Improving Salmon Runs with Better Flow Management Measures

The numbers of spawning salmon in the Skagit River in Washington State are increasing. This is due, in part, to Seattle City Light's flow management measures at its three hydro facilities.

By David E. Pflug, Edward J. Connor, and Suzanne Hartman

In the early 1970s, little was known about how operations of Seattle City Light's three-powerhouse 788-MW Skagit Hydroelectric Project on the upper Skagit River affected salmon habitat and survival. Against this backdrop, in 1973 the Federal Energy Regulatory Commission (FERC) operating license expired for this project.

During this same time period, as part of its statewide spawning escapement monitoring program, the Washington State Department of Fisheries (WSDF) was monitoring the return of chinook, chum, pink salmon, and steelhead to the upper Skagit River. The monitoring efforts identified two serious problems in the river: dewatering of redds (nests) and stranding of fry (small, recently hatched fish). When WSDF concluded operations of hydro projects were the cause of these problems, Seattle City Light became a target of public scrutiny.

Understanding that it needed to better operate its hydro projects for spawning salmon, Seattle City Light developed flow management measures in the late 1970s and early 1980s. These measures included reductions in the rate and frequency of daily flow downramping events after peak generation periods, as well as maintaining minimum flow requirements throughout the redd incubation period. These measures, implemented in 1981, were intended to minimize redd dewatering during spawning and incubation periods and to avoid stranding fry during emergence and out-migration.

David Pflug is senior fisheries biologist, Edward Connor is aquatic ecologist, and Suzanne Hartman is director of communications with Seattle City Light. Pflug and Connor performed the research work and data analysis contained in this article.

These flow management measures have been in place for more than 25 years. Due in part to these measures, numbers of spawning pink, chum, and chinook salmon in the Skagit River have greatly increased. In fact, the upper Skagit River supports the largest run of wild chinook salmon in the Puget Sound, as well as the largest spawning runs of pink and chum salmon in the coterminous U.S. This positive result comes at a time when salmon runs in unregulated sub-basins of the Skagit and in other Puget Sound rivers have been undergoing a long-term decline.[1,2]

Background on the Skagit project

The headwaters of the Skagit River begin in the Cascade Mountains of British Columbia, Canada, and drop over the border into Ross Lake in northern Washington. (See Figure 1 on page 36.) In 1924, Seattle City Light, a municipally owned and operated utility, dedicated the first dam on this river: 179-MW Gorge Dam and Powerhouse. In 1936, the utility completed the 159-MW Diablo project. At that time, Diablo Dam was the tallest dam in the world at 389 feet. In 1952, Seattle City Light opened the towering 540-foot Ross Dam, with a 450-MW powerhouse. These three dams — all within a 10-mile span along the upper Skagit River — are operated as the Skagit Hydroelectric Project.

The area around these dams has a unique effect on anadromous fish survival. Gorge Dam is located in a narrow and steep canyon that is a natural "dead end" for fish migrating upstream. Below the three powerhouses of the Skagit project, there are 94 miles of river that meander through the Skagit valley and delta and into Puget Sound. The 27 miles immediately below the Gorge project contain some of the most important spawning habitat for salmon and steelhead in the Skagit River basin.

Declining salmon runs in the Skagit River

After the dams were built, the upper Skagit River experienced frequent flow changes, such as daily flow operation peaking. As a result, egg and embryo mortality reached high levels, especially during the post-hatch, pre-emergence period. In addition, salmon fry were stranded on gravel bars and in potholes when flows were rapidly reduced.

In the late 1970s and early 1980s, Seattle City Light commissioned a number of studies to understand the effect of the Skagit project on salmon runs, in response to flow-related effects identified during the FERC relicensing process. Most of these studies were conducted by fisheries biologists with the University of Washington.[3,4] Studies included survival of eggs and alevins under various conditions of dewatering, as well as flow effects on periodicity and spatial distribution of spawners, spawning habitat area, and embryonic development and incubation timing. Additional studies were conducted on salmon and steelhead spawning behavior, redd selection, alevin and fry behavior during redd dewatering, and fry stranding mortality on gravel bars after flow reductions.

