Watershed Review

information on water and watersheds

Center for Water & Watershed Studies

Volume 1 Number 4 Autumn 2003

http://depts.washington.edu/cwws

King of fish: The thousand-year run of salmon

The following is excerpted from the preface and last chapter of the new book on the history of salmon runs in Europe, New England, and the Pacific Northwest by David R. Montgomery, CWWS affiliate faculty member, published by Westview Press in October 2003.

Salmon; the word conjures up images of the Pacific Northwest. But not too long ago salmon also filled the rivers of New England and before that Great Britain. What happened?

The stories of declining salmon runs are remarkably parallel across the English-speaking world, yet the similarities are not well known even by people running salmon recovery efforts. I trained to study how rivers and landslides shape topography and only came to study salmon after moving to Seattle to take a job at the University of Washington, where it is hard to study rivers without thinking about salmon. Intrigued by the connections between rivers and salmon, I began to explore how the changing landscapes of the Pacific Northwest affected the evolution and abundance of salmon. Digging into the history of the Atlantic and Pacific salmon fisheries, I found a fascinating story of how valuable public resources can gradually decline despite high-profile concerns over conservation.

Isaac Walton dubbed salmon the King of Fish in 1653. Today we know that much of what Walton wrote about salmon in The Compleat Angler is wrong. Yet, ironically, as knowledge of the salmon, their amazing life history, and their basic habitat requirements grew, the human impacts on salmon and their environment accelerated even faster. We now know more about the natural history of salmon than about how to save them.

continued on page 2

Director's message

Derek Booth

We are running a bit late with the final compilation and mailing of this issue, a consequence of a busy winter and a very successful Annual Review of Center research, held February 6th at the University of Washington. Over 300 people attended, and although we charged a modest registration fee we also took pains to accommodate all interested members of the professional community and general public regardless of their (or their employer's) ability to pay. Abstracts and reports from a number of those presentations will be appearing in the next few issues of this newsletter.

In this issue, we focus on several research projects that have been recently completed by graduate students in the departments of Forest Resources and Civil and Environmental Engineering. We also excerpt from a recently published book from one of our affiliate faculty members, reminding us that ignoring history condemns us to repeat it, not only in matters of state but also in our management and (mis)use of natural resources. ♦

In this issue...

King of Fish continued

Scientists typically argue that we need to do more research, that our understanding of complex natural systems is not yet complete enough, to confidently forecast their behavior. In a general sense this certainly is true. Much remains to be learned about salmon and rivers. The need for more research comes up all the time in salmon recovery efforts. I've made this argument myself at times. But as I learned more about both the history of salmon fisheries and the effects of habitat change on rivers and salmon, I realized that knowledge alone is not enough.

Salmon are not in trouble because people didn't know about the impacts of human actions on salmon runs. Forty years ago, in his opening speech to the Second Governor's Conference on Pacific Salmon in Seattle in January 1963, Washington state governor Albert D. Rosellini declared, "We are presently faced with a desperate situation on salmon. … [T]he ugly truth is that if we continue as we have during the past few years, our salmon stocks are doomed to extinction!" Ignorance was not the primary problem; neither was an incomplete knowledge of the natural history of salmon. The King of Fish is not in trouble because people didn't care about salmon. Laws to protect salmon have been on the books for over a century in the

The King of Fish is not in trouble because people didn't care about salmon.

Pacific Northwest, and attempts to save salmon date back hundreds of years in England. Efforts to save the Columbia River salmon began well before the first dam spanned the river. The biggest problem for salmon lies elsewhere—in the way we make decisions and in the mismatched time scales over which societal processes operate, as well as the slow accumulation of little changes into large impacts that over time can radically alter natural systems. Under human influences the landscape gradually evolved right out from under salmon.

This book is not meant to be a rallying cry to save wild salmon at all cost in every stream across the Pacific Northwest. Neither is it intended to support the rationalizations of those who seek to write wild salmon off in favor of unfettered land use. I don't care more about fish than I do about people. But neither do I believe that we can bring salmon back to their former glory across the region as the human population doubles over the coming century. I suspect that advocates on both sides of the salmon wars will find things to praise and to criticize in this book. Such is the risk of writing about an emotionally and politically charged subject.

