Effects of Contemporary Forest Harvest on Aquatic Ecosystems: Trask River Watershed Study

October 2008

Study Summary

The Trask Watershed Study is a multi-disciplinary, long-term research project designed to evaluate the impacts of current forest management practices on aquatic ecosystems. The study will utilize a whole watershed approach to compare onsite and downstream effects of forest harvest on public and private forestlands. Multiple headwater basins will be clearcut harvested; along the small non-fish bearing streams, forested riparian buffers will be retained on public land but not on private land. The investigations in the Trask River Watershed Study will comprehensively examine the mechanisms and processes that drive aquatic ecosystems. These mechanisms and processes include physical, chemical and biological responses to management and how those responses translate to downstream fish-bearing reaches. Field-collected data will be combined with process models to elucidate aquatic responses to forest management in headwaters and the manner and degree to which harvest in headwaters can influence downstream aquatic communities. The results from this experimental study will provide resource managers with expanded understanding of both direct and indirect effects of forest management on aquatic ecosystems.

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Overview

Introduction & Objectives

Experimental studies at a watershed scale have long played a role in the formulation and application of forest management techniques and regulations in the Pacific Northwest. Paired watershed studies have been implemented extensively on USFS Experimental Forests as a means of quantifying impacts of forest management on water quality and quantity and was instituted in Oregon in the early 1950's with the watershed studies at the HJ Andrews Experimental Forest in the Cascade Mountains and the Alsea Watershed Study in the Coast Range. The Alsea and later Carnation Creek studies on Vancouver Island expanded the scope of pre- vs. post-, treatment vs. reference watershed study design to examine the impacts of timber harvest on fish. The understanding gained from prior studies has been incorporated into Federal and State watershed and forest management guidelines on both public and private lands. The presence of riparian buffers, the decline in broad-cast burning, and the retention of coarse wood in streams are among the practices influenced by these and other studies.

The early studies of effects of forest management in the Pacific Northwest occurred during harvest of old growth conifer forests. Now, second growth forests are being harvested, stricter forest guidelines are in place and new questions occur about current best management practices. In response to these information needs, a new set of comparative watershed studies have begun in the Pacific Northwest. In Oregon, studies collaborating through the Watershed Research Cooperative (WRC; Figure 1) at Oregon State University are using comparable methods across sites to evaluate the effectiveness of the state forest practices regulations at minimizing impacts of timber harvest to aquatic resources. These studies are designed by multi-disciplinary teams of scientists working in cooperation with private landowners and public agencies.

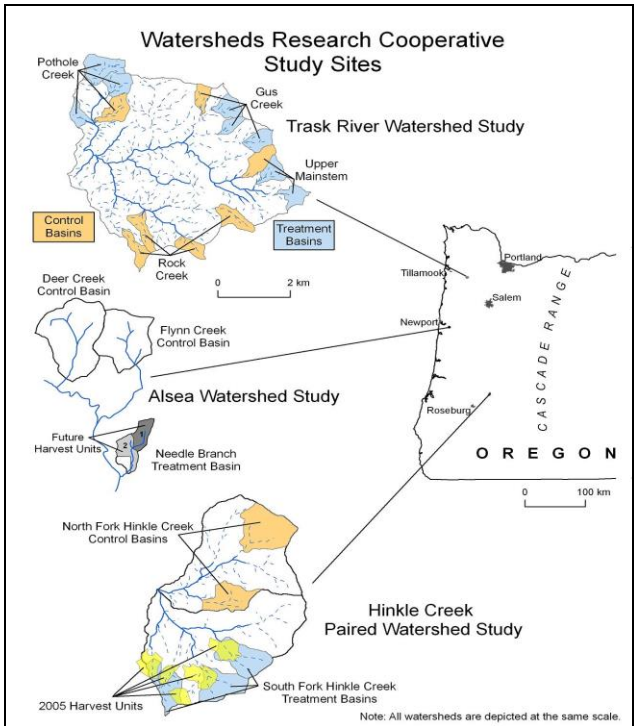

Figure 1. Locations of studies collaborating in the Watershed Research Cooperative

The Oregon Forest Practices Act was the first in the United States to include provisions for the protection of water quality and fish habitat. Presently, regulations for harvest along small, perennial, non fish-bearing streams are less stringent than along fish bearing streams or streams designated for drinking water use. In addition, publicly owned forests may have more stringent regulations than private timberlands. Harvest in the Trask River Watershed Study will meet current management guidelines on state and private forests. It will involve clearcutting on upslopes with riparian buffers along small streams on state land and no buffers on private land. However in the watershed managed by BLM, upslope harvest will be thinning.

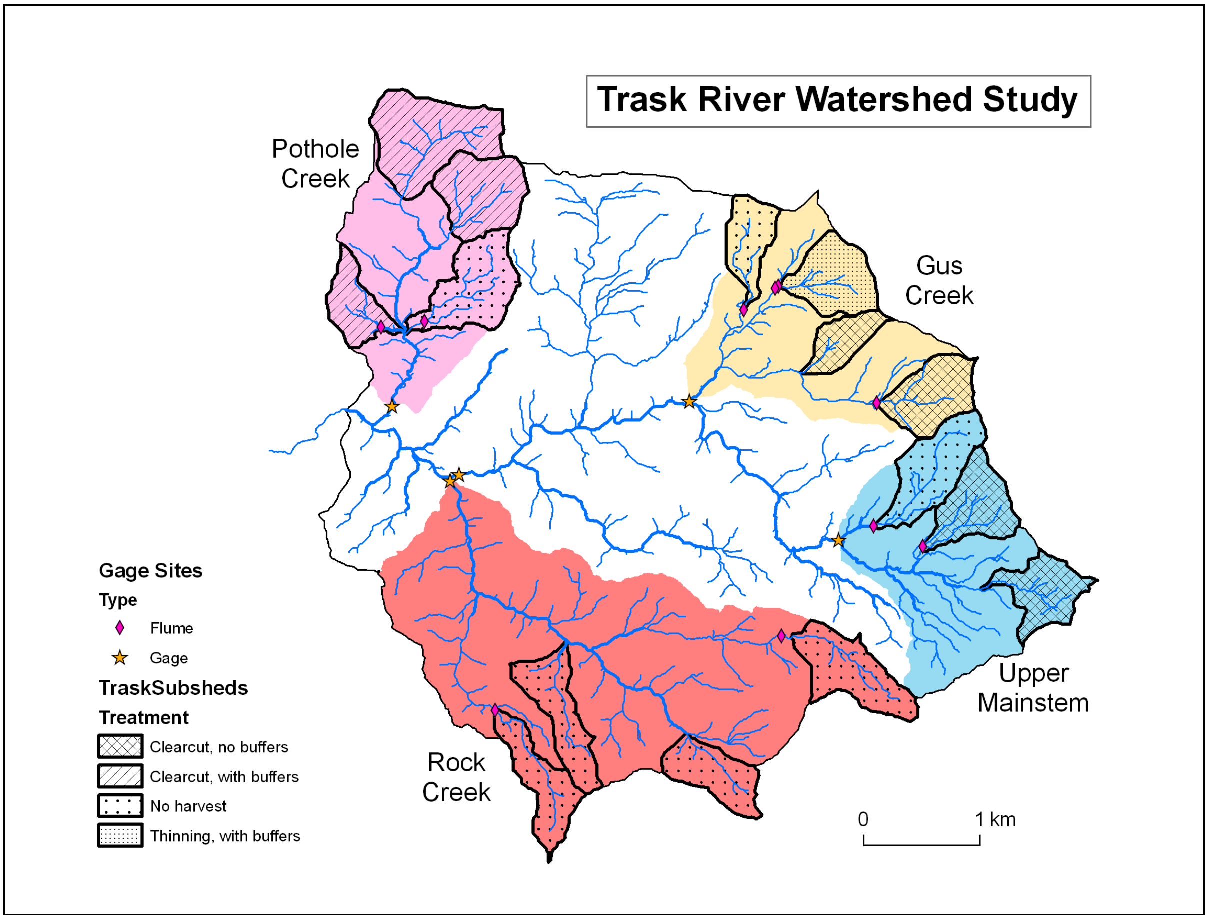

Figure 2. Trask River Watershed Study is being conducted in 4 basins. Planned harvest treatments include clearcut with no buffers, clearcut with buffers, thinning with buffers and no harvest. Downstream gage sites are locations of fish study reaches. Headwater study reaches are at the downstream point of delineated watershed.

The Trask River Watershed Study will use multiple basins (Figure 2) to assess not only the onsite impacts of forest management on aquatic ecosystems in headwaters but also the possible effects to downstream reaches containing fish. Over the ten plus year duration of the study, the Trask group will examine a suite of abiotic and biotic processes and linkages among trophic levels, including discharge, primary and secondary production, water temperature, macroinvertebrate communities and fish populations and behavior. Pretreatment period will be used to gather baseline data and characterize variability as well as examine processes driving these food web dynamics. Researchers plan to implement smaller-scale experiments in both the field and the laboratory. Results from findings will be incorporated to models to explore landscape implications and processes influenced by forest management.

The findings from this study will contribute to examinations of the effectiveness of current management practices on public and private forests, and will provide land managers with the tools and data to evaluate competing priorities in managing Oregon's forests in the future.

Background

Forest harvest and associated activities, including road construction, can lead to changes in local terrestrial and aquatic ecosystems through biotic and abiotic processes. Water quantity (timing, magnitude of flows), water quality (temperature, nutrients, sediments), inputs of riparian materials (leaves, wood), and watershed geomorphology can all be modified by forest management. Changes to these and other parameters can have both direct and indirect effects on the habitats, populations and communities of stream-dwelling organisms, including algae, invertebrates, amphibians and fish (see review edited by Salo and Cundy 1987; Meehan 1991; Northcote and Hartman 2004).

