Nisqually Basin Bibliography: Science, Resource Management, Land Use, and Public Policy

Fourth Edition

Nisqually Reach Nature Center

Olympia, Washington

September, 2003

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Introduction

This compilation consists of published and unpublished research reports; environmental management plans, studies, and inventories; and mapping and monitoring reports. The geographic area covered includes the Nisqually River Basin, the Nisqually Reach of Puget Sound, and adjacent areas. The scientific disciplines covered include the environmental sciences, the design sciences, and the cultural and historic sciences. A limited number of documents covering a broader geographic base are included when they contain especially useful information about the Nisqually area.

Version 1.0 of this compilation was prepared by Doug Canning and Lea Mitchell for a workshop on Research on the Nisqually Reach and Nisqually Delta jointly sponsored by the Nisqually Reach Nature Center and the American Littoral Society (March 16, 1991). Version 2.0 was updated by Doug Canning for the Second Workshop on Research on the Nisqually Reach and Nisqually Delta, again cosponsored by American Littoral Society and the Nisqually Reach Nature Center as a Coast Weeks event on September 26, 1992. Version 3.0 was updated by George Walter (Nisqually Indian Tribe) and Doug Canning following the Third Nisqually Research Symposium (June 3, 1995). The Fourth Edition was updated by Cami Knackstedt in 2002 and published in 2003.

This bibliography is a continuing, cooperative effort. If you know of published research not listed in this bibliography, please send a complete bibliographic citation in the form used by this document to:

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1 • Bibliography of Printed Resources

AGI Technologies. 1999. *Conceptual model of the McAllister Springs area*. Technical Memorandum 3. Dec 1999. Prepared for Cities of Olympia and Lacey Public Works Departments by AGI Technologies in cooperation with Jones and Stokes Associates, Evans-Hamilton Inc., and Hydrology Northwest. 66 pp plus appendices.

Aitkin, Kevin J. Aug 1998. *The Importance of Estuarine Habitats to Anadromous Salmonids of the Pacific Northwest: A Literature Review*. U.S. Fish and Wildlife Service, Western Washington Office, Aquatic Resources Division, in cooperation with the Puget Sound Program, Lacey, Washington.

Introduction

The importance of estuaries to anadromous salmonids has been well reviewed in the past (Iwamoto and Salo 1977; Dorcey et al. 1978; Meyer 1979; Shepard 1981; Hiss and Boomer 2986; Thorpe 1994), but this author was unable to find any review articles since 1994. This report will review the literature produced since Meyer's (1979) literature review. The catalyst for this report was the need to provide up-to-date information on salmonid utilization of estuarine habitat at the Nisqually Wildlife Refuge.

Under the direction of the 1997 National Wildlife Refuge (NWR) Improvement Act, Nisqually NWR staff are preparing a Comprehensive Conservation Plan (CCP) for the refuge. The CCP process provides a 15-year plan to guide refuge management. Issues of land acquisition, wildlife dependent recreation, public access, and habitat management/restoration are some of the major topics to be addressed by the CCP.

Development of a CCP for Nisqually NWR provides an important opportunity to investigate the feasibility, habitat benefits, and economic costs of restoring intertidal habitat by breaching dikes. In addition to these general ecological benefits, this process has the potential to significantly benefit salmon, depending on the alternative pursued. This is an especially important outcome, given the likelihood that Puget Sound Chinook salmon may soon be listed under the Federal Endangered Species Act. While qualitative information can be provided with existing information, more substantiated quantitative information on intertidal restoration will require additional research.

Estuarine habitat comprises only 10%-20% of the Pacific Coast and a large percentage has been lost to diking, channelization, and dredging and filling (Burg 1984). Burg (1984) reported that California has lost approximately 65%, Oregon has lost approximately 80%, the Columbia River has lost approximately 24%, and Washington has lost between 45% and 62% of their respective pre-settlement habitat (Simenstad et al. 1982; Schmitt et al. 1994). Bortleson et al. (1980) estimate that in the Nisqually River estuary, approximately 4.1 km^2 of the historical 5.7 km^2 of subaerial wetlands (area above mean high-water line)

remain, for a loss rate of 28%. In addition, approximately 5.8 km^2 of the historical 7.4 km^2 of intertidal wetlands (area between mean high-water line and mean lower low-water line) remain, for a loss rate of 22%.

There are eight species of native anadromous salmonids occurring in the Pacific Northwest. They are Chinook salmon (*Oncorhynchus tshawytscha*), Chum Salmon (*O. keta*), Pink Salmon (*O. gorbuscha*), Coho Salmon (*O. kisutch*), Sockeye Salmon (*O. nerka*), Steelhead (*O. mykiss*), Sea-run Coastal Cutthroat Trout (*O. clarki clarki*), and Sea-run Dolly Varden Char (*Salvelinus malma*). This report will primarily examine the utilization of estuaries by the first five species listed, as most of the information collected concerns them. This information includes the usage of estuaries by juvenile salmonids as rearing areas, as refugia, and as transition areas.

The objective of this report is to provide estuarine land managers with basic information on salmonid utilization of estuaries, and assist them in making educated restoration decisions. The geographic focus of this review is western Washington, although literature and information were drawn from a variety of sources throughout the Pacific Northwest.

Alcorn, Gordon, Dixy Lee Ray, & Gary B. Lewis. 1970. *The future of the Nisqually delta area: A memorandum report to the Washington State Legislative Council, Committee on Parks and Natural Resources*.

Amberson, S. and B. Fortune. 1992. The Nisqually, a delta under fire. *Underwater Naturalist* 21(1): 24-27.

Abstract

The Nisqually Delta and at its heart, the 2,800-acre Nisqually National Wildlife Refuge, contains some of the most magnificent wetlands in the world. Wonderfully pure and unpolluted, it is located at the southern end of Puget Sound, about 40 miles south of Seattle. The Refuge was set aside in 1974 as a result of citizen action which saved the area from proposals to turn it either into a sanitary landfill or a deep-water port. Today plans for large mixed-use developments once again imperil the Nisqually. Originating at the glaciers and on the flanks of Mt. Rainier, the Nisqually drains 722 square miles into Puget Sound and supports one of the region's best wild Steelhead Trout populations. In addition, all species of west coast salmon except the Sockeye run up river to spawn. There is an extensive commercial fishery for salmon as well a good Chum Salmon run for recreational fishermen. Salmon hatcheries are located on both the Nisqually and nearby McAllister Creek.

Comment: the authors are a bit excessive in their characterizations of "most magnificent" and "pure and unpolluted" so one should be cautious in using this document.

Ames, James L. & Patrick Bucknell. 1981. *Puget Sound river mile index*. Washington Department of Fisheries, Olympia.

Anderson, S.E. 1999. *Use of off-channel freshwater wetlands by juvenile Chinook and other salmonids: Implications for habitat restoration in Puget Sound.* Thesis. The Evergreen State College, Olympia, Washington.

Anthony, Janet, Douglas Canning, Susan Funkhouser, William Hashim, Michael Kent & Hugh O'Neil. 1985. *The Weyerhaeuser dock proposal: A case study of an environmental controversy*. Unpublished Mss. A Case Studies Thesis prepared for the Masters in Environmental Studies Graduate Program. The Evergreen State College. Olympia, Washington.

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Berge, Brent, Carolyn J. Burkhart, Catherine Joslin, Katie La Gory, Kirk La Gory, Robin Oakly & Helen Ulmschneider. 1974. Fall birds of the Nisqually Delta: Population fluctuations, habitat utilization and hunter harvest. pp 111-160 in: *The Nisqually Delta Group Contract. 1974. The Nisqually Delta*. The Evergreen State College, Olympia, Washington.

Biek, David. 2000. *Flora of Mount Rainier National Park*. Oregon State University Press, Corvallis.

This volume provides a comprehensive listing of the 8761 species of plants found in the Park and adjacent forests. The book features keys, line drawings, and descriptions for identification, as well as a guide to plant locations.

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Bortleson, G.C., M.J. Chrzastowski & A.K. Helgerson. 1980. *Historical changes of shoreline and wetland at eleven major deltas in the Puget Sound region, Washington*. US Geological Survey Hydrologic Investigations Atlas HA-617.

Bortleson, G.C., N.P. Dion, J.B. McConnell, & L.M. Nelson. 1976. *Reconnaissance data On lakes in Washington, Volume 3: Kitsap, Mason, and Pierce counties*. Washington Department of Ecology Water Supply Bulletin 43: Volume 3.

Bortleson, G.C., N.P. Dion, J.B. McConnell, & L.M. Nelson. 1976. *Reconnaissance Data on lakes in Washington, Volume 4: Clark, Cowlitz, Grays Harbor, Lewis, Pacific, Skamania, and Thurston counties*. Washington Department of Ecology Water Supply Bulletin 43, Volume 4.

Bowman, Katheryn J. & Andrea M. Dobos. 1975. Distribution and abundance of some small mammal species on the Nisqually National Wildlife Refuge, Thurston County, Washington. pp 199-213 in: *Results of natural history and field methods studies conducted by 35 undergraduate students at the Evergreen State College*. The Evergreen State College, Olympia..

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Brennam L.A., M.A. Finger, J.B. Buchanan, C.T. Schick, and S.G. Herman. 1991. Stomach contents of Dunlins collected in western Washington. *Northwestern Naturalist* 71:99-102.

Brennan, L.A., M.A. Finger, J.B. Buchanan, C.T. Schick, and S.G. Herman. 1990. Stomach contents of some Dunlins collected in western Washington. *Northwest Naturalist* 71:99-102.

Brown, Carol, Michael Denoyer & Dennis Meyers. 1974. Marine invertebrates on the Nisqually Delta. pp. 237-259 in: *The Nisqually Delta Group Contract. 1974. The Nisqually Delta*. The Evergreen State College, Olympia, Washington.

Brundage, W.C. 1960. *Recent sediments of the Nisqually River Delta, Puget Sound, Washington*. Unpublished Masters thesis, University of Washington. 178p.