Once these studies were completed in

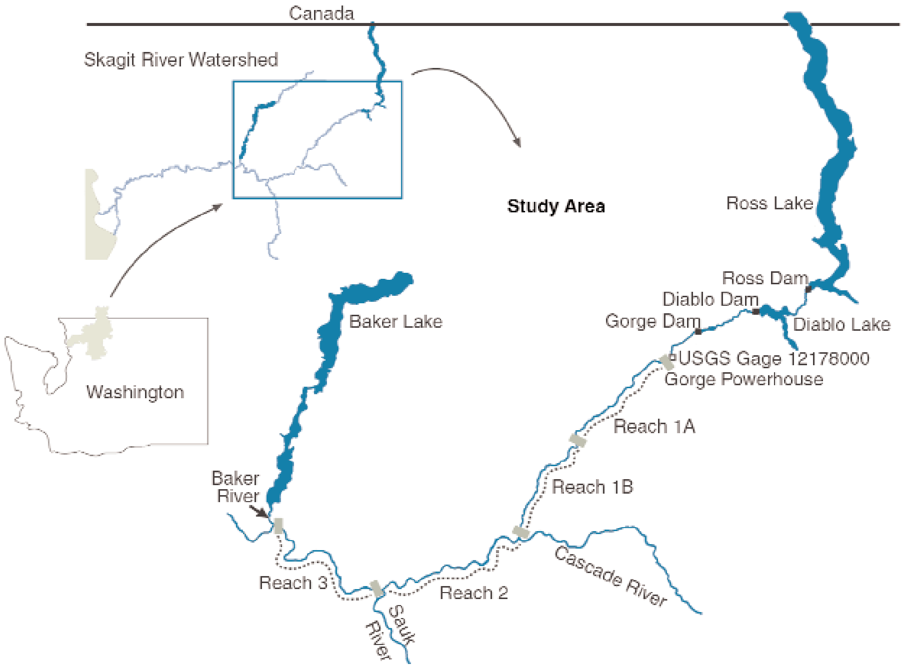

Figure 1: The 27-mile area of the Skagit River where flow management measures to protect salmon were undertaken and studied extends from the 179-MW Gorge Powerhouse to the confluence of the Baker River.

1981, Seattle City Light used the results to identify flow measures that could reduce the mortality of eggs and fry resulting from project operations.

Flow management measures implemented

As part of the FERC relicensing process during the 1970s for the Skagit project, Seattle City Light negotiated interim and final agreements with state and federal resource agencies and tribes, resulting in a number of flow-related changes to project operations. (See Table 1.) In 1981, Seattle City Light implemented interim flow management measures to better protect fish in the Skagit River. These included implementing a spawning flow range, increasing minimum flow releases, and setting a maximum downramp rate. The flow measurements required greater restrictions on flow fluctuations associated with daily peak power generation and required minimum flow releases throughout the winter and spring redd incubation period of salmon and steelhead.

Further refinements to these flow measures that provided higher levels of protection to fish were implemented in 1991 under a final settlement agreement. At the time of the settlement agreement, Seattle City Light estimated that the annual cost of implementation would be about $1.5 million per year. To a great extent, these changes were made in good faith because not much was known about the long-term effectiveness of flow-based habitat protection measures on salmon abundance.

The negative effects of flow fluctuations on fish populations below hydro facilities, including fry stranding and redd dewatering, are well documented.[5,6] Several studies have evaluated the short-term effects of fish protection flows on minimizing these effects.[7,8] However, the long-term benefits of fish protection flows have not been well documented or clearly understood.

After these flow management measures had been used for about 20 years, Seattle City Light set out to document the long-term effects on fish populations in the Skagit River. In the early 2000s, Seattle City Light performed a study using hourly and daily flow data from the U.S. Geological Survey (USGS) gauging station immediately downstream of the Gorge powerhouse. Three time periods were evaluated: 1) before the interim agreement (1950-1980); 2) after the interim agreement was reached (1981-1990); and 3) after implementation of the final agreement (1991-2001).

Changes in abundance and distribution of spawning salmon before and after implementation of the flow management measures were quantified and statistically analyzed. Researchers compared the abundance of fish in the regulated areas immediately below the Skagit project with downstream reaches of the river, and in unregulated reaches elsewhere in the basin. The period of spawner abundance data analyzed was 22 years for pink (spawning in odd years only), 29 years for chum, and 45 years for chinook salmon.

Seattle City Light also compared trends in spawner abundance in the study area with trends in nearby Puget Sound rivers both before and after implementation of the Skagit fish flow measures. The use of a before and after "treatment" analysis, combined with comparisons with local and regional spawner abundance trends, allowed the study team to better identify the effects of the flow measures from other sources of variability, including ocean productivity, salmon harvest levels, and local climate patterns.