The removal of overstory vegetation influences the amount of water intercepted or evaporated, the rate of snow accumulation and melt, soil moisture storage via evapotranspiration, and rates of soil disturbance and erosion. Peak discharges, which can increase after forest harvest (Jones and Grant 1996; Hartman 2004), have been linked with potential changes in sediment transport dynamics (Moore and Wondzell 2005b). Forest roads also have the potential to alter the rates and pathways of water and sediment delivery by intercepting and redistributing subsurface flow (Wemple and Jones 2003).

Removal of streamside vegetation canopy increases the total radiant energy reaching the stream surface, which in turn may lead to rises in water temperature, a parameter which controls the rates of numerous biological processes, such as growth of aquatic organisms. Increases in energy and light can also affect growth rates and abundance of aquatic primary producers, such as algae, which in turn will have impacts on aquatic species and stream food webs. The inputs of leaves and other terrestrial plant detritus, including large wood, are critical to the energy budget and in-channel habitat for many aquatic organisms and may be significantly changed by forest harvest. Additional changes to stream organisms may result from the short- or long-term changes to nutrient budgets associated with forest harvest (e.g., Bormann and Likens 1979; Hartman 2004).

The Trask River Watershed Study is examining these impacts of forest management operations on small, headwater streams and the extent to which these effects are transferred downstream. Small streams are tightly coupled with terrestrial ecosystems, making them potentially more responsive to forest harvest than larger, downstream systems (Moore and Richardson 2003). Small, non-fish-bearing streams may comprise 80% or more of the stream length in a drainage network (Benda et al. 2005). Impacts to small streams have the potential to have downstream repercussions because they transport water, energy, organic and inorganic materials, thereby influencing the characteristics of downstream aquatic communities and habitats.

Despite the potential for forest management in headwater streams to affect downstream aquatic areas, there have been comparatively few attempts to quantify the full range of physical, chemical and biological cumulative impacts (e.g., Reid 1998; Hartman 2004). Previous studies, whether experimental or descriptive, focused largely on local sites (reviews in Moore et al. 2005a; Moore and Wondzell 2005b), or fish populations (Moring and Lantz 1975; Hall 2008). Studies that examined downstream effects did so largely through post-hoc survey methods or employed a space-for-time substitution (e.g., Hicks et al. 1991; Beschta and 1988; Smith et al. 2003). There has been some studies interested in predicting cumulative effects of forest management (e.g., Ziemer et al. 1991; Reid 1993), but these efforts have lacked a strong empirical basis and generally focused on physical parameters.

Conceptual Design

The Trask River Watershed Study will use multiple sites to examine both the local and downstream impacts of forest harvest on a full range of both physical and biological parameters. The design includes long-term measurements both before and after forest harvest across a heterogeneous landscape. Stream ecosystems are complex with multiple linkages among system components and processes (Figure 3). Forest harvest and associated management can directly impact hydrology, sediment, nutrients and incoming energy; these effects have the potential to cascade through stream ecosystems influencing individuals, populations, communities, standing stocks, and connectivity at multiple points through space and time (Northcote and Hartman 2004). The Trask study will attempt to elucidate the underlying processes responsible for observed changes in system condition.

The Trask science team has constructed simple conceptual models to generate hypotheses and develop methods for evaluating physical and biological responses to forest harvest in headwater streams and downstream fish-bearing reaches. The goals are to document responses to forest harvest and to improve our understanding of processes and mechanisms responsible. Key individual, community and ecosystem processes have been identified through this initial modeling process and will form the basis of long-term measurements and experimental studies. The original conceptual models will be refined as linkages among ecosystem elements and processes are identified, and with increased understanding of relationships between headwater and downstream sites. Laboratory experiments will be conducted to quantify linkages that can not be determined through field observations.

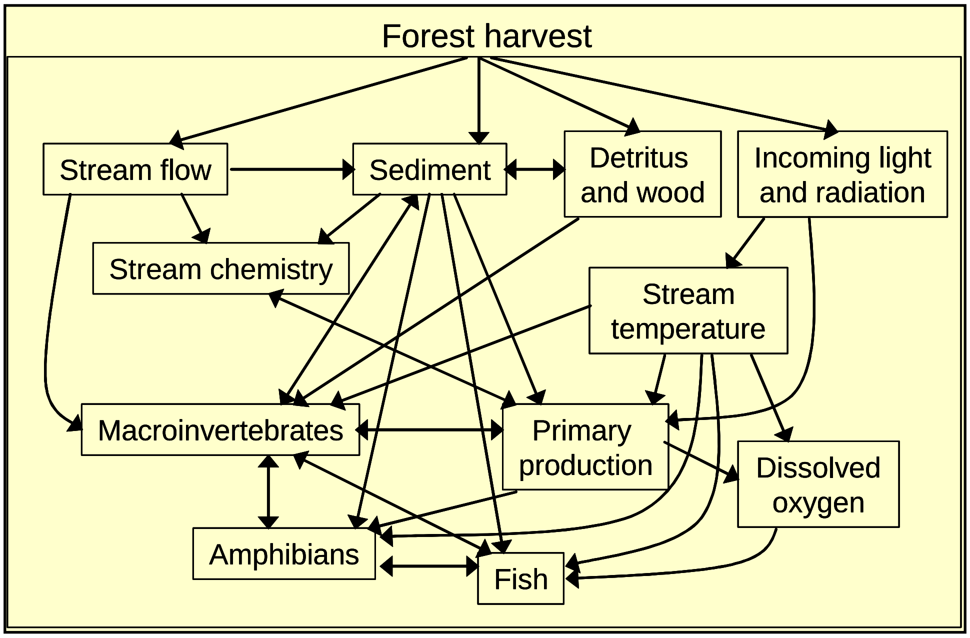

Figure 3: A simplified representation of stream ecosystem elements and linkages potentially influenced by forest harvest.

During the Trask study, we will be quantifying hydrologic and sediment dynamics as well as densities of vertebrates and invertebrates. However, many long-term studies have found wide fluctuations in abiotic and biotic parameters even in undisturbed systems; this variation can make detection of the effects of disturbance difficult to determine. We also recognize there is inherent landscape variability in both geology and landuse history in the study area, and therefore the responses of fishes, amphibians, macroinvertebrates, primary producers, aquatic habitat, and water quality and quantity will vary within and between treatments. Therefore, we will incorporate this variability by study of processes and will implement models with these data to evaluate effects of forest operations on abiotic and biotic responses. We will also expect that by studying processes, such as hydraulic retention, rates of production, shifts in timing of life history stages, growth and feeding, we will better understand responses to forest operations and be able to extrapolate our findings to new areas.

The experimental design for the Trask River Watershed Study incorporates nested and paired studies. On-site responses to forest harvest will be evaluated in small, non-fish bearing streams as well as downstream responses in fish bearing reaches. The Trask science team, in conjunction with managers, identified four basins within the Trask Study Area to be used for research: Pothole Creek, Gus Creek, Upper Main, and Rock Creek. Within each of these basins, three to four small streams in headwater watersheds (areas of 25 to 50 ha) will be intensively studied (Figure 4). Three of these basins will have forest harvest in the headwaters (Pothole Creek, Gus Creek, Upper Main) and one basin will remain a reference (Rock Creek). Within each basin, one watershed will not be harvested, thereby serving as a within-basin reference (Figure 4, Table 1). In these treated basins, harvesting will occur around the headwater, non-fish bearing portion of the stream network. In two of the basins, the type of harvest treatment will be uniform to better characterize the downstream responses to a specific type of harvest (Figure 4). However, due to mixed ownership in Gus Creek, one watershed will be thinned and two will be clearcut. In general, treatments will maximize the amount of harvest acres within normal operational approaches (i.e. 120 acre limit, road construction appropriate for harvest, no harvest around Oregon Type-F streams).