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Buchanan, J.B., L.A. Brennan, C.T. Schick, M.A. Finger, T.M. Johnson, an S.G. Herman. 1985. Dunlin weight changes in relation to food habits and available prey. *Journal of Field Ornithology* 56:265-272.

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Burg, M.E., Tripp, D.R. and E.S. Rosenburg. 1980. Plant associations and primary productivity of the Nisqually salt marsh on southern Puget Sound, Washington. *Northwest Science*. 54(3), 222-236.

Abstract

Vegetation was sampled along transects placed perpendicular to observed environmental gradients. Twelve plant associations were defined and a vegetation map prepared showing their extent and location. The distribution of associations appears to be determined by the combined effects of elevation-inundation and the fresh water influence of the Nisqually River. Productivity values were estimated for 8 associations using a clip-harvest method, with samples taken at monthly intervals. The average annual net productivity of these 8 associations is 814 g dry weight/m^2 with a range of 90 to 1390 g dry weight/m^2. The *Festuca rubra – Carex lyngbyei* association is the most productive of the associations found at high elevations while the *C. lyngbyei* association, found at low elevations, is the most productive of the associations sampled.

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Calambokidis, John, Kathryn Bowman, Suzanne Carter, James Cubbage, Pierre Dawson, Thomas Fletcher, Joanne Schuett-Hames, John Skidmore & Barbara Taylor. 1978. *Chlorinated hydrocarbon concentrations and the ecology and behavior of harbor seals in Washington state waters*. (A Student-Originated Study supported by the National Science Foundation) The Evergreen State College, Olympia, Washington.

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Canning, Douglas J. & W.A. Hashim. 1987. Nisqually River Management Plan. pp 3293-3305 in: *Coastal Zone '87: Proceedings of the Fifth Symposium on Coastal and Ocean Management*. American Society of Civil Engineers, New York.

Canning, D.J. & S.G. Herman. 1983. Gadwall breeding expansion into western Washington. *Murrelet*. 64(1):27-31.

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Carter, Susanne D., Mary K. La Gory, Sarah J. Madsen & Pamela Miller. 1975. An ecological survey of a mixed grassland on the Nisqually National Wildlife Refuge, Thurston County, Washington. pp 173-198 in: The Evergreen State College. 1975. *Results of natural history and field methods studies conducted by 35 undergraduate students at the Evergreen State College*. The Evergreen State College, Olympia, Washington.

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Clague, James C. 1990. Land applications of sewage sludge in the Nisqually River Basin science and controversy.

Cole, Don L., Richard M. Comstock, and Bill Harrington-Tweit. Feb 1986. *The Nisqually Chum Salmon Run: A Status Report*. Nisqually Indian Tribe and US Fish and Wildlife Service.

Abstract

Mark-recapture studies to estimate total run size and escapement were conducted on the chum run in the Nisqually River, Washington, during the 1974-75 through 1978-79 seasons. Run size and escapement were estimated for each season except 1977-78 when an illegal marine fishery precluded development of an escapement

estimate. Run size estimates ranged from 12,600 to 60,800 and escapement estimates from 8,700 to 33,600.

In addition to these post-season estimates, a method was developed for in-season projection of run size based on early season tag releases and recovery information in the river commercial fishery. Development of in-season run size projection was continued using this methodology through the 1981-82 season.

Biological information on length frequency, sex and age composition, and timing of the run was an important benefit of the studies. The population structure was heavily weighted towards three and four year old adults. Five year olds never constituted more than 2% of a run. Other maturation ages were rarely observed. The relative proportion of three and four year olds varied substantially between years, as did the sex ratio. The proportion of females in the run varied between 50 and 60%; the river gill net fishery, however, was selective for males. There was almost a 20 cm difference in mean fork length between three year olds and five year olds. The mean fork length of each age/sex cohort was quite consistent on an annual basis. Run timing in the river was influenced by the population structure; three year olds tended to enter earlier than fours and males earlier than females.

Collins, Brain D., David R. Montgomery, and Andrew D. Haas. 2002. Historical changes in the distribution and functions of large wood in Puget Lowland rivers. *Canadian Journal of Aquatic Sciences* 59: 66-76.

Abstract

Changes in wood abundance and function were examined in Puget Lowland rivers from the last similar to 150 years of land use by comparing field data from an 11 km long protected reach of the Nisqually River with field data from the Snohomish and Stillaguamish rivers and with archival data from several Puget Lowland rivers. Current wood abundance is one to two orders of magnitude less than before European settlement in the Snohomish and Stillaguamish basins. Most importantly, wood jams are now rare because of a lack of very large wood that can function as key pieces and low rates of wood recruitment. These changes in wood abundance and size appear to have fundamentally changed the morphology, dynamics, and habitat abundance and characteristics of lowland rivers across scales from channel unit to valley bottom. Based on our field studies, rivers had substantially more and deeper pools historically. Archival data and field studies indicate that wood jams were integral to creating and maintaining a dynamic, anastomosing river pattern with numerous floodplain channels and abundant edge habitat and routed floodwaters and sediment onto floodplains. Establishing the condition of the riverine landscape before European settlement sets a reference against which to evaluate contemporary conditions and develop restoration objectives.

Conley, E. and G. Cloud. 1988. Whole-field measurement of ice displacement and strain Rates. *Transactions of the ASME. Journal of Offshore Mechanics and Arctic Engineering* 110(2): 169-171.

Abstract

The flow of glacier ice is mapped using high-resolution photography and Noncoherent light speckle interferometry. Time-lapse, double-exposures of a straining surface yield Young's fringes when the resulting image is interrogated by a narrow beam of light. Such fringe patterns, when corrected for camera motion, are indicative of the surface displacement occurring between exposures. Results of glacier field experiments are consistent with those garnered by conventional methods at the Nisqually Glacier, Washington. The interferometric method seems amenable to other geophysical applications, such as mapping sea ice flow using terrestrial or space-based camera platforms.

Consoer, Townsend, & Associates. 1974. *Nisqually River Basin Water Quality Management Plan: Water resource Inventory Area No. 11, Consolidated Basin Planning Area No. 13-11-6*. Consoer, Townsend, & Associates, Tacoma Washington.

Cook-Taylor, Carrie. May 1999. *Fishes of the Nisqually River, Estuary, and Reach*. U.S. Fish and Wildlife Service Aquatic Resources Division, Lacey, Washington. 65 pp.

Introduction

Despite few fish investigations, the list of fish species that have been observed in the Nisqually basin, estuary, and reach is diverse. The list is made up of 94 species of 30 different families, including lampreys, salmonids, herring, cods, sculpins, rockfish, surfperches, pricklebacks, gobies, and flatfishes. Life histories and current stock status, when available, of the various fish species are organized below by family.

Cornell, Steven E., David Hames, John McRae & Dave Rumberger. 1974. The birds of Prey of the Nisqually Delta. pp. 161-188 in: *The Nisqually Delta Group Contract. 1974. The Nisqually Delta*. The Evergreen State College, Olympia, Washington.

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Dames and Moore. 1978. *Shallow Subtidal Benthos of the Nisqually Reach, Puget Sound, Washington*. Prepared for The Weyerhaeuser Co.

Damron, Barbara J. & Trucene A Obert. 1975. Ecological description of a small Woodland on the Nisqually National Wildlife Refuge, Thurston County, Washington. pp. 145-171 in: The Evergreen State College. 1975 *Results of a natural history and field methods studies conducted by 35 undergraduate Students at the Evergreen State College*. The Evergreen State College, Olympia, Washington.

Deibold, Gary A. & Wayne A. Parsons. 1985. *Study report on the upper Nisqually River for wild or scenic rivers evaluation.* Gifford Pinchot Forest, Vancouver, Washington.

DePaola, Angelo, Charles A. Kaysner, John Bowers, and David W. Cook. Nov 2000. Environmental Investigations of *Vibrio parahaemolyticus* in oysters after outbreaks in Washington, Texas, and New York. *Applied Environmental Microbiology* 66: 4649 – 4654.

Abstract

Total Vibrio parahaemolyticus densities and the occurrence of pathogenic strains in shellfish were determined following outbreaks in Washington, Texas, and New York. Recently developed nonradioactive DNA probes were utilized for the first time for direct enumeration of *V. parahaemolyticus* in environmental shellfish samples. *V. parahaemolyticus* was prevalent in oysters from Puget Sound, Wash.; Galveston Bay, Tex.; and Long Island Sound, N.Y., in the weeks following shellfish-associated outbreaks linked to these areas. However, only two samples (one each from Washington and Texas) were found to harbor total *V. parahaemolyticus* densities exceeding the level of concern of 10,000 g 1. Pathogenic strains, defined as those hybridizing with tdh and/or trh probes, were detected in a few samples, mostly Puget Sound oysters, and at low densities (usually <10 g/1). Intensive sampling in Galveston Bay demonstrated relatively constant water temperature (27.8 to 31.7°C) and *V. parahaemolyticus* levels (100 to 1,000 g/1) during the summer. Salinity varied from 14.9 to 29.3 ppt. A slight but significant ($P < 0.05$) negative correlation (0.25) was observed between *V. parahaemolyticus* density and salinity. Based on our data, findings of more than 10,000 g/1 total V. parahaemolyticus or >10 g 1 tdh- and/or trh-positive *V. parahaemolyticus* in environmental oysters should be considered extraordinary.

Dominguez, Larry G. and C. Jeff Cederholm. 2000. *Rehabilitating Stream Channels Using Large Woody Debris with Considerations for Salmonid Life History and Fluvial Geomorphic Processes*. CRC Press.