The thousand-year run of salmon illustrates how technological advances and land use change can magnify the effects of intensive resource use to eventually exhaust a public good. Details vary from region to region and from river to river. But recurring themes run through the strikingly similar stories of salmon declines throughout the animal's range.

Huge salmon runs initially provided an abundant food source that sustained subsistence economies in Europe, the Northeast, and the Pacific Northwest. In all three areas, native people relied on salmon fisheries they protected through cultural practices that restrained overexploitation. In the absence of technologies to preserve and export salmon, fishing intensity matched the modest needs of local consumption. As long as local human populations depended on local salmon there was a built-in ecological safeguard. People who overfished, or otherwise degraded their fishery, cut off their own life support.

In the thirteenth century, Edward I of England had no scientists, no professional fisheries managers, and no industry lobbyists to contend with. Yet he could see clearly what was needed to protect his country's salmon salmon—access to their habitat, an open connection to the sea, and fishing moderated so as not to overexploit individual runs. Mandates to enforce this vision worked for hundreds of years until fishing and industrial interests began to influence legislation as industrialization and urbanization transformed the landscape.

In the New World, where no authority was willing to limit entrepreneurial access to salmon, the populace increasingly ignored laws and traditional cultural restraints as immigrants less dependent upon salmon displaced native people. At first, an abundant supply of salmon helped feed the lower classes, and farmers considered salmon cheap fertilizer or livestock feed. Once merchants were able to preserve and ship salmon to distant cities, they quickly sent rivers of fish streaming to market. The accelerating pace of technological development compressed the time frame over which this occurred, from centuries for English salmon to one century for the salmon of New England and Canada to decades for the Columbia River runs. But in each region the original, publicly held resource became an overexploited commodity when technology for preservation and shipping made exporting salmon commercially viable.

The transformation of the salmon's habitat into into farms, towns, and cities amplified the detrimental effects of overfishing through reducing the capacity of rivers to support salmon. Clearing of logs and logjams, as well as channel straightening, diking, and damming for flood control degraded salmon habitat in river after river. Already stressed salmon populations crashed as forests were cut and dams blocked rivers and streams. In many areas, pollution from industrial and urban wastes polished off most, if not all, remaining salmon. Finally, urbanization converted some channels into inhospitable concrete-lined ditches. As these changes progressed, salmon conservation efforts failed over and over again as steps to address one cause were undermined by other causes and a general lack of will to enforce laws and regulations.

The English, in transforming the economic profile of their island, sacrificed their salmon for the modern age of the industrial revolution. New Englanders, too, traded salmon for a tamed landscape better suited to support their agricultural needs and industrial aspirations. The feverish rush to extract gold from riverbeds destroyed much of California's salmon. Even before the promise of cheap water and electricity drove the construction of dams that impeded the migration of Columbia River's salmon between the sea and their spawning grounds, most of the Columbia River's huge chinook had already been canned and shipped east. At the same time, the Pacific Northwest's ancient forests that structured salmon habitat were stripped off and converted to timber plantations. Unscreened irrigation diversions sucked not only water from rivers but also young salmon into farmers' fields. In each chapter of this saga salmon habitat or salmon themselves generated capital that helped finance regional development and placed further pressure on wild salmon.

Faith in the ability of hatcheries to produce more fish allowed overfishing and degradation of rivers to continue without acknowledging the loss of salmon as the price of unrestrained development. Modest initial successes of hatchery programs fueled a second round of commercial overharvest. For a time, hatchery fish sustained large commercial fisheries. But instead of rebuilding spawning runs, hatcheries propped up shrinking populations by pumping out smolts ill equipped to survive in the wild. In the end, reliance on hatcheries replaced wild salmon with hatchery fish, and delayed but did not reverse the ongoing decline in salmon abundance.

Once technology enabled intensive open-ocean fishing, even countries that never had, or had already lost, salmon from their rivers, such as Denmark and Japan, could chase salmon out at sea. With this new pressure salmon populations continued to plummet and whole fisheries collapsed. As the price of salmon rose, fish farming became not only profitable, but so successful that farmed salmon now outnumber wild salmon in Europe and New England. They are gaining on wild fish in the Pacific Northwest.

