and N from soils when averaged over fire-affected areas. Losses of C–essentially losses of soil organic matter–reduce soil structure and moisture-holding capacity. Fire-induced losses of N from organic matter combustion occur in concert with C losses, and further N may be lost from soils as post-fire stands regrow and transfer N from soils to above-ground vegetation. Whether such losses persist over long periods remains unknown, yet has important implications for understanding how changes in fire regimes due to climate, suppression or both will affect long-term sustainability of forest productivity and other processes in fire-dominated landscapes. To address this, we examined how time-since-fire influences forest floor and surface soil pools of C and N in natural unlogged stands of the western Cascades of Oregon.

Methods

Sites

Sites are in a 450-km^2 area in and adjacent to H.J. Andrews Experimental Forest in Oregon. The sites are on the western slope of the Cascade Range about 75 km east of Eugene, Oregon. They range in elevation from about 400 m to 1550 m and have a maritime-influenced, moderate climate, with wet, mild winters and dry, cool summers. The lower elevations are composed of volcanic rocks in mudflow, ash flow, and stream deposits. On upper slopes and benches, bedrock is Miocene andesite lava flows and younger High Cascades rocks. Glacial action, landslides, and alluvial and colluvial processes have produced a dissected and steep landscape.

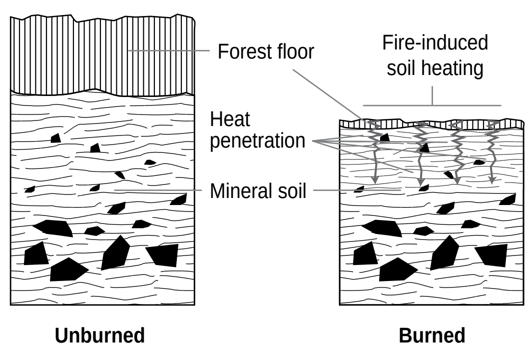


Figure 1. Cross section of forest floor/mineral soil, indicating the effects of high fire severity.

For this study, we sought natural, unlogged stands that had been generated in fire, either fairly recently ("young" sites) or quite some time ago ("old" sites). We selected likely stand locations by using two previous studies of fire and stand history that were conducted throughout the area by Weisberg and Giglia. These previous studies produced detailed fire histories of the area by examining tree-ring scars and other stand demographic information usually contained in rings of stumps located in recently created clear cuts. Using their GPS reference points, we were able to identify intact and unlogged stands located in the immediate vicinity of these previous fire-history studies; often our stands abutted directly against the fire-history stands. Minimum stands were about 150 m x 250 m, so that a 100-m transect would always be 75 m in from any edge to minimize edge effects. In total, we selected 12 young and 12 old stands for study. The 12 young stands burned an average of about 150 years ago. Of the 12 old stands, eight have been undisturbed for an average of about 450 years, and four have been undisturbed for at least 800 years, for an average time-since-fire of 550 years.

Sampling

Stands were sampled via 100-m transects, at least 75 m in from the edge, sampled each 5 m (Figure 2). All sample collection was done by one person in one season. A 10- x 10-cm area of forest floor (defined as Oe and Oa horizons) was collected, passed through a 9.5-mm sieve, and analyzed for moisture content (65°C), ash-free dry weight (AFDW, 450°C), and total N and C. In addition, a subsample of forest floor was incubated for 28 days in the laboratory to determine net N mineralization and nitrification. Soils were sampled in the same manner as forest floor, with the following exceptions: soil was sampled after removing the forest floor by inserting a 6.8 cm diameter x 14 cm long steel tulip bulb planter 10 cm deep, and placing the sample in a bag. Soils were sieved (2 mm) and subsampled for analysis as above.

Research Results

A detailed statistical analysis of the data is forthcoming. Here we present provisional results as arithmetic

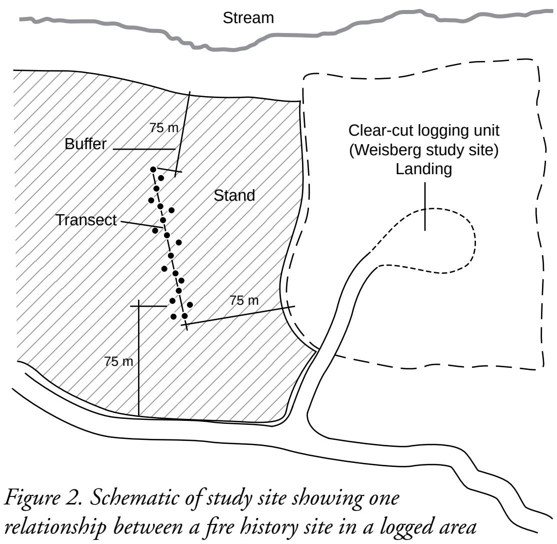


Figure 2. Schematic of study site showing one relationship between a fire history site in a logged area with a nearby unlogged remnant stand used for sampling in this study.

means and discuss patterns in the data without statements of statistical significance. Forest floor mass (g AFDW/cm^2) averaged ~ 20% higher in old sites (1.214 g/cm^2) than in young sites (0.999 g/cm^2), but mineral soil bulk density was similar in both fire history classes. Forest floor and mineral soil concentrations of N and C (g N or C/g soil), when adjusted to reflect only the organic fraction (AFDW), were virtually identical in old and young sites.

Sites unburned for 400 years had 15% more N in the forest floor (1054 kg/ha) than did sites burned recently (908 kg/ha). Carbon pools in the forest floor were 19% greater in old sites (36,469 kg/ha) than in young sites (30,630 kg/ha). These differences in C and N content are attributable to the trend of higher forest floor mass in old sites, since concentrations of C and N were virtually identical in young and old sites. Carbon or N content of mineral soil alone was quantitatively similar in young and old fire sites.

Potential net N availability in laboratory incubations (one 28-day constant-temperature-and-moisture incubation, AFDW-adjusted) showed much greater forest floor N mineralization (mg N/g forest floor) in old sites (60 mg/g) than in young (26 mg/g). N mineralization rates were comparatively low in mineral soil (<1 N mg/g soil), and were similar in young and old forests.

Nitrate accounted for only about 1% of net N mineralization in forest floor of both young and old sites. However, nitrification was an important contributor to net N mineralization in mineral soils and accounted for a higher proportion of mineralized N in young sites (54%) than in old (11%). In general, patterns of mineralization and nitrification were similar whether expressed per unit forest floor and soil mass or per unit N.

Discussion

Using literature values (data not shown), we estimate N losses accompanying stand-replacing fires, which also produce severe fire effects on the forest floor and soils, at 1500 to 2500 kg/ha per event. Such losses, however, occur in patches in which soils are severely impacted by the fire; losses averaged across the burned area are likely to be much less. This patchiness, coupled with potential successional differences in N inputs and losses over 400 years of post-forest development, may explain why we found only relatively small differences in forest floor and soil N (on the order of 259 kg N/ha relative to expected differences of 1500-2500 kg/ha). A formal statistical analysis is forthcoming to determine whether the difference we observed in forest floor and soil N capital is significant, or whether other factors such as elevation, aspect, and topography, may also be important.

Some authors have found that N mineralization decreases with succession, whereas others have found that mineralization increases with succession. We found that N mineralization, per gram of substrate or per gram of total N, increased substantially with age–although the explanation for this increase is unclear. Greater N mineralization in old forests suggests more readily available N, but runs contrary to traditional notions that very old forests act as the repository of more recalcitrant N forms. These results raise the possibility of more rapid cycling of N in old forests than previously realized, which may be used to fuel substantial plant N uptake and recycling in forests that have been undisturbed by fire for centuries.

High ammonium availability in forest soils often fosters high rates of conversion to nitrate. Surprisingly, we found that as net ammonium production increased with age, net nitrification stayed the same or decreased. This phenomenon appears unique to fire-adapted ecosystems. Other recent studies in coniferous forests show no stimulation of nitrate production when ammonium is added to soils. Charcoal from fire, however, may explain these conflicting results. Experimental charcoal additions to soils have been shown to stimulate nitrification, but the mechanism by which charcoal and nitrification interact is as yet unclear. It is thought, soon after fire, that fresh ("activated") charcoal adsorbs and deactivates polyphenol compounds that inhibit nitrification, thus permitting higher nitrification rates. Over decades to centuries, as charcoal is deactivated, polyphenols are no longer absorbed and remain active in soils, thus inhibiting nitrification. While the exact mechanism remains unclear, it is increasingly apparent that the availability of ammonium is not the only control over autotrophic nitrification in fire-adapted soils. Fire may thus influence forest N cycling both directly through effects on combustion losses of N and by legacy effects of charcoal throughout the life of the stand in controlling nitrification, and perhaps in the size of autotrophic nitrifying microbial populations. Collectively, the results of our and other studies suggest that information on soil N-cycling mechanisms developed in less fire-prone forests worldwide may have limited applicability to understanding key processes in fire-prone systems of western North America.

Management Implications

This study has several management-related implications. Fire exclusion, in time, may shift available N in soils towards ammonium and away from nitrate. Consequently, plant and microbial species that prefer the nitrate form of available nitrogen may be at a disadvantage in fire-excluded forests. In addition, the degree to which clear-cut logging mimics natural disturbance regimes in many Pacific Northwest forests may depend on whether fire is used as a site preparation technique afterwards. Fire may be necessary to add charcoal and restore fundamental soil N-cycling processes to conditions that are more representative of those occurring naturally following partial or stand-replacing fire.

Bureau of Land Management Density Management Study

John Cissel, Paul Anderson, Shanti Berryman, Sam Chan, Deanna Olson, Klaus Puettmann

The Bureau of Land Management (BLM), Pacific Northwest Research Station (PNW), U.S. Geological Survey (USGS), and Oregon State University (OSU) established the Density Management Study (DMS) in 1994 to develop and test options for young stand management to meet Northwest Forest Plan objectives in western Oregon. The DMS demonstrates and evaluates alternative approaches to managing 40- to 70-year-old forest stands on low-elevation sites in western Oregon to create and maintain late-successional forest characteristics.

Scientific and management objectives of the DMS include the following:

- ❑ evaluate effects of alternative forest density management treatments on important late-successional habitat attributes (large trees; standing and down dead wood; understory trees, shrubs, and herbs; vertical distribution of tree canopy; and spatial distribution of trees, shrubs, herbs, and dead wood)
- ❑ determine treatment effects on selected plant and animal taxa (amphibians, arthropods, mollusks, nonvascular plants, and fungi)
- ❑ assess the combined effects of density management and alternative riparian buffer widths on aquatic and riparian resources
- ❑ use DMS sites to develop operational approaches to implementation of new prescriptions and improve methods for effectiveness monitoring of plant and animal taxa
- ❑ use DMS sites to share results of on-the-ground practices and study findings with land managers, regulatory agencies, and policy-makers
- ❑ use results from DMS to conduct a long-term adaptive management process where management implications and policy changes are regularly evaluated and changed as needed

Methods

Study treatments

The DMS consists of three sets of treatments: initial thinning, rethinning, and riparian buffer widths (see http://www.fsl.orst.edu/cfer/pdfs/DMS.pdf for more details).

The initial thinning treatments were installed in 40- to 60-year-old stands that had never been commercially thinned. Four stand treatments of 30–60 acres each (1 acre = 0.405 ha) were established at each of seven study sites: 1) unthinned control, 2) high density retention (120 trees per acre [TPA]), 3) moderate density retention (80 TPA), and 4) variable density retention (40–120 TPA). Small (0.25–1 acre) leave islands were included in all treatments except the control, and small patch cuts (0.25–1 acre) were included in the moderate and variable density treatments.

Alternative riparian buffer treatments were nested within the moderate density retention treatment at each of the seven initial thinning study sites. Alternative riparian buffer width treatments included 1) streamside retention (one tree canopy width, or 20–25 ft [1 ft = 0.305 m]; 2) variable width (following topographic and vegetative breaks, approximately 70 ft), 3) one full tree height (approximately 220 ft), and 4) two full tree heights (approximately 440 ft). Physical limitations at each site usually prevented installation of all four treatments, and the two-tree-height treatment fit the ground on only two sites.

The rethinning treatments were installed in four 60- to 70-year-old stands that had been previously commercial thinned. Each study stand was split into two parts: one, an untreated control, and the other, a rethinning (30–60 TPA). The rethinning treatment was intended to represent a potential future option for a second entry thinning 15–25 years after an initial thinning.

Location

Study sites were selected on BLM lands to be broadly representative of mesic, low-elevation forests in western Oregon. Sites are located in both the Coast Range and the Cascade Range (Figure 1).

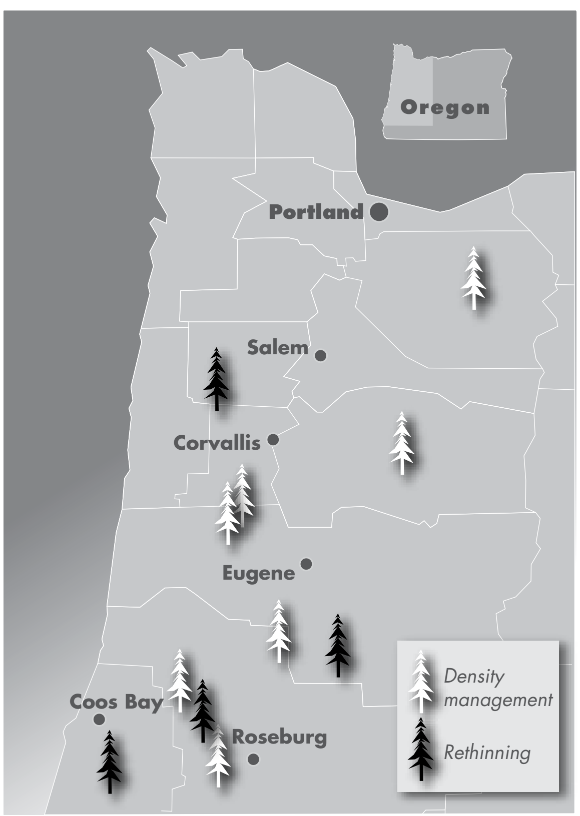


Figure 1. Location of the Density Management Study sites.

Component studies

Several component studies are currently underway addressing DMS objectives. Measurement, remeasurement, data management, and analysis were ongoing for each of these components in 2005.

Vegetation

Randomly allocated plots are scattered across all treatment areas to characterize treatment implementation and whole-treatment vegetation response. These plots also provide information about the influence of overstory conditions on understory vegetation diversity and development. Transects across patch-cut boundaries are being used to measure patch dynamics as affected by patch size and neighborhood. A full suite of overstory and understory tree, shrub, herb, and dead wood variables are being monitored. Klaus Puettmann (OSU) is the lead investigator for this component.

Microclimate and microhabitat

Microclimate and microhabitat gradients resulting from density management practices and alternative riparian buffer widths are being monitored at seven DMS sites along transects oriented perpendicular to streams and extending from stream center to approximately 240 ft past the end of the riparian buffer. Available light, air and soil temperature, streambed temperature, relative humidity, vegetation, and overstory trees are measured at points distributed along these transects. Paul Anderson (PNW) and Samuel Chan (OSU) are the lead investigators for this component.

Aquatic vertebrates

DMS sites are being used to assess potentially unique aquatic resources in managed headwaters and evaluate the effects of thinning in riparian reserves. Pre- and post-treatment surveys along streams with alternative riparian buffer widths and moderate retention thinning measure fish and amphibian abundances and their habitats. Terrestrial salamanders and mollusks are being monitored on two sites. Deanna Olson (PNW) is the lead investigator for this component.

Arthropods

Aquatic and terrestrial arthropods add significantly to the beauty and biodiversity of forest and stream ecosystems, are significant links in many food chains, and are important regulators of nutrient cycling processes. The biodiversity and biomass responses of aquatic and terrestrial arthropods to thinning and to alternative riparian buffer widths are being evaluated on three DMS sites using data collected with pitfall and emergence traps. Andrew Moldenke (OSU) leads this component.

Leave islands

Retention of leave islands during forest harvest operations has emerged as an important strategy to maintain plant and animal diversity. The objective of this component was to evaluate the relative effectiveness of leave islands in providing refugia for low mobility species including vascular plants, amphibians, mollusks, and arthropods. Species abundance and diversity in leave islands of different sizes were compared to thinned areas and to unthinned controls. Stephanie Wessell (currently with USGS), worked under the direction of Deanna Olson and Richard Schmitz (OSU) to complete this component of the study.

2005 Highlights

Overall study accomplishments

- ❑ Informal DMS findings and discussion workshop organized and hosted for the BLM
- ❑ Four DMS field tours hosted
- ❑ DMS findings presented at eight workshops and symposia
- ❑ GIS databases completed to a common standard for all DMS sites
- ❑ DMS Establishment Report and Study Plan manuscript *in review*
- ❑ Proposal for new study treatments to be implemented in 2009–2011 finalized and approved (BLM IM OR-2005-083)
- ❑ Outyear planning initiated for the five sites scheduled for implementation of new study treatments in 2009
- ❑ Potential to use stewardship contracting to implement the new treatments evaluated and rejected
- ❑ Plots established in the Ward Creek site in anticipation that this site will finally be implemented

Vegetation

- ❑ Analyses completed of overstory and understory vegetation dynamics (1 and 6 years postharvest) in stand matrix conditions at four initial thinning sites (Bottomline, Keel Mountain, North Soup, and OM Hubbard) and three rethin sites (Blue Retro, Sand Creek and Little Wolf)
- ❑ Overall understory vegetation response to the initial thinning treatments 6 years postharvest at four sites (Bottomline, Keel Mountain, North Soup and OM Hubbard) analyzed
- ❑ Variability of understory vegetation in relation to treatment complexity (i.e., gaps, leave island, stand matrix) assessed
- ❑ Field survey of overstory and understory vegetation and coarse woody debris at 231 new plots at Delph Creek, Green Peak, and Ten High initial thinning sites completed
- ❑ Overstory and understory vegetation remeasured at 151 thinning plots for three initial thinning sites (Delph Creek, Green Peak, and Ten High) and for 24 thinning plots at one rethinning site (Perkins Creek)
- ❑ In collaboration with Northwest Alliance for Computational Science and Engineering (NACSE), developed the vegetation database structure,

updated database with 2004 data, and created an interactive database on the DMS web site

- ❑ Results from understory vegetation responses to initial thinning treatments presented orally at the Ecological Society of America annual meeting and in poster format at the Science and the Northwest Forest Plan conference
- ❑ Canopy photographs on canopy gap gradient transects (900 photographs) collected and analyzed
- ❑ Understory vegetation diversity and community patterns analyzed on gradient transects across canopy gaps
- ❑ Initial results from the canopy gap analyses presented orally at the Ecological Society of America annual meeting and in poster format at the Northwest Scientific Association annual meeting and the Science and the Northwest Forest Plan conference

Microclimate and microhabitat

- ❑ Analyses of microclimate data revised, verifying conclusions stated in earlier draft report, but with a more conservative statistical model that avoids some potential confounding in the original analysis
- ❑ Microsite data cleaning: composited and reduced raw microsite data from pre-treatment through second post-treatment sampling
- ❑ Microsite data analysis completed: multivariate analysis of variance for buffer and upslope treatment effects with respect to four sets of variables (overstory structure, understory vegetation, forest floor, and physiography)
- ❑ Manuscript covering microclimate, understory light, and overstory structure prepared for presentation at Oregon Headwaters Conference and subsequent publication as a peer-reviewed journal article in a special edition for the conference
- ❑ Funding secured for new riparian sampling project to improve sampling methodology applied across riparian vegetation taxa and physiographic features; will lead to new riparian sampling design for DMS Phase II implementation beginning in 2008

Aquatic vertebrates

- ❑ New study initiated examining the use of down wood and other ground cover by amphibians and the microclimate buffering capacity of down wood of different sizes. Habitats will be assessed from stream banks to upslope conditions relative to streamside retention and variable width riparian buffers in the moderate thinning and control treatments
- ❑ Year 5 post-treatment field surveys of stream habitats and vertebrates conducted in spring and summer at three sites
- ❑ Second year of spring and summer pre-treatment surveys conducted at Ward Creek
- ❑ Site monumenting and metadata documentation conducted
- ❑ Analyses completed of year 1 and year 2 post-treatment habitat data in comparison with pre-treatment conditions
- ❑ Data entry and quality control conducted for year 5 post-treatment data
- ❑ Four presentations, four papers submitted, and five papers in preparation

Arthropods

- ❑ All specimens identified
- ❑ Web-based key for identification of species of adult stoneflies of Pacific Northwest completed
- ❑ Final analysis and manuscript in preparation

Leave islands

- ❑ Project completed June 2005: OSU Department of Fisheries and Wildlife M.S. thesis and manuscript, "*Biodiversity in Managed Forests of Western Oregon: Species Assemblages in Leave Islands, Thinned, and Unthinned Forests.*"
- ❑ Key findings include the following: over 400 species of four taxa (plants, arthropods, mollusks and amphibians) detected in young managed stands; thinning affected 30 species groups and numerous habitat components; leave islands affected 22 species groups and microclimate conditions; 0.25-acre leave islands were similar to thinned stands in plant composition and microclimate; 1-acre leave islands appeared to provide interior microclimate conditions and habitat for some late-successional species
- ❑ Electronic technology transfer, including streaming video of M.S. defense seminar, linked PowerPoint presentation, and manuscript posted on FSL website, available at: http://www.fsl.orst.edu/geowater/PEP/wessell/index.html
- ❑ Presentations at five regional and international conferences in four oral and two poster presentations
- ❑ Abstracts published in "Balancing ecosystem values: Innovative experiments for sustainable forestry: Proceedings of a conference" (PNW-GTR-635; available at http://www.fs.fed.us/pnw/publications/gtr635/index.shtml) and in *Northwestern Naturalist* 86
- ❑ Numerous consultations with university and state and federal agency personnel requesting information regarding leave island study results

Preliminary Research Results—Leave Islands

Retaining undisturbed standing trees at the time of timber harvest has become an important silvicultural method designed to maintain plant and animal diversity within managed forest stands. Retaining patches of green trees, termed leave islands, may promote species diversity by providing refugia or centers of dispersal for multiple taxonomic groups. However, data supporting the value of leave islands for old-growth associated species in second-growth forests undergoing continued management are few.

The objective of this project was to evaluate the relative effectiveness of various sizes of leave islands in providing refugia for ecologically sensitive, low-mobility species in managed forests. The specific goal was to evaluate differences in biota and habitat with respect to the size of leave islands. Specifically, we investigated the response of habitat conditions and multiple taxa to moderate thinning and to leave islands of three sizes embedded in thinned forest stands at four DMS sites: Bottomline and Green Peak in the Coast Range, and Delph Creek and Keel Mountain in the Cascade Range.

Data for habitat and biota were collected within a 20- x 20-m sampling area established at the center of each study unit (Figure 2). Each sampling area was comprised of four 100-m^2 (5- x 20-m) parallel transects, with transects aligned upslope. Habitat data corresponding to each study unit included microclimate (relative humidity, ambient and soil temperature), soil moisture, forest stand structure (downed wood volume, canopy closure, trees per hectare, basal area, and diameter at breast height), and substrate. Biotic response parameters included abundance and diversity of dispersal-limited species potentially adversely affected by habitat changes resulting from timber harvest: vascular plants, terrestrial amphibians, terrestrial mollusks, and arthropods.

We characterized the microclimate, forest stand structure, and biota in five types of forest: unthinned forest, moderately thinned forest (200 trees per hectare), and three sizes of leave islands (0.1 ha, 0.2 ha, and 0.4

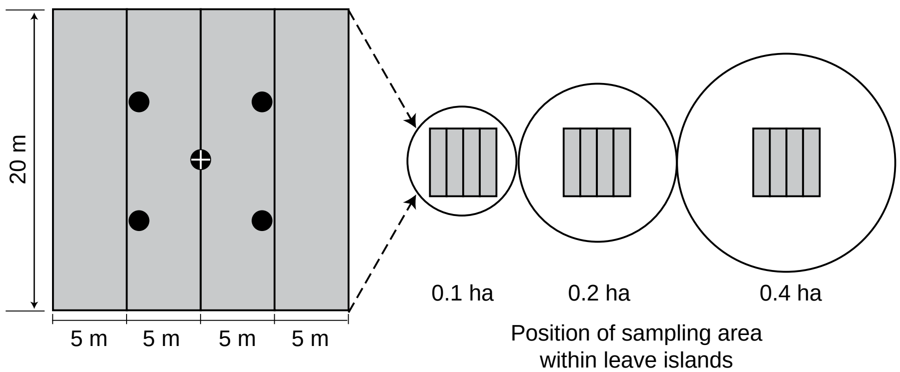


Figure 2. Schematic of sampling area showing four parallel transects sampled for vascular plants, amphibians, and mollusks. Five arthropod sampling plots (•) and one microclimate sampling point (+) are displayed.

ha). We used analysis of variance to test whether mean habitat or biotic measures differed between and among forest types, indicator species analysis (ISA) to identify species assemblages characteristic of each of the five types of forest, and species occupancy assessments to gauge occupancy patterns among all species sampled, including rare species not analyzed statistically. Finally, we used community analysis methods to examine differences in habitat and biota with respect to thinning and leave island size.

We identified a total of 120 vascular plant species: 83 herbaceous species, 8 subshrubs, 20 shrubs, and 9 trees. In soil litter samples, we captured 30,447 arthropods within 289 taxa. Finally, we captured 218 amphibians of 7 species and a total of 3,608 mollusks of 12 taxa.

We found multiple treatment effects of thinning and leave island size relative to microclimate, vascular plant diversity, and ground cover. The microclimate and vascular plant species composition differed between thinned and unthinned forest, while conditions within leave islands approximated conditions in unthinned forest. Proportions of exotic and early-successional species and species ground cover were higher in thinned forest than unthinned forest, and higher in small leave islands than larger leave islands. Treatment effects on arthropod, amphibian, and mollusk density were mixed. Of 118 parameters analyzed, negative effects of thinning on faunal species were detected for five arthropod species, low-mobility arthropod captures, one salamander species, one salamander family (Plethodontidae), amphibian species richness, and one mollusk species. Of 83 parameters assessed in arthropod analyses, positive effects of leave island size were found for arthropod species richness, overall density, density within six functional group measures, and six arthropod species groups. Treatment effects of leave island size were mixed for amphibians and mollusks with positive effects of leave island size for overall mollusk density, snail density, and density within three mollusk species groups. Indicator species analyses identified seven vascular plant and two arthropod species indicative of thinned forest, 0.2-ha and 0.4-ha leave islands.

Assessments of species occupancy patterns revealed insights regarding the potential utility of managing the forest matrix for habitat heterogeneity. For example, 71 (19%) taxa occurred only in leave islands and 139 (37%) taxa occurred only in leave islands and unthinned forest. These patterns may indicate occurrences of rare species and do not necessarily indicate associations with these unthinned forest types. Finally, community analyses highlighted the importance of addressing multiple spatial scales in forest management prescriptions by identifying distinct biotic assemblages occurring at forest type, study site, and mountain range scales.

Forest management activities can dramatically alter forest structure and habitat conditions for resident biota. Sustaining species adversely affected by silvicultural activities may require the implementation of innovative mitigation strategies such as retention of leave islands. Our retrospective study showed treatment effects on habitat and some biota resulting from thinning, and leave islands represented a potentially effective strategy to mitigate some treatment effects. The larger leave islands (0.2 ha and 0.4 ha) appeared effective in maintaining a semblance of interior forest conditions and several taxa within thinned forests. The smallest leave islands (0.1 ha) appeared analogous to thinned forests, as shown by several measures of microclimate and the presence of taxa associated with thinned forests. Leave islands may provide incidental benefits to a host of forest taxa.

Thinning most consistently affected microclimate, forest stand structure, and the composition and abundance of vascular plants. Microclimate differences followed intuitive predictions, with measures of ambient temperature and soil temperature consistently higher in thinned forest than unthinned forest, and measures of relative humidity consistently higher in unthinned forest than in thinned. Similarly, differences in forest stand structure followed logical patterns with measures of canopy closure, trees per hectare, and basal area consistently higher in unthinned forest than in thinned.

Thinning effects on resident biota were most pronounced for vascular plant species composition. Species assemblages in thinned forest included more early successional and exotic plant species, whereas unthinned forest assemblages comprised late-successional and native species. Thinning resulted in a less distinct pattern of effects on arthropods, amphibians, and mollusks. Our results suggest that leave islands may provide refugia for some low-mobility, ecologically sensitive species in managed forests of the Pacific Northwest.

Study Timeline

Thinning treatments were implemented on the 11 study sites between 1997 and 2002. Permanent vegetation plots were established in each stand soon thereafter. Remeasurement of permanent plots is scheduled to occur on a 5-year cycle. Each component study follows a similar timeline. Major analyses and reports are expected on a 5-year cycle. A second round of treatments is proposed to begin in 2009.

For more information on the current status of these studies, please contact John Cissel, DMS Coordinator (jcissel@or.blm.gov, 541-683-6410).

