3/30/2015

EFFECTIVENESS OF CONTEMPORARY FOREST PRACTICES: THE ALSEA WATERSHED STUDY REVISITED

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Abstract: The Alsea Watershed Study Revisited (AWSR) provides a unique opportunity to compare water and water-related resource responses to current forest practices with responses to logging practices of the 1960s. The original Alsea Watershed Study (AWS) assessed the effects of timber harvesting on water quantity and quality, aquatic habitat, and salmonid resources using a paired watershed approach. There were three small watersheds in that study. Flynn Creek was the undisturbed control watershed and remains undisturbed as a Research Natural Area under management by the USDA Forest Service. Deer Creek was partially cut and demonstrated the effectiveness of streamside management zones. Needle Branch was clearcut and slash burned, and large woody material was removed from the channel, all without a streamside management zone. Needle Branch showed dramatic water quality changes for temperature and dissolved oxygen (DO). Changes in discharge, sediment, nutrients, and coastal cutthroat trout populations were also documented. After 40 years the regenerated forest in the Needle Branch watershed was again ready for commercial harvest. The purpose of this study is to repeat the AWS to examine effects of current forest practices on water resources, and to assess cumulative effects. We hypothesize that timber harvesting under the current Oregon Forest Practices Act rules will not adversely change water quality, fish habitat, or fish. Timber harvesting will occur in two entries. The upper portion of Needle Branch–approximately half the basin area–was harvested in 2009. Phase 1 harvest resulted in statistically significant warming of the stream in the harvest unit, but the magnitude of change was small (0.7°C mean daily maximum in the peak summer temperature period) and drastically lower than during the previous harvest. Age 1+ cutthroat populations responded positively to harvest. There was no discernible effect on the coho salmon population. Nitrate concentrations increased after harvesting, similar to the original study. The Alsea study compliments similar work in the Hinkle and Trask paired watershed studies. These are being conducted simultaneously as part of the Watersheds Research Cooperative at Oregon State University.

1.0 INTRODUCTION

The first comprehensive forest watershed study in North America to test alternative forest practices and their effects on water quantity (discharge), water quality (sediment, temperature, dissolved oxygen, nutrients, etc.), stream habitat, and fish was the Alsea Watershed Study (AWS) established in 1958 in the central coast area of Oregon. The National Council for Air and Stream Improvement, Inc. (NCASI), in cooperation with Plum Creek Timber Company, Oregon State University, the Watersheds Research Cooperative (WRC), USDA Forest Service, and Colorado State University, is implementing a revisit in the same watersheds. The objective is to test the effectiveness of current Oregon Forest Practices Act rules and compare effects from contemporary forestry with those measured following road construction, clearcut harvesting, and prescribed burning in the 1960s.

2.0 STUDY DESIGN AND INFORMATION

Three watersheds are being monitored in this study. In the original AWS Flynn Creek served as a control. It remains undisturbed as a Research Natural Area under management by the USDA Forest Service. Deer Creek was partially cut and demonstrated the effectiveness of streamside management zones in protecting water quality. Needle Branch was clearcut with no streamside protection and then slash burned. Figure 1 shows the overall original AWS study design and Figure 2 shows upper Needle Branch after the harvest and prescribed burn. Needle Branch experienced dramatic stream temperature increases, and dissolved oxygen (DO) concentrations were dramatically lower than those observed in Flynn Creek (Ice 2008). Changes in discharge, sediment, nutrients, and larger-sized classes of cutthroat trout (*Oncorhynchus clarki*) were also documented (Moring and Lantz 1975).

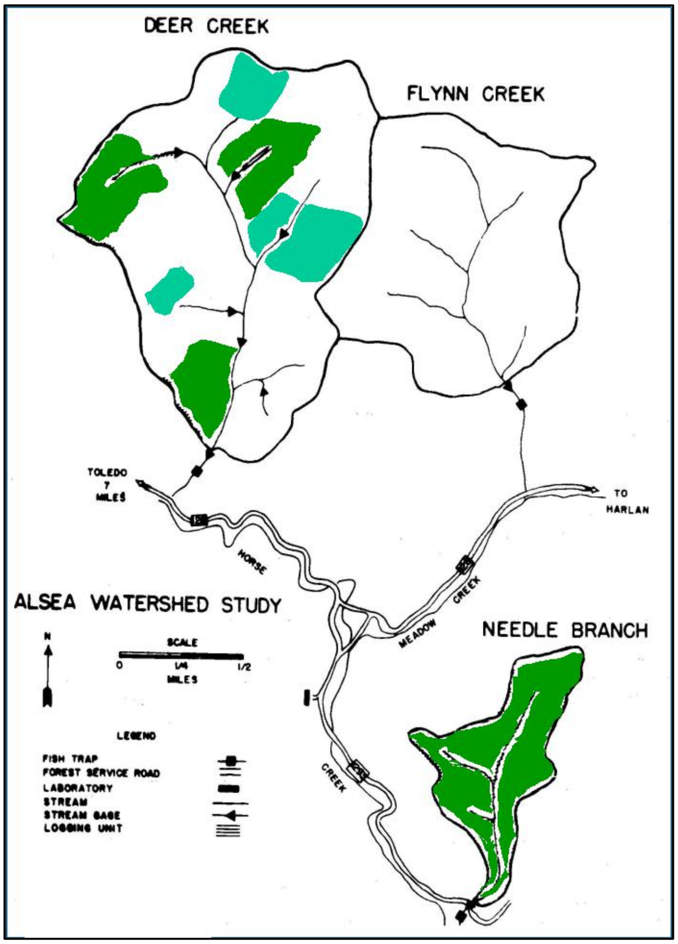

Figure 1. Alsea Watershed Study: dark green shows portions of basins harvested in original study; light green shows timber harvests in 1979, 1988, and 1989 [based on Moring and Lantz 1975]

Figure 2. Needle Branch after clearcutting through stream and broadcast burning [photo courtesy Dr. Jim Hall, Professor Emeritus, Oregon State University]

The Needle Branch watershed is again ready for harvesting and will be managed according to the Oregon Forest Practices Act rules, including riparian management areas adjacent to fish-bearing streams and green-up of adjacent harvest blocks (two harvests separated by time) (Figure 3).