The end result of these recurring chapters has created a story in which once-common salmon have become, or are becoming rare. Salmon returns to Pacific Northwest rivers are just 6 to 7 percent of historic levels. Failure to learn the lessons of past experience is leading to a familiar outcome—the exhaustion of salmon runs. Despite rhetoric to the contrary, modern management of salmon and their habitat provides a superb example of unadaptive management—the failure to learn by experience.

Salmon are resilient, robust animals that can rapidly colonize new environments. They are not like a sensitive bird that can only nest in a special type of tree that occurs in a particular type of forest in a couple places on Earth. Even so, we are managing to drive them to the verge of extinction across much of their range.

Many writers over the past century and a half have remarked that salmon and civilization appear to be mutually exclusive—that the development of the landscape for the use of modern societies must inevitably banish salmon to shrinking refuges uninhabited by people. I reject this argument. Although past experience certainly endorses this view, it is based on the faulty premise that we lack the ability to adapt our behavior to accommodate salmon. Salmon and civilization can co-exist, if we so choose. I hope that this book brings some longer-term perspective to current debates over how to accommodate salmon in the changing landscape of the Pacific Northwest, where the next several decades will be pivotal in determining whether salmon survive in significant numbers. It simply would be tragic to lose wild salmon in the Pacific Northwest because we failed to lean the lessons of Scotland, England, and the Northeast. Moreover, those lessons tell us as much (or more) about our societies and ourselves as they do about salmon. ♦

A male chum salmon fertilizing the eggs of a female.

Abstracts of theses and dissertations

Below are abstracts from recently completed theses and dissertations of affiliated graduate students. The web site has a list of all affiliated students who have graduated, many of their abstracts, and some entire theses or dissertations (http://depts.washington.edu/cwws/Theses/abstracts.html).

Characterizing lowland streams: Riparian and watershed influences on urban and non-urban channels

Catalina Segura Sossa, MS, Civil and Environmental Engineering

This thesis presents a suite of studies focused on the channel network of the Chico Creek watershed, a resource-rich stream system on the Kitsap Peninsula in western Washington State. These studies include: a rapid geomorphic assessment of the main stream network of the Chico Creek watershed, a comparative analysis of two channel-assessment methods, and an analysis of the morphological influences of the near-riparian zone on channel morphology and channel responsiveness to urbanization. In addition to study sites in the Chico Creek watershed, comparative sites were also included from the more highly urbanized watersheds of Juanita, Thornton, Squibbs, and Lewis creeks, all located in and east of the City of Seattle.

Examples of unstable banks in Chico Creek

The Chico Creek stream network has a variety of channel types, which reflect both human alteration and the interactions of geological, biological, and climatic conditions of the basin. Most of the surveyed reaches were classified as forced pool-riffle (FPR) and were located in low-disturbed areas dominated by forested cover. Plane-bed (PB) and constrained plane-bed reaches are in almost all cases the result of human alteration. Cascade and step-pool reaches were uncommon and located in high-gradient areas in the upper section of the basin tributaries.

A multimetrix index of geomorphic channel conditions, the Physical In-Stream Condition Index (PSCI), provided a coarse, but apparently robust, discrimination of the current geomorphic conditions across the channel network of the Chico Creek watershed. Comparisons with an alternative methodology indicated few scoring discrepancies, which were almost entirely located in reaches with gradients higher than about 0.02. Problems were evident from the inclusion of variables in channel-assessment and monitoring methods that are neither replicable across observers nor based on reference conditions common to all encountered channel types.

The PSCI scores were unrelated to the contributing basin land cover. However, some correspondence was found between the score and the local land cover, suggesting that the physical attributes measured by the PSCI are probably influenced by near-stream drivers.

Remarkably different channel morphology was observed between low and high urbanized reaches. Low-urbanized reaches of the Chico Creek watersheds (mostly FPR channels) have more instream wood, pools, and sediment storage and less bank erosion than reaches on the eastside (mostly PB and constrained morphologies) with equivalent gradient and basin area. Channel morphology in low-urbanized watersheds correlate to the level of channel confinement and to characteristics of the near-riparian vegetation. High-urbanized reaches are substantially less sensitive to the condition of the near-riparian zone, due to the disconnection of the stream with its floodplain triggered by the placement of armoring structures on the banks.

