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Statistical Support for Life-cycle Studies

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Bonneville Power Administration
P.O. Box 3621
Portland, OR 97208

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2006 Annual Report

Monitoring and Evaluation: Statistical Support for Life-Cycle Studies

Contract No. 25093

Project No. 1991-051-00

Prepared for:
Bonneville Power Administration
P.O. Box 3621
905 NE 11th Avenue
Portland, Oregon 97232

Prepared by:
John R. Skalski
Columbia Basin Research
School of Aquatic and Fishery Sciences
University of Washington
1325 Fourth Avenue, Suite 1820
Seattle, Washington 98101-2509

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Executive Summary

This report summarizes the statistical analysis and consulting activities performed under Contract No. 00025093, Project No. 199105100, funded by Bonneville Power Administration (BPA) during 2006. These efforts are focused on providing real-time predictions of outmigration timing, assessment of life-history performance measures, evaluation of status and trends in recovery, and guidance on the design and analysis of Columbia Basin fish and wildlife studies monitoring and evaluation studies.

Mission Statement

The overall objective of the project is to provide BPA and the rest of the fisheries community with statistical guidance on design, analysis, and interpretation of monitoring data, which will lead to improved monitoring and evaluation of salmonid mitigation programs in the Columbia/Snake River Basin. This overall goal is being accomplished by making fisheries data readily available for public scrutiny, providing statistical guidance on the design and analyses of studies by hands-on support and written documents, and providing real-time analyses of tagging results during the smolt outmigration for review by decision makers. For over a decade, this project has been providing in-season projections of smolt outmigration timing to assist in spill management. As many as 52 different fish stocks at 10 different hydroprojects are tracked in real-time to predict the “percent of run to date” and “date to specific percentile.”

The project also conducts added-value analyses of historical tagging data to understand relationships between fish responses, environmental factors, and anthropogenic effects. The statistical analysis of historical tagging data crosses agency lines in order to assimilate information on salmon population dynamics irrespective of origin. The lessons learned from past studies are used to improve the design and analyses of future monitoring and evaluation efforts.

Through these efforts, the project attempts to provide the fisheries community with reliable analyses and interpretations of monitoring data to evaluate hydrosystem operations and the recovery of endangered and threatened salmonid stocks.

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1.0 Project Overview

This project was initiated in 1991 in response to the Endangered Species Act (ESA) and the subsequent 1994 Council Fish and Wildlife Program (FWP) call for regional analytical methods for monitoring and evaluation. This project supports the need to have the "best available" scientific information accessible to the BPA, fisheries community, decision-makers, and public by analyzing historical tagging data to investigate smolt outmigration dynamics, salmonid life histories and productivity, and providing real-time analysis to monitor outmigration timing for use in water management and fish operations of the hydrosystem. To support real-time monitoring and provide information dissemination, the project provides real-time analyses of PIT-tag data and smolt passage indices to predict outmigration timing at 10 Snake and Columbia River dam sites. This information is coupled with travel time information and barging predictions in the Snake River Basin. Daily updates are provided for yearling and subyearling Chinook, steelhead, and sockeye from April through September of each year since 1994. These predictions, along with supporting information, can be retrieved and independently analyzed using interactive software and graphs on the internet (<http://www.cbr.washington.edu/rt/rt.html>). The second element this project provides is value-added analyses of historical tagging data by testing hypotheses, estimating parameters, and investigating interrelationships without the tremendous costs of additional field studies. The third element of this project is to provide statistical assistance to the BPA and the NW fisheries community on an as-needed basis. These efforts are used to provide BPA with independent assessment capabilities and provide technology transfer to regional investigators.

Specific objectives of the program include the following:

1. Provide in-season real-time predictions of juvenile smolt outmigration including "percent run to date" and "date to specified percentile" for all major stocks to all major hydroprojects on the Snake/Columbia River.
2. Assist in the development of statistical and data analysis tools for reviewing, summarizing, and investigating flow, temperature, smolt and adult counts, etc., on the second-tier database DART managed by the University of Washington (UW).