Nitrogen Dynamics across Gaps in Young, Thinned Forests of the Density Management Study

Aaron Thiel and Steven Perakis

Nitrogen (N) availability in soils plays a critical role in forest dynamics and development. Variations in N availability have been shown to affect tree growth and structural development, decay and turnover of leaves and woody detritus, diversity of understory and soil microbial communities, and many other factors. Consequently, understanding the spatial and temporal dynamics of N in forest soils can be crucial to understanding forest ecosystems as a whole.

The impacts of traditional silvicultural practices on N dynamics have historically been the subject of intense study. Clearcut forest harvest, for instance, has been shown to increase the production of nitrate (NO_3^-), a highly soluble ion, in forest soils. Subsequent N loss through NO_3^- leaching may lead to decreased site productivity and water quality levels. The potential impacts of modern silvicultural practices on soil N dynamics, as might result during gap creation to restore complex forest structure, remain less well understood.

The following study will investigate the effects of gap creation on N dynamics in young, thinned Douglas-fir forests. It will focus on three main questions:

- ❑ How do pools and cycling of plant-available N in soils vary across gaps and into the adjacent forest matrix?
- ❑ Does gap size affect the magnitude of these differences?
- ❑ What factors (e.g., quantity and quality of litter input, soil moisture, etc.) can explain dynamics of plant-available N in silviculturally created gaps?

Methods

Study Sites

This study will include three initial thinning sites from the BLM Density Management Study (DMS): Delph Creek, Green Peak, and Keel Mountain (Figure 1). Keel Mountain and Green Peak soils developed primarily from sandstone, whereas Delph Creek soils formed from a mixture of andesite, tuff, and volcanic ash. In all three sites, dominant overstory species are Western hemlock (*Tsuga heterophylla*) and Douglas-fir (*Pseudotsuga menziesii*), and characteristic understory species include sword fern (*Polystichum munitum*), bracken fern (*Pteridium aquilinum*), wood sorrel (*Oxalis oregano*),

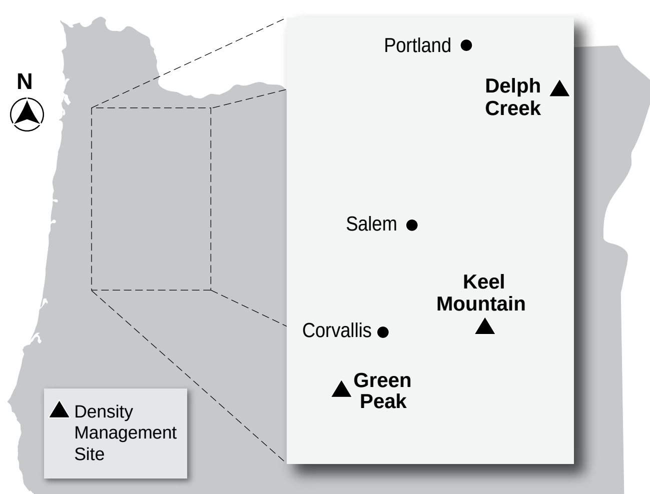


Figure 1. Location of the study sites.

salal (*Gaultheria shallon*), dwarf Oregon grape (*Mahonia nervosa*) and several *Rubus* species.

At each site, three large (0.4-ha) gaps and three small (0.1-ha) gaps will be chosen. Gaps were created between 1997 and 2000 and underplanted with Douglas-fir, western hemlock, grand fir (*Abies grandis*) and western redcedar (*Thuja plicata*) between 2000 and 2001. In most cases, gaps were created in moderate thinning treatments (80 trees per acre [TPA]), but some existed in variable thinning treatments (40–120 TPA).

Transect Setup

In each gap, transects will run through the center point and continue 40 m into the forest matrix on each side (Figure 2). In large gaps, nine 10- x 4-m plots will be placed along the transect: one at the center, two 20 m from the center, two at 40 m from the center (at gap edge), two 60 m from the center, and two 80 m from the center. In small gaps, similar plots will be placed at seven points along the transect: one at the center, two 20 m from the center (at gap edge), two 40 m from the center, and two 60 m from the center. Efforts will be made to maintain a north-south bearing on all transects but may range from 315 to 45 degrees to avoid roads, riparian areas, and other gaps and obstructions.

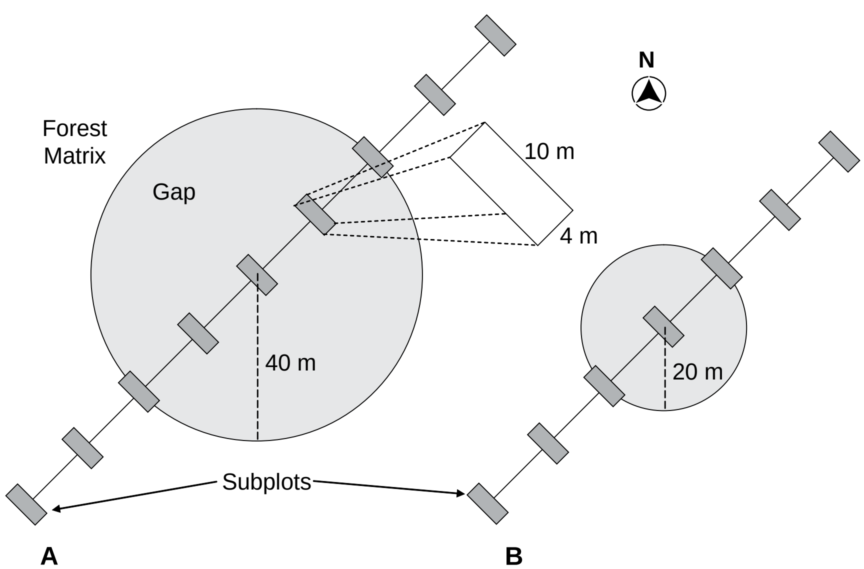


Figure 2. Transect and subplot layout of A) large gaps (0.4 ha) and B) small gaps (0.1 ha)

Field and Laboratory Measurements

We plan a series of field- and laboratory-based measures of N dynamics across gap transects. Field measures will provide information on how vegetation and microclimate act together to influence patterns of N dynamics across gaps. Laboratory measures of soil N availability under controlled laboratory conditions will seek to further disentangle the effects of vegetation from microclimate on N dynamics. Together, these measures will help to assess whether gaps influence N cycling directly by altering soil microclimate, or indirectly via more subtle effects of gaps on N recycling between soils and recovering vegetation.

Nitrogen recycling from plants to soils via litterfall will be estimated by collection of litter in two 37- x 25-cm litter baskets at each plot along gap transects. Litter will be sorted by species, dried at 65°C, weighed, and analyzed for total N and carbon (C) on an elemental analyzer. Mineral N in forest floor (Oe/Oa horizon) and mineral soil (0–10 cm) across transects will be assessed by measuring available pools of NO_3^--N and NH_4^+-N in soils after extraction with standard salt solutions. Another set of subsamples will be fumigated with chloroform prior to extraction to determine the content of C and N in soil microbial biomass. Net rates of N mineralization (the microbially-mediated conversion of organic N to NH_4^+) and nitrification (conversion of NH_4^+ to NO_3^-) will be determined seasonally in the forest floor and surface mineral soil (0–10 cm) of each plot using a combination of *in situ* incubations and ion exchange resin bags. All forms of soil and microbial N will be determined using standard methods of soil chemistry. For all samplings, a set of soil subsamples will be dried at 65° C for 48 hours to determine gravimetric moisture content. In addition, relative decomposition rates will be estimated across transects using mass loss of a standardized substrate (tongue depressors).

A lab incubation of forest floor and soil samples collected from each plot will determine the N mineralization and nitrification potentials of microbes under standardized conditions. Subsamples of forest floor and soil will be placed in flasks, left open to the air, maintained at 60% water holding capacity and incubated for 28 days at 25°C. Comparison of pre- and post-incubation NH_4^+ and NO_3^- concentrations in subsamples will determine rates of net N mineralization and nitrification in the absence of plant uptake and microclimate variations that exist across gaps in the field.

Data Analyses

Analysis of variance (ANOVA) will be used to determine statistical differences in plant-available N, net N mineralization and nitrification rates (both *in situ* and incubated), N microbial biomass, soil moisture, and litter inputs of N between different positions in gaps. ANOVA also will be used to determine if these variables differ at the same positions relative to the gap edge between large and small gaps. Multiple regression will be used to determine the correlation of N microbial biomass, soil moisture, and litter inputs with N on plant-available N and net N mineralization and nitrification rates (*in situ*).

Study Timeline

Litter inputs and decomposition rates will be assessed on a monthly basis from October 2005 to September 2006. Mineral N, soil moisture, and microbial C and N of forest floor and mineral soil will be measured in January 2005, May 2006, and August 2006 to coincide with the beginning of three 28-day *in situ* incubation events. Ion exchange resins will incubate in mineral soil in 3-month intervals from October 2005 to September 2006. Lab incubation of forest floor and mineral soil will occur in March 2006.

Large Woody Debris in the Terrestrial and Aquatic Riparian Zone: Production, Recruitment, Retention, and Function

Large wood in streams is important because it affects stream function. This wood also provides habitat for aquatic and terrestrial organisms. Although the role of large wood as a structural feature of coastal streams is known, the processes that control recruitment, retention, and redistribution of woody debris at broad spatial and temporal scales remain poorly understood.

Goal

The goal of this research theme is to develop a basin-level understanding of large woody debris, which includes:

- examining the processes and conditions that regulate input and
- examining the movement and removal of large woody debris.

2005 Highlights

- Former CFER-affiliated graduate student Thais Perkins published a paper in the journal *Biological Conservation* titled "The impacts of *Phalaris arundinacea* (reed canary grass) invasion on wetland plant richness in the Oregon Coast Range, USA, depend on beavers."
- Drs. Daniel Sarr and David Hibbs co-authored a publication in the *Quarterly Review of Biology* titled "A hierarchical perspective of plant diversity."
- A bibliography was compiled that addressed cumulative watershed effects in the Pacific Northwest. The product, in CD format, includes abstracts, PDF files of many of the publications, and software that allows for keyword, author, and title searches.

Continuing studies during the year under report are summarized in the following section.

Expected and Unexpected Effects of Fire Suppression in Riparian Forest

David E. Hibbs and Jeff Shatford

As we collected data for the study "Large Woody Debris Production and Input" (Hibbs and Shatford, *2004 CFER Annual Report*), we began to see unexpected patterns of vegetation composition and distribution. We found strong evidence for the effects of fire suppression in both wet and dry environments in western Oregon. This final report provides a review and discussion of this unexpected pattern and its implications for riparian habitat quality.

We collected data on riparian forest composition along streams in unmanaged, unharvested drainages in the central Coast Range (separating the spruce zone and the hemlock zone), the Santiam/McKenzie drainages of the Cascades, and southwestern Oregon. We sampled only along smaller 1st through 3rd order streams. To simplify this report, we will not discuss results from the Santiam/McKenzie drainages. We divided the Coast Range into the area known as the coastal fog belt, or Sitka Spruce Zone, and the central portion, which falls into the Western Hemlock Zone. We have called the former the Spruce Zone and the latter the Mountain Zone. We refer to the drier southwestern region as the Klamath Zone.

The mean fire-return interval over the last several thousand years has been given as 250 to 300 years for the Spruce Zone and 140 to 190 years for the Mountain Zone (Impara 1997, *Spatial and Temporal Patterns of Fire in the Forests of the Central Oregon Coast Range*. Ph.D. thesis, Oregon State University, Corvallis; Long and Whitlock 2002, *Quaternary-Research* 58:215–225) (Figure 1). Precipitation is high and landslides and debris flows may be common where slopes are steep. In contrast, the mean fire-return interval for the Klamath Zone is much shorter, from 15 to 50 years (Agee 1993, *Fire Ecology of the Pacific Northwest*. Island Press, Washington, D.C.). Precipitation is low enough that debris flows and landslides are uncommon.

Interpretation of diameter distributions of tree species is not precise. It requires knowledge of the forest type being examined and of the regeneration requirements of the species found there. With this knowledge, conclusions about relative ages of different sized trees can sometimes be made. The following interpretation of diameter distributions tries to be conservative.

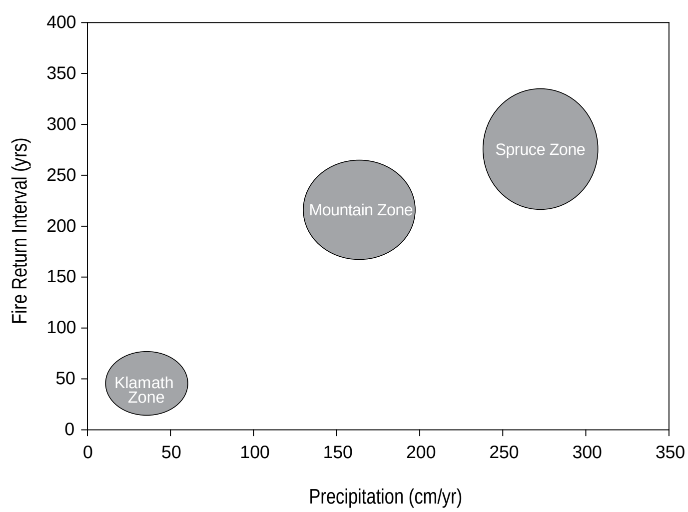


Figure 1. A schematic of the rainfall and fire-history for three sub-regions of western Oregon. High levels of precipitation in the coastal region reduce fire frequency but lead to extreme levels of fuel accumulation (both standing trees and woody debris).

Research Results

The diameter distribution of riparian tree species in the Spruce Zone is indicative of a self-regenerating, uneven-aged forest (Figure 2). Smaller alder, Sitka spruce and western hemlock trees are all abundant. Abundant small trees of red alder can occur only when reasonably large canopy openings and exposed mineral soil are present. Thus, the diameter distributions are not suggestive simply of succession to more shade-tolerant species (hemlock and spruce). Rather, riparian forests in this area appear to be maintaining their composition and density.

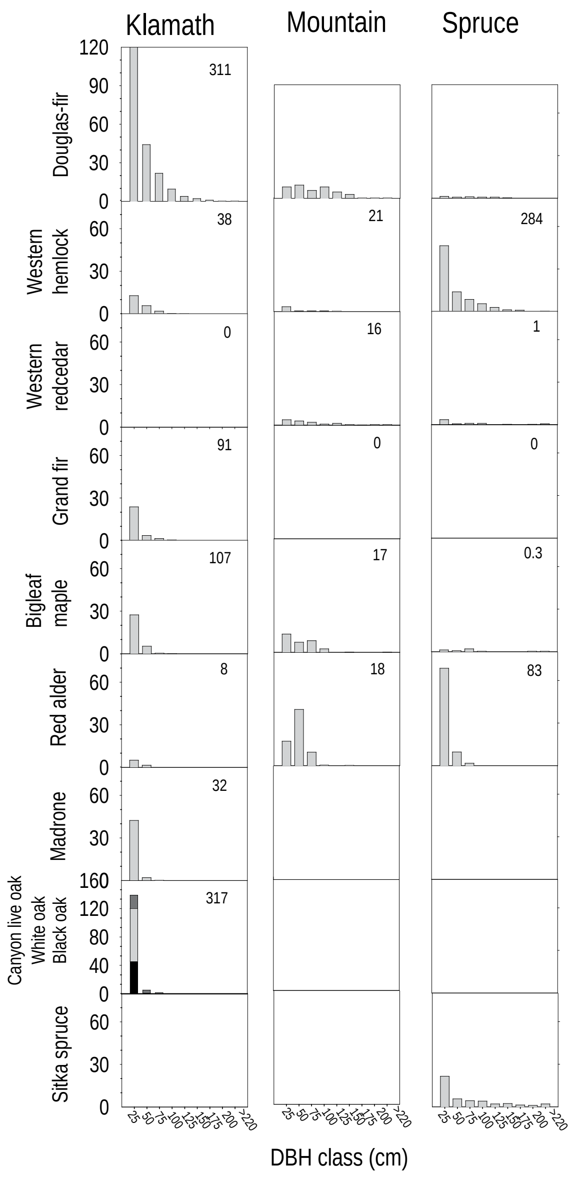


Figure 2. Diameter distribution per hectare for several dominant tree species in unmanaged riparian forests across three sub-regions of western Oregon. The density of regeneration (seedlings/ha) is also indicated (inset number).

This picture contrasts sharply with that seen in the Coast Range Mountain Zone (Figure 2). Here, there are very few small trees of either shade-tolerant or intolerant species. This is a riparian forest system that does not appear to be replacing itself. The *Siuslaw National Forest Plant Association and Management Guide* (Hemstrom and Logan 1986, USDA Forest Service R6-Ecol-220-1986a) suggests that both Douglas-fir- and red alder-dominated forests, in the absence of a seed source for shade-tolerant species like western hemlock, can succeed to a shrub-dominated community in this area. Hemlock was not common in these forests (Figure 2). Evidence for this successional pathway can be seen in Figure 3, a map of flood plain and terrace vegetation along one small stream in this region. There are many shrub-dominated patches. Evidence of the preceding alder stand could still be found under some of the patches at the time of this mapping. Thus, in spite of the relatively high frequency of landslides and debris flows, disturbance in the riparian area is inadequate to provide regeneration opportunities for species for which seed sources are present. Over time, the tree-dominated area will decrease and the area of shrub domination will increase.

In the Klamath Zone, the opposite conclusion is supported. There are large quantities of smaller trees of many species, both hardwoods and conifers. This abundance of smaller trees suggests that the riparian forest used to be much more open and has recently had an increase in tree regeneration. In this setting, smaller trees are defined as trees up to 25 cm diameter at breast height. For the shade-intolerant species (e.g., oak, pine, Douglas-fir), this translates into increased regeneration over the last 50–100 years. This coincides with the period of fire suppression. Increased tree density following fire suppression is a common observation, but this observation has not been extended to riparian areas. In addi-

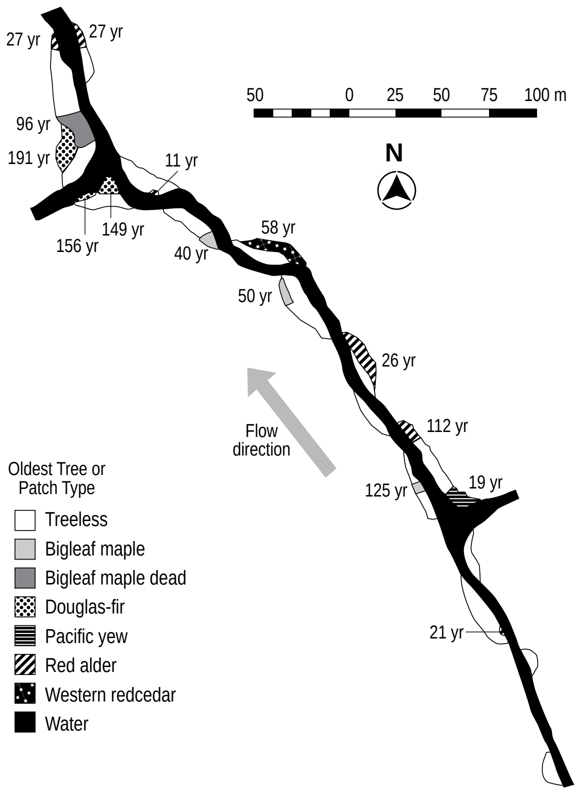


Figure 3. Variation in riparian vegetation composition along Skate Creek in the Oregon Coast Range indicates areas dominated by trees (conifers or hardwoods) and areas dominated by shrubs (treeless).

tion to these diameter distributions, we find supporting evidence for these changes in historic photographs and in the General Land Office 1850's survey records.

The diameter distribution found in the Klamath Zone also suggests a compositional shift is underway or will begin soon. Historically, the oaks and madrone were able to be a component of the forest of this region because fire kept the canopy density low and allowed the shorter hardwoods to survive among the taller conifers. As conifer density increases and the canopy closes over these hardwoods, the hardwoods die. An example of this is seen in the Willamette Valley, where Douglas-fir has invaded the oak savanna and shaded out the Oregon white oak. In southwestern Oregon riparian areas where conifer density is high, both the newer and the older hardwoods will soon be lost. In the long term, the riparian forest will be a closed canopy of conifers.

Management Implications

Fire suppression is profoundly affecting riparian forest dynamics in both dry and wet portions of western Oregon. As experience elsewhere would lead one to expect, fire suppression in a dry environment has led to an increase in forest density. In the long run, it will also simplify the tree species diversity by eliminating the short, shade-intolerant hardwoods. This will help reduce stream temperatures and increase sources for large wood. At the same time, it will reduce in-stream photosynthesis and both the quantity and quality of litter and availability of terrestrial insects that feed the aquatic food chain. Active management to remove the many younger conifers too large to be killed by a controlled burn will be required to maintain hardwoods in this system.

In the wet environment of the central Coast Range, we see evidence of tree canopy loss and a lack of tree regeneration. In much of this area, it has been about 150 years since the last large fire, and the alder is senescing. On wetter riparian soils, Douglas-fir is also being lost. In the absence of large disturbances (e.g., fire, debris flow), maintaining Douglas-fir for large wood and alder for habitat benefits and nitrogen-fixing abilities will require active regeneration efforts.

Influence of Landscape Pattern and Composition on Species in Forested Ecosystems of Western Oregon

Understanding effects of management at landscape scales is critical to managing for habitat and biodiversity. However, knowledge of the influence of landscape effects on many species is lacking. There is growing consensus that knowledge of the form, function, and historical context of landscapes is essential to research and management of ecosystems at a variety of temporal and spatial scales.

Goal

The goal of this research theme is to investigate the relationships among aquatic and terrestrial organisms, instream habitat, and riparian-area and upslope conditions across broad geographic areas in western Oregon.

2005 Highlights

- ❑ Former CFER-affiliated graduate student Jeb Wofford and researcher Dr. Robert Gresswell published a paper in the journal *Ecological Applications* titled "Influence of barriers to movement on within-watershed genetic variation of coastal cutthroat trout."
- ❑ Former CFER-affiliated graduate student Margo Stoddard and researcher Dr. John Hayes published a paper in the journal *Ecological Applications* titled "The influence of forest management on headwater stream amphibians at multiple spatial scales."
- ❑ An online geo-referenced bibliography for coastal cutthroat trout was developed to aid in determining the location, life-history form, estimated size, and likelihood of persistence for existing populations of coastal cutthroat trout in Oregon and Washington.

New and continuing studies during the year under report are summarized in the following section.

Effects of Landscape Patterns on Fish Distribution

Robert E. Gresswell, Christian E. Torgersen, Douglas S. Bateman, and David P. Hockman-Wert

Numerous studies have examined the relationships between physical stream habitat and the distribution and abundance of anadromous salmonids. It is difficult, however, to relate these interactions to fitness because anadromous fishes spend some part of their lives in a marine environment, where they are affected by a much different array of environmental variables, including shifts in ocean currents and commercial harvesting. In contrast, salmonids that migrate only in freshwater (potamodromous salmonids, including some populations of coastal cutthroat trout, *Oncorhynchus clarki clarki*) are dependent on suitable stream habitats throughout their lives. Therefore, it may be possible to relate variations in fluvial freshwater habitats to the ecology of potamodromous salmonids.

Changes in aquatic habitats resulting from land-management activities may be especially relevant for coastal cutthroat trout. During the last century, both the abundance and the distribution of this subspecies have declined across its entire range. Aquatic habitat degradation associated with timber harvest, road building, agriculture, and development has been identified as one of the potential causes of this decline. To date, however, most research on relationships between coastal cutthroat trout and freshwater habitat has been conducted on anadromous populations. Little effort has been expended on describing potamodromous populations or their linkages with aquatic habitat. This study examines the relationships between stream habitats and populations of potamodromous coastal cutthroat trout across broad spatial scales in western Oregon.

Methods

Study site selection and barrier database

Beginning in 1999, watersheds were randomly selected from a known population of streams in western Oregon. First, the population of mid-size watersheds (500–1,500 ha) west of the Cascade Range divide was derived from watershed delineations by using 30-m digital elevation models (DEM) and tools from the U.S. Geological Survey (USGS) GIS Weasel application (Gresswell and Bateman, *2001 CFER Annual Report*). Initial watershed size was set at 500 ha, and the ultimate size was determined by the location of the next downstream tributary junction.

Because a database with locations of isolated, potamodromous populations of coastal cutthroat trout did not exist, a sampling frame of isolated watersheds meeting this criterion had to be developed. Information obtained from an Oregon Department of Fish and Wildlife (ODFW) database and interviews with field biologists (active and retired) from ODFW, U.S. Forest Service (USFS), and the Bureau of Land Management (BLM) were used to locate barriers to upstream fish movement. After the sampling frame of watersheds was established, isolated watersheds with coastal cutthroat trout were stratified by ecoregion and erosion potential based on dominant bedrock lithology (i.e., sedimentary and igneous). A stratified random sample of 40 watersheds was selected with proportional allocation in each stratum.

Logistical constraints of field sampling limited the maximum basin area to 1,000 ha; therefore, in cases where a watershed exceeded 1,000 ha, the area above each tributary junction (moving progressively farther upstream) was estimated until at least one of the subwatersheds had an area of 1,000 ha or less. The portion of the watershed upstream from this point was then sampled. If watersheds contained two or more basins between 500 and 1,000 ha, one subwatershed was randomly selected to represent the watershed.

Instream habitat evaluation and fish surveys

Prior to initial surveys, stream segments were identified in each watershed by using existing databases, topographic and geologic maps, aerial photographs, and field reconnaissance. During field surveys, geomorphic stream reaches were classified in each segment, and channel units were delineated in each geomorphic reach. Stream habitat was inventoried with methodology developed in 1998 (Gresswell and Bateman, *1999 CFER Annual Report*). Physical variables that describe habitat unit size (e.g., length, depth, and width), substrate size class, channel type, valley segment type, and woody debris were estimated or measured for all sampled habitat units. To investigate interannual variation in habitat characteristics and coastal cutthroat trout distribution, Camp Creek, a tributary of the Umpqua River, has been resampled annually from 1998 through 2004 (Gresswell et al., *2004 CFER Annual Report*).

Estimating fish abundance and distribution

Following habitat-unit mapping of a study basin, the relative abundance of fish in all pools and cascades was assessed by one of two methods, depending on stream size and accessibility: 1) a single-pass removal using electrofishing to collect fish, or 2) visual estimation of fish numbers by snorkeling. The upstream extent of fish distribution in a tributary was determined by electrofishing in an upstream direction until a minimum of 10 pools containing no fish had been sampled. In each stream segment, 100 fish were measured (fork length to ±1 mm) and weighed (±0.1 g). Scale samples were collected for age determination from up to five fish in each 10-mm length category (see Rehe and Gresswell, this report).

To determine the feasibility of using sampling protocols to assess fish abundance and distribution, relative abundance estimates from the complete census from 1998 were compared to simple random and systematic samples of the census data. Initial evaluation suggested that estimates of mean number of fish per channel unit, mean channel unit area, and the correlations between these two variables were similar between the complete census and simple random samples of the units; however, distribution patterns of fish abundance from either of the samples lacked specificity necessary to detect longitudinal distribution of fish (Gresswell et al., *2000 CFER Annual Report*). Because it appeared that spatial patterns of fish distribution were directly linked to habitat characteristics, it was determined that the continuous assessments of relative abundance would be conducted in all of the sample watersheds. Subsequent research in 2001 suggested that the results of estimating relative abundance of coastal cutthroat trout on the basis of single-pass electrofishing were highly correlated with those from more labor-intensive multiple-pass removal techniques (Bateman et al., *2002 CFER Annual Report*). In combination, these results provided information necessary to assess distribution patterns of coastal cutthroat trout in watersheds of western Oregon in an economical and logistically efficient manner.

Watershed database development

Digital data layers for ecoregions, geology, elevation, vegetation, and hydrography were obtained for geographic information system (GIS) processing from numerous sources (e.g., BLM, USFS, ODFW, Oregon Department of Forestry [ODF], and Oregon State University [OSU]). Using dynamic segmentation methodology in Arc/Info GIS allowed stream survey data to be georeferenced to the stream network for the construction of a spatially explicit, relational database for each watershed. Landmarks, such as bridge crossings and tributary junctions, were used for calibrating the digital stream length to the actual surveyed stream length. Consecutively numbered habitat units and associated attributes, including habitat dimensions, wood, substrate, and fish numbers, were then joined to the calibrated stream network in a GIS database.

Three-dimensional maps of landscape terrain and subwatershed boundaries were generated for each watershed by using 10-m DEMs. Overlays of fish distribution and stream habitat data on the three-dimensional terrain provided a means of assessing patterns of fish abundance and channel morphology in a landscape context (Gresswell et al., *2002 CFER Annual Report*). Longitudinal elevation profiles have been developed from field measurements of stream channel slope. Landscape metrics (e.g., valley form, aspect, slope, and upslope disturbance potential) and channel slope are all being used as explanatory variables in statistical models of fish–habitat relationships.

Spatial data on forest stand characteristics, road density, landslide potential, and land ownership (federal, state, and private) have been entered into the GIS and are being analyzed in statistical models to investigate the relationship between management activities and fish distribution. Land use, landslide risk, and road coverages have also been included in these analyses. Forest cover and vegetation classifications from Landsat satellite imagery were obtained from the Coastal Landscape Analysis and Modeling Study (CLAMS) and the Interagency Vegetation Mapping Project (IVMP). Historical management information for each sample watershed was summarized from time-series satellite imagery (Stand Replacement Disturbance 1972–2002; S. Healey and W. Cohen, USFS, Corvallis, Oregon) to provide a temporal context concerning forest disturbance from timber harvest and fire.

