*Northwest Fisheries Science Center*
**Watershed Program Open House**
**January 24 & 25, 2001**
**Abstracts**

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## Factors limiting productivity of Pacific Northwest Streams – Peter Kiffney[1], John Richardson[2], Robert Edmonds[3], Phil Roni[1]

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Although most of the focus on factors limiting production of anadromous fishes in the PNW has been directed at the physical attributes of freshwater ecosystems, recent research has suggested that many of our rivers are in a nutrient deficit because of declining salmon runs. Thus there is a need to consider both the physical and biological habitat when addressing factors that may limit salmon stocks. In some locations, managers are attempting to boost stocks of Pacific salmon by dumping carcasses into watersheds, and this activity may increase across our region. Fertilization of streams as a restoration tool may prove to be successful in some cases, such as in streams where food is clearly limiting salmon populations. In other cases, however, adding carcasses or inorganic fertilizers may not be an appropriate form of restoration because other factors such as physical habitat may be more limiting. Using examples from our current research, we will address some of the landscape and reach level features that may affect the baseline productivity of stream ecosystems. We suggest there is need to understand the relative importance of the many different factors (habitat, light, nutrients, food web structure) that may control productivity across the diverse landscapes of the PNW before using fertilization or other techniques in stream restoration. We suggest multi-trophic food web models may provide a useful framework to help design studies and experiments that examine factors limiting stream productivity in the PNW. These models also provide a framework for interpreting data and generalizing results so that we can begin to understand the potentially critical role food plays in limiting stocks of Pacific salmon. **(8:45 am)**

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## Stable isotope ratio analysis: A tool for evaluating nutrient restoration in depleted salmon streams – Bill Reichert, Peter Kiffney, Phil Roni, Todd Bennett

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Salmon productivity has been strongly linked to a stream's nutrient status. One approach for nutrient assessment is the analysis of stable isotope ratios of carbon and nitrogen in juvenile salmon tissues. Stable isotope ratio analysis (SIRA) studies have confirmed that the nutrients from salmon carcasses are a significant factor in increased growth of juvenile salmonids and are also being incorporated into aquatic invertebrates and the vegetation associated with riparian habitats. These findings, as well as related studies, demonstrate the utility of SIRA as a tool for

measuring the flow of marine derived nutrients from salmon carcasses into stream/riparian habitats. Here we present an overview of stable isotope ratio analysis, how it is currently used, and how it will be used in several studies here at the Center. At present the Watershed Program has initiated programs to validate the use of the SIRA and to define the limits of interpretation for the isotope ratio data obtained from nutrient enhancement studies. The findings from these validation studies will contribute significantly to anadromous fish management. **(9:00 am)**

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### Utilization of nutrients from spawning salmon by juvenile chinook salmon and steelhead in the Columbia and Snake River basins – Bob Bilby[1], Phil Roni[2], Todd Bennett[2]

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The importance of salmon carcasses to the productivity of coastal streams and lakes has been the subject of increasing study, but little research has been conducted on inland river systems. We used stable isotope analysis of the $^{15}N/^{14}N$ ratio to determine the utilization of salmon carcasses by juvenile chinook salmon (*Oncorhynchus tshawytscha*) and steelhead (*O. mykiss*) in the Salmon and John Day basins. Our goals are to determine the extent marine-derived nutrients were utilized by juvenile salmonids, if there is a spawner density above which little increased $^{15}N$ uptake occurs, and if there is a relationship between the level of marine-derived N in juvenile salmonids and average fish density or size. Preliminary analysis of data from 15 streams indicates that juvenile steelhead and chinook biomass increased with carcass loading. Our results suggest that salmon carcasses are utilized either directly or indirectly by juvenile spring chinook salmon and that salmon carcasses are important for maintaining or increasing productivity in the interior Columbia River Basin. **(9:15 am)**

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### Floods and fish: Effects of peak flows on chinook salmon spawning success – George Pess[1], Eric Beamer[2], Ashley Steel[1]

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Freshwater habitat conditions and spawning density constrained chinook salmon (*Oncorhynchus tshawytscha*) productivity in two Puget Sound river basins. We examined six chinook salmon spawning populations in the Skagit and Stillaguamish River basins and compared flood return period to chinook salmon recruits per spawner between 1974 and 1990. We found that different parameterizations of the Ricker model, describing a density-dependent relationship between spawners and recruits per spawner, were required when flood recurrence intervals were < 15 years and when flood recurrence intervals were > 15 years. Specifically, chinook salmon recruits per spawner were always less than 1 for each spawning population when peak flows were greater than the 15-year recurrence interval. We conclude that long-term increases in peak runoff magnitude and frequency, due to changing climatic conditions or land use effects, may have

profound implications for chinook salmon spawning populations already at low population levels. **(9:35 am)**