3. Annually summarize ambient (i.e., flow, temperature, dissolved gas targets) and fish performance measures (smolt travel times and survival, smolt-to-adult ratio [SAR], etc.) to evaluate the effects of the hydrosystem on salmonid life histories and recovery.
4. Synthesize information from historical fish tagging studies to improve understanding of migration dynamics, demographics, hydropower effects, and climatic and ocean effects on salmonid recovery.
5. Develop improved monitoring and evaluation capabilities to provide more accurate and precise information for better inriver management to optimize operational and fish passage strategies for endangered and threatened salmon populations.

In these value-added analyses of historical tagging data, this program uses coded-wire-tag (CWT), passive integrated transponder (PIT) tag, balloon-tag, radio-tag, and acoustic-tag data collected across the Columbia River Basin. The investigations have included all life stages where pertinent tagging data exist and all major fish stocks from subyearling and yearling Chinook salmon, to coho, sockeye, and steelhead. Future efforts will include the analysis and summary of adult salmonid upriver survival, migration success, and any delayed effects from smolt transportation. Results of this effort have resulted in 52 technical and 14 peer-reviewed scientific papers.

2.0 Overview of Annual Accomplishments: 1 January – 31 December 2006

A summary of accomplishments in 2006 for Project No. 199105100 includes the following:

1. Program REALTIME monitored the time of smolt outmigration of 52 stocks, ESUs, and composite groups through 10 different hydroprojects in 2006.
2. In collaboration with tribes, agencies, and PUDs, smolt migration timing was monitored at an expanded number of smolt traps and hydro projects throughout the Columbia River system.
3. Implemented geographical interface for examining status and trends monitoring data on DART.

4. Added salmonid harvest data for 247 fish stocks, fisheries, and harvest locations to the Status and Trends Overview of DART.
5. Updated the adult escapement data and recovery targets for 48 fish stocks and locations for status and trends monitoring on the Status and Trends Overview website of DART using the new Interior Columbia River Basin Technical Recovery Team (TRT) data in 2006.
6. Developed a prototype website for a habitat mitigation database.
7. Participated in the Northwest Environmental Data (NED) discussion groups.
8. Updated coded-wire-tag (CWT) estimates of smolt-to-adult ratios (SARs) for 91 hatchery stocks in the Pacific Northwest.
9. Generated estimates of smolt survival and travel times for 17 hatchery stocks in 2006

2.1 RealTime Predictions of Outmigration Timing

Runs-at-large of passage-indexed salmon and steelhead were tracked and forecasted by Program RealTime in 2006 at Rocky Reach, Rock Island, McNary, and John Day dams. The PIT-tagged runs forecasted by Program RealTime at McNary Dam in 2006 include wild Snake River steelhead trout, Upper Columbia River steelhead trout, the combined run of steelhead, Snake River yearling chinook salmon, Snake River sockeye salmon, Snake River subyearling chinook salmon, and Upper Columbia River salmon. The wild runs tracked at Lower Granite Dam include Snake and Clearwater river steelhead trout and Snake and Clearwater river yearling chinook salmon.

The practice of releasing unmarked hatchery salmon of all *Oncorhynchus* species into the Snake River has continued since 1999. To provide run-timing information on wild runs-at-large since then, the RealTime forecasting project has monitored and forecasted wild, PIT-tagged subpopulations of salmon and steelhead at Lower Granite Dam, and beginning in 2001, at McNary Dam.

The list of stocks with real-time predictions of “percent-of-run-to-date” and “date-to-specified-percentiles” during the 2006 season are as follows.