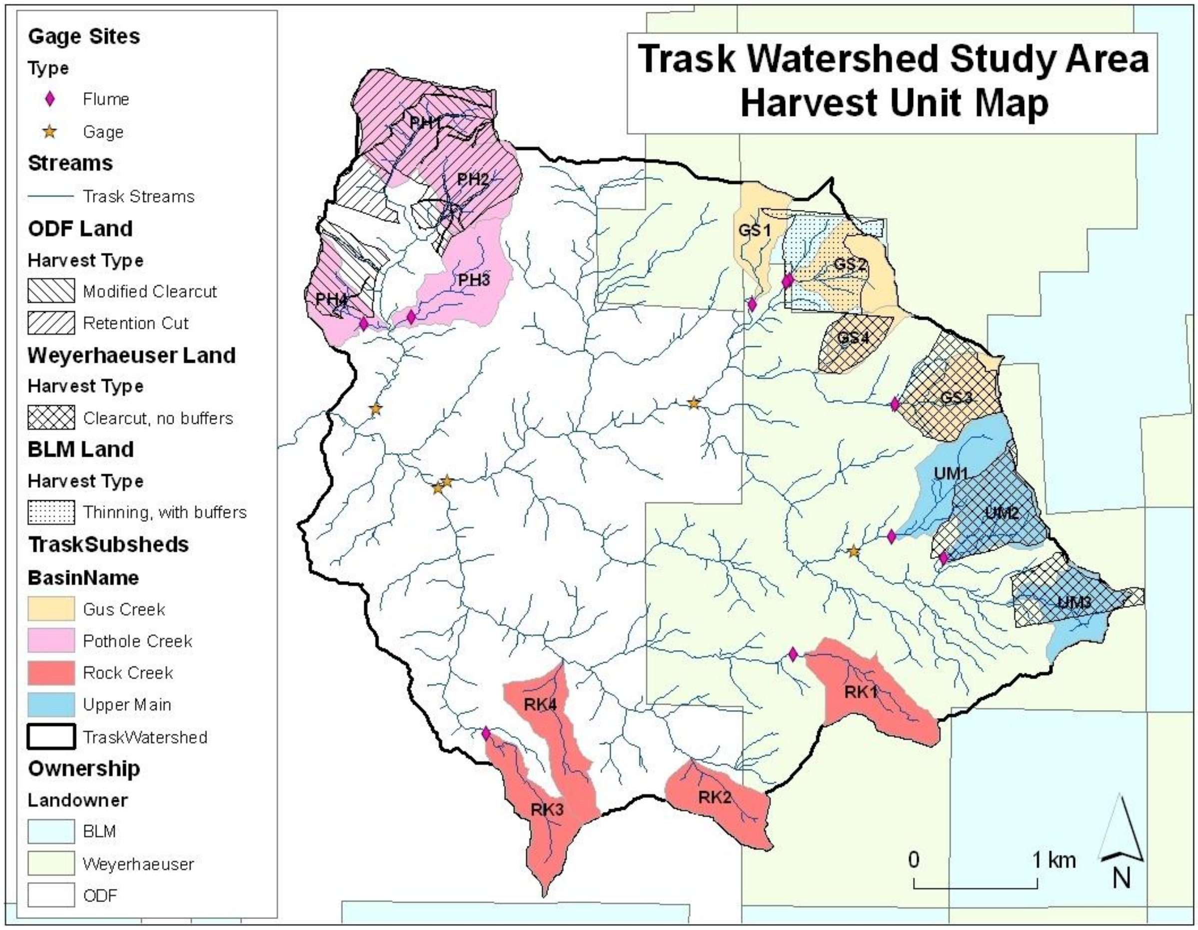

Figure 4. Planned harvest units in headwater watersheds. Ownership of land is shown. PH = Pothole, GS = Gus Creek, UM = Upper Main, RC =Rock.

Timelines

The study duration is 2006-2016. This study will provide long-term data for a number of variables both pre- and post-treatment. Exploratory data collection began in 2006 and more comprehensive studies in 2007.

- 2007-2010: Pre-treatment
- 2011: Road Construction
- 2012: Harvest
- 2013-2016 Post-harvest data collection

Research Team & Organization

Trask researchers are an interdisciplinary and interagency group of scientists with expertise in key areas. Dr. Sherri Johnson, *PNW Research, US Forest Service* and Dr. Bob Bilby, *Weyerhaeuser Company* serve as Co-Science leads. The Science team includes Dr. Jason Dunham, *USGS FRESC;* Dr. Arne Skaugset, *OSU Forest Engineering and Resource Management;* Dr. Michael Adams, *USGS FRESC;* Dr. Judy Li*, OSU Fisheries and Wildlife;* Dr. David Wooster, *OSU Ag Exp Station;* Liz Dent, *Oregon Dept of Forestry;* Maryanne Reiter, *Weyerhaeuser Company;* Doug Bateman, *OSU Forest Engineering;* Linda Ashkenas, *OSU Fisheries and Wildlife;* Nate Chelgren*, USGS FRESC;* Bill Gerth, *OSU Fisheries and Wildlife;* Amy Simmons, *OSU Forest Engineering and Resource Management;* Janel Sobota, *OSU Fisheries and Wildlife.*

Research planning, sampling logistics and results are discussed at frequent Team meetings and field trips. Additional scientists are frequently consulted for input on study plans and methods or to coordinate field visits to comparable projects. The Trask Science group also communicates regularly outside of the traditional scientific community; frequent interactions occur with community groups, including Tillamook County and NGOs (such as Watershed councils, EcoTrust, Oregon Trout and Tillamook Estuary Partnership); forest industry representatives (Oregon Forest Industries Council, National Council for Air and Stream Improvement), participating land owners (Weyerhaeuser Company, Oregon Dept. of Forestry, and Bureau of Land Management), industry representatives (Plum Creek Timber Company, Roseburg Timber Company), state agencies (Oregon Dept. of Environmental Quality, Oregon Dept of Fisheries and Wildlife) and federal agencies (USFS, USGS, BLM). Collaboration and integration also occurs among other studies within the Watershed Research Cooperative (Hinkle Creek and New Alsea Watershed Studies) and the H.J. Andrews Experimental Forest. Frequent interactions and sharing of results occur in many venues and as a result of overlap of individuals among projects and during local, regional and national scientific meetings and field tours.

A major responsibility for Trask researchers is providing data and metadata to networked databases so that others can use data in years to come. The Trask team has set up shared data directories in the OSU Forestry Computing Network. Web sites of the WRC and ODF are used to post study plans, cleaned data and metadata, participant activities and summaries of findings.

ODF and Weyerhaeuser Company are providing long term funding for the core Trask Watershed Research Study. Findings will be shared in tours, peer reviewed publications, reports, online datasets and workshops. Funding for additional research is being sought through competitive grants and proposals. Summaries of newly funded research projects or core studies that have obtained additional funding for expanded research are included in the appendices and will be updated regularly.

Expected Outcomes

Results from the first generation of watershed studies had a profound impact on development of contemporary forest practices (Hall et al. 2004). We expect findings of the Trask and other WRC studies will similarly benefit state and private forest landowners and natural resource managers by expanding the understanding of key linkages between forest practices and aquatic habitat. This improved understanding will enable state and federal agencies to develop and refine contemporary forest management strategies to protect and restore aquatic habitat while enabling forest owners to profitably manage their lands. In addition, Trask research in conjunction with other watershed studies in the region will provide fundamental information on the organization and function of stream ecosystems in the Pacific Northwest. This improved knowledge will ultimately enable more efficient and effective distribution of resources available to restore streams in western Oregon.

The results of this research must be easily accessible by technical and non-technical audiences to be most useful. Information will be disseminated to the scientific community through journal publications and presentations at scientific meetings and to managers and broader audiences through regional workshops, field tours, newsletters, and information posted on the Trask and WRC websites. The Trask and WRC are working with the outreach program at the OSU College of Forestry to ensure the communication strategies are as effective as possible.

Study specifics

Study Site Description

The study site is in upper 25 square km of the East Fork of the South Fork of the Trask River, in the northern Oregon Coast Range. The East Fork of the South Fork of the Trask eventually joins the main Trask River, and is one of the five major rivers flowing into Tillamook Bay. The primary landowners are the Oregon Department of Forestry (ODF, Tillamook State Forest) and Weyerhaeuser Company, with a small area administered by the Bureau of Land Management.

Elevations range from 1,100 m at the top of Trask Mountain to 275 m at the downstream terminus of the study area. This region experiences wet winters, relatively dry summers and mild temperatures throughout the year. Heavy precipitation results from moist air masses moving off the Pacific Ocean. Mean annual precipitation ranges from 175 cm to 500 cm, with the majority falling in the winter months of November, December, and January, occasionally as snow (OWEB 1995).

Fish bearing stream channels within the study area range from relatively wide, low gradient alluvial reaches to highly constrained, steep, bedrock channels. Headwater streams also exhibit a wide range of channel gradients and confinement due to variable geology. The bedrock geology of the study area is a mix of igneous and sedimentary formations dating back 40 to 60 million years (Wells et al. 1994). Lower-gradient, unconfined channels tend to be more prevalent on the sedimentary formations. Large wood is scarce in many streams throughout the watershed due to past fires and subsequent salvage logging.

Much of the study area was impacted by the Tillamook Burns, which consisted of at least four different fires between 1933 and 1951. The 1933 fire extended over 240,000 acres near Hebo. The second Tillamook fire occurred in 1939 and burned approximately 190,000 acres near Saddle Mountain. The third Tillamook Burn occurred in 1945 and consumed 180,000 acres between the Wilson River and Salmonberry Creek. The final burn in the Elkhorn and North Fork Trask area occurred in 1951 across 33,000 acres. All except the first fire included the Trask study area. Salvage logging of the both burned and unburned areas occurred in the 1950s within the research basin and areas were replanted during the 1950’s and 1960’s.

The present overstory vegetation is predominantly second-growth Douglas-fir (*Pseudotsuga menziesii*), while red alder (*Alnus rubra*) predominates along many stream channels and onto selected hillslopes. Since 2000, some thinning has occurred in ODF lands and a limited amount of clearcut harvest has occurred on portions of Weyerhaeuser property. In addition to the early logging legacy, the present-day road system in the Trask Study Area was developed prior to 1955. Both Weyerhaeuser and ODF have maintained this road network, with some additional spur construction (see Contextual Analysis for more detail). However, there are numerous old roads and skid trails still evident on the landscape.

Forest harvest treatments

- Clearcut with Forest Practices Act restrictions and no leave-tree buffers (Upper Main basin, Weyerhaeuser ownership). Upper Main 1 (headwater basin) will not be treated and will serve as the within-cluster reference.
- Clearcut with State Forest Management Plan leave-tree buffers (Pothole basin, Tillamook State Forest ownership). Pothole 3 (headwater basin) will not be treated and will serve as the within-cluster reference.

