U.S. Army Corps of Engineers
Northwest Division

ANADROMOUS FISH EVALUATION PROGRAM

FY 08 FINAL PROPOSALS

23 October, 2007

Title	Study Code
Spillway Passage Survival Of Juvenile Salmonids At Bonneville Dam	SPE-P-02-1
Acoustic Telemetry Study of Juvenile Salmonid Dam and Spillway Survival at Bonneville Dam in 2008	SPE-P-02-1
Acoustic Telemetry Evaluation Of A Behavioral Guidance Structure At Bonneville Dam Second Powerhouse	SPE-P-08-1
Effects Of Total Dissolved Gas On Chum Fry	SPE-P-07-1
Post-Passage Condition And Gatewell Retention Time Of Subyearling And Yearling Chinook Salmon Guided From Modified Bonneville Dam Second Powerhouse Turbine Intakes	SPE-P-08-3
Acoustic Telemetry Study To Evaluate Juvenile Fish-Passage Efficiency And Survival Associated With Surface-Spill Treatments At John Day Dam In 2008	SPE-P-08-2
Direct Survival and Injury Evaluation of John Day Dam's TSW	SPE-P-08-2
Studies Of Surface Spill At John Day Dam	SPE-P-08-2
Hydroacoustic Evaluation Of Fish Passage For Surface Flow Outlet Development At John Day Dam, 2008	SPE-P-08-2
Monitor Tailrace Egress And Hydraulic Conditions During Tests Of A Top Spillway Weir (TSW) At John Day Dam.	SPE-P-08-2
Smolt Responses To Hydrodynamic And Physical Characteristics Of Forebay Flow Nets Upstream Of Surface Flow Outlets	SBC-W-06-01 SBE-P-00-17
Fish Passage Survival at Lower Monumental and Ice Harbor Dams	SPE-W-05-1 SPE-W-07-1
Comparative Performance Of Acoustic-Tagged And PIT-Tagged Juvenile Salmonids.	SPE-06-2
Biological Index Testing At Turbines: Vertical And Horizontal Distributions Of Juvenile Salmonids Approaching A Turbine Distributor At John Day Dam, 2008	TSP-06-01 Objective 3
Pressure Investigations To Support Biological Index Testing Synthesis: Objective 6 - Assessment Of Population Level Risk Of Mortal Injury Resulting From Pressure Exposure During Turbine Passage	TSP-05-1 Objective 6
Investigation Of Adult Salmon And Steelhead Straying In The Lower Columbia River	ADS-00-4
Evaluation Of An Instream Passive Integrated Transponder Site To Monitor Adult Steelhead Movements In The John Day River - 2008	ADS-00-4

Title	Study Code
Evaluation Of Steelhead Kelt Passage Through The Bonneville Dam Second Powerhouse Corner Collector Prior To The Juvenile Migration Season	ADS-00-1 ADS-P-00-6
Migratory Pheromones: Potential Tools To Improve Performance Of Adult Lamprey Passage Structures At Dams.	ADS-P-00-8
Improving Adult Pacific Lamprey Passage And Survival At Lower Columbia River Dams - 2008	ADS-P-00-8
An Assessment Of Interdam Loss And Fates Of Adult Pacific Lamprey In The Lower Columbia River - 2008	ADS-P-00-8
Evaluating Methods To Estimate True Escapement Of Adult Pacific Lamprey Migrants At Bonneville And The Dalles Dams - 2008	ADS-P-00-8
Evaluation of Adult Pacific Lamprey Passage Success at McNary and lower Snake River Dams – 2008	ADS-P-00-8
Developing a Separator for Juvenile Lamprey	ADS-P-00-8
Evaluation Of California Sea Lion (Zalophus Californianus) And Other Pinniped Predation In The Bonneville Dam Tailrace	ADS-P-02-16
Studies To Estimate Salmonid Survival Through The Columbia River Estuary Using Acoustic Tags	EST-02-01
Evaluating Cumulative Ecosystem Response To Habitat Restoration Projects In The Lower Columbia River And Estuary	EST-02-P-04
Alternative Barging Strategies to Improve Survival of Transported Juvenile Salmonids	TPE-W-06-02
Evaluate the Effectiveness of Transporting Subyearling Chinook Salmon from McNary Dam	TPE-W-04-03
A Study to Determine the Seasonal Effects of Transporting Fish from the Snake River to Optimize a Transportation Strategy	TPE-W-04-1
Sampling PIT-tagged Juvenile Salmonids Migrating in the Columbia River Estuary	
Evaluating the Responses of Snake and Columbia River Basin fall Chinook Salmon to Dam Passage Strategies and Experiences	
Evaluate the Impacts of Avian Predation on Salmonid Smolts from the Columbia and Snake Rivers	AVS-W-03

RESEARCH PROPOSAL
SUBMITTED TO THE U.S. ARMY CORPS OF ENGINEERS UNDER THE ANADROMOUS FISH EVALUATION PROGRAM
2008 PROJECT YEAR

I. BASIC INFORMATION

A. TITLE OF PROJECT

Spillway Passage Survival of Juvenile Salmonids at Bonneville Dam – Characterization of Fish Passage Conditions using Sensor Fish

B. PROJECT LEADERS

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C. STUDY CODES

SPE-P-02-1.

D. ANTICIPATED DURATION

January 2008 - December 2008

E. DATE OF SUBMISSION

October 2007

II. PROJECT SUMMARY

A. GOALS

1. Distinguish differences in fish passage conditions between spillbays with flow deflectors located at elevations of 7 ft mean sea level (MSL) and 14 ft MSL during high and low spill flows.
2. Determine whether concrete erosion on the spillway ogee is affecting passage conditions that fish may be exposed to during spillway passage.

B. OBJECTIVES

1. Evaluate and compare passage conditions that fish may experience during spillway passage through bays with flow deflectors located at elevations of 7 ft MSL and 14 ft MSL at high and low spill flows.
2. Evaluate passage conditions observed at spillbays following erosion repair.

3. Identify potential regions within the passage route that may cause mortality or injury to live fish.

C. METHODOLOGY

We propose the use of Sensor Fish Devices to assess the conditions that live fish are exposed to during passage in spill at Bonneville Dam. The Sensor Fish is a 6 DOF sensor with tri-axial acceleration and rotation sensors and an absolute pressure sensor. Pressure, acceleration, and rotation time histories provide a detailed record of the sensor's response to hydraulic and mechanical forces (e.g. collision, shear, severe turbulence) during passage through the fish passage route. Analysis of these data permits detailed assessment of the fish passage route, identification of potential problem areas, and can be an important element in understanding biological test results.

Release elevations and other features of experimental design will be determined in collaboration with CE project managers. It is expected that the same release elevations and other features of experimental design will be very similar or the same as those for the live fish balloon tag study that is proposed to take place concurrently with the Sensor Fish study. At this time a minimum of 35 successful sensor releases per treatment (combination of release elevation, spillbay and total spill discharge, tailwater elevation, spillbay, and deflector elevation) will be required to achieve sample size objectives.

Collaboration with Normandeau Associates, Inc. (Normandeau) will be required for Sensor Fish release and recapture.

D. RELEVANCE TO THE BIOLOGICAL OPINION

This study addresses Biological Opinion Hydro Sub Strategy 1.4, *Project Configuration Research, Monitoring, and Evaluation,* providing information on passage efficiencies and survival through past projects and the evaluation of passage facilities, as well as the Reasonable and Prudent Alternative (RPA) Action 82 on spill survival which allows the investigation of spill patterns and per-bay spill volumes across a range of flow conditions.

III. PROJECT DESCRIPTION

A. BACKGROUND

The Corps of Engineers is committed to increasing survival rates for fish passage though its projects on the Columbia River. The success of management and site improvements are often measured by survival study results. During the last several years, direct survival rates have been measured using balloon tag studies in conjunction with Sensor Fish at projects on the Columbia and Snake Rivers. This team effort has provided information to identify and locate regions within the hydropower system (i.e. spillways, deflectors, stay vanes, runner, draft tubes, etc.) that may be detrimental to fish survival.

A.1. PROBLEM DESCRIPTION

Two types of flow deflectors are present on the downstream face of the spillbay ogees at Bonneville Dam. The older deflectors, installed in 1975, are positioned at 14 ft MSL and found in spillbays 4 through 15. In 2002, deeper spillway flow deflectors were installed in spillbays 1-3 and 16-18 at an elevation of 7 ft MSL. Following installation of the new deflectors, direct survival studies were conducted using balloon-tag techniques to evaluate direct injury and mortality. Survival for fish passing over the 14 ft elevation deflectors was compared to the survival of fish passing the 7 ft deflectors, but estimate precision was low. Results suggested that fish injury increased and survival decreased with low tailwater levels (Normandeau et al. 2003). Radiotelemetry studies conducted in 2004 and 2005 showed similar trends to those observed in the direct survival study: survival decreased as spill decreased and spillbays equipped with the higher 14 ft deflectors had lower survival than spillbays with the lower (7 ft) deflectors.

During early 2007 substantial erosion was observed on the concrete on the ogee of spillbays 9, 12, and 14, and on north and south areas of the basin apron. Effects of this erosion on fish passage conditions and passage injury and survival have not been determined.

A. 2. SITE DESCRIPTION

The Bonneville Project is located on the Columbia River at River Mile 146.1, approximately 40 miles east of Portland, Oregon. The project is composed of two powerhouses, a spillway, and fish passage facilities. The spillway consists of 18 spillbays, each 50 ft wide, and is located between Bradford and Cascades islands.

B. OBJECTIVES

1. Compare the passage conditions (as determined by the Sensor Fish) between spillbays with deflectors located at 7 and 14 ft MSL at high and low spill flows.
2. Identify regions of potential fish injury due to passage conditions at spillbays with deflectors located at 7 and 14 ft MSL at high and low spill flows.
3. Evaluate the effectiveness of erosion repair on the spillway surface.

C. METHODOLOGY

Sensor Fish releases will be integrated into direct injury fish study design so that both the Sensor Fish and live test fish experience the same handling methods and exposure conditions. Sensor Fish will be equipped with balloon tags and a radio transmitter tag, supplied by Normandeau, and introduced into selected spillbays through release pipes that will be fabricated and installed by another contractor. Normandeau will provide Sensor Fish retrieval utilizing their boat crews and equipment. At least one Sensor Fish will be released with each lot of 10 balloon tagged treatment fish, with a minimum sample size of 35 Sensor Fish per treatment condition. In the event that live fish testing meets its confidence limits with a smaller sample size than anticipated, Sensor Fish sample size will be maintained so that a nearly equal number of Sensor Fish data sets are acquired for each study treatment. In addition, several Sensor Fish will be used to evaluate release pipe elevations prior to the start of the study.

Field Work will include:

- Evaluation of release pipe injection elevations,
- Preparation of Sensor Fish for data acquisition and deployment,
- Assistance with injection of the sensors,
- Retrieval of Sensor Fish following boat crew recovery,
- Downloading acquired data using an infrared modem attached to a laptop computer,
- Evaluation of data for quality and function,
- Preparation of the Sensor Fish for its next deployment.

Field work will be divided into two distinct segments, spring (high flow ~100 kcfs total spill discharge) and summer (low flow~85 kcfs total spill discharge).

Data Processing and Analysis:

- Following acquisition, Sensor Fish data sets will be processed to convert acquired data from binary to ASCII format. Quality assurance checks will be performed and each data set will be incorporated into a database with accompanying metadata. Metadata records identify the time, treatment, and provide other information that qualifies the data by describing the conditions under which it was acquired and initially processed. Procedures for data entry and validation developed during the "TDA Spill Sensor Fish, Balloon Tag, Data Base Case Study" will be followed.
- Data processing includes standardization of the time base for the pressure and tri-axial linear and angular accelerations, followed by computation of the magnitude and angular arguments for the acceleration vectors and isolation of singular events such as strikes, collisions, and severe turbulence exposures. Analysis is conducted to: (1) compute summary statistics that describe hydraulic exposure conditions for each passage history, (2) quantify (magnitude, duration, location, etc.) and classify significant shear and collision events, (3) qualitatively and quantitatively compare passage conditions by treatment, (4) assess the likely impact on fish of the various passage treatments, and (5) relate exposure metrics to live fish direct mortality and injury test results.
- Data integration and collaboration with Normandeau Associates, Inc., and their live fish direct injury/survival study findings are necessary to provide rapid information transfer to Corps personnel. Sensor Fish data, as well as balloon tag study data, will be incorporated into the new Sensor Fish database to better facilitate data assimilation and conclusions. The resulting data base will be a joint deliverable of the Sensor Fish and Balloon Tag studies.

D. FACILITIES AND EQUIPMENT

The proposed project will require access to the Bonneville Dam during the period of study. Staff will attend any coordination, planning, and/or safety meetings with Portland District and

Bonneville Dam personnel, as required. PNNL will provide the sensor fish required for the study at no cost to the Corps. However, Sensor Fish lost or irreparably damaged during conduct of the study will need to be replaced by the Corps.

E. IMPACTS

The proposed project has no known or expected impacts on other ongoing or proposed research projects at Bonneville Dam.

F. COLLABORATIVE ARRANGEMENTS AND/OR SUB-CONTRACTS

The proposed project requires collaboration with Normandeau Associates, Inc. for the utilization of their balloon tags, radio tags, and for the retrieval of the Sensor Fish from the tailrace. They are proposing under a separate contract.

Collaboration with Normandeau will also be required to integrate balloon tag and Sensor Fish data results into a common database for data analysis and as a deliverable to the CE to satisfy both primary and secondary uses of these data sets. The Normandeau contribution to inclusion of data into a common data base will be expensed separately under the Normandeau contract.

No sub-contracts are expected.

IV. KEY PERSONNEL AND PROJECT DUTIES

The proposed project will utilize only fully qualified professional staff with applicable and pertinent expertise in the conduct of this work.

V. TECHNOLOGY TRANSFER

Management use of the information provided by this project will aid in the decision making for the optimization of spillway passage efficiency to improve survival of juvenile salmonids.

VI. REFERENCES

Normandeau Associates Inc., Mid Columbia Consulting Inc., and J. R. Skalski. 2003. *Juvenile Salmonid Survival and Condition in Passage through Modified Spillbays at Bonneville Dam, Columbia River*. Prepared for U.S. Army Corps of Engineers, Portland District, Portland, Oregon, by Normandeau Associated Inc., Drumore, Pennsylvania.