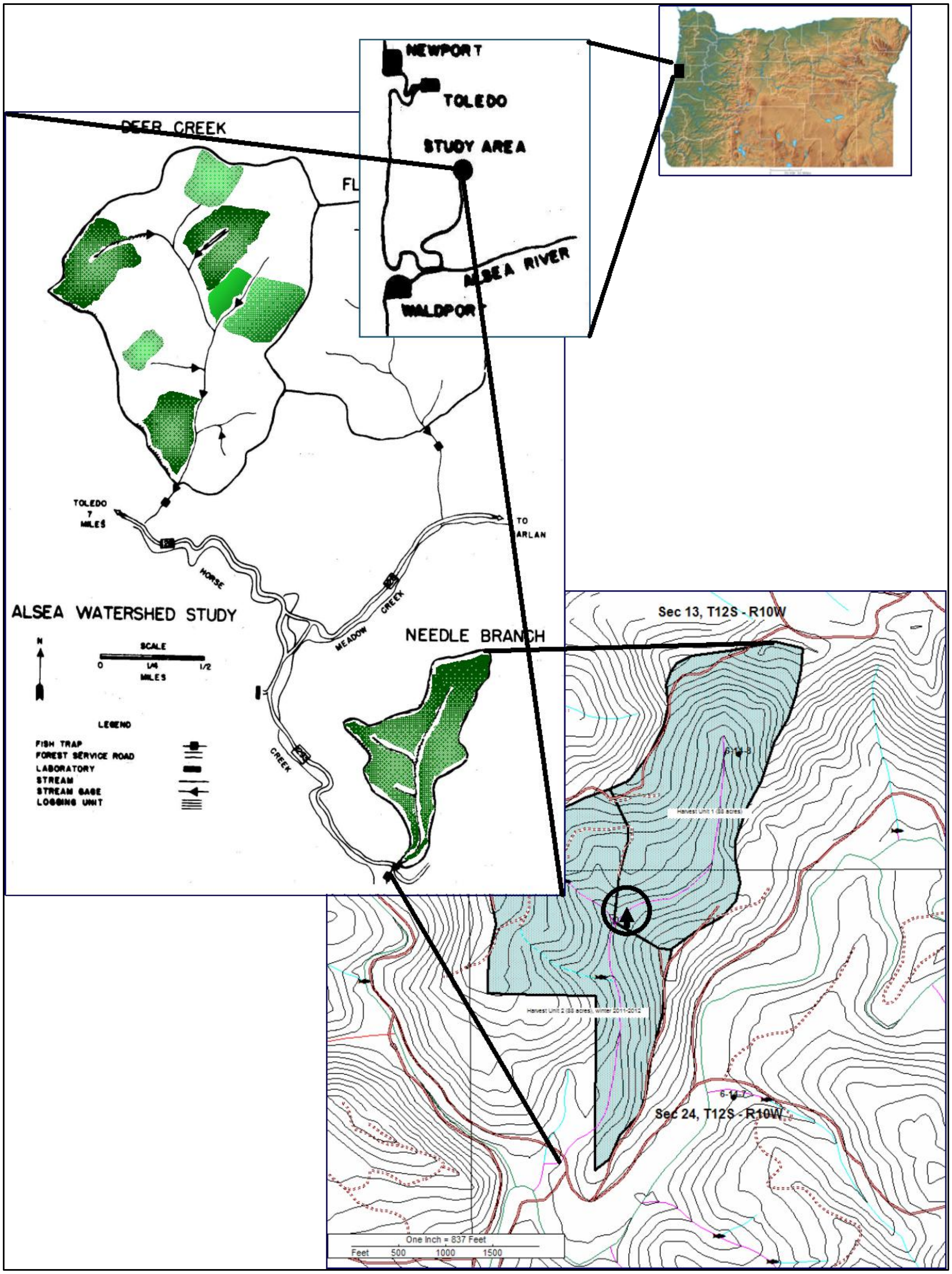

Figure 3. Alsea Watershed Study Revisited showing first (upper) harvest unit and second (lower) harvest unit; circle in center of Needle Branch watershed represents new gauging station at bottom of first harvest unit

This study provides one of the few opportunities to directly compare effects from past management with contemporary practices. Riparian protection under the rules of the Oregon Forest Practices Act is likely to dramatically reduce water resource impacts that were seen in the original study (Figure 4).

Figure 4. Example of contemporary riparian management areas contrasted with Figure 2 from the original study.

Research at the Alsea will address:

- effects of forest management on physical, chemical, and biological characteristics of small streams with resident trout and anadromous salmon
- influences of changes in hydrology and water quality on fish populations and macroinvertebrate communities
- effectiveness of contemporary forestry Best Management Practices (BMPs, forest practice rules) compared to historic impacts with no BMP usage measured in the same watersheds

Table 1 provides a list of water quantity, water quality, and biotic measurements being collected during the AWRS.

Table 1. Parameters measured in Flynn Creek and Needle Branch for the Alsea Watershed Study Revisited (gauging station parameters also measured in Deer Creek)

Gauging Station Measurements (Temporal Variability)	**Watershed-Wide Measurements (Spatial Variability)**
Discharge (cfs) continuous	
Turbidity (FTU) continuous	
Suspended solids (mg/L) TTS triggered; manual samples collected intermittently during stormflow	
Temperature (°C) continuous	Half-hourly temperature recordings throughout fish-bearing stream network during summer
Specific conductivity (µS/cm) continuous	Monthly specific conductivity measurements throughout network (*in situ*)
Dissolved oxygen (DO) (mg/L) continuous (luminescent DO probes)	Annual DO measurements throughout stream network(*in situ*)
Nitrogen (nitrate/nitrite; ammonia, total N) monthly (mg/L)	Nitrate and ammonia (through 2010) sampled monthly throughout stream network (grab)
Phosphorus (orthophosphate, total P) (mg/L)	
	Precipitation (cm) at multiple sites
	Stream shade measured throughout network with fish-eye photos and HemiView software (before and after harvests)
	Single-pass electrofishing census of all pools in fish-bearing stream network during late summer each year
	Fish habitat throughout fish-bearing network (pool area, length, depth), amount of dry channel, streambed surface fines, cover, large wood; measured annually in late summer
	Mark-recapture fish population estimates in index reaches in lower Needle Branch and Flynn Creek
Coastal cutthroat movement into and out of Flynn Cr. and Needle Branch via PIT-tag antennae	Coastal cutthroat movement behavior via bimonthly locations of individual PIT-tagged fish throughout fish-bearing network
	Biomass, abundance, size, growth, condition factor, survival (growth and survival not measured for coho)
	Fish diet (gut contents) in late summer each year
	Macrobenthic invertebrate community assemblage and density, three samples sites each drainage
	Aquatic insect emergence rates (mid-summer)

The AWSR compliments the WRC's efforts at Hinkle Creek and the Trask River (Skaugset 2007) by providing an extended record of monitoring (20 to 40 years of records) and by comparing radically different treatments on the same watershed. It is also being carried out at a scale that allows for finer resolution of spatial variability (through periodic synoptic surveys of water quality and fish, a high spatial density of temperature probes, and watershed modeling). For more information on the WRC visit (http://watershedsresearch.org). A retrospective on the findings from the original study and follow-up research through the early 1990s was published previously (Stednick 2008).

3.0 SUMMARY OF PHASE 1 FINDINGS AND PLANS FOR PHASE 2

The first timber harvest of Needle Branch since 1966 occurred during the summer of 2009, when 92 acres were harvested in upper Needle Branch, followed by a prescribed burn in fall 2009. Chemical site preparation occurred during late summer 2010. Intensive sampling for herbicides has provided new information about the effectiveness of contemporary practices to minimize introduction of chemicals to streams via stormwater.

Water quality monitoring at multiple stations allows us to assess how a riparian management area along fish-bearing reaches coupled with contemporary forest practices can protect water quality. Fish and macroinvertebrate monitoring are conducted to assess biotic responses to management.

Hale (2007) reported on pretreatment conditions of the study basins. He showed (see also Hale et al. 2007a, b) that discharge, sediment, temperature, and measured nutrients were within the 95% confidence limits established during the original pretreatment period, 1959 to 1965 DO monitoring in Needle Branch shows lower concentrations occurring naturally during the summer when low streamflows go subsurface (Ice 2008). Pre-treatment (calibration) monitoring of summer fish habitat (Gregory et al. 2008; Doug Bateman, unpublished data) revealed that much of the Needle Branch stream network goes subsurface in late summer even though this stream supports coho salmon (*Oncorhynchus kisutch*) and cutthroat trout.

A summary of findings from the first harvest entry (Phase 1) of the AWSR is provided below. Many of these findings were presented at a Watershed Research Cooperative Science Symposium at Oregon State University in April 2013. The presentations can be viewed via links on the WRC website (http://watershedsresearch.org). All components are scheduled to be published in a special edition of the journal *Forest Science*. Manuscripts are planned for submission in spring 2015. Research plans for the duration of the study, beginning with Phase 2 harvest in fall 2014, are also included.

3.1 Hydrology–Water Quantity

Although dramatic in physical appearance after timber harvesting without a streamside management zone, slash burning, and channel clearing by tractor, the original Needle Branch harvest resulted in water quantity changes that were similar to timber harvesting practices of the time (Harris 1977). The original study ran from 1959 to 1973. The three main stream gauging stations coupled with water quality sampling were reactivated from 1989 to 2002 with partial NCASI and Colorado State University support. Later support came from Oregon State University and NCASI under the WRC.

Using a paired watershed approach as in the original study, Flynn Creek remains undisturbed and serves as the control wherein water resource responses from harvesting were assessed for departures compared to pretreatment regressions between the control and the treatment watersheds. Annual water yield (annual streamflow expressed as a volume or depth over the watershed) increased up to 26 inches immediately after the original harvesting on Needle Branch (Harris 1977). Water yield increases were not detected in Deer Creek with three small clearcuts (25% of watershed area) and streamside buffers. Post-treatment monitoring for seven years (1967-1973) did not show a return to pretreatment conditions. A reactivation of stream gauges and water quality monitoring in 1989 and subsequent monitoring demonstrated that annual water yields in Needle Branch returned to pretreatment levels 31 years after harvesting (Stednick 2008). Other streamflow metrics, including peak flow and low flow events, did not change significantly during post-treatment compared to the pretreatment period. However, days of no flow were observed in Needle Branch that were not seen earlier, either pretreatment or after harvesting.

