# RESEARCH ON FRESHWATER HABITATS AND JUVENILE SALMONID ECOLOGY IN THE COLUMBIA RIVER BASIN – LESSONS AND APPLICATIONS

## Extended Abstract:

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As the two largest river systems in western North America, the Columbia and Yukon Rivers share many features; they are similar in terms of length, drainage area, and average discharge. As well, their hydrologic regimes are dominated by spring-summer snowmelt runoff with low flows occurring in fall and winter.  Each river possesses salmon runs that support important aboriginal, commercial, and recreational fisheries both in-river and at sea.  Despite these similarities, the freshwater environments of the two drainage systems are profoundly different. In addition to obvious climate differences (the Yukon R. freezes over in winter; the Columbia R. does not), the Columbia R. Basin has been extensively altered by a variety of human impacts resulting in a widespread loss of formerly productive habitats and a native fauna that faces substantial imperilment to a much greater extent than in the AYK region. Nearly half of the currently ESA-listed west coast salmon and steelhead stocks reside in the Columbia Basin, including five distinct Chinook salmon evolutionarily significant units (ESUs). Since 1999, anadromous salmonid returns to the river have increased relative to the previous six decades (Fig. 1), although the majority of returning adults are of hatchery origin. For Chinook salmon stocks inhabiting the interior basin, numbers of wild fish have continued to trend downward while the proportion of artificially produced fish has increased (Fig. 2).

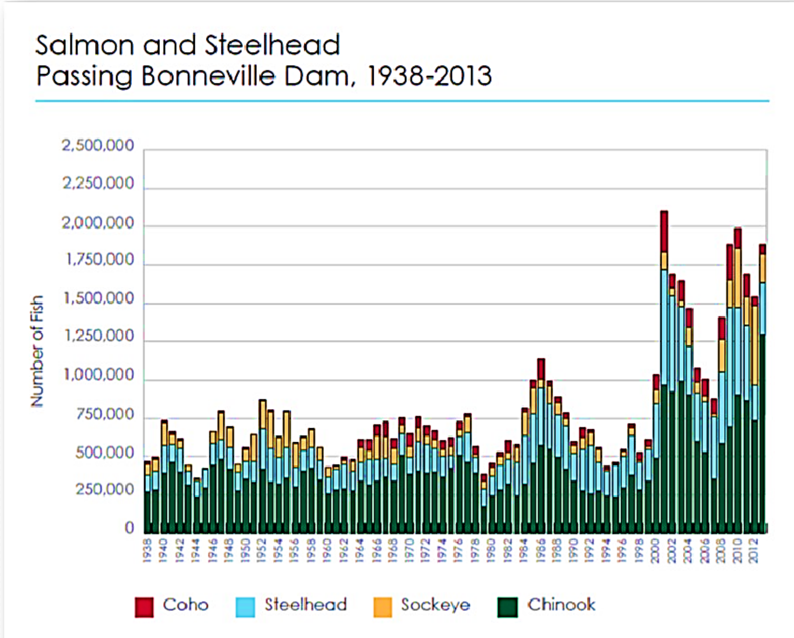
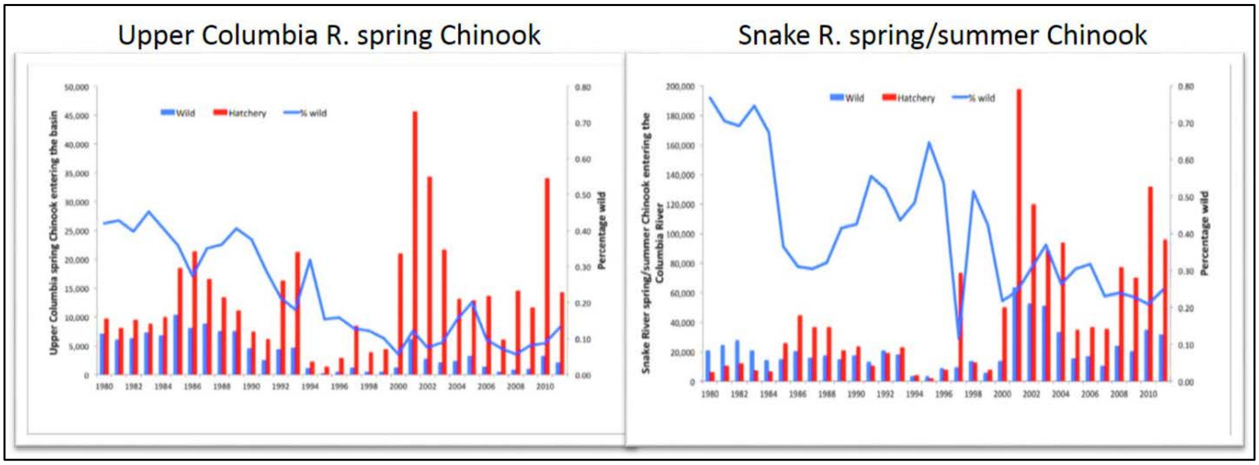


Fig. 1. Salmon and steelhead adults passing Bonneville Dam (river mile 146) from 1938 to 2013 (Northwest Power and Conservation Council 2014).