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## Relationships between beaver and coho salmon in the Pacific Northwest: Implications for the recovery of a threatened species – Michael Pollock[1], George Pess[1], Dave Montgomery[2]

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In much of the northern hemisphere, beaver activity has long been an important mechanism whereby wood is delivered to small streams. Beaver cut trees in riparian areas and use them to build dams, lodges, and caches. Where beaver populations have been allowed to expand, the effect of these activities has been to alter fundamental chemical, geomorphological and hydrological processes within drainage networks. This results in changes to the productivity, biological diversity and species composition of stream systems. Such changes are often far more dramatic than the changes observed when humans put wood in streams in their attempts to restore these system attributes. For example, in the Pacific Northwest, USA, large wood is often placed in streams for the purpose of creating pool habitat for juvenile salmonids. However, the wood placed by beaver to form one dam can increase the juvenile salmonid carrying capacity of a stream by two to three orders of magnitude over that of a pool formed by a piece of large wood. Dams built by beaver also increase the biological diversity of a number of taxonomic groups. Because beaver are highly effective in restoring multiple stream ecosystem attributes that are of value to humans, they may be the preferred method of bringing wood to streams. We suggest that in stream systems where the hydraulic and geomorphic conditions are such that Using a hierarchical statistical model to link salmonid abundance records to habitat characteristics (SWAM II) beaver can build stable dams, creating food supplies for beaver may be a far more effective restoration tool than direct attempts at habitat improvement through the placement of large wood. **(9:50 am)**

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## Habitat types and use by juvenile salmonids in a large Puget Sound river – Eric Beamer[1], Tim Beechie[2], Martin Liermann[2], Rich Henderson[1]

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The mainstems of most major rivers in the Puget Sound are heavily impacted by different forms of bank stabilization. To assess the local impact of this activity, we examined differences in habitat and juvenile salmonid use between natural and hydromodified banks along an 80-mile length of the Skagit River. The density of sub-yearling chinook (*Oncorhynchus tshawytscha*) and juvenile coho (*O. kisutch*) in natural banks was much higher than that of hydromodified banks. This pattern could be explained by a positive relationship between the densities of these fishes and the amount of available wood cover. In natural banks wood was the most common cover

type, while riprap and rubble were more common in hydromodified banks. The association with wood was not as strong for juvenile steelhead or rainbow trout (*O. mykiss*), and sub-yearling chum (*O. keta*), perhaps explaining the generally smaller differences between the densities of these fish in the two bank types. Juvenile steelhead or rainbow trout appeared to select riprap (but not rubble) and some specific types of wood cover, while sub-yearling chum tended to be most dense in aquatic vegetation or cobble. These findings suggest that the replacement of natural cover-types with riprap and rubble, when stabilizing banks, adversely affects sub-yearling chinook and juvenile coho, and that the use of rubble adversely affects all of the species studied. Use of natural cover types along with bank protection may mitigate some site-level impacts of hydromodification. **(10:05 am)**

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### In-stream factors affecting juvenile chinook salmon migration – Ashley Steel[1], Eric Hockersmith[2], John Williams[1], Steve Neuhauser[3], Peter Guttorp[4]

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Juvenile chinook salmon migration is regulated by a host of physiological and environmental variables. Research on controls of migratory behavior in other species and in other regions provides evidence that in-stream conditions such as water clarity and water temperature may have a strong role in determining fish movements. The results of two separate research projects are combined in this presentation. In the first, radio-telemetry data describe movements of individual hatchery fish through free-flowing reaches of the Snake River basin in 1997. In the second, capture rates at in-stream traps index movements of wild chinook salmon in the Skagit River, 1998. A comparison of the results from the two projects provides evidence of common patterns. Fish were more likely to travel during the night than during the day but reductions in water clarity or increases in flow increased the likelihood of daytime movements. Changes in water clarity, water velocity, and location within the migratory corridor influenced travel speed. Water temperature did not have a detectable effect on movement patterns at this scale. Land and water management actions affecting average water clarity levels and/or the timing of water clarity patterns may impact the quality of migratory habitat. **(10:45 am)**