Based on the analysis of flow and spawner abundance data, the study team was able to show that the flow management measures provided significant long-term benefits to salmon in the upper Skagit River.[2]

Table 1: Changes in Flow Operations at the Skagit Hydroelectric Project

	Spawning Flow Range (cfs)	*Minimum Flow Release (cfs)*	*Downramp Amplitude Limit (cfs)*[1]	*Maximum Downramp Rate (cfs)*	*Daylight Downramping (cfs/hour)*	*Best Effort Agreement*[2]
Pre-agreement	No limit	1,000	None	No limit	Allowed	No
Interim Agreement	4,200-7,000	1,000-2,300	None	4,000	Allowed	No
Final Agreement	2,500-5,000	1,500-2,600	4,000	3,000	Not allowed[3]	Yes

Notes:
[1] Difference between the highest and lowest flow release during any 24-hour period due to a flow reduction.
[2] Commitment to take voluntary actions that go beyond the required protection measures if conditions allow.
[3] Unless operational flow releases exceed an established threshold level of flow.

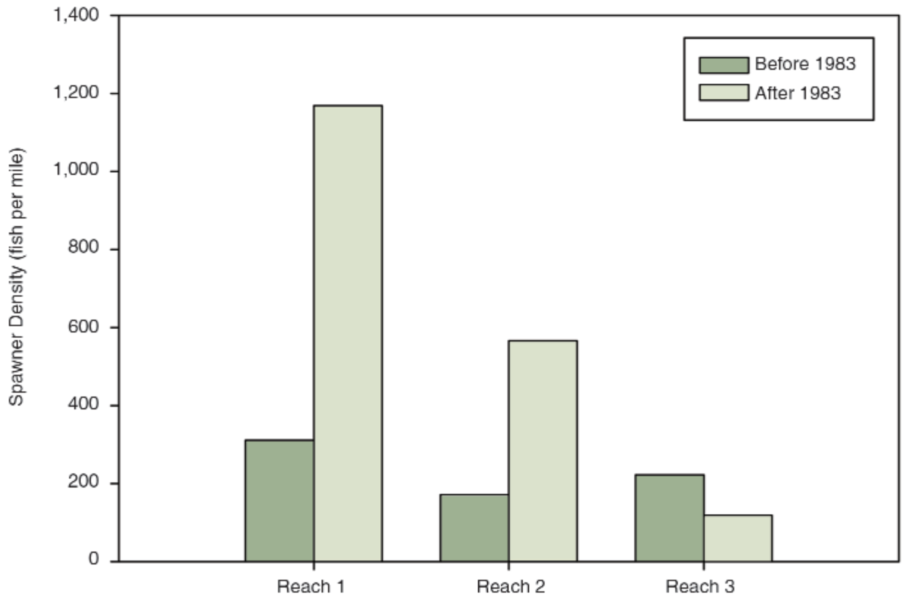

Figure 2: Pink salmon spawner densities increased significantly in two of the three study reaches below the 788-MW Skagit Hydroelectric Project once flow management measures were implemented in 1983.

Pink and chum response measured

Pink and chum salmon showed substantial increases in the number of spawners in the study area from 1985 to 2001, under the measures implemented under the interim and final flow agreements. (See Figures 2 and 3.) The first 16 miles of the study area immediately downstream from the hydro project were the most affected by the low minimum flow releases, high-amplitude flow fluctuations, and daytime down-ramping events before 1981. The increases in pink and chum salmon spawner abundance indicated that improved egg-to-fry survival rates of these two species during their incubation period contributed to the increase in adult spawners observed in the upper Skagit River after implementation of the flow measures. Additionally, less stranding of fry and improvement in fry survival rates were achieved by reducing the frequency and timing of flow fluctuations.

An endangered species rebounds

Sixty percent of the native chinook salmon in Puget Sound region — now listed as threatened under the Endangered Species Act (ESA) — spawn in the Skagit watershed. Of these, nearly 80 percent spawn in the uppermost reaches of the Skagit River, just below the Gorge Powerhouse. Since 1981, the flow management practices of Seattle City Light have helped sustain runs of chinook in the Skagit River during a period when native runs in other rivers declined. (See Figure 4 on page 4.)

Two factors seem to play the most important role for the improved chinook spawner abundance. The first is reducing flood and drought effects on redds immediately below the project by reducing the scour and dewatering of spawning habitat. The second is improving flow by minimizing the frequency of flow fluctuations and eliminating daytime downramping, which leads to fry stranding on gravel bars.

Status of salmon in the river today

Before implementation of the flow measures, the number of chum salmon spawning within the study area was declining by 29.8 percent per year. This was measured by 1974 to 1984 spawning returns affected by pre-agreement flows (chum salmon have a four-year life cycle, so effects of flow measures would not show up until 1985). This was a greater rate than was observed in the unregulated portions of the Skagit watershed.

