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September 2001

Prepared for
the U.S. Army Corps of Engineers
Portland, Oregon
Under Contract Number DACW57-00-D-0009, Task Order Case No. 3

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(a) BioAnalysts, Inc.

Executive Summary

The Portland District of the U.S. Army Corps of Engineers requested that scientists from Battelle and BioAnalysts, Inc., review and synthesize the fisheries research conducted at The Dalles Dam between 1982 and 2000. Battelle and BioAnalysts reviewed 29 reports prepared for the Corps describing research conducted using radio-telemetry and hydroacoustic technologies to evaluate the downstream passage of juvenile salmon through The Dalles Dam.

We were asked to 1) summarize fish behaviors including forebay approach patterns, residence times, and horizontal distribution of passage; 2) summarize fish passage efficiency and effectiveness; 3) identify uncertainties, limitations, and gaps in the data; and 4) provide recommendations for addressing deficiencies.

Results from the radio telemetry and hydroacoustic studies conducted at The Dalles Dam between 1982 and 2000 are summarized in Tables S.1, S.2, and S.3 and discussed below.

Based on our review, certain patterns in juvenile salmon migration at The Dalles Dam are evident. Yearling fish migrate in the main channel, and sub-yearlings are somewhat shoreline oriented. Smolts usually encounter the dam first at the east end of the powerhouse, which is oriented parallel to the river axis, unless there is a lot of spill in a juvenile pattern in which case more fish will encounter the northern spillway first.

Forebay residence times are typically very short; fish pass the dam within fractions of an hour after entering the forebay. Horizontal distribution of passage at the powerhouse depends on dam operations, but when all units are operating, distributions are either relatively uniform or are skewed toward higher number units. Diel trends in passage depend on route – spill and sluice passage were higher during the day than at night, whereas turbine passage was higher at night than during the day.

Once past the dam, smolts often encounter high densities of predators (both birds and fish) in the tailrace especially along the Oregon shore islands. Egress from the northern spill area is much quicker than elsewhere.

Spill efficiency ranges from about 60% at 30% spill to from 72% to 84% at 40% to 60% spill. Forty percent spill in juvenile pattern seemed optimum for spill efficiency and tailrace egress. Relative to the entire project, mean sluice efficiency has averages of 11% to 13% and ranges from 6% to 24%, but it accounts for a more substantial percentage of fish passing the powerhouse alone (e.g., 39% in spring and 24% in summer 1999).

Overall, project FPE ranged from about 80% at 30% spill to about 90% at 40% to 60% spill, which is acceptable.

Sluice, spill, and turbine survival in spring were about 92%, 96%, and 81% to 86%, respectively, and they were all lower than estimates for other projects in the Columbia River Basin. In summer, the average survival of sub-yearling chinook salmon was 92% for the spillway, 93% for the sluiceway, and 84% for turbines.

Table S.1. Spill Efficiency, Spill Passage Effectiveness, Sluiceway Efficiency, and Fish Passage Efficiency at The Dalles Dam, 1995 – 2000, based on Radio Telemetry. River discharge and spill ranges and averages were for times the radio-tagged fish passed the project. The numbers in parentheses are 95% confidence intervals.

Study Year and Species	Sample Size	Spill Efficiency	Average % Spill	Spill Effec-tiveness	Percent of Fish Passing Sluiceway	Spill Range $\times 10^3$ ft^3/sec	River Discharge Range $\times 10^3$ ft^3/sec	Fish Passage Efficiency (%)
1995								
CHIN 1	100	88	53.6	1.6:1	NA	120-160	227-290	NA
CHIN 0	71	82	53.2	1.5:1	NA	167-178	252-281	NA
1996								
CHIN 1	166	77	57.4	1.3:1	NA	90-247	276-417	NA
CHIN 0	121	66	50.1	1.3:1	NA	66-282	230-427	NA
1997								
STH 1	168	78	63.5	1.2:1	17.3	173-407	303-571	95.3
CHIN 1	152	72	63.5	1.1:1	22.7	173-407	303-571	94.7
CHIN 0	76	84	63.0	1.3:1	NA	132-198	206-315	NA
1999								
STH 1	309	66.0 (60.4-71.3)	30	2.2:1	25.2 (20.5-30.5)	74-114	233-363	91.3 (87.5-94.2)
STH 1	388	86.4 (82.3-89.9)	64	1.4:1	8.9 (6.1-12.4)	145-208	233-363	95.3 (92.4-97.3)
CHIN 1	324	51.5 (46.0-57.1)	30	1.7:1	21.9 (17.5-26.8)	74-114	233-363	73.5 (68.3-78.2)
CHIN 1	271	79.0 (73.6-83.7)	64	1.3:1	11.8 (8.2-16.3)	145-208	233-363	90.8 (86.7-93.9)
Pooled spp	633	58.6 (54.7-62.5)	30	2.0:1	23.5 (20.3-27.0)	74-114	233-363	82.1 (78.9-85.1)
Pooled spp	609	83.1 (79.9-86.0)	64	1.3:1	10.2 (7.9-12.9)	145-208	233-363	93.3 (91.0-95.1)
2000								
STH 1	793	85.4 (80.0-89.9)	39.6	2.1:1	5.8 (4.3-7.7)	73-109	184-286	91.2 (89.0-92.0)
CHIN 1	816	79.3 (76.3-82.0)	39.6	2.0:1	5.5 (4.0-7.3)	73-109	184-286	84.7 (82.1-87.1)
NA = Not available.								

Table S.2. Metrics and Sampling Characteristics of Fixed Aspect Hydroacoustic Studies Conducted in Spring from 1985 through 2000. Numbers in parenthesis following some metric estimates are 95% confidence intervals calculated from temporal variation in samples.

Sampling Metrics	Year							
	1985[a]	1986[b]	1990[c]	1995[d]	1996[e]	1998[f]	1999[g]	2000[h]
Performance/Passage Metrics								
Project FPE	0.32	0.55	NA	NA	0.79 (0.05)	0.94 (0.02)	0.79 (0.02)	0.92 (0.01)
Spill efficiency (spring/summer)	0.09/season; 0.23 instantaneous	0.19/season; 0.23 at 10% spill; 0.43 at 50% spill instantaneous	NA	NA	0.48 (0.05)	0.61 (0.04)	0.66 (0.02)	0.86 (0.0)
Sluice efficiency	0.23	0.36 (0.26-0.52)	NA	NA[i]	0.31 (0.04)	0.34 (0.05)	0.13 (0.01)	0.06 (0.01)
Turbine fraction	0.68	0.45	NA	NA	0.21	0.60	0.21	0.08
Spill effectiveness	Instantaneous	2.3 at 10% spill; 0.9 at 50% spill	NA	NA	0.83	1.28	1.41	2.16
Sluice effectiveness	13.6	51 reported; 26 calculated here	NA	NA	29.4 reported; 28.2 calculated here	21.22	8.57	3.22
Sampling dates	4/22-6/1	4/21-6/15	4/23-5/31	5/8-5/26	5/6-6/11	4/20-5/27	4/22-5/27	5/13-6/5
Sampling duration	41	56	39	19	37	38	36	24
Mean project discharge (ft^3/s)	228,000	275,609	221,585	264,000	364,981	278,492	286,383	235,258
Spill discharge fraction[i]	0.087	0.273	0.079	0.56	0.58	0.47	0.47	0.40
Sluice discharge fraction[i]	0.017	0.014	0.019	0.015	0.011	0.014	0.014	0.017
Turbines sampled	7 of 24	8 of 24	2 FU	2 of 24	13 of 24	All	All	All
Spill bays sampled	9 of 23	8 of 23	None	20 of 23	10 of 23	13 of 23	13 of 23	14 of 23
Sluices sampled	All	All	None	2 of 3	All	All	All	All
Run timing	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Turbine Metrics								
Horizontal distributions	Yes	Yes	Among 2 units	NA	Yes	Yes	Yes	Yes
Vertical distributions	Yes	Yes	Yes	2 intakes	Yes	Yes	Yes	Yes
Temporal distributions	Diel	Diel	No	0900-0200	Diel	Diel	Diel	Diel

Table S.2. (contd)

Sampling Metrics	Year							
	1985[(a)]	1986[(b)]	1990[(c)]	1995[(d)]	1996[(e)]	1998[(f)]	1999[(g)]	2000[(h)]
Sluice Metrics								
Horizontal distributions	No	Yes	NA	No	Yes	Yes	Yes	Yes
Vertical distributions	No	No	NA	Yes	Yes	Yes	Yes	Yes
Temporal distributions	Diel	0500-2100	NA	No	Diel	Diel	Diel	Diel
Spillway Metrics								
Horizontal distributions	Yes, sparse	Yes, bays 16-23	NA	NA	Yes	Yes	Yes	Yes
Vertical distributions	Yes	Yes	NA	NA	Yes	Yes	Yes	Yes
Temporal distribution	Day only	2100-1600	NA	NA	Diel	Diel	Diel	Diel
Detection threshold (dB)	-50	-50 to -55	-60	?	-55	-56	-56	-56
Detection modeling	?	Yes	No	Yes	Yes	Yes	Yes	Yes
Detectability corrected	No	No	No	No	?	?	Yes	Yes
Target strength used to correct detectability	No	No	For expansions only	No	No	No	Yes	Yes

(a) 1985 - Steig and Johnson (1986).
(b) 1986 - Ward et al. (1987).
(c) 1990 - Stansell et al. (1991).
(d) 1995 - Nagy and Shutters (1996).
(e) 1996 - BioSonics (1997).
(f) 1998 - BioSonics (1999).
(g) 1999 - Ploskey et al. (in press).
(h) 2000 - Moursund et al. (in review).
(i) Sluice efficiency was relative to total passage at the sluice and turbine intake sampled and ranged from 0.765-0.878.
(j) Calculated from historical flow data from DART; Sluice flow was calculated from: CFS = -30.179 x 2 + 10138 x (Forebay EL) – 844594.

Table S.3 Metrics and Sampling Characteristics of Fixed Aspect Hydroacoustic Studies Conducted in Summer from 1985 through 2000. Numbers in parenthesis following some metric estimates are 95% confidence intervals calculated from temporal variation in samples.

Sampling Metric	1982[a]	1985[b]	1986[c]	1989[d]	1990[e]	1995[f]	1996[g]	1998[h]	1999[i]	2000[j]
Performance/Passage Metrics										
Project FPE	NA	0.49	None	NA	NA	NA	0.86 (0.03)	0.94 (0.03)	0.79 (0.01)	0.81 (0.01)
Spill efficiency (spring/summer)	NA	0.23/season; 0.40 instan-taneous	None; Questionable passage estimates	NA	NA	NA	0.7 (0.04)	0.6 (0.04)	0.66 (0.02)	0.74 (0.03)
Sluice efficiency	NA	0.49	Not reliable	NA	NA	NA[i]	0.16 (0.03)	0.34 (0.06)	0.13 (0.01)	0.07 (0.01)
Turbine fraction		0.51	No estimate	NA	NA	NA	0.14	0.60	0.21	0.19
Spill effectiveness	NA	Instantaneous	None	NA	NA	NA	1.22	1.28	1.41	1.86
Sluice effectiveness	NA	13.2	None	NA	NA	NA	11-12 reported; 10.7 calculated here	21.22	8.57	3.27
Sampling dates	7/31-8/19	6/2-8/15	6/16-8/14	6/6-8/23	7/9-8/16	6/8-7/15	6/17-7/26	6/17-7/17	6/3-7/8	6/6-7/06
Sampling duration	20	75	60	79	39	38	38	41	36	30
Mean project discharge (ft^3/s)	175,000	134,000	155,528	126,523	152,564	248,935	277,368	246,190	319,842	192,990
Spill discharge fraction[i]	0.008	0.049	0.044	0.052	0.050	0.56	0.57	0.47	0.46	0.397
Sluice discharge fraction[i]	0.025	0.03	0.027	0.033	0.028	0.017	0.015	0.017	0.012	0.021
Turbines sampled	6 of 24	7 of 24	8 of 24	None	2 FU	2 of 24	13 of 24	All	All	All
Spill bays sampled	6 of 23	9 of 23	8 of 23	8 of 23	None	20 of 23	10 of 23	13 of 23	13 of 23	14 of 23
Sluices sampled	None	All	All	None	None	2 of 3	All	All	All	All
Run timing	Yes	Yes	Yes	Yes	Yes, fish units	Yes	Yes	Yes	Yes	Yes
Turbine Metrics										
Horizontal distributions	Yes	Yes	Yes	NA	Among 2 units	NA	Yes	Yes	Yes	Yes
Vertical distributions	No	Yes	Yes	NA	Yes	2 intakes	Yes	Yes	Yes	Yes
Temporal distribution	Night hours	Diel	Diel	NA	No	0900-0200	Diel	Diel	Diel	Diel

Table S.3. (contd)

Sampling Metric	1982[a]	1985[b]	1986[c]	1989[d]	1990[e]	1995[f]	1996[g]	1998[h]	1999[i]	2000[j]
Sluice Metrics										
Horizontal distributions	NA	No	No	NA	NA	No	Yes	Yes	Yes	Yes
Vertical distributions	NA	No	No	NA	NA	Yes	Yes	Yes	Yes	Yes
Temporal distribution	NA	Diel	Diel	NA	NA	No	Diel	Diel	Diel	Diel
Spillway Metrics										
Horizontal distributions	No	Yes; 10 day,	Yes, Bays 16-23	Yes, Bays 16-23	NA	Yes	Yes	Yes	Yes	Yes
Vertical distributions	No	Yes	Yes	Yes	NA	Yes	Yes	Yes	Yes	Yes
Temporal distribution	No	Day spill only	2100-0600	1700-0300	NA	Diel	Diel	Diel	Diel	Diel
Detection threshold	?	-50	-58	-56	-60	?	-56	-56	-56	-56
Detection modeling	?	?	Yes	No	No	Yes	Yes	Yes	Yes	Yes
Detectability corrected	?	No	No	No	No	No	?	?	Yes	Yes
Target strength used to correct detectability	No	No	No	No	For expansions only	No	No	no	Yes	Yes

(a) 1982 - Magne et al. 1983.
(b) 1985 - Steig and Johnson (1986).
(c) 1986 - Ward et al. (1987).
(d) 1989 - McFadden 1990.
(e) 1990 - Stansell et al. (1991).
(f) 1995 - Nagy and Shutters (1996).
(g) 1996 - BioSonics (1997).
(h) 1998 - BioSonics (1999).
(i) 1999 - Ploskey et al. (in press).
(j) 2000 - Moursund et al. (in review).
(k) Sluice efficiency was relative to total passage at the sluice and turbine intake sampled and ranged from 0.765-0.878.
(l) Calculated from historical flow data from DART; Sluice flow was calculated from: CFS = -30.179 x 2 + 10138 x (Forebay EL) – 844594.

Acknowledgments

Many people contributed materials that went into this report. We thank John Beeman, Theresa Liedtke, and Hal Hansel of the U.S. Geological Survey (USGS), Mike Langslay of the U.S. Army Corps of Engineers, Portland District (CENWP), and Tom Carlson of Battelle for providing references and reports in various stages as well as other information. Dennis Dauble (Battelle) coordinated the task implementation. Daniel Tano (Battelle) condensed the abstracts from the long-winded versions the authors originally prepared. We also appreciate the helpful written comments by reviewers including Tom Carlson, Mike Langslay (CENWP), Marvin Shutters (Walla Walla District), and Cliff Pereira (Oregon State University). Verbal comments by Dennis Rondorf (USGS), and Gary Fredericks and Steve Rainey of the National Marine Fisheries Service also were helpful. We also greatly appreciate the editorial support provided by Theresa Gilbride of Battelle.

Acronyms and Abbreviations

ACE	U.S. Army Corps of Engineers
BRZ	boat restricted zone
CHIN 0	subyearling chinook salmon
CHIN 1	yearling chinook salmon
CV	coefficient of variation
DSP	Digital Spectrum Processors
FCRPS	Federal Columbia River Power System
ft	ft
FGE	Fish Guidance Efficiency
FPE	Fish Passage Efficiency
FU	fish unit
h	hour
JDA	John Day Dam
kcfs	thousand cubic feet per second
km	kilometer
MU	main unit
NMFS	National Marine Fisheries Service
PSC	prototype surface collector
Q	river discharge
S	second
SMP	Smolt Monitoring Program
SPE	Spill Passage Efficiency
STH 1	yearling steelhead
STS	submerged traveling screens
USGS	U.S. Geological Survey

Contents

Figures

Tables

1.0 Introduction

Understanding fish-passage distribution and survival rates through spillways, turbines, bypass systems, and sluiceways under various dam operating conditions and configurations is critical for managing hydroelectric projects for fish passage. Juvenile fish passage at The Dalles Dam has been studied extensively over the past two decades using a variety of radio telemetry, hydroacoustic, and mark-recapture techniques. However, annual reports by different investigators have never been summarized to identify concordant and divergent results, and common passage metrics among years have not been compared. Thus, a thorough synthesis of existing annual reports is needed to provide regional fisheries managers with the current state of knowledge regarding fish passage at The Dalles Dam.

To help meet this need, the Portland District, U.S. Army Corps of Engineers (Corps), asked Battelle and BioAnalysts Inc. to summarize and synthesize results from existing reports on juvenile salmon and Steelhead passage research and monitoring conducted for the Corps at The Dalles Dam between 1980 and 2000.

1.1 Scope and Objectives

We reviewed and summarized 29 publications on radio telemetry, hydroacoustic, and survival studies of juvenile salmon at The Dalles Dam conducted between 1982 and 2000. Table 1.1 lists these reports by study type, authors, and year published. Appendix A briefly summarizes each of the publications reviewed.

Our objectives in reviewing these publications were to

- Describe the project, operations for fish, species composition, and run timing.
- Summarize spill passage effectiveness results.
- Summarize studies of juvenile salmon behavior including forebay approach patterns, residence times, and horizontal distribution of passage.
- Summarize tailrace egress results.
- Provide a general review of survival results.
- Integrate radio telemetry and hydroacoustic results
- Discuss limitations of data and sampling techniques.
- Identify key uncertainties and critical data gaps.
- Recommend standard ways of collecting, examining, and archiving data.

Table 1.1. Reports Reviewed for The Dalles

Authors	Year Published	Title
Fixed-Location Hydroacoustics		
Johnson et al.	2001, in review	Evaluation of Smolt Movements Using an Active Fish Tracking Sonar at the Sluiceway Surface Bypass, The Dalles Dam, 2000
Moursund et al.	2000, in review	Hydroacoustic Evaluation of Downstream Fish Passage at The Dalles Dam in 2000
Ploskey et al.	2001	Hydroacoustic Evaluation of Juvenile Salmon Passage at the Dalles Dam: 1999
BioSonics, Inc.	1999a	Hydroacoustic Evaluation and Studies at John Day Dam, Spring/Summer 1998
BioSonics, Inc.	1997	Hydroacoustic Evaluation and Studies The Dalles Dam Spring/ Summer 1996
Nagy and Shutters	1996	Hydroacoustic Evaluation of Surface Collector Prototypes at The Dalles Dam, 1995
Stansell et al.	1991	Hydroacoustic Evaluation of Juvenile Salmonid Fish Passage at the Dalles Dam Fish Attraction Water Units in 1990
McFadden	1990	Hydroacoustic Evaluation of Juvenile Salmonid Fish Passage at The Dalles Dam in Summer 1989
Johnson, Johnson, and Weitkamp	1987	Hydroacoustic Evaluation of the Spill Program for Fish Passage
Steig and Johnson	1986	Hydroacoustic Assessment of Downstream Migrating Salmonids at The Dalles Dam in Spring and Summer 1985
Magne, Nagy, and Maslen	1983	Hydroacoustic Monitoring of Downstream Migrant Juvenile Salmonid Passage at John Day and The Dalles Dam in 1982
Radio Telemetry		
Beeman et al.	2000 preliminary	Estimates of Fish-, Spill-, and Sluiceway Passage Efficiencies of Radio-Tagged Juvenile Steelhead and Yearling Chinook Salmon at The Dalles Dam, 2000
Counihan et al.	2000 preliminary	Survival Estimates of migrant Juvenile Salmonids in the Columbia River from John Day Dam through Bonneville Dam using Radio-Telemetry.
Allen et al.	2001a preliminary	Movement, Distribution, and Behavior of Radio-Tagged Yearling Chinook Salmon in the Tailrace of the Dalles Dam, 2000
Hansel et al.	2000	Estimates of Fish-, Spill-, and Sluiceway Passage Efficiencies of Radio-Tagged Juvenile Steelhead and Yearling Chinook Salmon at The Dalles Dam, 1999
Allen et al.	2000	Movement, Distribution, and Behavior of Radio-Tagged Yearling and Sub-Yearling Chinook Salmon in the Tailrace of The Dalles Dam 1999
Snelling and Mattson	1998	Behavior and Fate of Juvenile Salmonids Entering the Tailwaters of The Dalles Dam via Spill
Hensleigh et al.	1999	Movement, Distribution, and Behavior of Radio-Tagged Juvenile Chinook Salmon and Steelhead in John Day, The Dalles and Bonneville Dam Forebays, 1997

Table 1.1. (contd)

Authors	Year Published	Title
Normandeau, Skalski, and Mid-Columbia Consulting	1996	Potential Effects of Modified Spillbay Configurations on Fish Condition and Survival at The Dalles Dam, Columbia River
Holmberg et al.	1997	Movement, Distribution, and Behavior of Radio-Tagged Juvenile Chinook Salmon in John Day, The Dalles, and Bonneville Dam Forebays, 1996
Sheer et al.	1997	Movement and Behavior of Radio-Tagged Juvenile Spring and Fall Chinook Salmon in The Dalles and John Day Dam Forebays, 1995
Snelling and Schreck	1995	Movement, Distribution, and Behavior of Juvenile Salmonids Passing through Columbia and Snake River Dams
Shively, Sheer, and Holmberg	1995	Description and Performance of an Automated Radio Telemetry System to Monitor the Movement and Distribution of Northern Squawfish at Columbia River Dams
Hansel et al.	1995	Movements and Distributions of Radio-Tagged Northern Squawfish near The Dalles and John Day Dams
Clugston and Schreck	1994	Movement, Distribution, and Behavior of Juvenile Salmonids Passing through Columbia and Snake River Dams
Survival		
Dawley and Absolon	2000 preliminary	Relative Survival of Juvenile Salmon Passing through the Spillway of The Dalles Dam, 2000
Dawley et al.	2000	Relative Survival of Juvenile Salmon Passing through the Spillway of The Dalles Dam, 1999
Dawley et al.	2000	Relative Survival of Juvenile Salmon Passing through the Spillway and the Ice-Trash Sluiceway of The Dalles Dam, 1998
Dawley et al.	1998	Relative Survival of Juvenile Salmon Passing through the Spillway of The Dalles Dam, 1997

1.2 Background and Overview

Estimating the survival of the fish passing dams requires accurate information on the distribution of fish passage. Therefore, the focus of many past studies involved determining the distribution of fish passage among routes through the dams. The tools and techniques that have been employed at The Dalles Dam to collect fish passage data since the late 1970s have included gatewell dipping, trapping in the sluiceway, fyke net sampling, balloon tag testing, pit-tagging, radio telemetry monitoring, and hydroacoustic monitoring.

Applications of radio-telemetry and hydroacoustics in the early 1980s were primarily feasibility studies. Early success using tagged fish indicated that juvenile salmon could be tracked as they approached and passed through the The Dalles Dam powerhouse and spillway. Reductions in tag size along with improvements in monitoring hardware have allowed researchers to tag smaller fish and track multiple tags simultaneously. The technological advances have allowed researchers to describe specific routes of passage (i.e., Turbine 16) as opposed to general passage routes (north powerhouse). Hydroacoustic technology has undergone similar advances, including improvements in hardware and software that have allowed researchers to sample at higher pulse-repetition rates, determine the direction of fish movement across split-beams, and more accurately quantify differences in fish detectability among and within sampled volumes.

Battelle and BioAnalysts were asked to evaluate the validity of results from the hydroacoustic and radio telemetry studies conducted at The Dalles Dam over the past 20 years in light of these advances and to identify inconsistencies in reporting among investigators that prevented comparisons of data on a finer scale. Battelle and BioAnalysts were also asked to identify critical information gaps and recommend evaluations to address these. These data gaps are identified in Tables 1.2 and 1.3.

The focus of many of the past studies involved determining the distribution of fish passage among routes through the dams. Common metrics used to describe fish passage at The Dalles Dam are listed below. These metrics are presented in this report when data were sufficient to provide estimates.

- Spill Passage Efficiency (SPE) – the proportion of total fish passing the project that pass through the spillway.

- Spill Passage Effectiveness – SPE divided by percent of total discharge going over the spillway.

- Fish Passage Efficiency (FPE) – the proportion of fish that pass through non-turbine routes i.e., juvenile bypass system and spillway.

- Sluice Passage Efficiency – the proportion of fish that pass through the sluiceway.

- Sluice Passage Effectiveness – sluice passage efficiency divided by the proportion of project discharge passing through the sluiceway.

1.3 Report Contents

Chapter 2 of this report describes The Dalles Dam's spill operations and salmon run compositions during the study periods. Chapter 3 describes fish passage behavior, specifically forebay approach, residence time, horizontal distribution, tailrace egress, and predation. Chapter 4 summarizes fish passage information from radio telemetry and hydroacoustic studies conducted at The Dalles Dam. Chapter 5 describes the data on sluiceway passage of juvenile salmon at The Dalles Dam. Chapter 6 describes fish survival studies. Chapter 7 discusses limitations, uncertainties, and inconsistencies in the radio telemetry, hydroacoustic, and survival data reviewed. Chapter 8 provides conclusions and recommendations, as requested by the Portland District, Corps of Engineers. Chapter 9 lists references. Appendix A is an annotated bibliography of the 29 reports we reviewed.

Table 1.2. Availability of Fisheries Radio Telemetry and Survival Data for The Dalles Dam by Study Year

Data Type	Study Year and Citation												
	1990(a)	1992(b)	1993(c)	1993(d)	1995(e)	1996(f)	1997(g)	1997(h)	1999(i)	1999(j)	2000(k)	2000(l)	2000(m)
Telemetry Performance/Passage Metrics													
Fish passage efficiency	□	□	□	□	□	□	⊡	□	■	□	□	■	□
Spill passage efficiency	□	□	□	□	⊡	⊡	⊡	□	■	□	□	■	□
Spill passage effectiveness	□	□	□	□	⊡	⊡	⊡	□	■	□	□	■	□
Sluice passage efficiency	□	□	□	□	□	□	⊡	□	■	□	□	■	□
Sluice passage effectiveness	□	□	□	□	□	□	⊡	□	■	□	□	■	□
General route of passage	□	□	⊡	□	⊡	⊡	⊡	□	■	□	□	■	□
Telemetry Forebay Metrics													
Forebay approach	□	□	⊡	□	■	■	⊡	□	■	□	□	■	□
Forebay horizontal distribution	□	□	□	□	⊡	⊡	⊡	□	□	□	□	□	□
Forebay residence time	□	□	⊡	□	■	■	■	□	■	□	□	■	□
Telemetry Tailrace Metrics and Predation Studies													
Tailrace egress route	□	⊡	⊡	□	□	□	□	■	□	■	■	□	□
Tailrace egress residence time	□	⊡	⊡	□	□	□	□	■	□	■	■	□	□
Tailrace predator distribution	■	□	□	■	□	□	□	□	□	□	□	□	□
Probable predation events	□	□	□	□	□	□	□	⊡	□	■	■	□	□
Survival Metrics													
Radio telemetry	□	□	□	□	□	□	□	□	□	□	□	□	■
Study Year and Citation													
								1997(n)	1998(o)	1999(p)	2000(q)		
PIT tag at the spillway								■	■	■	■		
PIT tag at the sluiceway								□	■	□	■		

(a) Peterson et al. (1991).
(b) Clugston and Schreck (1994).
(c) Snelling and Schreck (1995).
(d) Hansel et al. (1995).
(e) Sheer et al. (1997).
(f) Holmberg et al. (1997).
(g) Hensleigh et al. (1999).
(h) Snelling and Mattson (1998).
(i) Hansel et al. (2000).
(j) Allen et al. (2000).
(k) Allen et al. (2000 – preliminary).
(l) Beeman et al. (2000 – preliminary).
(m) Counihan et al. (2000 – preliminary)..
(n) Dawley et al. 1998.
(o) Dawley et al. (2000).
(p) Dawley et al. (2000).
(q) Dawley et al. (2000 – preliminary).

■ = The study provided this data.
□ = The study did not provide this data.
⊡ = Information provided in report was based upon limited sample sizes or limited spatial sampling. Data may be of qualitative value.

Table 1.3. Data Availability for Hydroacoustics Studies at The Dalles Dam by Study Year

Sampling Metric	Study Year									
	1982[(a)]	1985[(b)]	1986[(c)]	1989[(d)]	1990[(e)]	1995[(f)]	1996[(g)]	1998[(h)]	1999[(i)]	2000[(j)]
Performance/Passage Metrics										
Fish passage efficiency	□	⊡	⊡	□	□	□	⊡	⊡	■	■
Spill passage efficiency	□	⊡	⊡	□	□	□	⊡	⊡	■	■
Spill passage effectiveness	□	⊡	⊡	□	□	□	⊡	⊡	■	■
Sluice passage efficiency	□	⊡	⊡	□	□	□	■	■	■	■
Sluice passage effectiveness	□	⊡	⊡	□	□	□	■	■	■	■
Turbine fraction	□	□	□	□	□	□	■	■	■	■
Run timing	☼	■	■	■	☼	■	■	■	■	■
Powerhouse Passage Distributions										
Horizontal	☼	Δ	Δ	Δ	☼ Δ	Δ	Δ	■	■	■
Vertical	□	■	■	□	☼	⊡	■	■	■	■
Temporal	□	■	■	□	□	□	■	■	■	■
Spillway Passage Distributions										
Horizontal	□	⊡	⊡	⊡	□	⊡	⊡	⊡	■	■
Vertical	□	■	■	■	□	■	■	■	■	■
Temporal	□	□	□	□	□	■	■	■	■	■
Sluiceway passage distributions										
Horizontal	□	□	■	□	□	□	■	■	■	■
Vertical	□	□	□	□	□	■	■	■	■	■
Temporal	□	■	□	□	□	□	■	■	■	■

(a) Magne et al. (1983).
(b) Steig and Johnson (1986).
(c) Ward et al. (1987).
(d) McFadden (1990).
(e) Stansell et al. (1991).
(f) Nagy and Shutters (1996).
(g) BioSonics (1997).
(h) BioSonics 1999.
(i) Ploskey et al. 1999.
(j) Moursund et al. (in review).