A. Tracked beginning at Lower Granite Dam:

1. PIT-tagged spring/summer Chinook stocks in the Snake River. The individual stocks include the following:
 - a. American River
 - b. Bear Valley Creek
 - c. Big Creek
 - d. Camas Creek
 - e. Cape Horn Creek
 - f. Catherine Creek
 - g. West Fork Chamberlain Creek
 - h. Elk Creek
 - i. Herd Creek
 - j. Imnaha River
 - k. Lake Creek
 - l. Lemhi River
 - m. Lolo Creek
 - n. Loon Creek
 - o. Lostine River
 - p. Marsh Creek
 - q. Meadow Creek
 - r. Minam River
 - s. Newsome Creek
 - t. Papoose Creek
 - u. Salmon River, South Fork
 - v. Secesh River
 - w. Sulfur Creek
 - x. Valley Creek
2. Snake River PIT-tagged, run-at-large of wild spring/summer Chinook.
3. Snake River subyearling fall Chinook salmon.
4. Snake River composite of hatchery-reared sockeye salmon from Redfish Lake Creek trap
5. Snake River run-at-large of wild steelhead.

B. Tracked beginning at McNary Dam:

1. PIT-tagged run-at-large wild of Upper Columbia River fall Chinook salmon.
2. PIT-tagged run-at-large of wild Snake River fall Chinook salmon.
3. PIT-tagged run-at-large of wild Snake River spring/summer Chinook salmon.
4. PIT-tagged run-at-large of wild Upper Columbia River steelhead.
5. PIT-tagged run-at-large of wild Snake River steelhead.
6. PIT-tagged run-at-large of wild combined Upper Columbia River and Snake River steelhead.
7. PIT-tagged run-at-large of wild Snake River sockeye.

C. Tracked beginning at Rock Island Dam in the Mid-Columbia:

1. Fall Chinook salmon
2. Spring/summer Chinook salmon
3. Sockeye salmon
4. Coho salmon
5. Steelhead

Online run-timing predictions were provided via the internet at <http://www.cbr.washington.edu/crisprt/> to the fisheries community throughout each smolt outmigration. Figure 1 illustrates two types of graphical displays available for each stock in the RealTime project.

Program RealTime performance is evaluated using MADs (mean absolute differences, the average of the absolute difference between predicted and true passage percentiles), calculated for the first and last halves of the outmigration, and for the season-wide outmigration.

The run-at-large of wild PIT-tagged Snake River yearling chinook salmon smolts monitored at McNary Dam was predicted very well in 2006, with a season-wide MAD of 3.1%. Predictions for the run-at-large of wild PIT-tagged yearling chinook salmon from the Snake River drainage outmigrating to Lower Granite Dam were comparable to previous years (MAD = 4.3%). Stocks from release sites that were monitored individually by Program RealTime in 2006 were predicted quite well based on the composite run (season-wide MAD = 2.3%) and on the average (mean MAD over all stocks for the entire season was 6.7%, down from 8.5% in 2005). Only 1 of 24 stocks had season-wide MADs larger than 10%. These larger prediction errors are mostly due to earlier, quicker migrations this year for those stocks.

Program RealTime predictions of the run-timing of wild PIT-tagged Snake River steelhead to Lower Granite and McNary Dams was down slightly this year (season-wide MADs averaging 4.3% at both dams compared to an average of 2.9% for both dams last year).

The run of wild PIT-tagged Snake River sockeye salmon monitored and forecasted at McNary Dam improved (season-wide MAD = 6.3% versus 7.9% last year). The season-wide MAD for PIT-tagged hatchery sockeye salmon from Redfish Lake forecasted at Lower Granite Dam was 1.9% compared to 5.6% last year.

Figure 1. Example of two types of graphical displays available for all stocks in the RealTime project. (a) Daily Prediction Graph - Program RealTime 2005 predictions of run-timing of sockeye salmon at Rocky Reach Dam (thick line, with 95% confidence intervals) compared to end-of-season observed run-timing (thin line) based on FPC passage-indices of combined wild and hatchery-reared fish. (b) Passage bar graph – historical and current year run-timing characteristics for Snake River subyearling Chinook PIT-tag detections at Lower Granite Dam.