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### The influence of estuaries on anadromous salmonids: What we know, what we don't know, and what we want to know – Casey Rice[1], Blake Feist[1], Charles Simenstad[2], and Michael Pollock[1]

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As an integral part of the Northwest Fisheries Science Center's salmon science and recovery planning efforts, the Watershed Program is often approached with questions regarding "the estuary," despite the Program's freshwater focus. Consequently, we analyzed literature reviews

to identify research gaps, and are using this to develop estuarine research projects for our Program. We concluded that basic critical functions of estuaries in the life cycle of salmonids (rearing, physiological transition, migration, and refuge) are known; however, there are major knowledge gaps, particularly with regard to anthropogenic stressors and carrying capacity. Current estuarine salmonid habitat research at the Center is focused on hydropower effects in the Columbia River estuary, and on the effects of chemical contaminants in coastal and inland waters of Washington and Oregon. To complement these efforts, we propose three initial projects: 1) relate the degree of watershed and nearshore development to the occurrence and condition of the most estuarine dependent populations in Pacific Northwest estuaries; 2) evaluate the consequences of non-indigenous species (e.g., *Spartina* spp.) expansion, as well as control and eradication measures, on the fitness of anadromous salmonids; and 3) relate patterns of shoreline development to the character of bird, fish, and submerged aquatic vegetation assemblages in nearshore Puget Sound. **(11:00 am)**

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### Factors influencing juvenile coho salmon in coastal Oregon basins: An overview – Cara Campbell[1], Martin Liermann[1], Rich Comstock[1], Peter Lawson[2]

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One of the tasks necessary for managing salmon populations is assessing overall basin production potential. We are developing a two-stage model that links landscape characteristics to juvenile coho density in the Alsea River basin in Oregon. The first stage will utilize GIS to predict in-stream habitat features from a combination of larger-scale, readily available, landscape variables and habitat survey data. The second stage will employ a modified Habitat Limiting Factors Model to predict coho density from these in-stream habitat features. This two-stage approach allows us to estimate coho density for the large, unsurveyed portions of the watershed. Because the results are spatially explicit, they may highlight those areas most in need of restoration, enhancement, or protection. Future work will examine the inclusion of other variables into the model to enhance its utility in predicting the effects of potential landuse decisions. **(11:15 am)**

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### Factors influencing juvenile coho salmon in coastal Oregon basins: A modeling approach – Martin Liermann[1], Cara Campbell[1], Rich Comstock[1], Peter Lawson[2]

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There is often a great deal of uncertainty in the relationships used for making predictions in the management of salmon habitat. We present a simple approach to estimating prediction uncertainty in the context of a model that predicts juvenile coho (*Oncorhynchus kisutch*) winter capacity for streams in the Alsea basin. The end result of the approach is a distribution that

provides an estimate of the probability of finding different densities of coho in a reach (assuming full seeding). **(11:30 am)**

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### The Salmonid Watershed Analysis Model (SWAM): A large-scale landscape analysis for identifying high priority areas for salmon habitat restoration – Blake Feist[1], George Pess[1], Ashley Steel[1], Bob Bilby[2]

**and**

### Using a hierarchical statistical model to link salmonid abundance records to habitat characteristics (SWAM II) – Ashley Steel[1], Blake Feist[1], George Pess[1], Bob Bilby[2]

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Various populations of anadromous salmon and trout have been designated as endangered or threatened under the Endangered Species Act on the west coast of the United States, initiating extensive recovery efforts. With limited resources, a scientifically defensible method for determining areas where recovery efforts should be focused is critical. We examine the relationships between the abundance of chinook salmon redds and freshwater habitat type and condition in the Salmon River basin, Idaho. We used time series of chinook salmon redd counts collected at 23 locations in the basin to assess the spatial distribution of salmon abundance. Relationships between redd density and geospatial datalayers of land use type, landscape characteristics, and climatic conditions were explored using hierarchical linear models. This statistical approach examined these relationships for each year of the redd-count record independently. Interannual consistency in the slope of the regressed habitat attributes was used to determine significance. Redd density was positively correlated with cumulative mean annual precipitation, and total area of naturally non-forested riparian vegetation (non-forested riparian wetlands). In contrast, abundance was negatively correlated with ambient air temperature, density of water diversions, and total area of rangeland. We constructed several predictive models of redd density using various combinations of the significant habitat variables. We used these models to predict redd densities over the entire Salmon River basin. The combination of mapped predictions and the identification of significant landscape and land use characteristics can be used to locate, design, and prioritize conservation efforts and management experiments aimed at salmon recovery. **(11:45 am, 12:00 pm)**