■ = The study provided this data.
□ = The study did not provide this data.
⊡ = There were problems with sampling that made some estimates questionable or sampling was sparse.
☼ = Sample was for part of a season.
Δ = Sampling was sparse.

2.0 Environmental Setting

The Dalles Dam, located at Columbia River Mile 192, includes a navigation lock, a spillway perpendicular to the main river channel, and a powerhouse parallel to the main river channel with non-overflow dams on each side (Figure 2.1). The Dalles Dam is the only Portland District project that has the powerhouse running parallel to the main channel of the Columbia River.

The powerhouse is 2,089 feet (ft) long and has two fish units (FU 1 and FU 2) and 22 main units (MU), numbered from the southwest (downstream) to the northeast (upstream) end. Each unit has three intakes, numbered again from southwest to northeast. Reference to a specific intake is expressed as the turbine unit and intake number, e.g., 2-3 for the east intake of MU 2 and 1-2 for the center intake of MU 1. Main units usually are operated within 1% of peak efficiency to reduce unit cavitation and injury to juvenile fish passing through them. Flow through the main units can range from about 9,000 to 17,000 cubic feet per second (ft^3/s) depending upon efficiency and factors that affect it (e.g., head and megawatt (MW) output). Flow averages about 15,000 ft^3/s. Two fish units are located southwest of MU 1; these have only two intakes each. The average discharge through the fish units is 2,600 ft^3/s,

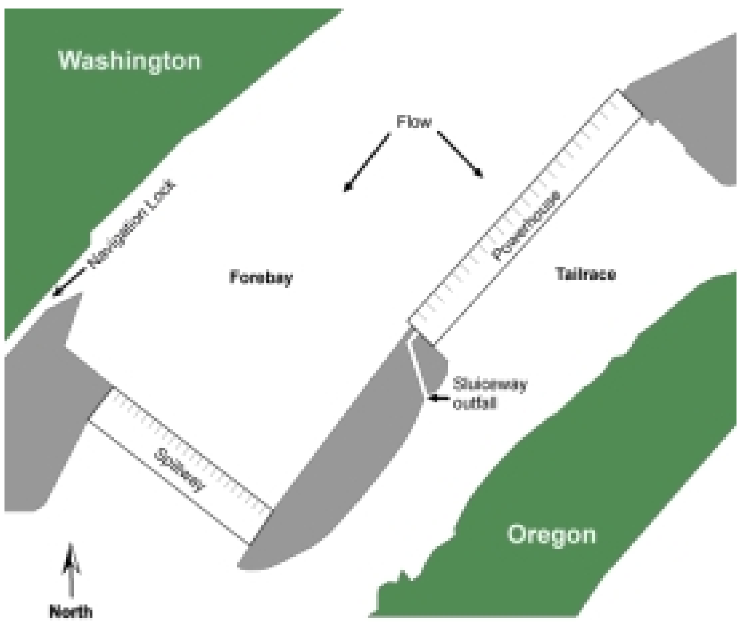

Figure 2.1. Plan View of The Dalles Dam Showing the Navigation Lock, Spillway, and Powerhouse

which provides auxiliary flow for the adult fish channel. An ice and trash sluiceway extends the entire length of the main units at the powerhouse. There are skimmer gates above every main turbine intake that open to the sluiceway. The maximum discharge of the ice and trash sluiceway is about 4,500 ft^3/s. Typically, the three gates at MU 1 are opened for a discharge of 1,500 ft^3/s each.

The spillway is 1,380 ft long and has 23 50-ft-wide bays, numbered from the Washington to the Oregon side. Individual spill-gate openings can range from 0 to 12 ft with about 1,500 ft^3/s of flow per foot of opening. Spill has ranged from 30%to 68% of river flow since 1995 but was less consistent and less dependent upon river flow in earlier years. Flow through the spillway has ranged from near zero to nearly 300,000 ft^3/s. Spill was sporadic in the 1980s and early 1990s depending upon river flow. From 1995 through 1999, spill patterns included a north-oriented spill at night for passing juvenile salmonids and a relatively uniform spill during the day for facilitating upstream passage of adult salmonids. In 2000, about 40% of the river was spilled in a north-oriented pattern 24 hours per day. The tailrace for the powerhouse is deep, but further downstream on the Oregon side it is shallow and has many islands and rock outcrops (Figure 2.2).

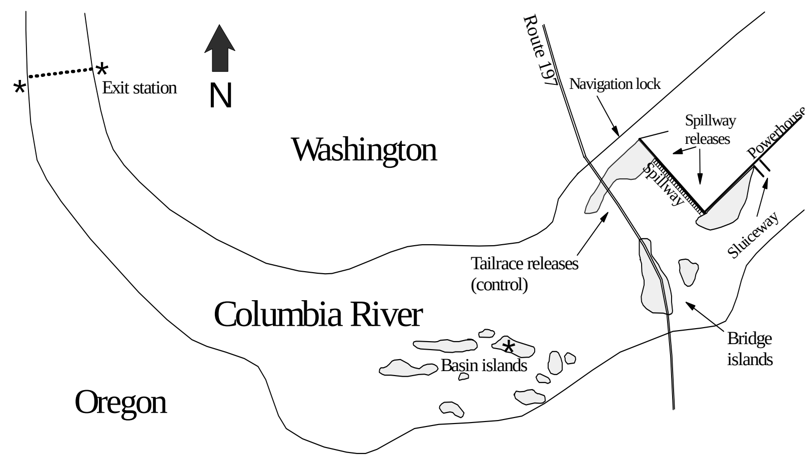

Figure 2.2. Plan View of The Dalles Dam Tailrace and Shoreline Showing Spillway, Sluiceway, and Powerhouse Outlets as Well as Bridge and Basin Islands. Fixed radio telemetry stations were established at the Basin islands and at the exit station (indicated with asterisks) in 2000 as detection locations to calculate tailrace residence time of tagged fish. Map distances are not to scale. Drawing provided by Theresa Liedtke of the Columbia River Research Laboratory, U.S. Geological Survey.

2.1 Project Operations for Fish

We examined reports for data on operations of The Dalles Dam spillway, ice and trash sluiceway, and powerhouse from 1982 to 2000. Spill for fish passage was very limited during study years between 1982 and 1990. For example, in spring, the spill fraction of project discharge was only 8.7% in 1985, 27.3% in 1986, and 7.9% in 1990. In summer, the spill fraction ranged from 0.8% to 5.2% of total discharge. This dam has long been operated to pass fish through the ice-trash sluiceway, which was quickly identified as an efficient passage route for juvenile salmonids (Nichols 1979; Nichols and Ransom 1981, 1982; Willis 1982; Steig and Johnson 1986; Johnson et al. 1987). After the 1995 Biological Opinion on Federal Columbia River Power System operations (National Marine Fisheries Service 1995), the fraction of project discharge spilled ranged from 30% to 69%. Studies to evaluate biological consequences of 30%

and 64% spill levels were implemented in 1996, 1998, and 1999. Before 1995, spill usually was limited to Bays 11-23, but in 1995 and thereafter, water was spilled according to patterns designed to enhance juvenile or adult fish passage. A juvenile pattern was run at night and concentrated spill on the Washington half of the spillway to prevent juvenile salmon from being flushed into islands that were downstream on the Oregon side of the tailrace. The adult pattern of spill was run during the day and spilled through most bays. The ice and trash sluiceway generally was opened only during the day before 1996 when 24-hour operation became the norm. Sluiceway flow made up about 1% to 1.9% of total project discharge in spring from 1985 through 2000 and from 1.2% to 3.3% in summer from 1982 through 2000.

2.2 Run Composition and Timing

The following species migrate downstream past The Dalles Dam:

Oncorhynchus tshawytscha	chinook salmon (yearling and sub-yearling)
O. mykiss	steelhead trout
O. nerka	sockeye salmon
O. kisutch	coho salmon

Migration timing varies somewhat from year to year, but run timing based upon juvenile bypass sampling at John Day Dam in 2000 is representative for the species and ages of migrating fish at The Dalles Dam (Figure 2.3). Data from John Day Dam were used because The Dalles Dam does not have a juvenile sampling facility. Sockeye and coho salmon pass in the lowest numbers, whereas yearling chinook salmon and steelhead are more abundant and have a more protracted migration (Figure 2.3). Historically, steelhead runs begin around April 20 and end by mid-June. Yearling chinook salmon runs begin about April 18 and end by about June 5, and most of the sub-yearling chinook salmon runs begin about June 1 and are over by about the end of July.

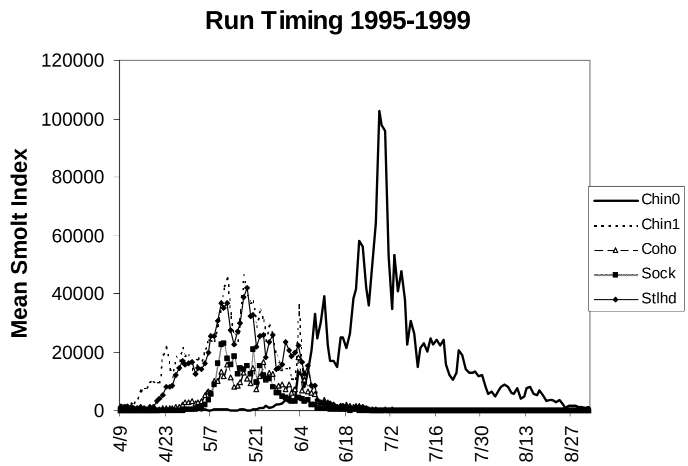

Figure 2.3. Run Timing for Salmon and Steelhead Smolts at John Day Dam. Data are expressed as the mean daily smolt index 1995-1999 from the Smolt Monitoring Program (SMP). (The SMP does not include The Dalles Dam.) Chin0 = sub-yearling *Oncorhynchus tshawytscha*; Chin1 = yearling *O. tshawytscha*; Coho salmon = yearling *O. kisutch*; Sock = yearling *O. nerka*; and Stlhd = juvenile *O. mykiss*.

3.0 Fish Behavior

This section describes the migration and passage behavior of juvenile salmonids at The Dalles Dam as determined by radio telemetry. We discuss species-specific migration and passage behavior at The Dalles Dam in five categories: forebay approach, horizontal distribution, residence time, and tailrace egress, and predation.

Several consistent behavior patterns of juvenile salmonids were apparent from available data from radio telemetry studies conducted over the past 8 years at The Dalles Dam. Emphasis is on the 1999 and 2000 studies, because the sample sizes of tagged fish were high enough to discern significant differences in fish behavior.

3.1 Forebay Approach

The approach of emigrating juvenile salmonids into the forebay of a mainstem hydroelectric dam may have very important consequences in terms of how quickly and where juveniles pass through the project. By examining project-operating conditions during the approach of radio-tagged juvenile salmonids, it may be possible to adjust project operations to more efficiently and effectively pass fish.

We break down forebay approach into two components: 1) reservoir migration routes, which are taken by radio-tagged fish from an upriver release site down to about 100 m upstream from the dam, and 2) near-dam forebay areas, which are the first entry locations of tagged fish into waters within 100 m of the dam.

The earliest study that examined forebay passage behavior of juvenile salmonids at The Dalles Dam took place in 1993 (Snelling and Schreck 1995). One study objective was to determine the feasibility of radio telemetry as a tool for discerning the forebay approach and passage behavior of juvenile salmonids. Tagged fish were released from the John Day Dam bypass. Forebay approach and passage data were collected for 14 radio-tagged yearling chinook salmon. Four of the fish arrived at The Dalles forebay before the spill period (night); their forebay residence time averaged 50 min and all presumably passed through the sluiceway. Detections were made by hand-held antennas on dam. The other 10 fish arrived while spill was occurring and nine presumably passed the spillway after an average residence time of 101 min. Spill ranged from 120 to 160×10^3 ft^3/sec with a river discharge of about 300×10^3 ft^3/sec. As this was just a feasibility study (with very small sample sizes, the residence time data should be considered qualitative.

From 1995 to 2000, the U.S. Geological Survey (USGS) conducted radio telemetry studies of the forebay approach and passage behavior of juvenile salmonids at The Dalles Dam (Sheer et al. 1997; Holmberg et al. 1997; Hensleigh et al. 1999; Hansel et al. 2000; Beeman et al. 2000 – Preliminary). The USGS studies determined forebay approach using boat mobile tracking. They monitored tagged fish movements from the release site to near the dam and then used an array of fixed station receivers and aerial antennas mounted on the dam to detect the specific area where fish first approached within 100 m of the dam.

In 1995, six groups of radio-tagged yearling chinook salmon (n=100 total) were mobile tracked from a point 4 km above The Dalles Dam down to the dam from May 2 to June 6, 1995 (Sheer et al. 1997). Results indicated that the first five groups approached the dam forebay from the south portion of the main channel and entered the near dam forebay at the east end of the powerhouse. Fish in Group 6 approached the forebay in the north edge of the main channel; they entered the near dam forebay toward the north part of the spillway and did not go near the powerhouse. Six groups of sub-yearling chinook salmon (n=71) were also mobile tracked, from a point 12 to 14 km above the dam down to the dam. The tagged fish either moved down along the Washington shore or in mid channel and most entered the near dam forebay at the east end of the powerhouse (Table 3.1).

In spring of 1996 using the same study design, radio-tagged yearling chinook salmon (n=166) moved down the reservoir fairly evenly dispersed in the main channel (Holmberg et al. 1997). As fish approached within ~100 m of the dam the majority moved toward the powerhouse. During most releases the majority of the tagged fish began moving toward the powerhouse, most often toward the east end, but a small portion kept moving along the north part of the forebay and straight toward the spillway. About 37% were first detected at the east powerhouse area. In the summer of 1996, radio-tagged sub-yearling chinook salmon (n=121) moved downriver from their release point along the south side of the main channel. About 39% of these fish entered the forebay at the east end of the powerhouse.

No mobile tracking was done in 1997, so only the fixed station monitoring data were available to determine the first area of entry into the near dam forebay (Hensleigh et al. 1999). About 60% of the radio-tagged steelhead (n=168) and 56% of the yearling chinook salmon (n=152) entered the near dam area at the east powerhouse area. In summer, sub-yearling more chinook salmon (n=76) were first detected entering the near dam area at the powerhouse than at the spillway (Table 3.1).

In 1999, again only fixed station monitoring was used to detect first area of entry into the near dam forebay (Hansel et al. 2000). During 30% spill, 67% of all radio-tagged steelhead and 73% of all yearling chinook salmon were first detected at the powerhouse and remaining fish were first detected at the spill-way. During 64% spill, 56% of steelhead and 53% of yearling chinook salmon were first detected at the powerhouse.

In 2000 (Beeman et al. 2000 – Preliminary), again no mobile tracking was done and only first detections in the near dam forebay were determined. Spill conditions were a constant 40% using the juvenile pattern. Most radio-tagged fish were first detected at the powerhouse. For steelhead, 91% were first detected at the powerhouse during the day and 70% at night. For yearling chinook salmon, 75% were first detected at the powerhouse during the day and 68% at night (Table 3.1).

Table 3.1. Summary of Forebay Approach Results from Studies Conducted in 1995 through 2000. Results show percent of first detections in four specific areas within 100 m of the dam under existing operating conditions described by concurrent estimates of mean spill, spill discharge, and river discharge.

	Sample Size	East Powerhouse	West Powerhouse	South Spill[(a)]	North Spill[(a)]	Mean % Spill	Spill Discharge Range × 10^3 ft^3/sec	River Discharge Range × 10^3 ft^3/sec
1995								
CHIN 1	100	41.7	16.7	11.6	30.0	53.6	120-160	227-290
CHIN 0	71	41.0	20.5	23.0	15.4	53.2	167-178	252-281
1996								
CHIN 1	166	37.1	17.5	26.2	19.2	57.4	90-247	276-417
CHIN 0	121	38.7	24.1	24.0	12.9	50.1	66-282	230-427
1997								
STH 1	168	60.1	7.8	11.3	20.8	63.5	173-407	303-571
CHIN 1	152	55.9	8.6	13.8	21.7	63.5	173-407	303-571
CHIN 0	76	34.2	25.0	19.7	21.1	63.0	132-198	206-315
1999								
		East and West Combined		South and North Combined				
STH 1	297	67		33		30	71-123	253-364
STH 1	313	56		44		64	145-205	253-364
CHN 1	298	73		27		30	71-123	253-364
CHN 1	248	53		47		64	145-205	253-364
2000								
STH 1	557	91		9		40 day	84-117	222-283
STH 1	223	70		30		40 night	84-117	222-283
CHN 1	432	75		25		40day	84-117	222-283
CHN 1	351	68		32		40 night	84-117	222-283

(a) Detections near the navigation lock were included in the North spill area and detections near the overflow wall were included in the South spill area.

3.2 Residence Time

The amount of time juvenile salmonids spend in the forebay prior to passing the dam is important for several reasons: 1) delay in emigration disrupts life history synchrony, 2) fatigue from searching and milling can lead to stress, which will increase the risk of predation due to reduced predator avoidance fitness (Mesa 1994), and 3) increased residence time may attract predators to areas of high prey density.

In a 1993 radio telemetry study, Snelling and Schreck (1995) collected information on the residence time of 14 radio-tagged yearling chinook salmon in The Dalles forebay. River discharge averaged 320,000 ft^3/sec and night spill ranged from 120,000 to 160,000 ft^3/sec. When radio-tagged yearling chinook salmon entered the near dam forebay during no spill (n=4), they resided for an average of 50 min before passing through the ice-trash sluiceway. When tagged yearlings entered the near dam forebay during spill (juvenile pattern), they resided for an average of 101 min before nine of the ten fish passed through the spillway.

From 1995 to 2000, the USGS collected data on the forebay residence time of radio-tagged juvenile salmonids, which they defined as the mean or median time a smolt spends in the forebay from first entry into near dam area (~100 m) until passage (Sheer et al. 1997; Holmberg et al. 1997; Hensleigh et al. 1999; Hansel et al. 2000; Beeman et al. 2000 - Preliminary). There were several significant findings. First, lower spill (30%) appears to significantly increase forebay residence times for steelhead yearlings. This was determined for 1999 only, so more test data are needed to verify this finding. Second, the time of arrival (day or night) and spill discharge level had a pronounced effect on the mean forebay residence time of steelhead yearlings. Steelhead arriving at night passed the project quickly regardless of spill discharge, but steelhead arriving during the day at spill levels less than 64% passed more slowly. The longer median residence times for steelhead during 30% day spill also appeared to be related to fish size. Steelhead shorter than 200 mm (fork length) had significantly shorter residence times (3.9 versus 0.7 h; $P<0.001$). Fish less than 200 mm long are more likely to be wild fish than hatchery fish. Forebay residence times of yearling chinook salmon did not vary with spill condition or time of day. In general, forebay residence times of radio-tagged fish were fractions of an hour (Table 3.2).

3.3 Horizontal Distribution

The horizontal distribution of radio-tagged fish in the forebay is not considered to be as meaningful a measure as route of passage at The Dalles Dam because tagged fish have very short residence times. Median residence time often was less than 0.3 hours, which indicates that fish are continually moving through the forebay and readily passing the dam. The USGS stopped reporting the horizontal distribution of fish in the forebay after 1997.

3.4 Tailrace Egress

The route of passage of juvenile salmonids into the tailrace and subsequent egress and residence time in the near dam tailrace may have a significant impact for survival of these fish. Direct mortality may occur through extreme hydraulic and physical forces and indirect mortality may occur through increased vulnerability to predators due to stress, injury, or disorientation.

Tailrace egress of juvenile salmonids at The Dalles Dam has been examined in several baseline studies at proposed smolt bypass outfall sites. In a spring 1992 study, Clugston and Schreck (1994) noted that 15 of 41 radio-tagged steelhead smolts held below the dam. The two main holding areas were the Bridge and Basin islands (Figure 2.2). These researchers observed faster egress for steelhead released from a downriver release site (~50 m below the bridge and ~50 m from the Washington shore) than for steelhead released from an upriver site (~200 m below the sluiceway outfall and ~50 m out from the

Table 3.2. Residence Time of Juvenile Salmonids in The Dalles Forebay

	Sample Size	Residence Time (hours)	% Spill (average)	Spill Discharge × 10^3 ft^3/sec	River Discharge × 10^3 ft^3/sec
1995					
CHIN 1	100	0.3 mean	53.6	120-160	227-290
CHIN 0	71	0.3 mean	53.2	167-178	252-281
1996					
CHIN 1	166	0.2 median	57.4	90-247	276-417
CHIN 0	121	0.2 median	50.1	66-282	230-427
1997					
STH 1	168	0.2 median	63.5	173-407	303-571
CHIN 1	152	0.2 median	63.5	173-407	303-571
CHIN 0	76	0.1 median	63.0	132-198	206-315
1999					
			% Spill & Pattern		
STH 1	241	2.3 median	30 adult/day	71-123	253-364
STH 1	295	1.4 median	30 juv/night	71-123	253-364
STH 1	244	0.3 median	64 adult/day	145-205	253-364
STH 1	310	0.3 median	64 juv/night	145-205	253-364
CHIN 1	181	0.3 median	30 adult/day	71-123	253-364
CHIN 1	296	0.3 median	30 juv/night	71-123	253-364
CHIN 1	161	0.2 median	64 adult/day	145-205	253-364
CHIN 1	247	0.2 median	64 juv/night	145-205	253-364
2000					
STH 1	557	1.1 median	40 day	84-117	222-283
STH 1	223	0.5 median	40 night	84-117	222-283
CHIN 1	431	0.6 median	40 day	84-117	222-283
CHIN 1	351	0.5 median	40 night	84-117	222-283

Oregon shore). In a similar study in 1993, Snelling and Schreck (1995) reported that holding (hence longer residence times) was four times more likely for radio-tagged yearling chinook salmon released at the upriver site (60% of the fish) compared to the downriver site (8% of the fish). Tagged fish were detected holding in the areas of the Bridge and Basin islands.

In 1997, Snelling and Mattson (1998) conducted a study to describe the migratory behavior of yearling and sub-yearling chinook salmon, and coho salmon in The Dalles tailrace after release through the north spillway, the south spillway, and the same downriver reference site. Two releases of yearling chinook salmon (n=53) were made May 1 and 4; eight releases of coho salmon (n=263) were made between May 11 and June 12; six releases of sub-yearling chinook salmon (n=269) were made between July 1 and July 18. For each release, about equal proportions were released through each of the three sites. Results indicated that from 88% to 98% of fish released at the reference site passed the 6-km exit transect, 92% to 100% of the north spill fish exited, and 65% to 88% of the south spill fish exited. The fish that did not pass the exit were presumed to be lost. They reported that fish predation befell 3% of the coho salmon from the south day spill, 25% of the sub-yearling chinook salmon through the south day spill, and 4% of the sub-yearlings from the south night spill. The tailrace migration times for the south spill released fish also were considerably longer than for fish released at the north or reference site.

In 1999, Allen et al. (1999) described the tailrace egress and behavior of radio-tagged yearling (n=339) and sub-yearling chinook salmon (n=329) released ~ 200 m upriver of the north and south spill bays at The Dalles Dam. River conditions did not vary significantly during the spring (April 27-May 27) or summer (June 19–July 14) study periods. River discharge ranged from 297 to 363×10^3 ft^3/sec in spring and from 263 to 351×10^3 ft^3/sec in summer.. The major study objectives were to determine 1) movement patterns and residence times in the tailrace, 2) relationships between juvenile salmonid routes of travel through the tailrace and residence times, 3) the influence of test conditions on tailrace residence times, and 4) hydraulic conditions likely experienced by fish in the tailrace through deployment of drogues. The test conditions were 30% versus 64% spill alternated in three-day blocks. Within each 24-h period, the spill pattern was alternated between adult (day) and juvenile (night) patterns. Researchers released 339 radio-tagged yearling chinook salmon in spring and 329 sub-yearling chinook salmon in summer.

Three release sites were chosen: in the forebay 200 m above the north spill bays, 200 m above the south spill bays, and at the reference site in the tailrace below the bridge. Following release, the tagged fish were monitored from fixed receiver stations on the dam, as well as several receivers on the Bridge and Basin islands and the shorelines. Boat mobile tracking was also used. Tagged fish released from all three sites during 64% adult (day) spill had the longest and most variable tailrace residence time (Table 3.3). The south spillway fish consistently had the highest residence time through all test conditions. "Predation event" was another measure recorded following each tagged fish release. Piscivorous predation was suspected when a tagged fish was continuously detected by a single fixed station for many hours or was located in the study area by boat tracking after all other fish had exited the study area. The majority of predation events involved south spill fish during 64% adult (day) spill. No predation events were detected during either migration period (spring or summer) during 30% juvenile spill (night). Predation events were generally localized near the Route 197 Bridge islands and the Basin islands on the south side of the river (Figure 3.2).

In 2000, the USGS (Allen et al. 2000a and 2000b Interim Reports) conducted studies similar to those done in 1999 to again describe the tailrace egress and behavior of radio-tagged yearling and sub-yearling chinook salmon. In the spring of 2000, the project conditions were a constant 40% spill using the juvenile pattern. From April 30 to May 27, 375 radio-tagged yearling chinook salmon were released for this study. The four release sites were in the forebay 200 m above the north spill bays, in the forebay 200 m above the south spill bays, in the ice-trash sluiceway, and at the reference site in the tailrace below the bridge. Following release, the tagged fish were monitored as in 1999. The sluiceway fish had significantly longer mean migration times (106 min) to the Basin island monitoring site than all other release groups, both day and night (Table 3.3). South spill fish were next highest, and north spill fish and control fish (below bridge site) were similar. There were no significant diel differences for any release. Seventeen predation events were recorded, six on fish that passed the spillway, five on fish that passed the powerhouse, three on fish that passed the sluiceway, and three on control fish released below the dam.

In summer 2000, the project conditions were a constant 40% spill using the juvenile pattern. From June 20 to July 18, 281 radio-tagged sub-yearling chinook salmon were released. The release sites and monitoring stations were the same as in spring 2000. Drogues were also released through the north and south spill bays during the same conditions the test fish experienced to study the hydraulic environment encountered by juvenile salmonids in the tailrace. In 2000, the exit site for sub-yearling chinook salmon was 6 km downriver. In 1999, spill treatments were 30% versus 64% and in 2000 spill was a constant 40% and day vs. night was tested. Fish released from the sluiceway had significantly longer migration times to the exit site than all other release groups, both day and night (Table 3.3). South spill fish were next highest, usually followed by north spill fish, and then control fish. There were no significant diel effects for any release. Predation events occurred as follows: 13 total events were observed – 10 on spillway fish, 1 on sluiceway fish, and 2 on control fish.

Table 3.3. Mean Tailrace Migration Time (hours) of Radio-Tagged Juvenile Salmonids Released through the Spillway into The Dalles Tailrace to the First Exit Point Transect, 1.7 km Downriver from the Dam. Means without letters in common are significantly different by Duncan's Multiple Range Test ($P<0.05$).

	N. Spill	S. Spill	Control	Sluiceway
1999				
CHIN 1 30	0.4 A	0.5 A	0.2 B	NA
CHIN 1 64	0.5 B	2.4 A	0.2 B	NA
CHIN 0 30	0.4 A	0.5 A	0.1 B	NA
CHIN 0 64	0.4 B	1.1 A	0.2 B	NA
2000				
CHIN 1 day	0.4 A	0.4 A	0.2 A	1.8 B
CHIN 1 night	0.3 A	0.7 A	0.2 A	1.3 B
CHIN 0 day	1.7 B	2.4 B	1.4 B	4.3 A
CHIN 0 night	1.7 B	3.3 AB	2.2 B	4.0 A

3.5 Predation

Studies at other dams also indicate that the northern pikeminnow is a major predator of juvenile salmon (e.g., Ward et al. 1995). For example, in one John Day Reservoir study, losses were estimated to be 2.7 million per year for 1983-1986, with monthly predation mortality ranging from 7% (of the total migrating populations) in June to 61% in August (Rieman et al. 1991). In that same study, the tailrace boat restricted zone (BRZ) for McNary Dam was by far the most concentrated area of predation by the northern pikeminnow – this small area accounted for over 20% of all losses in John Day Reservoir. Studies have shown that concentrations of northern pikeminnow are relatively high in the forebays and tailraces of Columbia River dams, especially in boat restricted zones (Poe et al. 1991; Vigg et al. 1991; and Ward et al. 1995). Consumption of juvenile salmonids by northern pikeminnow in these areas has been documented to be moderately high; ranging from about 0.2 smolts/predator/day (consumption index, Petersen et al. 1991) in spring to about 4.0 smolts/predator/day in the summer (Petersen et al. 1991). These rates are strongly affected by warm water temperatures and small smolt size in summer.

Some predation research has been conducted specifically in The Dalles Dam tailrace. In 1990, northern pikeminnow (*Ptychocheilus oregonensis*) were sampled in The Dalles tailrace as part of a larger study to determine the significance of predation on emigrating juvenile salmonids system-wide (Petersen et al. 1991). Of the 115 northern pikeminnow collected from 10 sampling zones (equal effort in each zone), 96 (84%) were taken from the zone near the sluiceway outfall. During the spring, 100% of the northern pikeminnow collected at this site had consumed salmonids, and in the summer, 75% had consumed salmonids. Thus, predation near the existing The Dalles sluiceway outfall is an important concern.