Quantifying spatial variability in fish distribution and landscape pattern

Fish abundance (by age group) and physical habitat characteristics were used to explore relationships between fish and aquatic habitat at stream reach, segment, and watershed scales. Effort has been focused on three-dimensional visualization techniques and semivariograms for detecting patterns and determining the spatial scales at which landscape characteristics influence fish distribution within and among watersheds (Gresswell et al., *2002 CFER Annual Report*).

Patterns of spatial variability in coastal cutthroat trout abundance were evaluated by comparing variograms among watersheds. Semivariograms were developed by using network distance (measured along the stream channel), as opposed to traditional Euclidean distance (the shortest distance between two points). Characteristics of the variogram, including the shape and the distance over which fish abundance was autocorrelated (i.e., the range of a variogram that fit a spherical model), were compared among watersheds with respect to landscape characteristics such as erosion potential, geology, ecoregion, and watershed characteristics (elevation, slope, and drainage density) (Gresswell et al., *2003 CFER Annual Report*). In order to evaluate distributional patterns and spatial dependence in fish abundance, semivariogram models were compared by using spatially continuous datasets and simulated data based on random resampling of original data.

Landscape influences on the spatial extent of fish distribution

To investigate the effects of landscape pattern on coastal cutthroat trout populations across a range of headwater environments, we evaluated the spatial extent of coastal cutthroat trout distribution in relation to broad-scale patterns in climate, topography, and land use (Gresswell et al., *2004 CFER Annual Report*). Fish distribution in each study basin was calculated in a GIS and normalized by watershed area (km/km^2). This variable, representing the length of stream occupied by coastal cutthroat trout, was compared among watersheds in order to identify broad-scale physiographic and climatic patterns that influence distribution. Multiple linear regression and Akaike's Information Criterion (AIC) were used to identify a set of best approximating models that predicted fish distribution on the basis of landscape explanatory variables derived from GIS layers (road density, geology, DEMs, spatially explicit climate models, and satellite imagery). Predictor variables in the regression analysis included mean stream slope (%), proportion of young forest (percent of watershed that has been clearcut since 1972), mean annual temperature (°C), mean annual precipitation (cm), land ownership (percent private/public), forest vegetation type (percent broadleaf/conifer), and geologic rock type (resistant/weak). We found that stream slope, precipitation, and the proportion of young forest in the watershed were the three variables most strongly associated with the spatial extent of coastal cutthroat trout distribution within watersheds. (Gresswell et al., *2004 CFER Annual Report*).

Effects of spatial scale on measures of fish abundance

We are currently using spatially continuous data on the distribution of coastal cutthroat trout to demonstrate the effects of spatial scale on estimates of fish population abundance. This novel approach to evaluating scaling relationships between population density and area sampled has never been applied to spatially continuous fish abundance data (i.e., a census of all pools and cascades in an entire headwater catchment). Spatially continuous data have the advantage that they can be analyzed over a range of spatial scales, as opposed to discrete scales determined at the time of data collection. To evaluate the scaling relationship between population abundance and area sampled, we calculated the "organism-weighted density" or "effective density". This metric addresses a fundamental problem with standard population density (number of individuals per unit habitat area), which assumes that all habitats within the sampled area are suitable for the organism. Effective density is calculated by weighting the standard density by the number of organisms in the unit. Because organisms are distributed unevenly in space, the effective density increases as sample area (i.e., spatial scale) decreases. The rate of decrease in effective density with increasing area varies depending on the scaling properties of an organism and its habitat.

Preliminary Research Results and Management Implications

Determining the appropriate scale for measuring population abundance is a fundamental problem in animal ecology. For example, if organisms are not uniformly distributed, the size, or spatial scale, of the sampling unit profoundly influences measures of population density. Therefore, spatial heterogeneity in the distribution of organisms makes it difficult to identify an optimal sampling area within which individuals are counted.

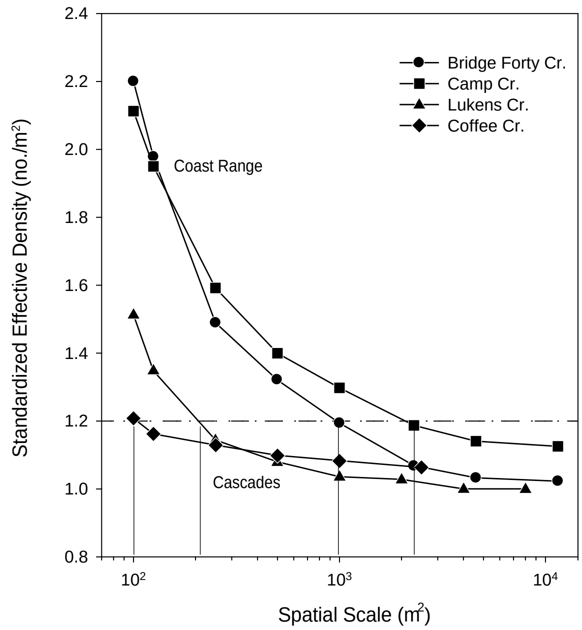


Figure 1. Effective density of coastal cutthroat trout at multiple spatial scales in headwater streams of western Oregon. Vertical lines indicate the approximate scales at which sampling would have to be conducted to ensure comparable density estimates among streams.

Analysis of coastal cutthroat trout data from headwater streams showed that density estimates of fish abundance were inflated by a factor of 2 over scales of 100–10,000 m^2 (Figure 1). The influence of spatial scale on effective density varied considerably among streams. For example, effective density in streams of the Coast Range ecoregion (Camp Creek and Bridge Forty Creek) was strongly influenced by the spatial scale of sampling (a steeper curve), but streams in the Cascades ecoregion (Lukens Creek and Coffee Creek) were much less affected by the area sampled (a more gradual curve). To obtain comparable density estimates among streams, different-sized areas would have to be sampled. Thus, in Coast Range streams, a much longer reach would have to be sampled in order to obtain a population density estimate that is comparable to that in Cascades streams.

Differences in effective density curves among streams may be related to geomorphic variation in channel shape and slope, both of which influence spatial patterns of salmonid abundance. These results have important implications both for understanding the scaling properties of animal distribution and for accurately estimating trout population abundance in fisheries management. Spatially continuous data made it possible to quantify the effects of spatial scale on measures of coastal cutthroat trout abundance at an extent and resolution that have not yet been described for stream fishes.

Study Timeline

Database development has been completed. Five papers on 1) the development of a sampling frame of watersheds, 2) geospatial techniques for quantifying spatial variability in the distribution of stream fishes, 3) geostatistical analysis in stream networks, 4) single-pass electrofishing methods for detecting spatial patterns in coastal cutthroat trout distribution, and 5) the genetic structure of coastal cutthroat trout within a barrier-isolated watershed have been published. Another paper on a spatially explicit approach for evaluating relationships among coastal cutthroat trout, habitat, and disturbance is in press. Two additional papers on 1) genetic structure of coastal cutthroat trout in 29 watersheds in western Oregon and 2) population-scale movement of coastal cutthroat trout in an isolated stream network were submitted to peer-reviewed journals in 2004 and 2005 and are currently in revision. Five more manuscripts investigating landscape effects on the spatial extent and variability of coastal cutthroat trout and sculpin distribution and the population structure and growth of coastal cutthroat trout in headwater streams are in preparation and will be submitted in 2005–2006.

Stream Connectivity and Emigration Rates in Headwater Coastal Cutthroat Trout Populations in Western Oregon

Douglas S. Bateman, Robert E. Gresswell, and David Hockman-Wert

Understanding how an organism will respond to a range of environmental conditions at a variety of spatial and temporal scales is a critical factor in the management of the organism. For example, coastal cutthroat trout (*Oncorhynchus clarki clarki*) are commonly found throughout western Oregon, but information on fluvial life-history strategies has most often been collected from the portions of streams where anadromous salmonids are present. A number of different behaviors have been documented for coastal cutthroat trout in these areas, but much less is known about coastal cutthroat trout that persist in small headwater streams, where they are often the only salmonid present. These populations can be isolated by naturally occurring barriers to upstream migration of anadromous fishes or, in some cases, by behavior of anadromous adults that fail to occupy areas for a variety of reasons. In this study, we compare downstream movement of coastal cutthroat trout across a gradient of stream channel connectivity in a watershed where the population is isolated by a migration barrier to trout movement in a stream network where the populations are behaviorally isolated.

Methods

Fish movement was monitored in Camp Creek and in North Fork and South Fork Hinkle Creek in the Umpqua River basin of western Oregon. Watershed size ranged from 858 to 1270 ha. The Camp Creek site was upstream from a natural barrier to upstream fish migration, and cutthroat trout was the only salmonid present. Steelhead and coastal cutthroat trout were sympatric in North Fork and South Fork Hinkle Creek.

In each watershed, all pool and cascade habitat types were surveyed with single-pass electrofishing annually during the summer low-flow period, and each captured cutthroat trout ≥100 mm (fork length) was implanted with a 23-mm half-duplex passive integrated transponder (PIT) tag. A network of fixed-station antennae located at the stream segment scale (Figure 1) provided relocation information as fish passed through a station (Gresswell et al., *2003 CFER Annual Report*). Additional antennae downstream from the sample catchments provided information concerning emigration from the study areas (Figure 1). Movement distance was based on position at time of relocation in relation to the previous location. In addition, continuous surveys of the wetted area in each stream were conducted during December, March, and June with mobile antennae. Relocation data collected during mobile antenna and electrofishing surveys were used to augment data collected from fixed-station antennae.

Because the fixed-station antennae could differentiate upstream and downstream movement, it was possible to classify movement as either local (small spatial and temporal movements) or more extensive and long-term. It was more difficult to identify emigrants from the study catchments because the number of downstream antennae was limited and migration was based on temporal criteria. Fish were classified as emigrants if they were detected leaving the watershed and did not return for ≥30 days. Fish that moved out of the catchment but returned in <30 days were assumed to be moving locally.

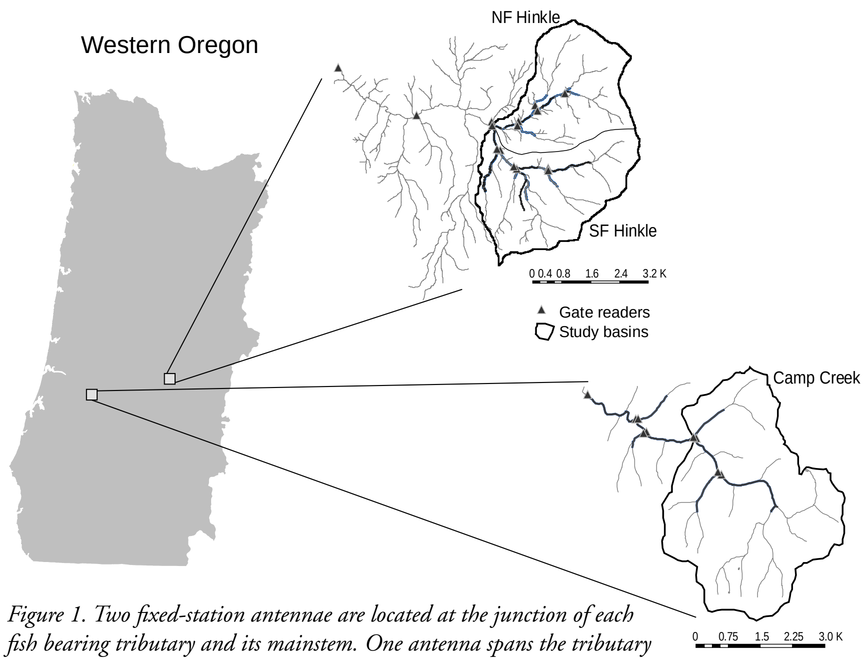


Figure 1. Two fixed-station antennae are located at the junction of each fish bearing tributary and its mainstem. One antenna spans the tributary while the other spans the mainstem just upstream from the tributary-mainstem junction. Heavy stream line corresponds to coastal cutthroat trout distribution in both watersheds. Additional antennae located downstream from the study watersheds are also depicted.

Research Results

Sampling began in North Fork and South Fork of Hinkle Creek in 2002. In North Fork Hinkle Creek, 741 coastal cutthroat trout have received PIT tags since the inception of the study; yearly totals were 264, 280, and 197 for years 2002, 2003, and 2004, respectively. In South Fork Hinkle Creek, 993 individuals were tagged, with yearly totals of 324, 275, and 394 for 2002, 2003, and 2004, respectively. Sampling in Camp Creek began in 2003. A total of 1127 fish received PIT tags, 538 in 2003 and 589 in 2004.

A distinct gradient in both the proportion and number of fish (Figure 2) classified as downstream migrants was observed in North Fork and South Fork Hinkle Creek. The increase in downstream migrants with basin area was not observed in Camp Creek (Figure 2). The proportion of downstream migrants per stream segment observed in Camp Creek was very similar to that found in the upper mainstem and tributaries of both forks of Hinkle Creek. In Camp Creek, the greatest proportion of emigrants from a segment during any year was 10%, compared with 43% and 40% for South and North Fork Hinkle, respectively (Figure 2).

Patterns of detection at the two readers located in lower mainstem Hinkle Creek (approximately 2.5 and 5 km downstream from the study basins) were similar to those seen in the study area (i.e., most fish had originally been tagged in the lower two segments of the North and South Fork Hinkle Creek). During 2002 and 2003 combined, 113 cutthroat trout were detected leaving North Fork and South Fork Hinkle Creek; 32 fish were detected at the antenna downstream of the study catchments. In Camp Creek, the fixed antenna was located at the falls 3 km downstream from the lowest fixed antenna in the study catchment, but the patterns of detection were similar at the two sites. Of the 29 fish classified as downstream migrants during 2003 and 2004 combined, 21 were detected passing over the falls.

The PIT technology provided new insights into patterns in behavior of coastal cutthroat trout in headwater streams, but antenna efficiencies can confound interpretation of results. Within-year patterns of relative movement reported here are useful, but comparisons of absolute numbers of downstream migrants among years could be distorted by differences in sampling efficiency. Therefore, comparisons of the number of downstream migrants observed leaving the study catchments and those observed at antennae located farther downstream are valid only for documenting that a proportion of fish leaving the study watershed continued downstream for substantial distances.

In both forks of Hinkle Creek, the proportion of downstream migrants increased sharply in segments with drainage areas >450 ha (i.e., corresponding to the most downstream mainstem segment in each catchment). These segments also corresponded closely with the dis-

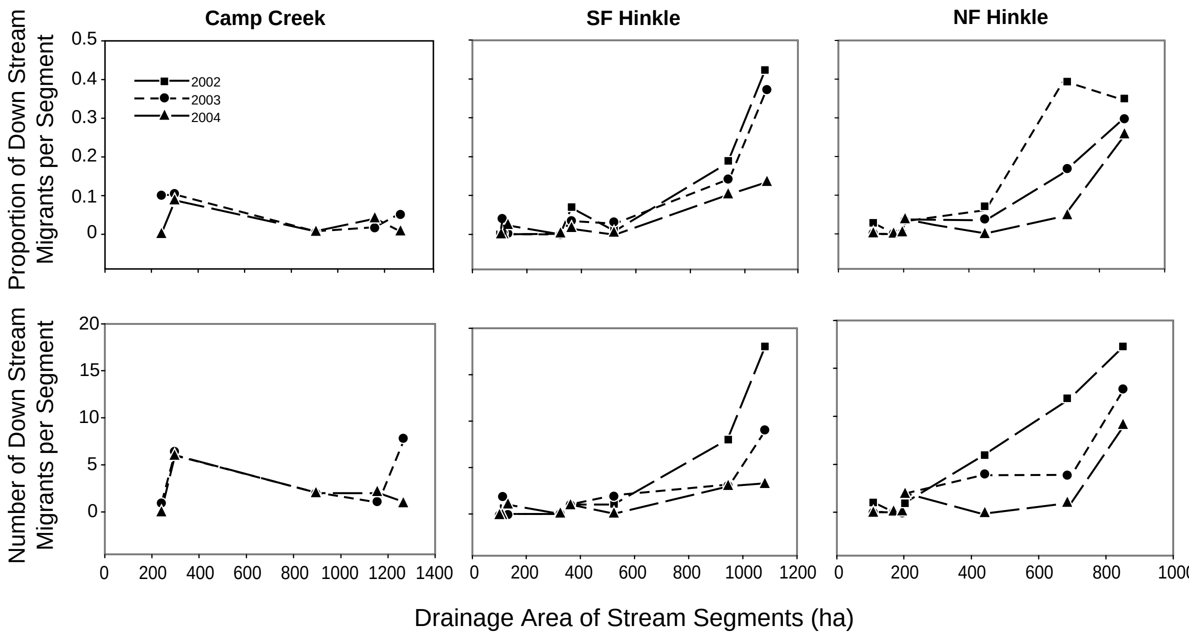


Figure 2. The top row of figures presents the proportion of tagged fish classified as downstream migrants and the bottom row presents the number of individuals. Symbol location along the x-axis corresponds to the total drainage upstream from a segment pour point. In North and South Hinkle Creek, the first four symbols correspond to the four segments of their respective mainstems from downstream to upstream. The remaining symbols correspond to the three fish bearing tributaries in each watershed. Camp Creek has three mainstem segments and two tributaries and follows the same pattern as Hinkle Creek with mainstem segments having the largest drainage areas followed by the tributaries.

tribution of juvenile steelhead in those catchments; in some years, however, steelhead are found in the lower portion of Segment 3 in South Fork Hinkle Creek. Although Camp Creek is a larger watershed, patterns of downstream movement were very similar to the upper mainstem and tributaries in both forks of Hinkle Creek. Through time, the waterfall in Camp Creek that acts as a barrier to immigration from below (i.e., reentry to the catchment following emigration) may have selected against downstream movement out of the system. Apparently, similar life-history expression is occurring in the upper portions (smaller catchments) of North and South Fork Hinkle Creek.

Management Implications

These data suggest that context is important and that the number of downstream migrants may vary substantially among watersheds of similar size. The location of movement filters may be important for understanding interactions within, and among, populations of coastal cutthroat trout. These data represent only three watersheds, however, and span a relatively short period during which no extreme environmental events, such as flood or drought, occurred in any of the study catchments.

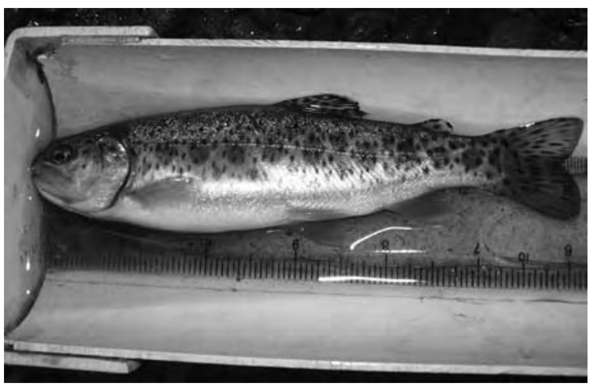
Study Timeline

Data collection is complete. Additional analyses comparing instream habitat characteristics among segments and streams will occur during winter and spring of 2006. A draft manuscript will be prepared and submitted by fall 2006.

Utility of Scales to Estimate Age and Growth Characteristics of Coastal Cutthroat Trout in Isolated Headwater Streams of Western Oregon

William G. Rehe and Robert E. Gresswell

Scales have been used to estimate age and growth characteristics of coastal cutthroat trout, *Oncorhynchus clarki clarki*, throughout their range. Most studies using scales have focused on anadromous or lacustrian populations; information pertaining to headwater stream populations is less common. An ongoing study focused on distribution of coastal cutthroat trout in 40 small stream networks (500–1000 ha) in western Oregon provided an excellent opportunity to expand current knowledge of age and growth characteristics of nonmigratory forms of this cutthroat trout subspecies. Sample watersheds were selected randomly from 269 headwater watersheds (500–5800 ha), located above barriers to upstream fish movement and where coastal cutthroat trout are the only salmonid fish species. Scale samples were obtained from 37 of the watersheds in the study.



Here we examine the age and growth characteristics for headwater populations of coastal cutthroat trout in western Oregon. Specific objectives were 1) to demonstrate that coastal cutthroat trout in headwater streams can be reliably aged by the scale method and 2) to describe age and growth structure for headwater streams across western Oregon.

Methods

Coastal cutthroat trout scales were collected using single-pass electrofishing. Captured fish were weighed (±0.1 g) and measured (±1.0 mm; fork length), and scales were removed from the area between the dorsal fin and the lateral line. In the laboratory, the distances from the scale focus to each circuli, annuli, and scale edge were measured and exported to a spreadsheet. Age was determined by a single reader to maintain consistency of results.

To reduce the influence of size-selective mortality (i.e., Lee's phenomenon), only the last full year of growth before capture was estimated for each fish. Growth increments were converted to average relative growth rates (GR) to reduce the effect of fish size on growth. The number of circuli to the first annulus was recorded and used to investigate potential lack of first-year annuli. By estimating the number of degree-days (i.e., 1 unit is accumulated for each degree Celsius >0 per day) from 1 April through 31 November for Camp Creek and Cavitt Creek (mean stream elevation 235 and 1019 m, respectively), it was possible to obtain a preliminary measure of the potential for growth of age-0 coastal cutthroat trout.

Age validation of coastal cutthroat trout was conducted by examining scales from individual fish that were marked and recaptured following a known time interval. Scale reader precision and bias were evaluated by using multiple readings of paired scales from these fish. Coefficient of variation was subsequently used to test the reproducibility of age estimated for three independent readings. Age frequency tables and age bias plots were used to visually detect systematic age differences between independent readings.

Research Results and Discussion

Our data suggest that scales can provide reliable estimates of age and growth for headwater populations of coastal cutthroat trout. Age was validated for 234 coastal cutthroat trout (length range = 80–175 mm) from two streams where individuals were marked and later recaptured. Almost all of the scales (97% and 94% of fish from the two streams) formed the expected number of annuli between capture dates. Reader precision and bias were estimated for mark-recapture fish (n = 234), known age brood stock from two hatcheries (n = 350), and samples collected from the 37 study watersheds (n = 3800). Coefficient of variation ranged from 4.8 to 8.3% for all of the readings. Age frequency and age bias plots suggested a slight bias between readings for older fish, mainly for age-5 fish (n = 17). Missing first-year annuli were not observed for populations of headwater coastal cutthroat trout in western Oregon. The mean number of circuli to the first annulus for fish from individual streams ranged from 5 to 8. Scales with more than eight circuli to the first annulus were common, but there was a strong relationship between the number of circuli to first annulus and elevation (r^2 = 0.85); counts were higher in lower elevation streams with longer growing seasons and a greater number of degree-days. For streams of the Intermountain Region of the United States, all cutthroat trout in a population formed a first-year annulus when the number of degree-days during the growing season exceeded 1500. Both Camp Creek and Cavitt Creek (2751 and 2159 degree-days, respectively) exceeded this estimated minimum number of degree-days. It is evident from our data that headwater stream populations of coastal cutthroat trout in western Oregon grow fast but do not live long. Longevity (maximum age) averaged 3–5 years for the 37 watersheds. Age composition varied among study watersheds (Figure 1). Only three of the populations exhibit a maximum age of 3 (8%); but the majority had a maximum age of 4 (70%) or 5 (22%).

Mean relative growth rates for the last full year of growth generally decreased with age and size. The mean relative growth rates by age group averaged from 0.18 to 0.76 mm/mm/year; growth rates dropped sharply following the first full year of growth (Figure 2A). Mean relative growth rates by 25-mm length groups showed a similar decrease in growth rates (Figure 2B). These growth rates are much greater than those found in other species of salmonids in the area. For example, brook trout (*Salvelinus fontinalis*) in a high-elevation Cascade

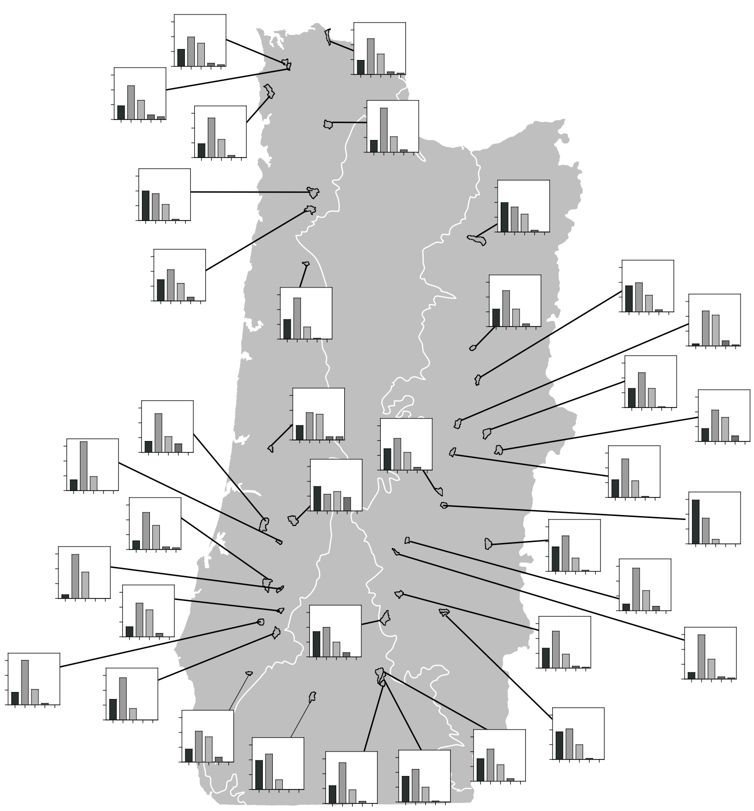


Figure 1. Age histogram for each study basin. Age composition varied among watersheds and across the landscape. Maximum age obtained (longevity) was between three and five years old for all populations of coastal cutthroat trout in western Oregon.

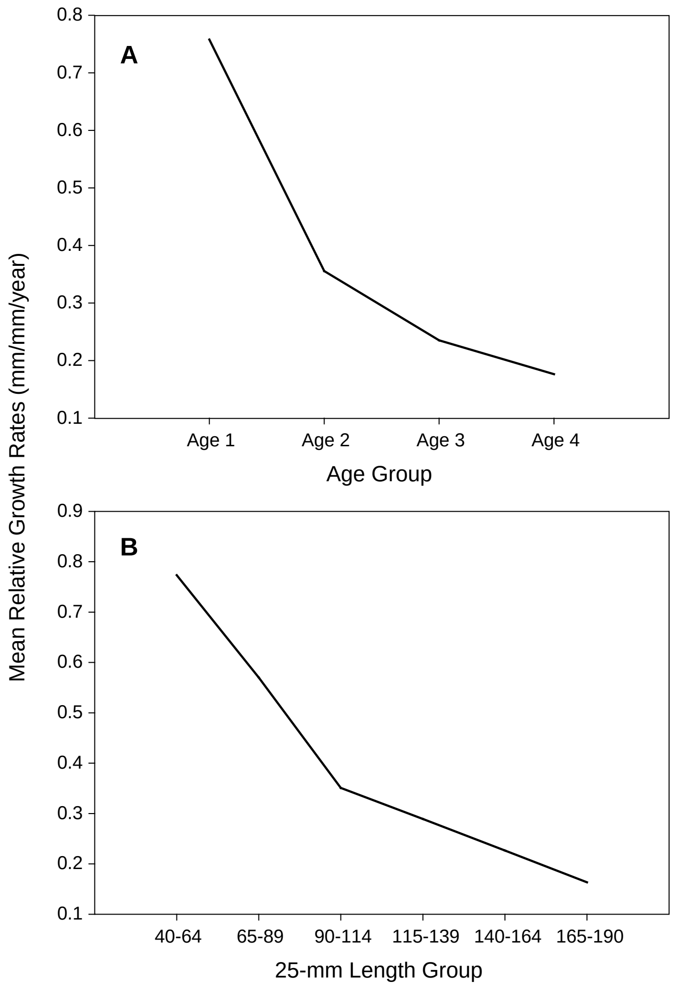


Figure 2. Mean relative growth rates for populations of coastal cutthroat trout decreased with age and size. A) The mean relative growth rates by age class (1–5), ranged from 0.18 to 0.76-mm year. There was a sharp drop in growth rates following the first full year of growth. B) Mean relative growth by length group showed a similar decline with larger fish size. Mean relative growth rates averaged between 0.15 to 0.79-mm per year.

Mountain lake had a mean relative growth rate between 0.08 to 0.40 mm/mm/year for age 1 through 5 fish.

Using scales to estimate age and growth characteristics has remained a viable method for age determination because of the ease of collection and preparation and the fact that sampling is nonlethal. Validation and reader precision and bias assessment are critical, and these additional steps are important for all methods of age determination. Estimating the number of degree-days from egg deposition until the end of the growing season provides valuable information for determining the probability of occurrence of first-year annuli.

Study Timeline

Age and growth analysis is complete and a draft manuscript has been completed. The manuscript will be submitted for publication in a peer reviewed journal in early 2006.