FINAL RESEARCH PROPOSAL

SUBMITTED TO THE U.S. ARMY CORPS OF ENGINEERS UNDER THE ANADROMOUS FISH EVALUATION PROGRAM 2008 PROJECT YEAR

I. BASIC INFORMATION

A. TITLE OF PROJECT

Acoustic Telemetry Study of Juvenile Salmonid Dam and Spillway Survival at Bonneville Dam in 2008

B. PROJECT LEADERS

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C. STUDY CODES

SPE-P-02-1: Spillway Passage Survival of Juvenile Salmonids at Bonneville Dam

D. DURATION

January 2008 to February 2009 (Draft Report) and then 60 d after receipt of regional comments

E. DATE OF SUBMISSION

August 16, 2007

II. PROJECT SUMMARY

A. GOAL

The goal of this study is to make dam and spillway survival estimates for juvenile salmonids tagged with JSATS acoustic tags by studies conducted upstream and downstream of Bonneville Dam (BON) based on detections of tagged fish on hydrophone arrays in the forebay and tailwater.

B. OBJECTIVES

1. Estimate single- and paired-release Dam survival for yearling Chinook salmon in spring and for subyearling Chinook salmon in summer.
2. Estimate single-release estimates of Dam survival for juvenile steelhead in spring. The USACE has decided that there will be no route-specific nor reference releases of steelhead at BON, so only single-release survival estimates will be possible for this species.
3. Estimate single and paired-release survival for spillway-passed yearling Chinook salmon in spring and for spillway-passed subyearling Chinook salmon in summer, each by spill bay deflector type. Individual spill bay of passage will be determined, but numbers passing individual bays are unlikely to be sufficient for precise survival estimates.
4. Estimate single-release survival for spillway-passed steelhead.
5. Compare spillway survival estimates from this study to estimates for the B2CC and B2 JBS, as determined in a separate study of a B2 Behavioral Guidance Device (BGS), and compare 2008 absolute estimates of dam survival and spillway survival with estimates in previous years.

C. METHODOLOGY

This proposed study will provide low-cost estimates of dam and spillway survival for JSATS-tagged salmonids from the 2008 John Day Dam (JDA) Survival Study[1]. We will create virtual releases from fish detected on a spillway array or on a forebay array located upstream of the trifurcation to the three project forebays. We will use the forebay virtual releases and Tailwater releases of yearling and subyearling Chinook salmon by the Post Federal Columbia River Power System (FCRPS) Study to make absolute survival estimates for juvenile Chinook salmon each season using paired-release models. There will be three survival arrays of autonomous nodes located at least 100 km downstream of BON to detect acoustically tagged fish and to estimate detection histories for survival models. We will use Cormack (1964), Jolly (1965), and Seber (1965) CJS models to make single-release estimates for juvenile Chinook salmon and steelhead. We will use a paired-release model like that described by Peven et al. (2005) to make absolute survival estimates for juvenile Chinook salmon each season. The USACE decision not to make Tailrace releases of steelhead will prevent us from estimating absolute survival for steelhead in 2008.

We anticipate that single-release survival estimates will be the primary metrics for comparing survival among types of bays, routes, or spill conditions for hypothesis testing. The hypothesis testing also will compare spillway survival estimates with B2CC and B2 JBS survival estimates made by a related B2 BGS Study.

We will compare paired-release survival estimates for juvenile Chinook salmon to paired-release estimates made in 2006 (Ploskey et al. 2007a) and 2007 (Ploskey et al., In preparation), and by radio telemetry studies in earlier years (Counihan et. al. 2002, 2003, 2006a, 2006b).

D. RELEVANCE TO THE BIOLOGICAL OPINION

As part of the remand process for the 2004 Biological Opinion on Federal Columbia River Power System (FCRPS) operations, the Action Agencies submitted to the U.S. District Court, District of Oregon a draft Proposed Action dated May 21, 2007. Hydrosystem Strategy 2 of the Proposed Action states, "Modify

[1] A JDA survival study will release 2,500 YC salmon and 2,500 steelhead (STH) in spring and 2,500 subyearling Chinook salmon (SYC) in summer in the McNary Tailrace. About 1000 each of YC salmon, STH, and SYC salmon are proposed for release at JDA to complete a triple-release model for the JDA study. If survival to BON is similar to that observed in previous years, arrivals at BON could number 3,037 YC salmon, 3,026 STH, and 2,526 SYC salmon. If spill efficiency (SPY) in 2008 is similar to the average SPY for the four non-drought years (2000, 2002, 2004, 2005), we expect to detect 1,306 YC salmon (SPY=43%), 1,150 STH (SPY=38%), and 1,308 SYC salmon (SPY=52.3%).

Columbia and Snake river dams to maximize juvenile and adult fish survival." This strategy includes the following measures for juvenile passage and survival at Bonneville Dam.

- Action 11 – Powerhouse Improvement Actions – "*Providing or enhancing powerhouse surface flow outlets" and "Making improvements to juvenile bypass systems…"*
- Action 12 – Spillway Improvement Actions – "*Making improvements to spillways to reduce injury, reduced tailrace predation, facilitate downstream egress, and reduced TDG levels*"

III. PROJECT DESCRIPTION

A.1. PROBLEM DESCRIPTION

Survival estimates for two types of spillway passage routes through Bonneville Dam are needed to provide additional information to help managers make decisions regarding optimal structural design or spillway operations to maximize survival. Preliminary results from a 2007 spillway survival study indicate that yearling and subyearling Chinook salmon survival exceeded 94% throughout spring and summer, but route-specific results are not yet available. In addition, substantial erosion of concrete within the stilling basin of the spillway was observed for the first time in early spring 2007. Areas most affected by this erosion were downstream of spill bays 9, 12, and 14, and the effects on dam safety as well as alternatives for fixing the ogee are currently being evaluated. The effect on fish-passage survival at this time is unknown.

A.2. BACKGROUND

Bonneville Dam was recognized as being one of the biggest total dissolved gas (TDG) producers in the Columbia River basin prior to the construction of additional spillway flow deflectors in 2002. During the winter of 2001-2002, six new spillway flow deflectors were constructed at Bonneville Dam to reduce the production of TDG during spillway discharge. The new flow deflectors in spill bays 1-3 and 16-18 were placed 7 ft deeper than the existing flow deflectors located in Bays 4 through 15. A new spill pattern was also implemented in conjunction with the addition of the new flow deflectors. A study was conducted throughout the 2002 spill season to determine the TDG exchange characteristics of spill operations at Bonneville Dam (Schneider et al. 2003). They found that the addition of six new flow deflectors and the corresponding change in spill pattern significantly reduced the TDG saturation when compared to similar spill rates observed prior to the 2002 spill season, but the degree of improvement over pre-2002 conditions declined with increasing discharge. The estimated reduction in TDG saturation for a spill discharge of 75,000 cfs was 10 percent of saturation. For low tailwater elevations, ranging from 10.2 to 13.7, the new flow deflectors generated considerably lower TDG pressures than the old deflectors.

Two types of spillway deflectors have been evaluated in direct survival studies using balloon tags (Normandeau et al. 1996 and 2003) and indirect survival studies using radio telemetry (Counihan et al. 2006a and 2006b). In both cases, trends were apparent, although usually not significant, and further evaluations are needed to identify effects and confirm results. New spillway flow deflectors were installed at bays 1-3 and 16-18 and new spill patterns were implemented at BON in 2002. Effects of the new deep deflector types at elevation 7 ft above MSL were compared with effects of old deflectors at elevation 14 ft above MSL in a balloon-tag study to measure the direct survival under a high and low tailwater. The 2002 data suggested that when tailwater surface elevations are low, injury increased and survival decreased. Survival for elevation 14-ft deflectors were compared with survival of fish released at bays with elevation 7-ft defectors, but estimates of precision were low (Normandeau et al. 2003). Radio-telemetry survival studies conducted in 2004 and 2005 showed a trend of decreasing survival for decreasing spill volumes, and bays equipped with the higher (14 ft) flow deflectors usually had lower survival than bays with the lower (7 ft) deflectors. Most results were not statistically significant, but there was some consistency in trends. One operational explanation for the lower survival was a new spill pattern, which used smaller gate openings and more spill bays for the 75,000 cfs day spill. In 2006, a total survival evaluation looked at 100,000 cfs spill for 24-hours per day in the spring and a modified Bi-Op spill with larger gate openings in summer. Unfortunately, effects of spill condition were confounded with a typical decline in the survival of subyearling Chinook salmon as summer progressed. There are a number of factors governing spill at Bonneville, including TDG limitations and effects of spill on adult passage. The former may preclude the ability to spill 100,000 cfs all of the time in spring. Therefore, a better understanding of the spillway mortality mechanism is needed so that decisions can be made regarding structural versus operational changes to improve survival.

The Corps of Engineers is committed to increasing survival rates for fish passing its projects on the Columbia River, and survival is one of the primary measures of success of management improvements at hydropower projects. The earliest survival studies at BON were conducted between 1939 and 1945, summarized by Holmes (1952), and estimated survival ranging from 85-89 percent. The next series of investigations that assessed the effects of turbine passage on smolt survival (as part of a much broader research effort) commenced in 1987 and continued in most years through 1992 (Dawley et al. 1988 and 1989; Ledgerwood et al. 1990, 1991, and 1994). Giorgi et al. (2005) pointed out that the scope of those studies was broad and involved a variety of treatments and reference (control) releases that varied through the years. Short-term survival was estimated using branded fish recovered with seines near Jones Beach. Long-term survival was to be based on recoveries of CWT at hatcheries and within the fishery. Unfortunately, adult return rates were so low that meaningful comparisons among treatment and reference groups was impractical (Gilbreath et al. 1992). Other indirect survival studies at Bonneville include Counihan et al. (2002), Counihan et al. (2003), Counihan et al. (2006a and b), and Ploskey et al. (2007). Indirect survival studies have been conducted at the spillway (Normandeau et al. 1996, 2003), B1 turbines (Normandeau et al. 2000), and the B2CC (Normandeau et al. 2001).

A.3. SITE DESCRIPTION

The primary study site includes the Bonneville Dam Forebay down to Kalama, WA (Figure 1). Survival arrays for this study will be ≥ 100 km downstream of BON in response to rare detections of a few dead fish released at BON in previous survival arrays, including a tertiary array previously located about 42 km below BON near Camas, WA.

B. OBJECTIVES

1. Estimate single- and paired-release Dam survival for yearling Chinook salmon in spring and for subyearling Chinook salmon in summer.
2. Estimate single-release estimates of Dam survival for juvenile steelhead in spring. The USACE has decided that there will be no route-specific nor reference releases of steelhead at BON, so only single-release survival estimates will be possible for this species.
3. Estimate single and paired-release survival for spillway-passed yearling Chinook salmon in spring and for spillway-passed subyearling Chinook salmon in summer, each by spill bay deflector type. Individual spill bay of passage will be determined, but numbers passing individual bays are unlikely to be sufficient for precise survival estimates.
4. Estimate single-release survival for spillway-passed steelhead.
5. Compare spillway survival estimates from this study to estimates for the B2CC and B2 JBS, as determined in a separate study of a B2 BGS, compare 2008 absolute estimates of dam survival and spillway survival with estimates in previous years.

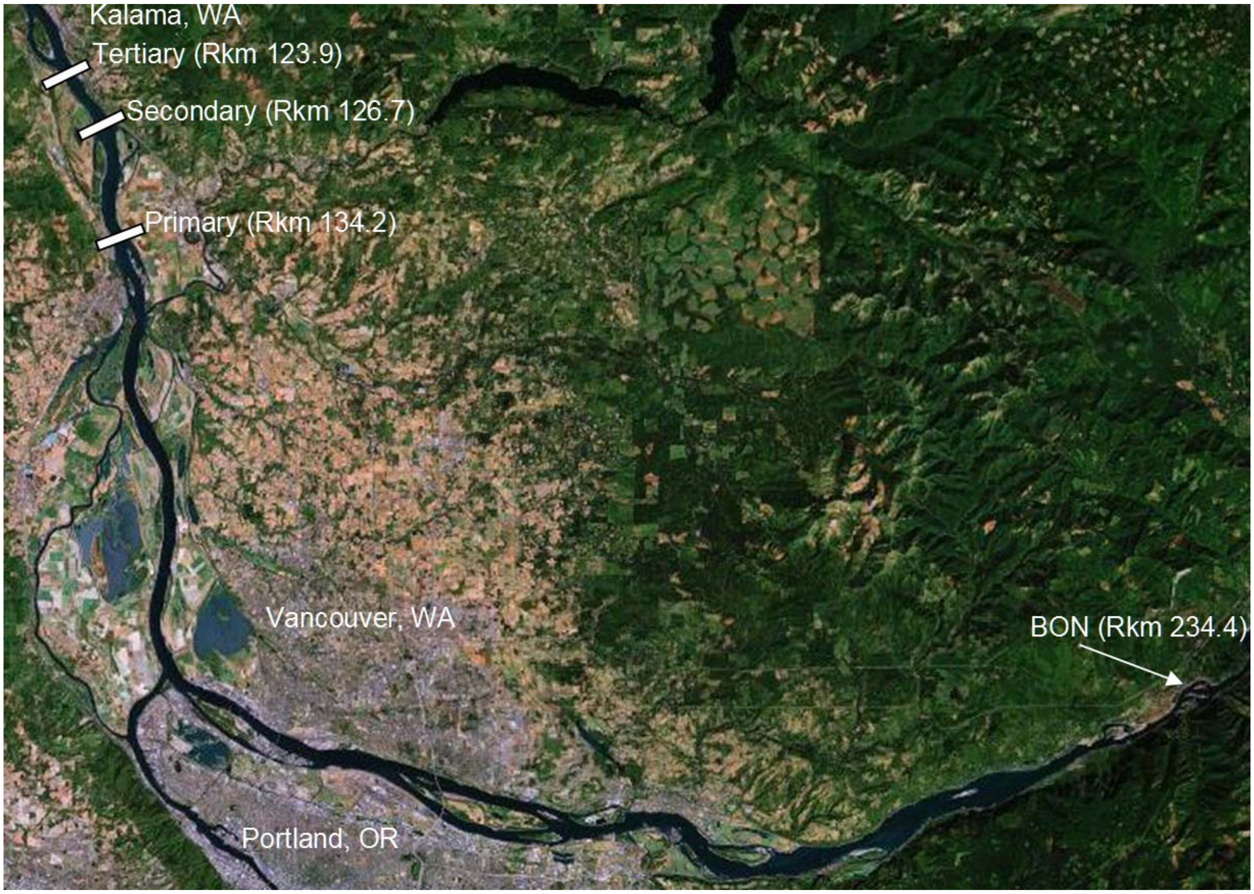

Figure 1. Map Showing the Primary Area for the Proposed 2008 Study. PIT-and JSATS-tagged fish will be released upstream in a JDA Survival Study and will be detected and regrouped on a spillway tracking array and on a BON entrance array above the trifurcation to the three Project forebays to form virtual releases of fish. The Post FCRPS Survival Study will make route-specific releases in the B2CC and reference releases in the BON Tailwater. All virtual, route-specific and Tailrace releases have the potential to be detected on the primary, secondary, and tertiary tailwater arrays located 100, 107.7, and 110.5 km downstream of the BON.