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### Effects of management on riparian-stream linkages – Peter Kiffney[1], John Richardson[2], Robert Edmonds[3]

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Riparian buffer zones are one of the cornerstones of management of streams and rivers in the PNW. It is well know that riparian vegetation plays a critical role in maintaining stream structure and function. Most of our current management of riparian zones is focused on protecting key physical variables such as light that influence in-stream factors such as temperature. Data documenting these relationships along a gradient of riparian buffers are rare, as are attempts to link changes in physical condition with biological properties. We discuss research from two riparian-stream projects: one a large-scale, replicated, small watershed experiment where we manipulated riparian buffer width and the second a study examining the influence of the type (alder vs. conifer dominated) of riparian vegetation on stream community and ecosystem properties. **(1:30 pm)**

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### Watershed-scale patterns of stream temperature change in a Puget Sound river basin – Tim Beechie[1], Brian Collins[2], Michael Pollock[1], George Pess[1]

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Summer stream temperatures are often increased by a variety of land uses that remove riparian forests or increase channel width, causing decreased salmon fitness or survival. However, natural potential shade derived from streamside trees decreases with increasing drainage area, so the relative impact to stream temperatures and the potential for recovery differ with position in the basin. To assess likely stream temperature reductions resulting from riparian restoration, we mapped estimated historical (prior to non-native American settlement) and recent (1990s) stream temperatures in the 1,770 $km^2$ Stillaguamish River basin using empirical models that estimate summer maximum temperature and diurnal fluctuation. We reconstructed historical and recent shade levels with a simple geometric model that required only channel width and riparian tree height as inputs. Channel widths and riparian forest conditions were measured or calculated from historical maps, notes, and aerial photographs. Channel widths were greater in 1990 than in 1860 on average, but fluctuated in the intervening years. A net channel widening and removal of riparian forests both contributed to decreased shade and increased maximum temperature or diurnal fluctuation. The average predicted increase in maximum temperature was 1.4°C, and ranged from a cooling of 0.8°C to a warming of 6.2°C. The largest increases in maximum temperature were in the smallest drainages, and the magnitude of increase decreased with increasing drainage area. Diurnal fluctuations increased an average of 1.1ºC, and were not related to channel size. Watershed restoration efforts are most likely to reduce maximum temperatures and diurnal fluctuations in channels < 60 m wide where shade levels are most responsive to changes in channel width or riparian tree height. **(1:45 pm)**

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### How riparian functions vary with buffer width in forested watersheds of the Pacific Northwest – Michael Pollock

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In the Pacific Northwest, riparian buffers are one of the most important habitat features needed to protect and restore salmonid habitat. Riparian forests regulate the flow of materials and energy into stream systems, thereby keeping streams suitable for salmonids. In this paper I review the important functions of riparian forests and analyze how these functions vary as the width of the riparian forest varies. I also analyze the cumulative effectiveness of riparian buffers on a watershed-scale and assess the likely amount of total riparian functionality that various management strategies will provide. I suggest that an accurate assessment of the effectiveness of riparian buffers in protecting stream habitat can best be obtained at the scale of watersheds rather than at the reach-scale. **(2:00 pm)**

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### GIS-based prediction of sediment supply to stream channels in the North Cascades, Washington – Tim Beechie, Blake Feist

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Sediment supply to streams in the North Cascades is dominated by mass wasting, which reduces salmonid survival and fitness by filling rearing pools, increasing scour or burial of redds, or increasing levels of fine sediment in spawning gravels. Attempts to reduce sediment supply by decommissioning roads and altering timber harvest patterns are common, but typically not identified based on the degree to which land uses have altered sediment supply. To better target restoration activities, we developed a simple technique for extrapolating existing sediment budget data across the landscape. Sediment budgets for 10 sub-basins in the Skagit show that natural rates of sediment supply vary from a low of 33 $m^3/km^2/yr$ in glacial sediments to 130 $m^3/km^2/yr$ in low-grade metamorphic rocks. Land uses such as logging and road building increase mass wasting rates by an average of 4 and 45 times, respectively. We extrapolated these relationships to remaining parts of the basin using GIS data for geology, logging roads, and clearcuts in the past 20 years, then calculated average sediment supply upslope of each 30-m cell in the basin. The resultant map indicates where land uses have increased sediment supply, and therefore where restoration actions are most needed. **(2:15 pm)**