A trapezoidal weir was installed and instrumented below the new (or upper) timber harvest unit in Needle Branch in 2006 to monitor water resources changes following the Phase 1 timber harvest. As part of a graduate student study, an H-flume was installed at the headwaters of Needle Branch (Hale 2012) and determined that residence time of precipitation waters was a function of local geology and can help address the question of streamflow generation mechanisms with respect to processing of meteoric (atmospheric) waters.

Precipitation gauges were co-located with the three main gauging stations and a weather station was installed at the bottom of Needle Branch in 2008. Approximately 44% of this precipitation record has been lost due to poor maintenance and servicing of the gauges, which has since been rectified. Phase 1 harvest of upper Needle Branch increased annual water yield up to 26 inches, similar to the water yield increase in the original study. Streamflows during summer and early fall months appear higher, but do not translate downstream (John Stednick, personal communication). The largest increases were in the fall months, when the soil moisture deficit is recharged and streamflow responds more quickly to precipitation events. Qualification of these results is needed because streamflow records of annual water yield from Flynn Creek suggest a significant decrease over the past 12 years due to gauging error (Stednick, personal communication). This complicates assessment of changes in Needle Branch after timber harvest. Alternative methods of streamflow interpretation at Flynn Creek and/or a switch to Deer Creek as the control watershed are being investigated.

Phase 2 Objectives

1. Maintain four stream gauging stations to correctly record stage and convert to streamflow; includes increased site visits and stream discharge measurements

2. Compile streamflow records for entire study period to assess effect of second timber harvest on streamflow metrics of annual water yield, low flow, and peak flows

3. Determine if cumulative streamflow effects occur from nested timber harvest units

3.1.1 *Approach*

Stream gauging will continue, with increased site visits and improved site servicing instructions to obtain better quality stage-streamflow measurements. As noted, Flynn Creek may not serve as a control watershed because sediment deposition behind the weir has compromised the stage-discharge relationship. Streamflow prediction models are being developed to estimate missing streamflows. Streamflow data will be analyzed with analysis of covariance (ANCOVA) and before-after control-impact (BACI) statistical methods.

3.1.2 *Timeline and Deliverables*

Database

Streamflow and precipitation data will be added to the hydrometeorological database with metadata as available.

Manuscripts

The effects of contemporary forest harvesting practices on water resources following timber harvesting in Needle Branch, Oregon Coast Range

Streamflow stationarity in forested watersheds in the Oregon Coast Range

3.2 Hydrology–Water Quality

The original AWS produced two key findings for water quality. First, the control watershed, Flynn Creek, had higher nitrate concentrations than either harvested watershed, either pre- or post-treatment. Nitrate was the only nitrogen form measured. Higher nitrate was attributed to the presence of nitrogen fixing alder; however, additional monitoring suggested that the story is more complex than the areal extent of alder (Kern and Stednick 1990). Second, nitrate concentrations in Needle Branch increased after harvesting and the increase lasted over the two year post-harvest monitoring period (Brown, Marston, and Gahler 1973). Part of that study calculated the nitrate nitrogen flux out of the watersheds. Science at the time identified maintenance of site productivity as a concern based on Hubbard Brook findings of significant nitrogen loss after harvesting (Bormann and Likens 1973).

Water quality monitoring from 1989 to 2002 showed that these patterns remained the same, nitrate concentrations and fluxes from Flynn Creek were higher than from the treatment watersheds (Kern and Stednick 1990; Hale 2008; Stednick 2008). As part of the AWSR subbasin water quality monitoring was initiated in all three study watersheds in order to identify spatial and temporal variability in nitrate concentrations. Water quality changes were variable, but exhibited consistent patterns between sites (Hale and Stednick, in prep).

Water quality monitoring before and after harvesting in Phase 1 with contemporary BMPs shows a remarkable similarity to nitrate responses without BMPs. Nitrate concentrations increase with ‘flushing’ of the soil mantle during fall storms and concentrations decrease over the hydrograph. Part of this is due to dilution of concentrations with streamflow and biological uptake during the growing season. Total nitrogen was measured, but in general nitrate represents 95+% of the total.

Ammonium concentrations were usually below detection limits. Similarly, orthophosphate and total phosphorus were measured, with the inorganic fraction (ortho) representing the bulk of the total phosphorus flux and neither showing much response to harvesting.

In Phase 2, monthly water quality monitoring will be reduced to sampling the main gauging stations (FC-G, DC-G, NBL-G) and the upper gauging stations (NBU-G, NBH) in Needle Branch. The subbasin water quality sampling program will be discontinued. Analysis for ammonia will be discontinued at all monitoring stations. Monthly grab samples collected at the gauging stations will be analyzed at NCASI's West Coast Regional Center laboratory for nitrate-nitrite, total nitrogen, and orthophosphate. Total phosphorus will be analyzed if the orthophosphate concentration in a sample is >0.04 mg/L, the 75th percentile of Flynn and Deer Creek gauging station data from Phase 1. Analyses will be conducted using the same analytical methods applied during Phase 1. Field duplicates will continue to be collected once a quarter as described in the Phase 1 quality assurance project plan (QAPP). Laboratory quality assurance measures will continue as described in the Phase 1 QAPP.

3.2.1 *Approach*

Stream gauging will continue, with increased site visits and improved site servicing instructions to obtain better quality stage-streamflow measurements. As noted, Flynn Creek may not serve as a control watershed because sediment deposition behind the weir has compromised the stage-discharge relationship. Streamflow prediction models are being developed to estimate missing streamflows. Streamflow data will be analyzed with ANCOVA and BACI statistical methods.

3.2.2 *Deliverables*

Database

Stream nutrient data will be added to the hydrometeorological database with metadata as available.

Manuscripts

The effects of contemporary forest harvesting practices on water resources following timber harvesting in Needle Branch, Oregon Coast Range

Landscape elements as determinants of nitrate concentrations on forested watersheds

Cumulative effects of timber harvesting practices on surface water quality

3.3 Suspended Sediment Dynamics

The effects of timber harvesting on suspended sediment concentrations and loads are major concerns, but are often catchment specific. Suspended sediment loads can be affected by elevated erosion rates as a result of soil disturbance. In addition, suspended sediment flux can be affected by higher discharge rates associated with reduced rates of evapotranspiration following forest disturbance. Increased sedimentation in streams may degrade water quality and habitat availability in stream ecosystems.

3.3.1 Objectives

Phase 1

1. Determine the effect of contemporary forest harvesting practices on suspended sediment concentration and load in Needle Branch

2. Determine if the effect of contemporary forest harvesting practices on suspended sediment is driven by higher discharge, soil erodibility, degree of hillslope/stream connection, or a combination of these mechanisms

3. Determine if the current suspended sediment being flushed originates in the lower portion of Needle Branch (downstream of treated area)

Phase 2

4. Determine if the additional harvesting activity in the lower half of Needle Branch will have a multiplicative effect on suspended sediment loads

3.3.2 *Approach*

Phase 1

To determine if contemporary timber harvesting practices have had an effect on suspended sediment dynamics in Needle Branch we will use a paired watershed approach to compare suspended sediment loads and concentrations at the upper gauge in Needle Branch to those at the gauges in Flynn and Deer Creeks. These comparisons will be made across pre- and post-treatment periods as well as for individual years and storms if data are robust enough to support such analyses. This will allow us to examine intra-annual and inter-annual variability in the relationships between precipitation, discharge, and sediment load. The analysis will probably highlight similarities and differences among watersheds. We will also examine sediment exceedance curves from all gauges in order to assess the impacts of harvesting practices on total suspended sediment (TSS) distributions.

Suspended sediment may be affected by discharge, soil erodibility, degree of hillslope/stream connection, precipitation intensity, or a combination thereof. In order to determine which of these mechanisms may be driving TSS dynamics, we will compare rating curves and coefficients (Warrick 2014). If precipitation data are robust enough, this analysis will be supported by comparing precipitation-discharge and precipitation-suspended sediment load relationships.