C.1. METHODS

As conceived, this proposed study will provide low-cost estimates of dam and spillway survival for JSATS-tagged salmonids using releases from the 2008 John Day Dam (JDA) Survival Study upstream and from the Post Federal Columbia River System (FCRPS) Study downstream. The JDA Study will make 16 releases of 2,500 yearling Chinook salmon, 2,500 steelhead, and 2,500 subyearling Chinook salmon into the McNary Tailrace and 16 releases of 1,000 of each fish type at or below JDA to form route-specific and reference releases for the JDA study. The Post FCRPS Study will make 16 releases of yearling and subyearling Chinook salmon into the Tailrace each season. Historical travel times for fish migrating from upstream releases to BON will be examined to accurately estimate days of arrival as a function of river flow. Tailrace-reference releases will be scheduled for morning (0700-0900 hours), afternoon (1400-1600 hours), and sunset (2100-2200 hours) so that those fish traverse the tailrace during the day, evening, and night to mix with treatment fish, which are expected to arrive 24-h per day.

We will create virtual releases from fish detected on a forebay array located upstream of the trifurcation to the three Project forebays or tracked to a specific spill bay of passage by 2-D tracking hydrophones mounted 60-ft apart on spillway piers (Figure 2). The 2007 study of spillway survival indicated that this linear array provides for adequate tracking resolution to accurately specify the spill bay that each fish will pass. A fish track is a time series of position estimates converted to real-world coordinates. The frequency of tag transmission and fish speed will affect the spacing between successive positions. Fish from the JDA study will have tags that will transmit once every 3 s. For example, a smolt with a 3-second tag moving 2 ft / s would have about 6 ft between successive detections.

Figure 2. Photograph of Bonneville Dam Showing the Coverage of 2-D Tracking Nodes Mounted on Spillway Piers and Five Autonomous Nodes, Indicated by White Dots at the bottom, Forming a Project Entrance Array

In addition to the Project entrance array, we will deploy three survival arrays of autonomous nodes at least 100 km downstream of BON to detect acoustically tagged fish and estimate detection histories by route of passage for survival models (Figure 3). The use of three detection arrays will allow us to fully populate capture histories for two estimates of detection probabilities and survival and to test independence assumptions of the single-release models using Burnham Tests 2 and 3 (Burnham et al. 1987).

The maximum range of detection based upon the receiving sensitivity of JSATS autonomous nodes and the source levels of acoustic micro-tags ranges from about 300 to 400 ft depending upon ambient acoustic conditions in the river. We will space autonomous detection hydrophones within 300 ft of shore and < 500 ft from one another to ensure complete coverage of the intended sample volume at a cross section and provide some redundancy against the loss of a node inside the near-shore nodes. All arrays will be spaced far enough apart to prevent simultaneous detection of tagged fish by two arrays. Given the node density proposed in 2008, most detection probabilities should exceed 90%.

All autonomous nodes in the three downstream survival arrays and the Project entrance array will be checked weekly to download data and synchronize clocks, and they will be sequentially serviced every 28 days to install fresh batteries. Downloaded data will be stored on two sets of media to provide backup.

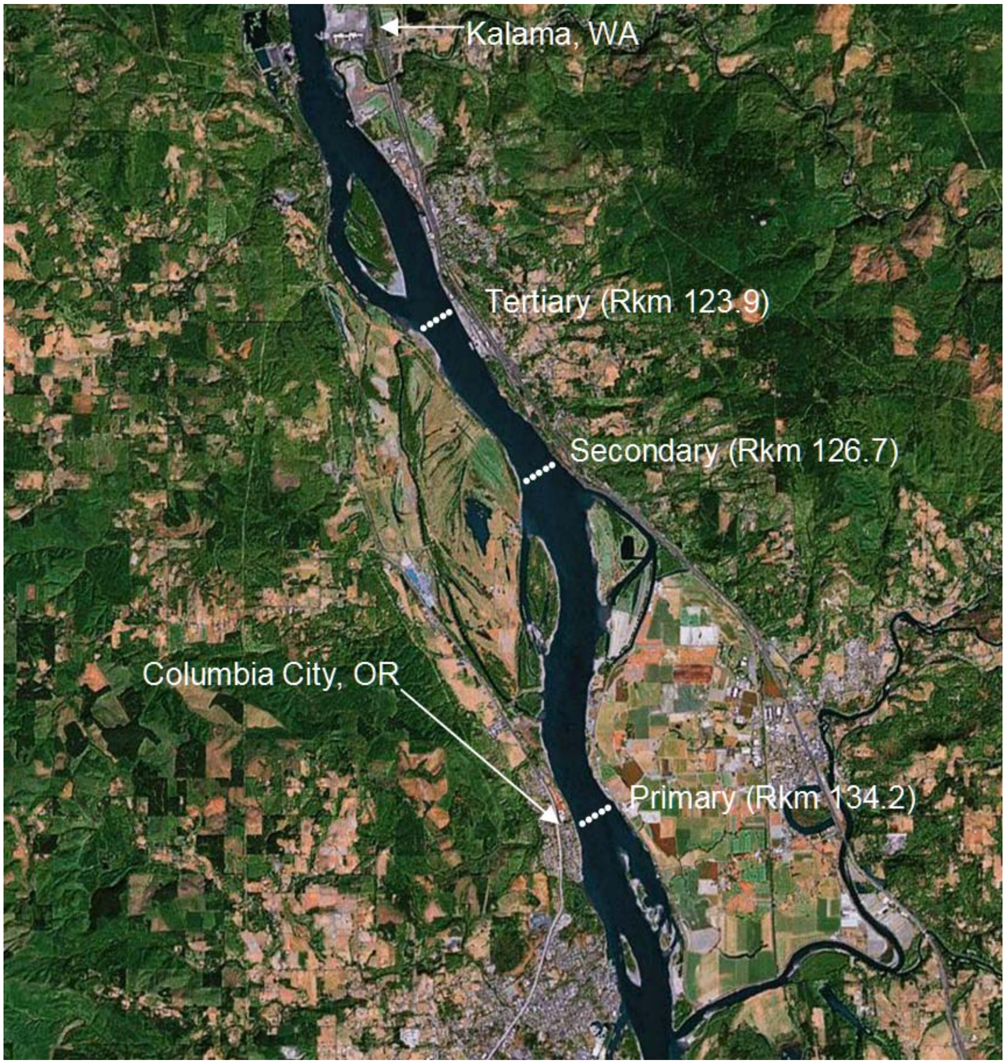

Figure 3. Picture of the Columbia River Illustrating the Autonomous Nodes in Three Survival arrays Proposed for the 2008 Study

We will use Cormack (1964), Jolly (1965), and Seber (1965) (CJS) models to make single-release estimates for juvenile Chinook salmon and steelhead. We will use a paired-release model described by Peven et al. (2005) to make absolute survival estimates for juvenile Chinook salmon each season, where absolute survival is defined as the ratio of two single-release estimates (Figure 4). We will estimate survival separately for fish released at different upstream locations (e.g., the McNary Tailrace, into the John Day Dam (JDA) JBS Channel, and into the JDA Tailrace). If survival estimates from forebay arrays to the primary survival array downstream of BON do not differ significantly, we also will provide estimates based on pooled numbers to improve precision.

We anticipate that single-release survival estimates will be the primary metrics for comparing survival among types of bays, routes, or spill conditions for hypothesis testing (Table 1) because single release estimates have higher precision than paired-release estimates at any given sample size. We also will compare spillway survival estimates with survival of fish passing the B2CC and B2 JBS, as estimated by a 2008 B2 BGS study (Table 1).

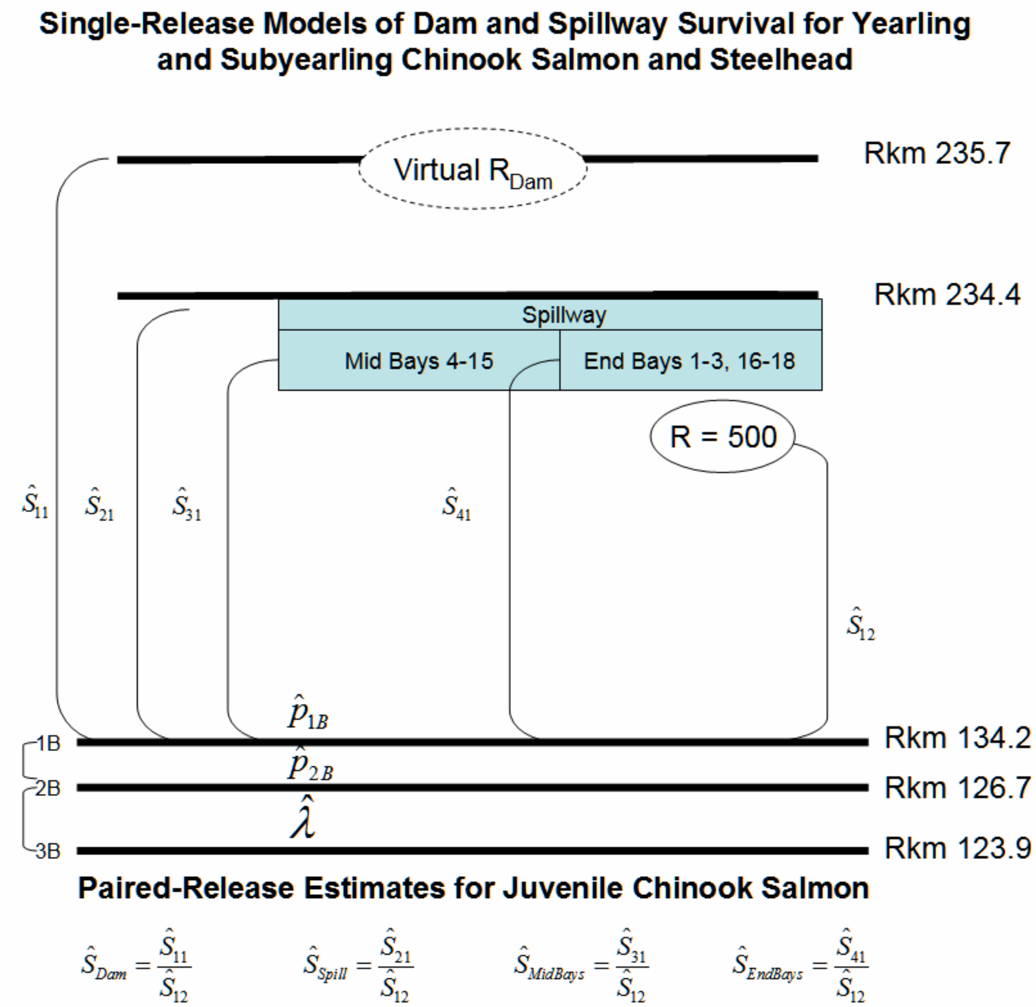

Figure 4. Diagram Illustrating Study Releases, Reaches, Arrays, and Single- and Paired Release Survival Estimates for the 2008 Study. Virtual releases will be formed from detections on a Project forebay array and on a 2-D tracking array at the spillway, and the Post FCRPS Study will release 500 yearling Chinook salmon in spring and 500 subyearling Chinook salmon in summer. Survival is indicated by $\hat{S}$, detection probability by $\hat{p}$, and $\hat{\lambda}$ represents the joint detection and survival probability to the tertiary array.

Table 1. Hypothesis testing based on single-release survival estimates to the primary survival array. One-tailed t-tests will have more power to reject the null hypothesis than would a two-tailed test on differences in mean survival.

H_0: Survival$_{\text{(Shallow Deflectors)}}$ not > Survival$_{\text{(Deep Deflectors)}}$
H_0: Survival$_{\text{(Eroded Deflectors)}}$ not > Survival$_{\text{(un-eroded Deflectors)}}$
H_0: Survival$_{\text{(B2CC)}}$ not > Survival$_{\text{(Spillway)}}$
H_0: Survival$_{\text{(B2CC)}}$ not > Survival$_{\text{(B2JBS)}}$
H_0: Survival$_{\text{(B2JBS)}}$ not > Survival$_{\text{(Spillway)}}$

We used SampleSize Version 1.3 software (after Lady et al. 2003), expected numbers of fish by route, and detection and survival probabilities from (Ploskey et al. 2007) to estimate likely one-half 95% confidence intervals for single-release model estimates of survival (Table 2).

Table 2. Virtual Release Treatment or Condition, Study Fish, Expected Numbers, and Estimated One-half 95% Confidence Intervals. Precision will improve if more fish than expected are released by upstream studies.