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

Michael Heck and Robert E. Gresswell

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 clarki clarki*) 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 causes 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 ecosystems. 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 are 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 late 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 (i.e., waterfalls) to anadromous fishes where coastal cutthroat trout are the only species of salmonid present. The drainage area above the migration barriers ranges from 804 ha to 1,489 ha. 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 (*1999 CFER Annual Report*). Stream habitat has been hierarchically classified into geomorphic segments, reaches, and habitat units. Severity of wildfire will be quantified for the riparian areas adjacent to each of the study streams using canopy photographs. In addition, abiotic variables such as water temperature and water chemistry were monitored in each stream.

All fish-bearing streams within these basins have been surveyed using a single-pass electrofishing method (Bateman et al., *2002 CFER Annual Report*). 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 are being analyzed to determine the age of fish in each stream. A random sample determined which scales are to be read in each size group. Relative growth rates will be derived from scales by back-calculation of age at length. If there is evidence of selected mortality (Lee's phenomenon), only the last complete year of growth will be used to calculate relative growth rates. Statistical analyses will focus on the effects of severity of wildfire, stream of origin, habitat, water temperature, and water chemistry on mean relative growth rates of coastal cutthroat trout. To detect changes in population age structure, age-length keys will be constructed for each stream and sample period. Population-scale changes in the relative abundance and distribution of coastal cutthroat trout will be 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 other basins in western Oregon (see Rehe and Gresswell, *2004 CFER Annual Report*).

Preliminary Research Results and Management Implications

Preliminary results from this study suggest that wildfire has affected growth of coastal cutthroat trout in these headwater streams of western Oregon. Although relative growth rate depended on the age/size of individual fish, coastal cutthroat trout growth was affected by reduced canopy and increased water temperatures. During the 2002 growth year (also the year of the wildfire), lower growth rates of younger, smaller fish gave evidence of apparent susceptibility to the direct effects of wildfire, but growth rates of older, larger fish were actually greater in catchments affected by wildfire (Figure 1). During the first part of the 2003 growth year (the year following the wildfire), fish in the two burned catchments grew at a faster rate during the spring and early summer following the wildfire (Figure 2). 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 minimal, and

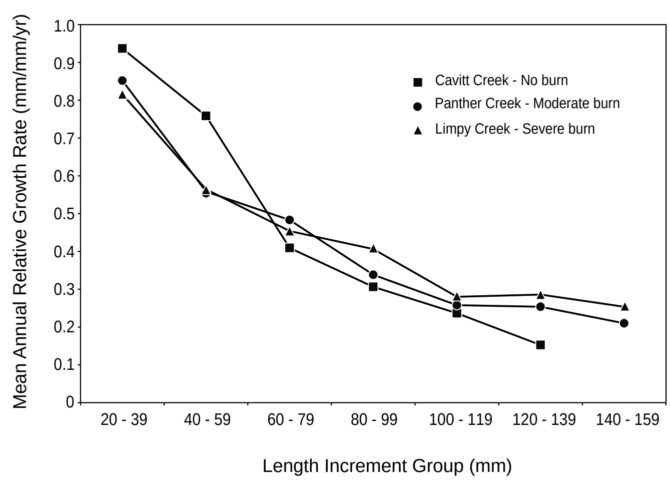


Figure 1. Mean annual relative growth rate by length increment group for coastal cutthroat trout captured in three headwater streams during summer 2003. The last complete year of growth was used to derive the mean annual relative growth rates.

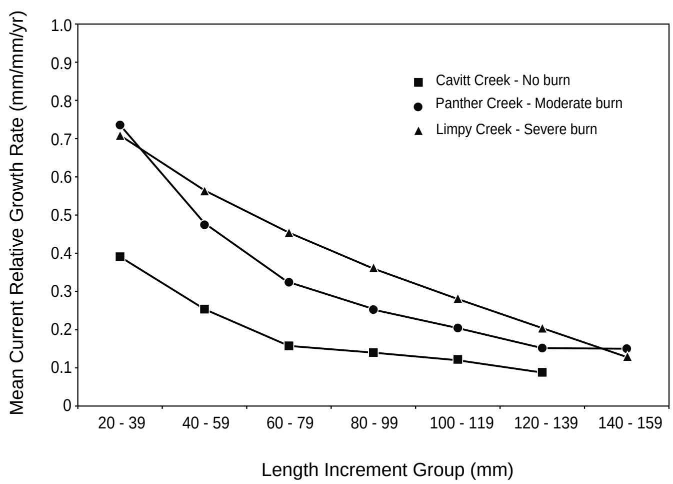


Figure 2. Mean current year relative growth rate by length increment group for coastal cutthroat trout captured in three headwater streams during summer 2003. The growth from the last annulus to the edge of the scale was used to derive the mean current year relative growth rates.

results suggest that the effects of wildfire on stream ecosystems may benefit some members of the aquatic community.

Study Timeline

Fish sampling and stream habitat inventories have been completed. A poster presenting preliminary results was completed for the Coastal Cutthroat Trout Symposium, 29 September–1 October 2005. Age and growth analyses of scale samples will continue through December 2005. Data analysis will continue through March 2005, and a final report and manuscript for publication will be submitted in June 2006.

Influence of Landscape Characteristics on Presence and Use of Habitat by Bat Communities in the Central Oregon Cascades

Ed Arnett and John P. Hayes

Twelve species of bats occur in Douglas-fir (*Pseudotsuga menziesii*) forests of western Oregon, and nine are known to roost in tree cavities and crevices. Availability, distribution, and quality of roosts are thought to be critical factors influencing population size and distribution of some species. Relationships of spatial distribution and availability of habitat features (e.g., roost structures, watering sites) to community richness, abundance, and habitat use by bats are poorly understood. Further investigation of these relationships could provide information to improve management prescriptions for providing habitat for bats through space and time.

This study was initiated in 1999 to evaluate the influence of availability of snags and roost trees on presence, relative abundance, and use of habitat by bats in managed forests of the western Oregon Cascades. Specifically, this study evaluated the influence of availability of roosts on presence and relative abundance of bats; the types of structures used for roosting by female and male long-eared myotis (*Myotis evotis*), female long-legged myotis (*Myotis volans*), and female big brown bats (*Eptesicus fuscus*); use of roost structures among species and among landscapes with various availabilities of roosts; and influences of characteristics of structures used as day roosts by bats at multiple spatial scales.

Cooperators for the project included Bat Conservation International, Bureau of Land Management (BLM; Eugene and Roseburg Districts), The Campbell Group, the Cooperative Forest Ecosystem Research program, Giustina Land and Timber Company, Jeff Allen Conservation Fund, National Council for Air and Stream Improvement, National Fish and Wildlife Foundation, Oregon Department of Fish and Wildlife, Oregon State University, Oregon Zoo Foundation, U.S. Army Corps of Engineers, U.S. Fish and Wildlife Service, U.S. Forest Service (USFS; Willamette National Forest), USGS Forest and Rangeland Ecosystem Science Center, and Weyerhaeuser Company.

Methods

The study area is located along the west slope of the Cascade Range between the Calapooya River north of Marcola, Oregon, and south into the North Umpqua River basin east of Roseburg, Oregon. This area encompasses lands managed by two federal agencies (BLM and USFS) and forests owned and managed by Weyerhaeuser Company and other private landowners. A diversity of habitat conditions and management histories occurs in this area.

Landscapes offering a range of snags and residual old-growth trees available for roosting by bats were randomly selected for sampling (n = 36). Bats were captured with mist nets placed over ponds within landscapes having low, medium, and high availability of roosts (12 ponds in each category of roost availability). Between six and nine surveys were completed at each pond between 1999 and 2001. Radio transmitters were attached to a sample of individuals of the three target species. We attached radio transmitters to 163 bats: 50 female big brown bats, 28 female long-eared myotis, 31 male long-eared myotis, and 54 female long-legged myotis. Roosts were located via radiotelemetry and recorded with a global positioning system. At each roost, we collected information of habitat characteristics to evaluate relationships between habitat characteristics and use of roosts at multiple spatial scales.

Randomly selected structures and snag availability were sampled in landscapes surrounding each capture site. The distance from each day roost to the capture site where each bat was marked was quantified, and it was determined that >85% of all roost sites for all three species studied occurred within 4.8 km (3 mi) of a capture site. Thus, a 4.8 km-radius buffer around each capture site was considered to be "available" to bats in this study. For our analyses, we assumed that any bat radio-tagged at a capture site had an equal chance of flying in any direction up to 4.8 km to direct its selection toward a particular roost structure. We identified 250 random points from a 20-m grid overlaying each landscape. Random points were located in the field by pacing along compass bearings taken from the nearest known location to a given random point. Once at the point, an azimuth was obtained from a random numbers table, and random roosting structures were searched along a transect 100 m long by 40 m wide. This procedure was repeated up to three times until a random structure was located; if one was not encountered, the point was discarded and the next point in the random order was sampled. We collected data on the first of any of the four possible structure types (snag, tree, stump, log) encountered at each random point, using the same variables and procedures as for used structures. In addition, we quantified characteristics of all available snags >20 cm DBH for each transect.

Relationships between availability of roosts, bat community richness and abundance, and patterns of roost-site utilization will be analyzed during this study. To date, we have analyzed relative abundance data (based on mist-netting data), using multiple regression and Akaike's Information Criterion as a model selection tool. We modeled the number of bat captures per visit in relation to three predictor variables: snag density in the landscape, linear kilometers of medium and large streams in a landscape (as a surrogate for riparian foraging habitat), and elevation at the capture site.

Research Results and Management Implications

Final analysis of data has not yet been completed. Therefore, all information in this report should be considered preliminary pending further analysis.

Relative abundance of bats

A total of 1,342 bats of nine species were captured during simultaneous mist-net surveys between 1999 and 2001. Silver-haired bats (*Lasionycteris noctivagans*; n = 350), big brown bats (n = 289), long-eared myotis (n = 259), long-legged myotis (n = 220), and California myotis (*Myotis californicus*; n = 137) were the most frequently captured species.

We found a positive relationship between number of captures of all bats with both elevation and snag density. Similarly, number of captures of all male bats was positively related to elevation and to snag density. Conversely, number of captures of female bats was negatively related to elevation. This finding is consistent with other studies that have demonstrated negative relationships between capture of female bats and increasing elevation. Snag density was not an important variable in models of female bat relative abundance, but this lack of association appeared to be strongly influenced by capture site location in relation to elevation. Snag-rich landscapes sampled during this study were biased towards higher elevation sites located on public lands. Males and females have different physiological requirements during the summer months and may partition their use of landscapes based on the influence of elevation on microclimatic conditions and food availability. Patterns emerging from these data suggest that managing for maternity roosts for bats at lower elevations may be important for conservation of bats in managed forests.

Use of day roosts

Female big brown bats and long-legged myotis selected snags used as day roosts that were larger in diameter than those randomly available. In contrast, mean diameter of snags used by male and female long-eared myotis was less than mean size of snags used by other species and than randomly available snags, although the confidence intervals for diameter of snags used by long-eared myotis and randomly available structures overlap and differences are likely not statistically significant (Figure 1).

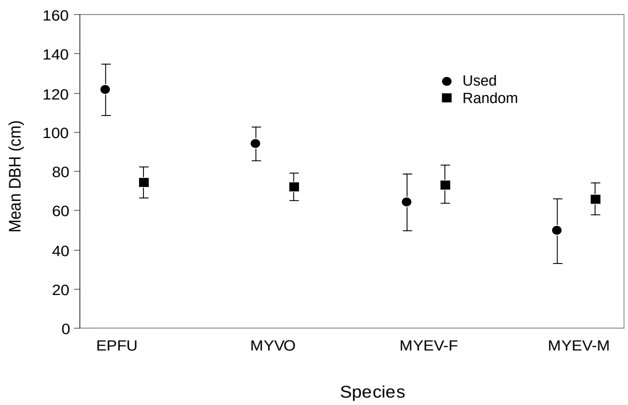


Figure 1. Mean diameter at breast height (DBH) and 95% confidence intervals for snags used as day roosts by each species of bat compared to snags randomly available in landscapes (EPFU = big brown bat, MYVO = long-legged myotis, MYEV = long-eared myotis females [F] and males [M]).

Snags used as day roosts by females of all three species and male long-eared myotis had more snags 10–50 cm DBH and snags >50 cm DBH within 20 m of the roost site than did randomly available snags (Figures 2 and 3). Additionally, snags used as day roosts by females of all three species and male long-eared myotis were closer to edges (defined as a gap >20 x 20m or a change in forest-age class) than were randomly available snags, but the confidence intervals for snags used by both genders of long-eared myotis and randomly available structures overlap (Figure 4).

Relative to physical position in the landscape, snags that were selected by females of all three species and male long-eared myotis were closer to the capture site than were randomly available snags (Figure 5). Female big brown bats and long-legged myotis also selected snags used as day roosts that were closer to small and large streams (Figures 6 and 7). Male long-eared myotis selected snags as day roosts that were significantly farther from small and large streams than those selected by female long-eared myotis, but not different from randomly available snags (Figures 6 and 7).

Although definitive conclusions await final analysis of the data, patterns emerging from these preliminary analyses suggest that managing for a range of sizes of snags is important when providing day roosts for sympatric species of bats, but larger bats (big brown bat and long-legged myotis) prefer larger diameter trees. As these large-diameter roosting structures are often uncommon in managed landscapes, management should focus primarily on retention and development of large snags in the future in situations where providing habitat for bats is a management goal. Retaining patches of snags appears to be an important consideration when managing snags for forest-roosting bats in this region. Finally, it appears that snags managed as day roosts for bats need to be in close proximity to open water and foraging habitat (e.g., riparian areas).

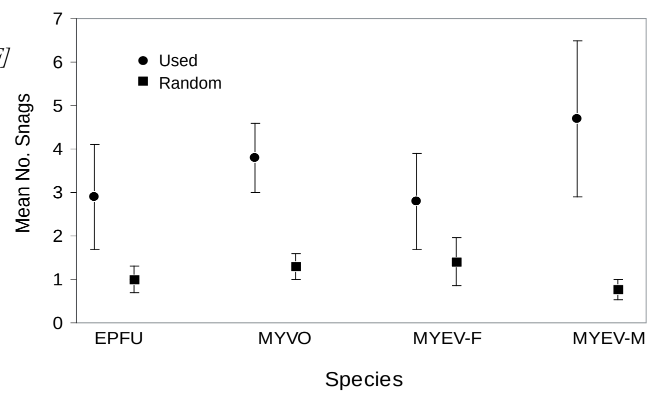


Figure 2. Mean number of snags 10–50 cm DBH within a 20-m radius plot and 95% confidence intervals for snags used as day roosts by each species of bat compared to snags randomly available in landscapes (EPFU = big brown bat, MYVO = long-legged myotis, MYEV = long-eared myotis females [F] and males [M]).

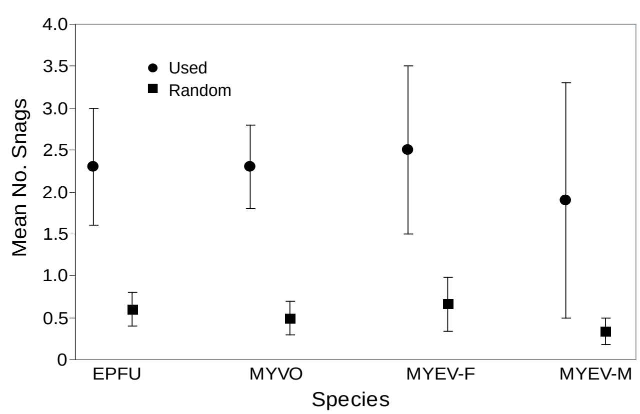


Figure 3. Mean number of snags >50 cm DBH within a 20-m radius plot and 95% confidence intervals for snags used as day roosts by each species of bat compared to snags randomly available in landscapes (EPFU = big brown bat, MYVO = long-legged myotis, MYEV = long-eared myotis females [F] and males [M]).

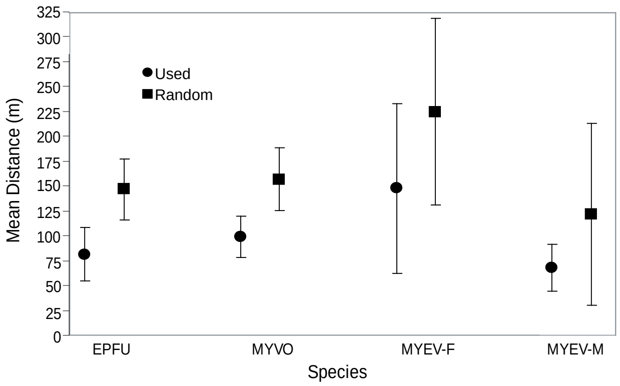


Figure 4. Mean distance to edge (>20 x 20m gap or change in forest type) and 95% confidence intervals for snags used as day roosts by each species of bat compared to snags randomly available in landscapes (EPFU = big brown bat, MYVO = long-legged myotis, MYEV = long-eared myotis females [F] and males [M]).

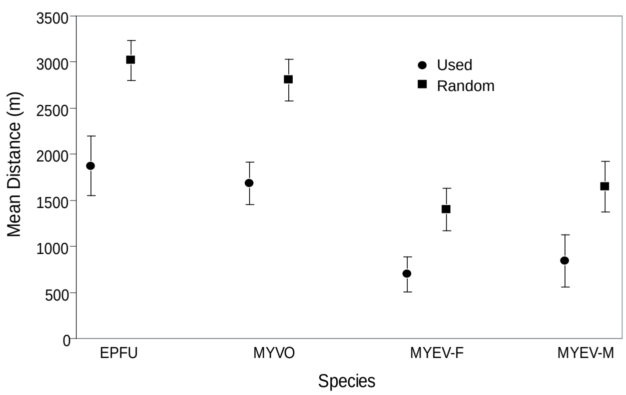


Figure 5. Mean distance to capture site and 95% confidence intervals for snags used as day roosts by each species of bat compared to snags randomly available in landscapes (EPFU = big brown bat, MYVO = long-legged myotis, MYEV = long-eared myotis females [F] and males [M]).

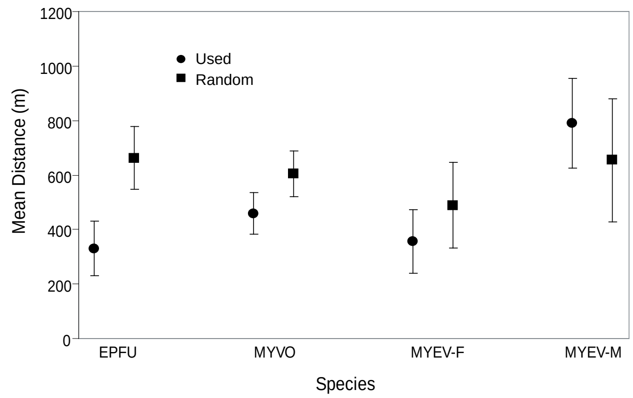


Figure 6. Mean distance to small stream and 95% confidence intervals for snags used as day roosts by each species of bat compared to snags randomly available in landscapes (EPFU = big brown bat, MYVO = long-legged myotis, MYEV = long-eared myotis females [F] and males [M]).

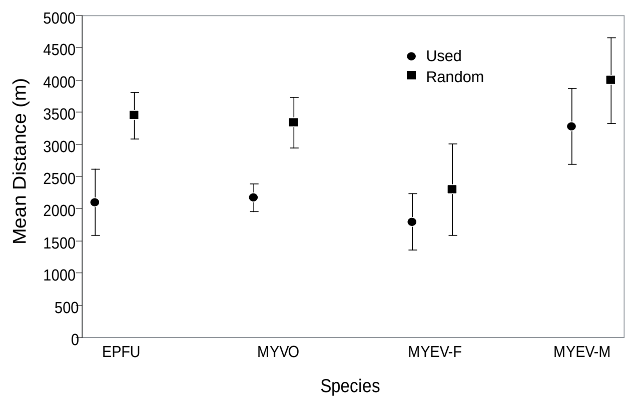
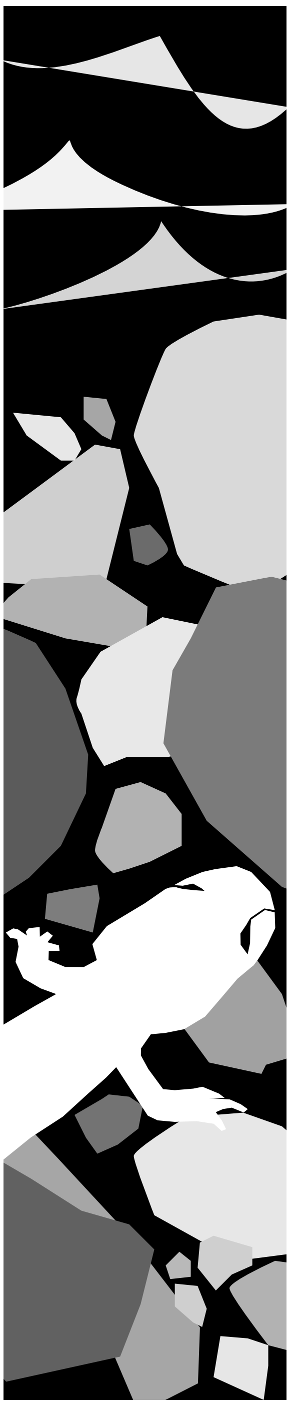


Figure 7. Mean distance to large stream and 95% confidence intervals for snags used as day roosts by each species of bat compared to snags randomly available in landscapes (EPFU = big brown bat, MYVO = long-legged myotis, MYEV = long-eared myotis females [F] and males [M]).

Study Timeline

All field data for this study have been gathered. Data analysis will be finalized in winter 2005/2006, with an expected completion and distribution of a final report in 2006.

Influences of Riparian Vegetative Community Composition on Animal Community Response



Riparian management objectives in forests of the Pacific Northwest have diversified considerably over the last two to three decades, from a primary focus on strictly utilitarian interests to goals that encompass a broader set of objectives that include conservation and restoration. Although this shift has yet to settle on clear statements of objectives for many ownerships, the transition in management directions has heightened the importance of scientific information about riparian areas.

Because the primary issues of concern for riparian areas are stream temperature and in-stream structural wood, regulations tend to promote the retention of existing conifers and conversion of hardwood-dominated areas to conifers. Because these regulations are relatively new, it is unclear how successful they will be in increasing riparian conifer dominance. However, the potential is great, and this has raised questions concerning the effect this conversion may have on habitat quality for both fish and wildlife. This research will examine the influences of woody plant community composition in riparian areas on food chains and response of consumer organisms of interest.

Goals

The three interrelated goals of this research theme are:

- to determine the influence of riparian woody plant community composition on in-stream productivity, aquatic vertebrate populations and communities, and terrestrial vertebrate communities;
- to determine the interactions among these components of the riparian ecosystem; and
- to predict the influence of riparian forest management practices on riparian aquatic and terrestrial vertebrate communities as mediated through food chains.

2005 Highlights

- Former CFER-affiliated graduate student Nico Romero and Drs. Robert Gresswell and Judy Li published a paper in the *Canadian Journal of Fisheries and Aquatic Science* titled "Changing patterns in coastal cutthroat trout (*Oncorhynchus clarki clarki*) diet and prey in a gradient of deciduous canopies."
- An informational *CD* summarizing CFER studies examining the influences of riparian vegetation composition on animal communities was developed by undergraduate students as part of a Fisheries and Wildlife capstone course.
- CFER graduate student Holly Ober was interviewed and taped conducting research on bats for a segment on Oregon Field Guide. The broadcast highlighted Ober's research on the role bats play in Oregon's coastal landscape.

New and continuing studies during the year under report are summarized in the following section.

Influence of Riparian Vegetation on Amphibian Communities and Amphibian Diet in the Oregon Coast Range

Paula Graff and W. Daniel Edge

In the Pacific Northwest, high amphibian densities and biomass have been recorded for terrestrial and aquatic systems, particularly riparian zones. These areas provide important biotic and abiotic features, such as logs, thermal cover, and abundant invertebrate prey that benefit many amphibian species. In spite of reported high densities, the role of amphibians in riparian food webs is not well known. Amphibians likely provide an important trophic link between terrestrial and aquatic systems because they exploit terrestrial and aquatic prey and are prey for other vertebrates.

Plant species composition in riparian zones may influence thermoregulatory cover and the availability and types of invertebrate prey for aquatic and riparian amphibian communities. In low order streams, allochthonous inputs, such as leaf litter and invertebrates, provide much of the energy at the base of the food web. Riparian vegetation composition may influence the invertebrate prey available to amphibians because the diversity of invertebrates falling from some tree species is higher than from others (Southwood 1961, *Journal of Animal Ecology* 30(1):1–8; Mason and MacDonald 1982, *Freshwater Biology* 12:305–311). It has been suggested, however, that vegetation composition is important only for providing thermal cover or microhabitat, and plays no role in amphibian diet (Dumas 1956, *Ecology* 37(3):484–495). For terrestrial amphibians, ambient temperatures and humidity may limit foraging opportunities, potentially restricting activities to times when soil moisture, soil and air temperature, or humidity levels are high. Few studies on amphibian diet address habitat influences or seasonality of prey sources.

Current management practices that promote retention of conifer trees over hardwoods in riparian forests in the Oregon Coast Range may unintentionally affect other species, such as amphibians. The goal of this project is to examine the relationships among riparian vegetation and aquatic and terrestrial riparian amphibian assemblages and their invertebrate prey. Amphibians offer an excellent opportunity to assess prey differences between habitats because they swallow their prey whole and have low metabolic rates, so items remain intact in their stomachs for extended periods. Additionally, many amphibians are relatively long-lived, have small home ranges, show strong site fidelity, are not highly mobile, and do not move away from areas after handling. The information gained can be used to evaluate the influence of different riparian vegetation on prey sources and amphibian communities. Understanding these relationships is important for providing baseline information for assessing potential impacts on amphibians of vegetation alteration in riparian management areas.

Methods

Study sites were located on 2nd- and 3rd-order streams in second-growth Douglas-fir (*Pseudotsuga menziesii*) in the Oregon Coast Range that reflected a range of conifer- and hardwood-dominated riparian conditions. A study site consisted of a 150-m stream length and the adjacent 30-m upslope area. We used pitfall traps, artificial cover objects, and area-constrained searches to capture terrestrial amphibians. We used randomly located 1- by 2-m quadrats for area-constrained searches and to measure vegetation and microhabitat characteristics of the riparian zone in fall of 2002 and spring of 2003. Aquatic surveys were conducted at all 10 sites in July and October 2002, and June 2003 in 10 permanent 2-m long transects in each stream. We measured vegetation characteristics in every other transect (for a total of five transects per stream) during each aquatic sampling period. A light-touch survey method was used at all times to ensure the least disturbance to areas that were repeatedly sampled and to facilitate future recapture of animals. Amphibians spotted outside of transects and quadrats were captured when possible.

All captured amphibians were measured and weighed. Animals were anesthetized in a solution of MS-222 (tricaine methanesulfate) buffered with sodium bicarbonate in order to collect stomach contents and mark individuals with a Visible Implant Fluorescent Elastomer tag. Each animal was released near a cover object at the point of capture after it had recovered.

We sampled terrestrial invertebrates by randomly locating 10 invertebrate pitfall traps within the study site and opening them for the duration of the amphibian trapping period at that site. In addition, soil samples were collected at random locations throughout the study site and litter- and soil-dwelling invertebrates were extracted by a Berlese funnel trap (OSU Dept. of Entomology). Aquatic benthic invertebrates were sampled with a 0.09-m^2 Surber sampler with a 500-u sieve at six random locations (excluding permanent transects) within each reach during each aquatic sample period. Benthic and terrestrial invertebrate samples were identified to the order level when possible.

Habitat

We developed a set of *a priori* habitat models based on literature review to identify possible microhabitat characteristics that might explain the presence of the larval *Dicamptodon tenebrosus* and terrestrial *Plethodon vehiculum* at these sites. We compared the strength of evidence of the candidate models by logistic regression and the information-theoretic approach, using Akaike's Information Criterion (AIC). AICc model selection was used because it carries a bias-correction term for sample sizes where the number of samples/number of estimated parameters is <40.

Diet

All amphibian stomach samples were photographed in a Petri dish and the amount of surface area covered by stomach contents was measured (mm^2) with Image ProPlus software (version 4.5.0.29). This approach allowed us to account for the miscellaneous, often unidentifiable and decomposed matter that was frequently present in stomach samples. As no measure of fitness has yet been developed that can be used on live amphibians in the field (Jaeger 1980, *Oecologia* 44:335-341), we developed an index of stomach fullness using this measure after accounting for the size of the individual. We used this index as the response variable to make comparisons between sites and seasons using single-factor ANOVAs with Tukey Multiple Comparisons. Prey items were identified to the taxonomic level of order when possible.

Research Results and Management Implications

Sites

All sites were located on perennial low-gradient streams (range 3–12%) in 2nd-growth timber stands that ranged in age from 40–80 years old. The most common trees found throughout the 10 study sites were red alder (*Alnus rubra*), bigleaf maple (*Acer macrophyllum*), Douglas-fir, and western hemlock (*Tsuga heterophylla*). Deciduous trees dominated the canopy directly over the wetted width of the stream at eight of the 10 sites (Figure 1). At five sites, Douglas-fir was the dominant tree species in the adjacent 30-m upslope (Figure 2). Vine maple (*Acer circinatum*) and salmonberry (*Rubus spectabilis*) were the most common understory shrubs at all sites.