From a management perspective, increased instream wood in PB reaches could yield an eventual morphologic shift to FPR. However, increased wood load in these channels is not the only requirement for generating such a shift. These channels also need to be reconnected to a forested floodplain and to the channel-bank sediment that provide long-term recruitment of both large woody debris and gravel. In the case of anthropogenically confined channels, restoration is even more challenging because sustainable morphologic improvements require the elimination of bank-armoring structures to facilitate that reconnection. The mere addition of logs is not likely to provide a sustainable solution, offering short-term improvements but not addressing the underlying geomorphic processes that commonly yield degraded channels in urban environments.

Spatial organization, position, and source characteristics of large woody debris in natural systems

Martin Fox, PhD, Forest Resources

The goal of this study was to assess the characteristics of natural large woody debris (LWD) organization, size, and riparian areas across forested regions of Washington State. Field data were collected from 150 stream sites with a diverse array of channel types and disturbance patterns within basins relatively unaffected by anthropogenic disturbance. Bankfull channel width was found to be the dominant factor influencing the grouping of LWD pieces. LWD group size as well as stability increased with channel size. Jams (groups = 10 pieces) contained proportionately similar diameter distributions regardless of size. As bankfull channel width increased, the percent of LWD volume decreased in the low-flow channel, but increased in the high-flow channel. Both the median LWD lengths and diameters increased with bankfull width and proximity to the low-flow channel, as well as with increasing LWD group size. As channel width increased, the proportion of pieces oriented parallel to the high-flow channel increased while the frequency of perpendicular pieces decreased, especially if rootwads were attached.

Forest zones, as defined by climatic influence and fire history, are the best regional predictors of riparian stand attributes such as tree height, basal area, stem diameter, and density. Observed riparian stand composition ranged from 8 to 17 tree species within each of six forest zones. Species richness was greater in milder climates and lower in more extreme climates. The greatest observed tree species diversity was within 35 m of the stream channel; however, stream influences on riparian characteristics were observed out to 65 m, the extent of the sample transect. Large streams with active floodplains had a significantly greater deciduous riparian component than channels less prone to fluvial disturbances. LWD volumes did not peak or plateau until adjacent riparian stands reached 550 years in age; however, LWD quantities were also high during the first 150 years of stand origin. The percent of instream wood quantities that could be attributed to an adjacent riparian source decreased with increasing channel size. Where restoration of instream wood and/or riparian areas are warranted, these characteristics offer guidance to the range of conditions found in natural systems to which aquatic and riparian species have adapted.

The local impacts of road crossings on Puget Lowland creeks

Christina Avolio, MSCE, Civil and Environmental Engineering

Urbanization in the Puget Sound region continues to place mounting strain on natural fluvial systems. As one component of urbanization, the road network is commonly understood to be a significant stressor of physical creek processes. Several studies have considered the effects of forest roads on creeks in mountainous and/or logged areas, but few have examined the impacts of road crossings on lowland creeks, where most urban development is concentrated. This project provides an analysis of the local effects of road crossings on Puget Lowland creeks.

This analysis was divided into three interrelated studies with the objectives of: 1) developing methods for measuring local road-crossing impacts to physical creek conditions; 2) determining specific physical processes and conditions altered by road crossings; 3) determining what road-crossing characteristics contribute to downstream alterations; and 4) assessing the significance of local road-crossing impacts relative to basin-wide urbanization impacts. The first study, conducted in the summer of 2002, included reach and cross-sectional geomorphic assessments upstream and downstream of 8 road crossings. Road crossings reduced downstream channel sinuosity and channel complexity, and increased gravel embeddedness and cementation. Road alterations of the channel cross section depended on the type of road crossing, its confinement, and the amount of associated armoring.