- Mixed: A combination of thinning with variable buffers and clearcut with FPA restrictions and no leave trees buffers (Gus Creek cluster; mixed Weyerhaeuser and BLM). Gus Creek 1 (headwater basin) will serve as the within-cluster reference.
- Reference: the entire Rock Creek drainage, including headwater study watersheds, will not have any further treatment (Tillamook State Forest and Weyerhaeuser ownership). The downstream site will serve as a reference for the fish bearing reaches in Pothole, Gus, and Upper Main.

Table 1. Areas and treatments in basins of the Trask River Watershed Study. Areas and distances based on LiDAR imagery.

Basin	Watershed	Treatment	Distance (m) to basin gage	Area (ha)
Upper Main	UM 1	no harvest	327	44.5
	UM 2	clearcut	1056	37.6
	UM 3	clearcut	1523	33.4
	Whole basin			278.8
Gus Creek	BS 1	no harvest	1069	26.6
	BS 2	Thinned with buffer	1426	39.1
	BS 3	clearcut	2050	37.8
	BS 4	clearcut	1211	21.1
	Whole basin			302.2
Pothole Creek	PH 1	cc with buffer	2350	67.2
	PH 2	cc with buffer	2099	45.1
	PH 3	no harvest	836	48.5
	PH 4	cc with buffer	852	26.4
	Whole basin			324.6
Rock Creek	RK 1	no harvest	4158	44.8
	RK 2	no harvest	3530	32.4
	RK 3	no harvest	2379	35.3
	RK 4	no harvest	2044	38.7
	Whole basin			667.6

Research studies, questions, and hypotheses

The Trask Watershed Study team has identified a series of hypotheses pertaining to both on-site and downstream effects of forest management. The particular ecosystem components to be studied include hydrology, suspended sediment, channel morphology, water quality, aquatic primary producers, macroinvertebrates, amphibians, and fish. The specific methods are designed to integrate responses of each of these ecological components at both headwater and downstream sites. Combinations of experimental, modeling, and before-after-control-impact designs are in place to allow the greatest flexibility, inference of responses, and integration across disciplines. By integrating multiple approaches to understand relationships between harvest type and ecosystem responses, we hope to overcome the limitations, as well as take advantage of the strengths, of each approach. The long-term nature of the

Trask will also facilitate more complete understanding of the natural variability of the system, and the impacts of forest management.

Abiotic Responses

Discharge

H1 Headwaters: The frequency of small to moderate peak flows is expected to increase slightly following harvest, and this change will be more evident in headwater streams with complete canopy removal.
H1 Downstream: Peak and winter base flows at downstream sites is not expected to change following harvest.

Methods for measuring discharge are grouped with methods for suspended sediment below.

Suspended sediment and turbidity

H2 Headwaters: Both turbidity and suspended inorganic sediment export is expected to increase during storms in headwater streams following harvest. The increase in transport will be associated with both increases in discharge and in mobility of sediment within harvested unit. These increases are expected to be more obvious in watersheds with complete canopy removal and/or geologically unstable soils, and should decline over time after forest harvest.
H2a Road related storm sediment
New roads are expected to result in greater increases in turbidity when and where roads are hydrologically connected to the stream. High traffic use combined with high intensity precipitation will result in local increases in turbidity where and when existing roads are hydrologically connected to the stream. Lacking this connection, no detectable change in turbidity and suspended sediment loads is expected due to roads constructed and maintained to current FPA standards given average winter storm conditions and road use.
H2 Downstream:
As distances from sediment sources increase, our ability to detect effects or harvest or road-related sediment will decrease. We expect to be able to detect downstream cumulative impacts on channel scour and deposition, turbidity, and suspended sediment if there are multiple episodic road-failures.

Methods for discharge, suspended sediment, and turbidity:
Each of the four basins will have two gaged headwater streams and one open channel downstream gaging site, except for the reference basin (Rock Creek), where only one headwater gage will be established because all are untreated.

In the headwaters of each basin, one gage will be located within a harvested watershed, and the other will be in an unharvested watershed. Pre-calibrated Parshall fiberglass flumes will be installed in headwaters for measuring discharge during 2008. Discharge, temperature, and specific conductivity will be measured every 10 minutes at each flume. The flume sites will be ready for Sigma samplers for nutrients or TTS stations for turbidity and suspended sediment if additional funding for these studies becomes available.

Open channel gaging stations have been installed in each basin at the downstream study sites and an additional site on the mainstem East Fork South Fork Trask, above the Rock Creek confluence. The mainstem site and Rock stations were installed in 2006 and others in 2007. Rating curves for stage and discharge are being developed at all five downstream gages. Each downstream gage site is instrumented with a data logger, pressure transducer, air and water temperature sensors, turbidity sensor, specific conductance probe, and an automated pump sampler. Measurements are recorded every 10 minutes. Collection of suspended sediment during storm events is triggered at pre-determined turbidity levels. Statistical relationships will be developed between in-stream turbidity and concentrations of suspended sediment and used to extrapolate real-time, in-stream turbidity values to sediment fluxes.

Road surveys will be conducted during pre-harvest, after road construction, immediately following harvest, and periodically thereafter for duration of the study. Road surveys will note hydrologic connection, functional rating for road surface, and risk of failure. Traffic use will be measured during harvest. With the road survey results, road segments most likely to affect water quality will be monitored. This may include the use of capacitance rods and flumes in ditches to estimate turbidity and suspended sediment delivery to streams from roads. A map of recreation trails is being developed and a subset of trails will be evaluated using road survey protocol

Nutrient concentrations and fluxes

H3 Headwaters:
In headwater streams, concentrations of nitrogen and phosphorus are expected to slightly increase during and after harvest. Increases will be greatest in the first autumn flows following harvest and where riparian buffers are removed. Headwater streams with alder-dominated canopies are likely to show more complex responses of organic and inorganic nitrogen fluxes, due to high N content of leaves. The amount of alder removed will have greatest impacts on nitrate concentrations, but dissolved organic nitrogen (DON) may change as well due to breakdown of post-harvest detritus.
H3 downstream:
Increases in nutrient concentrations are not expected to be detectible downstream, due to distance between upstream and downstream reaches.

Methods:
Pre-treatment nutrient samples will be collected during base flow seasonal synoptic surveys. Before and after harvest, fall water samples will be collected in headwaters using SIGMA samplers, where sampling is initiated by changes in discharge during storm flows. At downstream site, water samples will be collected as part of TTS sampling. All water chemistry samples will be returned to the lab, filtered, and analyzed by the Cooperative Chemical Analytical Laboratory (CCAL), OSU.

Stream temperature, shade and heat budgets

H4 Headwaters:
Solar radiation reaching headwater streams is expected to increase following harvest. This in turn will lead to increased maximum and minimum spring and summer stream temperatures. However, if logging slash covers streams after harvest, increases in temperature may be delayed until the slash decays or may not occur at all if streamside vegetation shades the channel before the slash decays. Sites where riparian buffers remain intact after harvest are not expected to show increased temperatures.
H4 Downstream:
Increases in headwater maximum stream temperatures are expected to decline with distance downstream from harvested areas and may not be measureable at downstream study sites. Major processes responsible for decline will be advection and conduction and dilution from cooler groundwater or hyporheic flows. Downstream study reaches may show increases in minimum summer temperatures after harvest.

Methods:
Gaged streams will have instantaneous measures of water and air temperature every 10 minutes year round. In-stream data loggers will be used to monitor half hour temperatures in ungaged streams from May through September each year; these thermistors will undergo accuracy checks prior to deployment. Changes to the vegetative cover near streams can have strong influences on microclimatic conditions. The amount of vegetative cover above the stream will be quantified using a densiometer in early spring (prior to leaf-out) and mid-summer (full canopy). These measurements of

overhead cover will be made along the thalweg in reaches that correspond to those used for aquatic biota. Hemispherical photos will be taken in each reach two years before harvest and two years after to quantify incoming radiation and shade. In addition, four portable microclimatic stations will allow us to evaluate microclimate at multiple sites and to study microclimatic responses downstream of harvested areas. The combination of this suite of temperature, solar radiation, and microclimate parameters will allow us to quantify heat budgets for streams (Johnson 2004) before and after harvest, and to examine influences of upstream harvest on downstream microclimates and heat budgets.

Please see **WEB LINK** for more details

Channel morphology and deposited sediment

H5 Headwaters:
Channel form may be moderately influenced by changes in inputs, transport and deposition of sediment following harvest. Increased deposition of fines is expected to occur. Majority of changes will occur in low gradient headwater reaches. However, changes are not expected to be dramatic, because major effects likely occurred following earlier harvest, fires, and post-fire salvage and channels may not have fully recovered from these past activities.
H5 Downstream:
Pools and depositional areas are expected to become slightly shallower with increases in fine sediment deposited on the stream bed.

Methods:
Gradients of study reaches will be measured on site in 2008. Widths, depths, substrate composition and particle sizes will be measured during each sampling for macroinvertebrates and algae standing stocks. In downstream fish reaches, geomorphic unit types (i.e. pools, riffles, etc), wetted area and volume, and residual volume of pools will be quantified during summer fish sampling.

In-stream deposition of fine sediments (<1 mm) will be quantified annually, during early summer sampling. Headwater sites and downstream reaches in each basin will be sampled for fine benthic organic and inorganic material. Samples will be collected from with detritus (see below) using the protocols designed by the national LINX study group (LINX 2004). This procedure samples fines on the surface and in the subsurface to 5 cm depth. Replicate samples at each site (4 from headwater, 6 from downstream sites) will be collected in the field, filtered in the laboratory, dried, and ashed. Standing stocks of fine organic and inorganic materials will be calculated for all study reaches. These results from low flow periods will be compared to turbidity data and suspended sediment measurements during high flows to evaluate if there are longer term residual effects of storm transport of sediment and possible biological impacts of increased turbidity and suspended sediments.