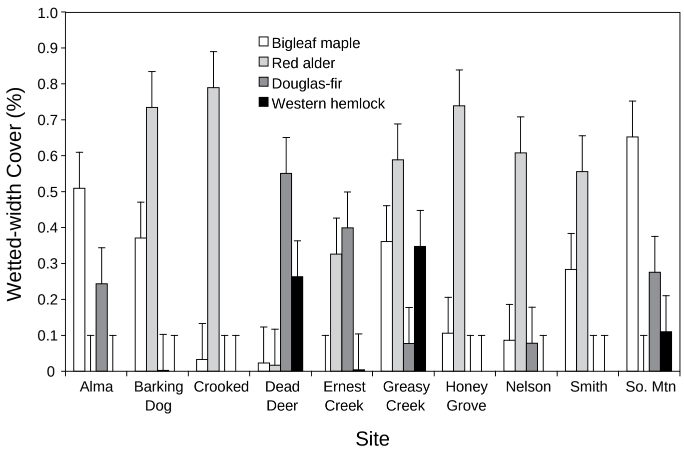


Figure 1. Average stream-channel canopy cover (%).

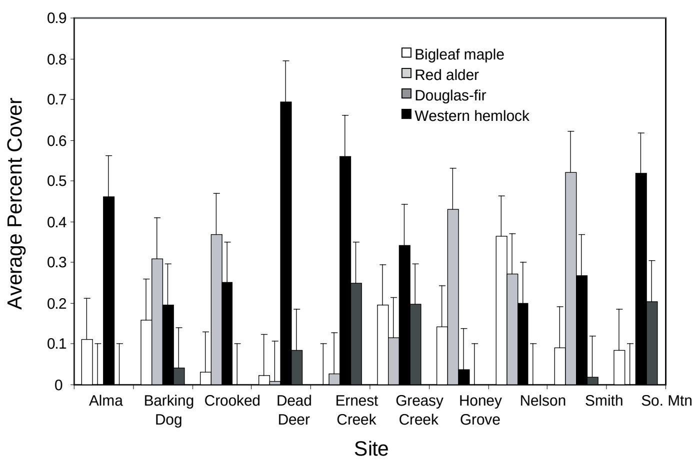


Figure 2. Average adjacent riparian canopy cover (%).

Amphibian surveys

We captured 285 individuals during the aquatic amphibian surveys in July and October 2002, and June 2003. The aquatic larval stage of *Dicamptodon tenebrosus* accounted for over 77% of all aquatic amphibians. Of these, 54% came from one site (Ernest Creek). No aquatic amphibians were found at the Smith Creek tributary site. We conducted terrestrial amphibian surveys in fall 2002 and spring 2003, and we captured 168 amphibians. The terrestrial salamander, *Plethodon vehiculum*, was the most frequently captured species, making up 55% of terrestrial captures, 41% of which came from one site (South Mountain); no *P. vehiculum* were found at either the Smith or Nelson Creek tributary sites. As numbers of other amphibian species were low, we considered only aquatic larval *D. tenebrosus* and terrestrial *P. vehiculum* for statistical analysis.

Dicamptodon tenebrosus-habitat

The amount of Douglas-fir cover over the wetted width of the stream, elevation, the amount of wood cover area, and the underlying lithology were the most important habitat variables associated with the presence of the aquatic *D. tenebrosus*. The best logistic model explained 97% of the variation associated with the likelihood of the presence of the larval *D. tenebrosus* in these Oregon Coast Range streams and was 56 times better than the next best model at explaining the variability of the data. In the top model, the odds of finding a larval *D. tenebrosus* improved as the amount of Douglas-fir cover overhanging the stream and the elevation increased. The odds decreased, however, in streams of underlying marine (as opposed to volcanic) lithology and as the amount of wood cover area (m^2 wood >5 cm diameter/m^2) increased. We also checked for seasonal differences in the likelihood of the presence of the larval *D. tenebrosus* and found none. The order of the top models did not change when we added a variable for season into the model set.

These results are probably influenced by the high numbers of *D. tenebrosus* found at the Ernest Creek site. Ernest Creek is 226 m higher than the next highest study site and 400 m higher than the lowest study site. Aquatic *D. tenebrosus* typically use interstitial spaces as foraging or protective cover. In general, higher elevation streams are associated with steeper gradients, thus providing larger stream substrate and more interstitial cover for salamander larvae. Higher gradient streams also tend to move small substrate particles more quickly downstream during periods of sediment input, keeping interstices from being filled by small particles. The increased likelihood of *D. tenebrosus* larvae being present in streams with underlying volcanic lithology suggests these streams may provide better interstices, as they are typically dominated by unconsolidated (larger) rock substrate. The streams included in this study, however, were generally dominated by gravel and pebble-sized (2–64 mm) rocks. In our study, the capture sizes for larval *D. tenebrosus* were skewed towards smaller size classes, as is typical with aquatic amphibian surveys where hand searching is used. We believe that the smaller substrate sizes in these stream sites likely provided better interstices for the smaller individuals that we found.

The positive association of Douglas-fir cover with aquatic *D. tenebrosus* suggests a response to the disturbance regime of these stream sites. Douglas-fir is not very flood tolerant and cannot survive long periods of inundation. Streams with high amounts of Douglas-fir cover likely have few high-water disturbance events over time, and are more dynamically stable than streams dominated by more flood tolerant species, and consequently are more likely to have *D. tenebrosus* present. We also found that the likelihood of *D. tenebrosus* larvae being present decreased with increased amounts of wood cover in the stream channel. Generally, greater amounts of small wood in streams provide better cover and foraging substrate for these larvae. Increasing amounts of downed wood in streams, however, could act as traps for fine sediments and organic debris that could clog potential larval cover spaces.

Plethodon vehiculum-habitat

Our strategy for AICc model selection was to consider all the models after accounting for spring plant growth, as leaf-out affected the amount of shade reaching the forest floor over the course of the spring survey period. Our analysis provided the five best approximating models, given our data, that are within 2 ΔAICc units of each other. Average upslope gradient of the site, capture distance from the stream, and an element of canopy cover, (amount of western hemlock, total overstory cover, red alder, bigleaf maple, and Douglas-fir, respectively) were important variables that explained the presence of *P. vehiculum* in these sites. There was little weight of evidence for a top model; the top five together, however, explained 86% of the variability of these data. The odds of finding *P. vehiculum* were improved with increasing slope, distance from stream, and increased tree canopy cover, although the likelihood of finding a *P. vehiculum* decreased as the season progressed.

Our results suggest that the odds of finding a terrestrial *P. vehiculum* depended more on the weather than on any other factor. Surface activity of this salamander is restricted to times when there is little risk of freezing or desiccation. We conducted terrestrial surveys over a 10-week period in the spring during which daily average temperatures steadily increased. As temperatures increase, the amount of time terrestrial salamanders spend on the surface of the forest floor generally decreases, as they remain under cover to decrease the risk of desiccation, making them harder to find.

Other variables included in the top models are more difficult to interpret. *P. vehiculum* is widely distributed in the Pacific Northwest, found in timber stands of all ages. It is typically found in dryer habitats than its congener, *P. dunni*. The increased odds of finding *P. vehiculum* farther away from the stream may reflect its ability to tolerate drier conditions found upslope of moist stream microhabitats. The relative importance of slope in the model set is likely influenced by the high average slope at the South Mountain site where 41% of *P. vehiculum* were captured. Whereas other studies in the Pacific Northwest have compared timber stand age and type with amphibian species presence, we have attempted to investigate whether tree canopy species may influence the presence of this species in riparian areas by limiting sites to similar stands within a narrow age range. Although deciduous trees dominated the canopy directly over the stream, there was always a component of both conifer and deciduous tree canopy along the stream and in the adjacent 30-m upslope area. The minor differences in the vegetation directly along the stream and 30-m upslope were usually associated with the shrub species. Canopy cover provides shade and helps moderate forest temperatures. Our results suggest that overall canopy cover is as important if not more important than the canopy tree species for this salamander.

Diet

All invertebrate identification was completed in spring 2005. We collected 219 stomach samples from larval *D. tenebrosus*. We identified 24 taxa in the stomach samples over three seasons; aquatic prey accounted for over 80% of all prey items. Ephemeroptera, Plecoptera, Diptera, and Trichoptera were the most abundant food items, together comprising 76% of all invertebrate prey. Stomach fullness differed significantly between seasons ($F_{2,215}$ = 15.34, P < 0.05). June samples consistently had a higher fullness index than either July or October samples (Figure 3). There was also weak evidence that stomach fullness differed among sites ($F_{8,209}$ = 1.85, P = 0.069).

We collected 80 *P. vehiculum* stomach samples over the fall and spring sampling periods. We identified 22 taxa in the stomach samples; Collembola and mites were the most abundant prey taxa found. They made up 45% and 16% of the total prey, both seasons combined. We found that stomach fullness differed ($F_{7,72}$ = 3.04, P = 0.007) between Dead Deer and Crooked and Greasy Creek (Figure 4). Our results agree with other published reports of *P. vehiculum* diet that Collembola and mites are the most numerous prey items consumed. We found weak evidence of seasonal differences in *P. vehiculum* diet ($F_{1,78}$ = 3.34, P = 0.07).

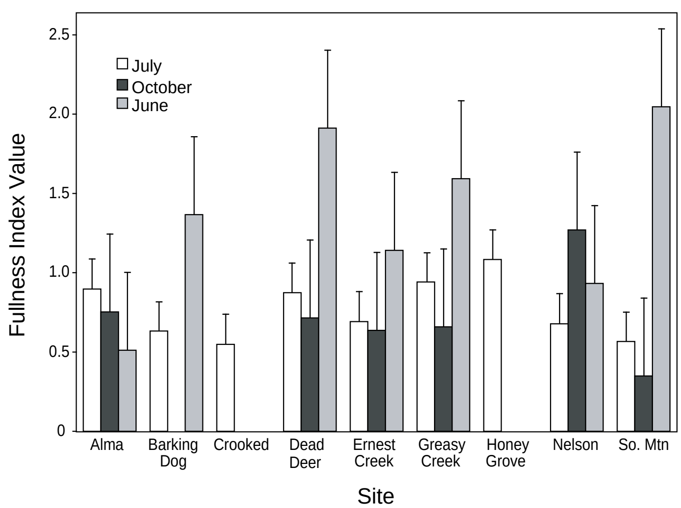


Figure 3. Larval Dicamptodon tenebrosus stomach fullness index by site and season.

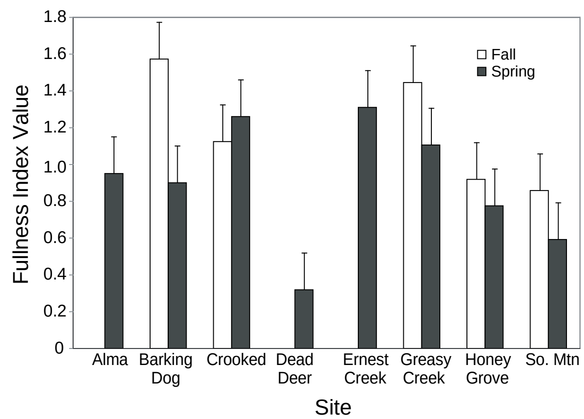


Figure 4. Plethodon vehiculum stomach fullness index by site and season.

STUDY TIMELINE

Analysis is in the final stages and thesis writing is underway. A graduate student thesis is expected to be completed fall term 2005.

Relationships Among Vegetation, Insects, and Bats in Riparian Areas

Holly Ober and John P. Hayes

Riparian areas provide crucial habitat for many species of wildlife. For example, all 12 species of bats that occur in the Pacific Northwest are insectivorous, and previous research has demonstrated that the abundance and biomass of nocturnal flying insects is greater in riparian areas than in forest interiors. Therefore, activity levels of the 10 species of bats found in the Douglas-fir (*Pseudotsuga menziesii*) forests of the Oregon Coast Range are high relative to bat activity in other habitat types, as bats presumably spend most of each night foraging along streams.

Riparian plants are important in supporting the insects on which insectivorous bats feed. In an effort to inform land managers of the potential impacts that proposed vegetation management schemes may have on bats, we are investigating the linkages among riparian vegetation, nocturnal insects, and bats. In this study we are examining the following linkages: 1) the relationship between bat use of stream reaches and vegetation composition bordering these reaches, and whether vegetation composition of the surrounding watershed influences these relationships; 2) the differences in abundance, biomass, and community composition of nocturnal flying insects in stream reaches dominated by deciduous versus coniferous vegetation; 3) the food habits of each of the bat species found in the region. This information should enable us to develop models for appraising implications of potential riparian vegetation management prescriptions on bats.

Methods

Bat use of riparian areas

Over the course of three summers we monitored bat activity in a total of 154 stream reaches throughout the Oregon Coast Range. In 2002, we monitored bat activity in 41 stream reaches in six randomly selected fifth-field watersheds, ranging from 141 to 514 km^2, in the central Coast Range. In 2003 we repeated this effort in 37 new stream reaches in six additional watersheds in the southern Coast Range, as well as in eight stream reaches from one watershed used the previous year. In 2004 we repeated this effort once again in 40 new stream reaches in six additional watersheds in the northern Coast Range, as well as in the eight stream reaches that were monitored each of the 2 previous years.

We monitored echolocation calls at each stream reach once during each 2-week period between mid-June and early September, for a total of four visits per reach in 2002 and five visits per reach in 2003 and 2004. Echolocation calls of bats were recorded from sunset until sunrise by calibrated, automated Anabat II detectors with Anabat zero crossings analysis interface modules. We used a blocked sampling design, simultaneously monitoring along 5–8 stream reaches within a given watershed each night. The use of a blocked sampling design improves precision in comparisons of activity levels among the different habitat types within a watershed by removing overall variability in bat activity among nights.

Vegetation composition in stream reaches where bat activity was monitored varied along a continuum from completely coniferous to completely deciduous. Vegetation was sampled extensively to characterize each stream reach where bat activity was monitored.

Insect use of riparian areas

We collected insects in 36 stream reaches throughout the Oregon Coast Range. In 2002, we sampled in six fifth-field watersheds in the central Coast Range, and in 2003 and 2004 we sampled in six new watersheds and one previously monitored watershed. Insects were collected once during each 2-week period between mid-June and early September, for a total of five visits to each stream reach each summer. We sampled insects from sunset until sunrise, using black-light and aquatic emergence traps. We used a paired sampling design, simultaneously sampling in one conifer-dominated and one deciduous-dominated stream reach within a single watershed each night. Again we characterized the vegetation in each stream reach where sampling was conducted via extensive vegetation surveys.

Bat prey selection

In 2002, we used mist nets to capture bats in each of the stream reaches where insects were collected (described above). Because of low capture rates with this method, in 2003 and 2004 we captured bats with H-nets and hoop nets while they night-roosted under bridges within each of the watersheds in which insects were collected. Bats were held in cloth bags for <1 hour; species, sex, age, mass, and forearm length were recorded before each bat was released. Guano was subsequently removed from each bag and stored in a labeled plastic vial. Vials were placed in the freezer within 10 hours of collection until time of analysis.

In the laboratory, we teased apart guano in a Petri dish containing 95% ethyl alcohol. All pellets collected from an individual bat were placed in a single dish and treated as a single sample. Using a dissecting microscope, we identified food items to order by comparing fragments to whole insects collected nearby on the same night the guano was obtained.

For each sample, we estimated the percentage volume of each order of insect visually. We then summarized the average percent volume for each order for all individuals of a given species of bat ([sum of individual volumes of insect order/total volume of all samples] x 100) to obtain an index of the proportional contribution of each insect order to the diet of each bat species. We also calculated the frequency of occurrence of each insect order for each bat species (number of samples in which a particular insect order occurred/total number of samples for that bat species) to obtain a standardized measure of the commonness of each insect order in the diet of bats. Finally, we calculated the arithmetic mean of the percent volume and percent frequency of occurrence of food items consumed across all bat species to assess the importance of each insect order in the diet of the entire bat community.

Preliminary Research Results

Bat echolocation calls

Overall bat activity (all species combined) from all three summers combined was variable among watersheds and was not strongly related to vegetation composition at the watershed scale (Figure 1). Similarly, bat activity was variable among stream reaches and did not appear to be strongly related to vegetation composition at the stream reach scale (Figure 2). Our data have not yet been subjected to rigorous statistical analysis, however, and apparent patterns should be interpreted with caution.

We will analyze echolocation data statistically during the fall of 2005, taking into account bat species groupings and examining the relationship between bat activity and 1) vegetative composition and clutter at the stream reach scale and 2) vegetation composition at the watershed scale. We will use an information-theoretic approach to develop habitat relationship models for determining which habitat characteristics are the best predictors of bat activity levels.

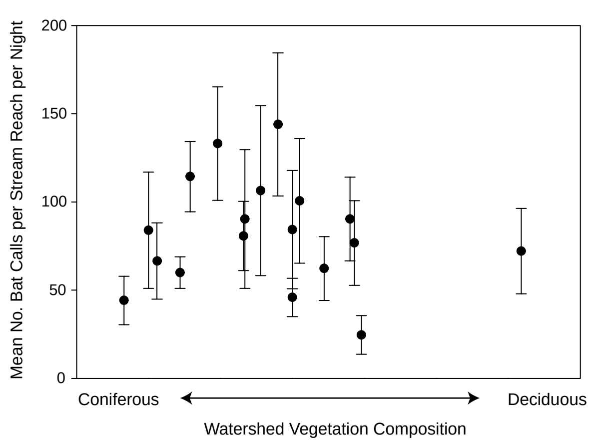


Figure 1. Mean number of bat echolocation calls per stream reach per night within each watershed in 2002, 2003, and 2004 combined as a function of watershed plant community composition. Error bars represent 95% confidence intervals.

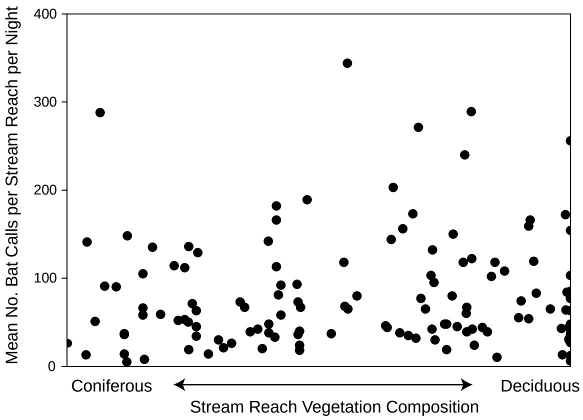


Figure 2. Mean number of bat echolocation calls per stream reach per night in 2002, 2003, and 2004 combined as a function of stream reach plant community composition.

INSECT SAMPLES

Preliminary analysis of data from all three summers combined suggests that abundance of two of the three most common orders, Diptera (n = 98,104) and Trichoptera (n = 16,911), were similar between coniferous and deciduous stream reaches ($F_{1,28}$ = 1.40, P = 0.247 for Diptera; $F_{1,28}$= 1.31, P = 0.2612 for Trichoptera) (Figure 3A, B). Lepidoptera (n = 19,195), however, were more abundant in deciduous reaches than in coniferous ($F_{1,28}$ = 8.97, P = 0.006) (Figure 3C).

During winter 2006 we will analyze insect data more thoroughly to further elucidate relationships between riparian vegetation composition and both abundance and biomass of all insect orders. Given the particular importance of Lepidoptera in the diets of bats in this region (see below) we will examine Lepidoptera distribution patterns in greater detail by looking at familiar, generic, and species richness and species diversity as well.

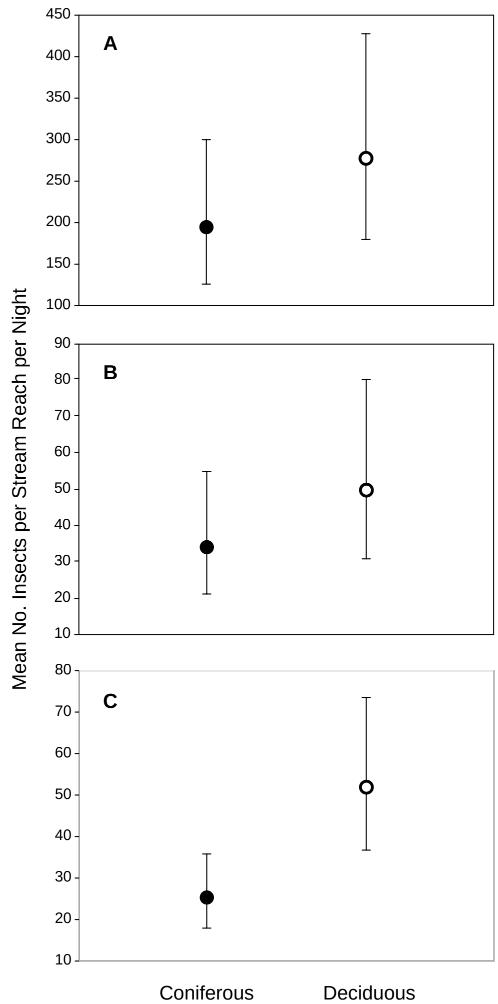


Figure 3. Mean number of insects captured via black light traps in each stream reach each night for the three most abundant orders, A)Diptera, B)Trichoptera, and C)Lepidoptera. Solid circles represent means for conifer-dominated stream reaches and open circles represent means for deciduous-dominated stream reaches. Error bars represent 95% confidence intervals.

BAT PREY SELECTION

We analyzed 378 guano samples from 10 species of bats. The average percent volume of each insect order consumed is summarized in Table 1. In decreasing rank order, primary insect prey types (comprising more than 5% of the volume of prey consumed by all bat species) included Lepidoptera (moths), Diptera (flies), Coleoptera (beetles), Hemiptera (true bugs), Araneida (spiders), and Trichoptera (caddisflies).

The average frequency of occurrence of each insect order consumed is summarized in Table 2. In decreasing rank order, insect types that occurred in more than 40% of samples from each bat species included Lepidoptera, Diptera, Coleoptera, Araneida, Hemiptera, and Trichoptera.

PRELIMINARY MANAGEMENT IMPLICATIONS

Collectively, our preliminary results suggest that deciduous riparian vegetation may play an important role in the nutrition of bats in the Oregon Coast Range. Lepidoptera was the only insect order consumed by an overwhelming majority of individual bats. Lepidoptera was also the only order that showed clear differences in abundance between conifer-dominated and deciduous-dominated stream reaches, with many more individuals found in deciduous-dominated reaches. Forest management activities that promote conifer dominance in riparian areas may affect bat foraging patterns by causing bats to commute to untreated areas where deciduous vegetation remains dominant.

Study Timeline

Data collection has been completed, and data processing has begun. A final report and manuscripts should be completed by summer 2006.

Table 1. Percent volume of food items consumed by bats in the Oregon Coast Range, summer 2002–2004.

	LACI (n = 2)	LANO (n = 4)	COTO (n = 4)	EPFU (n = 67)	MYCA (n = 15)	MYEV (n = 23)	MYTH (n = 20)	MYVO (n = 106)	MYLU (n = 58)	MYYU (n = 79)
Lepidoptera	40	24	95	29	30	35	21	71	10	16
Diptera	-	24	-	2	30	5	9	4	29	32
Coleoptera	5	8	1	37	8	12	14	1	4	2
Hemiptera	18	16	-	13	5	14	5	3	7	4
Araneida	3	-	4	<1	2	21	24	7	9	12
Trichoptera	3	10	-	3	7	3	2	<1	30	21
Isoptera	3	1	-	9	5	5	1	10	6	8
Homoptera	25	-	-	1	-	<1	19	1	<1	1
Neuroptera	3	14	-	4	7	3	2	1	2	3
Hymenoptera	3	4	-	2	5	1	1	<1	2	1
Orthoptera	-	-	-	-	-	1	4	-	<1	-
Acarina	-	-	-	<1	-	-	-	-	1	1
Psocoptera	-	-	-	-	1	<1	-	-	<1	<1
Ephemeroptera	-	-	-	-	-	-	-	-	<1	<1
Plecoptera	-	-	-	-	-	-	-	-	-	<1
Unknown	-	-	-	-	-	-	-	-	<1	<1
Total	100	100	100	100	100	100	100	100	100	100

LACI = Lasiurus cinereus; LANO = Lasionycteris noctivagans; COTO = Corynorhinus townsendii; EPFU = Eptesicus fuscus; MYCA = Myotis californicus; MYEV = M. evotis; MYTH = M. thysanodes; MYVO = M. volans; MYLU = M. lucifugus; MYYU = M. yumanensis

Table 2. Frequency of occurrence of food items consumed by bats in the Oregon Coast Range, summer 2002–2004.

	LACI (n = 2)	LANO (n = 4)	COTO (n = 4)	EPFU (n = 67)	MYCA (n = 15)	MYEV (n = 23)	MYTH (n = 20)	MYVO (n = 106)	MYLU (n = 58)	MYYU (n = 79)
Lepidoptera	100	100	100	97	100	100	90	100	84	80
Diptera	-	100	-	40	100	61	65	37	98	96
Coleoptera	100	100	25	93	53	78	75	10	22	9
Araneida	50	-	75	6	47	96	90	50	64	62
Hemiptera	100	100	-	79	47	57	40	33	29	22
Trichoptera	50	100	-	28	67	35	15	3	97	85
Neuroptera	50	100	-	55	73	35	25	13	26	22
Hymenoptera	50	50	-	22	40	9	15	5	19	18
Isoptera	50	25	-	28	7	13	10	19	17	18
Homoptera	50	-	-	7	-	4	40	5	3	9
Orthoptera	-	-	-	-	-	17	30	-	2	-
Acarina	-	-	-	3	-	-	-	-	14	13
Psocoptera	-	-	-	-	7	4	-	-	3	1
Ephemeroptera	-	-	-	-	-	-	-	-	2	1
Plecoptera	-	-	-	-	-	-	-	-	3	-
Unknown	-	-	-	-	-	-	-	-	2	1

LACI = Lasiurus cinereus; LANO = Lasionycteris noctivagans; COTO = Corynorhinus townsendii; EPFU = Eptesicus fuscus; MYCA = Myotis californicus; MYEV = M. evotis; MYTH = M. thysanodes; MYVO = M. volans; MYLU = M. lucifugus; MYYU = M. yumanensis

Influence of Aquatic and Terrestrial Invertebrates on Riparian Vertebrate Predators

Amanda Robillard and Judith L. Li

In riparian areas, terrestrial and aquatic habitats overlap, creating a zone where they interact, the aquatic-terrestrial interface. Coupling of the two systems allows for movement of energy between them and generates intertwining food webs. As a result, riparian consumers, such as fish or birds, have alternative prey items external to their respective habitats. The energy that flows between aquatic and terrestrial habitats has been recognized as an ecological subsidy (Polis et al. 1996, Time, space, and life history: Influences on food webs. Pages 435–460 in *Food Webs*; Nakano and Murakami 2001, *Proceedings of the National Academy of Sciences* 98:166–170).

Subsidies can occur in many situations; in this study we are examining reciprocal subsidies to terrestrial and aquatic predators in riparian areas. Emerging aquatic insects are available to riparian avian consumers, and terrestrial invertebrates may be consumed by fish. This exchange of prey between both habitats creates a potential mutually beneficial situation. But to what extent are the consumers utilizing these alternative prey sources?

Several studies show the reliance of salmonids on terrestrial insect input to streams. For example, Wipfli (1997, *Canadian Journal of Fisheries and Aquatic Sciences* 54:1259–1269) determined that terrestrial invertebrates may comprise over 50% of juvenile salmonid diet in Alaskan streams. Nakano et al. (1999, *Ecological Research* 14:351–360) found rainbow trout consumed more terrestrial insects than aquatic insects. Salmonid biomass was reduced when terrestrial invertebrates were excluded from a stream in Japan (Kawaguchi et al. 2003, *Ecology* 84:701–708).

Conversely, emerging aquatic insects contribute directly to the flow of energy from aquatic to terrestrial habitats. After macroinvertebrates metamorphose into their final life-history stage, the adult insects leave the water to reproduce. High densities of emerging aquatic insects are found along streams, subsequently increasing predator densities (Lynch et al. 2002, *Austral Ecology* 27:515–526; Murakami and Nakano 2002, *Ecology Letters 5:333–337*). In a grassland system, densities of insectivorous riparian birds were correlated with peak emergence of aquatic adult insects (Gray 1993, *American Midland Naturalist* 129:288–300). An observational study in a riparian area determined that 25.6% of the annual energy budget for several riparian bird species came from aquatically derived nutrients (Nakano and Murakami 2001, *Proceedings of the National Academy of Sciences* 98:166–170).