The behavior and distribution of 64 radio-tagged northern pikeminnow were monitored from May through September 1993 in the tailrace of The Dalles Dam (Hansel et al. 1995). Although this study was not designed to estimate the direct impact of predation on smolt survival, it confirmed that predation could be a potentially serious problem for smolts passing through The Dalles sluiceway and tailrace. The objective of the study was to aid in establishing biological criteria for the optimum locations of juvenile bypass outfalls and to examine modes of project operation that might potentially reduce predation in tailrace areas of dams. Radio-tagged fish were monitored with fixed receiver stations (arrays of antennas connected to data logging receivers) and frequent mobile tracking. Northern pikeminnow used areas away from the spillway stilling basin during periods of high spill (mostly in May) and frequented areas in the spill basin and at the powerhouse in July and August when sub-yearling chinook salmon were abundant and dam discharges were reduced. During the study, the river discharge peaked at 382×10^3 ft^3/sec on May 17 with maximum spill of 294×10^3 ft^3/sec on May 22. Most spill occurred at night.

About twice as many radio-tagged pikeminnow were contacted at night as during the day. This was thought to be a function of greater juvenile fish passage at night, hence predators would be more active then. The area of the sluiceway outfall was also closely monitored for aggregations of predators, and it had the highest recorded number of position observations of predators during the juvenile fish passage season. Other common tailrace habitats where northern pikeminnow were recorded include the Bridge and Basin islands, the east end of the powerhouse, the Oregon shore across from the sluiceway outfall, and the Washington shore below the north end of the spillway and below the navigation lock entrance. Radio-tagged northern pikeminnow responded to changes in dam operations by moving away from areas of high velocity (>1 m/s) as in the stilling basin when spill operations were initiated at night.

In 1999, Allen et al. (2000) in a radio telemetry study of tailrace egress and behavior of tagged yearling and sub-yearling chinook salmon (see tailrace egress subsection above) indicated that fish in The Dalles tailrace preyed upon 4% of the yearlings and 2.5% of the sub-yearlings. About 75% of all predation events occurred on radio-tagged fish released through the south spill bays during the 64% adult spill treatment. All predation events except one occurred in either the Bridge or Basin islands of the tailrace. Although these percentages are not high, they are indicators that there may be a much higher predation risk for juvenile fish dispersed by the south spillway bays into the Bridge or Basin islands.

4.0 Fish Passage

4.1 Radio Telemetry Results

In a radio telemetry study, the ability to detect statistically significant differences among passage metrics is highly dependent on sample size and the magnitude of difference between the passage estimates. As sample size and the difference between metrics being compared gets larger, the statistical power increases. Therefore the best comparisons for radio telemetry data are often those where the data have been pooled across blocks, seasons, or even species. Only in 1999 and 2000 were sample sizes of radio-tagged fish high enough to give reasonably precise passage metrics for analysis. Earlier studies provided very important behavioral information, and we can use the general estimates of spill passage efficiency and effectiveness to examine long-term trends, but the precision of those metrics could not be estimated from available data.

4.1.1 Estimated Route of Passage

Route of passage for radio-tagged juvenile salmonids is a key ingredient to estimate fish passage metrics such as FPE. It is very important to obtain accurate passage location data. From 1995 to 2000, the majority of radio-tagged fish passed through The Dalles Dam spillway (Sheer et al. 1997; Holmberg, et al. 1997; Hensleigh et al. 1999; Hansel et al. 2000; Beeman et al. 2000 – Preliminary). Passage route data are shown in Table 4.1.

4.1.2 Fish Passage Metrics

From 1995 through 1997, spill passage efficiency and spill passage effectiveness varied little regardless of species or age (Table 4.2). Although sample sizes were small, FPEs estimated for yearling steelhead and chinook salmon in 1997 were 95.3 and 94.7, respectively.

In 1999 and 2000, sample sizes were significantly larger and arrays of aerial and underwater antennas were significantly more extensive than in previous study years. This study design provided higher detection capabilities and more accurate and precise estimates of passage metrics. In the earlier radio telemetry studies conducted by the USGS at The Dalles Dam (1995-1997), routes of passage were estimated using only aerial antennas and standard receivers to locate the areas where the radio-tagged fish were last contacted. In 1999, the USGS conducted a study at The Dalles Dam to determine the proportion of radio-tagged juvenile steelhead and yearling chinook salmon passing through the spillway and powerhouse (via turbines or sluiceway) during 30% and 64% spill treatments (Hansel et al. 2000). Radio-tagged yearling chinook salmon (n=469) and yearling steelhead (n=479) were released 23 km above John Day Dam. An additional 300 steelhead and 297 yearling chinook salmon were also radio-tagged and released from the John Day juvenile bypass. Fixed monitoring stations with arrays of aerial antennas were mounted on the dam and underwater antennas were deployed to monitor turbine units, tainter gates, and the sluiceway.

Table 4.1. Distribution of Juvenile Salmon Passage at The Dalles Dam from 1995 through 2000 (Numbers are the percentages of radio-tagged fish at sampled locations.)

	Sample Size	East Powerhouse	West Powerhouse	Sluiceway	South Spill	North Spill	% Spill (average)	Spill Range × 10^3 ft^3/sec	River Discharge Range × 10^3 ft^3/sec
1995									
CHIN 1	100	5.0	6.6	NA	53.3	35.0	53.6	120-160	227-290
CHIN 0	71	0.0	17.9	NA	64.1	17.9	53.2	167-178	252-281
1996									
CHIN 1	166	3.1	20.1	NA	45.4	31.4	57.4	90-247	276-417
CHIN 0	121	5.1	28.4	NA	44.7	21.5	50.1	66-282	230-427
1997									
STH 1	168	2.4	2.3	17.3	39.9	38.1	63.5	173-407	303-571
CHIN 1	152	2.0	3.3	23.0	38.8	31.6	63.5	173-407	303-571
CHIN 0	76	2.7	13.1	NA	48.7	35.5	63.0	132-198	206-315
1999									
		Ph E&W Combined		SLU	Spill N&S Combined				
STH 1	309	9	---	25	66	---	30	71-114	233-336
STH 1	388	5	---	9	86	---	64	145-208	233-336
CHIN 1	324	26	---	22	52	---	30	71-114	233-336
CHIN 1	271	9	---	12	79	---	64	145-208	233-336
2000									
		Ph E	Ph W	SL	Spill N	Spill S			
STH 1	793	4	5	5	70	15	40	73-109	184-286
CHIN 1	816	6	9	6	62	18	40	73-109	184-286

Each spill treatment ran for three consecutive days within a 6-day block and repeated for four blocks in the spring. Operations consisted of a juvenile spill pattern (concentrated more at the north gates) at night and the adult pattern (concentrated more at the mid and south gates) during the day.

Results are shown in Table 4.2. Steelhead FPE was 91% during the 30% treatment and 95% during the 64% treatment. Yearling chinook salmon FPE was 73% and 91% during 30% and 64% treatments, respectively. Steelhead FPE did not differ significantly between treatments, but yearling chinook salmon FPE was significantly greater during the 64% treatment than the 30% treatment. Steelhead and yearling chinook salmon spill passage efficiency estimates were significantly greater during 64% spill than at 30% spill (Figure 4.1). Unlike the trend in spill passage efficiency, steelhead and yearling chinook salmon sluiceway passage efficiencies were significantly greater during 30% spill than 64% spill (Figure 4.1). Coverage was very good with both aerial and underwater antennas with fast scanning digital spectrum

Table 4.2. Spill Efficiency, Spill Passage Effectiveness, Sluiceway Efficiency, and Fish Passage Efficiency at The Dalles Dam, 1995 – 2000, Based on Radio Telemetry. River discharge and spill ranges and averages were for times the radio-tagged fish passed the project. The numbers in parentheses are 95% confidence intervals.

	Sample Size	Spill Efficiency	Average % Spill	Spill Effec-tiveness	Percent of Fish Passing Sluiceway	Spill Range × 10^3 ft^3/sec	River Discharge Range × 10^3 ft^3/sec	Fish Passage Efficiency
1995								
CHIN 1	100	88	53.6	1.6:1	NA	120-160	227-290	NA
CHIN 0	71	82	53.2	1.5:1	NA	167-178	252-281	NA
1996								
CHIN 1	166	77	57.4	1.3:1	NA	90-247	276-417	NA
CHIN 0	121	66	50.1	1.3:1	NA	66-282	230-427	NA
1997								
STH 1	168	78	63.5	1.2:1	17.3	173-407	303-571	95.3
CHIN 1	152	72	63.5	1.1:1	22.7	173-407	303-571	94.7
CHIN 0	76	84	63.0	1.3:1	NA	132-198	206-315	NA
1999								
STH 1	309	66.0 (60.4-71.3)	30	2.2:1	25.2 (20.5-30.5)	74-114	233-363	91.3 (87.5-94.2)
STH 1	388	86.4 (82.3-89.9)	64	1.4:1	8.9 (6.1-12.4)	145-208	233-363	95.3 (92.4-97.3)
CHIN 1	324	51.5 (46.0-57.1)	30	1.7:1	21.9 (17.5-26.8)	74-114	233-363	73.5 (68.3-78.2)
CHIN 1	271	79.0 (73.6-83.7)	64	1.3:1	11.8 (8.2-16.3)	145-208	233-363	90.8 (86.7-93.9)
Pooled spp	633	58.6 (54.7-62.5)	30	2.0:1	23.5 (20.3-27.0)	74-114	233-363	82.1 (78.9-85.1)
Pooled spp	609	83.1 (79.9-86.0)	64	1.3:1	10.2 (7.9-12.9)	145-208	233-363	93.3 (91.0-95.1)
2000								
STH 1	793	85.4 (80.0-89.9)	39.6	2.1:1	5.8 (4.3-7.7)	73-109	184-286	91.2 (89.0-92.0)
CHIN 1	816	79.3 (76.3-82.0)	39.6	2.0:1	5.5 (4.0-7.3)	73-109	184-286	84.7 (82.1-87.1)

processors (DSPs). Detection percentages were very high also. They were 81% for steelhead released for this study above John Day Dam, 89% for steelhead from the John Day bypass, and 79% for yearling chinook salmon from both release sites.

In 2000 (Beeman et al. 2000 – Preliminary), the USGS conducted a study at The Dalles Dam to determine the proportion of radio-tagged juvenile steelhead and yearling chinook salmon passing through the spillway and powerhouse (via turbines or sluiceway) during 40% spill. Radio-tagged yearling chinook salmon (n=912) and yearling steelhead (n=911) were released at the following locations at John Day Dam: 23 km above the dam, the juvenile bypass, the spillway, and the tailrace. Fixed monitoring stations with arrays of aerial and underwater antennas were deployed as in 1999. Results of the study are shown in Table 4.2. For steelhead, FPE was 91%; spill passage efficiency was 85%; and sluiceway passage efficiency was 6% during the 40% spill. For yearling chinook salmon, FPE was 85%; spill

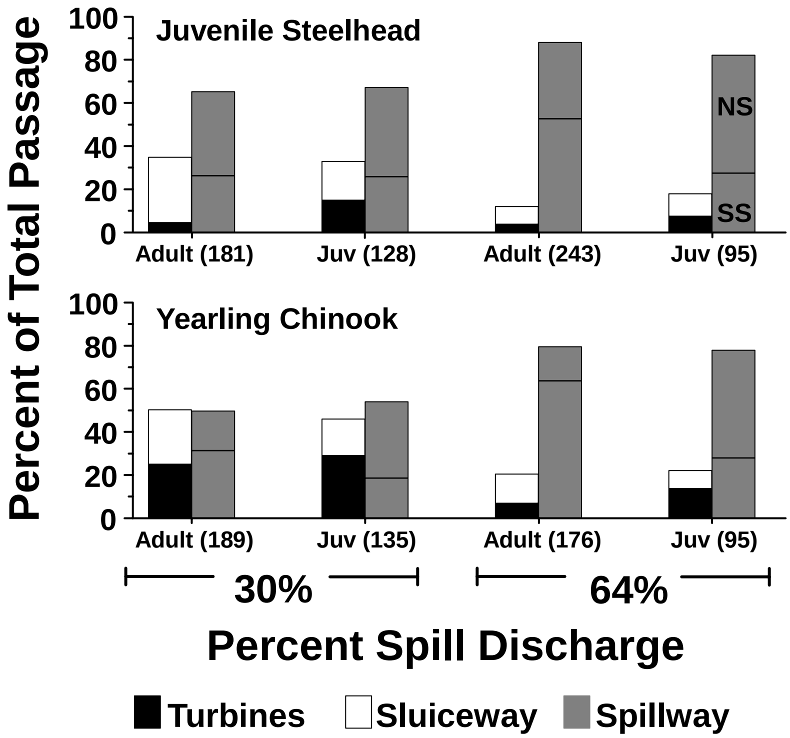

Figure 4.1. Percentage of Radio-Tagged Juvenile Steelhead and Yearling Chinook Salmon Passing through the Powerhouse (sluiceway and turbines) and the Spillway at 30% and 64% Continuous 24-h Spill Discharge during the Daytime Adult and Nighttime Juvenile Spill Patterns, The Dalles Dam, Spring 1999. SS=south spillway, NS=north spillway. Sample sizes are in parentheses. From Hansel et al. 2000.

passage efficiency was 79%; and sluiceway passage efficiency was 6%. Spill effectiveness estimates were 2.2:1 for steelhead and 2.0:1 for yearling chinook salmon. The high spill passage effectiveness may account for the low sluice passage efficiency relative to other years. Sample sizes were high for a radio telemetry study, and coverage was very good with both aerial and underwater antennas with fast scanning DSPs. Detection percentages were high also, with 87% of the steelhead and 89% of the yearling chinook salmon detected from all release sites.

In summary, from 1995 through 1999, a general comparison may be made among years for spill passage efficiency and spill passage effectiveness (Figure 4.2). When the spill percentage was similar (ranging from ~50% to 64%), both spill passage efficiency and spill passage effectiveness varied little among years, seasons, or species. Spill efficiency ranged from 72% for yearling chinook salmon in the spring of 1997 to 88% for yearling chinook salmon in the spring of 1995, with an overall average of about 80%. Spill effectiveness ranged from 1.1:1 for yearling chinook salmon in the spring of 1997 to 1.6:1 for yearling chinook salmon in the spring of 1995, with an overall average of about 1.3. Spill efficiency and

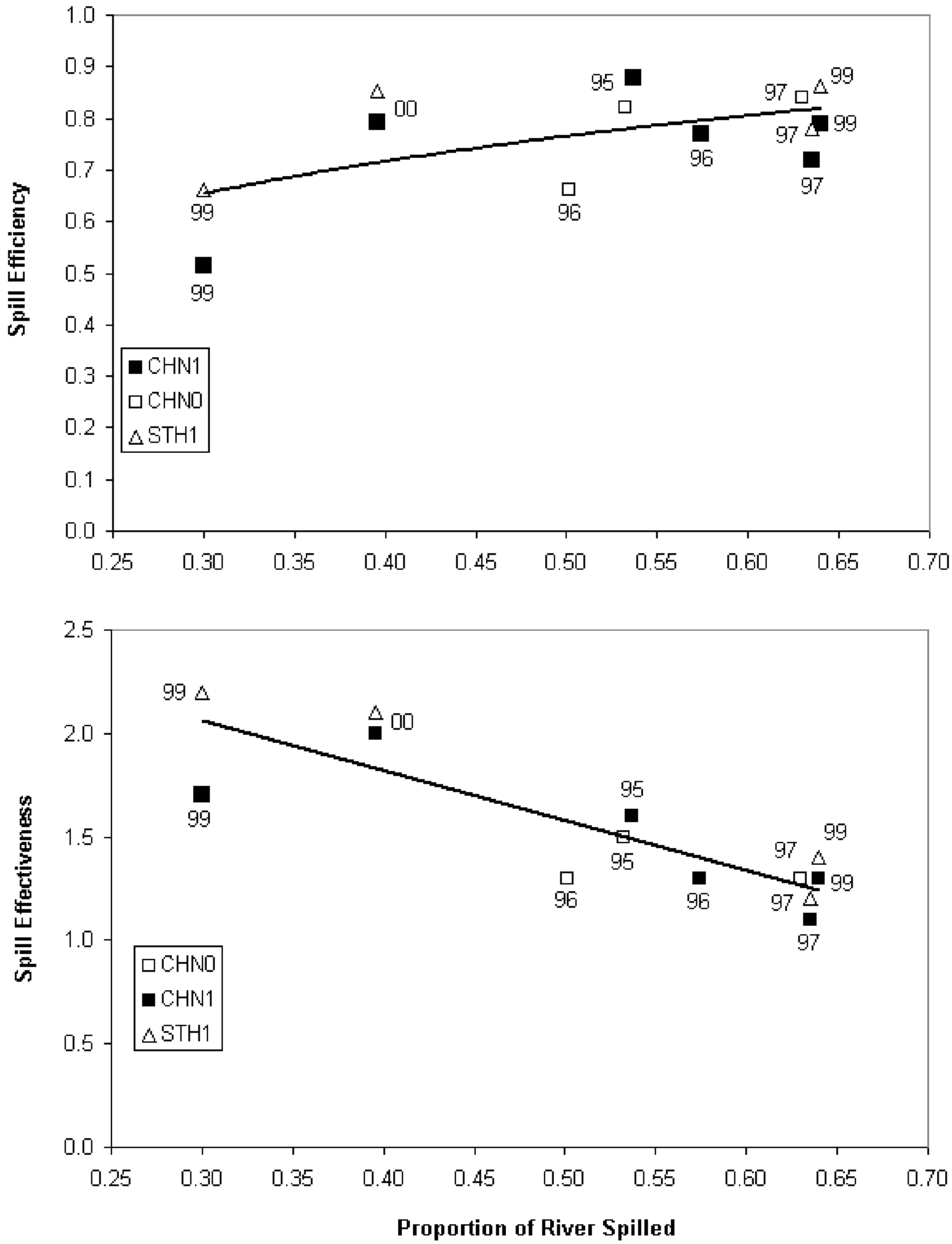

Figure 4.2. Spill Passage Efficiency and Effectiveness as a Function of the Proportion of the River Spilled at The Dalles Dam Based upon Radio Telemetry Studies

sluice passage efficiency in 2000 at 40% spill were more similar to efficiencies during 64% spill than during 30% spill in 1999. Spill effectiveness in 2000 was greater than expected from the 1999 results because when spill percentage increases the spill passage effectiveness decreases. Steelhead spill passage effectiveness in 2000 was the same as in 1999 (2.2:1) and for yearling chinook salmon it actually increased from 1.7:1 in 1999 to 2.0:1 in 2000. From these data, we concluded that 40% spill (with a juvenile pattern) was more effective than 30% or 64% spill. In 1999, FPE for yearling chinook salmon was significantly greater during 64% spill than 30% spill. However, for steelhead FPE did not differ between the two spill levels. FPE in 2000 for both species during 40% spill was intermediate between the FPE recorded at 30% and 64% spill.

Diel changes in passage conditions (day versus night and adult versus juvenile pattern) in 1999 did not seem to have any significant effects on spill passage efficiency, FPE, or sluice passage efficiency (Figure 4.3). Only for steelhead during 30% day spill were FPE and sluice passage efficiency statistically significantly higher than during night spill. The only other noticeable effect was that during the 64%

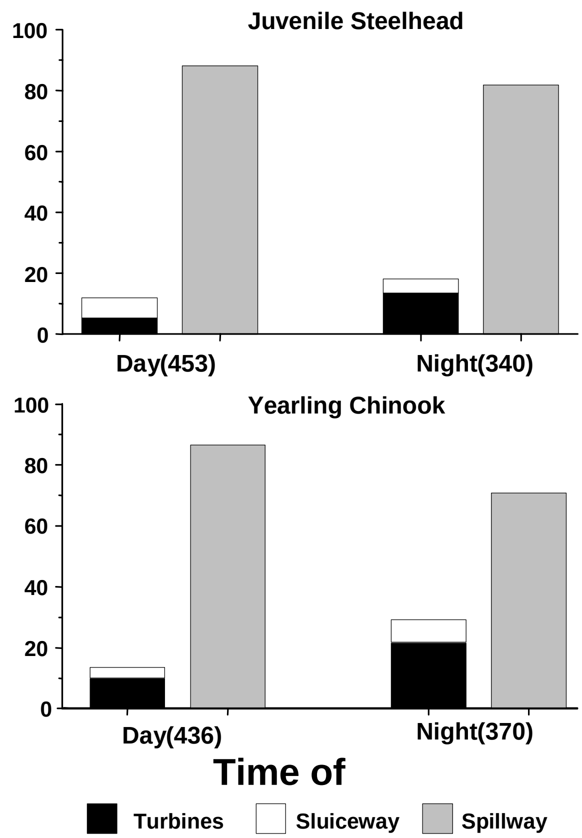

Figure 4.3. Percentage of Radio-Tagged Juvenile Steelhead and Yearling Chinook Salmon Passing through the Powerhouse (sluiceway and turbines) and the Spillway during Continuous 40% Spill Discharge at The Dalles Dam, Spring 2000. Day=0700-1659. Night=1900-0659. Sample sizes are in parentheses. From Beeman et al. 2000.

juvenile spill pattern in 1999, significantly fewer radio-tagged fish passed through the south half of the spillway as compared to the 64% adult spill pattern. In 2000, the most notable diel pattern was that spill passage effectiveness of yearling chinook salmon was much greater during the day (2.2:1) than at night (1.8:1) and this was during a constant spill of 40% with the juvenile pattern only.

The most notable difference in passage metrics between 1999 and 2000 was the significant drop in sluiceway passage efficiency in 2000 compared to 1999 (Figures 4.1 and 4.2). In 1999, sluice passage efficiency for steelhead was 25% during 30% spill and 9% during 64% spill; for yearling chinook salmon, it was 22% during 30% spill and 12% during 64% spill. Only a 10% increase in spill occurred in 2000 (over the 30% treatment) but sluice passage efficiency dropped to 5.8% for steelhead and 5.5% for yearling chinook salmon. One hypothesis to explain this shift is that a juvenile (north) spill pattern was used throughout 2000, and this pattern draws more juveniles toward the spillway area when approaching the near dam forebay. In 1999, the spill pattern was varied with the adult pattern occurring during the day and the juvenile pattern during the night.

4.2 Hydroacoustic Results

Hydroacoustic estimates of fish passage metrics such as FPE, spill passage efficiency, and sluice passage efficiency increase in precision as the duration of sampling increases, so seasonal estimates are much more precise than weekly or daily estimates. The accuracy of FPE estimates depends upon having or obtaining equal probabilities of detecting smolts at every major passage route. Comparability of results of hydroacoustic studies depends upon having many equivalent or nearly equivalent sampling deployments, acquisition settings, detectability, and processing techniques from year to year. Dam operations that may vary widely from year to year can have a profound effect on fish passage metrics.

4.2.1 Project-Wide Estimates

Tables 4.3 and 4.4 summarize fish passage metrics for fixed-aspect hydroacoustic studies conducted at The Dalles Dam in 1985 through 2000. We summarized fish-passage metrics from studies that provided estimates for the entire project and that were similar in transducer deployment. Six of eight spring studies and five of ten summer studies provided estimates of FPE and related metrics, but the remaining studies did not sample all passage routes. For example, Magne et al. (1983) sampled six of 24 turbine units and six of 23 spill bays in the first hydroacoustic survey of The Dalles Dam in 1982. McFadden (1990) only sampled the spillway on the Oregon side where most spill occurred. Stansell et al. (1990) focused on sampling two intakes of fish units, and Nagy and Shutters (1995) evaluated surface bypass structures deployed at the sluiceway and spillway. Nagy and Shutters (1995) sampled 20 of 23 spill bays but few turbines.

4.2.2 Average Metrics and Among-Year Variation

Difference among The Dalles Dam hydroacoustic studies are detailed in Tables 4.3 and 4.4 and important ramifications of these difference are discussed in Section 7.1 Data Gaps and Uncertainties.

Table 4.3. Metrics and Sampling Characteristics of Fixed Aspect Hydroacoustic Studies Conducted in Spring from 1985 through 2000. Numbers in parenthesis following some metric estimates are 95% confidence intervals calculated from temporal variation in samples.

Sampling Metrics	Year							
	1985[a]	1986[b]	1990[c]	1995[d]	1996[e]	1998[f]	1999[g]	2000[h]
Performance/Passage Metrics								
Project FPE	0.32	0.55	NA	NA	0.79 (0.05)	0.94 (0.02)	0.79 (0.02)	0.92 (0.01)
Spill efficiency (spring/summer)	0.09/season; 0.23 instantaneous	0.19/season; 0.23 at 10% spill; 0.43 at 50% spill	NA	NA	0.48 (0.05)	0.61 (0.04)	0.66 (0.02)	0.86 (0.0)
Sluice efficiency	0.23	0.36 (0.26-0.52)	NA	NA[i]	0.31 (0.04)	0.34 (0.05)	0.13 (0.01)	0.06 (0.01)
Turbine fraction	0.68	0.45	NA	NA	0.21	0.60	0.21	0.08
Spill effectiveness	Instantaneous	2.3 at 10% spill; 0.9 at 50% spill	NA	NA	0.83	1.28	1.41	2.16
Sluice effectiveness	13.6	51 reported; 26 calculated here	NA	NA	29.4 reported; 28.2 calculated	21.22	8.57	3.22
Sampling dates	4/22-6/1	4/21-6/15	4/23-5/31	5/8-5/26	5/6-6/11	4/20-5/27	4/22-5/27	5/13-6/5
Sampling duration	41	56	39	19	37	38	36	24
Mean project discharge (ft^3/s)	228,000	275,609	221,585	264,000	364,981	278,492	286,383	235,258
Spill discharge fraction[i]	0.087	0.273	0.079	0.56	0.58	0.47	0.47	0.40
Sluice discharge fraction[i]	0.017	0.014	0.019	0.015	0.011	0.014	0.014	0.017
Turbines sampled	7 of 24	8 of 24	2 FU	2 of 24	13 of 24	All	All	All
Spill bays sampled	9 of 23	8 of 23	None	20 of 23	10 of 23	13 of 23	13 of 23	14 of 23
Sluices sampled	All	All	None	2 of 3	All	All	All	All
Run timing	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Turbine Metrics								
Turbine transducers	15 deg. in forebay	15 deg. in forebay	6 deg. in turbine & 1 15 deg. in forebay	6 deg in turbine	6 deg in turbine	6.5 deg in turbine	6 deg in turbine	6 deg in turbine
Samples/hour	?	2-3	?	?	4	4	15	4
Sample duration (min)	?	2.5	?	?	2	2	1	2.5
Minutes/hour	8	5-7.5	?	?	8	8	15	10

Sampling Metrics	Year							
	1985[a]	1986[b]	1990[c]	1995[d]	1996[e]	1998[f]	1999[g]	2000[h]
Pings/second	?	4	?	?	10	10	14	15
Echoes/fish	4+	4+	3+	3+	4+ no wallflowers	4+ no wallflowers	4-30	4-30
Horizontal distributions	Yes	Yes	Among 2 units	NA	Yes	Yes	Yes	Yes
Vertical distributions	Yes	Yes	Yes	2 intakes	Yes	Yes	Yes	Yes
Temporal distributions	Diel	Diel	No	0900-0200	Diel	Diel	Diel	Diel
Sluice Metrics								
Sluice transducers	15 deg. in forebay	15 deg. in forebay	NA	2 in forebay	3 in forebay	3 in forebay	3-5 in forebay	3 in forebay
Samples/hour	?	2-3	NA	?	4	4	15	4
Sample duration	?	2.5	NA	?	2	2	1 minute	2.5
Minutes/hour	15	5-7.5	NA	?	8	8	15	10
Pings/second	?	10	NA	?	10	20	14	15
Echoes/fish	4+	2+	NA	?	4+ no wallflowers	4+ no wallflowers	4-60	4-60
Horizontal distributions	No	Yes	NA	No	Yes	Yes	Yes	Yes
Vertical distributions	No	No	NA	Yes	Yes	Yes	Yes	Yes
Temporal distributions	Diel	0500-2100	NA	No	Diel	Diel	Diel	Diel
Spillway Metrics								
Spill transducers	15 deg. upstream side	15 deg. upstream side	NA	None in spring	12 deg. upstream side	12 deg. upstream side	10 deg. under deck plates	10 deg. under deck plates
Samples/hour	?	2-3	NA	NA	4	4	3	3
Sample duration	?	2.5	NA	Na	2	2	2.5	2.5
Minutes/hour	7.5	5-7.5	NA	Na	8	8	7.5	7.5
Pings/second	?	10	NA	NA	10	20	24/sec	24
Echoes/fish	4+	4+	NA	NA	4+ no wallflowers	4+ no wallflowers	4-60	4-60
Horizontal distributions	Yes, sparse	Yes, bays 16-23	NA	NA	Yes	Yes	Yes	Yes
Vertical distributions	Yes	Yes	NA	NA	Yes	Yes	Yes	Yes

Sampling Metrics	Year							
	1985[a]	1986[b]	1990[c]	1995[d]	1996[e]	1998[f]	1999[g]	2000[h]
Temporal distribution	Day only	2100-1600	NA	NA	Diel	Diel	Diel	Diel
Detection threshold (dB)	-50	-50 to -55	-60	?	-55	-56	-56	-56
Detection modeling	?	Yes	No	Yes	Yes	Yes	Yes	Yes
Detectability corrected	No	No	No	No	?	?	Yes	Yes
Target strength used to correct detectability	No	No	For expansions only	No	No	No	Yes	Yes

(a) 1985 - Steig and Johnson (1986).
(b) 1986 - Ward et al. (1987).
(c) 1990 - Stansell et al. (1991).
(d) 1995 - Nagy and Shutters (1996).
(e) 1996 - BioSonics (1997).
(f) 1998 - BioSonics (1999).
(g) 1999 - Ploskey et al. (in press).
(h) 2000 - Moursund et al. (in review).
(i) Sluice efficiency was relative to total passage at the sluice and turbine intake sampled and ranged from 0.765-0.878.
(j) Calculated from historical flow data from DART; Sluice flow was calculated from: CFS = -30.179 x 2 + 10138 x (Forebay EL) – 844594.