Virtual Treatment or Condition		Juvenile Salmonid	Expected Number of Fish	½ 95% CI [3]
Bonneville Dam [1]		YC	3,037	0.021
		STH	3,026	0.021
		SYC	2,526	0.023
Spillway and Tailwater	(43% of Project passage)	YC	1,306	0.032
	(38% of Project passage)	STH	1,150	0.034
	(52.3% of Project passage)	SYC	1,308	0.032
Spillway by bay type	(assume 50% pass each type)	YC	653	0.045
	(assume 50% pass each type)	STH	575	0.047
	(assume 50% pass each type)	SYC	654	0.046
B2CC Survival	(19.5% of Project passage[2])	YC	577	0.047
	(41.5% of Project passage[2])	STH	1,256	0.032
	(20.5% of Project passage[2])	SYC	512	0.051
B2JBS	(34.5% of B2 passage[2])	YC	472	0.055
	(40% of B2 passage[2])	STH	545	0.049
	(23% of B2 passage[2])	SYC	261	0.070

[1] Assume that survival to BON is 85% for MCN Tailrace YC salmon and STH, 90% for JDA Tailrace YC salmon and STH, and 68% for MCN Tailrace SYC salmon, and 83% for JDA SYC salmon.
[2] B2 passage is assumed to be 45% of Project Passage.
[3] Assume that STH survival is similar to YC salmon survival and precision curves are for JDA turbine-passed fish from Ploskey et al. (2007) – Appendix I, Table I.15.

The precision of bay-specific spillway estimates will depend upon the number of fish passing each bay, so it makes sense to pool estimates by type of route when numbers passing through individual bays are low. We are unlikely to have enough fish to make useful estimates for most individual spill bays, but there should be enough fish to estimate spillway survival and perhaps by bays with different elevation deflectors or amount of ogee erosion.

Paired-release survival calculations for juvenile Chinook salmon will be compared to previous absolute survival estimates for the reach from forebay arrays (Project or spillway) to the Tailrace (Figure 4). All survival estimates will be accompanied by estimates of precision (one-half 95% confidence intervals). We will compare the paired-release survival estimates to paired release estimates made in 2006 (Ploskey et al. 2007a) and 2007 (Ploskey et al., In preparation), and to radio telemetry estimates in earlier years (Counihan et. al. 2002, 2003, 2006a, 2006b).

C.2. VALUE ADDED RESEARCH

This study is specifically designed to take advantage of PIT- and JSATS-tagged fish from upstream studies and therefore would not require tags, tagging, nor release of fish unless greater precision is desired.

C.3. LIMITATIONS/EXPECTED DIFFICULTIES

Tracking algorithms for the spillway were developed during a 2007 study so this time-consuming process should be much more efficient for this proposed study.

C.4. EXPECTED RESULTS AND APPLICABILITY

We expect the results to be consistent with those observed in 2006 (Ploskey et al. 2007) and 2007.

C.5. SCHEDULE

Spring data collection will occur from about May 1 through June 3, 2008.
Summer data collection will occur from June 15 through August, 2008.
Verbal or email communication of progress will be provided every 1-2 weeks
A summary of preliminary spring data will be compiled by September 30, 2008.
A summary of preliminary summer data will be compiled by October 31, 2008.
Present results at the Anadromous Fish Evaluation Program (AFEP) in November, 2008
A draft report will be completed by January 31, 2009.
A final report will be submitted within 60 days after receipt of regional comments.

We are aware that the study design will be reviewed by various State and Federal agencies, and is subject to the approval of the NOAA Fisheries, under the Endangered Species Act. We understand that this means that the study design may be modified prior to the start date.

D. FACILITIES AND EQUIPMENT

As designed, this study will require no purchase of tags, tagging, nor release of fish, although it relies on tagging by other studies. All autonomous nodes required are available. Most spillway hydrophones are also available but some cables and hydrophones need to be replaced.

E. IMPACTS

The acoustic frequencies transmitted in this study are above those that can be detected by or injure salmon. Autonomous nodes are designed without sharp edges and rigging so they are unlikely to injure fish. Ropes from the anchor to the acoustic release will be made of biodegradable material, since anchors will be sacrificed during retrieval of every node.

We plan to coordinate closely with the Bonneville Project to get the spillway hydrophones installed before the spill season begins. We also will coordinate with other researchers to avoid conflicts. We will need operations data for each spill bay and the B2CC, as well as total discharge data for B1, B2, and the spillway. We also will need elevation data at the same time scale as discharge and spill-gate-opening data.

F. COLLABORATIVE ARRANGEMENTS AND/OR SUB-CONTRACTS

The PNNL plans to subcontract with Dr. John Skalski, School of Aquatic and Fisheries Sciences, University of Washington, to develop maximum likelihood models and to provide statistical oversight. The PNNL also will subcontract with the Pacific States Marine Fisheries Commission to provide skilled biologists and technicians.

IV. LIST OF KEY PERSONNEL AND PROJECT DUTIES

Gene R. Ploskey (PNNL)	Senior Scientist and Project Manager - all aspects
Mark Weiland (PNNL)	Senior Scientist and Co-Leader - all aspects
Derrek Faber (PNNL)	Setup, node maintenance and related record keeping, and other as needed
James Hughes (PNNL)	Setup, node maintenance and related record keeping, and other as needed
Shon Zimmerman (PNNL)	Setup, node maintenance and related record keeping, and other as needed
Eric Fischer (PSMFC)	Setup, node maintenance and related record keeping, and other as needed
Jina Kim (PSMFC)	Setup, node maintenance and related record keeping, and other as needed
Jessica Vucelick (PNNL)	Tagging and Detection Database Management
John Skalski (UW) and Rich Townsend	Develop survival models and provision of statistical oversight

V. TECHNOLOGY TRANSFER

Information acquired during the proposed work will be transferred in the form of written and oral research reports. A presentation will be made at the Corps' annual Anadromous Fish Evaluation Program Review. Technology transfer activities may also include presentation of research results at regional or national fisheries symposia, or publication of results in a scientific journal.

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VII. BUDGET

A detailed budget will be provided under a separate cover.

FINAL RESEARCH PROPOSAL

SUBMITTED TO THE U.S. ARMY CORPS OF ENGINEERS UNDER THE ANADROMOUS FISH EVALUATION PROGRAM 2008 PROJECT YEAR

I. BASIC INFORMATION

A. TITLE OF PROJECT

ACOUSTIC TELEMETRY EVALUATION OF A BEHAVIORAL GUIDANCE STRUCTURE AT BONNEVILLE DAM SECOND POWERHOUSE

B. PROJECT LEADERS

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C. STUDY CODES

SPE-P-02-New: Evaluation of a Behavioral Guidance Structure at Bonneville Dam Second Powerhouse

D. DURATION

January 2008 to February 2009 (Draft Report) plus 60 d after receipt of regional comments

E. DATE OF SUBMISSION

October 16, 2007

II. PROJECT SUMMARY

A. GOALS

We will evaluate the performance of a 700-ft-long, 10-ft deep behavioral guidance structure (BGS) installed at Bonneville Dam (BON) Second Powerhouse (B2) for:

1. Guiding juvenile Chinook salmon and steelhead to the Second Powerhouse Corner Collector (B2CC)
2. Increasing survival of fish passing the Second Powerhouse (B2)[1]
3. Increasing the passage efficiency and effectiveness of the B2CC
4. Reducing fish passage through turbines 11-14

B. OBJECTIVES

1. We will evaluate the performance of the BGS for guiding YC salmon, steelhead, and SYC salmon to the B2CC by calculating a variety of statistical metrics. These metrics can be estimated by type of fish, season, and treatments, and for day or night periods within treatments (sample sizes permitting). Metrics include but may not be limited to:
   - BGS Guidance Efficiency = Number guided along the BGS (upstream or downstream of it) / (Number detected in the B2 forebay
   - B2 FPE = (Number passing in the B2CC + Number passing the B2 JBS) / B2 Passage
   - B2CC passage efficiency = Number passing into the B2CC / Number passing B2
   - B2CC passage effectiveness = B2CC passage efficiency / Proportion of B2 flow to the B2CC
   - B2 FGE = Number of PIT or acoustic tags detected in the B2 JBS / Number tracked passing into turbines
   - Occluded turbine passage = Number entering turbines 11-14
   - Occluded turbine passage efficiency = Number entering turbines 11-14 / B2 Passage
2. We will determine the survival of juvenile salmon that pass:
   - B2, the B2CC, B2 JBS, and B2 turbines
3. We will test several hypotheses comparing 2008 BGS-in treatments to mean estimates for 2004 and 2005 before the BGS was deployed (by fish type):
   - B2CC Passage Efficiency during BGS-in treatments is not greater than mean efficiency in 2004 and 2005
   - B2CC Passage Effectiveness during BGS-in treatments is not greater than mean effectiveness for 2004 and 2005
   - Occluded turbine passage efficiency is not reduced by the BGS from a mean estimate for 2004 and 2005
   - Survival in 2008 when the BGS is installed is not significantly higher than mean survival for 2004 and 2005
5. We will test the efficiency of the B2CC PIT-tag reader from the release of 500 dual tagged (PIT/acoustic) fish released into the mouth of B2CC by the Post Federal Columbia River Survival (FCRPS) Study.

C. METHODS

The study will be cost-effective because it will rely solely on fish implanted with Juvenile Acoustic Telemetry System (JSATS) tags by studies conducted upstream of BON[2], and reference releases for downstream

[1] Downstream survival arrays are proposed by a proposed spillway survival study and would have to be added to this study if the other proposed study is not funded.

[2] We anticipate that a Tag-Effects study will release 4,000 yearling Chinook (YC) salmon above Lower Granite Dam on the Snake River in spring, and a JDA survival study will release 2,500 YC salmon, 2,500 steelhead (STH), and 2,500 subyearling Chinook salmon (SYC) below MCN. About 1,000 each of YC, STH, and SYC are proposed for release in JDA Tailrace to serve as control releases for the JDA study. If survival to BON is similar to that observed by Ploskey et al. (2007a), the arrivals at BON could number 4,758 YC salmon, 3,026 STH, and 2,500 SYC salmon. If percent passage at B2 is similar to means in 2004 and 2005, B2 forebay arrivals could number 2,736 YC salmon, 1,800 STH, and 1,350 SYC salmon.

survival studies. We will deploy an array of 18 hydrophones on the face of B2 and four in the B2 forebay, and these will allow tracking of approaching acoustically tagged fish, quantification of responses to the behavioral guidance device (BGS), and assignment of the route of passage or fate of each tagged fish. The position of the BGS will be monitored continuously by five GPS data loggers attached 200, 300, 400, 500, and 600 ft from the upstream end. The upstream and downstream ends will be anchored. The forebay array of hydrophones could allow for three-dimensional tracking of tagged fish, but tracking in the horizontal plane is all that is needed for successfully completing this study. Performance also will be assessed by calculating a variety of quantitative metrics (see Objective 1 above) and comparing estimates for BGS-in treatments in 2008 with mean estimates for 2004 and 2005 before the BGS was installed. Survival estimates will be possible if three downstream survival arrays are installed in 2008, as requested in another proposal for evaluating BON spillway survival. Virtual releases of fish will be formed by tracking fish to their final route of passage and then using detections on downstream arrays to estimate detection histories and detection and survival probabilities. A variety of hypotheses have been formulated to determine whether the BGS makes a significant difference in performance metrics (see Objective 3 above). We have gained valuable experience in tracking fish at the BON spillway in 2007, and that experience will increase the efficiency of this study.

D. RELEVANCE TO THE BIOLOGICAL OPINION

As part of the remand process for the 2004 Biological Opinion on Federal Columbia River Power System (FCRPS) operations, the Action Agencies submitted to the U.S. District Court, District of Oregon a draft Proposed Action dated May 21, 2007. Hydrosystem Strategy 2 of the Proposed Action states, "Modify Columbia and Snake river dams to maximize juvenile and adult fish survival." This strategy includes Action 11, which our proposed study evaluates:

- Action 11 – Powerhouse Improvement Actions – "*Providing or enhancing powerhouse surface flow outlets" and "Making improvements to juvenile bypass systems…"*

III. PROJECT DESCRIPTION

A.1. PROBLEM DESCRIPTION

The post-construction evaluations of the new B2CC at B2 in 2004 and 2005 indicated that mean B2CC passage efficiency was significantly higher for STH (70%) than it was for YC (33%) or for SYC salmon (39%) – Evans et al. (2006); Reagan et al. (2006); Adams et al. (2006). Survival studies by Counihan et al. (2006a and b) indicated that the B2CC is a preferred route of passage because survival of juveniles passing through the B2CC was as high as or higher than that of juveniles passing by any other route. The U.S. Army Corps of Engineers is planning to install a shallow-draft, 700-ft long, 10 ft deep BGS into the forebay of B2 for the 2008 migration season. It is expected that strategically locating this BGS will significantly increase the efficiency of the B2CC for yearling and subyearling Chinook salmon and thereby increase their survival at B2 and the Bonneville Project.

A.2. SITE DESCRIPTION

The proposed study site primarily includes the B2 forebay (Figure 1), but if a survival component is included, the study will extend downstream of B2 to three survival arrays located near Kalama, WA (Figure 2). The installation and maintenance of survival arrays are included in a spillway survival proposal.

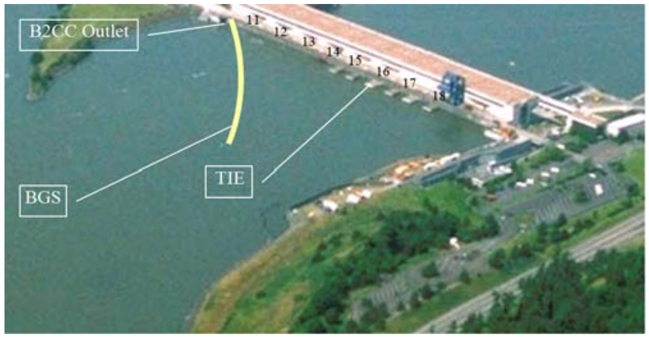


Figure 1. Photo of the B2 forebay showing the B2CC surface flow outlet, turbines 11-14 without turbine intake extensions (TIES), and turbines 15-18 with TIES. The yellow curved line represents the likely location of a 400-ft long BGS upstream of turbines 11-14. The BGS will be anchored to the Washington shore on the upstream end and just to the north of the B2CC outlet on the downstream end.

Figure 2. Map Showing the Primary Area for the Proposed 2008 Study. The Post FCRPS Survival Study will make route-specific releases in the B2CC and reference releases in the BON Tailwater. All virtual, route-specific and Tailrace releases have the potential to be detected on the primary, secondary, and tertiary tailwater arrays located 100, 107.7, and 110.5 km downstream of the BON.