It is clear that fish, particularly salmonids, consume terrestrial insects; gut analyses have shown the importance of this prey type (Wipfli 1997, *Canadian Journal of Fisheries and Aquatic Sciences* 54:1259–1269; Nakano et al. 1999, *Ecology* 80:2435–2441). Although birds have been observed consuming aquatic adult insects in riparian zones, there has yet to be a study that determined the aquatic contribution to bird diet from fecal samples. We are examining riparian food webs in Oregon Coast Range watersheds by sampling aquatic and terrestrial insects, riparian birds, and fish. Through the use of mist netting, avian fecal samples have been collected. Fecal analysis will potentially provide direct evidence of how aquatic secondary production is subsidizing riparian insectivorous birds. Fish diet will be analyzed directly through stomach content samples. Both will be compared to the composition and availability of aquatic and terrestrial invertebrates collected by four sampling methods.

By using these techniques in different seasons, we will estimate interdependence among these groups. Using diet analysis and information on invertebrate composition and abundance from summer and fall 2003 and spring 2004, we hope to address the following questions: Are fish able to utilize terrestrial insects when benthic invertebrates are naturally low? Is the emergence of aquatic insects used by birds in times when energy demands are high?

Methods

Study sites

This project contains two phases. The first study was conducted in June and September of 2003 on Honey Grove Creek in the Coast Range of Oregon. The second was conducted in spring 2004 and included two additional watersheds. Here we will address the 2003 project (for 2004 methodology, see *2003 CFER Annual Report*).

The Honey Grove watershed is located approximately 1 mile east of Alsea and empties into the North Fork of the Alsea River. The checkered ownership pattern consists of lands under Bureau of Land Management (BLM), private forest industry, and private residential ownership. Vegetation is characteristic of the Western Hemlock Vegetation Zone, and the riparian area is dominated by red alder (*Alnus rubra*) and bigleaf maple (*Acer macrophyllum*) as a result of timber harvest in the mid-1950s. There were three study reaches; two tributaries and the mainstem of Honey Grove Creek.

Invertebrate sampling

To sample emerging aquatic adult insects, four emergence traps were set on each of the three reaches ($n = 12$); the traps (1 m^2, pyramid-shaped, covered in fine-mesh screen) were placed in the middle of the stream. Benthic samples were taken with a Surber sampler (500-mm mesh size, 0.093 m^2) in six locations per reach ($n = 18$) immediately before electrofishing was conducted. Pan traps sampling 0.75 m^2 were set with an inch of water and fragrance-free detergent that broke the surface film; there were six pan traps per reach ($n = 18$).

Four emergence traps were placed on each 300-m reach—one in each of four 75-m segments. Placement within each segment was determined by using a random number generator. A similar process was used for pan-trap locations and Surber-sample collection sites. Benthic samples were collected once to get a "snapshot" of prey items available to fish; pan and emergence samples were collected every other day.

Diet sampling

To assess fish diet, fish were collected with a Smith-Root variable wave backpack shocker on all three reaches. After fish were anesthetized, stomach samples were obtained by gently flushing the stomach with water from a fine-tipped squirt bottle; stomach contents were collected on paper coffee filters and preserved in 95% alcohol. Fish weight and length were recorded at the same time. For every sampling effort, our goal was to capture 20 individuals of each fish species present. Data from one tributary reach are not included here because there were no anadromous fish present at that time. This is also the case with the benthic samples.

Bird fecal samples were collected on one tributary reach in both June and September of 2003. In early morning on three days during both seasons, bird fecal samples were obtained from individual birds after capture in mist nets. To collect these samples, birds were held in paper sacks for a short period; the fecal samples were taken from the bags and preserved with 95% alcohol. To date, only samples collected during June have been analyzed.

Research Results and Management Implications

The primary goal of this analysis was to identify the exchange of prey items to consumers in adjacent habitats. Initially each component of availability was enumerated, and then potential reciprocal subsidies were assessed by comparing density of terrestrial versus aquatic insects, particularly in pan traps. All invertebrate samples from Honey Grove Creek (2003) have been identified. Samples were grouped to get a watershed-scale view of the invertebrate community and the consumers' use of this resource.

A seasonal difference was apparent for the aquatic component of allochthonous input in the pan traps. More aquatic insects than terrestrial were found in the summer (Figure 1). Moreover, there were more aquatic taxa in pan traps in the summer (Figure 2). In the fall, there were more terrestrial insects falling into the stream (Figure 1).

Seasonally, the benthic insect community composition varied in density by order (Figure 3). On average, Ephemeroptera, Plecoptera, and Trichoptera were more numerous in the summer; Coleoptera and Diptera were more abundant in the fall.

There was also a seasonal difference in average density of aquatic insect orders collected by emergence traps (Figure 4). On average, Diptera and Ephemeroptera were more numerous in the summer; in the fall, Coleoptera, Plecoptera, and Trichoptera were more abundant.

Diet

The average seasonal abundance of aquatic and terrestrial insects found in the fish diet varied with species (Figure 5). Thirty-eight cutthroat trout (*Oncorhynchus clarkii*) were captured in the summer and 24 in the fall. This species consumed more aquatic insects in the summer and slightly more terrestrial insects in the fall. Among a similar number of coho salmon (*Oncorhynchus kisutch*), a different pattern in consumption was observed. Twenty coho salmon were collected in summer and 23 in the fall; on average, coho consumed more aquatic insects than terrestrial in both seasons.

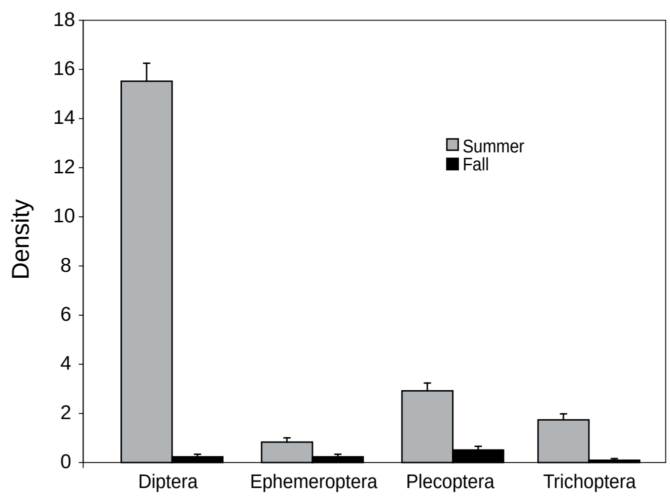


Figure 2. Average seasonal density of adult aquatic insect orders collected in pan traps. Density was calculated as the average number of invertebrates/trap/day/m². Error bars represent the standard error of the mean.

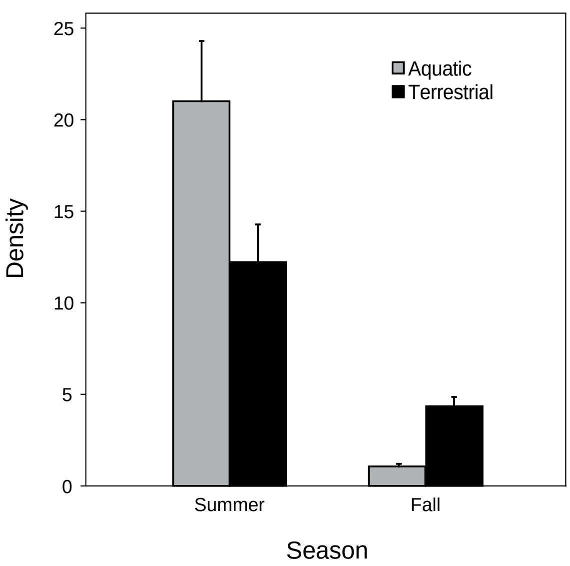


Figure 1. Average seasonal density of aquatic vs. terrestrial invertebrates from pan traps. Density was calculated as the average number of invertebrates/trap/day/m². Error bars represent the standard error of the mean.

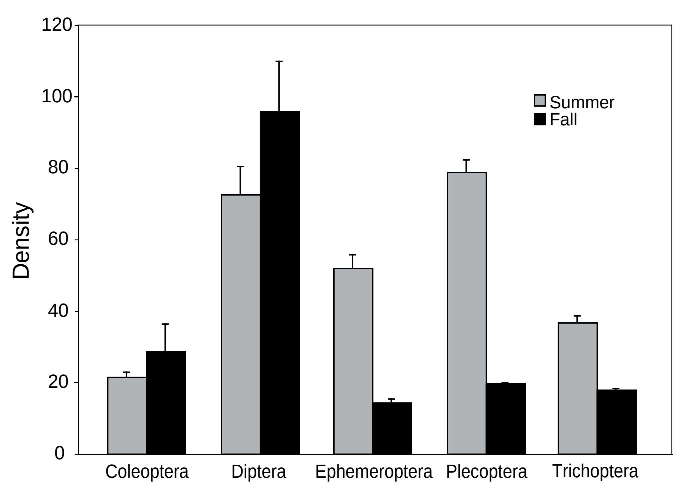


Figure 3. Average seasonal density of benthic insect orders. Density was calculated as the average number of invertebrates/trap/day/m². Error bars represent the standard error of the mean.

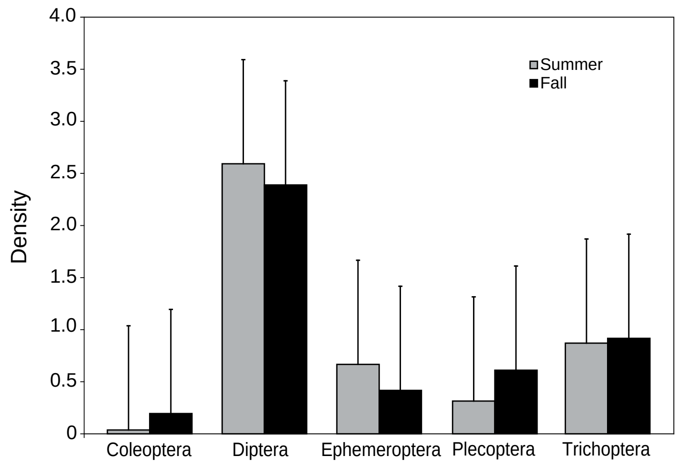


Figure 4. Average seasonal density of adult aquatic insects from emergence traps. Density was calculated as the average number of invertebrates/trap/day/m^2. Error bars represent the standard error of the mean.

In the Honey Grove watershed, it appears that birds are consuming a greater number of terrestrial than aquatic invertebrates (Figure 6). Only 13 of the 16 bird fecal samples have been analyzed, however, so bird diet analyses are still preliminary.

Study timeline

Identification of fish diet and its analysis should be completed by fall 2005. The Honey Grove 2003 study will be summarized in a thesis that will be completed in winter 2006. Analysis of comparative watersheds sampled in spring 2004 will continue in spring/summer 2006 with additional collections of bird diet and riparian invertebrate availability in spring 2006.

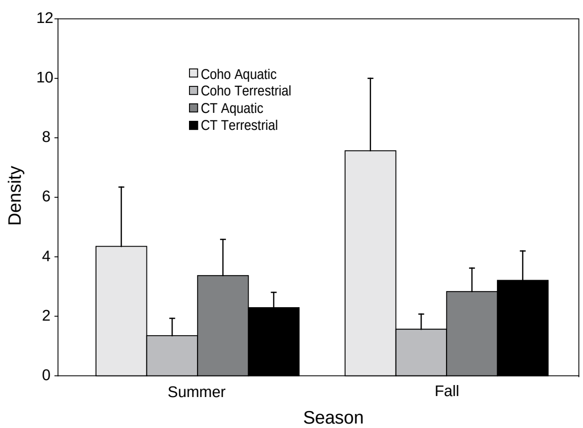


Figure 5. Average seasonal abundance of aquatic vs. terrestrial prey items in coho salmon and cutthroat diet. Error bars represent the standard error of the mean.

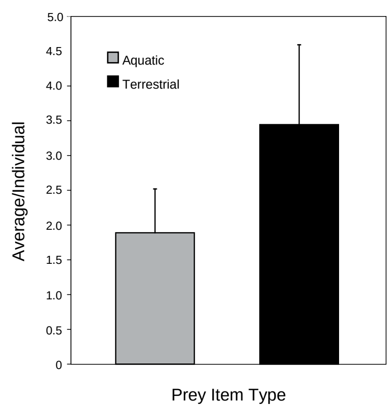


Figure 6. Average number of aquatic vs. terrestrial prey items found in bird diet. Error bars represent the standard error of the mean.

Riparian Litter Inputs to Streams in the Central Oregon Coast Range

Stephanie Hart, David Hibbs, and Steven Perakis

Greater attention to riparian forest management has increased the demand for scientific information about riparian areas. This need has pointed out what we know—and do not know—about riparian ecological structure and function. Riparian forests provide shade, large structural wood, and terrestrial litter that help maintain stream functions and processes. The interaction of aquatic and terrestrial systems may be especially pronounced in small streams, where litter inputs from riparian vegetation are likely to provide a majority of the energy and nutritional base for aquatic food chains. Little is known, however, about the quantity or source locations of litter input that are important in aquatic and terrestrial food chains.

Current management regulations in Oregon promote conversion of riparian forests dominated by red alder (*Alnus rubra*) to coniferous-dominated overstories, with the goal of increasing the long-term supply of structural large wood (LWD) to channels (Emmingham et al. 2000, *OSU Forest Research Laboratory Research Contribution* 24:1–34). Less is known, however, about the changes in non-LWD processes resulting from this management choice. In particular, aquatic and terrestrial riparian food chains often depend strongly on the quantity and quality of detrital inputs from riparian vegetation (Gregory et al. 1991, *BioScience* 41:540–551), and favoring coniferous over deciduous overstories may alter nutritional subsidies to these ecosystems.

There is a lack of knowledge about how riparian area characteristics, including lateral slope and vegetation composition and density, may lead to differences in input of both vertical litter (which falls directly from overhead) and lateral litter (which moves down the slope) to riparian food webs. Management decisions that favor coniferous-dominated overstories in riparian forests may therefore have unintended effects on the timing, quantity, and nutrient concentrations of litter inputs to riparian food webs in different forest types and topographic settings.

Studies that have measured vertical and lateral litter inputs suggest that, although lateral litter movement is greater on steeper slopes (Fisher 1977, *Internationale Revue der Gesamtem Hydrobiologie* 62:701–727; France 1995, *Freshwater Biology* 34:495–499), lateral movement may decrease with increases in the roughness, or spatial density, of understory riparian vegetation, large logs, and boulders. This project addresses the potential impacts of overstory vegetation on vertical and lateral inputs of litter to streams with varied slopes and vegetation compositions. More specifically, this report addresses the following objectives:

- to measure amounts and identify sources of vertical and lateral litter inputs
- to characterize the seasonal pattern of vertical and lateral litter movement
- to understand the role of understory vegetation in obstructing lateral litter movement

Methods

Study sites

Eight riparian sites with an overstory dominated by Douglas-fir (*Pseudotsuga menziesii*) and eight sites with an overstory dominated by red alder were selected in and adjacent to the Alsea River watershed in the central Oregon Coast Range. Sites were selected on the basis of vegetation composition, proximity to small streams, and steepness of adjacent hillslope. Each dominant overstory type has lateral slopes ranging from 0–65%. Several research sites are common to other CFER studies.

At each site, we randomly assigned four 8- x 30-m plots within selected uniform areas along a stream reach ≤300-m (total of 960 m^2 study area per site, Figure 1) to control areas and the following experimental treatments:

Cut: In a 5- x 8-m section adjacent to the stream, understory was cut every 2 months for the duration of the study. All understory plants >5 cm in height and <10 cm diameter at breast height (DBH) were cut and removed.

5-m fence: An 8-m-long fence was constructed parallel to the stream, 5 m from the stream edge. The fence blocked laterally moving litter originating upslope of the fence (data not presented here).

10-m fence: An 8-m-long fence was constructed parallel to the stream, 10 m from the stream edge. This fence blocked laterally moving litter originating upslope of the fence (data not presented here).

Vertical and lateral litter traps were deployed at each site to capture litter inputs to streams from above and from the side. Vertical traps constructed from laundry baskets and suspended mesh were set to capture overstory and understory litter falling vertically from a height of >0.33 m above the forest floor. Lateral traps were set to collect litter moving down the slope along the soil surface towards the stream, rather than falling directly from vegetation. Lateral traps were constructed of PVC rectangles with a mesh backing (Hart et al., *2003 CFER Annual Report*).

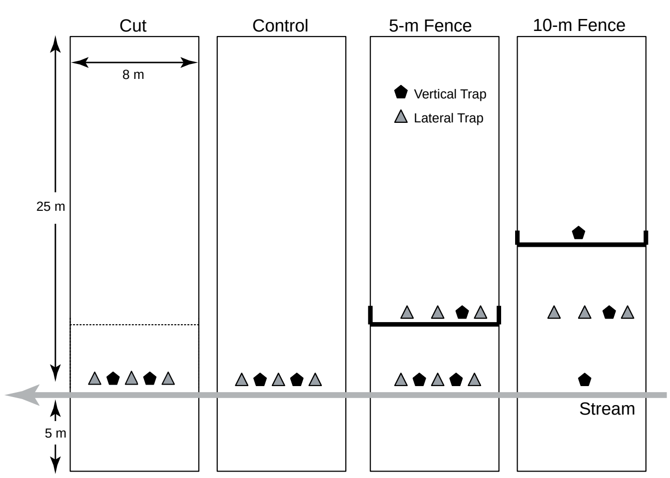


Figure 1. Schematic of treatments and placement of vertical and lateral traps on a hypothetical stream reach. Treatments are each 30 m × 8 m and were randomly assigned to nonrandomly selected uniform areas.

The cut, control, and 5-m fence treatments have two vertical and three lateral traps deployed at the stream edge. The 10-m fence treatment has no lateral traps at the stream edge, but, along with the 5-m fence treatment, each has one vertical and three lateral traps located 5 m from the stream. These fifteen lateral traps and eight vertical traps, plus two additional vertical traps in the 10-m fence treatment (at 0 m and 10 m from the stream), make a total of 25 traps at each site (Figure 1). In addition, four of the sites have vertical traps set directly over the stream for comparing vertical litter caught at the stream edge and over the stream.

Vegetation and Plot Sampling

Measurements of vegetation and plot characteristics were conducted between June and September 2003 for each site (Hart et al., *2003 CFER Annual Report*).

Litter Collection and Sample Preparation

Vertical and lateral litter was collected monthly between August 2003 and August 2004. After collection, litter was dried and sorted into seven litter types. Sorted samples of coniferous needles, coniferous-other, deciduous leaves, deciduous-other, understory, twigs, and leftover (unidentifiable litter parts) were weighed and analyzed for carbon and nitrogen content.

We collected 400 samples of leaf litter each month and have included results from all twelve months in this report unless otherwise specified. Total litter inputs was calculated on the basis of stream surface area and reach length so that a 20-m length of stream 4-m wide would have 80 m^2 of surface area and 40 m (20 m on each side) of lateral length.

Research Results and Management Implications

Deciduous-dominated sites provided 32% more litter inputs to streams than did coniferous-dominated sites. For each 20-m reach of an average stream, coniferous-dominated sites provided 34.0 kg and deciduous-dominated sites provided 44.7 kg of litter inputs. Lateral litter inputs comprised 7% of the total litter inputs at coniferous-dominated sites and 10% of the total litter inputs at deciduous-dominated sites for the equivalent of a 4-m-wide stream (Figure 2). These lateral litter input calculations are for all sites regardless of slope.

Seasonal patterns of vertical litter fall were as expected for deciduous- (peak in autumn) and coniferous-dominated sites. Vertical litter inputs from deciduous vs. coniferous sites were statistically different in several months, but November is certainly driving the annual vertical difference. This highlights the important role of seasonality as a factor distinguishing these two vegetation types (Figures 3 and 4).

Dominant overstory type (red alder vs. Douglas-fir) also resulted in different types of litter entering both vertical and lateral traps. Deciduous tree litter was the dominant litter type in vertical traps at all sites in autumn months (September, October, November and December). The abundance of deciduous litter on sites classified as coniferous-dominated can be explained by the presence of bigleaf maple (*Acer macrophyllum*) and red alder near the stream's edge at those sites. Coniferous tree litter was of secondary importance at coniferous-dominated sites in autumn months and was of minimal importance at deciduous-dominated sites in the same season. This likely is because there was little Douglas-fir or western hemlock (*Tsuga heterophylla*) at deciduous-dominated sites, particularly near the stream's edge. Deciduous-derived litter types were consistently present in moderate percentages at coniferous-dominated sites in winter (January, February and March) and spring/summer (April, May, June, July and August) seasons.

In winter months, vertical litter inputs were dominated by twigs from overstory and understory sources. At deciduous-dominated sites in winter months, deciduous-other litter types, mainly pistillate and staminate red alder catkins, were also present in high proportions. The spring/summer season vertical litter inputs were populated by the dominant overstory needles or leaves and deciduous-other litter types (Figure 5).

Qualitatively, lateral trap inputs were similar to the input patterns in vertical traps in each season and over-

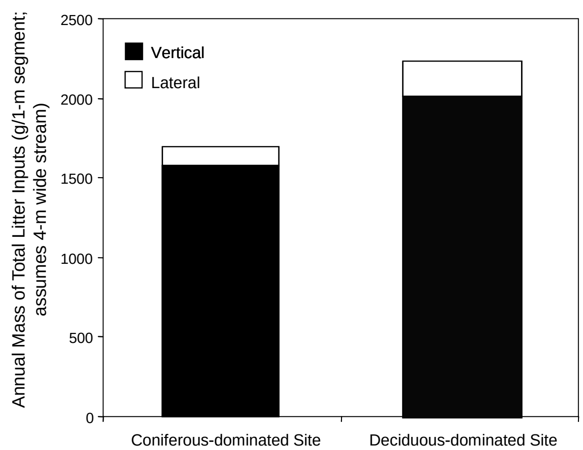


Figure 2. Total litter input amounts (g/1-m segment) to a 4-m-wide stream for September through March. The average stream width for this study, 4 m, was selected for calculating total litter inputs from vertical and lateral movement.

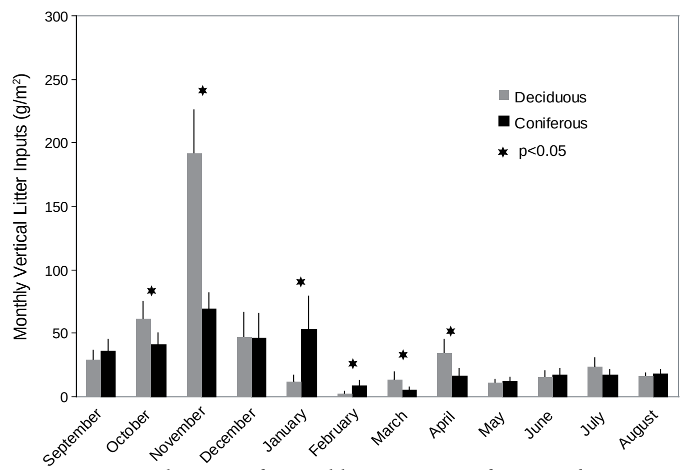


Figure 3. Seasonal pattern of vertical litter movement for September-August.

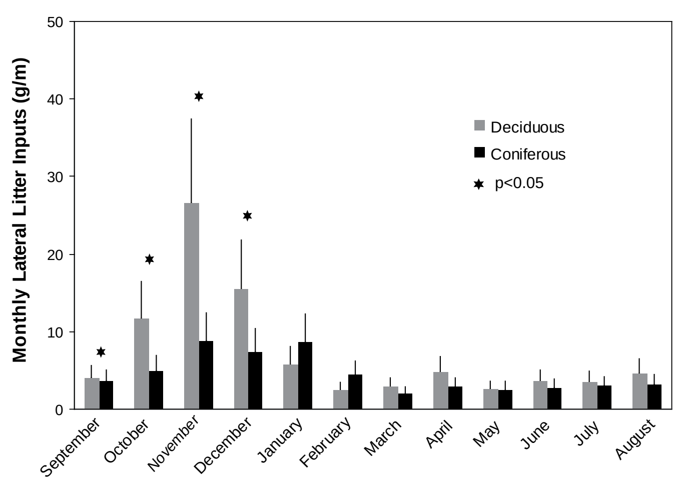


Figure 4. Seasonal pattern of lateral litter movement for September-August.

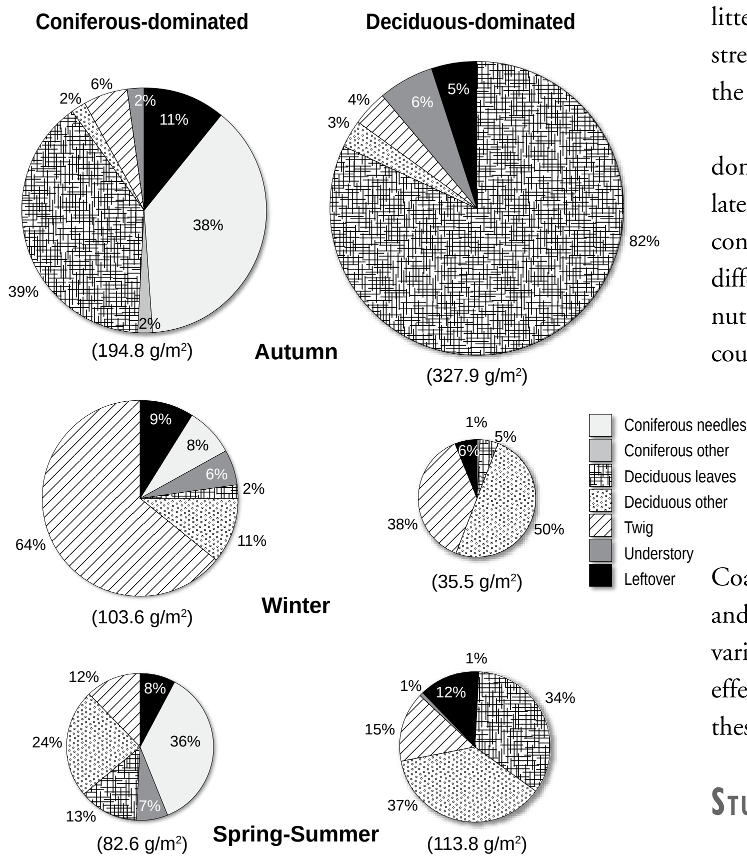


Figure 5. Litter type composition of vertical and lateral litter. The area of each pie chart is proportional to the average total litter mass (g/m²/month or g/m/month) collected from vertical and lateral traps in each month of each season-overstory-trap type combination. The number in parentheses is the average total litter mass for that season-overstory combination.

story type combination. Deciduous leaves, however, comprised a higher percent of moving litter in lateral traps at deciduous-dominated sites in winter months. Lateral trap litter types also consistently had larger percentages of "leftover" litter types than vertical traps because the litter was harder to identify to species and litter-type group.

Based on results from our manipulative treatments, understory vegetation does not appear to decrease lateral movement of total litter in most seasons at sites of either overstory type. Removal of understory vegetation did not alter the quantity of lateral litter at coniferous-dominated cut treatments from that of the controls in the spring/summer season (Figure 6). This does, however, suggest that steeper slopes are associated with more litter moving laterally and that litter moves laterally even at very small slope values. We estimate that lateral litter inputs were at least 7–10% of total litter inputs in streams 4 m wide or less, a small but significant part of the total inputs to streams in these sites.

Collectively, our results indicate that deciduous-dominated riparian forests provide more vertical and lateral litter and have a more pronounced seasonal litter contribution than coniferous-dominated forests. These differences, considered with potential variations in litter nutrient concentrations between the two overstory types could have important implications for the productivity of detritus-based aquatic food webs. This question is currently under investigation.

Our results suggest that forest management activities promoting the dominance of coniferous overstories in riparian zones of the central Oregon Coast Range would reduce litter inputs to terrestrial and aquatic riparian communities and reduce seasonal variability in timing of these inputs with yet unknown effects on food webs that depend on litter subsidies in these ecosystems.

Study Timeline

Vegetation data collection was completed in September 2003, and litter data collection was completed in August 2004. Processing of litter was completed in December 2004. Analysis and interpretation of data will continue through fall 2005. A final report will be completed in winter 2006.

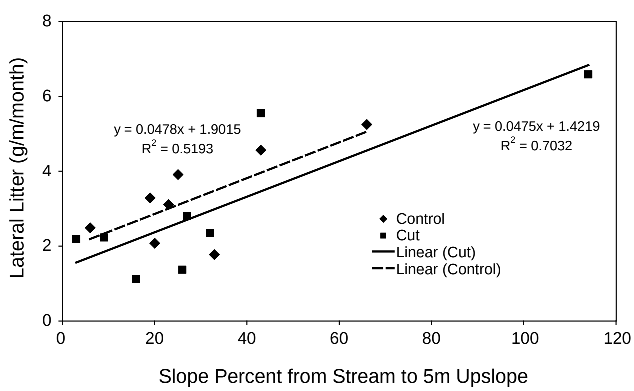


Figure 6. Relationship between lateral litter mass (g/m/month) in control and cut treatments and slope from stream to 5 m upslope at coniferous-dominated sites in spring-summer months.