A second geomorphic study was conducted in the spring of 2003 for 33 road crossings to associate road design and overall basin urbanization to observed geomorphology. In general, culverts produced greater downstream geomorphic impacts than bridges, but urban reaches (>20% total impervious area) were more sensitive to greater impacts from culverts than from bridges. A gravel entrainment study was conducted for two creeks during the winter/spring of 2002/2003 to explore road-crossing and outfall impacts to sediment transport. Although the outfall contributions were not enough to produce observable upstream-downstream differences in entrainment for the storm flows experienced, road-altered channel cross sections downstream required different amounts of shear stress to produce similar magnitudes of gravel entrainment.

Channel-initiation and surface water expression in headwater streams of different lithology

Kristin Jaeger, MS, Forest Resources

Past research has shown a strong correlation between channel-head location and an inverse source area-slope relationship. Upslope migration of the channel head can result from changes in land use, such as timber harvest or intensive cultivation. Research has been conducted in a range of lithologies and land uses, which include select sites subject to grazing and pastures in California, Australia, and northern Italy; forested sites in California, the southern coast of Oregon, and northern Italy; and agricultural landscapes in Spain. To date, however, no known published data exist for either Washington State or a basalt lithology. Due to the fractured character of basalt, there is a potential that this inverse source area-slope relationship at the channel-head would not apply to basalt lithology. However, if a source area-slope is found to exist, a predictive model can be developed that identifies the extent of the channel network within this lithology. The ability to predict the extent of the channel network provides insight into landform evolution, in addition to short-term applications in harvest management related to monitoring potential headward migration of channel heads as a result of timber practices, including road construction.

The purpose of this project was to identify whether geomorphic variables exist that determine channel initiation within a basalt lithology. Field measurements using a high resolution (within 3 meters) Global Positioning System device and information taken from a USGS 1:24,000 topographic map was used to build a simple digital terrain model such as the one developed by Dietrich et al. (1992), which predicts, with reasonable resolution, the channel head location. Channel head locations predicted by the model was field tested against a different set of study sites. In addition, predicted locations was compared to areas subject to logging roads.

Cathy Reidy tests the amount of hyporheic storage in Clarks Creek

This project is funded by the Washington Department of Natural Resources (DNR). All work was conducted on DNR state lands. Field work was completed during the fall and winter of 2002-2003 within Capitol State Forest, which is located west of Olympia, Washington. Data analysis and model development began during the winter of 2003, with final results by mid-2004.

Dietrich, W.E., Wilson, C.J., Montgomery, D.R., McKean, J., and Bauer, R. 1992. Erosion thresholds and land surface morphology. Geology 20: 675-679.

Variability of hyporheic zones in Puget Sound Lowland streams

Catherine Reidy, MS, Forest Resources

Seven small streams with varying land use in the Puget Sound lowlands of western Washington were evaluated with the following objectives: 1) to estimate the amount of hyporheic exchange and spatial extent of hyporheic zones; 2) to assess hyporheic water quality; and 3) to address seasonal variability of hyporheic exchange among these streams. The field study was conducted during 2001-2002, and methods included a combination of numerical modeling of stream tracer data, physical channel and substrate measurements, and analysis of hyporheic water samples collected from piezometers. Results illustrate broad heterogeneity in hyporheic zone exchange rate and spatial extent among the sites examined. Estimates of hyporheic exchange rate coefficient (a) ranged from 0.00004 /s – 0.01277 /s, and estimates of hyporheic zone cross-sectional area (AS) ranged from 0.013 m^2– 13.46 m^2 . With the exception of the maximum values for both a and AS, results fell within the range of those typically found in published data. An inverse correlation between relative amounts of impervious area within basins and the ability of chloride concentrations (tracer used) and electrical conductivity (surrogate measured) to maintain a linear relationship may have adversely affected modeled results from the stream tracer experiments. Overall, the surface channel and substrate parameters measured or estimated in this study were not tightly correlated to hyporheic exchange rate, spatial extent, or seasonal variation in exchange. Furthermore, fine sediment concentrations in the hyporheic zone did not correlate to hyporheic exchange parameters or dissolved oxygen concentrations as had been expected. Signatures of surface stream temperature dampening by the hyporheic zone varied among and within sites. ♦