B. TASKS TO COMPLETE OBJECTIVES

1. We will deploy four cabled, time-synchronized hydrophones on the BGS and sample this linear cluster of four hydrophones will allow for tracking of JSATS- tagged fish as they enter the forebay and initially approach the BGS. The BGS hydrophones will be located 300, 400, 500, and 600 ft from the upstream end.
2. We will continuously monitor the position of the BGS by installing five global positioning system (GPS) loggers on the structure 200, 300, 400, 500, and 600 ft from the upstream end.

3. We will deploy 18 cabled hydrophones on the face of B2, synchronize them to a common GPS clock, and sample to identify tracks of tagged fish in the horizontal plane around the lower 200 ft of the BGS. The vector formed by the last four position estimates and location of last tag detection will be used to assign a route of passage or fate.
4. We will conduct analyses on survival and calculate a variety of statistical metrics and the survival of fish passing routes at B2. The metrics will be used to evaluate the performance of the BGS for guiding YC salmon, steelhead, and SYC salmon to the B2CC. These metrics can be estimated by type of fish, season, and treatments, and for day or night periods within treatments (sample sizes permitting). The suite of analyses to be conducted is listed in the objectives.

C.1. METHODS

The study will rely upon fish implanted with Juvenile Acoustic Telemetry System (JSATS) tags by studies conducted upstream of BON[3]. If studies proposed for upstream sites are not funded, this proposal could still be preformed but juvenile salmonids would have to be collected, tagged, and released upstream of the B2 Forebay to test the BGS. Number of fish in those releases could be much lower than proposed for the upstream studies.

We will deploy an array of 18 hydrophones on the face of B2 and four hydrophones on the BGS (Figure 3), and these arrays will allow tracking of approaching acoustically tagged fish, quantification of responses to the behavioral guidance device (BGS), and assignment of the route of passage (fate) of tagged fish. The hydrophones on the dam face will be in a rectangular pattern. The proposed rectangular array at all B2 outlets will allow for 2D tracking to assign a route of passage everywhere in the forebay and will provide redundancy to protect the tracking baseline against hydrophone or cable failure. Data from the tracking hydrophones in the forebay areas will be downloaded daily and backed up off site. Data from the rectangular array also could be processed to obtain 3D tracks, although it would not be time or cost effective to process all data to that high level of resolution. Tracking in the horizontal plane is all that is needed to successfully complete this study. By placing a hydrophone slightly below the mid-line depth of each turbine opening and just below the minimum expected water level on every main pier at powerhouse turbines, the rectangular array will allow high resolution tracking throughout the volume where most fish pass into turbines and likely out to a range of 250 ft upstream of the powerhouse. Should a hydrophone fail, the proposed system would be redundant enough to continue to provide for 2-D tracking. In fact, use of any three hydrophones from one turbine and a fourth hydrophone from the next adjacent pier would provide even higher resolution tracking than the basic rectangular array. Therefore, the proposed deployment provides many options for increasing tracking resolution over what could be achieved within the rectangular-tracking baseline alone. An example of the resolution pattern of a rectangular array is illustrated in Figure 4. We gained valuable experience in tracking fish at the BON spillway in 2007, and that experience should reduce processing times required to turn around forebay tracking data and assign routes of passage.

The frequency of tag transmission and fish speed will affect the spacing between successive positions. For example, a smolt with a 5-second tag moving 2 ft / s would have about 10 ft between successive detections, whereas the same smolt with a 10-second tag would have about 20 ft between successive positions. Therefore, tags in Snake River fish, which will ping once every 10 seconds for about 60 days will produce sparser tracks than fish tagged and released below McNary Dam and JDA Dam, where there

[3] We anticipate that a Tag-Effects study will release 4,000 yearling Chinook (YC) salmon above Lower Granite Dam on the Snake River in spring, and a JDA survival study will release 2,500 YC salmon, 2,500 steelhead (STH), and 2,500 subyearling Chinook salmon (SYC) below MCN. About 1,000 each of YC, STH, and SYC are proposed for release in JDA Tailrace to serve as control releases for the JDA study. If survival to BON is similar to that observed by Ploskey et al. (2007a), the arrivals at BON could number 4,758 YC salmon, 3,026 STH, and 2,500 SYC salmon. If percent passage at B2 is similar to means in 2004 and 2005, B2 forebay arrivals could number 2,736 YC salmon, 1,800 STH, and 1,350 SYC salmon. While only John Day fish will be used for survival studies, the fish detected from Lower Granite releases can be used to calculate passage metrics, including metrics related to fish behavior along the BGS.

will be 3 s between tag transmissions. The difference in resolution caused by the different ping gaps should not affect the determination of route specific passage, and we still expect to use tagged fish from Snake River releases to bolster passage metric calculations. However, survival statistics will only be calculated from releases for John Day Dam, to avoid potential problems related to protracted tag effects (see Hockersmith et al. 2007).

We will subdivide powerhouse passage into turbine and JBS components by examining acoustic detections of fish in the JBS channel. Several mobile hydrophones will be deployed along the bypass channel to detect bypassed fish bearing acoustic tags. Tagged fish that pass into turbines from the forebay but are not detected by acoustic detectors in the bypass channel will be classified as turbine-passed fish.

We will assess BGS performance in guiding fish in two ways. First, we will visually examine plan-view plots of fish tracks relative to the BGS and count numbers of tracks passing under the BGS versus numbers passing along, either upstream or downstream of the structure. The position of the BGS will be monitored continuously by five GPS data loggers, as described earlier. Second, we will calculate a variety of quantitative metrics (see Objective 1 above) and compare 2008 estimates with mean estimates for 2004 and 2005 before the BGS was installed. Most of the metrics are self explanatory, except perhaps for passage and passage efficiency through "BGS occluded" turbines. Fish passage through B2 turbines usually is highly skewed toward the south end of the powerhouse and highest at units 11 and 12 (Ploskey et al. 2007a). Therefore, guidance of smolts by a BGS has the potential to significantly reduce passage at "BGS occluded" turbines, and this could be a highly responsive metric. A variety of hypotheses have been formulated to determine whether the BGS makes a significant difference in performance metrics (see Objectives 3).

Figure 3. Photograph Showing Proposed Locations (yellow dots) of Cabled Hydrophones. All locations on the face of the dam will would have one deep hydrophone near elevation 30 ft above mean sea level (MSL) and one shallow hydrophone near elevation 68 ft above MSL. Forebay locations will have single hydrophones attached to the BGS and facing upstream

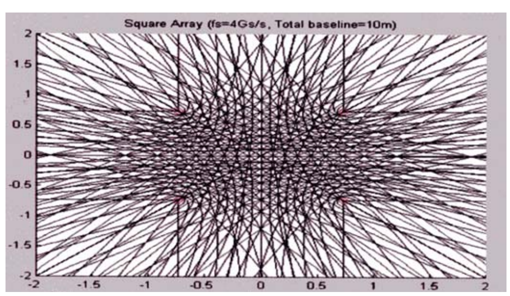


Figure 4. Drawing illustrating the dense resolution pattern within a rectangular array and degradation in resolution outside the tracking baseline. The upper hydrophones would be located just below the minimum expected water level and the lower hydrophones would be located about 1 m below the mid-line depth of turbine intakes and near the bottom of spill bay piers.

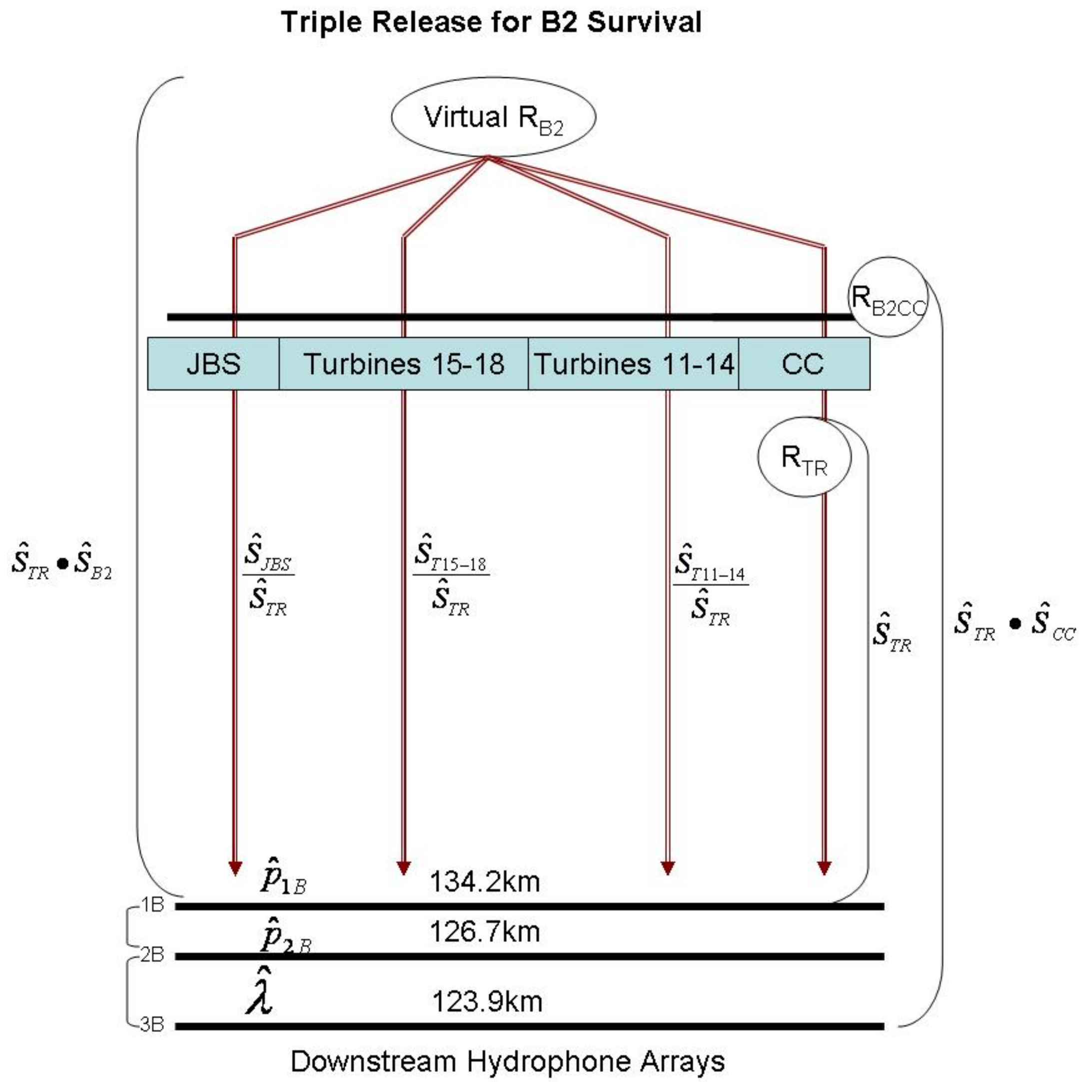
Survival estimates will be possible if three downstream survival arrays are installed in 2008, as requested in another proposal for evaluating BON spillway survival. Virtual releases of fish would be formed by categorizing passed fish by species/age, BGS treatment, and route of passage for all fish released below John Day Dam. Tagged fish that will be released at Lower Granite cannot be used for survival estimates due to differences observed in acoustic tag survival probabilities for these fish in the lower Columbia (Hockersmith et al., 2007). However, Lower Granite released fish will still be used to estimate passage metrics as they relate to the BGS. In addition to virtual releases, we will rely on 500 YC and 500 SYC acoustically tagged fish released by NOAA Fisheries into the B2CC and into the BON tailrace for use with a triple-release survival model (Peven et al., 2005). We will use detections on downstream survival arrays to obtain capture histories for every tagged fish within each virtual release group and then estimate detection and survival probabilities by release group by referencing B2CC survival (Figure 5). If percent passage at B2 is similar to means in 2004 and 2005, and B2 forebay arrivals could be 1,367 YC salmon, 1361 STH, and 1,137 SYC salmon. According to single release model estimates of required sample sizes at BON in 2006 (Ploskey et al. 2007b; Appendix I), one-half 95% confidence intervals for each treatment would be about 4.7% for YC salmon, 3.2 % for STH, and 5.1% for SYC salmon. Therefore, detection of significant differences between treatments probably will require survival differences > 6% for YC salmon, > 7.2% for STH, and > 8.2% for SYC salmon. Given that 70% of STH already pass through the B2CC, it seems unlikely that the BGS will further increase STH guidance and survival enough for us to detect significant differences between years. However, there is room for a significant increase in B2CC efficiency for YC and SYC salmon and that might produce large enough changes in survival to be detectable with expected precision.

The tracking and detection of dual tagged (acoustic/PIT) fish into the B2CC will also enable us to estimate the efficiency of the B2CC PIT tag detector. We will know the route and PIT tag codes of fish implanted with acoustic tags. This information will enable us to provide an estimate of PIT tag detection capability within the B2CC channel.

Table 1. Location, Study Fish, Expected Numbers, and Estimated One-half 95% Confidence Intervals. Precision will improve if more fish than expected are released by upstream studies.

Location		Juvenile Salmonid	Expected Number	½ 95% CI on Survival [1]
Powerhouse 2 [2]		YC	1,367	0.022
		STH	1,362	0.022
		SYC	1,137	0.024
B2CC Survival	(19.5% of Project passage)	YC	592	0.034
	(41.5% of Project passage[3])	STH	1,256	0.023
	(20.5% of Project passage)	SYC	518	0.037
B2 JBS	(34.5% of B2 passage)	YC	472	0.037
	(40% of B2 passage[3])	STH	545	0.035
	(23% of B2 passage)	SYC	262	0.048

[1] Assume that survival to BON is 85% for MCN Tailrace YC salmon and STH, 90% for JDA Tailrace YC salmon and STH, and 68% for MCN Tailrace SYC salmon, and 83% for JDA SYC salmon.
[2] Assume that B2 passage is 45% of Project Passage
[3] Assume that STH survival is similar to YC salmon survival and precision curves are for JDA turbine-passed fish from Ploskey et al. (2007) – Appendix I, Table I.15.



$$\hat{S}_{B2} = \hat{S}_{CC}\left[1 + \hat{P}_{Turbines}\left(\hat{R}_{Turbines/CC} - 1\right) + \hat{P}_{JBS}\left(\hat{R}_{JBS/CC} - 1\right)\right]$$

Figure 5. Summary of triple release-recapture analyses of virtual releases of YC salmon, STH, and SYC salmon based upon detection at B2 of JSATS tagged fish released below John Day Dam by season, treatment, and passage route. Triple release analysis will follow protocols set forth by Peven et al. 2005.