Qualitative evidence suggests that suspended sediment may have been deposited in the reach between the upper and lower gauges in Needle Branch. This will be evaluated using many of the previously mentioned analysis (e.g., inter-annual and intra-annual analyses of discharge vs. sediment load and sediment exceedance curves), except that the upper and lower gauges in Needle Branch will be compared to one another. In particular, we will examine the suspended sediment yields of both gauges. If material is being trapped in this lower reach we expect that yield will decrease between the upper and lower gauge. Other methods may also be used to determine if this process is occurring (e.g., changes in the turbidity TSS relationship between gauges).

Phase 2

If suspended sediment is being deposited into the lower reach of Needle Branch we expect higher runoff caused by the Phase 2 harvest to flush this material. This would result in higher than expected (from a climate discharge model) sediment loads and concentrations at the lower gauge. Impacts of contemporary forest harvesting practices in the lower reaches of Needle Branch will be analyzed using the same approach as Phase 1 to facilitate comparisons. The critical analysis will be comparing rating curves and coefficients for the upper and lower gauges pre- and post-Phase 2 harvest.

3.3.3 *Timeline and Deliverables*

Manuscript

Suspended sediment dynamics after clearcut harvesting using contemporary harvesting practices in the Oregon Coast Range

This manuscript will explore suspended sediment dynamics at all gauges after the Phase 1 harvest. We are waiting for quality assurance/quality control (QA/QC) on discharge and turbidity data. Once these data are furnished we expect to finish a draft of the manuscript within 6 to 12 months.

Preliminary report

Alsea Watershed Study Revisited: Suspended sediment dynamics after the Phase 2 treatments

We will prepare a preliminary report that examines suspended sediment dynamics after the Phase 2 treatments. In particular, we will explore the question of whether suspended sediment is settling in the lower reach and being flushed out by the second treatment. This report will require that discharge, turbidity, and suspended sediment data from the post-treatment period (summer 2014 to summer 2015) are processed and made available relatively efficiently. With that caveat, we expect to produce a report within 3 to 6 months of receiving the data.

3.4 Temperature

In the AWS the absence of a vegetative buffer, the stream cleanout, and the broadcast burn exposed the entirety of Needle Branch to direct solar radiation. Maximum post-harvest stream temperatures rose more than 10°C above pre-harvest levels for 1-2 years (Brown and Krygier 1970). This warming was believed to be a source of stress to the fish populations in Needle Branch, and may have contributed to direct mortality where dissolved oxygen was low (Hall 2008). In Deer Creek where streamside buffers were used along fish-bearing reaches, the stream temperature response was minimal. This contrasting response provided the rationale for riparian buffer strips (Lantz 1971). Shade retention for stream temperature protection was a key feature of Oregon’s first forest practice rules (Hairston-Strang et al. 2008). Recent research has shown that current rules for streamside management along small and medium streams in the Oregon Coast Range result in slight warming (0.7°C, on average, Groom et al. 2011). The effect of this warming on fish populations has not been quantified. The purpose of the AWSR is to measure how contemporary forest practices affect temperature and other stream characteristics, and to determine how fish respond. We hypothesize that small changes in temperature are likely to occur, but this will not have a negative effect on fish in Needle Branch, as compared to the Flynn Creek control.

3.4.1 Objectives

Phase 1

1. Quantify the magnitude of post-harvest temperature change in Needle Branch:
    a. the buffered (fish-bearing) reach
    b. the unbuffered reach upstream of the limit of fish distribution
    c. the lowermost gage site
2. Estimate the effect of this change on the salmonid rearing environment during summer

Phase 2

3. Quantify the magnitude of post-harvest temperature change in Needle Branch after full-basin harvest, and compare to results of original AWS
4. Quantify the recovery of temperature in upper Needle Branch after Phase 1 harvest

3.4.2 *Approach*

Phase 1

In the AWSR stream temperatures were measured at fixed locations throughout the study basins. At the gaging stations, temperatures were measured at 10-minute intervals year-round. At temperature-specific monitoring stations, data were recorded at 30 minute intervals during the summer warm weather period (June to August). Shade was measured pre- and post-harvest using a convex spherical densiometer and fisheye photographs. Pre-harvest shade averaged ~94% in Needle Branch and 80% in Flynn Creek. Post-harvest shade averaged 82% in the treated portion of Needle Branch. Changes in mean maximum daily temperature in Needle Branch were compared to sites in Flynn Creek with the best pre-harvest correlations using standard BACI statistical techniques (Stewart-Oaten et al. 1986; Stewart-Oaten and Bence 2001). The analysis was focused on three areas: (1) the upstream limit of fish distribution (immediately below the un-buffered headwaters); (2) the downstream end of the harvest unit; and (3) the lower-most gage. The mean daily maximum water temperature from mid-July to mid-August warmed 0.7°C, as measured downstream of the harvested reach. Small but marginally significant warming (0.5°C) occurred in the unbuffered portion of the harvest unit measured immediately above the limit of fish distribution. There was some evidence of warming at the lowermost gauge site, approximately 1000-m below the harvest unit, but this is believed to be related more to the proportion of surface vs. groundwater at the monitoring site than to conveyance of warm water from the harvested reach. Throughout the study, weekly maximum temperatures in the treatment reach remained well below the 16°C numeric criterion that is designed to protect core cold water rearing areas for salmonid fishes. Undisturbed Flynn Creek exceeded this criterion once (2006) during the seven years of this study. Deer Creek and lower Needle Branch also exceeded this criterion in 2006. Warming in Needle Branch exceeded the Protecting Cold Water Standard, which allows a 0.3°C increase due to human sources when waters are below the numeric criteria..***Phase 2***

In Phase 2 temperature monitoring will continue as before. The spatial density of temperature dataloggers was increased in 2014 (the summer before final harvest) to gather information for testing the utility of Newton's Law of Cooling in predicting changes in temperature associated with harvest (Davis et al., in prep). Stream temperature changes will also be examined in respect to their role in the fish response in Needle Branch. Methods for this will include calculation of degree-days using continuous temperature data from the gaging stations.

3.4.3 *Timeline and Deliverables*

Manuscript

Stream temperature response after clearcut harvesting using contemporary harvesting practices in the Oregon Coast Range

The focus of this manuscript will be a Phase 1 comparison of the AWSR with the AWS findings for temperature, including support for interpretation of the fish response. Estimated date for submission to journal: Fall 2015.

3.5 Dissolved Oxygen

The concentration of oxygen dissolved in water affects aquatic organisms and is a primary indicator of the condition of aquatic systems. States set water quality criteria or standards for dissolved oxygen (DO) to protect beneficial uses of water. Low DO concentration is one of the leading causes for streams to be listed as impaired under the Clean Water Act, although this is mainly a result of industrial and community waste discharges or nonpoint source loads unrelated to forest management.

The forest management community has long recognized that unrestrained logging and site preparation may depress DO concentrations in adjacent streams by exposing them to direct solar radiation resulting in elevated temperatures (with removal of riparian shade), impounding channels (reduced re-aeration rates), and adding fresh, oxygen-depleting slash (biochemical oxygen demand or BOD). The original AWS highlighted the potential to depress DO concentrations with unrestrained management practices. DO concentrations in Needle Branch in the AWS were depressed compared to a control watershed and to expected concentrations (based on flow data). Results from that study led to BMPs designed to protect streams from these types of impacts. However, monitoring and research now indicate that DO concentrations may be naturally low in some forest settings, including Needle Branch.

3.5.1 Objectives

Phase 1 & 2

1. Determine the effect of contemporary forest harvesting practices on dissolved oxygen concentrations in Needle Branch

A re-examination of the AWS finds that the unbuffered treatment stream had geomorphic and streamflow patterns that naturally resulted in low DO concentrations. Some researchers use variations in DO and other dissolved gases to detect gaining reaches (stream reaches that are being recharged by inflow of groundwater or hyporheic flow). Needle Branch is particularly susceptible to lower DO concentrations because late in the season some reaches flow subsurface and then re-emerge downstream. Oxidation of organic and inorganic material during subsurface flow without an opportunity for re-aeration can depress DO concentrations. The presence of alder and oxidation of alder-released nitrogen may also contribute to the response seen in Needle Branch. Based on a review of DO patterns before and after the most recent harvest (as part of the AWSR), contemporary forest management does not appear to exacerbate DO conditions. In fact, DO concentrations may be elevated by increased streamflow, as seen in other research.