Biotic responses

Detritus and in-stream wood

H7 Headwaters:
Where there is complete removal of overstory vegetation near streams, inputs and exports of detritus are expected to decrease immediately following harvest. However if slash remains over the streams, there may be short term increases in organic inputs. Amounts of wood in many streams are currently low. In streams where wood is present, we expect a decrease in wood abundance over time after harvest without buffers. Changes in the amount of downed word are not expected where buffers are retained.
H7 Downstream:
Detritus is expected to decrease in downstream reaches following harvest due to decrease in sources of litter from headwater with removal of riparian vegetation.

Methods:
Prior to harvest, in-stream and near-stream wood will be quantified during base flows. String transects (Wallace and Benke 1984, Swanson et al. 1984) will be conducted at each of the channel measurement transect sites, extending 30 m into riparian areas, and through each of the major accumulations within study reaches.
Standing stocks of detritus will also be quantified during summer sampling. A 15-cm diameter corer will be inserted up to 5 cm into substrate and benthic organic material within core collected. Then subsurface material will be stirred and suspended and a subsample of fine benthic organic material collected. The volume of supernatant within the corer will be recorded. Organic coarse matter samples will be dried (60ºC) and ashed (500ºC) to quantify AFDM/m2.

Primary producers: Abundance and rates

H6 Headwaters:
Increased light and nutrients following harvest are expected to result in increased chlorophyll *a* and algal biomass as well as rates of primary production. This will be most apparent in early summer on streams without riparian buffers.
H6 Downstream:
Effects of forest harvest on primary production will diminish with distance downstream from harvest. At downstream study sites, no increases in standing stocks or primary production are expected to be detectable.

Methods:
Standing stocks of benthic epilithon and chlorophyll *a* (an indicator of photosynthetic activity) will be measured at headwater and downstream sites. Collections are made in early spring (prior to leaf-out) and early summer. Sampling occurs in same reaches studied for invertebrates (see below), and are approximately 40 meters in length in headwater streams and 100 meters at downstream sites. Sample collection consists of scrubbing known areas of hard substrates (such as gravels, cobbles or small boulders) and washing scrubbed material into containers. Four samples are collected for each headwater site and six at downstream sites. Samples are placed in the dark on ice and returned to the laboratory within 48 hours of collection. An additional sample is collected for later taxonomic identification of algae or diatoms: these samples are collected from a know area, fixed with M3, and archived.

In the laboratory, each sample is split into two aliquots. One portion is filtered onto pre-combusted and pre-weighed Whatman GFF filters, dried at 60ºC, weighed to determine dry mass, combusted at 500ºC and reweighed to determine ash-free dry mass (AFDM). The second portion is filtered through a pre-combusted GFF filter and extracted for chlorophyll *a* and phaeophytin using the hot ethanol method (Sartory and Grobbelaar 1984). After a 24 hour incubation, the samples are analyzed on a Shimadzu UV-1700 UV-VIS spectrophotometer. Samples are processed within one month of field collection to prevent degradation of the photopigments.

Dissolved oxygen (DO) sensors will be deployed to evaluate spatial and temporal variability in DO and to quantify ecosystem production and respiration. These measures of whole stream metabolism provide a more robust estimate of overall benthic productivity than chamber techniques. Whole-stream metabolism will be measured over time frames of 3-7 days using the two-station method (Young and Huryn 1999), when possible. Re-aeration, discharge and travel times will be quantified using short-term (2-4 hour) conservative tracer releases (Bott 2007; Hall and Tank 2005). These conservative tracers will also provide estimates of in-channel and hyporheic storage areas and times. These parameters may also shift as a result of changes in channel morphology and/or changes in sediment deposition and delivery.

Macroinvertebrates

H8 Headwaters:
After harvest, abundances of benthic and drifting macroinvertebrates are expected to increase. The community composition of macroinvertebrates that feed by grazing is expected to increase. Other taxa may shift their diet from detritus to increased consumption of algae, resulting in a shift in their stable isotope ratios (lower $\delta^{13}C$ after harvest). After harvest, the size at emergence of representative taxa will decrease due to increased stream temperatures.

H8 Downstream:
After harvest, densities of drifting macroinvertebrates at downstream sites are not expected to show similar increases as in headwater sites. Changes in macroinvertebrate drift rates or benthic community structure at downstream sites following harvest are not expected unless there is an increase in primary production at those sites.

Methods:
The responses of macroinvertebrate communities will be evaluated through collections made from the substrate (benthic) and from the water column (drift) (Barbour et al. 1999, Frady et al. 2007). Macroinvertebrate communities will be sampled from both headwater and downstream sites in spring (March/April) and early summer (June) each year. At each headwater site, six benthic samples will be collected and composited before being counted. Drift samples will be collected at each site for 24 hrs. Water depth and velocity will be measured at the point of placement of drift nets to calculate the volume of water sampled. Additional sampling for macroinvertebrates will occur at the downstream sites when fish diets are being sampled in August. August sampling will not be conducted in the headwater sites due to low stream flows. As time and availability of field assistance allows, patterns of aquatic insect emergence will be studied in a select number of pre- and post harvest years. These samples will be taken continuously over the chosen late spring or mid-summer season using emergence traps over the stream and malaise traps in the riparian zone.

Samples will be processed in the Department of Fisheries & Wildlife at Oregon State University. A 500 count subsample will be taken from the benthic samples and the entire drift samples will be processed to assess community composition. Macroinvertebrates will be identified to the lowest feasible taxonomic category (genus for most insect taxa and order or family for non-insects). The presence and dominance of sensitive and tolerant taxa will be determined; these taxa will be identified from published work on macroinvertebrate responses to human disturbance (Barbour et al. 1999). Relative importance of food resources will be determined by assigning taxa to functional feeding groups (Merritt and Cummins 1996), and through stable isotope analysis.

After preliminary sampling, several taxa from representative insect orders will be selected as indicators. Developmental stage of individuals will be estimated from head capsule widths, wing pad development and in some cases, particular life stage. Biomass will be estimated by measuring length and comparing to published length-weight relationships, or by directly weighing dry weights of subsamples. Estimations of the time and size at emergence will be calculated based on the size and time at which late instars (based on head capsule width and wing pad development) are found. Examining individual as well as community and population metrics of macroinvertebrates may improve our ability to detect responses to forest harvest. Abundance of natural isotopes (^{13}C, ^{15}N) will be measured in several indicator taxa that are common across sites. Samples will be dried and sent to the Marine Biological Lab for analysis.

Additional funding is also being sought to study responses of crustaceans, signal crayfish, (*Pacifasticus leniusculus*) to forest harvest. At headwaters and downstream sites, crayfish will be captured using baited traps and individuals injected with a coded wire tag. Marked individuals will be sexed, weighed, and carapace and cheliped length measured. Reproductive status of females will be noted. Monthly trapping (April-June/July at headwater sites and April-September at downstream sites) will be conducted. Mark-recapture efficiencies will be used to estimate local crayfish population size. Individual growth rates will be determined for each sampling interval. Changes in reproductive status will also be noted. Diet of crayfish will be determined from a subsample of non-marked individuals using stable isotope analysis.

Amphibians

H9 Headwaters:
Tailed frog tadpole (*Ascaphus truei*) abundance and condition are expected to increase if light and algal abundance increase after harvest. Timing of metamorphosis is expected to shift to earlier in season due to interactions among food quality, availability, and temperature. Headwater watersheds with retained riparian buffers will exhibit less fluctuation in densities of both adult (terrestrial) and larval (aquatic) stages of tailed frogs and Pacific giant salamander (*Dicamptodon tenebrosus*). Terrestrial phase adults are expected to decline in headwater areas without shade or cover. After harvest, we expect to see a shift in the stable isotope ratios (^{13}C) associated with increased consumption and availability of algae following removal of overstory vegetation.
H9 downstream:
Adult and juvenile tailed frogs are rarely found at downstream sites, likely due to a combination of gradient, water temperature and sediment loads, and we expect this pattern to continue after harvest. Pacific giant salamanders are somewhat more broadly distributed at downstream sites, but are still at low abundances. Downstream effects of upstream harvest are not expected to be detectable on amphibians, related to low densities and the distance from forest harvest.

Methods:
Amphibians in the Trask study area have both aquatic and terrestrial life history stages. As such, they are uniquely suited to examining the impacts of forest management in both ecosystems. The variation in amphibian populations we expect to see over space and time will be related to variation other researchers quantify in environmental conditions, such as water temperature or algal abundance. Impacts on amphibian abundance may manifest indirectly through changes in body condition and growth that relate to future survival and fecundity.

Responses measured include abundance, size, condition index, and rates of larval survival, growth, development and movement (the latter will also include direction and distance measurements). Sampling will be conducted in 100 m reaches selected at each of the 12 headwater and 4 downstream sites. In a subset of these reaches, we will mark individual larvae with either elastomer or PIT tags to allow for individual recognition (needed for measurement of parameters such as growth rate). Abundance of natural isotopes (^{13}C, ^{15}N) will be measured in fin or toe clips from tadpoles and dicamptadon across sites. Samples will be dried and sent to Marine Biological Lab for analysis. A capture-mark-recapture protocol will be used in these reaches, with 3 primary and 2 secondary sampling periods each summer. We will use a combination of electroshocking and hand capture/rock turning to collect the animals.
Please see **WEB LINK** for more details.