We will process detection data for estimating survival using TagViz software to match codes detected at least four times in chronological order with released codes, develop detection histories for all tags detected and tracked in the B2 forebay at the detection arrays described in Figure 5. The software is useful for quickly eliminating improbable false detections based upon detection location and time relative to release times and prior detection locations and times. The TagViz data base will contain tag activation and detection histories for all ongoing JSATs studies in 2008, so information about releases and detections for a specific study or all related studies will be readily accessible.

C.2. VALUE ADDED RESEARCH

This study is specifically designed to take advantage of PIT- and JSATS-tagged fish from upstream and downstream studies and therefore will not require tags, tagging, nor release of fish unless greater precision is desired.

C.3. LIMITATIONS/EXPECTED DIFFICULTIES

We need to develop a method of deploying hydrophones on main piers between turbines that will allow for replacement of hydrophones during the fish-passage season without turbine outages, and the deployment cannot interfere with trash raking. We do not foresee problems with the execution of this research project in terms of forebay tracking, assignment of passage routes, estimation of metrics, nor hypothesis testing. Long lead times for cables, hydrophones, and pre-amplifiers could be a problem for getting everything in place before the fish-passage season.

C.4. EXPECTED RESULTS AND APPLICABILITY

We expect to provide a conclusive and definitive evaluation of BGS performance based on the design of this proposed study.

C.5. SCHEDULE

Spring data collection will occur from about May 1 through June 3, 2008.
Summer data collection will occur from June 15 through July 21, 2008.
Verbal or email communication of progress will be provided every 1-2 weeks
A summary of preliminary spring data will be compiled by September 30, 2008.
A summary of preliminary summer data will be compiled by October 31, 2008.
Present results at the Anadromous Fish Evaluation Program (AFEP) in November, 2008
A draft report will be completed by January 31, 2009.
A final report will be submitted within 60 days after receipt of the last regional comments.

D. FACILITIES AND EQUIPMENT

As designed, this study will require no purchase of tags, tagging, nor release of fish. However, hydrophones, cables, and other JSATS receiving equipment will need to be purchased.

E. IMPACTS

Early and careful coordination with the project probably can resolve a potential problem with deployments of hydrophones on main piers between turbines, which might interfere with raking trash. Other potential conflicts can be identified and resolved by frequent coordination with the Project and other researchers.

F. COLLABORATIVE ARRANGEMENTS AND/OR SUB-CONTRACTS

The PNNL plans to subcontract with Dr. John Skalski, School of Aquatic and Fisheries Sciences, University of Washington, to develop a statistical synopsis and to provide statistical oversight and quality assurance. The PNNL also will contract with the Pacific States Marine Fisheries Commission to provide skilled biologists for the study.

IV. LIST OF KEY PERSONNEL AND PROJECT DUTIES

Derrek M. Faber (PNNL)	Scientist, PI - all aspects
Gene R. Ploskey (PNNL)	Senior Scientist and Co-Leader - all aspects
Mark Weiland (PNNL)	Senior Scientist and support
James Hughes (PNNL)	Setup, surveying, and all other aspects
Shon Zimmerman (PNNL)	Setup and surveying
Zhiqun Deng (PNNL)	2D and 3D tracking
Eric Fischer (PSMFC)	Setup, node maintenance, data download, and other duties as needed
Jina Kim (PSMFC)	Tracking data management
Jessica Vucelick (PNNL)	Tagging and Detection Database Management
John Skalski (UW)	Provide statistical design and oversight

V. TECHNOLOGY TRANSFER

Information acquired during the proposed work will be transferred in the form of written and oral research reports. A presentation will be made at the Corps' annual Anadromous Fish Evaluation Program Review. Technology transfer activities may also include presentation of research results at regional or national fisheries symposia, or publication of results in a scientific journal.

VI. LIST OF REFERENCES

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VII. BUDGET

A detailed budget will be provided under a separate cover.

Final Research Proposal
Submitted to the US Army Corps of Engineers Under
The Anadromous Fish Evaluation Program
2008 Project Year

I. BASIC INFORMATION

A. TITLE OF PROJECT

Effects of Total Dissolved Gas on Chum Fry

B. PROJECT LEADER

David Geist
Pacific Northwest National Laboratory
P.O. Box 999, MS K6-85
Richland, Washington 99352
509-372-0590
Email: david.geist@pnl.gov

C. STUDY CODES

SPE-P-07-1

D. DURATION

1 October 2007 – 30 September 2008

E. DATE OF SUBMISSION

October 2007

II. PROJECT SUMMARY

A. GOALS

1. Determine whether total dissolved gas (TDG) concentrations are elevated in chum salmon redds downstream of Bonneville Dam.
2. Assess the physiological signs of elevated TDG in chum salmon sac fry.

B. OBJECTIVES

1. Determine depth compensated TDG concentrations at chum salmon redd sites downstream from Bonneville Dam.
2. Conduct toxicity tests on the formation of gas bubble signs in chum salmon fry at TDG levels ranging up to 113% saturation.
3. Conduct in-field TDG monitoring and field analysis of sac-fry in select locations using egg incubation vessels that represent actual redd locations.

4. Facilitate a workshop in the fall of 2008 that will be the first steps toward completion of a final synthesis report that combines and evaluates data from FY06-08 studies. Note that the final synthesis report will be completed in 2009 project year.

C. METHODOLOGY

We are proposing four objectives in FY 2008. The first objective is to repeat the field effort to collect empirical data on total dissolved gas (TDG) from Multnomah Falls and Ives Island. During FY 2008, we will use existing sensors and monitoring sites that were established (and monitored) in FY 2006 and 2007. The sensor recovery and re-deployment will occur every two weeks from March 1 through the end of June. The methods will be similar to work performed in FY 2007 using SCUBA divers that will access piezometer sites during high flows.

The second objective is to repeat laboratory toxicity tests on chum salmon fry[1]. Preliminary tests were conducted in FY 2007. The survival from hatch to emergence was lower at the highest gas level tested (113% TDG). Emergence occurred earlier in the 113% TDG group, presumably because conditions eventually became intolerable. Macroscopic evidence of gas bubble disease (GBD) included bubbles in the eyes, nares, over-inflated swim bladders, and bubbles in the hind gut. Bubbles were more pronounced at the highest levels tested, but there were bubbles also present in the control groups. Histological examination of samples taken at day 7 and day 19 of the treatment showed that the severity of the lesions was greater in fish from the 19 day sample than in fish from the 7 day sample, and the severity of epithelial hypertrophy and separation and swelling of the secondary lamellae exhibited a dose response with TDG. The incidence of moderate lesions were significantly more prevalent in the two highest gas levels tested (i.e., 108% and 113% TDG) than in the control group. The effective gas concentration that caused lesions to occur in the lamellae in at least half the fish occurred around 103% TDG (95% confidence interval was 100.5% to 104.7%). Results from the 2007 studies will be used to shape the specific questions we will answer in FY 2008. In general, we will evaluate lethal and sublethal effects of TDG on chum salmon embryos and sac fry at gas levels likely to occur downstream from Bonneville Dam when available water depths (depth compensation) and temperatures that occur during spring spill operations are considered. One addition to 2008 is that we will expose a portion of the fish to dissolved gas earlier in their development. Exposure in 2007 occurred near emergence. Data from concomitant field studies suggest that newly-hatched fry could be exposed to elevated dissolved gas. We will examine the effects of exposure (days to weeks) to 100, 103, 108, or 113% TDG on direct mortality, sublethal tissue damage, delayed mortality due to GBD injury incurred during exposure, and abnormal behavior. After the exposure, some individuals will be sacrificed for histopathological examination and the remaining individuals will be held for 30 days at 100% TDG and examined for post-exposure mortality and abnormal behavior.

The third objective involves sampling pre-emergent chum salmon fry from egg incubation vessels (i.e., egg tubes or egg baskets) below Bonneville Dam. Chum salmon fry will be examined for GBD. Signs of GBD in larval fish may include air bubbles in the yolk sac or between the yolk sac and perivitelline membrane, in the mouth, or on the body surface. Sampled fish will be anesthetized and immediately examined for these signs. Previous work has indicated that observations made within 1 hour of collection will not bias results. The degree of severity of GBD will be evaluated based on gas bubble:yolk sac volume, presence of multiple signs, percent occlusion of the airway, and other metrics as appropriate. Sampled sac fry will be allowed to recover and released in the Ives Island area. Water quality parameters

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[1] We are evaluating whether we can acquire Grays River or Washougal hatchery chum salmon for this portion of the study. If these stocks are not available, either natural spawners in the Ives Island area or Minter Creek hatchery fish will be used.

including TDG in subsurface (10-40 cm) and surface water, temperature, and dissolved oxygen will be measured during larval fish collection.

The final objective will be to hold a workshop in the fall/winter of 2008 that will gather agency biologists together to review and discuss the data collected thus far in this study. The outcome of this workshop will be a set of recommendations that will be used to develop a final synthesis report that can be used by managers to shape operations below Bonneville Dam that minimize TDG exposure to chum salmon sac-fry. It is expected that the final synthesis report and recommendations will be completed in calendar year 2009.

D. RELEVANCE TO THE BIOLOGICAL OPINION

The objectives of this project are consistent with the hydrosystem targets included in the FCRPS Action Agencies' 2005-2007 Implementation Plan (IP). Specifically, hydrosystem sub-strategy 1.3 of the UPA identifies measures that are needed to monitor TDG in mainstem spawning habitat. This proposed research would have addressed RPA Action 131 under the NOAA Fisheries 2000 Biological Opinion and contributes to the ESA commitments made by the Action Agencies under NOAA Fisheries' revised 2004 BiOp. Specifically, within the chum salmon sections of the NOAA Fisheries revised 2004 BiOp, page 5-97, it states that "efforts are also made to limit spill to a level, and/or provide higher flows for depth compensation, which would not exceed 105% TDG over established redds". The revised BiOp goes on to state on page 6-129 that "spill operations at Bonneville Dam, such as spill for debris removal, gas eneration/abatement testing, or juvenile fish passage, could create TDG concentrations high enough to kill yolk sac fry in redds in the Ives Island area".

III. PROJECT DESCRIPTION

A.1 PROBLEM DESCRIPTION

There are several spill operations which occur in the early spring at Bonneville Dam during the time when chum salmon sac fry are still present in the gravel. Spill occurs during March for the Spring Creek hatchery release and during April for juvenile migration needs at Bonneville Dam and in the lower river. Chum salmon begin emerging from the gravel in the Ives Island area beginning in late April. Thus, there is a period of about two to four weeks in late April when chum salmon sac-fry (i.e., alevins) are still in the gravel environment during periods of elevated total dissolved gas (TDG). The guidance that managers have used to provide protection for pre-emergent chum salmon fry has been to limit TDG to 105% after allowing for depth compensation. During adequate water years, water depths over chum salmon redds are sufficient to provide the depth compensation necessary for chum salmon sac fry to avoid the effects of elevated TDG (provided surface water TDG levels do not exceed 120% as per the current guidelines). However, during low water years, concerns about the effects of TDG on pre-emergent chum salmon fry have forced operators to choose between providing spill to improve juvenile fish passage or limit spill to protect incubating chum salmon.

Few data have been collected to evaluate the effects of TDG on chum salmon fry, and prior to initiating this study, we were unable to locate any previous research evaluating exposure of salmonid fry to TDG within spawning gravels (McGrath et al. 2006). Because chum salmon are spawning in environments that are very different than habitats previously studied, and because the presumed effects of elevated TDG on chum salmon sac fry are impacting spring spill management decisions at Bonneville Dam, field-determined TDG concentrations and the chum salmon fry's physiological response to them are needed. TDG effects on incubating fry may include behavioral effects, internal tissue damage, and delayed mortality. Testing TDG effects on sac fry under controlled laboratory conditions is necessary to fully evaluate effects of TDG exposure on chum salmon sac fry downstream from Bonneville Dam. Most studies identifying effects on incubating salmonids at low TDG levels are relatively old and methods used to quantify gas levels and GBD signs have advanced considerably since that time. In addition, studies conducted on larval fish did not include temperature, exposure duration, and TDG levels relevant to conditions occurring downstream from Bonneville Dam.

Concerns have been voiced by management agencies and tribes whether controlled laboratory studies are representative of TDG exposure in the river. Management agencies and tribes have recommended that pre-emergent chum salmon fry be sampled to determine if a problem actually exists. Efforts in FY 2007 used a water pump to wash redds of alevins. While successful in capturing fish, the technique did not allow a quantitative assessment of survival. Thus, we are proposing to modify objective 3 in 2008 that will use egg incubation vessels deployed in the field at Ives Island. These results will be combined with the laboratory bioassay work to more accurately assess impacts of TDG on chum salmon fry.

A.2 LITERATURE REVIEW

Chum salmon spawning and incubation downstream from Bonneville Dam near Ives Island and an associated site near Multnomah Falls collectively represent one of two remaining populations of the Lower Columbia River ESU listed under the Endangered Species Act. Spring spill from Bonneville Dam for the facilitation of downstream migrating salmonids, which produces gas supersaturation conditions, may be negatively impacting chum salmon incubating downstream from Bonneville Dam.

Gas supersaturation generated by spill from dams on the Columbia River was first acknowledged as an environmental concern in 1965 (Ebel and Raymond 1976). Following extensive assessment, the Environmental Protection Agency (EPA) adopted a nationwide standard of 110% TDG for the protection of aquatic life (NAS/NAE 1973). Beginning in the early 1990s, water quality agencies issued limited water quality waivers to facilitate spill for downstream juvenile salmonid migration. Existing empirical and modeling efforts reviewed in the Biological Opinions of 1995 and 2000 indicated that effects of TDGS levels between 110% and 120% had minimal impacts on aquatic biota in river environments (NOAA 1995, 2000). Waivers permitted up to 115% TDGS in downstream reaches where spill and powerhouse flows mixed and up to 120% TDGS in dam tailraces where flows from spillways were separated from those of powerhouse discharge (NOAA 1995).