Table 4.4. Metrics and Sampling Characteristics of Fixed Aspect Hydroacoustic Studies Conducted in Summer from 1985 through 2000. Numbers in parenthesis following some metric estimates are 95% confidence intervals calculated from temporal variation in samples.

Sampling Metric	1982[a]	1985[b]	1986[c]	1989[d]	1990[e]	1995[f]	1996[g]	1998[h]	1999[i]	2000[j]
Performance/Passage Metrics										
Project FPE	NA	0.49	None	NA	NA	NA	0.86 (0.03)	0.94 (0.03)	0.79 (0.01)	0.81 (0.01)
Spill efficiency (spring/summer)	NA	0.23/season; 0.40 instan-taneous	None; questionable passage estimates	NA	NA	NA	0.7 (0.04).	0.6 (0.04).	0.66 (0.02).	0.74 (0.03).
Sluice efficiency	NA	0.49	Not reliable	NA	NA	NA[i]	0.16 (0.03)	0.34 (0.06)	0.13 (0.01)	0.07 (0.01)
Turbine fraction		0.51	No estimate	NA	NA	NA	0.14	0.60	0.21	0.19
Spill effectiveness	NA	Instantaneous	None	NA	NA	NA	1.22	1.28	1.41	1.86
Sluice effectiveness	NA	13.2	None	NA	NA	NA	11-12 reported; 10.7 calculated here	21.22	8.57	3.27
Sampling dates	7/31-8/19	6/2-8/15	6/16-8/14	6/6-8/23	7/9-8/16	6/8-7/15	6/17-7/26	6/17-7/17	6/3-7/8	6/6-7/06
Sampling duration	20	75	60	79	39	38	38	41	36	30
Mean project discharge (ft^3/s)	175,000	134,000	155,528	126,523	152,564	248,935	277,368	246,190	319,842	192,990
Spill discharge fraction[i]	0.008	0.049	0.044	0.052	0.050	0.56	0.57	0.47	0.46	0.397
Sluice discharge fraction[i]	0.025	0.03	0.027	0.033	0.028	0.017	0.015	0.017	0.012	0.021
Turbines sampled	6 of 24	7 of 24	8 of 24	None	2 FU	2 of 24	13 of 24	All	All	All
Spill bays sampled	6 of 23	9 of 23	8 of 23	8 of 23	None	20 of 23	10 of 23	13 of 23	13 of 23	14 of 23
Sluices sampled	None	All	All	None	None	2 of 3	All	All	All	All
Run timing	Yes	Yes	Yes	Yes	Yes, fish units	Yes	Yes	Yes	Yes	Yes
Turbine Metrics										
Horizontal distributions	Yes	Yes	Yes	NA	Among 2 units	NA	Yes	Yes	Yes	Yes
Vertical distributions	No	Yes	Yes	NA	Yes	2 intakes	Yes	Yes	Yes	Yes
Temporal distribution	Night hours	Diel	Diel	NA	No	0900-0200	Diel	Diel	Diel	Diel

Table 4.4. (contd)

Sampling Metric	1982[a]	1985[b]	1986[c]	1989[d]	1990[e]	1995[f]	1996[g]	1998[h]	1999[i]	2000[j]
Sluice Metrics										
Horizontal distributions	NA	No	No	NA	NA	No	Yes	Yes	Yes	Yes
Vertical distributions	NA	No	No	NA	NA	Yes	Yes	Yes	Yes	Yes
Temporal distribution	NA	Diel	Diel	NA	NA	No	Diel	Diel	Diel	Diel
Spillway Metrics										
Horizontal distributions	No	Yes; 10 day, sparce spatial sampling	Yes Bays 16-23	Yes Bays 16-23	NA	Yes	Yes	Yes	Yes	Yes
Vertical distributions	No	Yes	Yes	Yes	NA	Yes	Yes	Yes	Yes	Yes
Temporal distribution	No	Day spill only	2100-0600	1700-0300	NA	Diel	Diel	Diel	Diel	Diel
Detection threshold	?	-50	-58	-56	-60	?	-56	-56	-56	-56
Detection modeling	?	?	Yes	No	No	Yes	Yes	Yes	Yes	Yes
Detectability corrected	?	No	No	No	No	No	?	?	Yes	Yes
Target strength used to correct detectability	No	No	No	No	For expansions only	No	No	No	Yes	Yes

(a) 1982 - Magne et a. 1983.
(b) 1985 - Steig and Johnson (1986).
(c) 1986 - Ward et al. (1987).
(d) 1989 - McFadden 1990.
(e) 1990 - Stansell et al. (1991).
(f) 1995 - Nagy and Shutters (1996).
(g) 1996 - BioSonics (1997).
(h) 1998 - BioSonics (1999).
(i) 1999 - Ploskey et al. (in press).
(j) 2000 - Moursund et al. (in review).
(k) Sluice efficiency was relative to total passage at the sluice and turbine intake sampled and ranged from 0.765-0.878.
(l) Calculated from historical flow data from DART; Sluice flow was calculated from: CFS = -30.179 x 2 + 10138 x (Forebay EL) – 844594.
NA = Not available.

Given differences in deployments, acquisition settings, and tracking criteria among the studies, the seasonal averages and 80% confidence intervals among years for the 1996-2000 studies are shown in Table 4.5. We are treating the samples as if they came from a simple random sample from some population of years. With autocorrelation, which is common in time-series data, the confidence intervals presented would be narrower than the true intervals for the population of years. Estimates from the individual spring and summer samples for each year are presented in Table 4.3-4.4, along with characteristics of sampling each year. The 1996-2000 studies were designed to account for temporal sampling variation only. No attempt was made to estimate spatial variation among intakes. Therefore, confidence limits presented are narrower than would be expected if all intakes had been sampled.

We limited the summary of metrics to four studies conducted in 1996, 1998, 1999, and 2000 because they had nearly similar deployments for sampling every fish passage route and relatively consistent data acquisition and processing criteria. The 1985 and 1986 studies had radically different deployments of transducers for sampling fish passage into turbines and had very limited spill relative to the later studies. The most comparable studies were conducted in 1999 and 2000. The FPE estimates of 0.32 and 0.55 in spring 1985 and 1986, respectively, and 0.49 in summer 1985 are significantly lower than the mean FPE estimates in Table 4.5 (0.85-0.86) and can be attributed to low spill and probably high counts of uncommitted fish sampled upstream of turbine intake trash racks. Studies conducted in 1996 and 1998 used different ping rates for the sluiceway and spillway and both used a less desirable deployment of spillway transducers than were used in 1999 and 2000.

Table 4.5. Means and 80% Confidence Limits on Project FPE, Spill Passage Efficiency, Sluice Passage Efficiency, Spill Passage Effectiveness, and Sluice Passage Effectiveness from Four Studies Conducted in 1996, 1998, 1999, and 2000

Metric	Spring Mean	80% Confidence Limit	CV	Summer Mean	80% Confidence Limit	CV
Project fish passage efficiency	0.86	0.07	9.4	0.85	0.06	7.9
Spill efficiency	0.65	0.13	24.4	0.68	0.05	8.8
Sluice efficiency	0.21	0.11	64.9	0.18	0.10	64.5
Spill effectiveness	1.42	0.45	38.9	1.44	0.24	20.1
Sluice effectiveness	15.6	9.74	76.3	10.94	6.16	68.8

The among-year coefficient of variation (CV) was less than 40% in spring and less than 25% in summer for FPE and spill metrics but greater than 60% for sluiceway metrics (4.3). The spring 1996 and 1998, sluiceway estimates were significantly higher than estimates in spring 1999 and 2000. In addition, the summer estimate for sluiceway efficiency in 1998 was higher than those reported in 1999 and 2000, probably because no swimming direction criterion was employed in 1996 and 1998, i.e., sluiceway passage was probably overestimated in 1996 and 1998 (Table 4.4). Reducing the spring 1996 and 1998 estimates of sluice passage efficiency by 48% (the average proportion of fish swimming away from the entrance in 1999 and 2000) would make the 1996 and 1998 sluice passage efficiency estimates much closer to those obtained in 1999 and 2000 and reduce the among-year variation in sluiceway estimates

(Table 4.6). Sluiceway efficiency relative to the powerhouse is substantially higher than the project-wide sluiceway efficiency of 11% to 13%. For example, in 1999, sluice efficiency was about 39% of total powerhouse passage in spring and 24% in summer.

Table 4.6. Means and 80% Confidence Limits on Project FPE, Spill Passage Efficiency, Sluice Passage Efficiency, Spill Passage Effectiveness, and Sluice Passage Effectiveness from Four Studies Conducted in 1996, 1998, 1999, and 2000 (after adjusting 1996 and 1998 metrics to account for likely overestimates in sluiceway passage because swimming direction information were not available in those years)

Metric	Spring Mean	80% Confidence Limit	CV	Summer Mean	80% Confidence Limit	CV
Project Fish Passage Efficiency	0.80	0.15	22.1	0.82	0.04	6.1
Spill Efficiency	0.68	0.14	25.4	0.72	0.03	4.9
Sluice Efficiency	0.13	0.04	36.4	0.11	0.04	40.4
Spill Effectiveness	1.47	0.46	38.4	1.50	0.21	17.3
Sluice Effectiveness	8.77	3.66	50.9	7.78	3.20	50.3

4.2.3 Daily Estimates of FPE

As expected, daily estimates of FPE were much more variable than estimates for seasons, often with slightly lower average estimates in summer than in spring in 1999 (Figures 4.4, 4.5, and 4.6). When average FPE estimates decreased between spring and summer in 1999 and 2000, the absolute magnitude of the decrease was only 6% to 11% for daytime estimates and 10% to 13% at night). In 1996, BioSonics (1997) found a slightly higher (7%) average FPE in summer than in spring. The lowest mean FPE estimate was reported for nighttime in summer 1999 (63%), and the two highest estimates were reported for summer 1998 (94%; day and night combined (Table 4.4) and for daytime in spring 2000 (95%; Table 4.7).

Table 4.7. Project Fish Passage Metrics by Season and Time of Day in 2000 (Moursund et al. 2001)

Season and Time of Day	Mean FPE	Mean Spill Efficiency	Mean Spill Effectiveness	Mean Sluice Efficiency	Mean Sluice Effectiveness
Spring day	0.95	0.89	2.22	0.07	3.51
Summer day	0.84	0.75	1.89	0.09	4.00
Spring night	0.89	0.83	2.09	0.06	2.93
Summer night	0.79	0.73	1.83	0.06	2.55

Hydroacoustic data from some years and seasons suggest that daily estimates of project FPE are affected by time of day (Figure 4.4; Table 4.7) and by spill percentage (see BioSonics spring 1999, Figure 4.5, and night estimates in spring and summer 1999, Figure 4.6). In 1999, differences in project FPE between spill levels were statistically significant at a 5% level at night and at a 10% level during the day.

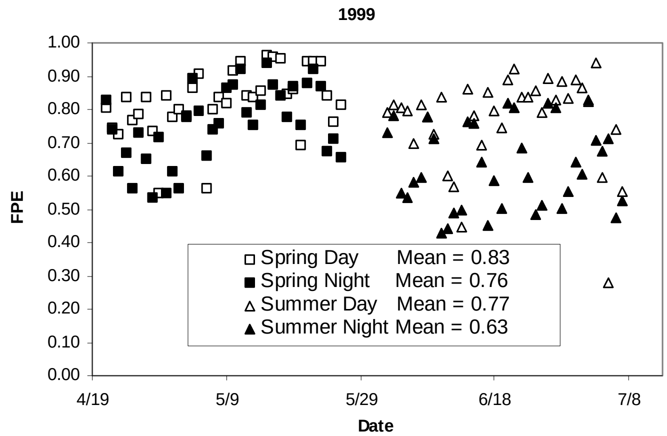

Figure 4.4. Day and Night Estimates of Project FPE by Date of Sampling in 1996 and 1998

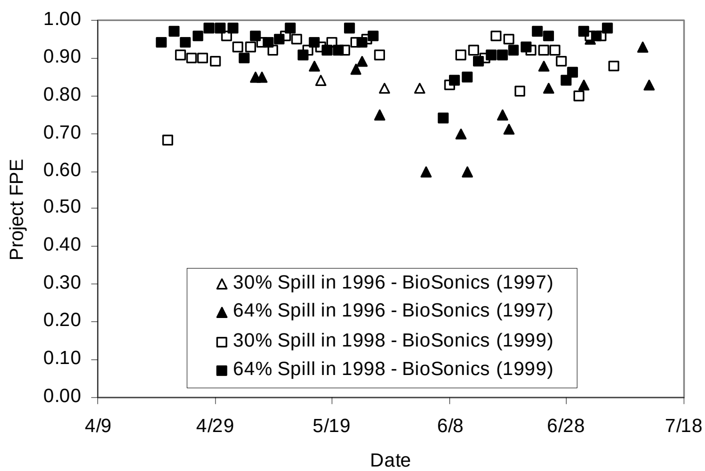

Figure 4.5. Project FPE by Date of Sampling and Spill Percentage in 1996 and 1998

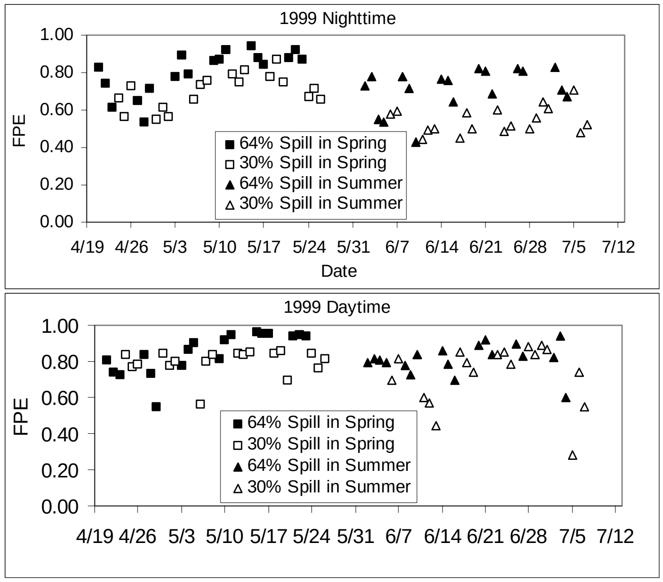

Figure 4.6. Seasonal Trends in FPE Estimates Comparing 64% and 30% Spill Levels during the Night (top), and during the Day (bottom) (Ploskey et al. 2001)

4.2.4 Variation in Fish Passage and FPE Among Hours of the Day

Project fish passage efficiency usually was slightly higher during the day than at night (7% to 13% higher in 1999 and 5% to 6% higher in 2000), although fish passage through the three major routes usually had significant diel patterns. For example, fish passage through turbines usually was higher at night than it was during the day (Figures 4.7-4.10), whereas sluiceway and spillway passage usually were higher during the day than at night (Figures 4.7-4.11). An exception was in summer 2000 (Figure 4.11; Table 4.7), when more fish passed through turbines during afternoon and evening hours than after midnight. As a ratio estimator based upon passage rates through three major routes, diel trends in project FPE were dampened more than diel fish passage estimates by route.

4.2.5 Effect of Dam Operations on Project FPE

Substantial changes in dam operations are required to produce a detectable difference in project FPE. For example, results suggest that doubling spill percentage (from 30% to 64%) provided only a 2% to 16% increase in project FPE. Spill treatments targeted at 30% and 64% of project discharge occurred during testing in 1996, 1998, and 1999. In 1996, estimated project FPE for each spill treatment were within 5% and 1% of each other in spring and summer, respectively, and treatment estimates had overlapping 95% confidence intervals. In 1998, BioSonics (1999) found significantly higher (2%) project FPE in spring during 64% spill (95%) than during the 30% spill (93%), but they detected no significant difference between the 64% treatment (FPE = 92%) and 30% treatment (FPE = 91%) in summer. In spring 1999, Ploskey et al. (2001) estimated project FPE at 84% during 64% spill and 76% during 30% spill. Closer inspection revealed that project FPE in spring was significantly higher ($p = 0.028$) during

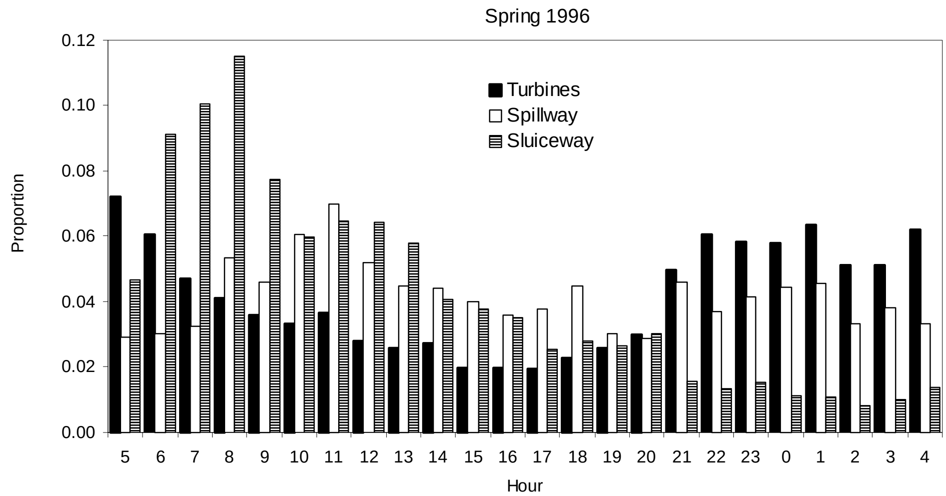

Figure 4.7. Diel Pattern of Fish Passage through Three Routes in Spring 1996 from BioSonics Data (1997). Fish passage was highest at the spillway (42%) followed by passage through the powerhouse turbines (37%) and then by passage into the sluiceway (21%).

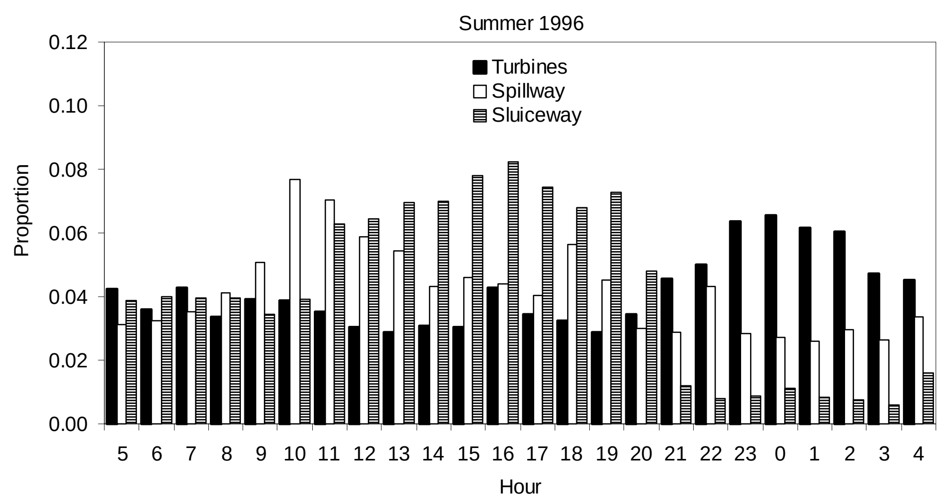

Figure 4.8. Diel Pattern of Fish Passage through Three Routes in Summer 1996 (from BioSonics 1997). Fish passage was highest at the spillway (67%) followed by passage through the powerhouse turbines (19%) and then by passage into the sluiceway (14%).

64% spill (81%) than during 30% spill (70%) at night but not during the day. Project FPE also was significantly higher (16% higher, $p = 0.028$) during 64% spill than during 30% spill at night, but no significant difference was detected during the day. Estimated FPE from summer 1999 was 76% during 64% spill and 64% during 30% spill.

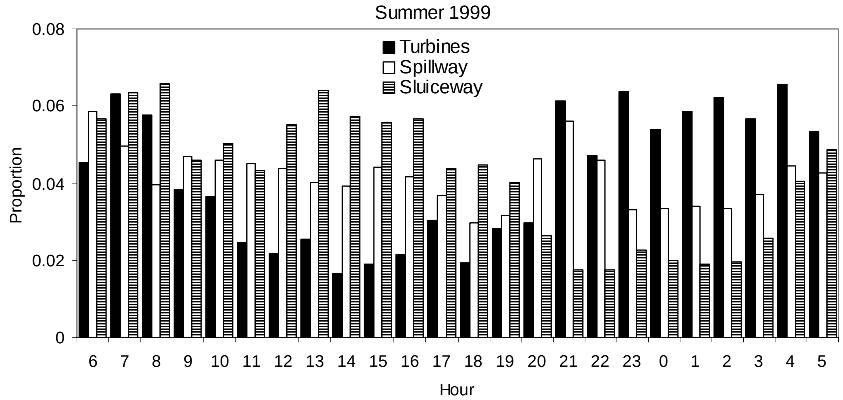

Figure 4.9. Diel Pattern of Fish Passage through Turbines and Sluice Entrances in Summer 1999 (Ploskey et al. 2001). Fish passage was highest at the spillway (59%) followed by the passage through powerhouse turbines (28%) and then by passage into the sluiceway (13%).

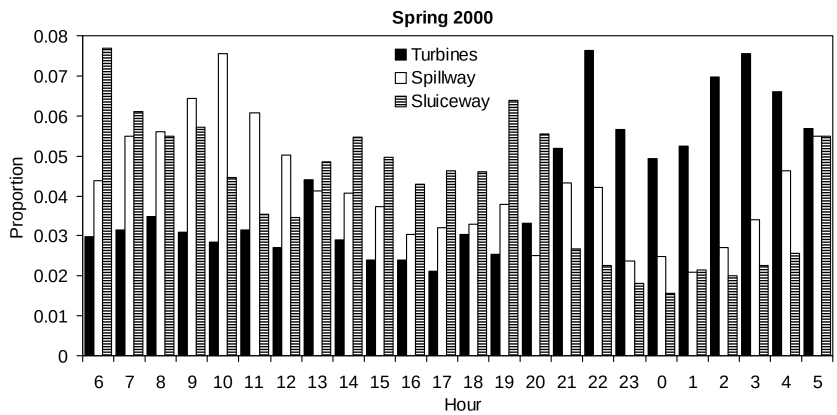

Figure 4.10. Diel Pattern of Fish Passage through Three Passage Routes at The Dalles Dam in Spring 2000 (Moursund et al. 2001 in review). Fish passage was highest at the spillway (86%) followed by the passage through powerhouse turbines (8%) and then by passage into the sluiceway (6%).

Modest increases in project FPE attained by increasing spill from 30% to 64% resulted from shifting proportions of fish passing through turbines to the spillway. However, fish were also shifted away from the sluiceway, which diminished the FPE benefit. Although sluiceway efficiency relative to the entire project (9-10%) did not differ among spill treatments during night or day in 1999, significantly more fish were detected passing through turbine intakes during 30% spill than during 64% spill at night (p=0.046). Turbine passage did not differ significantly by treatment during the day, although the p-value (0.075) was

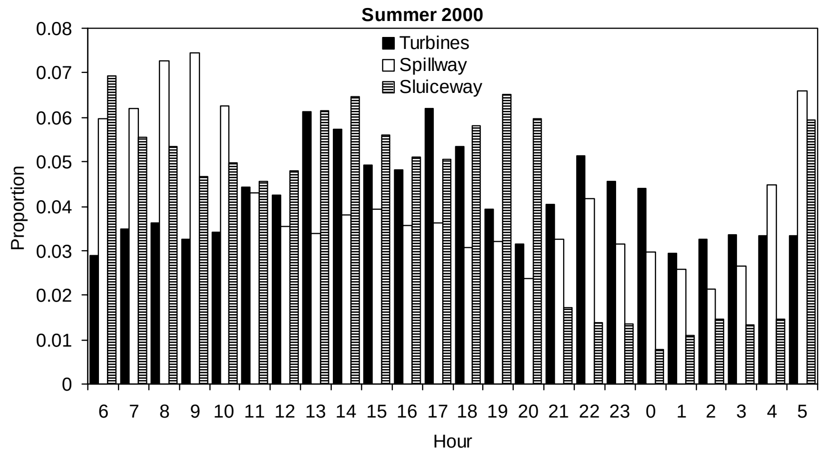

Figure 4.11. Diel Pattern of Fish Passage through Three Passage Routes at The Dalles Dam in Summer 2000 (Moursund et al. 2001 in review). Fish passage was highest at the spillway (74%) followed by the passage through powerhouse turbines (19%) and then by passage into the sluiceway (7%).

relatively small with the 30% treatment passing more, if not significantly more, fish. Results in 1998 suggest that increased spill also takes fish away from the sluiceway (BioSonics 1999), which shifts proportions without benefit for project FPE because both spill and sluiceway passed fish are part of the non-turbine fraction.

Although we refer to the treatments as "30% and 64% spill" treatments for expediency, the inferences that we make from our data more properly compare the effects of those two different suites of dam-wide operations that were used to achieve the two spill level treatments than the spill treatments alone. The 64% spill treatment was associated with much lower power generation than was the 30% treatment, particularly in the upstream end of the powerhouse. Units 15 to 22 usually did not discharge water during 64% spill.

4.2.6 Horizontal Distribution of Fish Passage Among Turbines

The horizontal distribution of numbers of fish passing through turbines per season has more to do with the amount of time each turbine was run, whereas distributions based upon rates of fish passage when turbines operated reflect distributions for an equally loaded powerhouse. The distribution of total passage tends to be skewed toward middle and lower numbered units during >50% spill because higher numbered turbines are shut down or run less (BioSonics 1997; BioSonics 1999; Ploskey et al. 2001). However, fish passage rates based upon hourly rates of passage when most turbines are operating often shows higher passage at middle or higher numbered turbines (Ploskey et al. 2001). In 2000, when spill was 40% or less and most turbines were operated, fish passage rates were relatively uniform among units in spring and the distribution was strongly skewed toward higher numbered units in summer (Moursund et al. 2001 in review).

4.2.7 Daily Estimates of Spill Efficiency

Like project FPE, daily estimates of spill passage efficiency were highly variable in contrast to seasonal estimates based upon a much longer sampling duration. Some of the daily variation was caused by 64% and 30% spill treatments that were tested in 1996, 1998, and 1999. In 1996 and 1998, most daily spill efficiencies ranged from about 40% to 80%. There was no visually obvious seasonal trend in spill-passage efficiency in 1998, although in 1996, spill-passage efficiency appeared to increase in summer (Figure 4.12). In 1999, daily spill efficiencies also ranged from about 40% to 80% during the first half of spring and most of summer and from about 55% to 90% during the second half of spring (Figure 4.13). Daytime spill efficiencies were higher than nighttime efficiencies in summer but not in spring of 1999. Both night and daytime spill passage efficiency estimates increased from about 55% at the beginning of spring to about 75% by the end of spring (Figure 4.13). No trend was obvious in summer. In 2000, average spill passage efficiency during the day was 6% higher than the nighttime spill passage efficiency in spring, but day-night differences were not significant in summer (Table 4.7).

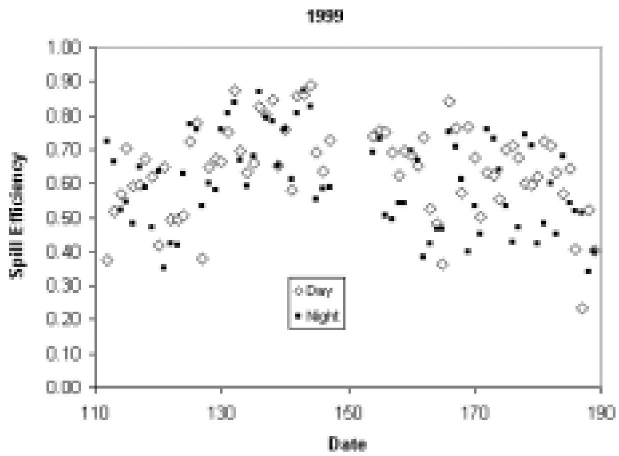

Figure 4.12. Project Spill Passage Efficiency by Date of Sampling in 1996 and 1998

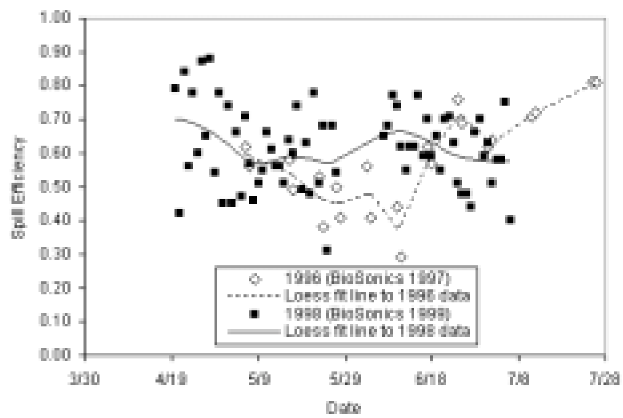

Figure 4.13. Day and Night Estimates of Spill Passage Efficiency by Date of Sampling in 1999

4.2.8 Effect of Dam Operations on Fish Spill Efficiency and Effectiveness

When significant differences could be detected between the 64% and 30% spill treatments in 1996, 1998, and 1999, increases in spill passage efficiency ranged from only 10% to 17% after a doubling of the spill fraction, while spill passage effectiveness declined significantly. No significant difference in spill passage efficiency could be detected between the two spill levels in 1996 because few 30% spill days occurred during that high-water year, but spill passage effectiveness declined significantly from 1.49 to 0.74 in spring and from 1.8 to 1.14 with increased spill (BioSonics 1997). In 1998, mean spill passage efficiency was 17% higher at the 64% spill level (0.694) than it was at the 30% spill level (0.524) in spring and it was 10% higher in summer (0.657 at 64% spill and 0.554 at 30% spill). The spill passage efficiency in spring 1999 averaged 66% and was 11% higher for the 64% treatment than for the 30% treatment with high variability at both spill levels.