Forecasting of wild PIT-tagged Snake River subyearling fall Chinook passage at Lower Granite Dam improved over previous years (season-wide MAD = 2.8%). The run of wild PIT-tagged Upper Columbia and Snake River subyearling fall Chinook salmon monitored at McNary Dam was adequately predicted in 2005 (season-wide MADs of 3.2% and 8.5% , respectively).

The results of program RealTime in forecasting run-timing and passage percentiles of FPC passage-indexed runs-at-large to Rock Island, McNary, John Day, and Bonneville dams were excellent this year. In particular, only 4 of 20 stocks had season-wide MADs above 5%; 9 of the remaining had MADs less than 3%, 5 less than 2%.

2.2 Post-Season Outmigration Success

At 11 hatcheries and smolt traps with a consistent pattern of annual PIT-tag releases, smolt survival and travel times are annually compiled and analyzed. These analyses include 25 different stocks of yearling and subyearling chinook salmon and steelhead. The specific PIT-tag stocks analyzed annually are listed below and illustrated in Figure 2.

Hatchery	Stock-Type	Release Years	
		From	To
Winthrop	Spring Chinook H	1996	2006
Wells	Summer Chinook H	1996	2006
Leavenworth	Spring Chinook H	1995	2006
	Fall Coho H	2002	2002
	Unknown Coho H	2005	2006
Priest Rapids	Fall Chinook H	1997	2006
Ringold	Fall Chinook H	1997	2002
	Summer Steelhead H	2004	2005
Lookingglass	Spring Chinook H	1995	2006
Rapid River	Spring Chinook H	1993	2006
Entiat	Spring Chinook H	1993	2006
Imnaha Trap	Summer Chinook H	1994	2002
	Summer Chinook W	1994	2006
	Summer Steelhead H	1994	2006
	Summer Steelhead W	1994	2006
	Summer Chinook W, overwinter	1994	2006
Sawtooth Trap	Spring Chinook H	1995	2000
	Spring Chinook W	1993	2006
	Summer Steelhead W	1993	2006
	Summer Sockeye H	1998	2006
	Summer Steelhead H	1995	1997
Clearwater Trap	Unknown Chinook H	1993	1995
	Unknown Chinook W	1993	2006
	Summer Steelhead H	1993	1995
	Summer Steelhead W	1993	2006

Figure 2. Map of release sites for PIT-tag survival and travel time analysis.

The PIT-tag analyses include reach survival and travel time estimates that can be accessed interactively at <http://www.cbr.washington.edu/pitSurv/>. Each year, as in 2006, the status and trends of the smolt survival and travel time estimates are updated. Figure 3 illustrates the type of data plots available on the DART system. An important additional set of information is the historical capture probabilities at the various PIT-tag detection facilities. These capture probabilities are useful in the design of future PIT-tag release-recapture studies.

2.3 Evaluation of Performance Standards

During 2006, additional performance measures were updated in the DART system in preparation for the 2006 check-in. Among the measures compiled include the following:

1. Adult dam counts
 - a. Bonneville, 1938-2006
 - b. Ice Harbor, 1962-2006
 - c. John Day, 1969-2006
 - d. Little Goose, 1970-2006
 - e. Lower Monumental, 1969-2006
 - f. Lower Granite, 1975-2006
 - g. McNary, 1956-2006
 - h. Priest Rapids, 1962-2006
 - i. Prosser, 1983-2006
 - j. Rock Island, 1977-2006
 - k. Rocky Reach, 1977-2006
 - l. Roza, 1940-2006
 - m. The Dalles, 1960-2006
 - n. Tumwater, 1999-2006
2. Adult Escapement
 - a. 48 Locations in WA/OR/ID by brood year, 1970-2002
3. Compliance with flow targets
 - a. Bonneville, 1949-2006
 - b. Lower Granite, 1975-2006
 - c. McNary, 1956-2006
 - d. Priest Rapids, 1961-2006

Figure 3. Illustrations of historical trends in survivals and travel times from Winthrop Hatchery to McNary Dam for spring chinook salmon smolts, 1993-2006.