Abstract

Pacific salmon (*Oncorhynchus* spp.) exist in fluvial systems that are physically and biologically dynamic. Salmonid life history characteristics and associated habitat requirements vary widely by species. Some species use the freshwater environment solely for incubation, while others use it for both incubation and extended rearing. Salmon species have evolved into several life history patterns that maximize their potential for survival and minimize their spatial and temporal overlap. To rehabilitate salmon habitat and thereby strengthen wild runs requires

knowledge of fish life histories and the aquatic system's potential range of conditions. Using large woody debris to rehabilitate stream channels is a popular management activity in the Pacific Northwest. Prior knowledge of factors such as spawning distribution and timing, incubation environment quality, seasonal rearing habitat needs (i.e. summer/winter), limiting factors in freshwater production, and the relative habitat quality and availability is imperative for successful projects. We review woody debris ecology in streams and provide planning information for woody debris placement projects. In addressing limiting aspects of properly functioning aquatic and riparian ecosystems, instream and riparian habitats can be created that provide the interim structural framework for streams until riparian and upland forests recover from past disturbances. The discussion is based on a decision flow diagram that guides the need assessment process and suggests appropriate rehabilitation technique. Visits to several stream rehabilitation projects, combined with information from literature and our own experience, led us to a number of conclusions supporting stream restoration for future sustainability of Pacific salmonids.

Dunlap, J.M. and R.F. Stettler. May 2001. Variation in leaf epidermal and stomatal traits of Populus trichocarpa from two transects across the Washington Cascades. *Canadian Journal of Botany* 79(5): 528-536.

Abstract

Epidermal and stomatal cell traits were examined on late leaves of 40 black cottonwood (*Populus trichocarpa* Torr. & Gray) clones originating from the mesic Nisqually, and xeric Yakima river valleys of Washington. Four leaves per clone were collected from 1 – year old trees in two replicated common gardens located in Puyallup (western Washington) and Wenatchee (eastern Washington). In Puyallup-grown material, Yakima clones had abaxially 14% smaller epidermal cell diameters (CDIAM) and 27% greater cell densities (CDEN; No. per mm super(2)0, and 25% smaller leaves than Nisqually clones (p less than or equal to 0.03). Abaxial stomatal densities (STDEN; No. per mm super(2)) were highest (206) in the lower elevation, xeric-origin Yakima clones, as compared with an average of 120 in Nisqually clones. A higher proportion of Yakima leaves had shorter stomates than those from the Nisqually at both sites (p less than or equal to 0.002). Besides shorter stomates (p less than or equal to 0.03), the lower elevation Yakima clones generally had higher STDEN and ratios of STDEN to CDEN than those clones from the upper group (p less than or equal to 0.098). Acclimation of Wenatchee-grown clones to the hotter, drier summer climate was also evident, as they generally had smaller CDIAM, and higher CDEN and STDEN than those grown at Puyallup. Genetic variances (among Rivers) ranged from 42 to 84% with clone being dominant for stomatal traits.

In the Yakima leaves, much of the genetic variance (group and clone within Group) resided in the group component. Broad-sense heritabilities averaged 72%, indicating moderately strong genetic control in most traits. This study provides further evidence of genetic variation in P. trichocarpa at the regional and local scales across the Washington Cascades.

Dunlap, J.M. and R.F. Settler. 1998. Genetic variation and productivity of Populus Trichocarpa and its hybrids. X. Trait correlations in young black cottonwood From four river valleys in Washington. *Trees – Structure and Function* 13(1): 28 – 39.

Abstract

A common-garden study of *Populus trichocarpa* Torr. and Gray was established in spring 1986 with 128 clones collected from sites along two mesic (Hoh and Nisqually) and two xeric (Dungeness and Yakima) river valleys in Washington. Two replicate plantations, one in Puyallup and the other in Wenatchee, Wash., were established with this material. Over 2 years data were taken on stem growth, leaf/crown characters, spring/autumn phenology, and the incidence of *Melampsora occidentalis* leaf rust. Combining clones from all four sources, correlation/regression analyses were used to examine clonal stability of traits between test sites and trait relationships with stem growth; broad-sense heritabilities (H superior 2) and genetic correlations revealed the genetic strength of these traits. At Puyallup, many leaf/crown traits predicted stem growth moderately to very well (r superior 2 greater than 0.50), e.g., total leaf area (TLA) to diameter gave an r superior 2 of 0.91 and current-terminal leaf size, of 0.79. Some regressions were quadratic, suggesting a threshold level in a trait (e.g., leaf size) beyond which stem growth levels off. Upper-crown TLA was more closely related to height than TLA of the lower sylleptics, but the reverse was true for diameter. A decline in r superior 2 values from upper to lower crown positions was sharper for correlations of TLAs with height than with diameter. Thus, leaf area allocation seems to differentially affect stem growth. When autumn leaf fall (LF) and rust incidence (R) were regressed with growth, r superior 2 values ranged from 0.58 to 0.71, but those of spring flush (SF) were only 0.10 to 0.12. Early LF and high R, both negatively affecting growth, had a strong geographic component as it occurred mainly on lower-elevation Yakima clones. At Wenatchee, field conditions were harsher and microsites more variable, so trait/growth relationships were weaker. Genetic correlations with growth revealed similar trends as phenotypic analyses. Unlike leaf/crown traits, clonal scores of LF, SF, and R were fairly stable across the two test sites (r superior 2: 0.58-0.80). These traits also showed strong genetic control (H superior 2: 0.96-0.98). The trait/growth relationships as well as trait stability within clones have implications for selecting clonal stock in poplar culture and conservation.

Dunlap, J.M. and R.F. Stettler. Oct 1996. Genetic variation and productivity of *Populus trichocarpa* and its hybrids. IX. Phenology and Melampsora rust incidence of native black cottonwood clones from four river valleys in Washington. *Forest Ecology and Management* 87(1-3): 233-256

Abstract

A common garden study of *Populus trichocarpa* Torr. And Gray was initiated in 1985 when material from 128 trees was collected along two mesic (Hoh and Nisqually) and two xeric (Dungeness and Yakima) river valleys. In spring 1986 cuttings were used to establish two replicate plantations, at Puyallup and at

Wenatchee, Washington. For 2 years trees were assessed for timing of spring flush, autumn bud set and leaf fall, and incidence of Melampsora occidentalis leaf rust. Seasonal patterns varied with trait, plantation, year, and origin of clones. Significant differences were found mainly between clones from the lower and upper elevations of the Nisqually (LN, UN) and Yakima (LY, UY). At both Plantations, clones from the cooler UN flushed later than those from the LN. In Contrast, cool canyon climates of some sites along the LY resulted in later spring flush of lower than upper clones. Factors affecting patterns of autumn phenology differed between trees from those river valleys. Later budset in LN vs. UN trees was again related to cold affecting the growing season length, but earlier budset and leaf fall in LY and UY clones at Puyallup was brought about by higher rust infection. The greater rust susceptibility of LY material likely reflects lower rust pressure in the more arid lower Yakima valley. Soil moisture deficit and the presence/absence of rust at the plantations also contributed to autumn phenology patterns. Genetic variances were larger for all traits at Puyallup. In Yakima trees, the large group component of the genetic variance (elevational group, clone) in leaf fall and rust points to a steep selection gradient along the Yakima. A similarly steep gradient seems also to influence spring flush along the Nisqually.

Heritabilities indicate moderately to very strong genetic control in these traits. The patterns of genetic variation have implications for short-rotation intensive-culture forestry and management of natural populations.

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Foster, R. Jan 1977. *Brood Chum and Pink rearing report*. Progress Report No. 10. Washington Department of Fisheries, Olympia.

Abstract

Adult Chum returns to Washington Department of Fisheries facilities in 1975 were below expectations and resultant egg takes were below the level desired. Eggs were taken at Hood Canal Hatchery, Satsop Springs, and Nemah Hatchery. Additional eggs were taken during several field operations in the following areas: Chambers Creek, Lackey Creek, Skagit Bay, and Perry Creek. Eggs of Nisqually

River stock and Japanese stock were also obtained. Release figures are summarized. Adult Pink returns to WDF facilities in 1975 were close to expectations. Eggs were taken at Skagit, Skykomish, Minter Creek and Hood Canal. Release figures are summarized.

Fowler, R.H. & A.O. Ness. 1954. *Soil survey of Lewis County, Washington*. USDA Soil Conservation Service Soil Survey, Series 1941, No. 10.

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Abstract

The ecology of fishes in the Nisqually Reach area of Puget Sound, Washington, particularly along the Dupont shoreline located to the east of the Nisqually River, was studied in 1977 and 1978. The project was initiated in response to a proposal by Weyerhaeuser Company and the City of Dupont, Washington, to construct a cargo loading dock in the area. Emphasis was placed on determining spatial and temporal distribution of juvenile salmonids, especially chum salmon. Other objectives included studying non-salmonid species, analyzing fish food habits, studying planktonic organisms, and assessing the use of Sequalichew Creek by anadromous species. Sampling gear included beach seine, townet, trynet, purse seine, bongo net, SCUBA, and in freshwater, a backpack electroshocker.

Juvenile Chum, Coho, Pink, and Chinook Salmon migrated along all shorelines in the Nisqually Reach. Peak outmigration of chum salmon was mid-May through late June. Early in the season (through mid-May), Chum fry were most abundant along the shorelines of Anderson Island and the mainland west of the Nisqually River. Later in the season (mid-May through June) an increase in abundance occurred along the Dupont shoreline, especially off-shore. Most Coho Salmon, nearly all of which were smolts, migrated along the shorelines of Anderson Island

during May. Coho were more abundant in beach seine than townet collections. Peak Chinook salmon abundance in the area was from late May through July along the mainland shorelines east and west of the Nisqually River. Several Chinook caught by beach seine were large sub-adult feeders (blackmouth). Catches of juvenile pink salmon were low during both years; peak catches were in the beach seine from the end of March through mid-April. Small, infrequent catches of cutthroat and steelhead trout occurred mostly along the Dupont shoreline.