At night the difference was significant (p = 0.028, 64% spill was more efficient) but not during the day (Figure 4.14). However, spring spill passage effectiveness in 1999 was significantly lower at the 64% spill level (1.2) than at the 30% level (2.0) and the difference was significant for both day and night (Figure 4.15). Similar trends in spill passage efficiency and effectiveness were observed in summer 1999 (Figures 4.14 and 4.15, respectively). In summer during night samples at 64% spill, efficiency averaged 64% and was 16% higher than night samples at 30% spill, which averaged 48%. Daytime efficiency was 67% during 64% spill and 58% during 30% spill in summer, but this difference was not significant. As during the spring, spill passage effectiveness in summer was significantly higher at the 30% spill level (1.78) than at the 64% level (1.09) and differences were consistent for both day and night (Figure 4.15).

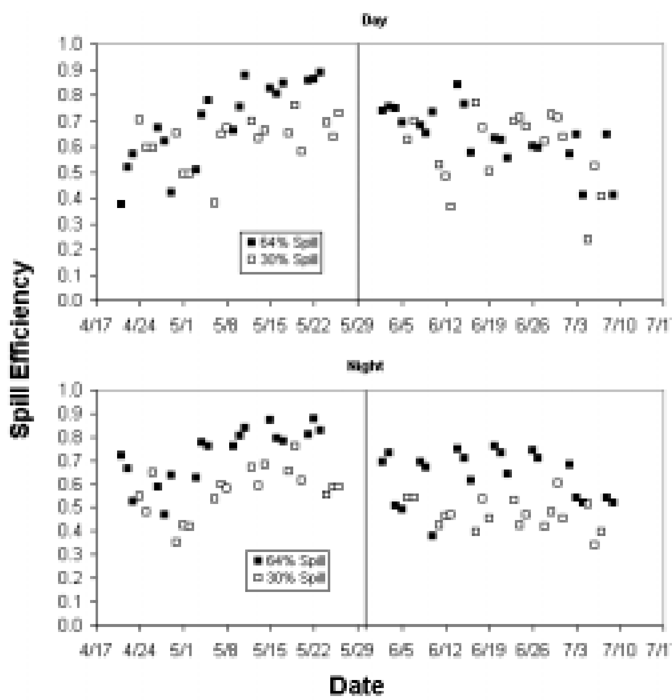

Figure 4.14. Daily Spill Passage Efficiency as a Function of Time of Day and Fraction of Water Spilled at The Dalles Dam in 1999

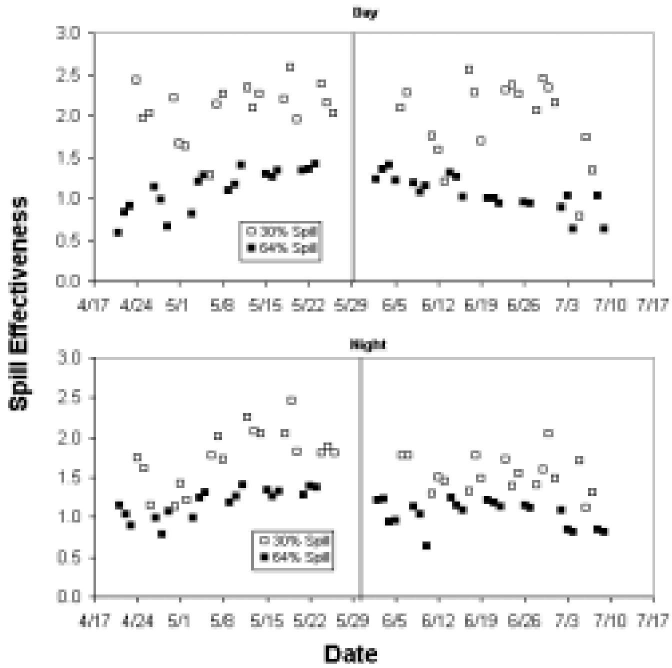

Figure 4.15. Daily Spill Passage Effectiveness as a Function of the Fraction of Water Spilled at The Dalles Dam in 1999

The relation between spill passage efficiency and spill rate is curvilinear according to a composite figure that includes data from 1985, 1996, 1998, and 1999 (Figure 4.16). The relation appears to be approximately linear up to 130,000 cfs, but then levels off. Data from 1985 (Steig and Johnson 1985) were included despite forebay deployments for sampling fish passage into turbines because the spill rate

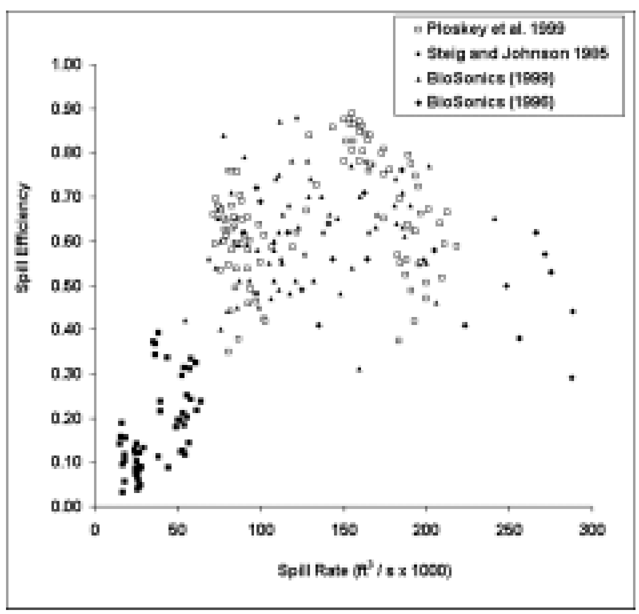

Figure 4.16. Relation Between Spill Passage Efficiency and Spill Rate

experienced that year was significantly lower than rates tested in subsequent years. Although those spill passage efficiency estimates probably are low because turbine passage likely was overestimated by the forebay transducer deployment, they are included to fill in the low range of possible spills. Data from 1986 (Johnson et al. 1987) were not included because reported discharge rates for the project were not reasonable. Johnson et al. (1987) reported project discharges ranging from 761,000 to 1,361,000 cfs while the maximum reported from DART for 1986 was 388,000 cfs.

Figure 4.17 shows a non-parametric smoothed line and 95% confidence intervals on predicted means fit to all data in Figure 4.16 by the loess-smoothing method. The fitted line indicates that the data in the 1985 report do not fit smoothly with data from later years, likely because spill efficiency was under-estimated in earlier studies, as described in the previous paragraph. The line also indicates that doubling spill rate from 80,000 cfs to 160,000 cfs only provides a modest 10% increase in spill efficiency compared with a 48% increase in efficiency when spill rate increased from about 20,000 to 80,000 cfs. The descending leg of the curve in Figure 4.17 may contain some questionable points with spill at >220,000 cfs. Those data were from the BioSonics (1997) study and probably should be dropped because they likely resulted from reduced detectability at high spill rates. The pulse repetition rate in that study was only 10 pings per second. Other points on the downward leg of the curve from the 1999 study are unlikely to represent low detectability at high spill rates because the pulse repetition rate was 24 pings per second and the average number of echoes per fish was the same for low and very high spill rates.

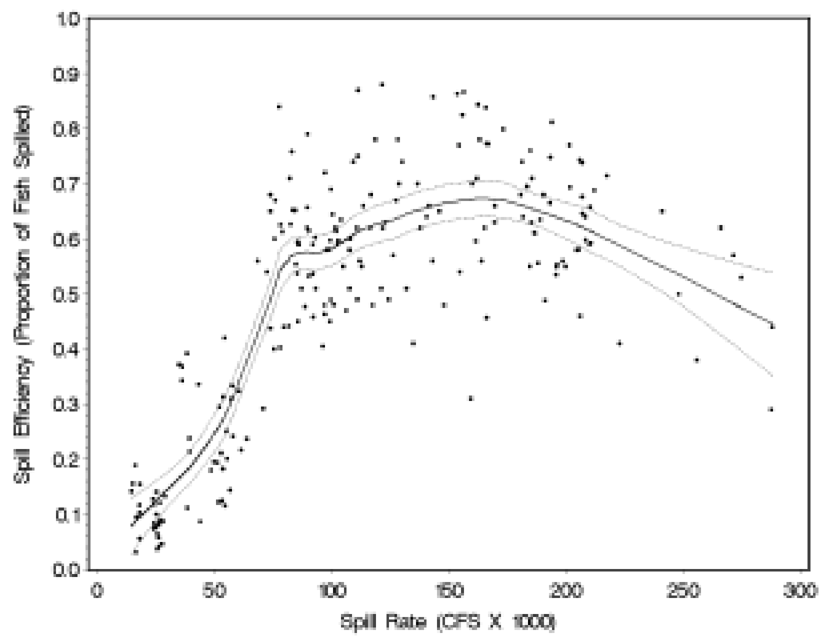

Figure 4.17. Loess Line Fitted to Spill-Rate and Spill Efficiency Data in Figure 4.16. Dotted lines indicate 95% confidence limits on predicted values of spill efficiency.

Clearly, increasing spill rate provides more incremental benefit at low levels than at high levels. Theoretically, if you spill the entire river, you must spill 100% of the fish. Nevertheless, as long as the Dam generates power and passes water through the ice and trash sluiceway, there will be competing routes through which fish may pass and a relation with a descending leg may be possible. It would suggest that fish avoid spill bays with very high spill rates. Residuals for the predicted line fit with a 0.3 smoothing parameter are plotted in Figure 4.18.

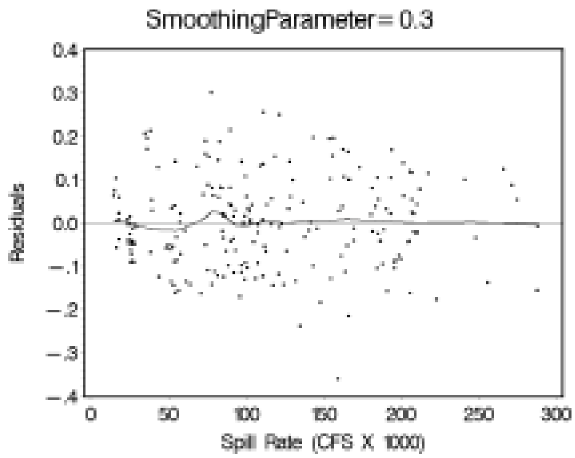

Figure 4.18. Plot of Residuals of the Loess-Fit Line in Figure 4.17. The response residual was smoothed with a 0.3 factor.

The same spill efficiency data can be plotted as a function of the proportion of the river spilled fraction to obtain a curve based upon a more common operational parameter than spill rate (Figure 4.19). Again, the loess-fitted line indicates that the 1985 data (spill proportion <0.25) do not fit smoothly with data from later years (Figure 4.20) perhaps because Steig and Johnson (1985) used forebay deployments to sample turbines and likely overestimated the fraction of fish passing through turbines. This overestimation of the turbine proportion would result in an underestimation of the spill proportion. The predicted line also indicates that differences between 30% and 64% spill are 10% or less.

4.2.9 Effect of Dam Operations on Sluiceway Efficiency

The most commonly observed effect of dam operations is that increased spill reduced sluiceway passage efficiency and effectiveness. In 1996, BioSonics (1997) observed that sluice passage efficiency was 4% higher in spring and 5% higher in summer at a low (<50%) spill level than at a high spill level (>50%), although neither trend between efficiency and spill level was statistically significantly at α=0.05. Results were more conclusive in 1998. Mean sluice passage efficiency was 6% higher in spring and 9% higher in summer during 30% spill than it was during 64% spill (BioSonics 1999). In 1999, nighttime estimates of sluice passage efficiency and effectiveness in spring were both significantly higher during 30% spill than during 64% spill (Ploskey et al. 2001). Daytime estimates were highly variable and did not differ significantly among spill treatments.

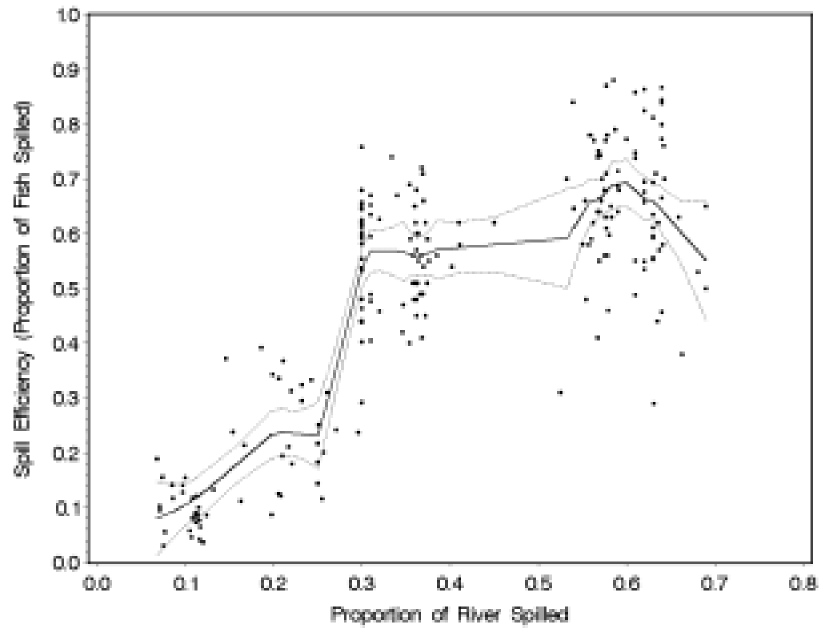

Figure 4.19. Spill Efficiency Plotted as a Function of the Proportion of the Columbia River Spilled at The Dalles. The solid line fitted to spill efficiency and river spill proportions was obtained by loess smoothing using a smoothing factor of 0.2. Dotted lines indicate 95% confidence limits on predicted values of spill efficiency.

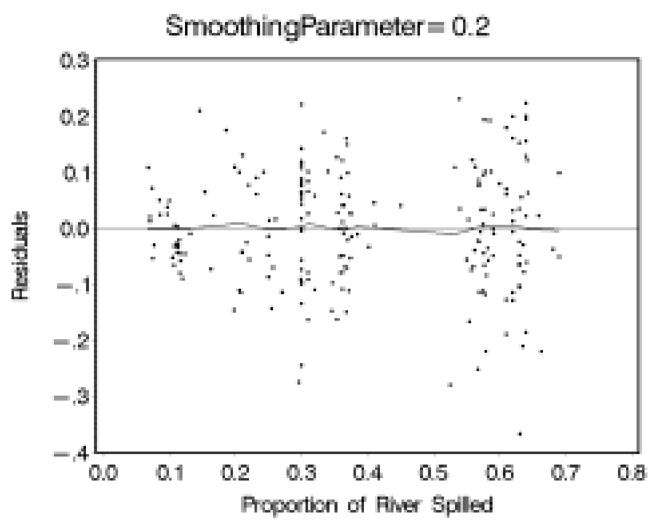

Figure 4.20. Plot of Residuals of the Loess Fit Line in Figure 4.19. The response residual also was smoothed by a factor of 0.2.

4.3 Comparison of Telemetry and Hydroacoustic Results

We limited our comparison of radio telemetry and hydroacoustic results to two spring seasons in 1999 and 2000 (Table 4.8) because those were the only years in which telemetry sample sizes were considered to be adequate to reliably estimate fish passage metrics (see Table 4.2). Radio telemetry estimates were simple averages for yearling chinook salmon and steelhead, species which run in similar numbers in spring (Figure 2.3).

Table 4.8. Comparison of Spring Estimates of FPE, Spill Passage Efficiency, Sluice Passage Efficiency, Spill Passage Effectiveness, and Sluice Passage Effectiveness by Radio-Telemetry and Hydroacoustic Methods

	FPE	Spill Efficiency	Sluice Efficiency	Spill Effec-tiveness	Sluice Effec-tiveness	Number of Fish	Mean % Spill	Project Discharge $ft^3 \times 10^3$	Spill Discharge Range $ft^3 \times 10^3$
1999									
Radio telemetry	82.1 (79-85)	58.6 (55-63)	23.5 (20-27)	2.0	16.8 (15-19)	633	30	286,383	85,915
Hydroacoustics	76.0 (73-79)	61.0 (58-64)	15.0 (12-17)	2.0	10.7 (7-12)	2,934,683	30	286,383	85,915
Difference	6.1	2.4	8.5	0.0	6.1		30		
Radio telemetry	93.3 (91-95)	83.1 (80-86)	10.2 (8-13)	1.3	7.3 (6-9)	609	64	286,383	183,285
Hydroacoustics	84.0 (81-88)	72.0 (70-74)	12.0 (7-15)	1.2	8.6 (7-10)	2,188,400	64	286,383	183,285
Difference	9.3	11.1	1.8	0.1	1.3		64	286,383	183,285
2000									
Radio telemetry	87.9 (86-90)	82.3 (80-84)	5.6 (5-7)	2.1	3.3 (3-4)	1,599	39.6	235,258	93,162
Hydroacoustics	92.0 (89-95)[a]	86.0 (83-89)[a]	6.0 (6-7)[a]	2.2	3.5 (3-4)	9,106,000	39.6	235,258	93,162
Difference (% diff)	4.1	3.7	0.4	0.1	0.2		39.6	235,258	93,162

(a) Range is the difference between day and night estimates instead of 95% confidence limits, which were <1%.
Note: The numbers in parentheses are 95% confidence intervals and for the radio telemetry CIs the values were calculated using the Fisher and Yates relationship between the F distribution and the binomial distribution.

In spring 1999 and 2000, differences in efficiency metrics estimated by radio telemetry and hydro-acoustics were <11% and support each other quite well, and effectiveness measures were close except for higher sluice passage effectiveness by radio telemetry during 30% spill treatments in 1999. Trends in fish passage metrics including sluice passage efficiency and effectiveness between spill treatments in the 1999 study were similar for both methods. Several studies have observed higher sluice passage efficiency and effectiveness during 30% spill treatments than during 64% spill treatments (BioSonics 1997; BioSonics 1999; Ploskey et al. 2001; Hansel et al. 2000).

5.0 Sluiceway Studies

This section reviews data collected specifically on sluiceway passage by juvenile salmon. These data include 1) sluiceway entrance gate operations, which were essentially established from sluiceway fyke net studies in the late 1970s and early 1980s, 2) trash rack occlusion plate studies in 1995 and 1996, and 3) baseline data without J-occlusions in 2000 on fish movements in the near field (<10 m) of a sluice entrance using a sonar tracker instrument. This review of the sluiceway work at The Dalles will provide background and context for the major J-occlusion test planned for 2001.

5.1 Entrance Gate Operations

Horizontal Location of Gate Openings – Nichols (1979) found the sluice gates at the west end of the powerhouse had the higher yearling salmon passage rates than gates in the middle. Nichols (1980) found that sluiceway passage with three gates open (1-1, 1-2, and 1-3) was not significantly different than passage with six gates open (1-1,…, 2-3). He also determined that there was less than a 10% increase in sluiceway flow between three and six gates because three gates can be opened more than six gates without flooding the sluiceway channel. Consequently, Nichols (1980) recommended west operations (Main Unit 1) for yearlings. For the most part, the sluiceway has been operated under this scenario ever since. One exception occurred during summer 1999 when additional Gates 2-1, 2-2, and 2-3 were opened because the forebay was lowered from El. 48.2 to ~47.6 m (158 to ~156 ft) for gas abatement at John Day Dam. Ploskey et al. (2001) reported that passage at sluice gates above Main Unit 2 was 2 to 3 times higher per entrance than that at Main Unit 1 sluice entrances.

Seasonal Changes in Gate Openings – Nichols (1980) hypothesized that subyearling fish, which tended to migrate relatively close to shorelines, might have higher passage rates at sluice entrances near the east (upstream) end of the powerhouse. In 1979, Nichols (1980) reported subyearling passage was significantly higher at Units 17 and 18 than Units 1 and 2. But, in 1980, Nichols and Ransom (1981) reported no significant difference. Current operation calls for no change between spring and summer.

Adjacent versus Split Gate Openings – Nichols and Ransom (1982) studied split (1-1, 1-2, 18-1, 18-2) versus adjacent (1-1, 1-2, 1-3) gate operations. They found no significant difference in total passage of subyearling or yearling salmon between split and adjacent gates. However, yearling salmon passage was significantly higher for the adjacent operation of three gates (1-1, 1-2, 1-3) than operation of two (1-1, 1-2) or four (1-1, 1-2, 1-3, 2-1) gates.

Diel Operation – Nichols (1980) recommended that the sluiceway be operated 24 h/d because noticeable numbers of smolts used the sluiceway at night, although highest passage was during daylight hours. Subsequent studies confirmed highest passage during daylight and the need for night operations also to maximize non-turbine fish passage (e.g., Nichols and Ransom 1981, Nichols and Ransom 1982; BioSonics 1997; Ploskey et al. 2001).

Entrance Flow – Maximum sluiceway flow is about 141.6 m^3/s (5,000 cfs) and is dependent on forebay elevation. Early studies examined the relationship between sluiceway passage and sluice flow. Nichols (1980, p. 16) said, "Our studies suggest that sluiceway passage for yearling salmonids is maximized with the largest surface flow possible through several gates open on the west end of the sluiceway (Units 1 and 2)." Nichols and Ransom (1981 and 1982) supported this finding. Recent data from the surface flow bypass investigation also back this statement (see review of surface bypass by Dauble et al. 1999).

5.2 Trash Rack Occlusions

In 1995, trash-rack occlusion plates (blockages on the upper three of six trash racks at Main Units 1-5) were tested as a way to increase sluiceway passage and decrease turbine passage. However, no significant differences in sluiceway efficiency were observed (Nagy and Shutters 1995). A sector-scanning split-beam transducer was used to collect data on fish movements relative to the occlusions (Johnson et al. 1995). This feasibility study was the first to couple water velocity measurements from a physical model with fish movement data in three dimensions at a Columbia River dam.

The effects of occlusion plates on sluice passage were evaluated again in 1996 (BioSonics 1997), but findings for spring and summer were quite different. In spring, sluice passage was significantly higher when trash racks were unblocked than when they were blocked. In summer when the upper three trash racks were blocked, fish passage through the sluiceway was higher than it was when the trash racks were not blocked. The researchers had difficulty estimating turbine passage behind the blockages. The 1996 occlusion plate evaluation also included sampling of fish movement data using a new tool called the sonar tracker. The tracking data showed strong downward trajectories of fish near the dam with the occlusion plates deployed. Overall, however, the results of 1995-1996 occlusion plate tests were inconclusive.

5.3 Baseline Data on Fish Movements Near the Sluiceway Entrance

In 2000, Johnson et al (2001 in review) conducted a baseline study to understand why the sluiceway is relatively effective. The objectives were to 1) track smolt movements in the near field (<10 m) of the Sluice 1-1; 2) estimate state[(a)] proportions; 3) estimate fate[(b)] probabilities; and 4) assess specific surface flow bypass premises about smolt movement in relation to The Dalles sluiceway.

The sonar tracker was used to sample smolt movements in the near field of Sluice 1-1. Once a smolt is detected with the digital split-beam hydroacoustic system, two high-speed stepper motors align the axis of the transducer on the target. As the target moves, deviation of the target from the beam axis is calculated and used to re-aim the transducer, thereby tracking the target. For each ping the target is tracked, three-dimensional fish position data are recorded. The sonar tracker provided high resolution (~5 cm), three-dimensional fish position data for the run-at-large. This system is particularly well suited for

(a) A *state* is a fish movement pattern in three dimensions (X, Y, Z). States are expressed as proportions, i.e., the proportion of fish moving in a particular direction(s).

(b) A *fate* is where smolts exit the sample volume. Fates are expressed as probabilities of passage into a particular area, e.g., the sluiceway.

acquiring data in the near field (<10 m). About 100,000 smolts were tracked and about 5,000,000 positions were located during the study from April 17 to July 7, 2000.

This baseline study of smolt movements in the near field (within 10 m) of Sluice 1-1 at The Dalles Dam in 2000 revealed the following new information:

1. Holding was not observed at the sluice entrances but was seen in front of the upper portion of turbine intake entrances (we only sampled the upper 6 m of the intake), and was especially prevalent at night off the west pier nose by the MU1-1 intake;

2. Smolts did not appear to actively avoid the sluice entrance.

3. When moving toward dam, smolts were more likely to also be moving up than down, but when moving away from the dam, they were more likely to move down than up.

4. A zone of entrainment was indicated by the state data, and appeared to be relatively small (2-3 m from the dam), but must be substantiated with water velocity data

5. The zone of influence of the sluice flow net may be at least 7 m from the dam in the surface layer (0-2 m) based on the fate data.

6. The probability of sluice passage was highest on the east side of the forebay immediately upstream of the Sluice 1-1 entrance (recall, there was an open sluice entrance to the east of Sluice 1-1, but not the west).

7. Attraction to the sluice flow net was indicated, although the mechanism is unknown.

The Dalles sluiceway is effective at bypassing smolts around turbines because, for the most part, the smolt population migrating through the powerhouse is surface-oriented and concentrated at the west end of the powerhouse (at least in spring). The fish concentrate upstream of the sluiceway, either after being attracted to the surface flow net or happening onto the flow net and concentrating there. They appear to be reluctant to sound when a shallow passage route provides an alternative to a deep route.

6.0 Fish Survival Studies

Recently published smolt survival estimates for The Dalles Dam provide some useful data for assessing the effects of project operations on juvenile salmonid survival. These survival estimates were obtained using two methods, balloon tags and passive integrated transponder (PIT) tags.

In 1995, Normandeau et al. (1996) conducted a balloon tag study to assess injury and direct mortality of juvenile salmonids passing through several modified spill bays and found high survival through every bay. The specific objectives of the study were to evaluate fish condition and survival of hatchery-reared chinook salmon in passage over an unmodified spill bay (Bay 3), a spill bay configured with a surface flow bypass vertical I-slot (Bay 4), and a spill bay with a surface flow bypass overflow weir (Bay 6). Additionally, a limited number of juvenile salmon were released through the ice-trash sluiceway to study fish condition and potential problems associated with this route of passage. The 48-h fish relative survival probability was 0.993 (90% CI 0.972-1.02) for Bay 4 (I-Slot); 0.990 (90% CI 0.951-1.0) for spill bay 6 (overflow weir); and 0.955 (90% CI 0.927-0.982) for Bay 3 (unmodified). Of the 100 fish released through the ice-trash sluiceway, 97 were recaptured alive, of which 95 remained alive after 48 hours. One fish was recaptured dead and 2 fish were not recaptured. Because of the limited number of tests and broad confidence limits, no significant differences could be identified.

Nevertheless, the relatively high mortality (~5%) of fish passing through unmodified Bay 3 raised concern that mortality through The Dalles spillway may potentially be higher than the typical spillway passage mortality of about 2% that many regional biologists believe occurs at most dams. In response to this concern, the NMFS conducted annual PIT tag survival studies at The Dalles Dam during 1997-2000 to determine the impact that spill has on the survival of juvenile salmonids that pass the project. A summary of the NMFS survival studies conducted from 1997 to 2000 is presented in Table 6.1. Also, during 1998 and 2000, PIT-tagged fish were released in The Dalles sluiceway to estimate relative survival due to both direct and indirect effects on juveniles passing through that route.

In 1997, Dawley et al. (1998) used PIT tags to estimate relative survival of yearling coho salmon and sub-yearling chinook salmon smolts passing through The Dalles Dam spillway when 64% of the river flow was spilled. Approximately 43,000 yearling coho salmon and 53,000 sub-yearling chinook salmon were collected at the Bonneville Dam Second Powerhouse and tagged with PIT tags. Half were released upstream from the spillway at The Dalles and half at a reference/control site immediately downstream from the Highway 197 Bridge, away from high turbulence and predator habitat. Test fish were introduced into the spillway through a release canister suspended in front of assorted spill bays. An average of 12% of the coho salmon and 14% of the sub-yearlings were detected at Bonneville Dam. Relative survival rates for fish passing the spillway were 87.1% (95% CI: 80.4-93.9%) for coho salmon and 92.1% (95% CI: 85,5-98.7%) for sub-yearling chinook salmon. Survival appeared higher for fish that passed the spillway at night (juvenile pattern) compared with those that passed during the day. However, sample sizes were too small to discern statistically significant difference between day and night rates of survival.

Table 6.1. River Flow and Point Estimates with 95% (confidence intervals) for Relative Passage Survival of Juvenile Salmon at The Dalles Dam, 1997-2000 (Preliminary for 2000). Data are from NMFS reports and presentations.

	Median Project Discharge ($\times 10^3$ ft^3/sec)	Range in Project Discharge ($\times 10^3$ ft^3/sec)	64% spill Spillway Survival % (CI)	30% Spillway Survival % (CI)	Sluiceway Survival % (CI)
Spring					
1997	455	379-557	87 (80-94)	---	---
1998	347	196-445	89 (82-95)	97 (88-107)	96 (87-105)[a]
1999	273	239-376	93 (90-97)	96 (92-101)	
2000[b]				95 (92-99)	95 (92-98)
Summer					
1997	301	213-503	92 (86-99)	---	---
1998	212	167-279	75 (68-83)	89 (80-99)	89 (81-98)
1999	300	221-369	96 (92-100)	100 (95-104)	
2000[b]				92 (83-101)	96 (88-104)

(a) Sluiceway survival at 30% spill.
(b) Spill in 2000 was a constant 40% with a juvenile spill pattern (north).