One of the mysteries from the Alsea is how fish are thriving in reaches that display very low DO concentrations. We hypothesize that high temporal and spatial variability in DO allows refugia to fish during critically low DO periods. Another anomaly for Needle Branch is its combination of low streamwater temperatures and low DO concentrations during late summer and early fall. Key research needs for the next phase of the AWSR include a synoptic survey to determine whether the hypothesized spatial variability in DO concentrations is real and related to subsurface reaches and downstream gaining reaches. Another valuable baseline dataset would be to collect water samples this summer for biochemical or chemical oxygen demand analysis to determine whether loads are substantially altered as a result of contemporary forest practices with the use of riparian management areas.

3.5.2 Approach

Phase 1

The findings from the AWS and AWSR on DO concentrations teach us important lessons about contemporary forest management and applications of water quality standards:

- Unrestrained forest management has the potential to depress DO concentrations, even for cold, high energy forest streams.

- BMPs can largely mitigate these impacts.

- Contemporary forest management does not appear to cause the same patterns of reduced DO concentrations, especially during early summer. There may even be an increase in DO concentrations as a result of elevated discharge and resulting reductions in the channel lengths experiencing subsurface flow.

- Natural factors, such as streamflow that goes subsurface across channel reaches, and the presence of nitrogen-fixing alder can cause a stream that appears well protected to experience depressed DO concentrations.

- Native fish are able to subsist and even thrive despite low DO concentrations. This is probably a result of high DO concentrations in some areas of the stream and low temperature stress being experienced by the fish.

- Forest streams have recovery mechanisms (e.g., re-aeration) that can improve water quality downstream and over time, whether those water quality conditions are caused by human or natural conditions.

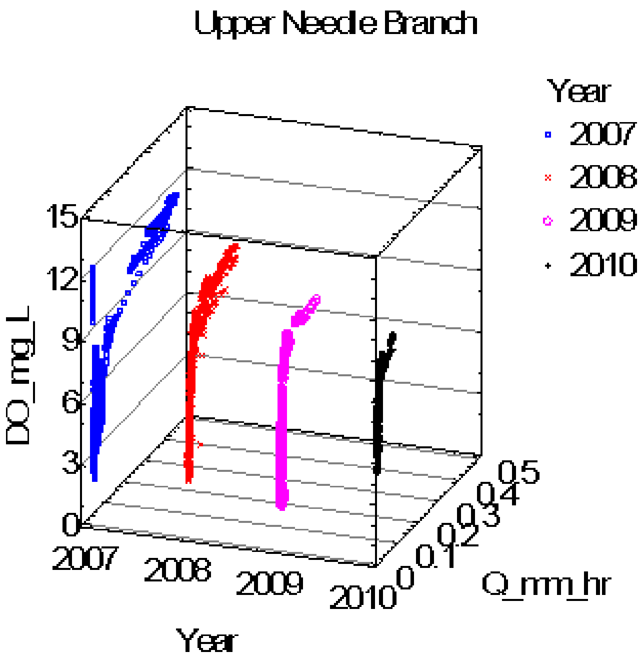

Figure 5. Three dimensional graph of DO concentrations before (2007-2008), during (2009), and after (2010) harvest in upper Needle Branch against discharge; DO concentrations consistently fall when discharge is low and increase with increased flow

Phase 2

In Phase 2 dissolved oxygen will be measured as before, and QA checked using the same criteria but spatially dense surveys will be used to pinpoint low DO locations during the summer low flow season.

3.5.3 Timeline and Deliverables

Manuscript

Stream dissolved oxygen response after clearcut harvesting using contemporary harvesting practices in the Oregon Coast Range

The focus of this manuscript will be a Phase 1 comparison of the AWSR with the AWS findings for dissolved oxygen, including support for interpretation of the fish response. Estimated date for submission to journal: Fall 2015.

3.6 Fish

The response of salmonid fishes to contemporary forest management is a focus of all three of Oregon's ongoing paired watershed studies. Coastal coho are listed as threatened under the federal Endangered Species Act, and forest practices are constantly under review. In the Alsea, cutthroat trout response is of particular importance because of the negative effects observed after the original harvest (Moring and Lantz 1975).

3.6.1 Objectives

Phase 1

1. Determine the effect of contemporary forest harvesting practices on fish habitat and salmonid fish populations in Needle Branch

3.6.2 *Approach*

Phase 1

Fish Sampling. Electrofishing surveys will be conducted every summer. Single-pass removal estimates (Bateman, Gresswell, and Torgersen 2005) will be made for all pools and cascade habitat units in both Needle Branch and Flynn Creek. In addition, mark recapture methods will be used to generate population estimates from four sites in both Flynn Creek and Needle Branch. These sites represent approximately 20% of the stream length sampled during the AWS and were established by Gregory et al. (2008) and expanded to estimate salmonid abundance over the area sampled in the AWS. Fork length and weight will be recorded for all salmonids. Scale samples will be collected from a subset of fish for age and growth analysis. All cutthroat trout ≥100 mm will receive a 23 mm half-duplex (HDX) passive integrated transponder (PIT) tag. Presence data will be collected on a habitat-unit basis for additional aquatic vertebrates including lamprey, sculpin, pacific giant salamanders, and tailed frog tadpoles. To provide a more precise estimate of abundance, approximately 10% of the channel length in each stream will be selected for mark-recapture sampling. Recapture areas will include all geomorphic habitat unit types. Survival and distribution of coastal cutthroat trout will be monitored via bimonthly continuous surveys of the channel using portable PIT antennae and a single fixed-site PIT station with two antennae located at the downstream weir in each watershed.

Statistical analyses. Potential effects of logging on all stream habitat and fish population responses except fish survival were analyzed using *t*-tests on the differences between catchments in each variable before and after logging; that is, a BACI analysis (Stewart-Oaten et al. 1986; Stewart-Oaten and Bence 2001).

Habitat Sampling. Habitat inventories were conducted for the fish-bearing portion of the channel prior to summer electrofishing surveys in both streams. Habitat measurements were nested hierarchically into segments (Frissell et al. 1986; Moore, Jones, and Dambacher 1997), geomorphic reach types (Montgomery and Buffington 1997), and pool, riffle-rapid, cascade, and vertical step habitat-unit types (Bisson et al. 1982). Estimates of wetted width, length, vegetative cover, active channel widths, and substrate were recorded for each habitat unit (Moore, Jones, and Dambacher 1997). Maximum depth was collected for each wetted habitat unit along with thalweg depth at each pool-riffle crest. In addition, cover provided by wood, vegetation, boulders, and undercut bank was summarize by zone of occurrence (Robison and Beschta 1990) for all pools. The geographic location of habitat features was referenced to a network of tree tags. Tags were placed at approximately 15 m intervals throughout the fish-bearing channel in both watersheds. Counts of large woody debris (minimum qualifying dimensions of 10 cm diameter by 2 m length) in zones 1 to 3 (Robison and Beschta 1990) were summarized by tree tag intervals and aggregations were noted. In order to get a more precise and less biased estimate of stream substrate composition, a digital photograph of substrate was collected (Whitman et al. 2003) in the thalweg adjacent to each tree tag.

<u>Results of Phase 1 Harvest</u>. The acute response of coastal cutthroat trout to contemporary timber harvest in Needle Branch under Oregon’s current forest practice rules was markedly different from that observed in the original AWS (Moring and Lantz 1975). Relative to the control watershed of Flynn Creek, fish biomass in Needle Branch significantly increased in response to forest harvest. This was primarily due to increases in the number of age 1+ cutthroat trout, the fish most negatively affected by forest harvest activity in the AWS. Habitat metrics have not changed markedly since harvest. A variety of factors probably account for the difference in the response of coastal cutthroat trout following contemporary harvest in comparison to the AWS. In particular, retention of riparian forest buffers, absence of stream cleaning, and improved logging technology under contemporary forest management practices probably contribute to differences between the two studies.