Shiner perch, Pacific Herring, Staghorn Sculpin, and Starry Flounder were the most abundant non-salmonids that occurred in the beach seine, whereas herring and sand lance were the most abundant non-salmonids in townet collections. The large catches of juvenile herring indicate that the area was used for rearing. English sole and rock sole dominated demersal fish catches by trynet at the three stations sampled. Embiotocids (shiner, pile, and striped perches) were the most abundant pelagic fishes, and Buffalo Sculpin and Painted Greenling were the dominant demersal fishes seen in SCUBA surveys near an existing dock in the area considered for a construction site.

Adult Coho, Chum, Chinook, and Steelhead were captured by purse seine along the DuPont shoreline in 1977. Peak migrations of Coho and Chum along the DuPont shoreline were probably September-October and December-January, respectively. Recoveries of tagged salmonids, mostly Coho, were primarily from freshwater sources south of the Tacoma Narrows area of Puget Sound.

Plankton studies indicated definite seasonal changes of zooplankton, fish eggs, and fish larvae. The greatest catches were in May. The composition of zooplankton at all stations sampled were similar; calanoid copepods, crab zoea, cnidaria, and caridean zoea were the dominant organisms. Pleuronectids and gadoids were both the most abundant fish eggs and larvae collected.

Studies of Sequalichew Creek in 1977 were limited by low flows. Juvenile Coho were the most abundant salmon occurring in both years. Fry from natural spawners were present in the stream and smolts were present in Sequalichew Lake from plants by the Washington State Department of Fisheries. Peak outmigrations of smolts from Sequalichew Lake were in May. Chum fry were observed in 1977 but not in 1987. Cutthroat trout, prickly and coastrange sculpin, threespine stickleback, largemouth bass, and an unidentified cantarchid young-of- the-year were also captured. Coho and cutthroat trout were the only adult salmonids observed in the creek.

Most of the 44 species examined fed principally on epibenthic plankton and macroinvertebrates. During the early period of their residence in the Nisqually Reach, juvenile chum, Coho, and Chinook salmon fed predominantly on epibenthic organisms (harpacticoid copepods, gammarid amphipods), whereas juvenile pink salmon fed primarily on pelagic prey (calanoid copepods). Later in the season, as fish size and pelagic plankton abundance increased, diets of all juvenile salmonids were dominated by pelagic organisms. Of the fish in the area, only maturing Chinook salmon (blackmouth), copper rockfish, and staghorn

sculpin were considered potential predators of juvenile salmon. Of the species observed during SCUBA surveys of the DuPont Dock, three embiotocids, a greenling, and a rockfish species fed on organisms characteristic of the piling community. Habitat factors other than food availability may influence the association of these species with the dock.

Gardner, James V. and E.J. van den Ameele. 2001. *Mapping Southern Puget Sound Delta Fronts after the 2001 Nisqually Earthquake*. U.S. Geologic Survey (USGS) and National Oceanic and Atmospheric Administration (NOAA).

Abstract

A magnitude 6.8 earthquake struck southern Puget Sound on February 28th, 2001, causing an estimated $0.7 to $1.4 billion in damages to the surrounding area. The epicenter was close to the Nisqually delta, one of three major deltas in southern Puget Sound. Although the Nisqually delta is a wildlife refuge, both the Duwamish delta in Seattle and the Puyallup delta in Tacoma have extensive infrastructure, including major port facilities, at the delta edges. Teams of USGS scientists inspected the area immediately after the earthquake and reported damage in the Ports of Seattle and Tacoma, as well as presence of "mud plumes" in the waters of Puget Sound. A joint NOAA/USGS cruise was rapidly assembled in March 2001 to map bathymetry of the delta fronts using the high-resolution multibeam systems of the NOAA ship Rainier. Results showed a variety of submarine failures on the Puyallup and Duwamish delta fronts that may be related to the earthquake.

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Harrington-Tweit, William & Paul H. Svoboda. 1980. *Nisqually River 1980 Nisqually River juvenile salmonid outmigration study.* Nisqually Indian Tribe Technical Report No. 2.

Harrington-Tweit, William & Paul H. Svoboda. 1982. *Nisqually River 1982 winter Steelhead redd aerial survey*. Nisqually Indian Tribe Technical Report No. 4.

Abstract

Nisqually tribal biologists operated an inclined plane trap in the lower Nisqually River to monitor juvenile salmonid outmigration from March 12 to July 3, 1981. During 580 nighttime hours of operation this device sampled outmigrating juvenile Chinook, Chum, and Coho Salmon as well as steelhead and trout. Wild Chinook outmigration rates were low during March, April and early May. Hatchery-reared smolts released 15-23 May, did not emigrate in large numbers until 25-28 May when river flows increased significantly. Catches of wild Chum Salmon appeared to peak in mid-April this year, while in 1980 the peak was in mid-May. Coho outmigration levels were fairly constant from mid-April through May with peak catches at the trap immediately following hatchery origin smolt plants in upstream tributaries. Catches of Steelhead smolts were largest during

periods of high water in late April and again in later May. Results from this year's operation were similar to findings in the 1980 study using this device.

Harrington-Tweit, Bill and Paul H. Svoboda. Nov 1982. *Nisqually River 1982 Winter Steelhead Redd Aerial Survey*. Nisqually Indian Tribe Technical Report Number 5.

Abstract

Five aerial surveys of the Nisqually River were conducted from April through June 1982 to evaluate the native winter run Steelhead escapement in the mainstem. The 1982 escapement index is 2350 redds, essentially twice the indices from 1980 and 1981, of 1200 and 1100 redds respectively. The 1982 peak of spawning was during the latter half of April. Spawning distribution was similar to that observed in 1981.

The escapement index was calculated using different methods than the previous two years. It is an average of two estimates; one derived from plotting redd locations on aerial photographs of the mainstem river and the other from a new model that estimates the number of redds seen on a survey that were also observed on previous surveys. This redd accumulation-redd deterioration models stochiastic, but rather simplistic as it expresses redd deterioration as a linear function.

Harrington-Tweit, William & Paul H. Svoboda. Jan 1983. *Nisqually River 1982 juvenile salmonid outmigration study*. Nisqually Indian Tribe Technical Report No. 6.

Abstract

Nisqually tribal biologists and technicians operated an inclined plane trap in the lower Nisqually River to monitor juvenile salmonid outmigration from April 12 to June 8, 1982. During 355 nighttime hours of operation the trap caught 3,470 outmigrating juvenile Chum, 7,011 Chinook, 564 Coho Salmon as well as 72 steelhead. Outmigration of naturally produced chum peaked in mid to late April, approximately one week later than the 1981 peak. Wild Chinook outmigration rates were low throughout the study. Hatchery-reared Chinook emigrated in large numbers for one week following their releases on April 20 and June 4. Coho outmigration levels were fairly constant through April and May, peaking near the end of May. The peak Coho outmigration coincided with a slight rise in water velocity. The last Coho hatchery release was April 14. Some hatchery origin Coho smolts reared for better than a month in tributary streams and the mainstem before emigrating with the rising flow. Catches of Steelhead smolts were low until late in the study when an electroshocker was utilized in conjunction with the trap.

Harrington-Tweit, William & Paul H. Svoboda. 1983. *Estimation of chum salmon escapements in Muck Creek, a Nisqually River tributary*. Nisqually Indian Tribe Technical Report No. 7.

Abstract

For nine successive Nisqually River chum runs, fisheries personnel from the Nisqually Indian Tribe, Fort Lewis and the Fisheries Assistance Office, U.S. Fish

and Wildlife Service have conducted several cooperation projects, all aimed at assessing Chum Salmon (*Oncorhynchus keta*) usage of Muck Creek, a major lower river tributary of the Nisqually River. These cooperative efforts have demonstrated conclusively the critical importance of Muck Creek as a spawning area for the Nisqually late timing Chum. The creek, in most years, supports at least a quarter of the entire escapement. The projects to date have also generated a large amount of biological information on Chum Salmon spawning. Data exist on patterns of entry into the creek, utilization of spawning areas, and relative length of time spent reaching the creek and spawning in the creek. Much of that data remain unanalyzed.

In this report we analyze spawning ground survey information in an attempt to develop a method for accurately estimating spawning escapement in the creek. Knowledge of annual levels of chum utilization of the creek affords tribal fisheries managers an opportunity to assess the effects of tribal harvest patterns on a very important segment of the chum run. Annual estimates of chum escapement in Muck Creek also aid in estimating annual chum escapement in the Nisqually system as a whole.

Harrington-Tweit, William & Paul H. Svoboda. 1983. *Nisqually River late chum jawtagging studies 1979/80 through 1981/82*. Nisqually Indian Tribe Technical Report No. 9.

Abstract

The run sizes of Nisqually late native chum from 1979/80 through 1981/82 were estimated in-season by the Nisqually Tribe using limited jawtagging studies. This method of estimation performed poorly for all three years, largely because the method is very sensitive to variations in run timing for which it cannot compensate.

Extensive biological sampling of the harvest and escapement was conducted in conjunction with the tagging studies. Scale sampling, sex ratio determination and fork length measurements at tagging were analyzed. The age composition of these three runs varied dramatically; the three year old segment ranged from 18% to 72%. The spawner : recruit ratio from the parent years of these runs also varied greatly, from 1:1.3 to almost 1:5. Within a run year, the percentage of males in the harvest decreased linearly over time, about 4% per week. Similarly, the proportion of three year old fish of each sex in the harvest also declined in a linear fashion over time.

Harrington-Tweit, William & Paul H. Svoboda. 1983. *Nisqually River 1983 juvenile Salmonid outmigration study*. Nisqually Indian Tribe Technical Report No. 10.

Abstract

Five aerial surveys of the Nisqually River were conducted from April through June 1983 to evaluate the native winter run steelhead escapement in the mainstem. The 1983 escapement index is 1670 redds, above the indices from 1980 and 1981, of 1200 and 1100 redds respectively, and below the 1982 index of

2350. The 1982 peak of spawning was during the latter half of April. Spawning distribution was similar to that observed in 1981 and 1982.