In 1998, Dawley et al. (2000) conducted a PIT tag survival study at The Dalles using the same approach as in 1997. The study objectives were to determine relative passage survival of smolts passing through the spillway at high (64%) and moderate (30%) spill levels, and through the ice-trash sluiceway during daytime periods when spill was near 30%. Approximately 64,000 yearling coho salmon and 80,000 sub-yearling chinook salmon were collected at the Bonneville Dam Second Powerhouse, tagged with PIT tags, and then transported to The Dalles. About equal portions (20%) were released through the spillway at 64% spill, the spillway at 30% spill, and the sluiceway at 30% spill; about 40% were released at the Highway 197 bridge reference site. An average of 12% of the coho salmon and 4.8% of the sub-yearlings were detected at Bonneville Dam. At 64% spill, the relative survival rates for fish passing the spillway were 89% (95% CI: 82-96%) for coho salmon and 75% (95% CI: 68-83%) for sub-yearling chinook salmon. At 30% spill, coho salmon survived at 97% (CI 88-107%) and sub-yearlings at 89% (CI 80-99%). Relative survival for sluiceway passage was 96% (CI 87-105%) for coho salmon and 89% (CI 81-98%) for sub-yearlings.

In 1999, Dawley et al. (2000) repeated the PIT tag survival study at The Dalles to estimate relative survival for juvenile salmon passing through the spillway at high spill (64%) and moderate spill (30%). The ice-trash sluiceway was not tested in 1999 to increase the number of test fish available for the spill evaluation, with the intention of increasing overall precision. Approximately 139,000 yearling chinook salmon and coho salmon (spring migrants) and 167,000 sub-yearling chinook salmon were collected at John Day Dam and tagged with PIT tags. About 50% were released through the spillway at either 30% or 64% spill, and about 50% were released at a reference site used in previous years. An average of 16% of the spring yearlings and 12% of the sub-yearlings were detected at Bonneville Dam. Relative survival rates were 94% (95% CI: 90-97%) for spring migrants and 96% (95% CI: 92-100%) for sub-yearling chinook salmon at the 64% spill condition. At 30% spill, the estimated survival for spring migrants was 95% (CI 91%-98%) and 100% (CI 96%-104%) for sub-yearlings. Analyzing three years of data, they found that relative survival rates during the night were significantly higher than daytime survival rates for both yearling spring migrants (coho salmon and chinook salmon combined) and sub-yearling chinook salmon.

In 2000, Dawley and Absolon (2000 Preliminary) conducted the fourth year of PIT tag studies at The Dalles to estimate juvenile salmon relative passage survival through the spillway, the ice-trash sluiceway, and turbines. Under a new operation, spill was maintained at 40% and the juvenile spill pattern was used day and night. Approximately 89,920 yearling chinook salmon, 45,555 coho salmon (spring migrants) and 161,862 sub-yearling chinook salmon were tagged with PIT tags. About equal numbers were released at each of the above sites and the standard reference site. An average of 20% of the spring migrants and 3.5% of the sub-yearlings were detected at Bonneville Dam. In the spring, relative survival was 95% (95% CI: 92-99%) for fish passing the spillway, 95% (95% CI: 92-98%) for fish passing the sluiceway, and 81% (95% CI: 78-84%) for fish passing the turbines. During the summer, survival of sub-yearling chinook salmon was 92% (95% CI: 83-101%) at the spillway, 96% (95% CI: 88-104%) at the sluiceway, and 84% (95% CI: 76-92%) at the turbines. In contrast to previous years, no significant differences between night and day periods were observed.

In a separate study conducted in 2000, USGS investigators used radio telemetry techniques to estimate smolt survival at The Dalles Dam. They generated estimates of spillway, turbine, and sluiceway survival at that site. Their protocols and analytical models were consistent with those of similar investigations being conducted broadly throughout the basin. The estimates reported herein are preliminary and were extracted from a workshop presentation provided by Tim Counihan of UGGS at Cook, Washington. The suite of estimates comports closely with the NMFS estimates derived using PIT tag technology. They estimated that 92.9%, 97.6%, and 85.6% of the spring migrating smolts survived passage through the spillway, sluiceway, and turbines, respectively. Unlike the NMFS study, these tagged fish were exposed to a broader range of conditions since they were released well upstream from the dam over a protracted period spanning several weeks.

7.0 Data Limitations

7.1 Data Gaps and Uncertainties

Limitations, uncertainties, and inconsistencies in the radio telemetry, hydroacoustic, and survival data for fish passage at The Dalles Dam over the past 20 years are discussed below.

7.1.1 Radio Telemetry

In the earlier radio telemetry studies conducted by the USGS at The Dalles Dam (1995-1997), routes of passage were estimated using only aerial antennas and standard receivers to locate the areas where the radio-tagged fish were last contacted. This was generally acceptable practice for major passage routes such as the powerhouse or spillway. This method is not accurate enough, however, to distinguish more specific routes of passage such as through particular spill bays, turbine units, or the sluiceway. To obtain more accurate passage data from radio-tagged fish passing a specific route, arrays of underwater antennas connected to receivers and Digital Spectrum Processors (DSPs) are needed. The DSPs can simultaneously monitor all antennas and pulse-coded transmitters so the probability of missing a tagged fish that passes through the volume monitored by an antenna is almost eliminated. This technique was first used at The Dalles Dam in 1997 (Hensleigh et al. 1999) to monitor for radio-tagged juvenile salmonids passing through the sluiceway and was then used extensively at The Dalles Dam in 1999 and 2000 (Hansel et al. 2000; Beeman et al. 2000 preliminary).

The single greatest limitation for most radio telemetry studies is that the relatively low number of tagged fish released does not permit daily or perhaps even weekly estimates for most passage estimates. This becomes an important concern if numbers must be apportioned among operational treatments that change over time steps of days or weeks, as well as among assorted passage routes. For example, sample sizes of radio-tagged juveniles were only large enough to discern differences in forebay residence times during spill tests and diel periods in 1999 and 2000. Also, transmitters can only be implanted in the larger sized individuals within a population of smolts, which could introduce size biases. The range of tag detections at The Dalles has varied from a low of 59% in 1997 to a high of about 90%. High tag detection is necessary for accurate mark recapture survival models. With extensive antennae arrays like those used in 1999 and 2000, average tag detection is about 90%.

Another limitation associated with radio telemetry in general is the inability to clearly define the size of detection zones, particularly using aerial systems. A shallow tag can be detected at a far greater horizontal distance than one at depth. Furthermore aerial systems have a maximum detection depth of 25 to 30 feet, under water conductivity levels that prevail in the Columbia River. Underwater antennas have a much more localized and uniform, albeit compact, detection field, generally scribing a sphere with a radius ranging from about 20 to 30 feet, depending on conductivity. Submerged antennas also are much less affected by noise than aerial antennas.

Other potential limitations of radio telemetry methods are more difficulty in identifying, assessing, and including the effects of tagging, handling, tag presence, and release on the health, behavior, and distributions of tagged fish. Radio telemetry has an explicit assumption that tagged fish behave the same as untagged fish, and researchers go to considerable lengths to ensure that effects are minimized. For example, numerous studies have been done to examine the effects of surgically and gastrically implanted radio-tags on the growth, feeding behavior, and predator avoidance ability of juvenile salmonids (Adams et al. 1998a; Adams et al. 1998b; Martinelli et al. 1998). As long as tagging criteria were met (e.g., tag weight did not exceed 6% of the body weight of the fish in air) no significant tag effects were noted for up to 1 week. Nevertheless, it may be desirable to conduct studies to compare vertical distributions of radio-tagged fish to vertical distributions of run-of-river fish to determine whether significant differences exist that might differentially affect the fate of tagged and untagged fish. If untagged fish migrated deeper than tagged fish, then they may be more likely to pass through turbines than through a sluiceway or spillway.

7.1.2 Hydroacoustics

Many factors need to be considered when comparing or pooling results from different hydroacoustic studies. For example, ping rates, fish-detection thresholds, and fish-tracking criteria affect the relative detectability of fish by hydroacoustics and make it risky to pool results from studies that use greatly different settings. For example, the -50 dB threshold used by Steig and Johnson (1986) was 5 to 6 dB higher than that used in most other studies (Appendix A) and 8 to 10 dB higher than some (Ward et al. 1987 in summer; and Stansell et al. 1990). However, thresholds were consistent in studies conducted from 1996 through 2000. Low pulse repetition rates also reduce detectability, particularly for high velocity areas; rates were higher in later studies (BioSonics 1998; Ploskey et al. 2001, and Moursund et al. 2000) than in earlier studies (Appendix A). Between 1996 and 1998, BioSonics doubled the ping rate for the sluiceway and spillway transducers to 20 pings/second although they left the rate at 10 pings per second for in-turbine transducers.

Conservative criteria for the number of echoes per fish trace are generally better for ensuring that traces are not formed by the chance alignment of echoes from non-fish targets such as noise from entrained air induced by waves, turbulence, or vortices. We believe that the two-echo minimum criteria used in some studies were too liberal and ensure counting noise as fish. Requiring four or more echoes per trace and modeling and correcting for the effect of trace selection criteria on detectability is most appropriate. Studies conducted after 1995 all required at least four co-linear echoes per trace, and the 1999 and 2000 studies used modeled estimates of effective beam angles to adjust spatial expansions for differential detectability with range and among transducers.

Of the studies that sampled all passage routes, there were significant differences in turbine sampling deployments between studies conducted before and after 1990 and in study treatments and project discharge among studies conducted after 1995. In the 1985 and 1986 studies, 15-degree transducers sampling fish passage at turbines were deployed deep on piers upstream of trash racks and aimed about 25 degrees upstream of the plane of the trash racks. These hydroacoustic beams would have reached the surface of the water 102 ft from the transducer, and the center of the beam would have been about 45 ft from the face of the dam. Most smolts migrate in the upper 30 ft of the water column. Even at a depth of

30 ft, the hydroacoustic beams would still have been about 32 ft from the face of the dam, where it is unlikely that most detected fish moving toward the dam would be entrained in turbines. Later hydroacoustic studies recognized the benefits of deploying transducers inside turbines where the fate of detected fish was more certain.

All deployments in 1996 and 1998 were identical, as were deployments used in 1999 and 2000, but spillway deployments in the two earlier studies were different from deployments in the last two studies. Before 1999, most studies deployed down-looking transducers on long pipes extending from the parapet wall on the upstream side of the spillway down to about elevation 156 ft msl. From this position, hydroacoustic beams were located about 40 ft upstream of the tainter gate. By deploying from the upstream wall and aiming straight down or even 5 degrees upstream (e.g., Ward et al. 1987), researchers were able to use slower pulse repetition rates because fish were not moving too fast (10 pings per second or less was common).

Unfortunately, smolts detected in the upper water column were not always certain to pass and under low spill operations may have been counted multiple times (BioSonics 1999). In 1998, this problem was recognized and addressed but could not be eliminated by using more stringent fish-tracking criteria. The problem was more severe under low-spill than under high-spill treatments and more during the day than at night because fish hold more during the day and are not necessarily entrained at 30% spill levels. Therefore, spillway passage estimates in 1996 and 1998 probably were reasonable at >30% spill or at night during either spill treatment. In the 1999 and 2000 studies, transducers sampling the spillway were deployed about 12 ft downstream of the parapet wall under deck plates. The transducers also were aimed 8 degrees downstream to ensure that detected fish were entrained, and transducers were sampled at 24 to 25 pings per second to achieve adequate detectability in that high flow area.

Another difference in deployments was that the two latest studies deployed one split-beam transducer with the same placement and aiming angle as all single beam transducers at each major passage route to determine direction of travel and target strengths of passing fish. In 1999, about 20% of smolts near sluice entrances were excluded from the count because their direction of travel was not toward the sluice entrance. In 2000, 76% of fish near the sluice were excluded from counts because they were swimming away from the opening. Therefore, 20% to 76% of the decrease in sluice efficiencies from the 1996-1998 studies to the 1999-2000 studies resulted from increased scrutiny of the direction of fish movement. In 2000, researchers also excluded fish swimming upstream at the spillway (18%) and turbines (0%), which differed from the 1999 study where swimming direction was only considered at the sluiceway entrance.

Main Units 1-5 were subjected to blocked and unblocked trash-rack treatments during randomly selected 2-day periods in both spring and summer of 1996, whereas those units were unblocked throughout the 1998, 1999, and 2000 studies. Thirty percent and 60% spill treatments were applied on alternating days in 1998 and on randomly selected 3-day blocks in 1999 to determine the effect of spill level and associated turbine operations on fish-passage metrics. Project discharge was significantly higher in 1996 than in 1998-2000 and it was lowest in 2000. Based upon the 1996 results, the effect of blocking trash racks was minimal and probably did not significantly alter project FPE estimates. In contrast, the 30% and 60% spill treatments and associated turbine operations had a significant effect on most fish passage metrics (BioSonics 1998; Ploskey et al. 2001), although it is not clear whether the cause was increasing spill to 64% of project discharge or shut down of one half of the project turbines required to achieve the higher spill level (Ploskey et al. 2001). Results of most hydroacoustic studies indicate that project discharge and operations affect fish-passage metrics.

Another factor that can create sizable differences in results of hydroacoustic studies is nearly impossible to assess from study reports alone and that is how technicians processed echograms to extract fish traces. Three years of data from processing echograms from The Dalles and Bonneville dams indicate that different trained technicians can produce markedly different counts from the same hydroacoustic data sets (Figures 7.1 and 7.2). Greater individual differences are associated with higher levels of structure and acoustic noise. Even extensive training, including tracking large data sets as individuals and then tracking the same data sets again as a group, did not reduce differences to acceptable levels. Trackers with multiple years of experience and using the same explicit criteria had large differences in fish counts from the same noisy data sets.

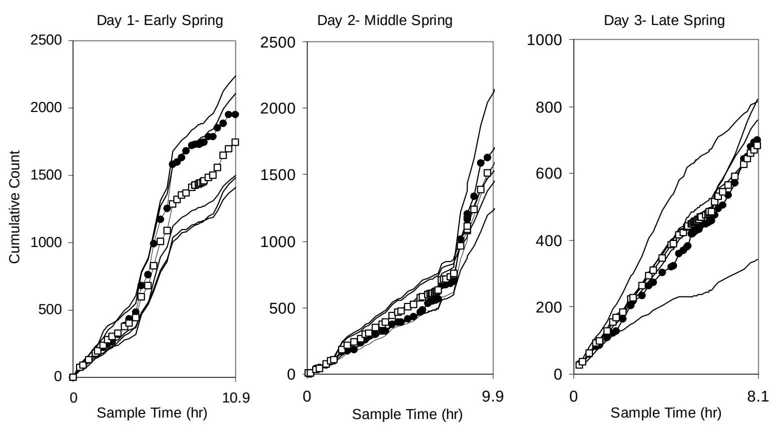

Figure 7.1. Cumulative Counts by Human Trackers (lines are individuals; open squares are the mean) and by an Autotracker (line with black dots)

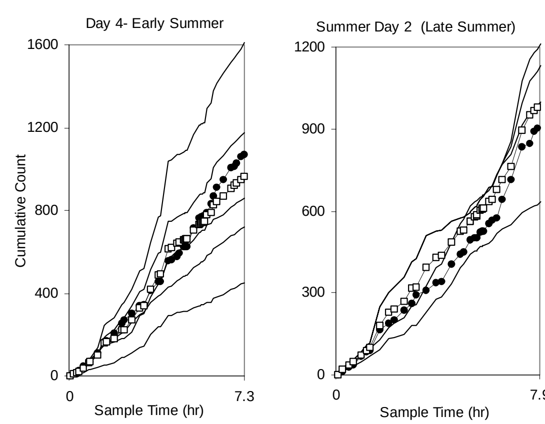

Figure 7.2. Cumulative Counts by Human Trackers (lines are individuals; open squares are the mean) and the Autotracker (line with black dots)

The problem is too pervasive to be resolved by spot-checking a small sample of the data. The inter-tracker bias can be especially serious if different individuals are assigned different hydroacoustic systems or passage routes since human differences accumulate over time to bias results and conclusions. Automated tracking, carefully and frequently calibrated to the average of several trained human trackers, can provide cost-effective processing free of inter-tracker bias among technicians. If automated tracking is not possible then within-hour or hourly data from all passage routes must be distributed among technicians so that individual differences are averaged over the smallest possible time step.

7.1.3 Survival

Smolt survival through The Dalles spillway appears to be quite variable during the years 1997-2000, with point estimates ranging from 87% to 96% during the spring and 75% to 100% in the summer evaluations. It is interesting to note that only one of the estimates equaled or exceeded the commonly held survival standard of 98% (Peters et al. 1999) as adopted for spillways at Columbia Basin dams. More importantly, many of the estimates fall well short of that standard. In years when both high and low spill treatments were tested (1998 and 1999), the trend is for survival to be lower at the high spill proportions. This is apparent in both spring and summer evaluations. In the two remaining years (1997 and 2000), only one spill level was tested each year, precluding the ability to distinguish between year or spill-level effects.

Thus far analysts have assumed that percent of spill is the primary independent variable influencing survival through that route. This may not be entirely true. Hydraulic conditions in the tailrace from the stilling basin to points well downstream drive the mechanisms that affect survival. These conditions dictate the impact with which smolts contact the receiving water, the speed of egress from the tailrace, the path smolts traverse though the tailrace, and the physical displacement of predatory fish. Hydraulic conditions are sensitive to tailrace elevation, and volume spilled, as well as percent spilled. These additional variables should be considered or incorporated into any future analyses.

Sluiceways are often considered alternative fish bypass systems and smolts are presumed to survive at a rate similar to designed bypass systems. That survival rate is typically assumed to be near 98% (Peters et al. 1999). However, based on two years of evaluation, sluiceway survival appears to be consistently less than that standard, with point estimates ranging from 89% to 96% survival.

Only 81% of the spring migrants and 84% of the summer migrants released into turbine units survived in a PIT study conducted in 2000. That same year USGS researchers reported that approximately 86% of radio-tagged spring chinook salmon survived passage through the powerhouse. These estimates are well below the 90% standard commonly presumed to apply at dams in the Federal Columbia River Power System (FCRPS; Peters et al. 1999). However, a single year's estimate is insufficient for characterizing survival processes at this or any site. It is advisable to acquire additional turbine survival estimates.

The suite of survival estimates obtained thus far at The Dalles indicates that passage survival at this site is probably the lowest in the FCRPS.

7.2 Consistencies and Differences Between Methods

In spring 1999, under each of two spill treatments and in spring 2000 under constant spill, most fish passage efficiency estimates by radio telemetry and fixed-aspect hydroacoustics were within 11% of each other, and effectiveness measures were close except for higher sluice passage effectiveness by radio telemetry during 30% spill treatments in 1999. This latter difference is of concern because it is large enough to suggest some systematic bias in one or both methods. The hydroacoustic methods that produced fish passage metrics that were within 1.8% of radio telemetry estimates in spring 1999 under 64% spill and in spring 2000 under constant spill were identical to those used to make the estimate for 30% spill in spring 1999. We know that the effectiveness of fish counting at the sluiceway is highly dependent upon the amount of turbulence and entrained air in the forebay. If 30% spill treatments happened to be noisier than 64% spill treatments at the sluiceway entrance then that could account for low hydroacoustic estimates relative to radio telemetry estimates. However, when we examined a noise index for the sluiceway deployments, we found no significant difference in the noise level during 30% and 64% spill treatments.

Another factor that can reduce hydroacoustic counts of fish relative to radio telemetry counts is the lateral distribution of fish passing through the sluiceway. If fish happened to pass more frequently near piers rather than through the center of the sluice opening then hydroacoustic estimates would be low relative to radio telemetry estimates that were not subject to a distributional bias. For example, sluiceway sampling at Bonneville Dam with four video cameras revealed that twice as many fish passed through the lateral two-thirds of a sluiceway entrance as passed through the center one-third of the same entrance (Ploskey et al. 1998). This lateral skew in the distribution of fish passage into a sluiceway would result in passage estimates that were 50% low relative to radio telemetry estimates. However, this type of bias would not explain why hydroacoustic and radio-telemetry estimates were so close in 2000 when spill was about 40% all season.

Another possibility is that the radio telemetry estimates of sluiceway passage were biased high because tagged fish tend to migrate higher in the water column than untagged fish and were distributed closer to the sluiceway during 30% spill than during 64% spill. Juvenile salmon are known to gulp air to adjust their buoyancy after radio tags are inserted (Noah Adams, USGS, Personal Communication). Over compensation could lead to an upward skew in the vertical distribution of fish that might make tagged fish more likely to pass into a sluiceway than untagged fish.

We believe that the use of both radio telemetry and hydroacoustics to determine project-wide fish passage performance is much more desirable than using either method alone. Having independent estimates is the best way to ensure the reliability of conclusions and to identify potential biases in either method. In addition, the two methods are more complementary than redundant (see Tables 7.1 and 7.2). Over the years, calculation errors have been caught after differences were identified in estimates by the two methods. For example, the 1998 hydroacoustic estimates of fish passage efficiency through 20-ft-wide PSC slots at Bonneville Powerhouse 1 were significantly lower than estimates from radio telemetry and those differences led the hydroacoustic researchers to double check all spatial and temporal expansions. An error in the hydroacoustic estimate for the 20-ft slot resulted from using the same spatial expansion factor for both 20- and 5-ft slots. In 2000, preliminary radio telemetry estimates of PSC fish

Table 7.1. Sampling Attributes for Fixed-Aspect Hydroacoustics and Radio Telemetry Studies

Sampling Attribute	Hydroacoustics	Telemetry
Species specific	No	Yes (whatever is tagged)
Travel and residence time	No	Yes
Detectability	High within but low among sample volumes	High
Route-specific passage	Proportions and passage rate estimates	Proportions only
Route-specific survival	No	Yes
Number of observations	>300,000	<3,000
Inference	All fish	Tagged fish
Spatial resolution	High within but low among sample volumes	Low
Track length	<2 m	100s of m
Vertical distribution data	Yes	Some
Run timing	Yes (data are continuous)	No
Diel timing	Yes (data are continuous)	Depends on release/arrival times
Behavior	Fine scale (within sampled volumes)	Broad scale
Invasive	No	Yes (whatever is tagged)

Table 7.2. Strengths and Weaknesses of Hydroacoustic and Radio Telemetry Methods

Hydroacoustic Strengths	**Radio Telemetry Strengths**
1. Samples detect hundreds of thousands of run-of-river fish	1. Certainty of fish identity
2. Permits estimates of proportions of fish passing different routes.	2. Permits estimates of proportions passing different routes.
3. Permits expansion to numerical passage estimates for structures and projects	3. Provides travel times
4. Relatively high spatial resolution within sample volumes. Many different centimeter-scale ranges (single-beam) or 3-D positions (split-beam or multi-beam) per second	4. Each antenna interrogates a relatively large water volume
5. Noninvasive	5. Tag identity is unambiguous
6. Time (seasonal and diurnal) and route of passage unaffected by release time and place.	6. Can provide route specific survival estimates
Hydroacoustic Weaknesses	**Radio Telemetry Weaknesses**
1. Inherent ambiguity of fish identity	1. Data are collected on relatively fewer (hundreds to several thousand) fish of a relatively large size class.
2. No travel time or survivorship data	2. Relatively low spatial resolution (meter or larger-scale position every few seconds).
3. Each transducer interrogates a relatively small water volume (except for multi-beam).	3. Invasive
4. Requires assumptions about detectability and detectability modeling to adjust spatial expansions	4. Tagging, tag presences, transport, and release may affect behavior such as vertical distribution that could influence estimates of fish passage metrics.
5. Acoustic noise, especially echoes from entrained air, can obscure fish and affect detectability.	5. Passage time (seasonal and diurnal) and route may be affected by release time and place.
6. Detection depends on trace identification and selection by a person or program.	6. Does not permit expansion to numerical passage estimates for structures and projects.

passage efficiency were about 50% until differences between hydroacoustic estimates and radio telemetry estimates were compared and questioned. Correction of an error in radio-telemetry calculations resulted in revised estimates that were within 10% of hydroacoustic and sonic-tracking estimates of fish passage efficiency. Estimates by both methods are very complicated to make and need careful scrutiny to ensure accuracy.

8.0 Conclusions and Recommendations

8.1 Conclusions

The following subsections summarize findings from our synthesis of reports on radio telemetry and hydroacoustic studies of fish behavior in The Dalles Dam forebay, fish passage, and fish survival.

8.1.1 Fish Behavior

Radio Telemetry

Forebay Approach – Migration routes of radio-tagged juvenile salmonids from release sites up river (as determined by boat mobile tracking) indicate that the majority of spring migrants (yearling chinook salmon and steelhead) move downriver in the main channel. At about 1 km above the dam, most of the fish approach the forebay heading toward the powerhouse. Summer migrants (sub-yearling chinook salmon) move downriver closer to the shorelines than yearling fish, often along both north and south shores, but also usually first approached the forebay at the powerhouse.

The configuration of the project appears to have an important effect on where juvenile salmonids first enter the near-dam area. Most fish entering the near-dam forebay are first exposed to the powerhouse flow net, because the powerhouse is upriver of the spillway and parallel to the main channel. The data from the 1995 to 1997 studies support that pattern with the majority of juvenile salmonids first entering at the powerhouse areas. In 1999, however, this pattern shifted somewhat when spill discharge was alternated between 30% and 64%. Higher proportions of both steelhead and yearling chinook salmon first entered at the north part of the forebay moving toward the spillway when spill was increased from 30% to 64%. Only in the 1999 study was a test with two different spill treatments conducted with a high enough sample size of fish passing during each of the test conditions to give detailed results. These tests showed that project operations might have some influence on the forebay approach pattern of juvenile salmonids. In 2000, with a constant 40% spill discharge and a juvenile (north) spill pattern, the majority of tagged juveniles entered the near dam forebay again at the powerhouse with a shift to more fish entering the spillway area at night than during the day.

Residence Times – Lower spill (30%) appears to significantly increase forebay residence times for steelhead yearlings. The time of arrival (day or night) and spill discharge level had a pronounced effect on the mean forebay residence time of steelhead yearlings. Steelhead arriving at night passed the project quickly regardless of spill discharge, but steelhead arriving during the day at spill levels less than 64% passed more slowly. The longer median residence times for steelhead during 30% day spill also appeared to be related to fish size. Steelhead shorter than 200 mm (fork length) had significantly shorter residence times (0.7h versus 3.9; $P<0.001$). Fish less than 200 mm long are more likely to be wild fish than hatchery fish.

Horizontal Distribution – Horizontal distribution in the forebay is not considered a meaningful measure because tagged fish have very short residence times at The Dalles Dam.

Tailrace Egress – The south spill fish at the 64% spill condition had significantly longer tailrace migration times in 1999. In 2000, south spill fish and especially sluiceway release fish, had significantly longer tailrace migration times than north spill or control fish. Predation events were few, but fish passing through the southern part of the spillway appear to be most vulnerable to predators, especially in summer.

Predation – Studies confirm concerns about heavy predation by the northern pikeminnow. The majority of predation events also were recorded for south spill fish, especially during the 64% adult pattern.

8.1.2 Fish Passage

Passage Metrics – Based on studies conducted from 1995 through 1999, when spill percentage was similar (ranging from ~50% to 64%), both spill passage efficiency and spill passage effectiveness varied little among years, seasons, or species. Spill effectiveness in 2000 was greater than expected from the 1999 results because when spill percentage increases, spill passage effectiveness decreases. Steelhead spill passage effectiveness in 2000 was the same as in 1999 and for yearling chinook salmon it actually increased. We concluded from these data that 40% spill (with a juvenile pattern) was more effective than 30% or 64% spill.

Diel Effects – Diel changes in passage conditions (day versus night and adult versus juvenile pattern) in 1999 did not seem to have major effects on spill passage efficiency, FPE, or sluice passage efficiency, in contrast to effects on fish passage estimates by route and spill effectiveness. Project fish passage efficiency usually was slightly higher during the day than at night (7% to 13% higher in 1999 and 5% to 6% higher in 2000), although fish passage through the three major routes usually had significant diel patterns. In 2000 the most notable diel pattern was that spill passage effectiveness of yearling chinook salmon was much greater during the day (2.2:1) than at night (1.8:1) and this was during a constant spill of 40% with the juvenile pattern only.

Effect of Dam Operations on Sluiceway Efficiency – The most commonly observed effect of dam operations is that increased spill reduced sluiceway passage efficiency and effectiveness.

Comparison of Telemetry and Hydroacoustic Results – We limited our comparison of radio telemetry and hydroacoustic results to two spring seasons in 1999 and 2000 because those were the only years in which telemetry sample sizes were considered to be adequate to reliably estimate fish passage metrics. Radio telemetry estimates were reduced to simple averages for yearling chinook salmon and steelhead, species which run in similar numbers in spring. In spring 1999 and 2000, differences in efficiency metrics estimated by radio telemetry and hydroacoustics were <11% and support each other quite well. Effectiveness measures were close except for higher sluice passage effectiveness by radio telemetry during 30% spill treatments in 1999. Trends in fish passage metrics including sluice passage efficiency and effectiveness between spill treatments in the 1999 study were similar for both methods.

Several studies have observed higher sluice passage efficiency and effectiveness during 30% spill treatments than during 64% spill treatments (BioSonics 1997; BioSonics 1999; Ploskey et al. 2001; Hansel et al. 2000).

Sluiceway Studies – Sluiceway studies at the Dalles Dam have included sluiceway entrance gate operations, which were essentially established from sluiceway fyke net studies in the late 1970s and early 1980s, 2) trash rack occlusion plate studies in 1995 and 1996, and 3) baseline data without J-occlusions in 2000 on fish movements in the near field (<10 m) of a sluice entrance using a sonar tracker instrument. The Dalles sluiceway is effective at bypassing smolts around turbines because, for the most part, the smolt population migrating through the powerhouse is surface-oriented and concentrated at the west end of the powerhouse (at least in spring). The fish concentrate upstream of the sluiceway, either after being attracted to the surface flow net or happening onto the flow net and concentrating there. They appear to be reluctant to sound when a shallow passage route provides an alternative to a deep route.