Fish

H10 Downstream:
Length at age, condition, and survival of salmonids and sculpins are not expected to increase at downstream sites, as a function of limited changes in temperature and food availability at the downstream sites. However, fish condition may decline if there are sufficient increases in water temperature and sedimentation to offset any benefits due to increased trophic productivity.

Methods:
To evaluate how forest operations are influencing biota, it is important to understand how habitat and organisms are distributed in both space and time as well as how organisms interact across gradients of habitat, relative abundance and season. We will monitor individual fish to understand how physiological and behavioral responses are linked to observed changes at the population and community levels (e.g., Railsback et al. 2003). This research will also incorporate processes

responsible for any observed changes in fish populations. As a result, we expect to be able to understand cause-and-effect linkages between fish and spatial and temporal changes in habitat, and also to identify responses most sensitive to habitat changes linked to forest management. Over the longer-term, we intend to use this life history information in life cycle models for key species (e.g., coho; Lawson et al. 2004) and to understand responses to changes in habitat caused by forest harvest within the context of other factors fish experience during their lifetimes (e.g., Holtby 1988).

The most dominant in the downstream sites are sculpin and coastal cutthroat trout. Coho are present at Rock and Pothole reaches. Detailed site-specific studies of individual fish condition, growth, mortality, immigration, and emigration will be coupled with monitoring of physical habitat conditions in the stream (e.g., channel structure, water quality) and biotic conditions (e.g., primary and secondary productivity) to understand how fish and habitat interact at this scale. Our depiction of pathways of influences leading to fish responses recognizes both individual and population-level factors. For individual fish, we recognize three factors of primary importance: food availability, predation risk, and metabolism. Much of our logic is based on that offered by inSTREAM (http://www.humboldt.edu/~ecomodel/instream.htm).

The upper most end of fish distributions were determined in 2006 for the streams draining the study basins, and distance markers placed every 25 m along the streams to indicate stream distances on the ground for future work.

Starting in 2007, to address the variety of individual and population-level responses, we will establish weirs within selected downstream reaches, enclosing 200-250m sections of stream with two-way (upstream/downstream) traps at the top and bottom. Fish growth and behavior will be monitored during summer low flows, which a time of year when survival of larger (age 1+) cutthroat trout has been shown to be lowest in other watershed studies (Hinkle Creek). Abundance of natural isotopes (^{13}C, ^{15}N) will be measured in fin clips from cutthroat trout and sculpins from each site. Samples will be dried and sent to Marine Biological Lab for analysis. The Oregon Department of Fish and Wildlife has two screw traps located downstream of the Trask study area. These traps will capture out-migrating salmon and trout, providing additional information on individuals at a later time.

Please see **WEB LINK** for more details

Broader understanding: Experiments, food webs and modeling of abiotic and biotic parameters

In this study, we will base field efforts in the Trask Watershed. We wish also to generate results that can be applied to a variety of forest land ownerships (e.g., BLM and Forest Service, as well as ODF and private lands) and impacts (e.g., temperature, sediment, etc.). By using a combination of experiments and modeling, we intend to examine a broad variety of potential scenarios that are relevant to the Trask as well as to general forest land management.

In the Trask study, we intend to provide:

- An integrated and biologically realistic analysis of *process* that is not possible with classical statistical approaches focused on pattern detection (e.g., BACI or "Before-After-Control-Impact).
- Models to simulate potential future scenarios (e.g., "futuring" the longer-term effects of forestry and climate change) that are impossible to examine with empirical data alone. Modeled scenarios are useful in developing rigorous hypotheses and testable predictions about how aquatic ecosystems respond to the potential impacts of forestry.
- Perspectives on stream responses to forestry that can be generalized outside of the Trask Watershed and can provide useful insights regardless of the outcome of the planned forest treatments. Such results can be applied across much broader scales than the time and location of the Trask study.

Experiments are a valuable complement to observational field studies and simulation studies because they can effectively isolate the influences of one factor at a time. Patterns, processes, and uncertainties identified through the first years of field work in the Trask, as well as initial model simulations, can help to identify the critical questions that are most important to address under experimental conditions. We have access to a new facility that offers an opportunity to conduct controlled, manipulative experiments in semi-natural conditions that offer a useful complement to inferences from the field. For experimental work we hope to use new experimental stream channels at the Oregon Hatchery Research Center, http://www.dfw.state.or.us/OHRC/.

Models allow us to examine our best understanding of processes and to simulate potential future scenarios (e.g., "futuring" the longer-term effects of forestry and climate change) that are impossible to examine with empirical data alone. We intend to explore multiple types of models, including empirical models, ecosystem process models and Baysian Belief Networks, to explore linkages between organisms and their environments as well as linkages among trophic levels. We will develop rigorous hypotheses and testable predictions about how aquatic ecosystems respond to the potential impacts of forestry and compare to our findings post- harvest.

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Appendices - Additional studies and grants

Project Title: Oregon Plan Effectiveness: Effects of Contemporary Forest Harvest on Aquatic Ecosystems in Trask, Hinkle, and Alsea Watersheds

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Funded by Oregon Watershed Enhancement Board 2007

Objectives:
Three watershed studies (Trask River, Hinkle Creek and Alsea Revisited) described in this proposal are evaluating the question "Are contemporary forest management strategies adequate to sustainability meet Oregon Plan goals for this state's forested watersheds?"

Specifically, we are examining the responses of aquatic systems to forest harvest in headwaters, and quantifying downstream impacts as well. Uncovering the underlying processes responsible for observed changes in system and species condition is not simple. Stream ecosystems are complex and there are multiple linkages among system components and processes. While contemporary forest practice rules are designed to minimize negative impacts, forest harvest may affect elements or linkages at multiple points in the network and these effects may then cascade through the system. As such, there are multiple hypotheses, with the overall objectives to investigate:

1) The effects of forest harvest on the physical, chemical and biological characteristics of small headwater streams,

2) The extent to which alterations in stream conditions caused by harvest along headwater channels influences the physical, chemical and biological characteristics of downstream fish-bearing streams.

We request funds to purchase necessary equipment to conduct these studies. Operating funds have already been secured. The three studies complement each other by using comparible designs and methods for research across a range of environments. Hinkle and Trask are investigating linkages between small streams and downstream fish bearing streams for multiple parameters. Alsea is smaller area but has a long-term data to compare impacts of contemporary forest practices with those from historic logging. The Alsea also will investigate the effect of instream wood placement on fish habitat and fish populations.

Rationale:
This proposal requests capital equipment funds to purchase and install instruments for research on watershed processes in these 3 projects. These research projects will evaluate the effectiveness of forest management practices in achieving Oregon Plan goals relating to water quality, aquatic habitat and fish. These studies focus on the impact of forest practices on small, headwater streams and the extent to which these impacts are transferred downstream. These collaborative WRC studies are watershed-scale, manipulative experiments involving teams of multidisciplinary scientists from multiple research organizations. These experiments are in cooperation with private industrial, state, and federal forest

landowners, who are providing substantial financial support and have altered management plans to accommodate these studies.

Forest management has the potential to greatly influence Oregon's Coastal and Cascade watersheds. Questions remain about effectiveness of contemporary forest management (e.g. fish response, cumulative effect) that are best addressed at through watershed studies. Use of similar methods in these 3 watersheds provides greater ecological context to address effectiveness questions.

Flow characterization is a critical component of aquatic habitat and watershed processes involving material and energy flux. Flume installations and TTS systems will provide a high degree of measurement accuracy. Equipment and supplies are requested to evaluate fish condition, growth, behavior, feeding, and movement habits. We will purchase instruments to examine influences of forest harvest on multiple other instream processes including stream temperature, benthic production, whole stream metabolism, DO, microclimate, incoming radiation, and primary production. The approaches taken in the three studies are complementary and information from each will aid interpretation.

Expected Outcomes:
WRC findings will benefit state and private forest landowners and natural resource managers by expanding our understanding of linkages between forest practices, aquatic habitat, and fish. This improved understanding will enable state and federal agencies to develop and refine forest management strategies that protect and restore aquatic habitat while enabling forest owners to profitably manage their lands. Fundamental information on the organization and function of stream ecosystems will enable more efficient and effective distribution of resources available to restore streams in western Oregon.

A unique outcome of watershed scale research is the ability to link harvest effects with habitat and fish population responses. Often fish abundance is the only attribute measured in response to forestry treatments or altered habitat conditions. However, abundance represents the combined influences of multiple and sometimes opposing processes, and it can be difficult to discern the cause of observed population responses. Our approach will enable us to identify key responses that are most sensitive to forest management. Over the long-term, we intend to use this life history information in life cycle models for key species (e.g. coho). Our combined empirical and modeling work will enhance our understanding of relationships between fishes and forestry and will broadly apply to Coast and Cascade streams throughout the Pacific Northwest.

The results of the WRC research will be easily accessible by technical and non-technical audiences with the use of multiple communication strategies. Study results will be disseminated to the scientific community through the traditional means of journal publications and presentations at scientific meetings. WRC results will be provided to broader audiences through regional workshops, newsletters, and information posted on WRC and project websites. The WRC has an outreach program to ensure the communication strategy is effective.

Title: Pre harvest Habitat measures – Riparian and instream 2008
Funding provided as part of the OWEB Grant 2007 (above)

The intent is to:

- Link channel responses with in-stream processes influencing biological characteristics of the stream and other biological hydrological sampling locations (i.e. fish habitat, macroinvertebrates, and amphibians)
- Link with management practices that may influence substrate characteristics (i.e. stream crossings and harvest units)

Sampling will occur in headwater basins within already established biological sample reaches above planned harvest unit boundaries and at downstream fish sites.