Phase 2

Phase 2 of the AWSR will be critical for broadening our understanding of the effects of contemporary forest harvest on fish populations. Patterns emerging from the Hinkle Creek study and Phase 1 of the AWSR suggest that short-term fish population responses are concentrated in stream reaches adjacent to harvest activity. For example, in Hinkle Creek changes in fish biomass in response to forest harvest were strongest immediately below harvest units in fishless headwaters. Likewise, in Needle Branch short-term responses of fish biomass and abundance were most pronounced in stream reaches adjacent to Phase 1 forest harvest. These responses may result from a variety of localized changes in factors such as surface discharge, light availability, and secondary production of aquatic invertebrates, which influence the carrying capacity for stream salmonids (Murphy and Hall 1981; Nislow, Sepulveda, and Folt 2004; Harvey, Nakamoto, and White 2006). Phase 2 of the AWSR will allow us to test hypotheses about the mechanisms underlying fish population responses to forest harvest. For example, if the treatment increase in cutthroat biomass observed in Phase 1 was primarily from upstream subsidies, we would predict that Phase 2 changes in biomass would be smaller or would not occur. If, however, the Phase 1 increase in biomass was primarily from changes in light levels we would expect a similar response in Phase 2. In addition, completion of Phase 2 will be necessary to fully compare the effects of contemporary forest management with the original AWS, because Phase 2 involves forest harvest adjacent to the lower reaches of Needle Branch that were the focus of the AWS.

Paired watershed studies are providing important information about the effects of contemporary forest harvest practices on fish populations in headwater streams. Intensive fish sampling conducted as part of these studies is also providing new perspectives on effective monitoring approaches for headwater salmonid populations. In particular, the Alsea and Hinkle Creek studies have employed more spatially continuous sampling of stream habitat than has been traditionally used in fisheries studies. Traditionally, index stream reaches have been monitored and assumed to be representative of conditions throughout the stream network (Gregory et al. 2008). Spatially continuous sampling has revealed that the index reach approach may overlook important spatial patterns in factors influencing fish abundance. Thus, spatially continuous sampling provides a more complete picture of spatial patterning of headwater fish populations and their potential response to contemporary forest harvest. This work has resulted in a number of peer-reviewed publications. Phase 2 of the AWSR will provide crucial data for additional manuscripts planned or in preparation.

3.6.3 Timeline and Deliverables

Manuscript

Salmonid fish population response after clearcut harvesting using contemporary harvesting practices in the Oregon Coast Range

This manuscript will focus on Phase 1 results. Estimated date for submission to journal: Fall 2015.

3.7 Macroinvertebrates

Stream macroinvertebrates are good indicators of both habitat and water quality (Rosenberg, Resh, and King 2008) as well as important components of fish diet (Huryn 1996; Romero, Gresswell, and Li 2005). We are assessing potential changes in these attributes within the Alsea watershed. This study on Flynn Creek and Needle Branch will contribute to our work in the three WRC paired watersheds. Using similar techniques and study designs, these three studies together will provide a robust view of invertebrate responses to contemporary forestry practices in western Oregon. We appreciate the historical significance of the Alsea in particular, and believe that adding invertebrate studies will be an important contribution to the new studies of the watershed.

Our completed paired watershed study at Hinkle Creek in the foothills of the Cascades in southern Oregon (manuscript in preparation) provides context for the Alsea study. At Hinkle Creek, timber harvests were carried out in four replicate fishless headwater drainages in the South Fork watershed. These were compared to four sites in fishless unharvested drainages in the North Fork watershed. By comparing those sites, we found statistically significant increases in benthic macroinvertebrate densities and in aquatic insect adult emergence rates, and changes in benthic macroinvertebrate assemblage composition related to adjacent forest harvests. However, no effects of fishless headwater timber harvests were detected on macroinvertebrates downstream at sites in fish-bearing tributaries or in mainstems.

Following subsequent harvests downstream along the South Fork Hinkle mainstem that also included a dam-break flood, we observed similar statistically significant increases in aquatic insect adult emergence rates and changes in benthic macroinvertebrate assemblage composition after harvest, but no significant changes in benthic densities. The lack of increase in benthic densities in the mainstem sites may be related to consumption of invertebrates by fish that were absent from the headwater sites. Individual fish in mainstem sites changed the type of prey they consumed, reflecting changes in benthic invertebrate communities after harvest.

Macroinvertebrates studies at Alsea are smaller in scope than those occurring at the other two WRC watersheds (Hinkle Creek and the upper Trask watershed) because Flynn Creek and Needle Branch are of more limited size. Concurrent replications of harvest units were also not possible at Alsea, so we are not able to test for headwater versus downstream harvest effects. Instead, we will test for effects on whole streams (comparing Flynn Creek to Needle Branch) during two periods differing in harvest intensity (Figure 6). After the first entry in summer 2009 only the headwater portion of the Needle Branch watershed was harvested; only one invertebrate sample site was within the cut zone. After the second entry in summer 2014 the lower Needle Branch watershed was also harvested. Now most of the watershed is harvested, and all three sampling locations in Needle Branch are within the cut zone. Because the level of harvest in the watershed is greater, invertebrate responses will potentially be more pronounced.

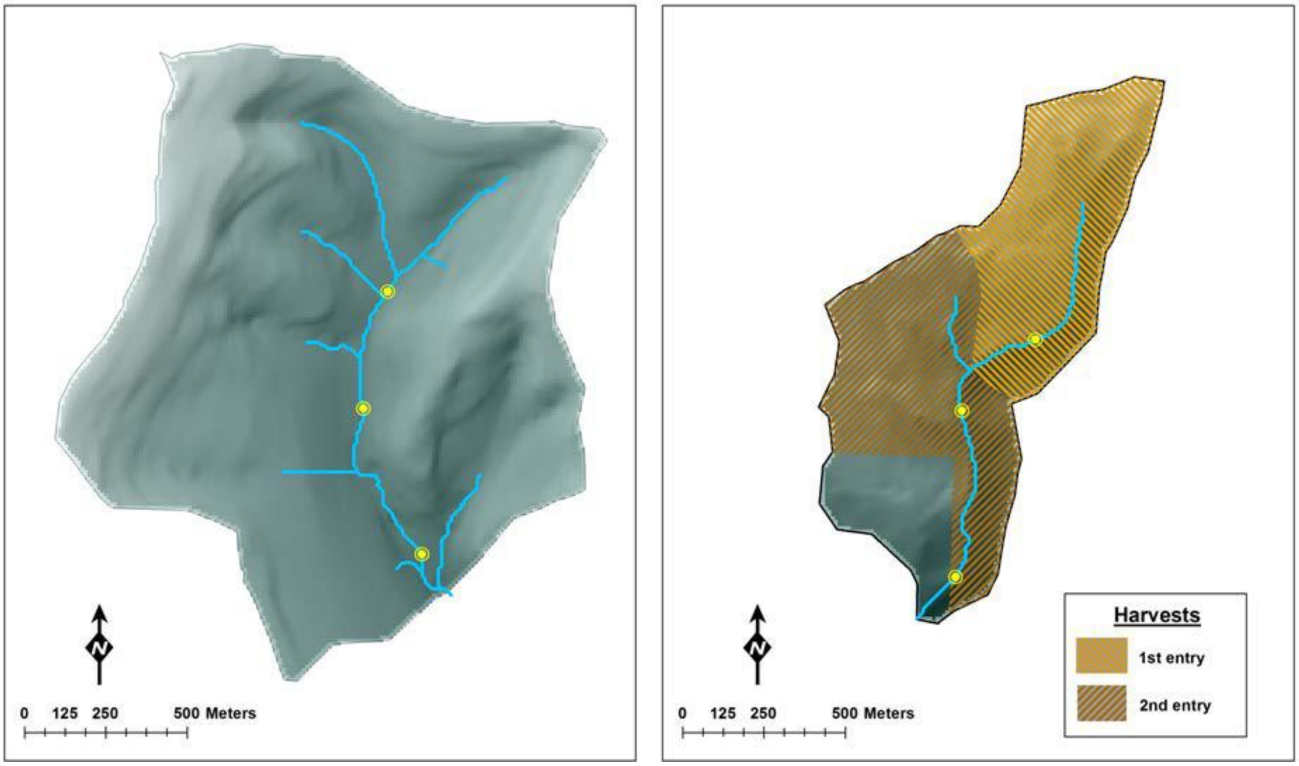

Figure 6. Maps of Flynn Creek and Needle Branch watersheds; yellow dots indicate locations of 30 m macroinvertebrate and fish diet sampling sites

3.7.1 Approach

We use several approaches to understand potential responses to harvest activities. Measures related to productivity include benthic densities and aquatic insect emergence rates. Benthic assemblage composition is related to biodiversity and differential tolerances of taxa. Some or all of these measures may change with altered physical conditions.