Snapshot of current research

Reproductive success of steelhead

Todd Seamons, PhD, Fisheries

Understanding biotic processes, such as life history traits, is esstential to salmon population management. In the project, which focuses on steelhead trout, we are directly measuring the effects of parental size and arrival date on the reproductive success of individual adult salmonids through the three main life history phases (juvenile, smolt/sub-adult, adult) of their offspring over multiple brood years. Previous work in this area was limited in application to natural populations over the entire lifetime of offspring. Analysis already complete on juvenile and smolt samples reveal that young-of-the-year offspring size was correlated with maternal sized and maternal breeding date. The number of offspring per female, however, is only marginally related to maternal size and not at all related to maternal arrival date. Many smolt offspring may not necessarily mean more returning adult offspring. To determine the ultimate reproductive success of individual steelhead, parents will be assigned to returning adult offspring. Further analysis of returning offspring will determine if overall patterns of reproductive success are determinants in the freshwater or marine life histories.

Technical assessment for WRIA 20

Abby Hook, MS, Forestry

In 1998, the Washington State Legislature adopted the Watershed Planning Act (RCW 90.82) in order to provide a voluntary, participatory planning process for stakeholders such as citizens, tribes, and governements to develop watershed management plans. As part of this process, WRIA 20 (Hoh-Soleduck) has completed phase one of the plan and organized a planning unit comprised of local landowners, three tribes, local non profits, and government agencies. This planning unit has selected water quality, water quantity, habitat, and instream flow as components to address within the watershed management plan. Now in phase two of the planning, I am completing the technical assessment and literature review for the selected components. The information for this technical assessment will be used to develop strategies for filling in technical data gaps in order to provide the most complete assessment on which to base the final watershed plan.

Hydrological partitioning of ungaged mountain basins

Anne Weekes, PhD, Forest Resources

In the mountainous landscapes of North Cascades and Mt. Rainier National Parks, complex geology and/or geomorphology, steep topography, and variable climate create patchy ecological communities. The channel networks that drain these regions are divided into process zones distinguished by a mosaic of different disturbance regimes. Typically a majority of the channel network in these regions consists of headwater streams with flow regimes that are as varied as the landscape. With the exception of large USGS gaging stations along main stem rivers generally outside park boundaries, there is little gage data available to model or predict channel flows, especially the numerous headwater channels.

In an effort to monitor ongoing changes in the aquatic attributes of the park, monitoring staff would like to ascertain the flow regimes

Anne Weekes and Ashley Adams installing pressure tansducers at Thunder Creek.

characteristic of community types found in the parks. Using partitioning to test relationships between hydrological response, physical processes, and biological mosaics, the NPS Hydrograph Project seeks to characterize the surficial hydrology of this complex and variable terrain. The results of hydrological partitioning will be tested at a variety of scales using stream gages, GIS remote sensing, and other tools.

Bioavailability of particulate phosphorus

Micaela Ellison, MSE, Civil and Environmental Engineering

In the Pacific Northwest, streams tend to be phosphorus limited because nitrate concentrations

continued on page 8

Particulate phosphorus continued

are naturally high due to the abundance of red alders in riparian vegetation. The use of total phosphorus concentrations to estimate eutrophication risk is problematic for management purposes as only some forms of phosphorus are biologically available to phytoplankton. This study will assess the bioavailability of one form of phosphorus, particulate phosphorus (PP), across a gradient of land cover/land uses. The results will show whether PP is an important consideration in the creation of management plans for phosphorus input reductions based on the bioavailability of PP. In addition, the range of bioavailable PP concentrations measured in this study for different land types can be used in building eutrophication models for Pacific Northwest streams. ♦

Upcoming events

Details for these events can be found at http://depts.washington.edu/cwws/Outreach/Events/seminars.html

30 March – 1 June	Tuesday Morning Seminar Series, 8:30 to 9:30 am, 22 Anderson Hall, UW Campus
1 April – 10 June	Monster Seminar Jam, 11 am to 12 pm, Northwest Fisheries Science Center, 2725 Montlake Blvd. East

Professional development programs

For more informatin on cost, registration, and other details, see http://www.engr.washington.edu

May 18-19	Geology and Geomorphology of Stream Channels (register by May 4th)

Center for Water and Watershed Studies
University of Washington
Box 352100
Seattle WA 98195-2100