8.2 Recommendations

The region should consider testing passage improvements at The Dalles Dam, possibly including spill bay overflow weirs, spill pattern testing, J-occlusions at the powerhouse, sluiceway modifications to increase sluice discharge, and testing alternative locations of the sluiceway entrances and the sluiceway outfall. Concurrent hydroacoustic and telemetry research using standardized techniques should be the core of monitoring efforts for evaluating these passage improvements.

8.2.1 Data Collection and Management

We recommend that both radio telemetry and hydroacoustic methods be used to determine routes of passage for the reasons described above in Section 7.2, Consistencies and Differences between Methods.

8.2.1.1 Hydroacoustics

We recommend that the methods used in 1999 and 2000 become the minimum standard for future hydroacoustic FPE studies at The Dalles Dam unless better ways of sampling are identified in the future. Hydroacoustic sampling equipment and methods have improved over the last 20 years and transducer deployments have evolved over time so that data collected in later years is not directly comparable to data collected in early years. It is imperative that future studies acquire and process data consistently so that future syntheses of reports and analysis of metadata include more years than were available in this report. The standardization of data processing software that was funded by the District in 2001 is an important step in providing for data comparability in future years. Other recommendations for improving sampling and data processing for various passage routes at The Dalles Dam are presented in Table 8.1.

Table 8.1. Recommended Procedures for Future Hydroacoustic Sampling at The Dalles Dam

Recommendation	Turbines	Sluiceway	Spillway
Coverage	Randomly sample at least 1 of 3 intakes at every turbine	Sample every sluiceway entrance	Sample at least 50% of operational spill bays and preferably every spill bay to avoid interpolation
Deployment	In turbine from aimed upward 25 degrees off of the trash-rack plane from the bottom of the 5th trash rack for intakes without occlusions. Aimed downward 20 degrees off the trash rack plane from the middle of the first trash rack when the turbine is occluded.	Up-looking beam as near the entrance as possible using a consistent fish passage model with regard to fish swimming direction and range of interest (see below). Mounted on top of 4th trash rack from top for non-occluded intakes and on the occlusion near the bottom of the 3rd trash rack for occluded intakes	Under deck plates with transducers aimed 8 degrees downstream of vertical so that detected fish >2.3 m from transducers are entrained when counted.
Split beams	Deploy at least 1 like all single beams to obtain back scattering cross section data for detectability modeling	Deploy at least one split-beam at every entrance but experiment with more aggressive sampling	Deploy at least 1 split beam like all other single beams to obtain back scattering cross section data for detectability modeling
Pulse repetition rate	≥14 pings/second	≥14 pings/second or more	≥24 pings/second
Trace acceptance criteria Trace characteristics Noise around trace Acceptable sample Range and time	 ≥4 echoes with a maximum 4 ping gap and ≤30 pings long Light 70% of range and time trackable	 ≥4 echoes with a maximum 10 ping gap and ≤60 pings long Moderate 70% of range and time trackable	 ≥4 echoes with a maximum 4 ping gap and ≤60 pings long Light >50% of range and time trackable
Direction of movement	None	Azimuth direction through up-looking beam = 205-235 degrees where 270 degrees is directly into the opening; Count all such fish from maximum range down to the weir elevation (2 m range) and those from maximum range to 3 m below weir when fish as moving upward	Downstream toward spill gate and downward from 2.3 to 7 m range; flat or downward from 7-10 m range. Azimuth direction could be very wide (e.g., >180 degrees and <360 degrees where 270 degrees would be directly downstream toward the gate.
Transducers	Nominal 6-8 degrees	Nominal 6-8 degrees	Nominal ≥10 degrees
Detectability modeling	Model detectability (including any trace acceptance criteria), present all inputs and outputs, and describe in detail how results were used to adjust spatial expansions		
Noise modeling	Use a noise model to describe the fraction of time that could be tracked and use that information to discard poor samples with <50% trackable time and to expand fish counts based upon the fraction of time that was tracked.		
Receiver gains	Present table showing equalized receiver gains and other important calibration data and describe any significant changes in receiver gains between the preseason and postseason calibrations.		
Data compendium	In addition to figures and tables presented for interpreting results, an appendix should be included that provides hourly estimates of expanded fish counts and variances by sample location and includes all interpolations and hourly flow estimates by turbine, sluice entrance, and spill bay. This appendix would assure that future assessments of metadata for The Dalles Dam have all fish passage and operations data to recalculate any metric. These data also should be provided on a compact disk or other media suitable for archival.		

Computational fluid dynamics models that can link dam operations to forebay flow conditions and acoustic telemetry methods that can accurately track fish in three dimensions promise to further refine our understanding of operational effects. The use of these tools should be applied whenever possible.

8.2.1.2 Radio Telemetry

We have the following recommendations regarding future radio telemetry studies at The Dalles Dam.

- Make sure that sample sizes of tagged fish are large enough to detect statistically significant differences among key passage or behavioral metrics for whatever treatments are tested.
- Improve detection arrays of underwater antennas so the probability of detecting tagged fish is very high. The goal should be to consistently achieve >97% detection of tags.
- Work toward standardizing techniques sufficiently so year-to-year comparisons may be made.
- Make certain study designs are coordinated with other concurrent research studies so resulting data can be crosschecked and integrated.

8.2.1.3 Survival

We recommend that three issues regarding passage survival at The Dalles be addressed in the future.

1. Incorporate additional independent variables in analyses directed at describing factors affecting smolt survival though the spillway. Important variables to consider in addition to percent spill include, volume spilled, tailwater elevation, and perhaps water temperature, if it varies among treatments.
2. Acquire additional survival estimates through turbines at The Dalles to properly characterize survival though that route.
3. Use available and any new survival estimates to update passage models and associated system survival analyses, such as those that appeared in the NMFS Biological Opinion.

8.2.2 Project Operations

Aside from testing specific spill levels and associated project operations, the best way to evaluate the affect of project operations on fish passage metrics is by analysis of multiple years of data in a metadata analysis. For that reason, it is imperative that every report includes hourly flow information. Project operations data can be readily incorporated in every report on The Dalles Dam if hourly flow estimates through every turbine, spill bay, and sluiceway entrance were included in an appendix and in electronic form on a compact disk. The hourly flow estimates could easily be included in an appendix of reports along with hourly fish passage data after interpolation to un-sampled units and spill bays.

While several studies suggested that the focus of surface bypass at The Dalles sluiceway should be on the downstream end of the powerhouse, hourly passage data suggest otherwise. The horizontal distribution of fish passage for a season can be misleading with regard to conclusions about where fish pass and where fish protection measures are most needed. For example, during 64% spill in 1999, most of the higher numbered turbines at The Dalles Dam were shut down and horizontal distributions were definitely skewed toward lower numbered units. However, when the hourly rate of fish passage was examined, trends in 1999 and summer 2000 indicated that the highest hourly rates of passage were actually through higher numbered turbines. We recommend that both short-term and long-term rates of fish passage be examined to evaluate the effects of operations. If higher number turbines on the upstream end of The Dalles Dam usually are going to be off then conclusions based upon seasonal distributions would be reasonable. However, if a future priority were to favor the use of higher numbered units and those units also passed the most fish per hour, then concluding that the west end of the powerhouse was most critical could be disastrous. Radio telemetry data from 1995 through 1997 usually showed that most fish were first detected at the east end of the powerhouse.

Excessive forebay delay only appears to be a problem for steelhead yearlings when spill discharge is less than 64%. This appears to be because fish are surface oriented during the day and deeper at night. When they arrive at the dam during the day and spill is less than 64%, they resist passing the project during the day. This likely explains why daytime hydroacoustic counts during 30% spill treatments were so high and questionable in 1996 and 1998 when transducers were deployed off the upstream side of the spillway. During the day at 30%-40% spill levels, yearling steelhead are near the surface and may not detect flow-net cues that could lead them to deeper passage routes under a tainter gate. Increasing spill discharge during the day (>40%) may reduce this passage delay for steelhead or overflow weirs could be installed at several spill bays to provide a surface outlet for yearling steelhead.

Radio telemetry and survival data clearly indicate that a juvenile (north) spill pattern with 30-40% spill reduced tailrace egress times and increased survival of juvenile salmonids passing through the spillway. Radio-tagged juvenile salmonids passing through the north spillway had much shorter tailrace residence times and fewer predation occurrences than tagged fish passing through the south spillway. During 64% spill, predation events increased relative to what was observed during 30% spill.

We recommend that the District set spill discharge at 40% and use juvenile spill pattern 24 hours per day to maximize spill passage efficiency, even though spill passage effectiveness is similar at 30% and 40% spill. Spill efficiency was significantly higher under 64% spill than under 30% spill in 1999, but 40% spill in 2000 provided efficiencies that were within 1% of those observed at 64% spill in the previous year for every radio tagged group of fish. Hydroacoustic results also showed that most of the incremental benefits of higher spill occur between 30% and 40% spill rather than between 40% and 64% spill. Spill effectiveness tends to be higher for 30% and 40% spill levels than for 64% spill, but the difference in effectiveness between 30% and 40% spill was insignificant.

Sluice passage efficiency could be increased by spilling 30% instead of 40% or 64% of the river and by using a daytime adult spill pattern that discharges water more through end spill bays during low project discharge and more uniformly across all bays during high discharge. However, results suggest that such operations would not deliver the highest project FPE because the current sluice design is not efficient enough to offset the loss in spill passage efficiency when spill drops from 40-64% to 30%. However, more study of both sluice entrance design and spill pattern, as discussed below under Specific Studies below might increase both spill and sluiceway passage efficiencies at 40% spill and thereby improve overall FPE for the dam.

We recommend spilling 40% of the river and using a 24-hour juvenile spill pattern to maximize both FPE and survival of juvenile salmon. Radio telemetry data indicate that project FPE can be maximized by spilling 64% of the river (mean=93.3%), but radio telemetry and hydroacoustic results suggest that spill 40% of the river and using a juvenile spill pattern 24 hours per day delivers about the same benefits (mean=87.9-92.0%). More importantly, spillway survival study results (1997-2000) indicate that both spring and summer smolt survival was consistently higher at 30%-40% spill compared to 64% spill. Also, when comparisons could be made, a juvenile spill pattern (north) resulted in higher survival than an adult spill pattern (north and south).

We recommend a thorough study of J-occlusions to determine whether they can significantly increase sluice passage or decrease turbine passage. Beginning in 2001, studies should include the use of hydraulic modeling, radio telemetry, and hydroacoustic techniques to:

- Quantify and map hydraulic conditions in the forebay, including the near field of the sluiceway, with and without the J-occlusions;

- Integrate observed smolt movement data with hydraulic data from a CFD;

- Assess specific hypotheses about smolt movements, such as: a) the zone of influence of the sluiceway will be larger with J-occlusions than without; b) the proportion of fish moving upward and toward the sluice entrances will be higher with J-occlusions than without; and c) the overall probability of passage into the sluiceway will be higher with J-occlusions than without.

- Future studies should test locations and patterns of J-occlusions and sluiceway entrances, if 2001 studies indicate that J-occlusions increased sluiceway efficiency or reduced turbine passage. Given available horizontal distribution information from hydroacoustic sampling and first-contact proportions from radio telemetry studies, the focus of future efforts should not be limited to the west end of the powerhouse.

8.2.3 Specific Studies to Address Data Limitations and Uncertainties

A concerted effort should be made to improve hydroacoustic sampling of sluiceway passage by trying new deployments and comparing them to old ones. Although sluiceway passage is a relatively small passage route compared to turbines and the spillway, the fraction of fish using this route justifies increased sampling effort. Problems with traditional sluice entrance sampling include poor spatial coverage with an up-looking transducer deployed too far upstream to sample entrained fish, the potential for a lateral skew in the distribution of fish passage and high acoustic noise on windy turbulent days. Anywhere from 20% to 80% of the fish detected with an up-looking beam at the sluiceway are moving in the direction of the opening, and this makes assignment of fate very difficult.

We recommend sampling with two opposing split transducers mounted on the top of the sluice gate and one split-beam transducer mounted about 8 m deep and aimed upward in more the traditional way (Figure 8.1). Deploying two laterally aimed transducers has the potential to solve several problems encountered previously. First, the sample volumes of individual beams would be less than similar beams sampling at greater range so that volume reverberation would be reduced and signal to noise ratios of fish targets would be improved. Second, virtually all fish passing over the sluice gate would be entrained by the time they were detected and researchers would not have to rely on direction of movement data. Third, the lateral distribution of passage would be sampled, and could be assessed in fine detail. The up-looking beam could assess the vertical distribution of fish passage to identify potential biases in sampling with laterally aimed transducers. By deploying the up-looking transducer only 8 m deep, the sample volume would be deceased by about one half and signal to noise ratios for detecting fish should improve significantly.

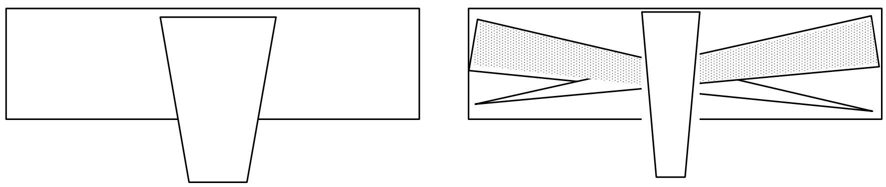

Figure 8.1. Rectangular Sluice Opening and Potential Coverage of Hydroacoustic Beams Used in Traditional Sampling (left) and Proposed Sampling to Evaluate a New Approach (right)

Previous studies have provided some insight into the effect of spill level on fish passage metrics, but we still know very little about the effect of spill patterns on those same metrics. Several studies have indicated that increasing the level of spill provides modest increases in FPE and spill passage efficiency but that the greatest benefits occur at lower spill levels where effectiveness is high. Effectiveness falls off markedly as spill levels increase. It also appears that running a juvenile spill pattern during the daytime takes fish away from the sluiceway as well as turbines so that sluice passage efficiency is diminished to increase spill passage efficiency.

The only two spill patterns that have been tested are a daytime adult pattern and a nighttime juvenile pattern and those results are confounded by diel differences in passage. If water available for spill is limited, it would be good to know what the most efficient spill pattern might be to maximize effectiveness. The objective would be to evaluate fish-passage metrics for several spill patterns while spill volume or percent spill is held constant. For example, would it better to spill lower volumes per bay uniformly across all operational bays or would it be better to spill higher volumes through every other bay while reducing spill through intervening bays? Are end bays more important than center bays? Horizontal distribution data collected to date do not consistently support the latter hypothesis. Some data from Bonneville Dam in 2000 suggest that the highest fish passage rates are rarely through bays spilling the most water. If this suggestion hold true for The Dalles Dam, it may be that identifying effects of spill pattern could provide yet another way to optimize fish passage metrics that The Dalles Dam.

Another study that is clearly needed includes testing a mix of standard spill bays with modified bays with overflow weirs that might reduce daytime holding of steelhead during 30% spill by providing surface flow clues at some spill bays. Radio telemetry results indicate that yearling steelhead hold during the day when spill is about 30% of river discharge because the fish are very surface oriented. It might be that having overflow weirs at one in three or four bays could reduce daytime holding and increase spill passage efficiency to levels attained at higher spill rates.

As depth tags and acoustic telemetry become more established, it would be important to compare vertical distributions of tagged fish with those of untagged fish sampled by hydroacoustics. This would be a good quality control check for radio telemetry. If differences are found between vertical distributions, then potential biases in fish passage metrics may result and should be assessed. Vertical distributions could be determined by using depth sensitive tags or acoustic tags for tagged fish, and hydroacoustics could be used to sample the vertical distribution of untagged fish. At Bonneville Dam in 2000, approximately 44% of the radio tagged fish in a prototype surface collector passed over a shallow weir and into the sluiceway (Scott Evans, USGS, Personal Communication), whereas hydroacoustic sampling detected very high numbers passing through the PSC and into the upper part of the turbine. Those data suggest that there were differences in the vertical distributions or behavior of tagged and untagged fish at that location.

More effort needs to be directed at dissecting the causes of mortality of fish passing through north and south spill, the sluiceway, and turbines because survival and not fish passage efficiency per se appears to be the problem at The Dalles Dam. Conditions resulting in direct mortality at various locations need to be characterized and combined with studies of route specific injury and direct mortality studies to clearly quantify those conditions and losses. If predation below the powerhouse and sluice outfall and down through the Bridge and Basin Islands are as high as some data suggest, then physical losses may play a minor role. However, physical injury likely increases susceptibility to predation and should be studied further.

Additional sluiceway and turbine survival studies are needed using both PIT tagging and radio telemetry. At this time there are only 2 years of results (1999 and 2000) where summer survival estimates varied greatly (89% in 1998 and 96% in 2000). The low turbine survival estimates of 81%-84% are cause for concern, but they were based upon one year's estimates of both direct and indirect effects by two different methodologies. We recommend that verification of these estimates be undertaken as soon as is practical. Radio telemetry and pit-tag studies also are needed to determine whether increased tailrace residence time equates to lower juvenile salmon survival.

In order to fully assess the impacts on the smolt population passing The Dalles Dam, passage-modeling analyses are required using this assortment of survival information in conjunction with passage route efficiency estimates. We recommend the COE conduct such modeling using either the CRISP or SIMPAS passage models or both.

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Appendix A

Annotated Bibliography

Appendix A

Annotated Bibliography

We sorted references in this annotated bibliography by study type (hydroacoustics, radio telemetry, and survival), study year (not publication date), and then alphabetically by lead author to make the material readily accessible for readers with particular interests.

A.1 Fixed-Aspect Hydroacoustics

Magne, R. A., W. T. Nagy, and W. C. Maslen. 1983. *Hydroacoustic Monitoring of Downstream Migrant Juvenile Salmonid Passage at John Day and The Dalles Dams in 1982*. Report of the U.S. Army Engineer District, Portland.

The Dalles Dam portion of this study was limited to summer and was designed to determine the temporal distribution of nighttime smolt passage at the powerhouse, the horizontal distribution of powerhouse passage, and to monitor fish activity at six spill bays to support spill operations for fish passage.

The horizontal distribution of smolt detections across six monitored turbine units showed that 80 percent of total passage was through Units 1, 3, and 5 on the west end of the powerhouse. Eleven percent of total passage was through turbine Unit 22, and the remaining 9 percent passed through turbine Units 10 and 15. The Dalles Dam temporal distribution of nightly detections peaked during the second hour of monitoring (2200-2300) and 59 percent of the nightly passage completed by midnight. Intermittent daytime monitoring did not show any appreciable fish movement into the monitored turbine intakes suggesting that any passage during the day was through the sluiceway.

Results of sonar monitoring at The Dalles spillway were inconclusive due to limited operation of the spillway and low fish passage associated with this period in the migration. The spillway was operated only once on 6 August.

Steig, T. W., and W. R. Johnson. 1986. *Hydroacoustic Assessment of Downstream Migrating Salmonids at The Dalles Dam in Spring and Summer 1985*. Bonneville Power Administration Report under Contract No. DE-AC79-85 BP23174.

The primary objective of this study was to estimate the effectiveness of the spillway and sluiceway in passing smolts in spring and summer seasons from April 22 to August 15, 1985. Secondary goals of this study were to provide information on the horizontal, vertical, and temporal distributions at major passage routes.

Ten hour instantaneous spill tests indicated that spill passage efficiency was lower in spring (23.2%) at a 21.8% spill level than it was in summer (39.9%) at a 17.8% spill level. In spring, when turbines, the spillway, and the sluiceway were all operating, the sluiceway was the most effective method of passing fish on a percent flow basis. Sluiceway fish passage was 23.2% of project passage in only 1.6% of the total average river volume (24-h average). In summer, water flow into the sluiceway averaged 3.7% of the daily average river flow but passed 48.7% of all fish. At the turbines, 68% of fish passed in 88.1% of the river flow in spring and 51% of fish passed in 96.3% of river flow in summer. In spring, the horizontal distribution across the powerhouse showed the most fish passing through Turbine Unit 3 and the least through Unit 22. In contrast, Units 3 and 22 passed nearly equal percentages of fish during the summer study. The vertical distributions showed that the fish were deeper in the water column at night than they were during the day.

The authors recommended testing a wide range of controlled spill levels and the use of fewer more open spill gates to better define the relation between spill and fish passage by spill.

Johnson, W. R., L. Johnson, and D. E. Weitkamp. 1987. *Hydroacoustic Evaluation of the Spill Program for Fish Passage*. Contract Report No. DACW57-86-C-0062 prepared by Associated Fisheries Biologists, Incorporated, and Parametrix Incorporated for the U.S. Army Engineer District, Portland.

A 116 day hydroacoustic evaluation of juvenile fish passage was conducted at The Dalles Dam from April 21 through August 15, 1986. Objectives included in-season reports on run-timing to optimize spill and to evaluate spill and sluiceway efficiency for bypassing juvenile salmonids.

In spring, Project FPE was estimated at 55.4%, but it could not be estimated in summer because reliable fish passage estimates could not be made for the sluiceway for the period June 15–August 15. Observed spill passage effectiveness was 2.3 and 0.9 during 10% and 50% spill discharge nights, respectively.

Fish densities through lower numbered turbines were consistently lower during 50% spill levels than during 10% spill levels.

McFadden, B. D. 1990. *Hydroacoustic Evaluation of Juvenile Salmonid Fish Passage at The Dalles Dam in Summer 1989*. Contract Report DACW57-80-C-0070 of BioSonics Incorporated to the U.S. Army Engineer District, Portland.

The primary objective of the study was to monitor nighttime fish passage at the spillway and provide hourly estimates of fish passage in summer. Additional objectives were concerned with assessment of run timing and vertical and horizontal distributions of passage at spill bays 16-23 where most spill occurred.

The seasonal horizontal distribution showed higher numbers of fish passing through the spill bays 21 and 19 which had more discharge compared to the other monitored bays. The vertical distribution of fish remained relatively constant over the season at seven to 10 meters deep. Vertical distribution shifted slightly deeper as the monitoring season progressed. Nighttime fish passage at the spillway increased from 1700 to 2100 hours and declined linearly from 2100 to 0400 hours. The scope of this study did not permit estimation of FPE, spill passage efficiency, or spill passage effectiveness.

Stansell, R. J., L. M. Beck, W. T. Nagy, and R. A. Magne. 1991. *Hydroacoustic Evaluation of Juvenile Salmonid Fish Passage at The Dalles Dam Fish Attraction Water Units in 1990*. U.S. Army Corps of Engineers, Portland District.

The Fisheries Field Unit (FFU) conducted hydroacoustics monitoring and gatewell dipping from April 23 to 16 August to determine whether or not juvenile salmonids pass through fish units in significant numbers.

During the spring, hydroacoustic estimates of the average hourly fish passage through either of the fish units ranged from a low of seven fish per hour to a high of 37 fish per hour. Activity outside of Fish Intakes F2 ranged from a low estimate of 25 fish per hour to a high of 33 fish per hour. During the summer, hydroacoustic estimates of the average hourly fish passage through either of the fish units ranged from a low of 22 fish per hour to a high of 67 fish per hour. Activity outside of F2 ranged from a low estimate of five fish per hour to a high of ten fish per hour.

The lack of correlation of numbers detected outside and inside F2-2 in spring suggests that fish sampled in the forebay may not be entrained or representative of fish passage through turbines.

Nagy, W. T., and M. K. Shutters. 1996. *Hydroacoustic Evaluation of Surface Collector Prototypes at The Dalles Dam, 1995*. Draft Report of the U.S. Army Engineer District, Portland.

The objectives of this study were to 1) develop adequate hydroacoustic sampling methods to measure and characterize fish passage through surface collection structures; 2) compare fish passage into the ice-and-trash sluiceway with and without blocked trash racks at sluice gates 1-2 and 2-2 and compare sluice gate passage with concurrent turbine passage at intake slots 1-2 and 2-2; 3) compare fish passage into the sluiceway through a modified vertical slot entrance at 1-2 to passage into an unmodified entrance with and without blocked trash racks at 2-2; 4) compare fish passage into spill bays with vertical slot entrances (slotted bulkheads) to passage into unmodified spill bays; and 5) determine the horizontal, vertical, and diel distribution of fish passage through the spillway.

There was no significant difference in mean FGE for Intakes 1-2 and 2-2 during blocked and unblocked treatments, where FGE was defined as fish passage through the sluiceway divided by the sum of passage through the sluiceway and the turbine below it. However, mean FGE was significantly higher at Intake 1-2 (87.9%) than it was at Intake 2-2 (76.5%) when data from both treatments were pooled.

Daytime and nighttime horizontal distributions at the spillway were nearly indistinguishable because only one spill regime was in effect during sampling. This pattern of fish passage across the spillway had no particular resemblance to the pattern of spill discharge.

The vertical distribution of smolts upstream of turbines and the sluiceway entrances highly skewed toward the surface (mean and median depths were 3.0 and 3.2 meters, respectively). At unmodified spill bays, the mean depth was 5.6 meters and the median depth was 5.9 meters. Depth distribution varied little with time of day.

BioSonics Incorporated. 1997. *Hydroacoustic Evaluation and Studies at The Dalles Dam, Spring/ Summer 1996*. U.S. Army Engineer District, Portland.

The primary objectives of the study were to evaluate the effects of occlusion plates in front of turbine intakes at Main Units 1-5 and the effects of spill level on fish-passage metrics.

Spillway passage efficiency values averaged 42% in spring and 67% in summer. In spring, the average spill bypass efficiency was 51% for 30% spill, and only 39% for the 64% spill levels and this difference was significant. Further, fish entrainment into the turbines was significantly higher at the 64% spill level compared to the 30% level. In summer, the opposite was true: the higher spill levels had significantly higher passage rates (72% versus 61%). However, there was no significant difference in turbine passage rates between high and low spill levels for the summer period. The authors concluded that fish detectability was very similar at all locations under both spill treatments and that the observation of significantly higher fish passage through the spillway at 30% spill compared with 64% spill was real, as well as observed higher turbine entrainment rate associated with the 64% spill. The horizontal distribution in the number of fish passing the powerhouse was strongly skewed toward Main Units 1-5 and away from higher number units in spring and summer. The horizontal distribution at the spillway was skewed toward the end bays in spring and was relatively uniform between the end bays. In summer, passage was nearly twice as high on the Washington side of the spillway as it was on the Oregon side.

The investigation of effects of occlusion plates on fish passage into turbines was inconclusive because fish were milling behind trash-rack blocks and counted multiple times, which made blocked treatments appear to increase turbine passage relative to unblock treatments.

BioSonics, Incorporated. 1999. *Hydroacoustic Evaluation and Studies at The Dalles Dam, Spring/ Summer 1998*. U.S. Army Engineer District, Portland.

Fixed location hydroacoustic techniques were used at The Dalles Dam during spring and summer 1998 to examine the impacts of two spill levels on fish passage at the spillway. The experimental treatment was to vary the spill level so that either 30% or 64% of total river discharge was spilled.

In general, total fish passage at the spillway was higher at the 64% spill level, largely due to higher daytime passage rates observed under this experimental condition for both study periods. Turbine and sluiceway passage estimates were higher for both day- and nighttime periods at the 30% spill level for both the spring and summer studies.

Powerhouse operations during 30 and 64% spill greatly affected the horizontal distribution of fish at the powerhouse largely because higher numbered turbine units ran little or none during high spill levels, which skewed the distributions to middle and lower numbered units. At 30% spill, middle and higher numbered units, except Units 20-22 in summer, passed as many or more fish than lower number units, particularly during the day. Changes in fish passage distributions at the spillway were largely influenced by spill pattern and more so during 30% spill than during 64% spill because more gates had to be closed to create the juvenile pattern, which is skewed toward the Washington shore at night as opposed to the daytime adult pattern.

Ploskey, G. R., M. E. Hanks, G. E. Johnson, W. T. Nagy, C. R. Schilt, L. R. Lawrence, D. S. Patterson, P. N. Johnson, and J. R. Skalski. 2001. *Hydroacoustic Evaluation of Juvenile Salmon Passage at The Dalles Dam*: 1999. Technical Report ERDC/EL TR-01-11, U.S. Army Engineer Research and Development Center, Waterways Experiment Station, Vicksburg, Mississippi.

The objectives of this fixed-location hydroacoustic study were to 1) estimate fish-passage rates through three major routes (spill bays, turbines, and the sluice openings), 2) calculate a variety of fish-passage metrics for comparing 30%- and 64%-spill treatments, 3) describe horizontal, vertical, and diel distributions of passage, and 4) evaluate assumptions in the acoustic screen model by exploring detectability modeling and adjustment of counts among locations.

In spring, project fish passage efficiency (FPE) was estimated at 0.84 during 64% spill and 0.76 during 30% spill. Estimated FPE from summer sampling was 0.76 during 64% spill and 0.64 during 30% spill. Overall, spillway efficiency was estimated at 0.72 during 64% spill and 0.61 during 30% spill. In spring, sluiceway efficiency relative to the entire project was estimated at 0.12 during 64% spill and 0.15 during 30% spill. In summer, sluiceway efficiency was 11%-14% during the day and 5-8% higher than it was at night (6%), and there was no significant difference between treatments during either day or night sampling. Spill treatments had some effect on horizontal distributions of fish passage. Vertical distribution data from turbines in spring indicated that fish were slightly deeper during 30% spill than during 64% spill. Diel distribution data indicate that more fish passed the turbines at night than during the day, whereas that pattern was reversed at the sluiceway. At the spillway, fish exhibited typical crepuscular peaks in passage soon after dark and in early morning. Hourly fish passage rates at the powerhouse were higher at turbines on the east end than at turbines on the west end, whereas the opposite was true for the cumulative distribution by season.