4. Compliance with temperature targets
 - a. Bonneville, 1995 - 2006
 - b. Ice Harbor, 1995-2006
 - c. John Day, 1995-2006
 - d. Little Goose, 1995-2006
 - e. Lower Granite, 1995-2006
 - f. Lower Monumental, 1995-2006
 - g. McNary, 1995-2006
 - h. The Dalles, 1995-2006
5. Compliance with dissolved gas targets
 - a. Bonneville, 1995-2006
 - b. Lower Granite, 1995-2006
 - c. McNary, 1995-2006
 - d. Priest Rapids, 1995-2006
 - e. Ice Harbor, 1995-2006
 - f. John Day, 1995-2006
 - g. Little Goose, 1995-2006
 - h. Lower Monumental, 1995-2006
 - i. The Dalles, 1995-2006
6. Harvest
 - a. Washington, Chinook, Chum, Coho, Sockeye, Steelhead, 1962-2005
 - b. Oregon, Chinook, Chum, Coho, Sockeye, Steelhead, 1985-2004
 - c. Idaho, Chinook, Steelhead, 1954-2004
7. Smolt survival, travel time, and capture probability
 - a. Clearwater Trap, 1993-2006
 - b. Dworshak, NFH, 1997-2006
 - c. Entiat NFH, 1993-2006
 - d. Imnaha Trap, 1994-2006
 - e. Leavenworth NFH, 1995-2005
 - f. Lookingglass Hatchery, 1995-2006
 - g. Lyons Ferry Hatchery, 2004-2006
 - h. Priest Rapids Hatchery, 1997-2006
 - i. Rapid River Hatchery, 1993-2006
 - j. Ringold Hatchery, 1997-2005
 - k. Sawtooth Trap, 1993-2006
 - l. Wells Hatchery, 1996-2006
 - m. Winthrop NFH, 1996-2006

8. ROSTER analysis

- a. Adult Survival by brood year, 1999-2004
- b. Adult Survival by return year, 2000-2006
- c. D (system wide, LGR, LGS, MCN) by brood year, 1997-2004
- d. Ocean Survival by brood year, 1999-2004
- e. SAR by brood year, 1996-2004
- f. Smolt Survival by brood year, 1996-2004
- g. T/I (system wide, LGR, LGS, MCN) by brood year, 1997-2004

Each response can be interactively examined to identify decadal means, decadal trends, as well as long-term patterns of response.

2.4 Geographic-Based Data Searches and Displays

The Status and Trends Overview website on DART (<http://www.cbr.washington.edu/trends/index.php>) presents interactive displays of status and trends monitoring data with compliance targets for wild and hatchery adult and smolt salmon and related hydrosystem conditions. The database is searchable by performance measure (e.g., escapement, survival, travel time, temperature, etc.), species, hydroelectric site, province, subbasin, and now through a map interface.

The map interface was programmed using the Google Maps API (application programming interface). Built-in capabilities allow a user to move the map from side to side, zoom in or out, and switch back and forth between the “map” view with roads, borders, city names, and, most importantly, rivers—or the satellite view. In addition to these built-in features, we added markers for hatcheries and hydro sites and regional boundaries for the provinces and subbasins.

Clicking on a visible marker causes a description balloon for the location to appear, overlaid on the map. This balloon contains location-specific information and links to the Status & Trends database. For instance, Figure 4 shows the description balloon for Lower Granite Dam.

The “Trends” tab provides links to all available compliance data and performance measures. Clicking one of these links pops up a window with a table showing all available data for the given performance measure.

Figure 4. Pop-up balloon providing context-related links to Status & Trends data.