After implementation of flow measures, chum salmon abundance increased by 145 percent during the 1985-2001 spawning return period affected by the flow measures, compared to the returns measured during the 1974-1984 period before the flow measures. This represents a major reversal in spawner abundance trends.

Pink salmon exhibited an even greater response, with abundance increasing by 267 percent during the 1983-2001 spawner return period affected by the flow measures (pink salmon have a two-year life cycle) over the abundance measured during the 1974-1982 period.

Chinook do not exhibit the same robust results as chum and pink salmon. Chinook salmon abundance in the upper Skagit River remained relatively stable, increasing by 3 percent during the 1985 to 2001 period when returns of spawning chinook were affected by the flow measures, compared to the 1974-1984 period before the flow measures. During

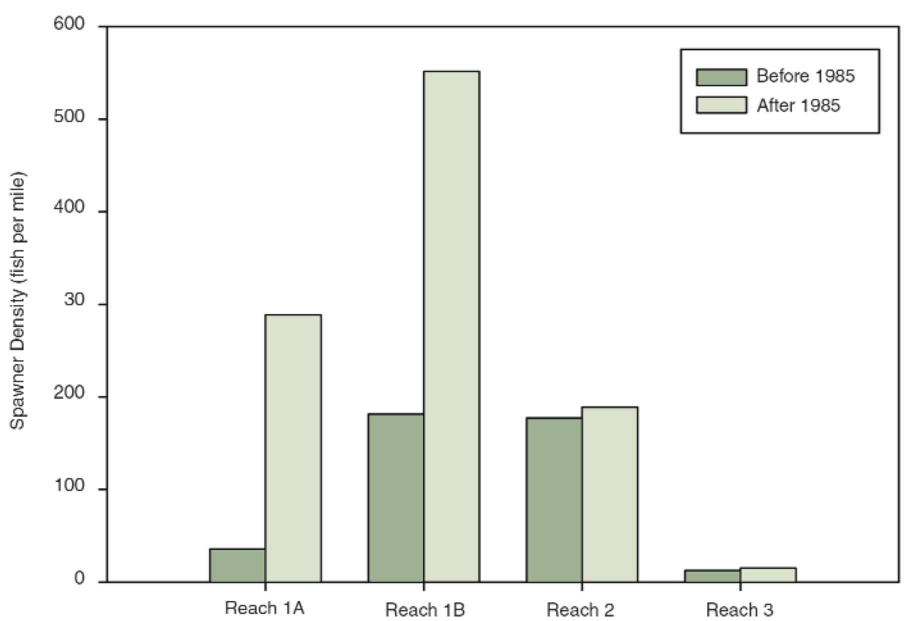

Figure 3: Chum salmon spawner densities increased significantly in two of the reaches below the 788-MW Skagit project once flow management measures were implemented.

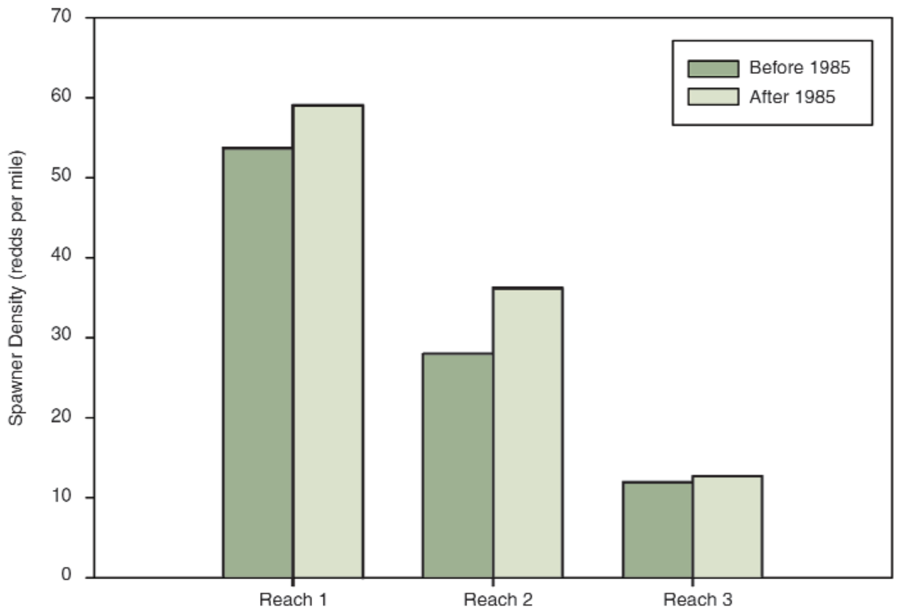

Figure 4: Chinook salmon spawner densities increased slightly in three reaches below the 788-MW Skagit Hydroelectric Project once flow management measures were implemented.

the same 1985-2001 time period, chinook abundance levels declined 41 percent in the lower Skagit River and 52 percent in the Sauk River (a major unregulated tributary), compared to 1974-1984. The results suggest that Seattle City Light's flow management actions are working.