Field Methods
Measurements for sample reaches will include cover, riparian characterization, channel morphology, substrate particle size distribution and characterization of roughness elements (i.e. wood volume and function).

Monumented sample reaches will be established within each headwater stream catchment and at the 5 downstream fish reaches. The reach lengths will be 100 m in headwaters and 200-300 m at downstream fish sampling reaches. Metal fence posts will be driven into both banks at the downstream end of reach. PVC will be inserted into left and right banks at intersection of perpendicular transects with stream (25m, 50m, 75m, 100m).

Vegetation transects will be established (a) perpendicular and (b) parallel to the stream on each side of the stream. In headwaters, they will be 25 m apart starting at downstream end of reach. At transects Perpendicular to Stream on Each Side, overstory tree species, diameter and distance from stream will be estimated. Shrub Plots will be within the transects, a 5X5m plot at the start and end of each 30 m transect. Percent understory cover by layer for low shrub and high shrub will be noted and number of tree seedlings estimated.
Belt transects parallel to stream will be established at the edge of active channel and parallel to the stream, on both sides of the stream. On every third 5m long x 2 m wide plot, percent overstory cover by species and percent understory cover by species

Shade and cover over the stream will measured at the center of each perpendicular transect, 0.5 m above the stream surface. Hemispherical photography will be taken when the sun is at low angles. Estimate of cover using spherical densiometer also collected at each photo point.

Downed wood will be quantified in stream and riparian areas using line intercept methodology at four riparian transects and 5 instream transects. Diameter at intercept (minimum size 10 cm), length of wood (minimum size 1m) and decay class will be recorded.

Channel and substrate metrics will be recorded instream. Widths, depths, channel unit type, and substrates will be measured at 10 transects per reach. Bank slope and incision will be estimated by the difference in height between the low water level and points in the riparian area at 1.5 and 3 m away from stream edge on each bank at each perpendicular transect

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Title: Quantifying use and selection of hiding cover by salmon and trout across paired watershed studies in western Oregon

Lead Investigator Jason Dunham with Heidi Vogel
Funded by FRL 2007-2008

Background/Relevance. Three paired watershed studies are now underway in western Oregon, and include Hinkle Creek (Umpqua River basin) and two watersheds in the headwaters of the Alsea and Trask Rivers in the central and northern coast range, respectively. These studies seek to quantify influences of forest practices on habitats supporting native fishes and amphibians by comparing environments and populations before and after harvest in streams with and without harvest. Much work has focused on fish growth, movement, population abundance and size structure. Less has focused on specific *mechanisms* influencing survival. It is well-established that survival may vary seasonally for many species, but *why* survival is lower or greater is not well understood. In other words, is survival tied to starvation, predators, disease, or other factors? We suspect predators play a major and unstudied role.

Predators like birds and mammals in particular have strong impacts on salmon and trout in larger lakes and rivers, but studies in small streams such as those studied in the three paired watersheds are lacking. One reason is that observing these predators directly is a daunting logistical challenge. Predators may only visit an area once in a year or even less frequently and have an important influence on fish populations. Thus, it is necessary to devise indirect approaches for understanding how fish may interact with predators in small streams, and how the ability of fish to avoid predators is tied to local habitat conditions. This is a key linkage between the response of fishes to forestry and natural processes that influence availability of habitat that fish may need to avoid predators (hiding cover).

In this study we propose to measure characteristics of hiding cover and quantify use and selection of hiding cover by salmon and trout in the three paired watersheds. We will take advantage of existing marked fish to study their patterns of habitat use in relation to unused habitats to measure the strength of selection of habitats by individuals. By understanding what hiding cover is, and obtaining a measure of the quality of hiding cover (i.e., selectivity), we will have a much better sense of how fish use habitat to avoid predation. Work will occur during seasonal low flows in summer and fall, where fish may be more confined and vulnerable to predators (D. Bateman, personal communication). To determine if fish are using hiding cover, we will approach the stream with mobile antennas submerged to detect locations of marked individual fish. Fish that do not move after detection are assumed to be using hiding cover, whereas fish that leave the vicinity are assumed to be using a different tactic (evasion) for avoiding what they perceive to be predators (humans entering their habitat). When possible, underwater observation will be used for verification. Measures of hiding cover will include size of pools (e.g., area, depth) and availability of instream cover (e.g., wood, un-embedded substrate, undercut banks, boulders, turbulence). Other factors (e.g., velocity, light) may also be important. At the level of individuals, natural selection should drive individuals to select habitats that provide greater opportunities for feeding and for surviving the threat of predators. The relative benefits of different habitats should also be conditioned on characteristics of the individual (e.g., size) and external factors such as temperature and the density of con-specific and hetero-specific competitors, as well as availability of different habitat types (e.g., if cover is abundant and available, then selectivity should be lower).

Objectives: 1) measure habitat use and availability for coastal cutthroat trout, steelhead trout, and coho salmon to model patterns of habitat selection within individual locations (stream reaches); 2) compare results among locations to understand conditions that may modify habitat selection (e.g., among paired watersheds, sites); 3) identify habitat characteristics within each location that are most important to different species in terms of the strength of selection observed by individual fish.

Title: Riparian birds and their diet

Lead Investigators Joan Hagar and Judy Li, Marcia Humes, Oregon Department of Forestry
Funded by Forest Science Partnership 2008

Background and relevance

Although riparian management strategies are primarily concerned with aquatic resources, they also have an important influence on terrestrial wildlife, especially those species associated with streamside habitat. Small stream ecosystems in particular are tightly coupled with terrestrial systems, so management actions in riparian zones will undoubtedly influence both systems in complex, interactive ways. For this reason, understanding the ways in which management actions implemented to achieve goals for aquatic habitats also influence terrestrial organisms is important for managers. We propose to add a component to the Trask Watershed study to assess the response of songbirds to the riparian management activities being evaluated. We chose songbirds as a study subject because 1) several species are associated with riparian habitat along headwater streams and respond measurably to the proposed harvest treatments (Hagar, J.C. 1999. J. Wildl. Manage. 63:484-496); 2) some of these species may be linked to aquatic systems through trophic interactions: riparian birds feed on adult aquatic insects that emerge from streams (Robillard 2006 (CFER project)); and 3) they are relatively easy and inexpensive to sample.

Research Objectives:

Harvest treatments on the Trask watershed study will be implemented in 2011, so a primary objective of this proposal is to collect baseline data describing the species composition, abundance, and habitat associations of riparian songbird assemblages prior to treatment. As well as providing a powerful means of evaluating treatment effects, baseline data also can be useful in addressing basic research questions about ecological patterns and processes. We will address the following research questions with pre-treatment sampling:

1) *How is variation in the abundance of emergent aquatic insects (prey for riparian-associated bird species) related to aquatic variables such as primary productivity, sediment and nutrients?*

Approach: We will sample emergent aquatic insects in the riparian zone at all established Trask study sites. Model selection procedures will be used to identify the aquatic variables (collected by other members of the interdisciplinary team) that best explain variation in abundance of emergent insects.

2) *Which habitat and resource variables best explain variation in the density and territory size of selected bird species associated with riparian habitat (e.g., Pacific-slope flycatcher, winter wren, Swainson's thrush).*

Approach: We will use territory mapping methodology to estimate density and territory sizes of songbirds at all established Trask study sites. We also will collect data on key habitat variables describing vegetation composition and structure to use in habitat relationships modeling. Abundance of emergent aquatic insects (above) will be used as a predictor variable.

Study Relevance:
The Trask Watershed study represents a substantial investment by multiple land management agencies in well-designed and scientifically rigorous research to increase understanding of management effects at an ecosystem scale. Adding a component to the established study that addresses riparian-associated birds is a very cost-effective means of addressing questions about effects of riparian zone management on terrestrial wildlife.
These questions are important to managers because goals of riparian zone management for most agencies include the protection of habitat for terrestrial wildlife as well as aquatic systems (e.g., see BLM Aquatic Conservation Strategy; and ODF, NW State Forests Management Plan, Chapter 4).

Title: Quantifying riparian stand structure and microclimate/-site attributes and connecting to stream ecosystem drivers

Lead investigators Temesgen Hailemariam (OSU), Joan Hagar (USGS FRESC), Bianca Eskelson (OSU, PhD candidate), Liz Dent (ODF)

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Project Summary: Leaving trees along stream systems has become the accepted mechanism for achieving goals related to stream and wildlife protection when adjacent uplands are harvested. Riparian composition and structure are major attributes driving these riparian ecosystems services. In riparian ecosystems, forest structure varies widely as a result of differences in tree distribution patterns, species composition, and differentiation in the vertical (e.g., height diversity), horizontal (e.g., light, moisture, nutrient availability, gaps), and temporal dimensions. This variability is a key driver-exerting strong influence on functions and attributes such as large wood recruitment, microclimate, water quality, and presence and abundance of flora and fauna.

Riparian monitoring is complex requiring detailed measurement and analyses over time of riparian structure. Companion measures that quantify linkages between forest structure and stream ecosystem services (e.g. microclimate, stream temperature and dissolved nutrients) are required to evaluate effectiveness. The high within- and among-riparian variations contribute to the difficulty of quantifying and connecting riparian structure to stream ecosystem drivers. Cognizant of these facts, this study proposes an evaluation of the efficiency and suitability of selected methods to quantify and connect stand structure to stream ecosystem drivers while considering the longitudinal and vertical variations within and among riparian zones.