Harrington-Tweit, William & Paul H. Svoboda. 1984. *Nisqually River 1984 winter steelhead redd aerial survey*. Nisqually Indian tribe Technical Report No. 11.

Abstract

Six aerial surveys of the Nisqually River were conducted from April through June 1984 to evaluate the native winter run Steelhead escapement in the mainstem. The 1984 escapement index is 805 redds, below the indices from 1980-1983, of 1200, 1100, 2350 and 1670 redds respectively. The 1984 peak of spawning was not discernable, counts were steady from late April to late May. Spawning distribution was similar to that observed in 1983.

Harrington-Tweit, William & Paul H. Svoboda. 1985. *Nisqually River 1985 winter Steelhead redd aerial survey.* Nisqually Indian Tribe Technical Report No. 12.

Harrington-Tweit, William & Edward J. Tierney. 1985. *Nisqually River 1985 juvenile Salmonid outmigration study*. Nisqually Indian Tribe Technical Report No. 13.

Abstract

Studies of outmigrant population of juvenile salmonids were conducted in the lower Nisqually River during the spring of 1985. Three capture gears were employed: beach seining, a panel trap installed on one side of the mainstem and electroshocking along the banks of the mainstem. Large numbers of summer/fall Chinook smolts released from hatchery facilities were captured by nighttime beach seining operations. The panel trap was the most efficient gear for capture of chum juveniles. The average fork length of 38.2 mm was similar to the average observed in previous years. The nighttime beach seine was the only effective capture gear for steelhead smolts, although it may have been biased. Most of the catch were the one year-old smolts, averaging 134.4 mm in length. Relatively few two year-old smolts, averaging 203.3 mm, were caught. It is possible that they can actively avoid the net.

Harrington-Tweit, William. 1986. *Nisqually River 1986 winter steelhead redd aerial survey*. Nisqually Indian Tribe Technical Report No. 14.

Abstract

Five aerial surveys of the Nisqually River were conducted from mid-April through mid-June 1986 to evaluate the native winter run steelhead escapement in the mainstem. The 1986 escapement index is 1000 redds, somewhat less than the 1980-1985 average index of 1350 redds. The 1986 peak of spawning was in late April. Spawning distribution throughout the river was quite even.

Harza Northwest, Inc. 1991. *Nisqually hydroelectric project FERC No. 1862*. Prepared For City of Tacoma Department of Utilities Light Division for submittal to the Federal Energy Regulatory Commission.

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Haugen, Geraldine Vander, and Anita Swanson. Jun 2002. *Using semi-natural rearing habitat to improve smolt-to-adult survival of Chinook salmon*. Final Report for IAC Contract 01-044. Washington Department of Fish and Wildlife, Olympia.

Hiss, J. & B. Harrington-Tweit. 1982. *Downstream migration of juvenile rainbow/steelhead trout in the Nisqually River and Muck Creek.* US Fish and Wildlife Service, Olympia, Washington.

Introduction

The U.S. Fish and Wildlife Service (USFWS) monitored the downstream migration of juvenile rainbow/steelhead trout (*Salmo gairdneri*) on Muck Creek, a tributary of the Nisqually River, in the spring of 1980. The USFWS also monitored the juvenile outmigration on the mainstem Nisqually River in the spring of 1981 in cooperation with the Nisqually Indian Tribe.

The Nisqually has both winter and summer-run steelhead. The winter run consists of both native fish and hatchery fish of outside origin, but it is managed for natural production. This run contributes to both the Nisqually Indian commercial and non-Indian sport fisheries on the river. The summer run consists of hatchery fish of outside origin and contributes to a small non-Indian sport fishery on the river.

The population dynamics of naturally-produced steelhead are not well known in most western Washington streams. Only the Washington Department of Game (WDG) Snow Creek station monitors escapement, hatching survival, rearing density, outmigration, and adult return on the same population. Outmigration has been widely studied elsewhere, but parr and fry migration patterns have been studied less frequently than smolt migration.

Knowledge of population size and survival of life stages on the Nisqually would help refine pre-season run size prediction and help establish escapement goals.

An index of escapement has been calculated from aerial surveys (Nisqually Tribe 1979), and escapement to Muck Creek was counted with a weir in 1978-79, 1979-80, and 1980-81 (Hiss 1981). Life history of winter-run fish has been obtained from scale analysis of lower mainstem commercial catch and Muck Creek weir returns (USFW 1981; Eric Knudsen, Fisheries Research Services, personal communication). Distribution and relative abundance of juveniles has also been studied (Tyler 1979; Svoboda 1987; Harrington-Tweit and Svoboda 1980), but number and characteristics of outmigrants have not been studied until now.

The objectives of this study were:

(1) to investigate rainbow/steelhead life history on muck Creek to complement WDG studies on Snow Creek and previous adult trapping on muck Creek, and specifically to define smolt migration. Secondary objectives were to evaluate

productivity of escapement and to estimate the timing and length-age composition of the outmigration; and

(2) to investigate, in cooperation with the Nisqually Tribe, steelhead outmigration on the Nisqually River. Secondary objectives were to estimate the length-age composition of natural smolt run and evaluate the contribution of hatchery plants.

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Larson, A.G. 1983. The influence of geology on the chemical composition of two Washington rivers. *Northwest Science* 57(4): 256-266.

Abstract

The Hoh and Nisqually rivers of western Washington originate in major national Parks having similar vegetation but dissimilar geology. The Hoh River, originating from three glaciers on the flanks of 2428 m Mt. Olympus, drains approximately 80,000 ha underlain by marine sediments, primarily a $CaCO_3$ cemented greywacke. The Nisqually River, originating from glacier melt on 4392 m Mt. Rainier, drains approximately 150,000 ha underlain by flows of pyroxene andesite. Differing bed-rock mineralogy results in striking differences in major ion concentrations between rivers. Ionic concentrations increase rapidly within undisturbed national parks but remain relatively stable, maintaining characteristic differences, as rivers traverse lower watersheds influenced by forestry farming, and urbanization. With minor expectations, geochemical reactions control the chemical composition of the Hoh and Nisqually rivers.

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McCain, B.B., D.C. Malins, M.M. Krahn, D.W. Brown, W.D. Gronlund, L.K. Moore and S.L. Chan. 1990. Uptake of aromatic and chlorinated hydrocarbons by juvenile Chinook salmon (*Oncorhynchus tshawytscha*) in an urban estuary. *Archives of Environmental Contamination and Toxicology* 19(1): 10-16.

Abstract

A study was conducted to assess the potential for uptake of toxic chemicals by down-stream migrant salmon in an urban estuary. Juvenile Chinook salmon (*Oncorhynchus tshawytscha*) were collected from the Duwamish Waterway (located in Seattle, Washington) and from the Nisqually River (a reference site). The mean concentrations of aromatic hydrocarbons and polychlorinated biphenyls (PCBs) in the stomach contents (food organisms) of salmon from the Duwamish Waterway were approximately 650 times and 4 times, respectively, higher than those in salmon from the Nisqually River. Similarly, the mean concentration of bile metabolites of aromatic compounds which fluorescence at benzo(a)pyrene wavelengths was 24 times higher in the urban salmon compared to the reference salmon, whereas the mean concentration of PCBs in liver of urban salmon was 3 times higher than that in reference salmon. The study clearly demonstrates that, during their residency in this urban estuary, juvenile Chinook salmon bioaccumulate substantial levels of toxic chemicals.

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Abstract

A study of glacial sediments throws light on rates and mechanisms of glacial erosion on Mount Rainier, Washington. Suspended-sediment transport measurements suggest that most of the Nisqually River's suspended-sediment load has been entrained by the time the stream emerges from beneath the terminus of Nisqually Glacier. Calculations of the englacial- and superglacial-debris loads of Nisqually Glacier indicate that more than two-thirds of the stream sediment must be derived subglacially. Lithologic composition of outwash and theoretical considerations also suggest that valley glaciers on Mount Rainier have exceptionally high subglacial erosion rates.

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Introduction

Salmon are important to the economic, social, cultural, and aesthetic values of the people in the Nisqually River Basin. In recognition of the importance of Nisqually Chinook salmon, the Nisqually Chinook Recovery Team (NCRT) was formed to develop a plan for its recovery. The recovery of Nisqually Chinook is best achieved within the context of a comprehensive plan that takes into account all of the factors that affect productivity, abundance, and diversity across the migratory range of species. The proposed recovery plan is an initial product of a three-year effort to develop an integrated multi-species plan for the Nisqually Basin. Restoration of the Nisqually Chinook production will contribute toward the recovery of the Puget Sound Chinook stocks that are listed as "threatened" under the Endangered Species Act (ESA).

The health of a salmon population depends on the condition of its environment and the genetic fitness of that population. Information about the past and current Nisqually River Chinook populations, and their environment, provides clues to the causes of their decline and to the potential for their recovery.

The Nisqually Basin, like most of Southern Puget Sound, has a long history of hatchery enhancement. Hatchery production is important for maintaining harvest opportunities in the basin, by providing a necessary replacement for natural production lost to habitat degradation and ocean harvest pressures. As a consequence of harvest rates associated with the hatchery program, native components of the Chinook salmon populations have long been extirpated. The recovery plan, therefore includes a strategy for hatchery programs that is compatible with the development of a locally adapted, naturally spawning Chinook population in the Nisqually Basin.

In developing this plan, the NCRT analyzed Chinook salmon using Ecosystem Diagnosis and Treatment (EDT) method. The resultant plan is thus based upon long-term recovery goals and a wide range of habitat, harvest, and hatchery management options; it takes into account all of the known impediments to, and likely opportunities for, achieving Chinook salmon recovery goals in the basin. Predicted outcomes of the actions are only hypotheses, and selected actions must be validated through a carefully designed monitoring plan and supported by a decision-making process that is responsive to new information..

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Nisqually River Task Force. 1986. *Nisqually River Management Plan: Draft And Environmental Impact Statement*. Washington Department of Ecology. Olympia, Washington.