Moursund, R. A., K. D. Ham, B. McFadden, and G. E. Johnson. In Review. *Hydroacoustic Evaluation of Downstream Fish Passage at The Dalles Dam in 2000*. Draft Final Report by Battelle Incorporated to the U.S. Army Engineer District, Portland.

Fixed-location hydroacoustic data of juvenile salmon passage were collected at The Dalles Dam in 2000. Objectives were to estimate the proportion of smolts passing through the spillway, powerhouse turbines, and the sluiceway. Efficiency estimates also were calculated relative to the proportion of discharge (effectiveness). The results were described in terms of day/night and spring/summer for the May 13 to July 6 study.

Overall FPE was 86%, and it was significantly higher (t-test, $p<0.001$) in spring (92%) than in summer at (81%). Spill efficiency was 86% in spring and 74% in summer, and spill passage effectiveness was 2.16 in spring and 1.86 in summer. Relative to the entire project, sluice passage efficiency was 6% in spring and 7% in summer. Sluice effectiveness was 3.22 in spring and 3.27 in summer, and these estimates were significantly higher than spill passage effectiveness during the respective seasons. The sluiceway passed over 40% of all fish that went through the powerhouse in spring and summer. Fish passage was highest through Spill bays 5 and 7 for both the spring and summer periods and was skewed toward the upstream end of the powerhouse in summer.

The distribution of fish passage among turbines was relatively uniform in spring. Vertical distribution at the turbines showed fish passed in the upper portion of the water column near the intake ceiling. Passage both above and below the sill of the sluice opening (El. 151 ft) showed that fish passage had a central tendency around El. 143 ft. Fish were slightly higher in the water column as they entered the intakes of the powerhouse during the day than they were at night, although distributions generally were similar. The opposite trend was evident at the sluice and spillway. Fish passage through spill and the sluiceway tended to be higher during the day than at night. More fish passed through turbines at night than during the day in spring. Passage through turbines was uniform in summer with no obvious diel pattern given overlapping error bars on hourly estimates.

Johnson, G., J. Hedgepeth, A. Giorgi, and J. Skalski. In review. *Evaluation of Smolt Movements Using an Active Fish Tracking Sonar at the Sluiceway Surface Bypass, The Dalles Dam, 2000*.

The objectives of this study were to track smolts within the near field of sluice 1-1 at The Dalles Dam with an active sonar tracking transducer and to estimate the proportions of fish moving in different directions (states), the probability of smolts going into the sluice, turbine, or forebay upon leaving a sample volume (fates), and assess surface flow bypass premises about smolt movement relative to the sluice entrance. About 100,000 smolts were tracked and 5 million positions estimated during the study from April 17 through July 7, 2000. A wide variety of new observations and several confirming observations about smolt behavior in the vicinity of the sluice entrance were identified in this study and should prove valuable for future surface bypass development. Examples include 1) holding was observed in front of the upper portion of turbine intake entrances; 2) smolts did not appear to actively avoid the sluice entrance; 3) when moving toward dam, smolts were more likely to also be moving up than down, but when moving away from the dam, they were more likely to move down than up; 4) a zone of entrainment was indicated by the state data, and appeared to be relatively small (2-3 m from the dam); 5) the zone of influence of the sluice flow net may be at least 7 m from the dam in the surface layer (0-2 m) based on the fate data; 6) the probability of sluice passage was highest on the east side of the forebay immediately upstream of the Sluice 1-1 entrance; 7) attraction to the sluice flow net was indicated, although the mechanism is unknown; 8) fish moved from east to west in the near field and slowed down in front of Sluice 1-1.

A.2 Radio Telemetry

Clugston, D. A., and C. B. Schreck. 1994. *Movement, Distribution, and Behavior of Juvenile Salmonids Passing through Columbia and Snake River Dams*. Pages 75–105, *in* Poe, T. P. and D. M. Gadomski (eds.), Significance of selective predation and development of prey protection measures for juvenile salmonids in Columbia and Snake River reservoirs. Annual Report of Research, 1992 (DOE/BP-91964-3), by the U.S. Fish and Wildlife Service to Bonneville Power Administration.

Objectives: 1) develop techniques to radio-track outmigrating smolts in The Dalles tailrace, 2) evaluate which of two potential bypass outfall sites best moves smolts downstream and out of the immediate tailrace area, and 3) investigate what effects different levels of stress might have on the outmigration and dispersal behavior of these fish.

Methods, Key Results, and Data Quality Assessment: This was a feasibility study to determine if radio-telemetry would be a successful technique to study tailrace egress of juvenile salmonids released at several potential bypass outfall sites in The Dalles Dam tailrace. River flow ranged from 157,000 to 227,000 ft/sec during fish releases and there was almost no spill (<5%). Results indicated that radio-tagged juvenile salmonids could be tracked in tailrace outfall areas to determine egress patterns and residence times. Fifteen of 41 radio-tagged steelhead smolts held below the dam in spring 1992. The two main holding areas were the Bridge and Basin islands. These researchers observed faster egress for steelhead released from a downriver release site (~50 m below the bridge and ~50 m from the Washington shore) than for steelhead released from an upriver site (~200 m below the sluiceway outfall and ~50 m from shore). Detection percentage was fair to poor, sample size very low, data should be considered somewhat qualitative.

Hansel, H. C., R. S. Shively, G. S. Holmberg, T. P. King, and M. B. Sheer. 1995. *Movements and Distributions of Radio-Tagged Northern Squawfish Near The Dalles and John Day Dams*. In Poe, T. P. (ed.) Significance of selective predation and development of prey protection measures for juvenile salmonids in the Columbia and Snake river reservoirs. Annual Report of Research, 1993 (DOE/BP-91964-4), by the National Biological Survey to the Bonneville Power Administration, Portland, Oregon.

Objectives: To determine the behavior and distribution of radio-tagged northern pikeminnow in the tailrace of The Dalles Dam to acquire information to aid in establishing biological criteria for optimum location of juvenile bypass outfalls and to examine modes of project operation that may potentially reduce predation in tailrace areas of dams.

Methods, Key Results, and Data Quality Assessment: Radio-tagged pikeminnow (n=64) were monitored May 12 through September 30, 1993, with fixed receiver stations (arrays of antennas connected to data logging receivers) and frequent mobile tracking. The highest concentrations of radio-tagged predators were recorded near the sluiceway outfall and the outfall eddy when the sluiceway was operating (daytime). Radio-tagged northern pikeminnow responded to changes in dam operations by moving away from areas of high velocity (>1 m/s). Thus, while this study was not designed to estimate the direct impact of predation on smolt survival, it confirmed other research findings that predation on smolts passing through The Dalles sluiceway could be a potentially serious problem. Detection was 86% overall (some fish were later found >50 km from The Dalles). They obtained good detail on a significant number of individual fish were detected >1000 times in the near dam tailrace.

Shively, R. S., M. B. Sheer, and G. S. Holmberg. 1995. *Description and Performance of an Automated Radio Telemetry System to Monitor the Movement and Distribution of Northern Squawfish at Columbia River Dams*. In Poe, T.P. (ed.) Significance of selective predation and development of

prey protection measures for juvenile salmonids in the Columbia and Snake River reservoirs. Annual report of research, 1993 (DOE/BP-91964-4) by the National Biological Survey to the Bonneville Power Administration, Portland Oregon.

Objectives: To develop, test, and describe an automated data-logging radio-telemetry system capable of monitoring northern pikeminnow movements within the boat restricted zone of dam tailrace areas. Test objectives were to 1) determine the efficiency and reliability of information collected by fixed site receiver stations, 2) compare results obtained with fixed stations to data collected by mobile tracking methods and determine the benefits and limitations of each method of data collection, and 3) compare the area within the range of the fixed receivers where northern pikeminnow were most likely to be located with positions estimates obtained by mobile tracking.

Methods, Key Results, and Data Quality Assessment: Five fixed stations with a total of 34 Yagi antennas and 1 coaxial cable antenna. Radio transmitters were digitally-encoded and frequencies were spaced 20 KHz apart from 149.820-150.000 MHz. Receivers were programmed to sequentially scan individual antennas for each frequency, within about 4 min. The number of individual fish contacted by fixed stations was not significantly different from mobile tracking when both methods were conducted simultaneously. The advantage of fixed station systems was that continuous monitoring of fish could be achieved, but the disadvantage was that only general movements are recorded. Mobile tracking provided more precise position data but relatively few data points per fish could be obtained. Recommendation is to use a combination of both techniques. Fixed-station receivers only monitor general fish movements ±50 m.

Snelling, J. C., and C. B. Schreck. 1995. *Movement, Distribution, and Behavior of Juvenile Salmonids Passing through Columbia and Snake River Dams*. Oregon Cooperative Fishery Research Unit, Oregon State University. In Poe, T.P. (ed.) Significance of selective predation and development of prey protection measures for juvenile salmonids in the Columbia and Snake river reservoirs. Annual Report of research, 1993 (DOE/BP-91964-4) by the National Biological Survey to the Bonneville Power Administration, Portland Oregon.

Objectives: To determine egress routes and residence time of radio-tagged yearling chinook salmon released at two potential bypass outfall sites in The Dalles tailrace. Incidental information on forebay approach and behavior was also collected on several radio-tagged yearling chinook salmon released from the John Day bypass.

Methods, Key Results, and Data Quality Assessment: Six releases of radio-tagged yearling chinook salmon (n=50) were made April 28-May 28 at two potential bypass outfall release sites. One site was located about 200 m downriver and about 50 m offshore from the current ice-trash sluiceway outfall and the other site was located about 50 m below the bridge and 50 m offshore. Holding was four times more likely for yearlings released at the upriver site (60% of the fish) compared to the downriver site (8% of the fish). Tagged fish held in the areas of the bridge or basin islands. Forebay near dam residence time averaged 50 min for 4 fish entering during no spill (all passed the sluiceway) and 10 fish arriving during spill averaged 101 min (nine of ten passed the spillway). Sample sizes were small. Locations of fish were determined by rough triangulation. Forebay data were collected with a hand-held antenna and should be considered qualitative.

Sheer, M. B., G. S. Holmberg, R. S. Shively, H. C. Hansel, T. L. Martinelli, T. P. King, C. N. Frost, T. P. Poe, J. C. Snelling, and C. B. Shreck. 1997. *Movement and Behavior of Radio-Tagged Juvenile Spring and Fall Chinook Salmon in The Dalles and John Day Dam Forebays, 1995*. Annual Report, 1995 to the Army Corps of Engineers, Portland District, Portland, Oregon.

Objectives: This was a study to determine the feasibility of collecting detailed passage behavior data of radio-tagged juvenile salmonids in the forebays of John Day and The Dalles dams. Specific objectives of the study were to examine: 1) distribution and approach patterns of radio-tagged juvenile salmonids upriver of both dams, 2) the behavior and distribution of fish once inside the near-dam forebay in relation to dam operating conditions and hydraulic environment, and 3) time and route of passage.

Methods, Key Results, and Data Quality Assessment: From May 2 to June 8 seven groups of yearling chinook salmon (n=100) were radio-tagged and released 8 km above John Day Dam. Downriver migration followed two patterns with three groups moving downriver along the Washington shore and 3 groups moving downriver mid-channel. Almost all fish avoided the John Day River plume. A majority (~70%) of the tagged fish first entered the near dam forebay in the powerhouse area. Once inside the near dam forebay fish concentrated at the south end of the powerhouse and mean residence time before passing was 10.3-h. They estimated that 24% of the radio-tagged fish passed through the spillway and 76% passed through the powerhouse (unguided plus guided). At The Dalles Dam the overall mean residence time once in the near dam forebay was 0.3 h, indicating that fish readily passed the dam. A majority (88%) of the radio tagged fish passed through the TDA spillway. Powerhouse and sluiceway passed fish could not be separated. Sample sizes were moderate, and there was no coverage of juvenile bypass system so FPE could not be determined.

Holmberg, G. S. and eight co-authors. 1997. *Movement, Distribution, and Behavior of Radio-Tagged Juvenile Chinook Salmon in John Day, The Dalles, and Bonneville Dam Forebays, 1996*. Annual Report of Research, 1996, by the U.S. Geological Survey to the U.S. Army Corps of Engineers – Portland District.

Objectives: Determine: 1) the general behavior, distribution, and approach patterns of radio-tagged juvenile salmonids upriver and in the forebay areas of John Day Dam, The Dalles Dam, and Bonneville Dam; 2) the behavior of juveniles once inside the near-dam forebay area; 3) time and route of passage; and 4) the changes in behavior of fish associated with tests of surface bypass concepts and prototype surface bypass structures.

Methods, Key Results, and Data Quality Assessment: Two specific tests of surface bypass concepts were conducted in 1996. Blocked and unblocked trash rack tests were done during high (64%) and low (30%) spill conditions to determine if blocking the upper parts of turbine entrances could cause fish to seek more surface oriented passage routes. At the spillway, two spill baffle structures were installed to provide alternatives to the normal deep spill route under the tainter gates. In spring, yearling chinook salmon approached the forebay of the dam dispersed evenly across the main channel. In summer, the sub-yearlings moved downriver in the south part of the main channel. The first detections in the near dam forebay indicated that both yearlings and sub-yearlings entered the near dam area at the east end of the powerhouse. Residence times (medians) were 0.2-h for yearling chinook salmon and 0.2-h for sub-yearling chinook salmon. At 30% spill, 70% of the yearling chinook salmon and 57% of the sub-yearlings passed through the spillway. At 64% spill, 80% of the yearlings and 68% of the sub-yearlings passed through the spillway. During the blocked trash rack tests, yearlings passed the sluiceway (or west end of the powerhouse) in similar percentages (20% when blocked and 26% when unblocked). For sub-yearlings, 42% were estimated to pass the sluiceway (or west end of powerhouse) when blocked and 31% when unblocked. Too few fish passed through the spill baffles to determine any effect. The detection rate was good (90% of spring migrants were detected and 88% of summer migrants). The sluiceway was not monitored with a fast scanning DSP so FPE could not be determined and blocked trash-rack tests were inconclusive. Sample size was moderate.

Normandeau Associates, J. R. Skalski, and Mid Columbia Consulting. 1996. *Potential Effects of Modified Spillbay Configurations on Fish Condition and Survival at The Dalles Dam, Columbia River*. Prepared for the U.S. Army Corps of Engineers, Portland District, Portland, Oregon.

Objectives: Evaluate fish condition and survival of hatchery-reared chinook salmon in passage over an unmodified spill bay (Bay 3) and a spill bay configured with an I-slot (Bay 4), and a spill bay overflow weir (Bay 6). Additionally, a limited number of juvenile salmon were released through the ice-trash sluiceway to determine fish condition and potential problems associated with this route of passage.

Methods, Key Results, and Data Quality Assessment: HI-Z Turb'N Tag-recapture technique. The 48-h fish survival probability was 0.993 (90%CI 0.972-1.02) for Bay 4 (I-Slot); 0.990 (90% CI 0.951-1.0) for Bay 3 (unmodified), and 0.955 (90% CI 0.927-0.982) for Bay 6 (overflow weir). Of the 100 fish released through the ice-trash sluiceway, 97 were recaptured alive, of which 95 remained alive after 48-h. One fish was recaptured dead and 2 fish were not recaptured. Because of the limited number of tests and relatively wide confidence intervals, it is difficult to predict which combination of spill and slot configuration would provide the best fish survival.

Hensleigh, J. E. and nine co-authors. 1999. *Movement, Distribution, and Behavior of Radio-Tagged Juvenile Chinook Salmon and Steelhead in John Day, The Dalles and Bonneville Dam Forebays, 1997*. Annual Report of Research, 1997, by the U.S. Geological Survey to the U.S. Army Corps of Engineers – Portland District.

Objectives: Determine: 1) the general behavior, distribution, and approach patterns of radio-tagged juvenile salmonids upriver and in the forebay areas of John Day Dam, The Dalles Dam, and Bonneville Dam; 2) the behavior of juveniles once inside the near-dam forebay area; 3) time and route of passage; and 4) the changes in behavior of fish associated with tests of surface bypass concepts and prototype surface bypass structures.

Methods, Key Results, and Data Quality Assessment: No tests of surface bypass concepts were conducted in 1997. Radio-tagged yearling chinook salmon, yearling steelhead and sub-yearling chinook salmon were released above the dam. Most first detections in the near dam forebay were at the east end of the powerhouse. Residence times (medians) were 0.2-h or less for all species/types. The major route of passage was the spillway, passing 70.4% of yearling chinook salmon, 78.0% of the steelhead, and 84.2% of the sub-yearling chinook salmon. The sluiceway was still efficient even at these spill percentages, passing 17.3% of the steelhead and 23.0% of the yearling chinook salmon. Detection rates were low. Project FPE could be estimated, but low detections reduce confidence in this estimate.

Snelling, J.C., and S.A. Mattson. 1998. *Behavior and Fate of Juvenile Salmonids Entering the Tailwaters of The Dalles Dam via Spill*. Annual Report of Research, 1997, by the Oregon Cooperative Fishery Research Unit – Oregon State University to the U.S. Army Corps of Engineers, Portland District.

Objectives: The objective of this study was to describe the migratory routes and tailrace residence time of yearling and sub-yearling chinook salmon, and coho salmon in The Dalles Dam tailrace after release through the north spillway, south spillway, and a downriver reference site.

Methods, Key Results, and Data Quality Assessment: Two releases of yearling chinook salmon were made May 1 and 4, eight releases of coho salmon were made between May 11 and June 12, and six releases of sub-yearling chinook salmon were made between July 1 and July 18. For each release, about equal proportions were released through each of the three sites. Results indicated that the percent of fish passing the 6 km exit transect was 88% to 98% for fish released from the reference site, 92% to 100% for fish released in north spill, and 65% to 88% for fish released into south spill. They reported that fish predation befell 3% of the coho salmon from the south day spill, 25% of the sub-yearling chinook salmon through the south day spill, and 4% of the sub-yearling from the south night spill. The migration times for south spill fish were also significantly longer than for north spill or reference fish. Sample sizes were moderate. We found it difficult to determine if fish recorded as “not exiting” were not detected or did not survive to the exit transect.

Allen, M. B. and eight co-authors. 2000. *Movement, Distribution and Behavior of Radio-Tagged Yearling and Sub-Yearling Chinook Salmon in the Tailrace of The Dalles Dam, 1999*. Annual Report of Research, 1999, by the U.S. Geological Survey to the U.S. Army Corps of Engineers – Portland District.

Objectives: To determine: 1) movement patterns and residence times in the tailrace, 2) relationships between juvenile salmonid routes of travel through the tailrace and residence times, 3) the influence of test conditions on tailrace residence times, and 4) hydraulic conditions likely experienced by fish in the tailrace through deployment of drift drogues.

Methods, Key Results, and Data Quality Assessment: The test conditions were 30 versus 64% spill and the pattern was alternated between adult (day) and juvenile (night) patterns. Tagged fish released from all 3 sites during 64% adult (day) spill had the longest and most variable tailrace residence time. The south spillway fish consistently had the highest residence time through all test conditions. The majority of predation events involved south spill fish during 64% adult (day) spill. No predation events were detected during either outmigration period (spring or summer) during 30% juvenile spill (night). Sample sizes high for radio telemetry study, detection rate good to fair (90% spring and 75% summer).

Hansel, H. C., J. W. Beeman, T. D. Counihan, J. M. Hardiman, B. D. Liedtke, M. S. Novick, and J. M. Plumb. 2000. *Estimates of Fish-, Spill-, and Sluiceway Passage Efficiencies of Radio-Tagged Juvenile Steelhead and Yearling Chinook Salmon at The Dalles Dam, 1999*. Annual Repot of Research, 1999, by the U.S. Geological Survey to the U.S. Army Corps of Engineers – Portland District.

Objectives: 1) determine the proportion of radio-tagged juvenile steelhead and yearling chinook salmon passing through the spillway and powerhouse (via turbines or sluiceway) at The Dalles Dam during 30% and 64% spill treatments, and 2) obtain information on behavior of radio-tagged fish including: forebay approach, residence time, time of passage, and route of passage.

Methods, Key Results, and Data Quality Assessment: Radio-tagged yearling chinook salmon (n=469) and yearling steelhead (n=479) were released 23 km above John Day Dam. An additional 300 steelhead and 297 yearling chinook salmon were also radio-tagged and released from the John Day juvenile bypass. In 1999, tests were conducted at The Dalles Dam to determine spill and fish passage efficiency during 30% and 64% spill treatments. Each spill treatment (i.e., 30% or 64%) was run for three consecutive days within a 6-day block and repeated for four blocks in the spring. A juvenile spill pattern (concentrated at north gates) was run at night and the adult pattern (concentrated at mid gates) was run during the day. Steelhead FPE did not differ significantly between treatments, but yearling chinook salmon FPE was significantly greater during the 64% treatment than the 30% treatment. Steelhead and yearling chinook salmon spill passage efficiency estimates were significantly greater during 64% spill than at 30% spill. Sample sizes were high for a radio telemetry study. Coverage was very good with both aerial and underwater antennas with fast scanning DSPs. Detection percentages were very high also, with 81% of the steelhead from above John Day Dam and 89% of the steelhead from the John Day bypass detected and 79% of the yearling chinook salmon detected from both release sites.

Allen, M. B. and nine co-authors. 2001a (Preliminary). *Movement, Distribution and Behavior of Radio-Tagged Yearling Chinook Salmon in the Tailrace of The Dalles Dam, 2000*. Annual Report of Research, 2000, by the U.S. Geological Survey to the U.S. Army Corps of Engineers – Portland District.

Objectives: To determine: 1) movement patterns and residence times of yearling chinook salmon in the tailrace, 2) relationships between juvenile salmonid routes of travel through the tailrace and residence times, 3) diel differences in tailrace passage behavior, and 4) hydraulic conditions likely experienced by fish in the tailrace through deployment of drift drogues.

Methods, Key Results, and Data Quality Assessment: The project conditions were a constant 40% spill, using the juvenile pattern. From April 30 to May 27, 375 radio-tagged yearling chinook salmon were released. The sluiceway fish had significantly longer mean residence times to the basin island monitoring site than all other release groups, both day and night. South spill fish were next highest, and north spill fish and control fish were similar. There were no significant diel effects for any release. Predation events have not yet been analyzed for this study. Sample sizes were high, and the detection rate was good (90%).

Beeman, J. W., H. C. Hansel, P. V. Haner, and J. M. Hardiman. 2000 - Preliminary. *Estimates of Fish-, Spill-, and Sluiceway Passage Efficiencies of Radio-Tagged Juvenile Steelhead and Yearling Chinook Salmon at The Dalles Dam, 2000*. Annual Repot of Research, 2000, by the U.S. Geological Survey to the U.S. Army Corps of Engineers – Portland District.

Objectives: 1) determine the proportion of radio-tagged juvenile steelhead and yearling chinook salmon passing through the spillway and powerhouse (via turbines or sluiceway) at The Dalles Dam during 40% spill, and 2) obtain information on behavior of radio-tagged fish including forebay approach, residence time, time of passage, and route of passage.

Methods, Key Results, and Data Quality Assessment: Radio-tagged yearling chinook salmon (n=912) and yearling steelhead (n=911) were released 23 km above John Day Dam and in the John Day juvenile bypass, spillway, and tailrace. In 2000 tests were conducted at The Dalles Dam to determine spill and fish passage efficiency during a constant 40% spill with a continuous juvenile (north) spill pattern. Steelhead FPE was 91%; spill passage efficiency was 85%; and sluiceway passage efficiency was 6%. For yearling chinook salmon, FPE was 85%, spill passage efficiency was 79%, and sluice passage efficiency was 6%. Spill effectiveness estimates were 2.2:1 for steelhead and 2.0:1 for yearling chinook salmon. The high spill passage effectiveness may account for the low sluice passage efficiency relative to other years. Sample sizes were high for a radio telemetry study. Coverage was very good with both aerial and underwater antennas with fast scanning DSPs. Detection percentages were very high also, with 87% for steelhead and 89% of the yearling chinook salmon detected from all release sites.

A.3 Survival

Dawley, E. M., L. G. Gilbreath, E. P. Nunnallee, and B. P. Sandford. 1998. *Relative Survival of Juvenile Salmon Passing through the Spillway of The Dalles Dam, 1997*. Report to the U.S. Army Corps of Engineers, Portland District, Contract E96970020. 48p.

Objectives: Estimate the relative survival of juvenile coho salmon and sub-yearling chinook salmon passing through The Dalles Dam spillway when 64% of the river flow passed through the spillway.

Methods, Key Results, and Data Quality Assessment: Approximately 43,000 yearling coho salmon and 53,000 sub-yearling chinook salmon were collected at the Bonneville Dam Second Powerhouse and tagged with PIT tags. Half were released upstream from the spillway at The Dalles Dam and half at a reference site below the 197 Highway Bridge, away from high turbulence and predator habitat. An average of 12% of the coho salmon and 14% of the sub-yearling chinook salmon were interrogated at Bonneville Dam. Relative survival rates for fish passing the spillway were 87.1% (95% CI: 80.4-93.9%) for coho salmon and 92.1% (95% CI: 85,5-98.7%) for sub-yearling chinook salmon. Survival appeared higher for fish that passed the spillway at night (juvenile pattern) compared with those that passed during the day. However sample sizes were too small to be statistically significant. Coho salmon used exclusively instead of chinook salmon yearlings. Sample sizes were too small to detect differences related to any factors (e.g., spillway location, gate openings, spill patterns, etc.) other than overall spillway versus reference survival. Confidence intervals were fairly wide.

Dawley, E. M., L. G. Gilbreath, R. F. Absolon, B. P. Sandford, and J. W. Ferguson. 2000. *Relative Survival of Juvenile Salmon Passing through the Spillway and the Ice-Trash Sluiceway of The Dalles Dam, 1998*. Report to the U.S. Army Corps of Engineers, Portland District, Contract E96970020. 85p.

Objectives: Determine the juvenile salmonid relative passage survival through the spillway at high spill (64%) and moderate spill (30%), and through the ice-trash sluiceway during daytime periods of 30% spill.

Methods, Key Results, and Data Quality Assessment: Approximately 64,000 yearling coho salmon and 80,000 sub-yearling chinook salmon were collected at the Bonneville Dam Second Powerhouse and tagged with PIT tags. About equal portions (20%) were released through the spillway at 64% spill, the spillway at 30% spill, and the sluiceway at 30% spill; about 40% were released at a reference site below the 197 Highway Bridge. An average of 12% of the coho salmon and 4.8% of the sub-yearlings were interrogated at Bonneville Dam. Relative survival rates for fish passing the spillway at 64% were 89% (95% CI: 82-96%) for coho salmon and 75% (95% CI: 68-83%) for sub-yearling chinook salmon. At 30% spill, coho salmon survived at 97% (CI 88-107%) and sub-yearlings at 89% (CI 80-99%). Relative survival for sluiceway passage was 96% (CI 87-105%) for coho salmon and 89% (CI 81-98%) for sub-yearlings. Coho salmon were used exclusively instead of chinook salmon yearlings. Confidence intervals were quite wide. Detections of tagged sub-yearling chinook salmon at Bonneville were low (5.3%).

Dawley, E. M., C. J. Ebel, R. F. Absolon, B. P. Sandford, and J. W. Ferguson. 2000. *Relative Survival of Juvenile Salmon Passing through the Spillway of The Dalles Dam, 1999*. Report to the U.S. Army Corps of Engineers, Portland District, Contract W55QKZ83437725. 42p.

Objectives: Determine the juvenile salmonid relative passage survival through the spillway at high spill (64%) and moderate spill (30%). The ice-trash sluiceway was not tested in 1999 in order to increase test numbers for the spillway and increase overall precision.

Methods, Key Results, and Data Quality Assessment: Approximately 139,000 yearling chinook salmon and coho salmon (spring migrants) and 167,000 sub-yearling chinook salmon were collected at John Day Dam and tagged with PIT tags. About 50% were released through the spillway at either 30 or 64% spill, and about 50% were released at a reference site below the 197 Highway. Bridge. An average of 16% of the spring yearlings and 12% of the sub-yearlings were interrogated at Bonneville Dam. Relative survival rates for fish passing the spillway at 64% were 94% (95% CI: 90-97%) for spring migrants and 96% (95% CI: 92-100%) for sub-yearling chinook salmon. At 30% spill, spring migrants survived at 95% (CI 91-98%) and sub-yearlings at 100% (CI 96-104%). Nighttime relative survival rates were substantially higher than daytime survival rates. Numbers of tagged fish were higher and precision was higher than in previous studies.

Dawley, E. M., and R. F. Absolon. 2000 (Preliminary). ***Relative Survival of Juvenile Salmon Passing through the Spillway of The Dalles Dam, 2000*****. Abstract to the U.S. Army Corps of Engineers, Portland District, for presentation at the AFEP Annual Research Review.**

Objectives: Determine the juvenile salmonid relative passage survival through the spillway, the ice-trash sluiceway, and turbines.

Methods, Key Results, and Data Quality Assessment: Approximately 89,920 yearling chinook salmon, 45,555 coho salmon (spring migrants) and 161,862 sub-yearling chinook salmon were tagged with PIT tags. About equal numbers were released at each of the above sites plus at a reference site below the 197 Highway Bridge. An average of 20% of the spring migrants and 3.5% of the sub-yearlings were interrogated at Bonneville Dam. Spill level was kept at 40% throughout the study and the juvenile pattern was also. In spring, relative survival was 95% (95% CI: 92-99%) for fish passing the spillway, 95% (95% CI: 92-98%) for fish passing the sluiceway, and 81% (95% CI: 78-84%) for fish passing turbines. In summer, sub-yearling chinook salmon survival was 92% (95% CI: 83-101%) for the spillway, 96% (95% CI: 88-104%) for the sluiceway, and 84% (95% CI: 76-92%) for turbines. No significant differences were found relative to the diel period. Detections of tagged sub-yearling chinook salmon at Bonneville were quite low (3.5%). Confidence intervals were wide for summer tests.