Recently, gas supersaturation as a water quality issue has resurfaced (USACE et al. 2004), in particular regarding total dissolved gas levels in the incubation environment downstream from Bonneville Dam during spring spill. Elevated TDG levels within salmon redds may diminish survival of chum salmon progeny downstream from Bonneville Dam. Occurrence and effects of TDGS up to 120% supersaturation on naturally spawning (listed) chum salmon downstream from Bonneville Dam are uncertain.

Field studies to measure TDG in hyporheic habitats have only recently been initiated. During the 2006 and 2007 spring spill, the US Army Corps of Engineers (Corps) funded the Pacific Northwest National Laboratory (PNNL) to monitor hyporheic TDG levels in the mainstem Columbia River downstream from Bonneville Dam (Figures 1 and 2). Results from 2006 suggest that TDG levels in the Ives Island spawning area during spring spill operations exceeded 103% but that depth-compensated TDG at the depth of an egg pocket are less than 103% TDGS (Figures 3 and 4; Arntzen et al. 2007). The data from 2007 are still being analyzed at this time. TDG levels as low as 103% have been documented to cause mortality in sac fry (McGrath et al. 2006).

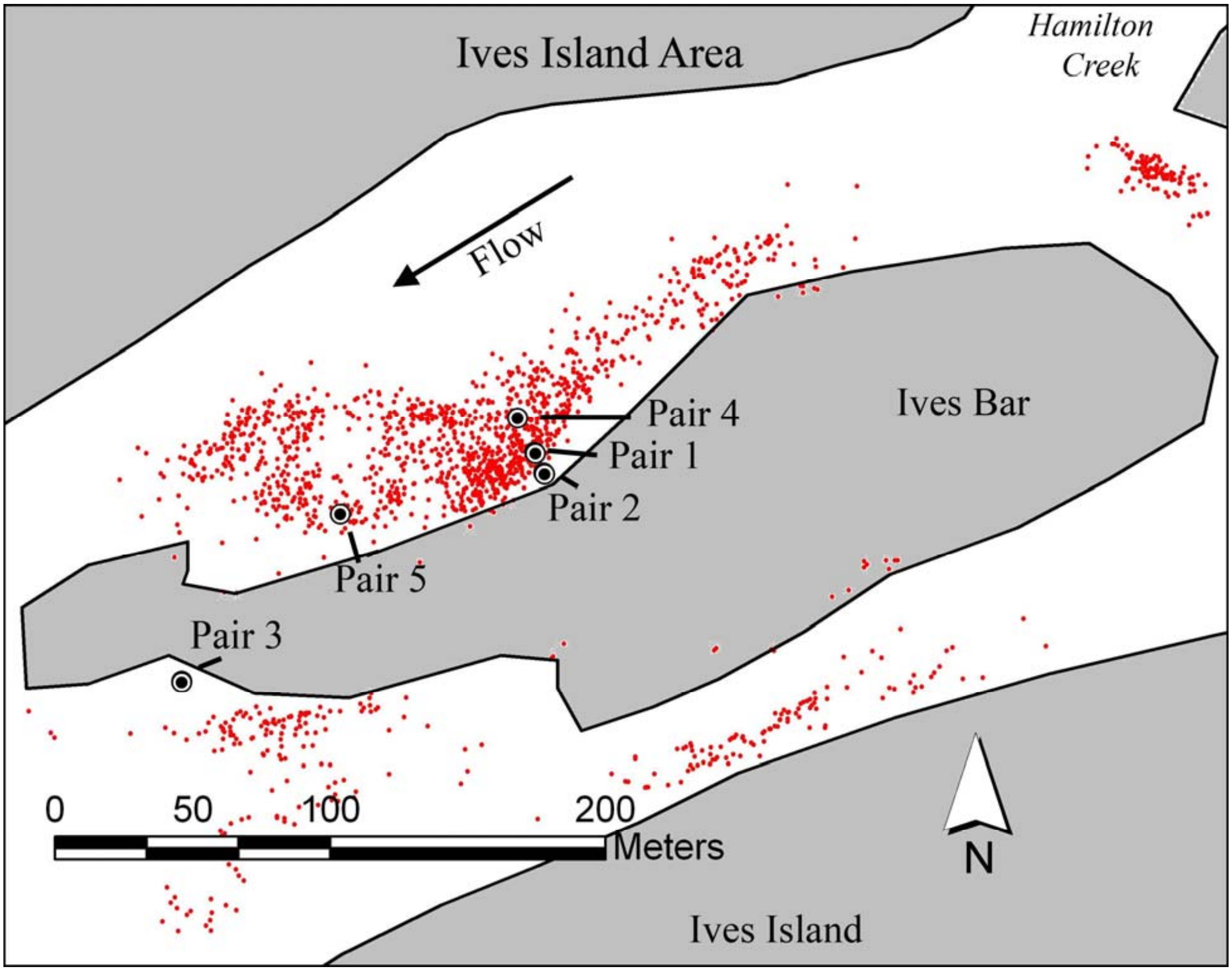

Figure 1. Location of TDG sensors installed in 2006 and 2007 at Ives Island study area (pairs 1-5) and chum redds (red circles).

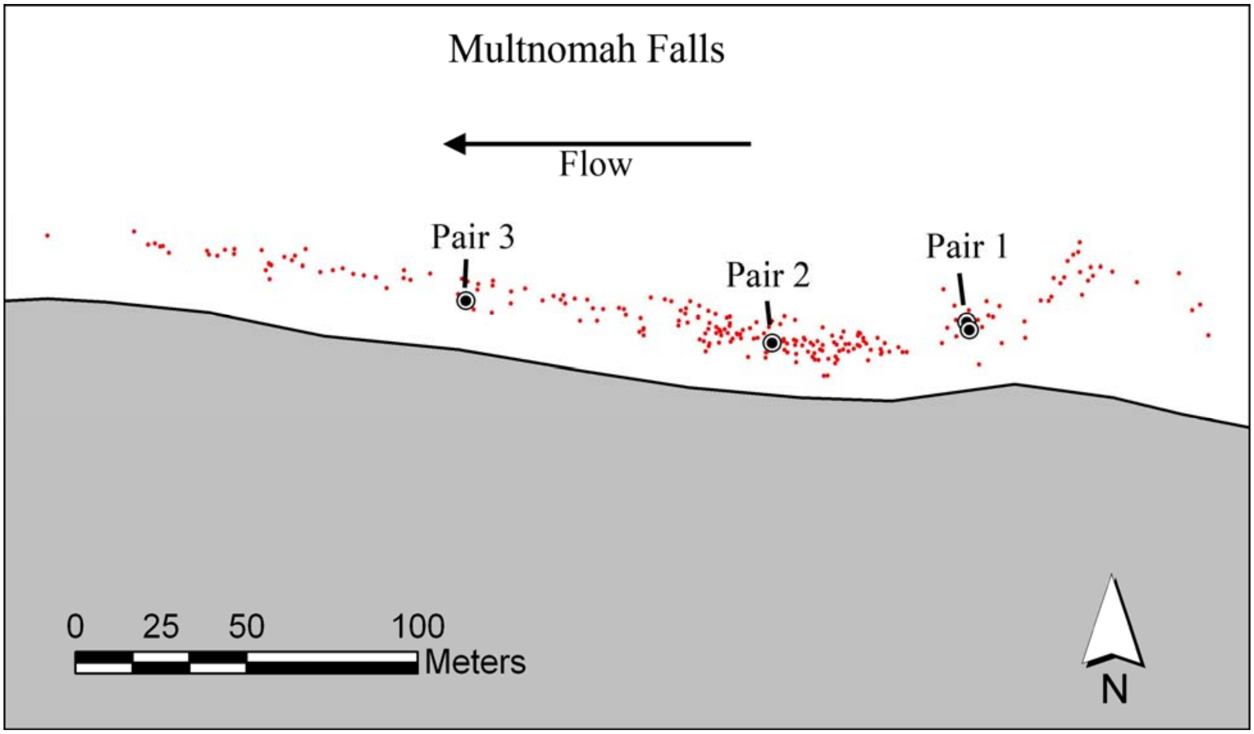

Figure 2. Location of TDG sensors installed in 2006 and 2007 at Multnomah Falls study area (pairs 1-3) and chum redds (red circles).

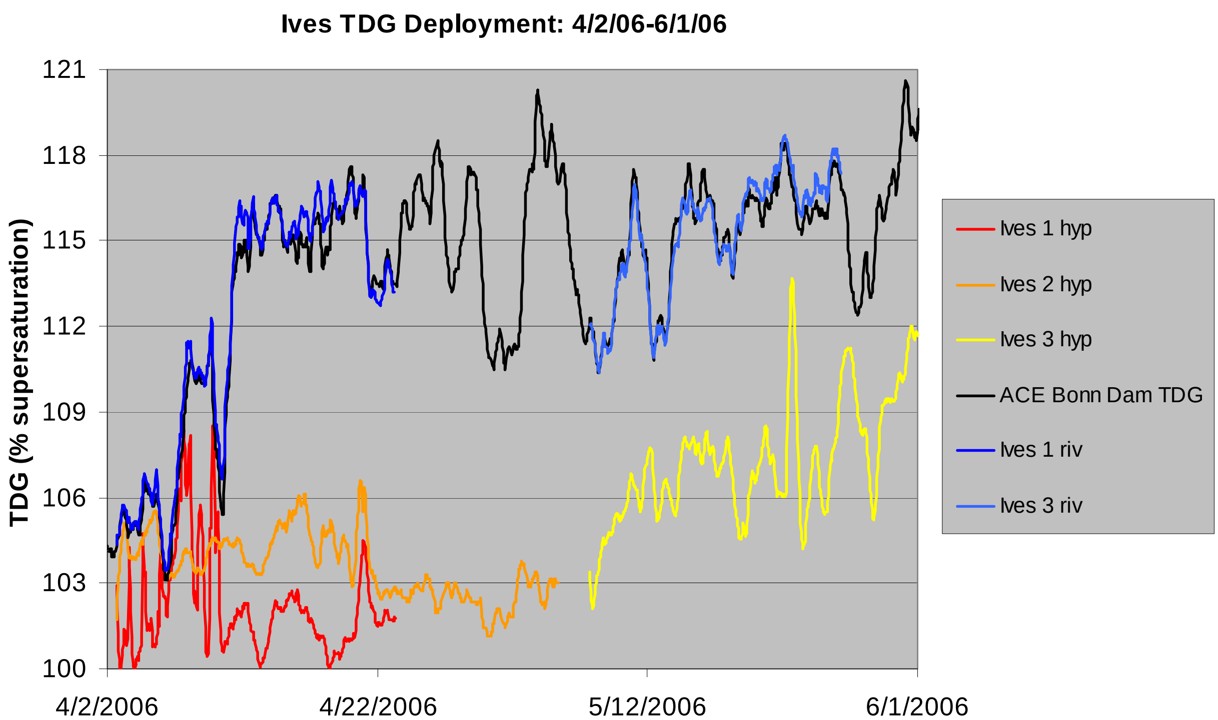

Figure 3. TDG levels at Ives Island from 2 April, 2006 through 1 June, 2006.

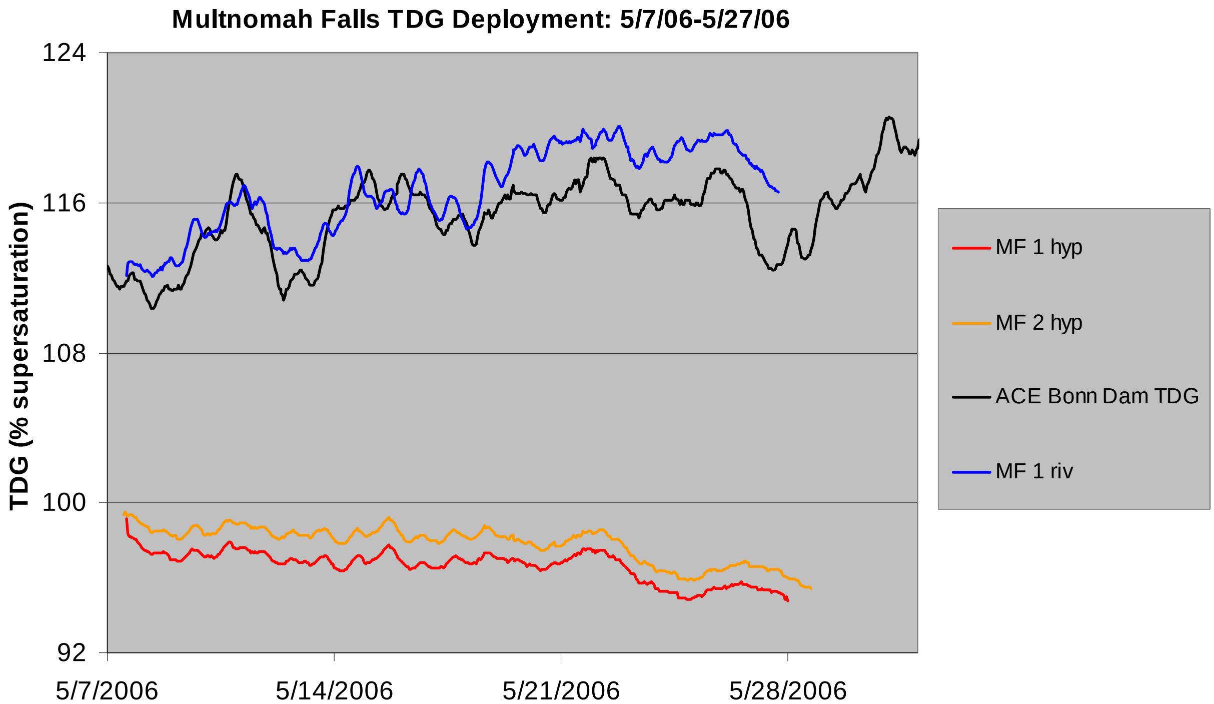

Figure 4. TDGS levels at the Multnomah Falls site from 7 May, 2006 through 28 May, 2006.