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One of the research sites occupied in researching a definition of aquatic lands under the Shoreline Management Act was along McAllister Creek on Nisqually Delta.

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Peterson, D.L., D. Bowers, S. Brace. Nov 1999. Tropospheric Ozone in the Nisqually River Drainage, Mount Rainier National Park. *Northwest Science* 73(4): 241-254.

Abstract

We quantified the summertime distribution of tropospheric ozone in the topographically complex Nisqually River drainage of Mount Rainier National

Park from 1994 to 1997. Passive ozone samplers were used along an elevational transect to measure weekly average ozone concentrations ranging from 570 m to 2040 m elevation. weekly average ozone concentrations were positively correlated with elevation, with the highest concentrations consistently measured at the highest sampling site (Panorama Point). Weekly average ozone concentrations at Mount Rainier National Park are considerably higher than those in the Seattle-Tacoma metropolitan area to the west. The anthropogenic contribution to ozone within the Nisqually drainage was evaluated by comparing measurements from a "reference" site in the western Olympic Mountains. The comparison suggests there is a significant anthropogenic source of ozone reaching the Cascade Range via atmospheric transport from urban areas to the west. In addition, temporal (week to week) variation in ozone distribution is synchronous within the Nisqually drainage, which indicates that subregional patterns are detectable with weekly averages. The Nisqually drainage is likely the "hot spot" for air pollution in Mount Rainier National Park. By using passive ozone samplers in this drainage in conjunction with a limited number of continuous analyzers, the park will have a robust monitoring approach for measuring tropospheric ozone over time and protecting vegetative and human health.

Pierepiekarz, Mark R., Donald B. Bllantyne, and Ronald O. Hamburger. Jun 2001. Damage report from Seattle. *Civil Engineering* 71(6): 78.

Abstract

The occurrence and damage from the Nisqually earthquake of a 6.8 magnitude in Western Washington State with the epicenter approximately 11 miles northeast of Olympia, the state capital are reported. The quake caused liquefaction, sand boils, landslides, soil slumping in rural areas, and damage to homes.

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Abstract

The geographical distribution and intensity of PSP has increased in Puget Sound since the mid 1970s. Formerly a rarity in central Puget Sound, now all but parts of southern Puget Sound (SPS) and central and southern Hood Canal (CHC and SHC) are affected by shellfish toxicity due to PSP from toxic dinoflagellate *Alexandrium catenellum*. Monitoring data and preliminary experiments are given that suggest supply and vertical distribution of nitrogen in the water column prevents *A. catenellum* growth during the summer in the unaffected areas. After the spring diatom bloom, surface and subsurface (10 m) waters of CHC are annually depleted of nitrogen until fall, while deeper water (30 m) are nutrient rich. Filtered water from the surface and subsurface depths of this area did not support growth of *A. catenellum*, and unexpectedly, neither did the nutrient-rich deep water. These factors, along with slow physical transport in CHC, apparently form a barrier to the passage of *A. catenellum* to the more nutrient-rich SHC. SPS water (except Carr Inlet and Nisqually Reach) are seasonally depleted of surface and subsurface nitrogen, similar to CHC. Increased nutrification from rapid urbanization and non-point sources could lead to annual PSP problems in areas presently unaffected by PSP, unless mitigative measures are taken.

Roberts, PJW. 1980. Current measurements and mathematical modeling in southern Puget Sound. Estuarine and Wetland Processes with Emphasis on Modeling. *Marine Science* 11: 269-284

Abstract

Field observations and mathematical modeling were conducted in order to understand the circulation patterns in Nisqually Reach, Southern Puget Sound. Analysis of the current data showed the currents to consist of a first principal component which was essentially parallel to channel walls.. This component was primarily tidal, although both high and low frequency content was apparent. The high frequency content was attributed to fairly small-scale turbulence. The low power spectra showing a secondary peak at 2.5 days. Typical circulation patterns predicted by the mathematical model are presented. Limitations of the model are discussed in light of the analysis of the current meter data.

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Abstract

Four aerial surveys of the Nisqually River were conducted in the spring of 1988 to evaluate native winter run steelhead escapement. Consistently poor visibility prohibited a desirable fifth survey from being conducted, and disrupted the timing of the surveys. The 1988 escapement index was determined to be 1182 redds, and the spawning density index was determined to be 30.8 redds/mile. These indices are slightly below the average of recent years. Spawning activity was distributed evenly throughout the river, peaking in early May.

Schnepf, Kenneth & Edward Tierney. 1989. *Nisqually River 1989 winter steelhead redd aerial survey*. Nisqually Indian Tribe Technical Report No. 18.

Schwartz, M. & D. Hatfield. 1982. *Thurston County, Washington net shore drift*. Coastal Consultants, Inc., for the Washington State Department of Ecology.

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Scott, J.L. 1982. Sediment Transport Study along a delta shoreline. *Bulletin of the Association of Engineering Geologists* 16(2): 101-116.

Abstract

A sediment transport study was conducted along the east shoreline of the Nisqually River Delta, Southern Puget Sound, Washington, to provide baseline data for an Environmental Impact Statement and preliminary design criteria for a forest products exporting wharf. The study was concerned with determining the characteristics of beach and deltaic sediments, the factors affecting sediment transport along the shoreline and on the delta, and the directions and rates of sediment transport. Sediment transport on the beach was determined by interpretation of beach profiles and sediment textural characteristics and by a beach grain tagging experiment. An estimate of sediment movement on the delta platform was obtained from sediment trap data and an historical chart comparison. Results of the study are discussed.

Sherrod, B.L. Apr 1999. Earthquake-induced subsidence about 1100 years ago around Southern Puget Sound, Washington. *Seismological Research Letters* 70(2): 233-234.

Abstract

Forests and marshes subsided about 1100 years ago, probably during an earthquake, in two areas at the latitude of Olympia, Washington. One area is located south of Shelton (at Little Skookum Inlet), and the other about 30 km to the east on the Nisqually delta (sites along Red Salmon Creek, Nisqually River, and McAllister Creek). The evidence for subsidence consists of forest and marsh soils that appear to have been abruptly submerged in tidal water. At Little Skookum Inlet and Red Salmon Creek, Douglas-fir stumps in growth position are covered by salt marsh peat. Along McAllister Creek and Nisqually River, soils of high salt marshes are overlain abruptly by laminated tideflat mud. Liquefaction coincided with subsidence at McAllister Creek. Sand erupted through the salt-

marsh soil and formed a small volcano. The flanks of the volcano rest directly on the soil surface and beneath the tideflat mud that subsequently buried the soil. Amounts of subsidence were estimated from fossil seeds and diatoms, and the timing of subsidence indicated by radiocarbon ages. On this basis, the subsidence was greater at Little Skookum Inlet (about 3 m) than at the Nisqually delta localities (0.5-1.2 m). The subsidence took place around AD 900. Conventional radiocarbon dates of plant remains suggest that it happened between AD 690-1160. High-precision radiocarbon dates of Douglas fir stumps narrows the timing of subsidence to AD. 860-940 at Red Salmon Creek and AD 800-970 at Skookum Inlet. Several alternatives exist for inferring which fault caused the subsidence. A low-angle thrust fault continuous with the Seattle fault is among the possibilities because all the above age ranges include 900-930, the probable time of a large earthquake on the Seattle fault. However, the Seattle fault approaches the surface some 75 km to the north of the subsided areas. An alternative explanation invokes the 'Legislature fault' located just south of the subsided area (fault is known mainly from gravity and magnetic mapping).

Sherrod, Brian L. Oct 2001. Evidence for earthquake-induced subsidence about 1100 yr Ago in coastal marshes of southern Puget Sound, Washington. *The Geological Society of America Bulletin* 113(10): 1299.

Abstract

Buried forest and high marsh soils indicate abrupt changes in relative sea level at four coastal localities in southern Puget Sound. At Little Skookum Inlet and Red Salmon Creek, Douglas fir stumps in growth position are buried by salt-marsh peat. At localities along McAllister Creek and the Nisqually River, high marsh soils are buried by tidal-flat mud. Localized liquefaction coincided with submergence of high marsh soil at McAllister Creek.

Dramatic changes in seed and diatom assemblages across these contacts confirm rapid submergence. At Little Skookum Inlet and Red Salmon Creek, salt-marsh peat immediately above a buried forest soil contains diatoms indicative of low marsh and tidal-flat environments. At McAllister Creek and Nisqually River, low-marsh and tidal-flat diatoms are abundant in laminated mud directly over high marsh peat. Inferences from modern analogs indicate at least 1 m of subsidence at each site and possibly up to 3 m at Skookum Inlet.

Abrupt burial of lowland soils in southern Puget Sound is best explained by coseismic subsidence. Some of the submergence may be the result of coseismic compaction and postearthquake settlement. Widespread buried soils, large amounts of subsidence, coeval submergence across a wide area, and ground shaking at the time of subsidence all point to a large earthquake between 1150 And 1010 cal yr BP in southern Puget Sound as the most likely case of subsidence.

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Smoker, W.A., H.M. Jensen, D.R. Johnson, and R. Robison. 1952. *The Nisqually River Indian fishery*. State of Washington. Department of Fisheries. Olympia, Washington.

Sparks, J.P. and R.A. Black. 1999. Regulation of water loss in populations of *Populus trichocarpa*: The role of stomatal control in preventing xylem cavitation. *Tree Physiology* 19(7): 453-459.