LITTER DECAY IN COAST RANGE RIPARIAN ZONES: BIOGEOCHEMICAL CONTROLS AND IMPLICATIONS FOR TERRESTRIAL AND AQUATIC FOOD CHAINS

Joselin Matkins, Steven Perakis, and David E. Hibbs

Decomposition of leaf litter plays a vital role in riparian area function. Both aquatic and terrestrial food chains rely on energy and nutrients derived from riparian forests. Current management regulations in western Oregon encourage conversion of forests dominated by red alder (*Alnus rubra*) to forests dominated by conifers, such as Douglas-fir (*Pseudotsuga menziesii*), primarily in order to increase long-term supplies of structural large wood to streams. Such changes in vegetation may also impact subsidies of leaf litter inputs that fuel riparian food webs, yet there is little information on the rate and timing of energy and nutrient release associated with litter decay in these two riparian forest types. This study is designed to examine the influence of leaf litter characteristics and overstory species composition on decomposition patterns for both red alder and Douglas-fir litter, in the context of understanding how vegetation management could impact nutritional subsidies and nutrient cycles within these riparian systems.

Vegetation plays many critical roles in the productivity of riparian terrestrial and aquatic habitats. The decomposition of senesced leaf litter and the subsequent release of carbon and nutrients provide the energetic base of food chains. Only a few organisms, however, primarily insects, feed directly on riparian vegetation. Instead, most organisms derive their nutrition from food chains, which are supported at their base by the breakdown and incorporation of decaying leaf litter.

Leaf litter breakdown in both terrestrial and aquatic systems is a complex interaction among chemical, physical, and microbial processes. The rate of leaf litter decay is affected by both internal factors of the litter—the chemical and physical qualities of the leaves themselves—and external environmental factors, moisture, temperature, and nitrogen (N) being the most important.

In terrestrial environments, the lignin:N ratio has been shown to be a good predictor of leaf litter decomposition rates and nutrient dynamics from species to species. High quality litter like that from red alder has relatively low lignin:N ratios, decomposes rapidly, and quickly releases energy and nutrients. This results in faster nutrient cycling and greater soil productivity. In contrast, litter of lower initial quality (higher lignin:N), such as Douglas-fir needles, decays more slowly, leading to lower nutrient cycling rates and soil fertility. Despite such broad generalities, there is virtually no information on how variations in quality within a single species might influence decay rates.

Controls of litter decomposition are fundamentally similar in aquatic and terrestrial habitats; however, important differences exist. The nutritional budget of stream ecosystems is complex and relies on energy captured within the stream (photosynthesis), from riparian communities bordering the stream, and from nutrients carried by groundwater. Water flow also fragments leaf litter, speeding up litter decay.

In this study, we are experimentally examining the influences of litter source on rates of leaf litter decay, both across species (red alder vs. Douglas-fir) and within a single species (DF1-8, Table 1). We are also looking at the influence of environmental conditions on leaf litter decay in both terrestrial and aquatic environments. Justification for this research is twofold. First, knowing how and when energy and nutrients are made available to food webs is integral to understanding the structure

Table 1. Initial litter quality for eight Douglas-fir litter sources and one red alder litter source.

Source Litter	Species	%N	% Lignin	Lignin:N
DF1	Douglas-fir	0.62	34.07	55.00
DF2	Douglas-fir	0.72	41.85	57.96
DF3	Douglas-fir	0.89	37.48	42.02
DF4	Douglas-fir	0.92	37.12	40.53
DF5	Douglas-fir	0.93	36.52	39.22
DF6	Douglas-fir	1.00	42.63	42.82
DF7	Douglas-fir	1.16	42.85	36.86
DF8	Douglas-fir	1.26	39.53	31.27
RA	Red alder	2.41	22.58	9.37

and function of riparian areas of the Oregon Coast Range, particularly in relation to N cycling. Second, although there is extensive evidence that the lignin:N ratio is a good predictor of rate of decay across species, the relationship has not been tested across a broad lignin: N range within a single species. This research will further our understanding of both the patterns and the controls of leaf litter decay, providing new information on the consequences of conversion of riparian stands from red alder to Douglas-fir.

This report addresses the following questions for the terrestrial component of this study: Does litter source (Douglas-fir vs. red alder) influence the rate of litter decay? Does decomposition environment (Douglas-fir- vs. red alder-dominated riparian forests) influence breakdown rates for common litters? Does externally added N affect the breakdown rate of Douglas-fir litter? How does a wide range of initial litter quality (lignin:N ratio) affect the breakdown rate of litter from a single species (Douglas-fir)?

Methods

Decomposition of red alder and Douglas-fir leaf litter was measured by the litterbag method in which preweighed material was confined within mesh bags. Changes in mass, nutrient content, and carbon chemistry were measured over 1 year. Source litter samples were gathered during September and October 2003 by shaking branches of 20- to 35-year-old trees and collecting the resulting litter on tarps placed beneath the trees. Douglas-fir litter gathered from eight sites ranged in initial N concentration from 0.62% to 1.26%. Red alder litter was collected at a ninth collection site. The initial N concentration was typical for red alder leaves, 2.41% (Table 1). Red alder and Douglas-fir sites chosen for decay plots were a subset of sites studied previously by Emily Scott (*2003 CFER Annual Report*) in the central and southern Coast Range.

In total, 3,500 litterbags made of 1-mm nylon mesh were placed on the soil surface in November 2003 in one of two overstory habitat types: red alder or Douglas-fir. There were four replications of each overstory type and three plots in each replicate. At each Douglas-fir site, three additional replicate plots were added and fertilized monthly with N. This setup is designed to examine the influence of the different environmental conditions on leaf litter decay such as those found in red alder and Douglas-fir overstory habitat and in unfertilized and fertilized treatments under Douglas-fir.

Ten replicate litterbags of each litter source (Table 1) were randomly placed in each plot for a total of 90 bags per plot. Replicate bags from each litter source were collected after 2 weeks, 1 month, 2 months, 4 months, 8 months, and 1 year. Additional collections are scheduled for 2, 3, and 4 years after initiation. At each collection, one replicate litterbag of each litter source was collected from each plot and the contents of the bag reweighed for mass loss. The ratio of the final mass to the initial mass of each litterbag was then used to calculate the decay constant k (yr^{-1}), an integrated measure of the rate of decomposition over time. The values for k (yr^{-1}) were then used to compare among overstory types of red alder, Douglas-fir, and fertilized Douglas-fir, as well as among litter sources.

The aquatic component of this research was initiated in September 2004. The aquatic experiment used the same litter sources and litterbag methods described above. On the basis of other research showing correlations between dissolved N concentrations in stream water and the amount of red alder in the watershed, we selected study sites to span a range of aquatic N levels as indexed by the percentage of watershed area dominated by red alder. Water samples were subsequently taken and tested for ammonium, nitrate, and total dissolved N concentrations. We established eight aquatic sites; four with high stream water N and four with low stream water N. Litterbags from this experiment were collected 1 day after initiation to evaluate a 24-hour leaching period. Subsequently, collections were conducted after 1 week, 2 weeks, 1 month, 2 months, 3 months, 4 months, and 5 months, with the last collection in February 2005.

Analysis of variance (ANOVA) was used to determine if there are significant differences in decay rates between source litter and decomposition environments. Significant effects are reported at $\alpha = 0.05$. The AIC (Akaike's Information Criterion) index was used to evaluate the single variable regression models for predicting k (yr^{-1}). Lignin:N, % N, and % lignin were examined as predictors of decay rate. The smallest value for AIC indicates which model best predicts decay rate.

Preliminary Research Results

Red alder litter decayed much more rapidly than Douglas-fir litter in all field settings ($P < 0.001$) (Figure 1). Decay of red alder litter was more rapid under red alder overstory than in either fertilized or unfertilized Douglas-fir habitat ($P < 0.001$). Our results for red alder versus Douglas-fir litter also supports previous work of an inverse curvilinear relationship across species between lignin:N and decay rate. Red alder has a lower lignin:N ratio and decays more rapidly than Douglas-fir with its higher lignin:N ratio.

In contrast, decay rates of Douglas-fir litter did not differ statistically between red alder and Douglas-fir overstories, or between unfertilized and fertilized treatments (Figure 2). Within Douglas-fir litter sources, % N and lignin:N were significant predictors of decay rate for all Douglas-fir litter sources (Table 1); % lignin alone was not statistically significant. AIC analyses indicated that litter N concentration is the best predictor of decay rate (Table 2). Surprisingly, Douglas-fir litter decayed

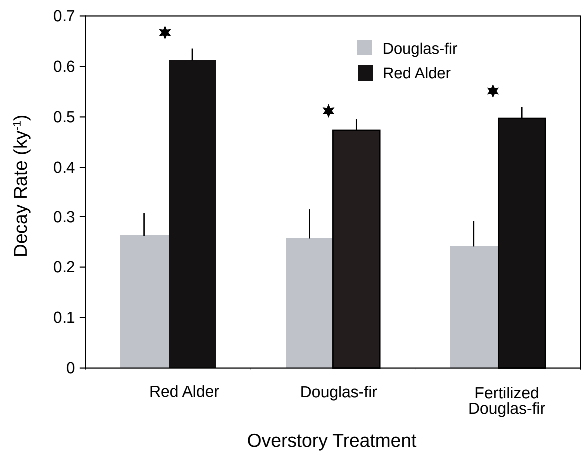


Figure 1. Decay rate for red alder vs. average of eight different Douglas-fir litter sources in red alder, unfertilized Douglas-fir, and fertilized Douglas-fir riparian areas.

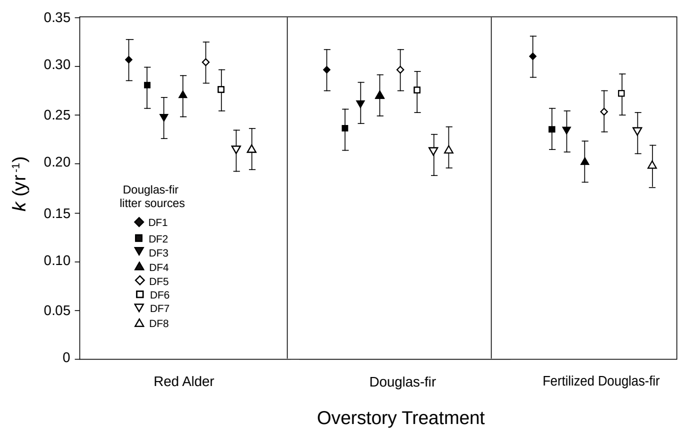


Figure 2. Douglas-fir litter source in red alder, unfertilized Douglas-fir, and fertilized Douglas-fir riparian areas.

most rapidly when litter % N was low and lignin:N ratio was high.

Discussion

The decay constant "k (yr^{-1})" is an integration of leaf-litter decay rate over time. A high value for k (yr^{-1}) indicates faster decay, while lower values indicate slower decay. The consistently high k (yr^{-1}) values that we observed for red alder leaf litter in comparison to Douglas-fir agree with previous studies of these species in upland

Table 2. AIC analysis indicates that %N is the best predictor of decay rate when compared with similar analyses of % Lignin and the Lignin:N ratio.

Explanatory Variable	AIC	Delta AIC	Residual Error
% Nitrogen	-307.4	0	0.001453
% Lignin	-273.9	33.5	0.001747
Lignin:N	-271.0	36.4	0.001718

habitats. Collectively, this work suggests that red alder releases carbon and energy more rapidly into food chains than does decomposing Douglas-fir. Comparisons of % N and lignin:N ratio between these species agree with standard conceptual models relating leaf litter quality to decay rates. The higher % N of red alder litter (2.4% N) in comparison to Douglas-fir (0.6–1.3% N), and the lower lignin:N ratio of red alder (lignin:N = 9) in comparison to Douglas-fir (range = 31–55) both indicate a higher litter quality for red alder. These differences offer a reasonable explanation for its nearly two-fold more rapid decay than Douglas-fir in all habitats. Red alder decomposes rapidly, releasing carbon, N, and other nutrients to the system. Douglas-fir decay rates are much lower, releasing carbon and nutrients more slowly.

Although broad decay patterns of red alder versus Douglas-fir leaf litter followed expected trends, the results of examining leaf litter decay within Douglas-fir were highly unexpected. Decay of different Douglas-fir litter sources was related negatively to litter quality measures, so that decay was negatively related to % N in litter and positively related to lignin:N ratios. These surprising patterns stand in stark contrast to generally accepted conceptual models indicating faster decay at high % N and lower lignin:N ratio. Our results raise the possibility that traditional litter quality indices can predict decay rates effectively only for comparisons made across species (e.g., red alder vs. Douglas-fir). Traditional litter quality indices may not be sufficiently mechanistic to predict decay rate variations within species, and other unexplored factors of species identity may be as (or more) important than lignin and % N as predictors of leaf litter decay.

Conclusion

Red alder litter decays more rapidly than Douglas-fir litter in all overstory habitats. Red alder litter also decays more rapidly in N-fertilized treatments than in unfertilized treatments. However, overstory habitat does not strongly influence decay rates of the different Douglas-fir litter sources, nor does added N significantly affect decay rate for Douglas-fir litter. Overall, our results suggest that both litter quality and habitat factors associated with red alder may accelerate litter decay and incorporation in riparian food webs. Conversion of red alder riparian areas to Douglas-fir may therefore slow rates of energy, carbon, and nutrient cycling that could limit food resource availability to consumer organisms.

Study Timeline

The terrestrial experiment was initiated November 2003. Data collection for a graduate student thesis will continue through November 2005 with additional collections in November 2006 and 2007. The aquatic experiment was initiated September 2004. Data collection was completed in February 2005. Lab work began during spring 2004, and data analysis will continue through fall and winter of 2005/2006. Thesis writing will occur during the winter and spring of 2006.

INFORMATION EXCHANGE

Finding effective ways of delivering and sharing information is a priority for the CFER program. A strong expression of that priority was the formal establishment of an information exchange program in 1998 to assess information needs and facilitate information flow to CFER cooperators and the broader scientific and management communities in the Pacific Northwest.

GOALS

The information exchange program maintains a set of goals that guide the development of activities and products by personnel exclusively assigned to these duties. The goals of the information exchange program are to:

- ❑ identify and prioritize research topics by assessing needs of managers and researchers within the cooperating organizations;
- ❑ develop appropriate mechanisms to convey information;
- ❑ ensure effective and timely transfer of research information to the scientific and management community; and
- ❑ facilitate continual two-way communication between managers and researchers

2005 HIGHLIGHTS

- ❑ CFER researchers gave over 40 presentations at professional meetings and conferences, delivered 12 seminars and lectures, and participated in 15 workshops and field tours as presenters or organizers.
- ❑ CFER scientists held multiple workshops with BLM and ODF resource specialists, field managers, and program managers to identify their research needs and priorities. This information is being used to help guide a strategic plan now being developed by the CFER Research Program.
- ❑ A searchable bibliography on cumulative watershed effects was developed that included approximately 60 journal articles, books, and other printed and electronic publications.
- ❑ The CFER program hosted the BLM's Density Management and Riparian Studies Workshop to bring together forest managers and researchers to share information and discuss early project results.

2005 Activities and Products

The CFER information exchange program has carried out numerous activities since the program's inception. Many of these were developed to create an awareness of the CFER program and its research. With the completion of many of CFER's initial projects, the emphasis for information exchange has shifted to the dissemination of research results. Communication efforts during this phase of the program will promote the development of materials and planning of events that present research outcomes and management considerations to help with the implementation of effective forest practices.

The following are descriptions of activities and products from year 2005.

CFER Web Site

The CFER web site continues to be an important means of disseminating information about CFER's research and information exchange activities. Because of growth-related changes, we have redesigned the existing interface to increase site usability. The redesign includes reformatting of the main navigation menu to include "Publications" as a primary heading. This will increase accessibility to the growing number of programmatic publications and products available for download. Among the publications available are copies of our newsletter, fact sheets, student abstracts, and this report. In addition, database-driven pages have been developed, which will allow for quicker updating as new research themes are developed and the web site continues to grow. The CFER web site is located at http://www.fsl.orst.edu/cfer.

CFER Newsletter

The program's newsletter, *CFER News*, continued to inform cooperators and the general public about CFER's research and activities. Each issue of *CFER News* was circulated to approximately 800 people and organizations during 2005. The newsletter was established to highlight research and activities of interest to people making decisions about land management. Recurring features include summaries of completed research, updates on current research and field activities, and publication highlights. An example of a recent newsletter article was the "comical" look at research conducted by Dr. Joan Hagar. She teamed up with graphic artist Gretchen Bracher to develop a comic strip to communicate her research results in a clear and entertaining format. The comic helped to illustrate the importance of understory shrub species in maintaining biodiversity in managed forests without the use of graphs and error bars. To receive future entertaining articles, contact the CFER program office (541-737-6593; CFER@fsl.orst.edu). Current and past issues of *CFER News* may also be viewed or downloaded from our web site as a PDF file.

CFER Roving Seminar Series

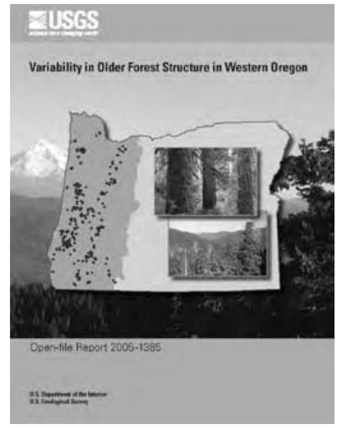
To further enhance linkages between research and management, the CFER program established the 'CFER Roving Seminar Series' in 2002. This is a program of CFER scientists traveling to Oregon Department of Forestry (ODF) and Bureau of Land Management (BLM) offices to present seminars and discuss issues of interest to managers. The seminar series is aimed at increasing face-to-face communication between researchers and research-users. We invite you to contact the CFER program office to arrange a presentation for your agency or organization.

Cumulative Watershed Effects Bibliography

In response to the information needs of BLM land managers, CFER compiled a bibliography of publications on the topic of cumulative watershed effects in the Pacific Northwest. The resulting bibliography includes approximately 60 journal articles (including abstracts when available), books, and other printed and electronic publications. The citations address a variety of subjects including peakflow responses to forest practices, effects of clearcutting on stream temperature, sediment routing and storage, and implications for predicting and managing cumulative watershed effects. Most sources were published between 1995 and the present; however, a limited number of key citations were published prior to 1995. Where possible, links were provided to sources that are available on the Internet. A CD including the citations with abstracts and the free bibliographic database viewer "BiblioExpress", is available upon request from the CFER program office (BiblioExpress a simple reference manager that allows searching by keyword). To facilitate access to the bibliography, a PDF of the bibliography along with the database and software are available online (http://www.fsl.orst.edu/cfer/research/pubs/pubs.html). We hope the bibliography will be useful as you and your colleagues address this complicated issue.

Report Describing Variability in Older Forest Structure in Western Oregon

State and Federal land managers charged with developing older forest characteristics in young stands in western Oregon require fundamental information about older forest structure. To provide land managers with such information, a unique database was created using complete inventories of all conifer trees greater than one foot in diameter from over 500 recently harvested older forests on Bureau of Land Management districts in western Oregon. The database contains tree census data for over 16,400 acres of late-successional old-growth forests. In addition, the spatial variability of trees and snags at 14 late-successional old-growth sites was characterized using structural data collected along one or more long (396–2178 ft) belt transects at each site. The results of these analyses are published in a USGS open-file report, and the data and associated documentation are also available. The report can be downloaded as a PDF and the raw data files can be downloaded as a zip file (1.6 MB) from the CFER web site (http://www.fsl.orst.edu/cfer/research/pubs/pubs.html).



Students and Natural Resource Communication

Because natural resource issues are confusing and complex, natural resource professionals must possess more than the traditional set of technical skills to effectively address these issues. Solid communication skills are among the most beneficial tools of today's land manager. Last academic year, Drs. Janet Erickson and Judy Li offered a course through the Department of Fisheries and Wildlife at Oregon State University designed to provide students with the concepts and techniques necessary for successful communication in natural resource organizations. In the course, undergraduate students developed a communication product related to studies within the "Riparian Linkages" research theme of the CFER program. The students, working as a group, reviewed the studies about riparian influences on fish and wildlife food webs (e.g., cutthroat trout, bats, spiders, birds, amphibians), choose and analyzed their audience, designed

clear messages related to this research, and managed a communication project through to completion. The final product developed by the students was an interactive CD using video, PowerPoint slides, and other media. A poster describing their year-long project won first place in the "educational division" among competing undergraduate projects.

BLM's Density Management Study Workshop

The Density Management Study (DMS) was initiated by a partnership between the BLM and the U.S. Geological Survey, which quickly grew to include Oregon State University (OSU), the U.S. Forest Service Pacific Northwest Research Station (PNW), and Region Six of the U.S. Forest Service. The CFER program provides administrative and outreach support for the DMS.

A one-day workshop, sponsored by the CFER program, was organized to bring researchers together with forest managers to share information and early results from the Density Management and Riparian Buffer Studies. The 7 November meeting was limited to 55 participants and featured nine presenters. Topics addressed during the presentations included vegetation response to density management treatments, headwater forest response to thinning, leave islands as refugia for low-mobility species, and many other topics.

Upcoming Conference

An upcoming conference co-sponsored by CFER, the US Forest Service, Oregon State University, and others is being organized to provide information relevant to the wide diversity of publics interested in the conservation and management of biodiversity in Pacific Northwest forests. This includes owners of small woodlands, conservation organizations, natural resource managers, biologists, and ecologists from federal and state land use agencies and industrial forestry companies. Invited oral presentations by regional experts will address the following topics:

- ❑ Effects of fire and fuels on biodiversity management
- ❑ Stand management strategies and opportunities
- ❑ Monitoring and measuring success
- ❑ Effects of fire and fuels on biodiversity management
- ❑ Stand management strategies and opportunities
- ❑ Monitoring and measuring success

The event titled "Managing for Biodiversity in Pacific Northwest Forests: Strategies and Opportunities" will be held 5–7 June 2006 in Portland, Oregon. For questions or additional information, please call (541-737-2329) or email (forestry.outreach.education@oregonstate.edu) the Forestry Outreach Education Office, Oregon State University.

CFER Communications

Conference Presentations

February 16–18, 2005. Poster presentation: "Using passive integrated transponder tags to evaluate fish distribution at a watershed scale." 41st Annual Meeting of the Oregon Chapter of the American Fisheries Society. Corvallis, Oregon. (Bateman, Gresswell, Torgersen, Hockman-Wert)

February 16–18, 2005. Paper presentation: "Longitudinal patterns of stream fishes, aquatic habitat and water temperature in the lower Crooked River, Oregon." 41st Annual Meeting of the Oregon Chapter of the American Fisheries Society. Corvallis, Oregon. (Torgersen, Gresswell, Bateman, Hockman-Wert)

February 16–18, 2005. Paper presentation: "Seasonal persistence of coastal cutthroat trout distributions in a headwater stream." 41st Annual Meeting of the Oregon Chapter of the American Fisheries Society. Corvallis, Oregon. (Novick, Gresswell)

February 16–18, 2005. Paper presentation: "Landscape influences on the spatial extent of coastal cutthroat trout distribution in low-order forested watersheds of western Oregon." 41st Annual Meeting of the Oregon Chapter of the American Fisheries Society. Corvallis, Oregon. (Torgersen, Gresswell, Bateman, Hockman-Wert)

February 16–18, 2005. Poster presentation: "What's for dinner? Seasonal differences in riparian consumer diet and insect communities in an Oregon Coast Range watershed food web." 41st Annual Meeting of the Oregon Chapter of the American Fisheries Society, Corvallis, Oregon. (Robillard, Li)

February 24, 2005. Paper presentation: "Post-fire breeding bird use in forests affected by the Biscuit Fire." Joint Meeting of the Oregon Chapter of The Wildlife Society and the Society for Northwestern Vertebrate Biology. Oregon State University, Corvallis, Oregon. (Cannon, Hayes)

February 24, 2005. Paper presentation: "Influence of riparian vegetation on amphibian communities and amphibian diet in the Oregon Coast Range." Joint Meeting of the Oregon Chapter of The Wildlife Society and the Society for Northwestern Vertebrate Biology. Oregon State University, Corvallis, Oregon. (Graff, Edge)

February 23, 2005. Poster presentation: "CFER: Science in support of management." Joint Meeting of the Oregon Chapter of The Wildlife Society and the Society for Northwestern Vertebrate Biology. Oregon State University, Corvallis, Oregon. (Erickson, Hibbs)

March 23–25, 2005. Paper presentation: "Alder: Its management and potentials." International Symposium on Red Alder: A State of Knowledge. University of Washington, Seattle, Washington. (http://www.ruraltech.org/video/2005/alder_symposium) (Hibbs, Bluhm)

March 23–25, 2005. Paper presentation: "Density management in alder stands." International Symposium on Red Alder: A State of Knowledge. University of Washington, Seattle, Washington. (http://www.ruraltech.org/video/2005/alder_symposium) (Hibbs, Bluhm)

March 23–25, 2005. Paper presentation: "Growth and yield of alder." International Symposium on Red Alder: A State of Knowledge. University of Washington, Seattle, Washington. (http://www.ruraltech.org/video/2005/alder_symposium) (Hibbs, Bluhm)

March 23–26, 2005. Paper presentation: "Riparian litter inputs to streams in the central Oregon Coast Range." Northwest Scientific Association 78th Annual Meeting. Oregon State University, Corvallis, Oregon. (Hart, Hibbs, Perakis)

March 23–26, 2005. Paper presentation: "Responses of breeding birds following the Biscuit Fire." Northwest Scientific Association 78th Annual Meeting. Oregon State University, Corvallis, Oregon. (Cannon, Hayes)

March 23–26, 2005. Poster presentation: "Riparian vegetation recovery in the Biscuit Fire of southwest Oregon." Northwest Scientific Association 78th Annual Meeting. Oregon State University, Corvallis, Oregon. (Halofsky, Hibbs)

March 23–26, 2005. Poster presentation: "Contributions of riparian vegetation to terrestrial food chains: Contrasting red alder and Douglas-fir." Northwest Scientific Association 78th Annual Meeting. Oregon State University, Corvallis, Oregon. (Matkins, Perakis, Hibbs)

March 23–26, 2005. Paper presentation: "Variation in phosphorus and pH in soils beneath four tree species in Oregon Coast Range old-growth forests." Northwest Scientific Association 78th Annual

Meeting. Oregon State University, Corvallis, Oregon. (Cross, Perakis)

April 19, 2005. Poster presentation: ”Cooperative Forest Ecosystem Research (CFER): Science supporting resource management.” Conference on Science and the Northwest Forest Plan: Knowledge Gained over a Decade. Red Lion Hotel on the River, Portland, Oregon. (Erickson, Hibbs)

April 19, 2005. Poster presentation: “Predicting input of riparian trees in western Oregon.” Conference on Science and the Northwest Forest Plan: Knowledge Gained over a Decade. Red Lion Hotel on the River, Portland, Oregon. (Hibbs, Shatford)

April 19, 2005. Poster presentation: “Is brush for the birds? The role of understory vegetation in maintaining diversity in managed forests.” Conference on Science and the Northwest Forest Plan: Knowledge Gained over a Decade. Red Lion Hotel on the River, Portland, Oregon. (Hagar, Starkey)

April 19, 2005. Poster presentation: “Response of birds to thinning young Douglas-fir forests.” Conference on Science and the Northwest Forest Plan: Knowledge Gained over a Decade. Red Lion Hotel on the River, Portland, Oregon. (Hayes, Weikel, Huso)

April 19, 2005. Poster presentation: “Riparian litter inputs to streams in the central Oregon Coast Range.” Conference on Science and the Northwest Forest Plan: Knowledge Gained over a Decade. Red Lion Hotel on the River, Portland, Oregon. (Hart, Hibbs, Perakis)

April 19, 2005. Poster presentation: “Spatially explicit modeling of alternative futures for forest landscapes.” Conference on Science and the Northwest Forest Plan: Knowledge Gained over a Decade. Red Lion Hotel on the River, Portland, Oregon. (Hockman-Wert, Torgersen, Cissel, Sheridan, Guetterman)

April 19, 2005. Poster presentation: “The influence of habitat structure on headwater stream amphibians at multiple spatial scales.” Conference on Science and the Northwest Forest Plan: Knowledge Gained over a Decade. Red Lion Hotel on the River, Portland, Oregon. (Stoddard, Hayes)

May 22–27, 2005. Paper presentation: “Seasonal differences in riparian consumer diet and insect communities in an Oregon Coast Range watershed food web.” 2005 Joint Assembly of the American Geophysical Union and the North American Benthological Society. New Orleans, Louisiana. (Robillard, Li)

May 22–27, 2005. Invited presentation: “Geomorphic heterogeneity at the valley segment scale: Effects on habitat structure, aquatic organisms, and stream-riparian food web linkages.” 2005 Joint Assembly of the American Geophysical Union and the North American Benthological Society. New Orleans, Louisiana. (Baxter, Torgersen)

May 22–27, 2005. Paper presentation: “A spatially explicit approach for evaluating relationships among coastal cutthroat, habitat, and disturbance in headwater streams.” 2005 Joint Assembly of the American Geophysical Union and the North American Benthological Society. New Orleans, Louisiana. (Gresswell, Bateman, Torgersen, Guy, Hendricks, Wofford)

May 22–27, 2005. Invited presentation: ”Landscape pattern, network structure, and the distribution of coastal cutthroat trout in headwater streams.” 2005 Joint Assembly of the American Geophysical Union and the North American Benthological Society. New Orleans, Louisiana. (Torgersen, Gresswell, Bateman, Hockman-Wert)