To characterize invertebrates and fish diets in the two streams in the Alsea study, we collect samples at six sites (three in Flynn Creek and three in Needle Branch, Fig. 6). Benthic samples are collected in late May/early June each year. We chose this time of year rather than later in the summer because prior to the first harvest in Needle Branch watershed, portions of Needle Branch would go subsurface during summer. Sampling earlier in the year ensures that enough water is present to collect macroinvertebrate samples. Fish diet samples are collected just after benthic sampling in early June. Adult aquatic insect samples are collected after this for an extended period through the entire month of July.

Benthics

Six samples are collected with 0.09 m^2 Surber samplers at randomly selected points within each 30 m long sampling site and preserved in ethanol. Because sample points are selected randomly, multiple stream habitats are sampled roughly in proportion to their occurrence at the site. As a result, the combined macroinvertebrate samples represent the assemblage at the site as a whole. Samples are composited in the laboratory and subsampled using a gridded sieve (Caton 1991) to obtain approximately 500 individuals/site. These are identified to the lowest possible taxonomic level (generally genus), except for Chironomidae that are identified to subfamily/tribe.

Adult aquatic emergence

Adult aquatic insect emergence sampling was added to the AWSR in 2011 because this kind of sampling suggested significant responses to harvest at the other two WRC watersheds. Because this sampling began after the first harvest at Alsea, insect emergence responses will test only for changes related to second entry harvest at lower and middle sites on Needle Branch and Flynn Creek. To collect emerging adults of aquatic insects, four 0.18 m^2 emergence traps are set at randomly selected points over the stream. To avoid contamination of emergence nets set in these narrow streams, samples are collected once a week for two weeks at downstream sites in each stream, then once a week for two weeks at middle sites. These samples are collected after benthic and fish diet samples are complete. All individuals are enumerated and identified to lowest possible taxonomic level (generally genus or species, but chironomids to family).

Fish diet

To measure consumption of prey directly we employ stomach lavage on salmonid fish >60 mm in length collected at invertebrate sampling sites. Fish crews sample specifically for salmonid (cutthroat trout and juvenile coho salmon) diet using lavage techniques in June. Because previous studies have shown great variation between gut samples from individual fish, we try to collect diet samples from 20 fish per site to optimize pattern detection. Because the streams are small, on average about eight to ten fish were captured per pre-harvest site. Fish are anesthetized prior to lavage, and held for full recovery before being returned to the stream.

Types and abundance of prey are identified under a binocular microscope in the laboratory, and prey are measured using an ocular micrometer. Biomass/prey item is calculated by linear regression for specific benthic, emerging adult aquatic, and terrestrial invertebrates (Hodar 1996;

Benke et al. 1999; Sabo, Bastow, and Power 2002). Because we noted a significant positive linear relationship between the log of prey biomass and log of fish weight in our Hinkle Creek work, we standardize prey consumption by fish weight before comparing between Flynn Creek and Needle Branch. Identification in the laboratory also provides information on sources and diversity of prey.

Deploying a BACI design, the study schedule is:

Benthic invertebrates and fish diet

Pre-harvest: 2007-2009

- 3 sites at Needle Branch where successive harvests occurred later in the study
- 3 sites at Flynn Creek serve as control where harvest did not take place

Post-first entry harvest at upper Needle Branch: 2010-2014

- 1 site at Needle Branch adjacent to harvest
- 2 sites at Needle Branch downstream of harvest
- 3 control sites at Flynn Creek

Post-second entry harvest at lower Needle Branch: 2015-2017

- 1 upstream Needle Branch site, adjacent to first entry harvest
- 2 lower Needle Branch sites adjacent to second entry harvest
- 3 control sites at Flynn Creek

Adult aquatic emergence

Pre-second entry harvest at lower Needle Branch: 2011-2014

- 2 sites at Needle Branch downstream of first entry harvest
- 2 control sites at Flynn Creek

Post-second entry harvest at lower Needle Branch: 2015-2017

- 2 sites at Needle Branch adjacent to second entry harvest
- 2 control sites in Flynn Creek

3.7.2 Analytical approach

Benthic macroinvertebrates

We will use ordinations to assess changes in benthic invertebrate assemblage composition. We will also test for changes in univariate macroinvertebrate metrics using analyses of variance (ANOVA). For example, below we compare benthic invertebrate densities (number of individual invertebrates per square meter of stream bottom) before and after the first entry harvest (Fig. 7). Using the plotted data in a two-way ANOVA (main effects: year and stream), we find that invertebrate densities differ from year to year ($p < 0.01$) but there are no overall differences between densities in Flynn Creek and Needle Branch ($p = 0.82$), nor were there density differences between Flynn Creek and Needle Branch in any of the years (interaction: p = 0.72). With the second entry harvest, effects on benthic invertebrates may become apparent with more harvest in close proximity to all invertebrate sampling sites at Needle Branch. In the future we will use repeated measures ANOVAs with Alsea benthic data, as we did with Hinkle Creek data.

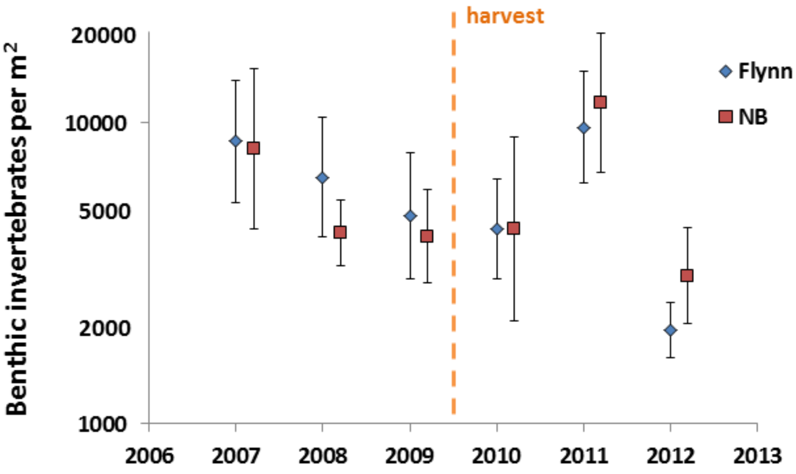

Figure 7. Comparisons of benthic macroinvertebrate densities at sites in Flynn Creek and Needle Branch in years before and after first entry headwater harvest in Needle Branch; red and blue points are mean values for three sites, error bars are standard deviations

Adult aquatic emergence

Because we set emergence sampling up later in this study, aquatic insect emergence data will only be used to assess changes related to the second entry harvest. Even prior to the second harvest going in, aquatic insect emergence rates were higher in Needle Branch compared to Flynn (Table 2). However, as with analyses of stream temperature, we can determine the relationship between emergence rates in Flynn Creek and Needle Branch in the pre-second entry harvest period (Fig. 8). If the second entry harvest affects aquatic insect emergence rates, we would expect the post-harvest values to fall consistently above or below the pre-harvest regression line and mainly outside the confidence bands. As with the benthic data, we will also look for changes in taxonomic composition of emerged insects using ordination.