Abstract

Variations in resistance to drought-induced xylem cavitation, xylem air-entry points, stomatal behavior, and hydraulic conductivity were measured in four populations of *Populus trichocarpa* Torr. and A. Gray collected along an east-west humidity and temperature gradient in Washington State, USA. Xylem air-entry points were less negative in trees from moist environments (-0.71 and -1.32 MPa in the Hoh and Nisqually populations, respectively) than in trees from dry environments (-1.55 and -1.67 MPa in the Palouse and Yakima populations, respectively). Xylem cavitation in response to experimental drought was consistent with air-injection measures of xylem air-entry points for a given population. Populations vulnerable to cavitation also exhibited higher stem specific hydraulic conductivities and limited stomatal control compared with resistant populations. Populations exhibiting vulnerability to cavitation and limited stomatal control desiccated more rapidly during drought compared with resistant populations. This study provides evidence of interpopulation variation in resistance to drought-induced xylem cavitation, stomatal behavior, and hydraulic conductivity within *Populus trichocarpa*.

Stalmaster, M.V. and J.L. Kaiser. Oct 1997. Flushing responses of wintering bald eagles To military activity. *Journal of Wildlife Management* 61(4): 1307-1313.

Abstract

We studied flushing responses of wintering bald eagles (*Haliaeetus leucocephalus*) to military, firing activity, helicopter overflights, and boating on the Nisqually River and Muck Creek on the Fort Lewis Army Reservation, Washington, during 1991-94. Eight percent of 1,452 eagles monitored near Muck Creek flushed during 373 firing events; 45% from ordinance explosions, 9% from automatic weapons fire, 6% from artillery impacts, 4% from mortar impacts, and 3% from small arms fire. Flushing by eagles decreased with increasing distance from firing events (16% flushed at 0.5-1.0 km, 9% at 1-2 km, 4% at 2-4 km, and <1% at 4-6 km). Forty-seven percent of 919 eagles flushed in response to 48 helicopter overflights, 37% on the Nisqually River and 53% on muck Creek. Sixty-one percent of 1,825 eagles flushed in response to 52 experimental boat disturbances on the Nisqually River. Subadults flushed more often than adults, and eagles feeding or standing on the ground flushed more often than those perching in trees. Our data suggest that ordinance explosions, low level helicopter overflights, and boating should be restricted near eagle foraging areas.

Stalmaster, M.V. and J.L. Kaiser. Aug 1997. Winter ecology of bald eagles in the Nisqually River drainage, Washington. *Northwest Science* 71(3): 214-223.

Abstract

We studied the winter ecology of a population of bald eagles (*Haliaeetus leucocephalus*) on the Nisqually River and a tributary, Muck Creek, in Washington, for 3 years. Peak eagle numbers on the river and creek combined occurred in early February and were 168 in 1991-92, 128 in 1992-93, and 156 in 1993-94. For the 3 years, 79% of eagles used the Nisqually River and 21% used Muck Creek. Eagle use of the river was high between 8 and 18 km (5 and 11 miles) upstream of Puget Sound and the mouth of Yelm Creek; use on Muck Creek was concentrated on the lower 4 km (2.5 miles). The subadult proportion in the study area was 46% in 1991-92, 41% in 1992-93, and 43% in 1993-94; it increased throughout each winter; and it was higher where most eagles congregated. Chum salmon (*Oncorhynchus keta*) was the primary food source, and this eagle population was predicted to consume 1,100 salmon carcasses each winter based on the yearly average of 6,952 eagle days on the river and creek. Black cottonwood (*Populus balsamifera*) was the most widely used tree species by both perching (53% of 1,423 eagle sightings) and roosting (53% of 94 roost trees) eagles, and 8 of 9 communal roosts were located in old-growth forests. Management to enhance chum salmon runs, maintain forest habitat, and regulate human disturbance is needed to protect this eagle population.

Steiger, G.H. and J. Calambokidis. 1986. California and northern Sea Lions in southern Puget Sound, Washington. *Murrelet* 67: 93-96.

Steiger, G.H., J. Calambokidis, J.C. Cubbage, D.E. Skilling, A.W. Smith, and D.H. Gribble. 1989. Mortality of harbor seal pups at different sites in the inland waters of Washington. *Journal of Wildlife Diseases* 29: 319-328.

Stober, Q.J. & M.C. Bell. 1986. *The feasibility of anadromous fish production above the Alder/LaGrande hydroelectric projects on the Nisqually River*. Final report for the Nisqually Indian Tribe (FRI-UW-8609). Fisheries Research Institute, University of Washington, Seattle.

Stratton, David H and Glen W. Lindeman. 1977. *Survey of historical resources at the Dupont site*. Pullman, Washington.

Strong, James M. 1993. *Nisqually Delta study, June 15-August 27, 1993. South Sound Community College, Saint Martin's College, and University of Puget Sound.* South Sound Community College. Olympia, Washington.

Svodoba, P. Jul 1980. *Nisqually fisheries enhancement program*. Nisqually Indian Community, Olympia, Washington. 129 p.

Abstract

The Nisqually Indian Community (Puget Sound Indian tribe), as a signator to the Medicine Creek Treaty of 1854, initiated the development of a tribal fisheries program. The Nisqually fisheries enhancement program is presented in three segments. The studies summarized are population assessment; stream

rehabilitation; chum salmon enhancement; engineering survey and design studies; and Chinook salmon enhancement. Five appendices contain the specific details of each study in the program.

Svoboda, Paul H. & William Harrington-Tweit. 1980. *Nisqually River 1980 winter Steelhead redd aerial survey*. Nisqually Tribe Technical Report No. 1.

Introduction

The Nisqually Indian Tribe, with cooperation from the Washington State Game Department (W.D.G.), conducted aerial surveys of winter steelhead (*Salmo gairdneri*) redds in the Nisqually River, during the spring of 1980. Aerial surveys of steelhead redds had previously been conducted by W.D.G. from 1966 through 1969, in 1972 and 1973, and by the Fisheries Assistance Office, U.S. Fish and Wildlife Service (U.S.F.W.S.), in 1974 and 1975. The Tribe resumed aerial surveys to generate data on steelhead escapement and spawning patterns in the mainstem. This data is crucial for effective management of the tribal steelhead fishery and the water resources of the mainstem Nisqually River to maintain healthy, native stock of Nisqually steelhead.

Svoboda, Paul H. & William Harrington-Tweit. 1981. *Nisqually River 1981 winter steelhead redd aerial survey*. Nisqually Indian Technical Report No. 3.

Abstract

Four aerial surveys of the Nisqually River were conducted from April through June 1981 to evaluate the native winter run steelhead escapement in the mainstem. The 1981 escapement index was 1100 redds, slightly lower than the 1980 index of 1200 redds. Spring floods in 1981 complicated observations, thus the 1981 index is conservative. The peak of spawning could have been two weeks earlier than during 1980. Spawner distribution in the mainstem varied moderately from the 1980 pattern.

Two methods were used to calculate number of redds actually observed. The widely used method of factoring redd visibility lives into daily redd counts agreed very well with an estimate derived from plotting redd locations on aerial photographs of the mainstem.

Svoboda, Paul H. & William Harrington-Tweit. 1983. *Estimating chum salmon escapements in the Nisqually River system from spawning ground data for the Years 1975/76-1982/83*. Nisqually Indian Tribe Technical Report No. 8.

Abstract

Chum salmon escapements in the Nisqually River system were estimated for four years with a mark/recapture study. The extreme turbidity of the mainstem of the Nisqually, in which a large percentage of the chum spawn, make the estimation of escapements from direct observations impossible. The alternative to mark/recapture studies is to relate measures of chum spawning abundance in discrete segments of the system to overall levels of escapement, using observations from the mark/recapture years as the basis for comparison. Data from the first mark/recapture study was useless for this purpose, leaving only

three data points for determining the form of the relationship of the segments to overall spawning levels. This limitation, and the undesirability of lumping segments with known escapements with those of unknown escapements, determined that two independent variables would be used to estimate escapement only into segments such as the mainstem in which escapement could not be estimated directly. One independent variable is the average number of chum carcasses sampled on surveys of gravel bars on the mainstem per year, and the other is the escapement into Yelm Creek, the most easily surveyed tributary. The estimated escapements from spawning ground survey data correspond closely with those from the mark/recapture studies, though there may be a tendency for the survey estimates to underestimate low escapements.

Tall, Lyssa, Jackie Ferry, and Barbara MacGregor. 1995. *Where the River Meets the Forest: An Educator's Guide to the University of Washington's Pack Experimental Forest*. Nisqually River Education Project.

Tanner, C.D. 1999. *Nisqually National Wildlife Refuge GIS analysis*. Prepared for the Nisqually National Wildlife Refuge and Ducks Unlimited by the U.S. Fish and Wildlife Service, Western Washington Office. Olympia, Washington. 22 pp.

Introduction

Western Washington Office (WWO) staff of the U.S. Fish and Wildlife Service have been providing assistance to Nisqually National Wildlife Refuges (NWR) staff currently engaged in the development of a Comprehensive Conservation Plan (CCP) for the refuge. Ducks Unlimited is also assisting the Refuge in completion of the CCP, providing technical expertise and support in habitat management and restoration. The scope of the CCP is broad, as it is intended to provide guidance on the full range of issue and activities which involve Nisqually NWR. Major issues to be addressed in the CCP include:

- Changing the mix of habitat types at Nisqually NWR
- Trail access and configuration
- Waterfowl hunting
- Refuge expansion and acquisition

WWO staff have been specifically requested to assist the Refuge in the development and evaluation of habitat management alternatives, including restoration of intertidal habitat at Nisqually NWR, and to help describe and quantify effects of restoring portions of the area which is currently diked to tidal influence. Towards the end, we have completed three tasks:

1. Literature review summarizing documented importance of estuarine habitats to anadromous salmonids (Aitkin, 1998).

2. Summarized known fishery resource information for incorporation into the CCP and associated NEPA documents (Cook-Taylor, 1999).

3. GIS analysis described in this report.

The intent of the last task, and the subject of this report is to provide a regional context for analyzing the significance of restoring portions of the diked floodplain at Nisqually NWR to tidal influence. In order to do so, this study seeks to address the following questions:

1. What historic changes have occurred in Nisqually River estuary wetlands?

2. What is the current extent of wetland habitats within the south Puget Sound region?

3. What estuarine and palustrine habitats are most prevalent within the study area and the region?

4. What effect would restoration of intertidal conditions at Nisqually NWR have on the estuarine and palustrine wetland resources of the region?