Upper Columbia R. spring Chinook

Snake R. spring/summer Chinook

Fig. 2. Numbers of adult Chinook Salmon returning to the upper Columbia R. and Snake R. from 1980 to 2011 (Independent Scientific Advisory Board 2013, based on Joint Columbia River Management Staff 2012, Tables 8&9).

Causes of imperilment of Columbia R. salmon have been ascribed to the so-called Four Hs: habitat loss, harvest levels that exceed sustainable levels, development of the hydroelectric network in the mainstem and tributaries, and losses related to hatchery fish production. Much of the funding for salmon restoration and monitoring comes from the Bonneville Power Administration (BPA), as guided by the Northwest Power and Conservation Council (NPCC). Over $500,000,000 are budgeted each year to protect stream habitats, improve fish survival through a maze of tributary and mainstem dams, purchase water rights, control pollutants, and operate numerous hatcheries through the Columbia River Fish and Wildlife Program. This very ambitious ecological restoration program includes almost $100,000,000 annually for freshwater habitat research and juvenile salmonid studies. The budget, scope and diversity of research on juvenile salmon ecology in the Columbia Basin likely surpasses other west coast river systems. To ensure that the Fish and Wildlife Program is based on the best available scientific information, the NPCC formed two committees of independent scientists in the 1990s: the Independent Scientific Advisory Board (ISAB), which provides scientific advice on large programmatic issues such as climate change, food webs, and landscape ecology, and the Independent Scientific Review Panel (ISRP), which reviews individual restoration projects and new proposals. Many of the conclusions in this paper have been taken from ISAB and ISRP reports.

In the three decades following establishment of the Fish and Wildlife Program an enormous amount of information about juvenile salmon and their habitats has been collected in the Columbia River Basin. What has been learned and applied from these studies? First, we have learned that although volumes of habitat data have been collected by various organizations over the years, differences in measurement protocols and inadequate data archiving have hampered data sharing and analyses. Freshwater habitat surveys have been conducted by many federal, state, tribal, and non-governmental organizations, but survey protocols are frequently different and alternative environmental features have been measured in accordance with the organizations' interests. Further, data often consist of field notes that languish in filing cabinets, may or may not be summarized in annual reports, are not readily available on the internet, and are rarely published in peer-reviewed journals. To improve the consistency of survey methods and to provide a clearinghouse for freshwater habitat data, an ambitious project, the Columbia Habitat Monitoring Program (CHaMP - https://www.champmonitoring.org/) has been initiated to apply standardized habitat measurement protocols to select tributaries in the Columbia River and to make habitat summaries available on-line to facilitate the characterization of habitat status and trends in different areas. CHaMP uses a rotating generalized random stratified tessellation (GRTS) approach to selecting monitoring locations within 26 watersheds across the Columbia River Basin and has attracted support from both federal and tribal partners. Another problem has been simply locating the multitude of restoration projects that have taken place over the years. This is problematic because restoration practitioners may not be aware of previous habitat improvement actions on or near the site of interest. To help remedy this, the BPA has established an on-line project location and tracking system called Taurus (http://www.cbfish.org/Home.mvc/Index), which facilitates identifying individual restoration actions and their associated metadata, and also includes regional summaries of restoration implementation that displays different categories of habitat improvement quantitatively, e.g., miles of stream fenced to exclude livestock. Together, CHaMP and Taurus have made considerable progress in improving habitat monitoring standardization and in providing ready access to information about BPA-supported projects.