August 7–12, 2005. Paper presentation: “Local and regional tree species-soils relationships in old-growth forests of the Oregon Coast Range.” 90th Annual Meeting of the Ecological Society of America. Montreal, Canada. (Cross, Perakis)

August 7–12, 2005. Paper presentation: “Riparian litter inputs to streams in the central Oregon Coast Range.” 90th Annual Meeting of the Ecological Society of America. Montreal, Canada. (Hart, Hibbs, Perakis)

September 11–15, 2005. Invited presentation: “Effects of spatial scale on measures of salmonid abundance in headwater streams.” American Fisheries Society 135th Annual Meeting. Anchorage, Alaska. (Torgersen, Gresswell, Bateman, Hockman-Wert)

September 11–15, 2005. Paper presentation: "Changing patterns in coastal cutthroat diet and prey in a gradient of deciduous canopies." American Fisheries Society 135th Annual Meeting. Anchorage, Alaska. (Romero, Gresswell, Li)

September 11–15, 2005. Invited presentation titled "Factors influencing the distribution and extent of cottids within and among watersheds in western Oregon." American Fisheries Society 135th Annual Meeting. Anchorage, Alaska. (Bateman, Gresswell, Torgersen, Hockman-Wert)

September 29–October 1, 2005. Paper presentation titled "Effects of landscape pattern on the distribution of coastal cutthroat trout in headwater catchments in western Oregon." Coastal Cutthroat Trout Symposium: Biology, Status, Management, and Conservation sponsored by the USFWS, Oregon Chapter of the American Fisheries Society, Port Townsend, Washington. (Torgersen, Gresswell, Bateman, and Hockman-Wert)

September 29–October 1, 2005. Poster presentation titled "Effects of wildfire on growth and demographics of coastal cutthroat trout in headwater streams." Coastal Cutthroat Trout Symposium: Biology, Status, Management, and Conservation sponsored by the USFWS, Oregon Chapter of the American Fisheries Society, Port Townsend, Washington. (Heck)

September 29–October 1, 2005. Paper presentation titled "Stream connectivity and emigration rates in headwater coastal cutthroat trout populations in western Oregon." Coastal Cutthroat Trout Symposium: Biology, Status, Management, and Conservation sponsored by the USFWS, Oregon Chapter of the American Fisheries Society, Port Townsend, Washington. (Bateman)

September 29–October 1, 2005. Paper presentation titled "Influences of landscape variables on age and growth of coastal cutthroat trout in headwater streams." Coastal Cutthroat Trout Symposium: Biology, Status, Management, and Conservation sponsored by the USFWS, Oregon Chapter of the American Fisheries Society, Port Townsend, Washington. (Rehe)

September 29–October 1, 2005. Paper presentation titled "Cutthroats above the rest: Waterfalls, microsatellites, and isolated populations of coastal cutthroat trout." Coastal Cutthroat Trout Symposium: Biology, Status, Management, and Conservation sponsored by the USFWS, Oregon Chapter of the American Fisheries Society, Port Townsend, Washington. (Guy)

November 9, 2005. Poster presentation titled "Litter decay in Coast Range riparian forests: Biogeochemical controls and implications for terrestrial food chains." Third Annual Research Advances in Fisheries, Wildlife, and Ecology Symposium. Fisheries and Wildlife Graduate Student Association, Oregon State University, Corvallis, Oregon. (Matkins, Perakis, Hibbs)

November 9, 2005. Poster presentation titled "Riparian litter inputs to streams in the central Oregon Coast Range." Third Annual Research Advances in Fisheries, Wildlife, and Ecology Symposium. Fisheries and Wildlife Graduate Student Association, Oregon State University, Corvallis, Oregon. (Hart, Hibbs, Perakis)

November 9, 2005. Oral presentation titled "Tree species: Soils relationships in Oregon Coast Range old-growth forests." Third Annual Research Advances in Fisheries, Wildlife, and Ecology Symposium. Fisheries and Wildlife Graduate Student Association, Oregon State University, Corvallis, Oregon. (Cross, Perakis)

November 9, 2005. Poster presentation titled "Linkages between riparian vegetation, insect distributions, and bat diets." Third Annual Research Advances in Fisheries, Wildlife, and Ecology Symposium. Fisheries and Wildlife Graduate Student Association, Oregon State University, Corvallis, Oregon. (Ober, Hayes)

November 17–18, 2005. Poster presentation titled "Riparian litter inputs to streams in the central Oregon Coast Range." Science and Management of Headwater Streams in the Pacific Northwest. Symposium sponsored by The Oregon Headwaters Research Cooperative. Corvallis, Oregon. (Hart, Hibbs, Perakis)

November 17–18, 2005. Poster presentation titled "Hydrologic losses of nitrate from Oregon Coast Range soils." Science and Management of Headwater Streams in the Pacific Northwest. Symposium sponsored by The Oregon Headwaters Research Cooperative. Corvallis, Oregon. (Sinkhorn, Perakis)

November 17–18, 2005. Poster presentation titled "Stable isotope 15-N abundances in coastal Oregon riparian forests: Evidence for a legacy of N-fixing red alder." Science and Management of Headwater Streams in the Pacific Northwest. Symposium sponsored by The Oregon Headwaters Research Cooperative. Corvallis, Oregon. (Scott, Perakis, Hibbs)

November 17–18, 2005. Paper presentation titled "Landscape pattern and coastal cutthroat trout distribution in forested montane catchments." Science and Management of Headwater Streams in the Pacific Northwest. Symposium sponsored by The Oregon Headwaters Research Cooperative. Corvallis, Oregon. (Bateman, Torgersen, Gresswell, Hockman-Wert)

Other Presentations, Events, and Workshops

January 6, 2005. Invited seminar titled "Pattern detection, scope, and perception in riverine landscapes." College of Forest Resources, University of Washington, Seattle, Washington. (Torgersen)

January 11–14, 2005. Invited workshop presentation titled "The fate of nitrogen inputs to terrestrial ecosystems" at the National Center for Ecological Analysis and Synthesis. Santa Barbara, California.(Perakis)

February 16, 2005. Workshop with Bureau of Land Management (BLM) resource specialists, field managers, and program managers from western Oregon and CFER scientists to identify BLM research needs and priorities. Eugene District Office, Eugene, Oregon. (CFER scientists)

March 1, 2005. Invited presentation titled "Geography matters" given to a civil engineering class on geospatial data and Geographic Information Systems (GIS) at Oregon State University. Oregon State University, Corvallis, Oregon. (Lienkaemper, Hockman-Wert)

March 1 and 21, 2005. Workshop and field trip with Oregon Department of Forestry, BLM, and Weyerhaeuser Company managers to evaluate the upper Trask River basin for a watershed-scale effectiveness monitoring study site. McMinnville, Oregon. (Bateman, Gresswell, Torgersen)

April 18, 2005. Seminar presentation titled "What's for dinner? Seasonal differences in riparian consumer diet and insect communities in an Oregon Coast Range watershed food web. " Department of Fisheries and Wildlife, Oregon State University, Corvallis, Oregon. (Robillard)

April 22, 2005. Workshop with Oregon Department of Forestry (ODF) Salem Office and District staff and CFER scientists to identify ODF research needs and priorities. Richardson Hall, Oregon State University, Corvallis, Oregon. (CFER scientists)

May 15-16,2005. USGS and U.S. Fish and Wildlife Service biological research needs and capabilities workshop with managers and biologists to discuss science in Idaho, Oregon, and Washington. USGS Idaho District Office, Boise, Idaho. (Torgersen)

May 16, 2005. Invited speaker on the role of institutions of higher education in international forestry. United Nations Forum on Forests. One UN Plaza, New York, New York. (Hayes)

May 23–27, 2005. Invited workshop provided on GIS in Landscape Ecology to faculty from liberal arts colleges at a workshop hosted by the National Institute for Technology and Liberal Education. University of the South, Sewanee, Tennessee. (Torgersen)

June 17, 2005. Presentation and research needs consultation on spatially explicit landscape modeling provided to the BLM, Medford District, Oregon. (Torgersen, Cissel)

June 23, 2005. Presentation titled "Landscape classification of forested headwater basins in western Oregon" at a workshop on effects of timber harvest on fisheries and watershed processes with OSU, BLM, ODF, and Oregon Department of Fisheries and Wildlife forest managers and biologists in the Watersheds Research Cooperative. Roseburg, Oregon. (Torgersen)

June 28, 2005. Invited presentation titled "Effects of landscape pattern on the distribution of stream fishes." USGS Western Fisheries Research Center, Seattle, Washington. (Torgersen)

July 6–7, 2005. Invited workshops provided on spatial statistics in river networks to researchers at the USFS Pacific Northwest Research Station Fire and Environmental Research Applications Team and the Urban Ecology Program, College of Forest Resources, University of Washington, Seattle, Washington. (Torgersen)

July 8, 2005. Seminar presentation titled "Riparian forest dynamics in Oregon." University of Melbourne, Australia. (Hibbs)

July 20, 2005. Tour on alder research in Cascade Head Natural Area for the Hardwood Silviculture Cooperative. Cascade Head, Oregon. (Hibbs)

August 4, 2005. Research needs consultation on landscape pattern and stream fish distribution provided to USFWS managers in La Grande, Oregon. (Torgersen)

September 9, 2005. Invited presentation on enhancing wildlife habitat in forests given as part of the Master Woodlands Managers' Mini-College. Sponsored by OSU Extension and Oregon Forest Resources Institute (OFRI). Oregon State University, Corvallis, Oregon. (Hayes)

September 28, 2005. Invited workshop field tour titled "Influences of post-salvage harvest on wildlife populations." OFRI Post-fire Restoration Science Tour and Workshop. Bend, Oregon. (Hayes, Manning, Cameron)

September 29, 2005 Invited workshop presentation titled "Incorporating science in post-fire management decision-making." OFRI Post-fire Restoration Science Tour and Workshop. Bend, Oregon. (Hayes)

October 4, 2005. Workshop with Oregon Department of Forestry and Weyerhaeuser Company managers on intensively monitored watershed studies for evaluating effects of timber harvest on fisheries and watershed processes. Oregon State University, Corvallis, Oregon. (Gresswell, Bateman, Torgersen, Dunham)

October 6, 2005. Invited presentation titled "Detecting multiscale spatial patterns in stream fish habitat relationships." Weekly Monster Seminar Jam. NOAA/NMFS Northwest Fisheries Science Center and the University of Washington Center for Water and Watershed Studies, Seattle, Washington. (Torgersen)

October 19, 2005. Workshop with Bureau of Land Management (BLM) resource specialists, field managers, and program managers to discuss information needs and priorities for fire management. Medford District Office, Medford, Oregon. (CFER scientists)

October 25–27, 2005. Invited presentation titled "Effects of landscape pattern and disturbance on coastal cutthroat trout distribution in headwater catchments." 6th Annual USGS Conference on Science in Oregon and Washington. Seabeck, Washington. (Torgersen, Gresswell, Bateman, Hockman-Wert)

October 31, 2005. Invited guest lecture on spatial statistics in river networks. Department of Geosciences, Oregon State University, Corvallis, Oregon. (Torgersen)

November 1–3, 2005. Participant in the Joint Fire Science Program Principal Investigator's Annual Workshop. San Diego, California. (Shatford, Hibbs)

November 7, 2005. Sponsorship of the Density Management and Riparian Buffer Studies Workshop. LaSells Stewart Center, Oregon State University, Corvallis, Oregon. (CFER Program)

November 16, 2005. Participant as GIS specialist for GIS Day 2005, an event that helps to teach local students how to navigate with GPS technology. Oregon State University, Corvallis, Oregon. (Hockman-Wert)

November 17–19, 2005. Invited keynote address on riverscapes in stream fish ecology. Geosalar International Workshop on Geomatics and Fish Habitat Modelling in Rivers and Estuaries, INRS-Eau, Terre et Environnement, University of Quebec, Quebec City, Canada. (Torgersen)

2005 Publications

Publications by CFER Scientists

Bateman, D. S., R. E. Gresswell, and C. E. Torgersen. 2005. Evaluating single-pass catch as a tool for identifying spatial pattern in fish distribution. J*ournal of Freshwater Ecology* 20:335-345.

Ganio, L. M., C. E. Torgersen, and R. E. Gresswell. 2005. A geostatistical approach for describing spatial pattern in stream networks. *Frontiers in Ecology and the Environment* 3:138–144.

Gresswell, R. E., C. E. Torgersen, and D. S. Bateman. *In press*. A spatially explicit approach for evaluating relationships among coastal cutthroat trout, habitat, and disturbance in headwater streams. *In* R. Hughes, L. Wang, and P. Seelbach, editors. Influences of Landscapes on Stream Habitats and Biological Communities. *American Fisheries Society.* Bethesda, Maryland.

Gomez, D. M., R. G. Anthony, and J. P. Hayes. *In press*. Influence of thinning of Douglas-fir forests on population parameters and diet of northern flying squirrels. J*ournal of Wildlife Management*.

Hayes, J. P., and S. Loeb. *In press*. The influences of forest management on bats in North America. *In* M. J. Lacki, J. P. Hayes, and A. Kurta, editors. Conservation and Management of Bats in Forests [Working title]. John Hopkins University Press, Baltimore.

Hayes, J. P., S. H. Schoenholtz, M. J. Hartley, G. Murphy, R. F. Powers, D. Berg, and S. R. Radosevich. 2005. Environmental consequences of intensively management forest plantations in the Pacific Northwest. *Journal of Forestry* 103:83-87.

Herlihy, A. T., B. Gerth, J. Li, and J. Banks. 2005. Macroinvertebrate community response to natural and forest harvest gradients in Western Oregon Headwater streams. *Freshwater Biology* 50:905-919.

Lacki, M. J., J. P. Hayes, and A. Kurta, editors. *In press*. Conservation and Management of Bats in Forests [Working title]. John Hopkins University Press, Baltimore.

Manning, J., and W. D. Edge. *In review*. Small mammal responses to silvicultural fuels management in southwest Oregon. *Journal of Wildlife Management.*

Perakis, S. S., D. A. Maguire, T. D. Bullen, K. Cromack, R. H. Waring, and J. R. Boyle. *In press*. Coupled nitrogen and calcium cycles in forests of the Oregon Coast Range. *Ecosystems*.

Perakis, S. S., G. R. Shaver, and G. A. Agren. 2005. Terrestrial C sequestration at elevated CO_2 and temperature: The role of dissolved organic N loss. *Ecological Applications* 15:71-86.

Perkins, T., and M. Wilson. 2005. The impacts of *Phalaris arundinacea* (reed canary grass) invasion on wetland plant richness in the Oregon Coast Range, USA, depend on beavers. *Biological Conservation* 124:291-295.

Poage, N.J., 2005. Variability in Older Forest Structure in Western Oregon: USGS Open-file Report 2005-1385, 2005, p. 28.

Poage, N. J., and J. C. Tappeiner. 2005. Tree species and size structure of old-growth Douglas-fir forests in central western Oregon, USA. *Forest Ecology and Management* 204:329-343.

Rlastetter, E. B., S. S. Perakis, G. R. Shaver, and G. I. Agren. *In review*. Carbon sequestration in terrestrial ecosystems under elevated CO_2 and temperature: Role of dissolved organic versus inorganic nitrogen loss. *Ecological Applications*.

Richardson, J. S., R. J. Naiman, F. J. Swanson, and D. E. Hibbs. 2005. Riparian communities associated with Pacific Northwest headwater streams: Assemblages, processes, and uniqueness. *Journal of the American Water Resources Association* 41 (4):935-947.

Romero, N., R. E. Gresswell, and J. L. Li. 2005. Changing patterns in coastal cutthroat trout (*Oncorhynchus clarki clarki*) diet and prey in a gradient of deciduous canopies. *Canadian Journal of Fisheries and Aquatic Sciences* 62:1797–1807.

Sarr, D., D. E. Hibbs, and M. Huston. 2005. A hierarchical perspective of plant diversity. *Quarterly Review of Biology* 80:187-212.

Sarr, D., D. Odion, D. Hibbs, J. Weikel, R. Gresswell, R. Bury, N. Czarnomski, R. Pabst, J. Shatford, and A. Moldenke. 2005. Riparian Zone Forest Management and the Protection of Biodiversity: A Problem Analysis. Technical Bulletin No. 908. Research Triangle Park, N.C. National Center for Air and Stream Improvement (NCASI), Inc. 107 pp plus appendices.

Stoddard, M. A., and J. P. Hayes. 2005. The influence of forest management on headwater stream amphibians at multiple spatial scales. *Ecological Applications* 15:811-823.

Torgersen, C. E., C. V. Baxter, and H. W. Li. *In press*. Landscape influences on longitudinal patterns of stream fishes: Spatially continuous analysis of fish-habitat relationships. *In* R. Hughes, L. Wang, and P. Seelbach, editors. Influences of Landscapes on Stream Habitats and Biological Communities. *American Fisheries Society.* Bethesda, Maryland.

Waldien, D. L., J. P. Hayes, and M. M. P. Huso. *In press*. Use of downed wood for movement by Townsend's chipmunks in western Oregon. *Journal of Mammalogy*.

Wofford, J., R. Gresswell, and M. A. Banks. 2005. Influence of barriers to movement on within-watershed genetic variation of coastal cutthroat trout. *Ecological Applications* 15:628-637.

CFER Student Theses and Dissertations

David Waldien (Ph.D., Department of Fisheries and Wildlife): *Population and Behavioral Responses of Small Mammals to Silvicultural and Downed Wood Treatments in the Oregon Coast Range*.

Forest managers are challenged to provide timber revenues and other resources for society while protecting and enhancing components of biodiversity that are often associated with older forests or older forest structure, such as dead wood. We examined small mammal response to timber harvest in stands 8–10 years following group-selection, two-story, and clearcut harvest, how provision of new downed wood influenced small mammals in group-selection and clearcut stands, and use of downed wood by Townsend's chipmunks (*Tamias townsendii*) in group-selection stands.

Densities of adult and reproductive female deer mice (*Peromyscus maniculatus*) were greatest in harvested stands, whereas other measures for deer mice and Townsend's chipmunks (e.g., densities of male deer mice and male chipmunks), and densities of Oregon voles (*Microtus oregoni*) and Pacific shrews (*Sorex pacificus*) were similar among all stand conditions. Density of vagrant shrews (*Sorex vagrans*) was greatest in clearcut stands and decreased with decreasing harvest intensity. Although limited data precluded statistical analysis, abundances of northern flying squirrels (*Glaucomys sabrinus*) and western red-backed voles (*Clethrionomys californicus*) were similar between unharvested control stands and group-selection stands. Within two years following augmentation of downed wood, we did not detect any response of small mammal populations to the downed wood. Our results suggest that small mammal populations can benefit from alternative silvicultural treatments that retain overstory trees and that stands with areas of closed-canopy forest can provide habitat for species that are more abundant in intact and mature forest conditions (e.g., northern flying squirrels).

In our study of use of wood by Townsend's chipmunks, the model indicating disproportionate use of paths with downed wood by Townsend's chipmunk was 22.6 times more likely than the null model, and a chipmunk was 3.0 times more likely to select locations with downed wood at average wood densities (paths with 26% wood). Chipmunks selected wood that was 1.2 times larger in diameter than randomly available wood and there was no evidence that chipmunks disproportionately used wood that was elevated. Our findings document that downed wood is an important habitat component for Townsend's chipmunks and suggest that downed wood influences movements of chipmunks.

2005 Budget Summary

	OSU	USGS	Total
Stand Structure Project	121,032	135,000	**256,032**
Riparian Wood Project	0	0	**0**
Landscape Project	5,833	150,000	**155,833**
Riparian Linkages Project	152,183	0	**152,183**
Information Exchange	99,872	0	**99,872**
Administration and PI Salaries	190,835	0	**190,835**
Indirect Costs[1]	120,245	0	**120,245**
Total[2]	**690,000**	**285,000**	**975,000**

[1] Indirect costs for OSU in 2005 are based on an indirect rate of 20% on $408,333 requested from USGS, 18% on $42,373 requested from BLM, and 26% on $119,048 requested from ODF.

[2] The total annual budget for 2005 is based on $775,000 provided by USGS, $150,000 provided by ODF, and $50,000 provided by BLM.

CFER Staff

Principal Investigators

Jason Dunham joined the CFER Research team in June of 2005 as an Aquatic Ecologist with the USGS Forest and Rangeland Ecosystem Science Center. Jason's research has focused on the ecology and conservation biology of native fishes and their habitats. His most recent work has addressed the influence of natural disturbance on fish populations and habitats in streams, population monitoring for stream fishes, modeling fish-habitat relationships, and nonnative fish invasions. Jason has degrees in Zoology from Oregon State University (BS, 1987) and Arizona State University (MS, 1995), and a degree in Ecology, Evolution, and Conservation Biology from the University of Nevada-Reno (Ph.D., 1996).

W. Daniel Edge is the Department Head in the Department of Fisheries and Wildlife at Oregon State University and one of the wildlife ecologists on the CFER science team. Dan received a B.S. in Wildlife Biology, a B.S. in Forestry, an M.S. in Wildlife Biology, and a Ph.D. in Forestry, all from the University of Montana. Dan's primary research interests are the impacts of forestry and agricultural practices on wildlife communities.

Robert E. Gresswell received degrees from the University of New Mexico (B.S.), Utah State University (M.S.), and Oregon State University (Ph.D.). Since 1997, Bob has been working as an aquatic ecologist for the USGS Forest and Rangeland Ecosystem Science Center and the CFER Program. In 2004, he accepted a position with the USGS Northern Rocky Mountain Science Center in Bozeman, Montana, but will continue to play an important role with CFER, especially in the areas of aquatic ecology and fish biology.

John P. Hayes is a wildlife ecologist for the CFER program. He also serves as the Associate Dean of International Programs for the College of Forestry and as a professor in the Department of Forest Science at Oregon State University. John received his B.S. in Wildlife Science at Oregon State University, his M.S. in Biology at Southern Oregon State College, and his Ph.D. in Ecology and Evolutionary Biology at Cornell University. His research interests include the influence of forest management on wildlife populations, the influence of spatial scale on habitat selection, and the ecology and management of bats.

David Hibbs is program coordinator and a forest ecologist for the CFER program. He is a professor in the Department of Forest Science at Oregon State University where he teaches forest community ecology and directs the Hardwood Silviculture Cooperative. He has his B.S. in Plant Ecology from Carleton College, his M.S. in Forestry from the University of Massachusetts, and his Ph.D. in Forest Ecology from the University of Massachusetts. His research interests include stand development and succession in temperate and tropical forests.

Judith L. Li is an assistant professor in the Department of Fisheries and Wildlife at Oregon State University where she has been a member of the faculty for 11 years. She is a stream ecologist with particular interest in freshwater invertebrates and food webs. Her studies have ranged from forested systems of the Oregon coast and the Cascades to arid eastern Oregon. Her research is most often multidisciplinary in which she, her students, and colleagues examine the interactions among stream vertebrates and invertebrates in mesic, arid, and urban settings. Judy has degrees from the University of California, Berkeley (B.S.); the University of California, Davis (M.S.); and Oregon State University (Ph.D.).

Steven Perakis is a research ecologist with the USGS Forest and Rangeland Ecosystem Science Center. Steve's research centers on understanding biogeochemical cycles in terrestrial ecosystems, and he has particular interest in discerning how processes and activities within forests shape nutrient losses, whole-system nutrient balances, and linkages between terrestrial and aquatic ecosystems. Steve has degrees in Ecology and Ecosystem Science from the University of Pennsylvania (B.S.), the University of Washington (M.S.), and Cornell University (Ph.D.), with a year of post-doctoral experience from Stanford University. He also holds a courtesy appointment in the Department of Forest Science at Oregon State University.

Christian Torgersen is a research landscape ecologist with the USGS Forest and Rangeland Ecosystem Science Center and a fish ecologist for the CFER program. He will soon be relocating to Seattle, Washington where he will reopen the FRESC Cascadia Field Station at the University of Washington and continue to collaborate with CFER scientists in landscape modeling and stream fish ecology. A graduate of Oregon State University (Ph.D., 2002), Christian has an interdisciplinary background in fisheries science and geography and is interested in the influences of landscape pattern and habitat fragmentation on the distribution of stream fishes. His research involves the use of geospatial applications, such as remote sensing and GIS, and statistical modeling to predict the occurrence and abundance of coastal cutthroat trout in western Oregon.

Collaborating Scientists

John Cissel is the BLM science liaison for western Oregon and for CFER. He is a BLM state office employee and has offices in Corvallis and Eugene. John has extensive experience working at the science and management interface, and has particular interests in landscape ecology and landscape management planning. He has a B.S. in Forestry from Michigan State University, an M.S. in Forest Management and Operations Research from Pennsylvania State University, and has completed additional graduate coursework in forest ecology at Oregon State University.

Klaus Puettmann is an associate professor in the Department of Forest Science at Oregon State University. Klaus received his diploma from Albert-Ludwig University, Freiburg, Germany, and his Ph.D. from Oregon State University. His research interests include silviculture of temperate forests, regeneration dynamics in diverse structured forests, plant interaction, and density management. He recently joined the CFER research team as an investigator with the BLM's Density Management Study.

Research Assistants and Biological Technicians

Doug Bateman is a research assistant for the CFER program. He has worked for the College of Forestry at Oregon State University since 1989. Doug received his M.S. in Fisheries Science from Oregon State University in 1998. His interest in disturbance ecology and the natural history of aquatic organisms has led to research on the effects of landscape patterns on fish distributions in watersheds in western Oregon.

David Hockman-Wert is a research technician for the CFER program studying landscape pattern and fish distribution using geospatial techniques. He received his B.A. in Biology from Eastern Mennonite University and his M.A. in Environmental Studies from the University of Oregon. His multidisciplinary interests include GIS, landscape ecology, cultural geography, and the human dimensions of natural resources.

Tom Manning is a research assistant currently working with CFER on the Davis Lake Salvage study, investigating the effects of salvage logging on wildlife populations. He received his M.S. in Environmental Biology from the University of Minnesota, Duluth in 1989 and has worked in OSU's Department of Forest Science since 1995. His work since then has centered on effects of forest management practices on small mammal populations.

Jeff Shatford is a research assistant in plant ecology for the CFER program studying understory vegetation in young forests and the production and input of coarse woody debris into streams. He received his B.S. in Biology from Queen's University and M.S. in Forestry from the University of British Columbia. His research interests include the regeneration of forbs and shrubs in forests and grasslands and the maintenance of plant diversity in managed landscapes.

Information Exchange

Janet Erickson is the information exchange specialist for the CFER program. She is responsible for conveying information about the CFER program and its research projects to land managers and other audiences. She develops and manages the production of a variety of information products, such as the CFER web site, written publications, videos, displays, field tours, and symposia. Janet received her B.S. in Biology from Pacific Lutheran University and her M.S. and Ph.D. in Wildlife Science from the University of Washington.

Graduate Students

Ed Arnett is a Ph.D. student in the Department of Forest Science. He is investigating the influence of landscape structure on bats.

Alison Cross is a Master's student in the Department of Forest Science. She is investigating tree species controls on soil nutrient dynamics in mixed old-growth stands in the Oregon Coast Range.

Michelle Donaghy Cannon is a Ph.D. student in the Department of Forest Science and the Department of Fisheries and Wildlife. She is studying how birds are distributed in large severely burned patches relative to remnant unburned forest.

Tom Giesen is a Master's student in the Department of Forest Science. His research examines how time-since-fire influences forest floor and surface soil pools of carbon and nitrogen in natural unlogged stands of the western Cascades of Oregon.

Paula Graff is a Master's student in the Department of Fisheries and Wildlife. She is investigating food web relationships of amphibians in riparian areas dominated by conifer and hardwood plant communities.

Jessica Halofsky is a Ph.D. student in the Department of Forest Science. She is investigating factors that affect fire severity and post-fire vegetation recovery in riparian areas in the Biscuit Fire of southwest Oregon.

Stephanie Hart is a Master's student in the Department of Forest Science. She is investigating the movement of allochthonous inputs of headwater stream riparian areas.

Mike Heck is a Master's student in the Department of Fisheries and Wildlife. He is investigating the effects of fire on growth and demographics of coastal cutthroat trout.

Joselin Matkins is a Master's student in the Department of Forest Science. She is investigating how nitrogen and other factors influence the decay of Douglas-fir and red alder leaf litter in both terrestrial and aquatic habitats of riparian zones.

Holly Ober is a Ph.D. student in the Department of Forest Science and the Department of Fisheries and Wildlife. She is studying the influence of bats in riparian areas.

Bill Rehe is a Master's student in the Department of Fisheries and Wildlife. He is examining the influences of landscape variables on age and growth of coastal cutthroat trout.

Amanda Robillard is a Master's student in the Department of Fisheries and Wildlife. She is conducting a study to assess a riparian food web with emphasis on ecological subsidies.

Aaron Thiel is a Master's student in the Department of Forest Science. He is conducting research on the patterns of nitrogen dynamics across gaps in thinned forests of western Oregon.

David Waldien recently completed his doctoral degree from the Department of Fisheries and Wildlife at Oregon State University. Currently he is a conservation scientist and co-director of programs for Bat Conservation International.

CFER Cooperative Forest Ecosystem Research

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