Table 2. Aquatic emergence (number of emergers/m^2/day)

Year	Flynn Creek lower	Needle Branch lower	Flynn Creek middle	Needle Branch middle
2011	22.6	42.3	19.4	54.4
2012	8.6	22.0	33.9	64.3

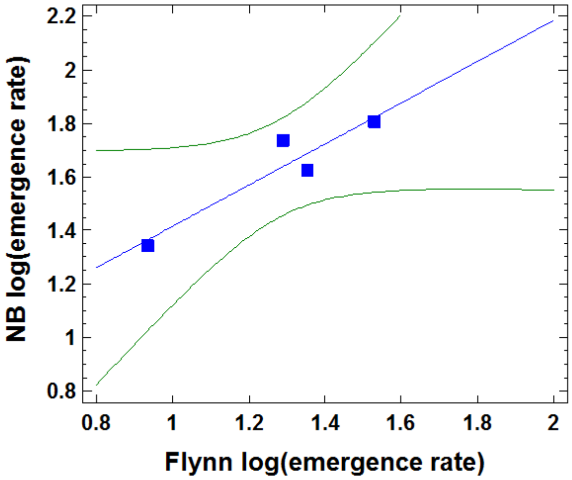

Figure 8. Pre-second entry harvest relationship between aquatic emergence rates at Flynn and Needle Branch sites with 95% confidence intervals; regression shows data from 2011 and 2012, final pre-harvest relationship will have eight points (two per year, 2011-2014)

Fish diet

For fish diet, we will determine if salmonids change the amount they eat or the types of prey they consume following harvests in Needle Branch watershed. Fish diet samples at Alsea are primarily from coastal cutthroat trout. Less than 10% of the fish collected for diet sampling so far were coho salmon. Because of the limited number of coho sampled and the likelihood that these two salmonid species feed differently, we will focus on trout diet but will have some anecdotal information on coho diet as well. On average fish appear to feed somewhat differently in Flynn Creek and Needle Branch both before and after harvest in samples examined to date (Fig. 9). Salmonids ate proportionally more winged adults of aquatic insects and proportionally fewer aquatics in Flynn Creek vs. Needle Branch. Terrestrial prey was important in the diet in both streams.

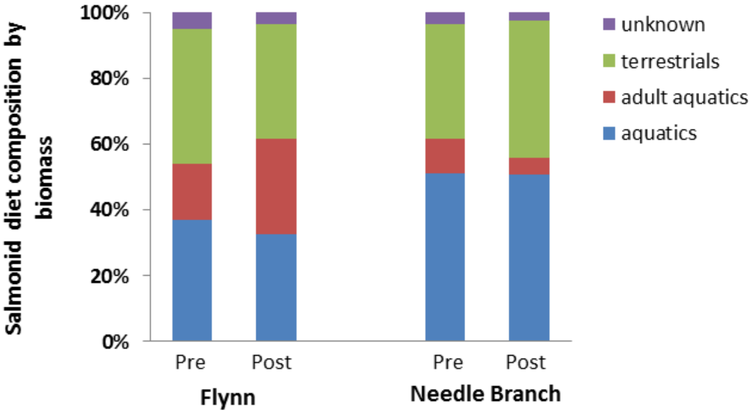

Figure 9. Sources of prey biomass in salmonid diet samples before and after first entry, headwater harvest in Needle Branch watershed

In order to determine whether fish in Needle Branch change the amount they eat after harvest, we first have to account for differences in sizes of fish captured at the various diet sampling locations. We are working with our statistician colleagues to figure out the best way to standardize the amount of prey biomass consumed for fish size. Once we do that, we will calculate the average standardized prey consumption at each site. At that point we will use an ANOVA just like we use for the benthic invertebrate data to compare consumption at the Flynn Creek vs. Needle Branch sites.

Changes in the types of prey being consumed will be assessed with ordination or other multivariate statistical techniques.

The context with other regional watershed studies will be a great strength of this study of Alsea invertebrates. Preliminary results have already indicated that each watershed of the WRC has unique characteristics. Although the low number of sampling sites in the Alsea streams potentially limits statistical power, we can look at significant results from the other two WRC watersheds and determine if the same trends are occurring at the AWSR sites. This would prevent us from missing potentially important biological results that may not appear statistically significant due to the limited number of sites at Alsea. In contrast to AWSR studies of historical harvests, our sampling effort will provide a more comprehensive biological response to contemporary harvest practices. Invertebrates are being considered not only for their potential response to habitat conditions, but also as prey availability to fish. Because fish response at Alsea after the first entry harvest has been strong, we will be particularly interested in comparing invertebrate responses in the presence of fish with those at Hinkle Creek mainstem sites. We hope these varied cross-site comparisons will provide a more robust understanding of responses to contemporary harvest practices in small forested streams of the Pacific Northwest. We expect to have sufficient post-harvest information from Hinkle, Trask, and Alsea by late 2015 to develop a publication comparing invertebrate responses in those watersheds, and will collaborate with our colleagues in developing a multidisciplinary analysis and manuscript about the same time.

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BUDGET

WRC Project	**Alsea**	**Biology**			**Alsea**	**Hydrology**		
Academic Salaries	Number of Individuals	**Cost/ month**	**months**		Number of Individuals	**Cost/ month**	**months**	
1) PI				$0				$0
2) Co-PI				$0				$0
3) GRA	1	$2,667	0	$0	1		0	$0
4) Supervisor (Doug Bateman)	1	$4,756	5	$23,780	1	$4,756	0	$0
5) GS-11 Statistician	1	$6,520	0	$0	1	$6,520	0	$0
6) GS-11 GIS/database(David Hockman-Wert)	1	$4,987	2	$9,974	1	$4,987	0	$0
7)Field Technicians (non-students)	2	$2,324	0	$0	2	$2,324	0	$0
8)Field Technicians	3	$2,305	1	$3,458	3	$2,305	0	$0
9) Crew leader (David Leer)	1	$3,961	3	$11,882	1	$3,961	7	$19,381
10) Assistant crew leader (Steve Clark)	1	$2,769	0	$0	1	$2,769	0	$0
Total Salaries and Wages (OSU)				**$39,119**				**$19,381**
Total Salaries and Wages ("FRESC)				**$9,974**				**0**
Other Payroll Expenses		rates				rates		
1) PI		0		0		0		0
2) Co-PI		0		0		0		0
3) GRA		0		0		0		0
4) Supervisor		1		12344		1		0
5) GS-11 Statistician		0		0		0		0
6) GS-11 GIS/database		0		2992		0		0
7) Field Technicians (non-students)		0		0		0		0
8)Field Technicians (ampibCrewBoss)		0		346		0		0
9) Crew leader		1		7156		1		11673
10) Assistant crew leader		0		0		0		0
Total OPE(OSU)				**$19,846**				**$11,673**
OPE (FRESC)				**$2,992**				**$0**

WRC Project	**Alsea**	**Biology**			**Alsea**	**Hydrology**		
Academic Salaries	Number of Individuals	**Cost/ month**	**months**		Number of Individuals	**Cost/ month**	**months**	
Services & Supplies								
Supplies				$3,000				$3,000
Vehicles				$4,000				$4,000
Travel				$3,500				$3,500
Total Services and Supplies				**$10,500**				**$10,500**
Total Direct Costs(OSU)				**$69,465**				**$41,554**
Total Direct Costs (FRESC)				**$12,966**				**$0**
Indirect Costs								
OSU	rate=	0.18		**$12,504**	rate=	0.18		**$7,480**
FRESC		0.2		**$2,593**		0.2		**$0**
			Field crew salary and travel without Doug, Steve, David					
Total				**$97,529**				**$49,034**
				Total Annual		**$146,563**		

Alsea Paired Watershed Study Revisited - macroinvertebrate budget

Salaries & wages	**Time**	**Annual Cost**
Faculty Research Assistant salary (Bill Gerth)	3.25 months	$10,881
Student field worker	3 ten-hour field days	$300
Work-study student (sample picking in lab)	90 hours	$225
Total Salaries and Wages		**$11,406**
Other Payroll Expenses		
Faculty Research Assistant OPE (Bill Gerth)		$7,608
Total OPE		**$7,608**
Services & Supplies		
Transportation-field vehicle		$450
supplies (alcohol, vials, sample bags, etc)		$400
Total Services and Supplies		**$850**
Total direct costs		**$19,864**
Indirect costs		
OSU Overhead @18%		**$3,576**
Grand total		**$23,440**

This budget covers Bill Gerth's time for annual field work (1.5 weeks), benthic sample ID (1.5 weeks), emergence sample ID (2 weeks), fish diet ID (5 weeks), and analysis and contribution to starting the 3 watersheds manuscript (3 weeks). The overall budget is a bit higher than before reflecting the extra time for contributing to a manuscript.