2.5 Analysis of Historical Life-Cycle and Transportation Data

A major effort in 2006 was applying Program ROSTER (River-Ocean Survival and Transportation Effects Routine) to analyze the life-history, PIT-tag data of yearling Chinook salmon and steelhead from 1996 to the present (i.e., 2004, because of the lag time for adult returns). The PIT-tag analysis is being used to estimate, among other things:

1. Juvenile downriver survival
2. Ocean survival (i.e., Bonneville to Bonneville)
3. Adult upriver survival
4. Delayed mortality (D)
5. Smolt-to-adult ratios (SARs)

These results will be posted in the Status & Trends website of DART and a technical reports submitted to BPA in early 2007. So far, the results have been presented at the Annual Anadromous Fish Evaluation Program in November 2006 and to the COMPASS (comprehensive fish passage model) developers for their use.

3.0 Technical Reports and Presentations

The following technical reports have been completed and made available to the fisheries community during the last year as a consequence of this BPA project and its technology transfer.

Papers

1. Buchanan, R. A., J. R. Skalski, and S. G. Smith. 2006. Estimating the effects of smolt transportation from different vantage points and management perspectives. *North American Journal of Fisheries Management* 26:406-472.

Presentations

1. Buchanan, R. A., J. R. Skalski, and J. Lady. 2006. Historical trends in river and ocean survival and associated transport effects for Chinook and steelhead, 1996-2004. US Army Corps of Engineers. Anadromous Fish Evaluation Program, November 13-16, 2006, Portland, OR.

2. Diefenderfer, H. L., R. M. Thom, G. C. Roegner, A. H. Whiting, G. E. Johnson, A. B. Borde, K. L. Sobocinski, E. M. Dawley, J. R. Skalski, and B. D. Ebberts. 2006. Evaluating cumulative ecosystem response to restoration projects in the Columbia River estuary. US Army Corps of Engineers. Anadromous Fish Evaluation Program, November 13-16, 2006, Portland, OR.
3. Heisey, P. G., D. Mathur, S. Adams, and J. R. Skalski. 2006. Direct survival and injury of juvenile salmon passing Ice Harbor spillway under plunging, skimming, and undular tailwater conditions. US Army Corps of Engineers. Anadromous Fish Evaluation Program, November 13-16, 2006, Portland, OR.

Reports

1. Geiselman, J., R. Buchanan, J. Anderson, J., N. Beer, N., T. Hillman, A. Giorgi, C. Paulsen, R. Hinrichsen, J. Skidmore, R. Schiewe, J. Piccininni, and J. R. Skalski. 2006. Cumulative effects hypothesis for latent and unaccounted mortality. Report for the Collaboration Framework Workgroup of the FCRPS BiOp Remand Process.
2. Johnson, G. E., F. Khan, J. B. Hedgepeth, R. P. Mueller, C. L. Rakowski, M. C. Richmond, J. A. Serkowski, and J. R. Skalski. 2006. Hydroacoustic evaluation of juvenile salmonid passage at The Dalles Dam sluiceway, 2005. Prepared for U.S. Army Corps of Engineers, Portland District, Contract DE-AC05-76RL01830. Pacific Northwest National Laboratory, Richland, WA.
3. Normandeau Associates, Inc., and J. R. Skalski. 2006. Comparative assessment of spillbay passage fish condition and survival for installation of a removable weir at Lower Monumental Dam, Snake River. Prepared for the U.S. Army Corps of Engineers, Walla Walla District, Walla Walla, WA.
4. Normandeau Associates, Inc., and J. R. Skalski. 2006. Comparative direct survival and injury rates of juvenile salmon passing the new removable spillway weir (RSW) and a spillbay at Ice Harbor Dam, Snake river, Washington. Prepared for the U.S. Army Corps of Engineers, Walla Walla District, Walla Walla, WA.