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### Responses of fishes and salamanders to in-stream restoration efforts in western Oregon and Washington – Phil Roni[1], Tom Quinn[2]

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Thirty streams in western Oregon and Washington were sampled during summer and winter to determine the responses of juvenile salmonids, juvenile lamprey (*Entosphenus tridentatus* and *Lampetra spp.*), sculpin (*Cottus spp.*) and giant salamanders (*Dicamptodon spp.*) to artificial large woody debris (LWD) placement. Total pool area, pool number, LWD loading, and LWD forming pools were significantly greater in treatment (LWD placement) than paired reference reaches. Juvenile coho salmon (*Oncorhynchus kisutch*) salmon densities were 1.8 and 3.2 times higher in treated reaches compared to reference reaches during summer and winter, respectively. Densities of age 1+ cutthroat trout *(O. clarki*) and steelhead (*O. mykiss*) did not differ between

treatment and reference reaches during summer but were 1.7 times higher in treatment reaches during winter. No significant difference was detected between densities in treatment and reference reaches for trout fry (age 0+ cutthroat and steelhead), giant salamanders, sculpin or larval lamprey. Lamprey and coho response to LWD placement was positively correlated with LWD forming pools. Mean lengths of all species were similar in treatment and reference reaches. These results indicate that the largest fish response to restoration occurs for those species that prefer pools such as coho and lamprey and at those sites with the largest increase in LWD and pool area. However, the results of my study in no way negate the need to focus on restoring natural processes that create and maintain rather than relying on in-stream manipulations. **(2:30 pm)**

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## Restoration of off-channel habitats for Pacific Salmon – Sarah Morley, Patricia Garcia, Phil Roni

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Off-channel habitats, such as sloughs, alcoves, wall-based channels, ponds, wetlands and other permanently or seasonally flooded areas are important rearing areas for juvenile salmonids. However, off-channel habitats normally associated with floodplains have been routinely isolated or impacted by floodplain and hillslope land uses such as transportation, agriculture, forestry practices, urbanization, and flood control, including the removal of beaver (*Castor canadensis*). While creating off-channel habitat is thought to be one successful form of restoration, little monitoring or evaluation of this approach has occurred. The objectives of this project are to determine the effectiveness of various off-channel habitat restoration techniques by 1) gathering and summarizing known information on off-channel salmonid production, and 2) determining what physical, biological, and hydrological features (e.g., morphology, accessibility, and invertebrate fauna) produce the most successful projects. We have selected 16 off-channel sites in the Skagit River basin of Washington State for evaluation in 2001. Fish density, condition, and seasonal growth by species will be estimated in summer and winter using mark-recapture techniques. We will evaluate the specific relationships between fish density and condition with physical, chemical, hydrologic, and biological site characteristics. These data will help to establish future guidelines for the design and construction of off-channel habitats. **(2:45 pm)**

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## Monitoring of large-river in-stream restoration projects – George Pess[1], Mike McHenry[2], Mike McHugh[3], Tim Beechie[1], Peter Kiffney[1], Martin Liermann[1], and Roger Peters[4]

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The placement of large logjams is becoming a larger component of bank protection and salmon habitat restoration efforts in larger river systems (e.g., greater than 30 meters bankfull width) in

the Pacific Northwest. Over the next several years we will monitor how such restoration efforts affect biological and physical factors such as fish habitat, salmonid abundance, invertebrate production and biodiversity in two large rivers in Western Washington, USA – The Elwha and Stillaguamish. We will attempt to put these efforts in a watershed context by identifying how other physical factors such as changes in sediment supply, riparian condition, and floodplain dynamics affect biological response. We will use a before/after, control/treatment (BACT) design to evaluate how these large logjams affect fish habitat unit evolution, juvenile and adult salmonid use, and relative primary productivity on a habitat-unit (e.g., pool, riffle, glide) and stream-reach (e.g., 0.5 to 1.0 km) scale. Preliminary results suggest that salmon abundance and diversity was positively correlated with primary and secondary habitats created by logjams in both river systems at both scales. Juvenile and adult salmon response to habitat change provides a means to evaluate the hypotheses that underlay in-stream restoration efforts. **(3:00 pm)**

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