This project is part of the longer-term Trask River Watershed Study evaluating the effects of harvesting on riparian structure and linkages with micro-climate and ecosystem processes. This project has the following four primary objectives.

1) Evaluate methods to quantify riparian stand structure and how it drives ecosystem services such as microclimate.

The evaluation will focus on suitability of selected methods to quantify riparian structure, microclimate, and other microsite parameters for describing spatial patterns at multiple scales. We will provide methods to monitor inherent spatial variation of microclimate and microsite attributes in riparian forests as well as changes that result from harvesting.

2) Characterize and quantify relationships between riparian structure and composition and diversity of understory vegetation.

More recently neighborhood-based measures have been used to describe complex forest structures. Such measures include trees distribution patterns, size differentiation, spatial aggregation and species mingling.

3) Test the suitability and predictive abilities of neighborhood-based measures to quantify forest structure and to link forest structure and microclimate/-site attribute attributes to stream ecosystem drivers.

Neighborhood-based measures quantify spatial forest structure without measuring distance between trees or establishing tree coordinates, and allow quantitative comparisons among complex forest structures. Moreover, these measures are capable of detecting subtle structural changes (e.g., height differentiation due to competition) and quantifying the effect of management activities and competition on stand structure. As a result, these indices are suitable for long term forest monitoring.

4) Quantify linkages between riparian structure and riparian services such as microclimate, wildlife habitat, and water quality.

The diversity and complexity of riparian vegetation and proximity to water resources make them critical landscape features for managing wildlife habitat, water quality and other related landscape level processes such as habitat fragmentation and stream bank stabilization. While the knowledge base for riparian structure and riparian services is still relatively new and evolving, managers are making decisions today and need to make these decisions on the best currently available science. It is imperative that managers have simple methods for relating and developing empirical relationships to link riparian structure and riparian services.

Value to forest land managers: There is a long history of leaving trees in riparian buffers along streams to protect stream resources. An improved understanding of linkages between riparian stand structure and stream resources being protected will benefit managers and policy makers by providing reliable, repeatable, and cost effective methods to quantify these linkages. This knowledge is critical to understanding the effectiveness of riparian strategies in achieving goals for riparian-dependent ecosystem services. Furthermore, the project provides forest managers and policy makers with a tool that will strengthen the “scientific basis of ecological monitoring” thorough data collection and analytical methods that consider both “lateral and longitudinal” variations.

How the project would support a particular theme area.

Attaining the objectives outlined above improves the accuracy of predicting riparian stand structure and microclimate/-site attributes, and improves predictive ability of neighborhood-based measures across spatial scales. The results of the study help us to understand “riparian processes and functions” and to advance “the scientific basis of ecological monitoring”.

Title: Experiment on temperature influences on macroinvertebrate growth and emergence

Principal investigators Judy Li and Sherri Johnson

We are conducting laboratory experiments at the Oregon Hatchery Research Center to examine influences of temperature on growth, biomass and timing of emergence for indicator species of macroinvertebrates. According to existing but limited research, increases in temperature lead to faster growth through each instar (Vannote and Sweeney 1980, Harper and Peckarsky 2006). This faster growth has been suggested to translate into smaller sizes and reduced biomass as well as earlier emergence. For insect taxa with multiple generations per year, temperature changes could result in more generations per year of smaller individuals. Fish diets are greatly influenced by the biomass of insects they consume, and we know little about the factors influencing the biomass of their prey.

We will examine experimentally the influences of stream temperature on macroinvertebrate size and biomass, as well as the timing of emergence, all of which would influence the life cycle of the invertebrates and their availability to fish. We will measure aquatic larval growth rates, sizes, wing development and timing of emergence as adults for representative mayflies, stoneflies and caddisflies. Larval macroinvertebrates will be collected from nearby headwater streams and reared in at the flow-through systems provided by the Oregon Hatchery Research Center (OHRC).

Responses of macroinvertebrates to stream water of three temperature regimes will be studied. Temperature treatments will consist of three different regimes: (1) temperatures typical of undisturbed headwater stream; (2) elevated temperatures of 2-3^{o}C, such as might be expected of headwater streams where riparian vegetation has been removed. Most growth and temperature experiments in the literature have been conducted at constant temperatures (Quinn et al. 1994), however these two treatments will be allowed to fluctuate with natural diel regimes. The third thermal treatment will control for these diel fluctuations by warming water to a constant 18^{o}C. These experiments will begin July 2007 and if successful, a second set of will begin in spring 2008 to examine responses to increased temperature in spring and early summer.

Title: EFFECTIVENESS OF MODERN FOREST PRACTICES FOR MAINTAINING WATER QUALITY AND FISH HABITAT IN HEADWATER STREAMS OF WESTERN OREGON

Investigators Dr. Bob Bilby, Weyerhaeuser Company; Dr. Jason Dunham, USGS; Dr. Bob Gresswell, USGS; Dr. Sherri Johnson, USFS PNW Research Station; Jeff Light, Plum Creek Timber Company

Funded by Agenda 2020 and US Forest Service Pacific Northwest Research Station

Rational

The Oregon Forest Practices Act (FPA) was the first in the United States to include provisions for the protection of water quality and fish habitat. The FPA provides a set of rules defining the Best Management Practices (BMPs) for commercial forest operations in the state. High levels of compliance with these regulations has been demonstrated in many watersheds of Oregon’s Coast Range and Cascade Mountains; however, questions remain about the effectiveness of contemporary BMPs in meeting water quality goals and biological objectives for fish and other aquatic biota. Many of these questions are best addressed at a watershed scale.

Objectives and Hypotheses

The three WRC studies have complementary objectives and designs and are measuring similar response parameters (Table 1). Both biological and abiotic characteristics of stream and riparian systems are being evaluated. The range of approaches and methods are intended to maximize the applicability of the results to watersheds throughout the Pacific Northwest. The whole-basin focus of the Hinkle and Alsea sites allows detection of patterns and changes at the watershed scale, and requires statistical techniques to address issues of spatial and temporal autocorrelation of these continuous data. The high-resolution site-level focus on biological processes in the Trask will provide insight on mechanisms behind any changes in patterns detected at the watershed scale. The long sampling history in the Alsea will provide a better understanding of temporal patterns of disturbance and recovery that are crucial for interpreting forest management effects. These design features, along with a common before-after, control-impact approach, will help make the most of the paired watershed approach.

Our work on fish acknowledges that population responses to changes in habitat related to forestry and natural influences can be highly complex. Accordingly, we have adopted both population and individual-based analyses of fish responses to changes in ambient conditions across all three watershed studies. Our intent is to understand both patterns over time and space and the underlying processes or mechanisms that are responsible. Without understanding broad patterns, the relevance of individual processes is unclear. Without understanding processes that create patterns, our ability to understand how management can influence populations is diminished. With an approach that combines these different perspectives, we will obtain results that are more relevant to management goals and management actions.

<u>Objective 1</u>. Long-term monitoring of patterns of abundance, distribution, and movement of fish in relation to natural and forestry-related changes in habitat, including changes in stream discharge, sedimentation, temperature, and channel structure.

<u>Hypotheses</u> – Because forestry can have influences on many physical processes that may directly or indirectly influence fish in headwater streams, we anticipate the possibility of a distinctive change in population-level responses following forest harvest. These responses should be linked to measured changes in stream discharge (low flow and high flow events), sedimentation (e.g., suspended sediment and deposition), temperature, and channel structure. This is the traditional “before-after” comparison of patterns that has been used in past studies of fish-forestry interactions to understand fish population responses. A vast array of literature relating fish populations to the basic physical measures in this study suggests that responses are possible if changes are great enough. Our design allows consideration of the influences of natural variability on populations by collecting pre-treatment data and including an untreated reference stream as a comparison. This statistical comparison will complement our more detailed look at individual responses and actual processes that contribute to population dynamics.

<u>Objective 2</u>. Understanding of processes that drive population-level responses of fish in headwater streams, including variability in the feeding ecology of individuals, fine-scale habitat use, immigration, emigration, individual growth, condition, and survival.

<u>Hypotheses</u> – We know that population dynamics is an emergent property from the consequences of individual behaviors leading to variability in birth, death, immigration, and emigration. Consequently we have employed different designs to examine seasonal movement and survival across the year (Hinkle Creek and Alsea Watershed), as well as measurements of growth, condition, and fine-scale patterns of habitat use and movement within the Trask Watershed. In the latter we are focused on summer low-flow processes, a time period when survival is lowest (Berger 2007) and fish growth appears to be limited (D. Bateman, unpublished). Studies in Hinkle Creek and the Alsea Watershed will continue through winter, as they are focused on seasonal distribution and movement. Our examination of individual behaviors and condition will allow us to understand how population dynamics emerge and to identify specific factors that contribute to population dynamics, including those influenced by forestry. For example, changes in availability of cover and in extent and duration of summer and fall low-flows can influence predation risk and survival. Changes in temperature can alter metabolism and growth of fish. The influence of other species in the system (e.g., sculpins and Pacific giant salamander) can alter the trophic ecology of salmon and trout, our focal species.

Deliverables

As noted above, the primary product of the Agenda 2020 effort will be a report, which will be completed at the end of the 3-year funding period. We anticipate that the report will address:

- A comparison of growth rate estimates from scales and mark recapture.
- The influence of fish community composition on the growth and production of cutthroat trout.
- Effect of variations in channel physical characteristics on the growth and production of cutthroat trout.
- A conceptual model of food web organization which will be used to generate hypotheses on the processes governing cutthroat trout growth and production.