For chinook in the upper Skagit River, the future appears bright. The ESA recovery goal range for upper Skagit chinook is 17,000 to 35,000. Before 2004, there was only one year (1980) with a return topping 20,000 since 1974. More recently, the upper Skagit chinook return has exceeded 20,000 for three years in a row (2004-2006).

There is a note of caution to the good news. Although it appears that increases in spawners and egg-to-fry survival rates can be linked directly to local flow management effects, there are other considerations beyond the scope of flow management research. The sustainability of long-term success for the remainder of the license period will require continuation of flow measures in combination with other factors that are beyond Seattle City Light's control.

The avoidance of future deterioration or loss of habitat in the lower 70 miles of river below the project reach and in the estuary and marine nearshore habitats is vital to sustaining healthy salmon runs. If conditions worsen in any of these areas of the salmon lifecycle, the potential for survival will be reduced despite continued efforts to provide safe flows in the upper watershed.

In addition, future changes in harvest management, regulatory protections for habitat, and hatchery practices will continue to influence the number of salmon spawning in the Skagit.

Future work planned to protect fish

For the upper Skagit study area, flow measures appear to have contributed to increased pink and chum salmon runs and sustained a healthy population of chinook salmon. Long-term monitoring will be required to validate the combined effectiveness of flow management along with habitat restoration and protection measures. Monitoring programs will continue over the term of the Skagit license.

The results of our study on the Skagit River indicate that flow measures targeted at improving salmon populations below hydroelectric projects can be highly successful.

Hydro producers throughout the Northwest should consider active engagement in long-term monitoring to improve the long-term success and sustainability of salmon. This approach can protect and perhaps enhance project-related investments in salmon protection. ■

The authors may be reached at Seattle City Light, 700 Fifth Avenue, Suite 3300, P.O. Box 34023, Seattle, WA 98124-4023; (1) 206-386-4575 (Pflug), (1) 206-615-1128 (Connor), or (1) 206-615-0050 (Hartman); E-mail: dave. pflug@seattle.gov, ed.connor@seattle.gov, or suzanne.hartman@seattle.gov.

Notes

[1]"Salmonid Stock Inventory 2000: Washington State," Washington Department of Fish and Wildlife, Olympia, Wash., 2002.

[2]Connor, Edward J., and David E. Pflug, "Changes in the Distribution and Density of Pink, Chum, and Chinook Salmon Spawning in the Upper Skagit River in Response to Flow Management Measures," *North American Journal of Fisheries Management,* Volume 24, No. 3, August 2004, pages 835-852. Available at www.seattle.gov/light/environment/ fish.

[3]Graybill, J.P., *et al,* "Assessment of Reservoir-Related Effects of the Skagit Project on Downstream Fishery Resources of the Skagit River, Washington," Final Report for City of Seattle, Department of Lighting, prepared by University of Washington, Fisheries Research Institute, Seattle, 1979.

[4]Stober, Q.J., S.C. Crumley, D.E. Fast, E.S. Killebrew, R.M. Woodin, G.E. Engman, and G. Tutmark, "Effects of Hydroelectric Discharge Fluctuations on Salmon and Steelhead in the Skagit River, Washington," Final Report for December 1979 to December 1982, prepared by University of Washington, Fisheries Research Institute, Seattle, 1982.

[5]Cushman, R.M., "Review of Ecological Effects of Rapidly Varying Flows Downstream from Hydroelectric Facilities," *North American Journal of Fisheries Management,* Volume 5, No. 3a, July 1985, pages 330-339.

[6]Hunter, M.A., "Hydropower Flow Fluctuations and Salmonids: A Review of Biological Effects, Mechanical Causes and Options for Mitigation," Technical Report 119, State of Washington Department of Fisheries, Olympia, Wash., 1992.

[7]Weisburg, S.B., and W.H. Burton, "Enhancement of Fish Feeding and Growth after an Increase in Minimum Flow below the Conowingo Dam," *North American Journal of Fisheries Management,* Volume 13, No. 1, February 1993, pages 103-109.

[8]Travnichek, V.H., M.B. Bain, and M.J. Maceina, "Recovery of a Warmwater Fish Assemblage after the Initiation of a Minimum-Flow Release Downstream of a Hydroelectric Dam," *Transactions of the American Fisheries Society,* Volume 124, No. 6, November 1995, pages 836-844.