5. Normandeau Associates, Inc., J. R. Skalski, and R. L. Townsend. 2006. Performance evaluation of the new advanced hydro turbine system (AHTS) at Wanapum Dam, Columbia River, Washington. Prepared for PUD No. 2 at Grant County, Ephrata, WA.
6. Skalski, J. R. 2006. Top-down design for regional monitoring. Prepared for Battelle, Pacific Northwest National Laboratory, Portland, OR.
7. Griswold, J., Townsend, R. L., and J. R. Skalski. 2006. Evaluation of the 2005 predictions of the run-timing of wild and hatchery-reared salmon and steelhead smolt to Rock Island, Lower Granite, McNary, John Day and Bonneville dams using Program RealTime. Volume XIII in the Design and Analysis of Salmonid Tagging Studies in the Columbia Basin. Bonneville Power Administration, Portland, OR.
8. Johnson, G. E., H. L. Diefenderfer, B. D. Ebberts, C. Tortorici, T. Yerxa, S. McEwen, J. Leary, J. R. Skalski, and B. Sutherland. 2006. Federal Columbia River estuary research, monitoring, and evaluation program. Prepared by the Pacific Northwest National Laboratory for the Bonneville Power Administration in conjunction with NOAA Fisheries and U.S. Army Corps of Engineers, Portland District, and collaboration from the Lower Columbia River Estuary Partnership, Portland, Oregon.
9. Skalski, J. R. 2005. Recommended design and analysis for the Upper Columbia River fish tissue sampling program. Prepared for CH2M Hill, Bellevue, WA, for U.S. Environmental Protection Agency.

4.0 Summary of Technology Transfer Efforts

Each year, research staff of this project are asked to assist fisheries investigators in the design and interpretation of monitoring and evaluation studies. These efforts are used to help elevate the precision and cost-effectiveness of studies supported by the Fish and Wildlife Program. Support is provided to federal and state agencies, tribes, and public utility districts dealing with smolt and adult salmonid tagging studies. These efforts are summarized, in part, by the joint authorship of technical reports and papers listed in Section 3.0. Other efforts are characterized by attending technical support meetings in the community, direct person-to-person assistance, and collaboration on monitoring and evaluation studies.

The technical support is of two categories of effort. Direct effort supported by funds of this project. Typically, these efforts are focused at assisting BPA and other action agencies in designing better monitoring and evaluation studies and program. Example of activities during 2006 include the following:

1. Reviewed 2006 Comparative Survival Study (CSS) Annual Report by the Fish Passage Center and the CSS 2006 Design and Analysis Report by Kristen Ryding of Washington Department of Fish and Wildlife and the CSS Oversight Committee, for the Fish Passage Center.
2. Participated in the COMPASS efforts by incorporating the most recent PIT-tag results from Program ROSTER.
3. Coordinated with Pacific States Marine Fisheries Commission (PSMFC) on developing better PIT-tag information in PTAGIS for purposes of joint juvenile-adult analyses.
4. Participated with US Army Corps of Engineers research team on development of monitoring and evaluation protocols for the Columbia River estuary.
5. Designed a sampling scheme for US Environmental Protection Agency to sample contaminant levels in fish in the Upper Columbia River.

The second type of support is indirect support where funds are not directly used to support consulting efforts. Rather, technical support exists because of the capabilities and long-term staffing made available by BPA ongoing funding. In these circumstances, agencies and investigators avail themselves of UW Columbia Basin Research assistance by funding such efforts themselves. Nevertheless, such assistance and technological expertise would not exist if it were not for BPA ongoing funding. Table 6 summarizes the levels of direct and indirect support provided the fisheries community during the period 1 January – 31 December 2006.

Table 6. Summaries of direct and indirect BPA support of fish tagging studies, 1 January – 15 December 2006, by this project.

Organization	Staff/Hours	
	Direct	Indirect
US Army Corps of Engineers	10	40
Battelle/US Army Corps of Engineers	8	28
Idaho Fish and Game	4	48
Douglas County Public Utility District		41
Washington Department of Transportation	4	24
NOAA	89	0
CH2M Hill/Environment Protection Agency		36
Total	115	240