Tetra Tech/KCM, Inc. Apr 2001. *Yelm Creek Comprehensive Flood Management Plan Draft Report*. City of Yelm, Washington. Project Number 2940130.

Thom, Ronald, Charles A. Simenstad, Robert C. Wissmar, and Ernst O. Salo. 1985. *Nisqually River estuary study design project: An environmental baseline and Monitoring program*. (Prepared for Nisqually Indian Tribe.) Fisheries Research Institute, University of Washington, Seattle.

Abstract

The Nisqually Indian Tribe commissioned the Fisheries Research Institute, University of Washington, to provide detailed plans for environmental studies in the region of the Nisqually River estuary. The plans include a baseline study, a juvenile salmonid outmigration study, and a monitoring program. These plans are based primarily upon a review of pertinent literature and discussions with experts in appropriate fields.

The study region centers on the Nisqually Flats and includes estuarine portions of nearby rivers, creeks and passes, and Nisqually Reach. A conceptual model of the ecological system is proposed which has physical, chemical, and biological components. The baseline study is divided into three levels of parameter sampling: I. Structural parameter documentation; II. Rates and fluxes; and III. Processes and interactions.

The literature review indicated that the region is reasonably well studied; however, with the possible exception of the environmental sampling conducted for the proposed Weyerhaeuser dock at DuPont, the studies are not integrated. Data are either incomplete or lacking on mudflat benthos, water column properties, juvenile salmonid use of the estuary, and deep subtidal infauna. The review indicated the possible critical importance of estuarine habitat to juvenile salmonids and other resource species.

The recommended baseline study includes the following major topics or components: Habitat mapping; Benthic microalgae; Seaweeds; Eelgrass; Marsh phanerograms; Bivalves; Infauna; Epibenthic crustacea; Emergent insects; Sediment characteristics; Water properties; Hydrology; Phytoplankton; Zooplankton; Pelagic and demersal fish; and, Atmospheric characteristics. The

baseline study of juvenile salmonid use of the estuary includes: Structural hatchery releases; Intensive sampling of fish in the region; Otolith microstructure analysis; and, Stomach content analysis. Nine components selected from these two studies are recommended for long-term monitoring. In addition, studies are suggested to evaluate the effects of dike removal on the ecology of the region. Methods, approaches, sampling design, quality assurance, quality control, data handling and analysis, and a decision process are detailed. Finally, estimates of costs for individual study components are provided.

Thomas, T.B. and A.B. Carey. 1996. Endangered, threatened, and sensitive plants of Fort Lewis, Washington: Distribution, mapping, and management recommendations for species conservation. *Northwest Science* 70(2): 148-163.

Abstract

The loss of native species and their habitats has increased with urban development, agriculture, and resource utilization. According to the Washington National Heritage Program, 20 plant listed as endangered, threatened, or sensitive are suspected to occur on the glacial outwash soils of south Puget Sound. In our study, more than 3,000 ha of prairie, wetland, and moist-forest plant communities were systematically sampled at Fort Lewis, Washington, and rare plant species, their habitats, and associated species were mapped. Four rare species, *Aster curtus*, *Trillium parviflorum*, *Carex comosa*, and *C. interrupta* were found. *Aster curtus*, the most abundant of these four species, attained highest cover and frequency on prairies dominated by *Festuca idahoensis*, other graminoids, and native forbs. It also was present on some sites dominated by trees or non-native species. *Trillium parviflorum* was found in moist-forest communities with an overstory of conifers and hardwoods. *Carex comosa* was found on the margins of two wetlands, and *C. interrupta* was found growing on a gravel bar of the Nisqually River. Major threats to the four rare species are discussed, and recommendations are made for management of rare plant habitats with the goal of preserving the species.

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Introduction

The Nisqually River supports runs of Chinook, Coho, chum, pink, and steelhead which are important to the commercial and sport fisheries of the region and particularly to the Nisqually Indian Tribe which conducts a fishery within the river. During the approximate 40-year period for which river catch data are available the annual Tribal harvest has average 1,016 Chinook, 3,381 Coho, 17,259 chum, 5,727 pink (odd years), and 1,833 steelhead. Ratios of catch to escapement have been estimated for several species of the Nisqually River indicating that approximately 3 Chinook, 4 Coho and 2 pink are caught by commercial and sport fisheries for each one of these species escaped. In the years 4,200 Coho and 6,125 pink (odd years); however, the data bases for these estimates were fragmentary and incomplete.

The Nisqually River has a long, varied history of hatchery production and plantings from other facilities beginning in 1900. Annual hatchery plantings in recent years have averaged 415,000 Chinook, 319,000 Coho, 935,000 chum and 20,000 steelhead.

As a result of hearings held under jurisdiction of the Federal Energy Regulatory Commission to establish a flow regime which adequately protects the fisheries resource in that section of the Nisqually River between the City of Centralia's Yelm Project diversion dam and the associated powerhouse, it was determined that further studies would be helpful in establishing the flow requirements of anadromous fishes in the Nisqually River. Toward this end flow studies were to be conducted under direction of the Washington State Department of Fisheries to estimate the flow requirements of salmonids for transportation, spawning, and rearing, and fisheries studies were to be conducted by the Fisheries Research Institute to provide information on the timing and locations of spawning, incubation, and rearing.

The studies were to be conducted in a 42.5-mile reach of the Nisqually River below the City of Tacoma's Alder (RM 44.2) and LaGrande power dams (RM 42.5). Of special concern in these studies was the 13.6 mile section from which water is diverted (Yelm Reach) between river mile (RM 26.2) and (RM 12.6) (Figs. 1 and 2).

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Abstract

Rhizosphere soil solution is the direct source of nutrients for plant uptake. The Nutrient composition of rhizosphere soil solution can be very different from that of bulk soil solution due to root exudation, nutrient uptake and rhizosphere Microorganism activity. This study examined the nutrient composition of Douglas-fir rhizosphere soil solution in two soils belonging to the Nisqually and Pitcher soil series and compared rhizosphere solution with that of bulk soil solution. Fertilized and unfertilized Nisqually soils were also compared. Soil solutions were collected using centrifugation. Results indicated that nutrient compositions in the rhizosphere solutions were typically higher than that of bulk soil solutions when no fertilizer was applied. Differences in the concentrations of nutrients between the rhizosphere and bulk soil solutions were masked by the addition of fertilizers. Rhizosphere solution pH also appeared to be affected by the concentration of NH inferior 4 and NO inferior 3 in the solution. With a higher concentration of NH inferior 4 to NO inferior 3 in the rhizosphere soil solution, the solution pH of the rhizosphere was lower than that of the bulk soil, but with a lower concentration of NH inferior 4 relative to NO inferior 3, the solution pH of the rhizosphere was higher than that of the bulk soil solution.

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Abstract

The southern Puget Sound region of Western Washington received a strong reminder that earthquake country does not stop at the California state line when a moment magnitude (M) 6.8 earthquake struck the region on February 28, 2001 at

10:54 am Pacific Standard Time. The earthquake occurred on a fault within the subducted Juan de Fuca plate, at a depth of approximately 52 km beneath the Nisqually Delta, and centered approximately 18 km northeast of Olympia and 58 km southwest of Seattle. The Nisqually earthquake is known as an intraslab subduction zone event, which occurred along a high angle normal fault due to tension in the down-going Juan de Fuca plate.

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Willson, Tim. 2001. *Nisqually River 2001 winter Steelhead Aerial Escapement Survey*. Nisqually Indian Tribe.

Abstract

Two aerial surveys of the Nisqually River (RM 2.4 – 40.8) were conducted during the spring of 2001 (May – June) to evaluate native winter run steelhead escapement in the mainstem.

Using only the data from the two flights, the 2001 mainstem escapement index was estimated to be 150 redds. Based on 1.6 fish / redd, minimum spawning escapement projected to be 240 steelhead.

A more realistic escapement estimate was attempted, by comparing the 2001 data to the data from the past five years (1996-2000), to account for spawning during the first three missed surveys. This produced a general feel for the 2001 run strength and a minimum escapement redd estimate of 400 redds, resulting in a minimum spawning escapement projection of 640 steelhead.

Willson, Tim. Feb 2000. *Nisqually River 1999 Winter steelhead Aerial Escapement Survey*. Nisqually Indian Tribe.

Abstract

Five aerial surveys of the Nisqually River (RM 2.4 – 40.8) were scheduled for the spring of 1999 (early April through mid June) to evaluate native winter run steelhead escapement in the mainstem. Due to helicopter scheduling, only four surveys were conducted.

The 1999 escapement index was estimated to be 331 redds. Based on 1.6 fish / redd, total mainstem spawning escapement was projected to be 530.

Willson, Tim. Nov 2000. *Nisqually River 2000 Winter steelhead Aerial Escapement Survey*. Nisqually Indian Tribe.

Abstract

Five aerial surveys of the Nisqually River (RM 2.4 – 40.8) were scheduled during the spring of 2000 (mid April – mid June) to evaluate native winter run steelhead escapement in the mainstem.

The 2000 mainstem escapement index was estimated to be 257 redds. Based on 1.6 fish / redd, total mainstem spawning escapement was projected to be 411.

Willson, Tim. Nov 1998. *Nisqually River 1998 Winter steelhead Aerial Escapement Survey*. Nisqually Indian Tribe technical report Number 27.

Abstract

Five aerial surveys of the Nisqually River (RM 2.4-40.8) were scheduled for the spring of 1998 (early April – mid June) to evaluate native winter run steelhead escapement in the mainstem. Good weather and water conditions enabled all five surveys to be conducted.

The 1998 escapement index was estimated to be 451 redds. The spawning density index was determined to be 11.74 redds / mile. Based on 1.6 fish / redd, total mainstem spawning escapement was projected to be 721.

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