The second lesson we have learned is that technological advances (e.g., geospatial mapping and PIT-tagging) have facilitated real improvements in understanding habitat status and trends at large geographic scales, as well as more detailed insights into juvenile salmonid movements, survival patterns, and environmental limiting factors. The Interior Columbia Basin Ecosystem Management Project (http://www.icbemp.gov/) was commissioned by President Clinton in 1993 to develop land and water management plans for the interior Columbia River Basin. This project made extensive use of geographic information system (GIS) technology, using existing habitat data, to identify locations on the federally-managed landscape where aquatic habitats were impaired, as well as places that served as nodes of aquatic productivity, i.e., biological "hotspots" (Quigley and Arbelbeide 1997). It was the first coordinated effort to address freshwater habitat status across the Columbia River Basin and it set a precedent for succeeding landscape assessments. Another technological advance that has contributed to increased understanding has come from advances in fish tagging that have enabled better understanding of juvenile salmon movements. As radio, acoustic, and passive integrated transponder (PIT) tags have become smaller, their use in monitoring juvenile salmon movements is providing new insights into the habitat needs of different life cycle stages, as well as where and when in the river network young fish are vulnerable to environmental damage. Tagging studies have enabled estimates of improved juvenile survival when passing mainstem dams that have been modified to improve fish passage, and have also demonstrated how juvenile salmon are adapting to the river's altered conditions. For example, Connor et al. (2005) found that some juvenile fall Chinook Salmon have adopted a "reservoir-type" life history and smolt after spending their first summer and winter in a mainstem Snake River reservoir instead of emigrating during their first summer. This apparent adaptation to the altered river environment allows juveniles to reach a much larger size before going to sea and is believed to have improved smolt to adult survival.
The third lesson we have learned is that quantitative relationships between juvenile abundance and specific habitat attributes have been very difficult to determine in the field due to many sources of variation. It is hard to establish the efficacy of habitat restoration projects in quantitative terms where policy makers wish to know the cost and benefit tradeoffs

(implementation costs, additional fish produced, improved survival rates) of habitat restoration actions. Traditionally, expert opinion has been used to forecast the benefits of habitat restoration, but levels of uncertainty associated with the judgments of experts are often quite high when applied to site-specific predictions. Developing predictive relationships between juvenile salmon and the benefits of habitat restoration has trended away from expert opinion toward quantitative life-cycle modeling (ISAB 2013b). An example is the Integrated Status and Effectiveness Monitoring Project (ISEMP) - a companion project to CHaMP - that is employing a network of intensively monitored watersheds to develop quantitative relationships between habitat attributes and salmonid abundance using novel statistical approaches (see http://www.nwfsc.noaa.gov/research/divisions/cb/mathbio/isemp.cfm). Further details are given in C. Jordan's presentation at this workshop.

Fourth, we have learned that there are major categories of habitat factors such as food webs and environmental contaminants that are incompletely monitored and whose influence on juvenile salmonid abundance and survival are inadequately understood. Columbia River ecosystems have been extensively transformed not only by human development but also by the establishment of a wide variety of non-native species, yet the effects of food web changes on juvenile salmon and how these changes can be managed remain largely uninvestigated (Naiman et al. 2012).

Likewise, the Columbia River and its tributaries receive anthropogenic contaminants from agriculture, municipal discharges, and other sources, and these too remain incompletely studied (Independent Scientific Advisory Board 2011). Both topics deserve additional research. Finally, we have learned that new insights from freshwater habitat research and monitoring have often not been fully considered across different realms of salmon management. For example, releases of hatchery salmon typically do not take annual variation in freshwater habitat quantity and quality into account, i.e., numbers are not adjusted to match weather-related changes in seasonal flows that could increase or decrease negative interactions between hatchery and wild fish. In addition, environmental planning in the Columbia River Basin has acknowledged climate change, but climate modeling has predicted extensive changes in the basin's water temperature and hydrologic regimes (Mantua 2009) that will render large areas of currently suitable salmon habitat unsuitable by the latter half of the 21st century, yet there are relatively few projects that explicitly anticipate these changing conditions and take steps to mitigate their harm. Failure to take these factors into account could jeopardize the success of hatchery programs and habitat restoration efforts.

Recently, some scientists have called for a shift in biological objectives for salmon and steelhead in the Columbia River Basin to a strategy based on protecting and restoring habitat diversity and environmental resilience (Independent Scientific Advisory Board 2013a). To assist in accomplishing these objectives four steps have been suggested to improve freshwater monitoring strategies: (1) support the development of high level indicators of habitat condition and fish population performance; (2) implement monitoring to evaluate progress against new quantitative objectives such as environmental diversity metrics, life stage-specific survival goals, and habitat restoration benefits; (3) implement social monitoring to better evaluate and improve acceptance of restoration programs at local scales, and develop opportunities for citizen engagement in monitoring activities; and (4) design monitoring to support adaptive management and structured decision making by providing data to test current knowledge and revise management programs.

These objectives will be difficult to achieve in an era of shrinking monitoring budgets and will require creative new approaches, but they have the potential to improve learning opportunities from one of the nation's largest ecological restoration programs.

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