River levels during spring 2006 were sufficient to keep the TDG sensors below the calculated compensation depth (Figure 5), as expected during above average water years. However, TDG levels at egg pocket depth were sufficiently high that toxicity to sac fry might be expected during lower water years when compensation depths are not available. If water levels were lower than the compensation depth, there is a potential impact to chum salmon sac fry at these TDG levels. Previous data on water depths in the Ives Island area shows this occurs during normal to low water years.

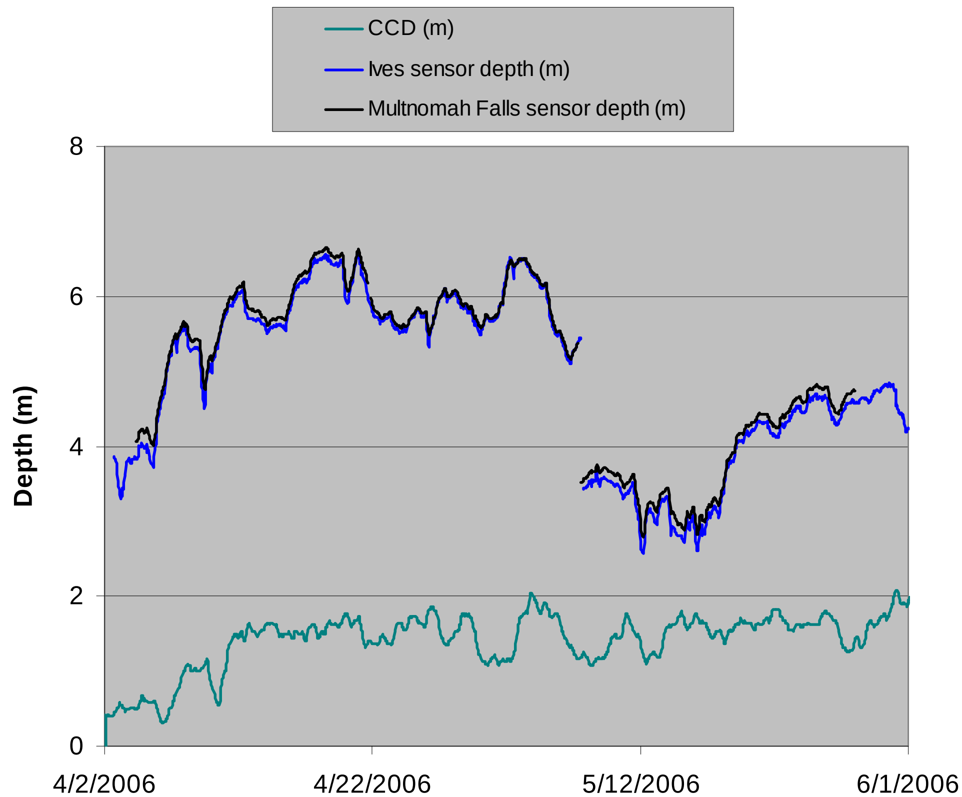

Figure 5. Water depths at Ives and Mulnomah TDG sensor locations and the calculated compensation depth (CCD) from 2 April, 2006 through 1 June, 2006.

Although considerable research has been conducted during the past 30 years on gas supersaturation effects on salmonids, primarily juveniles, relatively little attention has been given to other life stages, including incubating salmonids. Although direct and indirect effects of gas bubble disease have been documented in juvenile chum salmon (Birtwell et al. 2001; Greenbank et al. 2001), no information exists regarding the effects of gas supersaturation on incubating chum salmon. Studies of other salmonid species have only limited applicability because sensitivity to supersaturation varies among species within the salmonids (Weitkamp and Katz 1980). A preliminary laboratory TDG bioassay study on larval chum salmon was conducted at PNNL in FY 2007 and data from these experiments are still being analyzed.

Incubating salmonids are vulnerable to GBD, and hyporheic areas may present a special case of supersaturated TDG exposure. Total dissolved gas (TDG) toxicity and gas bubble disease (GBD) in alevins have been documented at TDG levels as low as 101-108% (Harvey and Cooper 1962; Wood 1968; Krise and Herman 1989). For example, Rucker and Kangas (1974) found 12 to 83% mortality in Chinook salmon fry from hatching to 50 days old in response to 112-128% TDGS. Sockeye salmon alevins experienced GBD and mortality at 108-110% TDGS (Harvey and Cooper 1962). Wood (1968) observed air bubbles and death in advanced yolk-sac and newly buttoned-up salmon fry at 103 to 104% TDGS. Krise and Herman (1989) found intracranial hemorrhaging and subcutaneous bubbles in lake trout sac fry after 15 days exposure to 101% TDGS and visible bubbles (intra-orbital, head, and abdomen) after 40 days exposure to 105% TDGS. Nebeker et al. (1978) reported mortality of steelhead yolk sac fry exposed to 115% TDGS beginning after 52 days of exposure and reaching 45% after 92 days of exposure. Montgomery and Becker (1980) found gas bubbles and some mortality of rainbow trout sac fry at 113%

TDGS. Most studies identifying effects at low TDG levels are relatively old and methods used to quantify gas levels and GBD signs have advanced considerably since that time. In addition, most studies conducted on larval fish did not include temperature, exposure duration, and TDG levels relevant to conditions occurring downstream from Bonneville Dam.

Gas bubble disease appears differently in larval fish than in juvenile or adult fish (Weitkamp and Katz 1980). Gas bubbles may appear in the gut or mouth, or exterior surface or yolk sac, causing fish to rise or swim abnormally or erratically (Wood 1968; Rucker and Kangas 1974). Birtwell et al. (2001) and Harvey and Cooper (1962) suggested that sublethal effects of gas bubble disease include impaired swimming performance and sensory capabilities, with affected individuals floating and/or swimming head or abdomen up. Cause of death can be due to bubbles in the buccal cavity, causing suffocation (Fidler 1988) or hemistasis (disruption of circulation; Bouck 1980; Counihan et al. 1998). Sublethal TDG exposure may produce tissue damage that results in infection and weakening of exposed fish, and may lead to increased indirect mortality (Lutz 1995; Toner and Dawley 1995).

Water depth and temperature affect toxicity of supersaturation (Weitkamp and Katz 1980). Depth is important since with each increase in depth of 1 m, gas solubility increases by approximately 10%. It is unclear whether salmonids are able to detect and avoid lethal gas concentrations by moving to deeper water (Ebel 1971; Weitkamp and Katz 1980) and the response may be species-specific. For example, Meekin and Turner (1974) showed that juvenile Chinook salmon successfully avoided supersaturated water whereas coho salmon did not, and Dawley et al. (1976) showed that Chinook salmon and steelhead that were able to move lower in the water column had higher survival rates. Salmonid alevins in the incubation environment may not have the ability to move to depth to avoid TDG exposure due to limited mobility. In general, it is known that hyporheic temperature and dissolved oxygen levels can fluctuate significantly with changes in river stage. Arntzen et al. (2006) documented this occurrence within fall Chinook salmon spawning areas of the Hanford Reach. Geist et al. (in press) measured similar fluctuations in hyporheic temperature as a function of changing river stage within Ives Island chum spawning areas during 2001-2004. Results from this study in 2006 found that DO levels fluctuated similarly with changes in river stage (Arntzen et al. 2007). Temperature affects TDG exposure because dissolved gas solubility decreases with increasing temperature. This has important implications for incubating chum alevins because hyporheic temperature tends to increase during periods of decreasing river stage, increasing TDG during periods when less depth compensation is available (Geist et al., in press). Although TDG is the primary concern, during periods when TDG is >100% another potential problem is the ratio of dissolved oxygen to dissolved nitrogen. Nebeker et al. (1976) found a significant increase in mortality of fish tested in O_2/N_2 ratios that were low. Preliminary analysis of our TDG results using techniques outlined in Dawson (1986) suggest the O_2/N_2 ratio is drastically lowered within the hyporheic zone during periods low river stage (when DO decreases and less depth compensation is available).

A.3 RELATIONSHIP TO OTHER ON-GOING RESEARCH

Pacific Northwest National Laboratory (PNNL) has been involved in chum salmon research in the Ives Island area downstream of Bonneville Dam since 1999. We have been working with several state and federal agencies to implement BPA project 1999-003-01. The research proposed here is directly related to, and will be coordinated with, Project 1999-003-01.

B. OBJECTIVES

1. Determine depth compensated TDG concentrations at chum salmon redd sites downstream from Bonneville Dam.
2. Conduct toxicity tests on the formation of gas bubble signs in chum salmon fry at TDG levels ranging up to 113% saturation.
3. Conduct in-field TDG monitoring and field analysis of sac-fry in select locations using egg incubation vessels that represent actual redd locations.
4. Facilitate a workshop in the fall of 2008 that will be the first step toward completion of a final synthesis report that combines and evaluates data from FY06-08 studies. Note that the final synthesis report will be completed in 2009 project year.

C. METHODOLOGY

C.1. DESCRIPTION OF PROPOSED STUDY

The following activities are proposed to accomplish these objectives in FY 2008:

Objective 1 - Determine depth compensated TDG concentrations at chum salmon redd sites downstream from Bonneville Dam

Methods for monitoring empirical TDG levels in 2008 will be similar to methods used in 2006 and 2007. In 2006 and 2007, we deployed TDG sensors (Hydrolab Minisonde 5) to monitor water quality at egg pocket depth (30 cm) and within the water column at a study area near Ives Island and at a second study area near Multnomah Falls (Arntzen et al. 2007; PNNL, unpublished data). The Ives Island site is located about 230 river kilometers (rkm) from the mouth of the Columbia River and 4.3 rkm downstream from Bonneville Dam. The Multnomah Falls site is located about 14.8 rkm downstream from Bonneville Dam and approximately 220 rkm from the mouth of the Columbia River. Chum salmon spawn at both areas and the sensors were located where annual surveys conducted since 1998 as part of BPA Project 1999-003-01 indicated chum salmon consistently spawn.

At present there are 5 pairs of piezometers at the Ives Island site (Figure 1) and 3 pairs at the Multnomah Falls site (Figure 2). Each piezometer pair consisted of one piezometer screened at egg pocket depth and one piezometer screened to the river (also referred to as a standpipe). Paired piezometers enabled simultaneous measurement of water quality in the hyporheic zone and water column. Piezometers were emplaced in the riverbed using a post-pounder or pneumatic hammer until the desired depth below the riverbed surface was achieved. This method is described in detail by Geist et al. (1998). Once the piezometers were installed, we developed them by removing fines with a hand pump. Finally, we recorded the locations of the piezometers with a global positioning system (GPS). We placed caps on piezometers that did not have sensors deployed in them to keep sediment from accumulating in the pipes. The same piezometers will be used in FY 2008.

We are using Hydrolab Minisonde 5 multi-parameter water quality sensors to record water quality data; the same sensors will be used in FY 2008. Each Minisonde weighs 1.3 kg, measures 74.9 cm long, and has an outer diameter of 4.4 cm. Nearly all the Minisondes are equipped with sensors for measuring TDG, and DO, as well as conductivity, water level, and temperature. The additional water quality parameters will be used to determine the extent of groundwater – surface water mixing in the incubation environment. Groundwater could affect TDG levels either directly due to elevated concentrations of nitrogen, by altering water temperatures which could decrease gas solubility in water and increase potential impacts of gas bubble trauma, or by lowering dissolved oxygen, which would decrease the ratio of dissolved oxygen to nitrogen. We suspect this could be important to assessing potential impacts to chum salmon because chum salmon preferentially select groundwater upwelling sites to spawn (Geist et al. 2002).

Following field deployments, Minisonde sensors will be downloaded and checked for accuracy using a side-by-side field test with a laboratory-calibrated sensor. We place the laboratory-calibrated sensors and the recovered sensors in the river at an approximate depth of 90 cm for the side-by-side deployment. Following each recovery, all TDG membranes will be exchanged for those previously tested for proper function in the laboratory. The used membranes are transported back to the laboratory and tested to confirm data integrity. Following each deployment, each TDG pressure sensor will be tested for accuracy using a Druck ® pressure calibrator at 100, 200, and 300 mmHG. If the pressure reading is off by more than 1 mm Hg, we recalibrate the unit. The stated accuracy of the sensor is ± 0.01% of the span (or 2 mmHG). After recalibration, the sensor is rechecked at all pressure levels. We calibrate the DO, specific conductance, and depth sensors following procedures in the Minisonde user's manual. We then give each Minisonde new batteries. Upon return to the laboratory, each membrane is tested for functionality before reuse.

Compensation depth influences TDG concentrations and therefore physiological effects on sac fry. We will compute the compensation depth using the equation of Tanner and Johnston (2000) modified from Colt (1984):

Compensation Depth = [TDG Pressure (mmHg) – Barometric Pressure (mmHg)] / 23

This is the method currently used by the US Army Corps of Engineers (i.e. the USACE online water quality data include compensation depth computed by this method). We will compute the percentage reduction (compensation) in supersaturation based on the pressure of the water column using an equation from Knittel et al. (1980):

Percentage Compensation = [Water Depth (cm) x 0.740 (mmHg/cm water)] 100/Barometric Pressure (mmHg)

PNNL will provide divers for sensor recovery and redeployment. Recovery and redeployment will continue every 2 weeks until early July.

Objective 2 - Conduct toxicity tests on the formation of gas bubble signs in chum salmon fry at TDG levels ranging up to 113% saturation.

We will evaluate lethal and sublethal effects of total dissolved gas (TDG) on chum salmon embryos and alevins at gas levels likely to occur downstream from Bonneville Dam when available water depths (depth compensation) and temperatures that occur during spring spill operations are considered. In addition to direct mortality, indirect mortality from injury incurred during exposure and associated disease development has been documented (Harvey and Cooper 1962; Lutz 1995; Toner and Dawley 1995). We will test the hypotheses that these TDG levels do not cause:

- direct mortality,
- sublethal tissue damage,
- delayed mortality due to gas bubble disease (GBD) injury incurred during exposure, or
- abnormal behavior.

Four dissolved gas levels will be tested (100, 103, 108, or 113% TDGS) at a constant temperature of approximately 10°C[2]. Exposure to elevated gas levels will occur for up to four weeks during the incubation period before emergence. These four gas levels approximate a range in gas levels from a level that we assume will not elicit a response (100% TDGS) to a level where we assume a response will occur (113% TDGS). The use of a gas level at 103% TDGS corresponds to the threshold value in the literature for salmonid sac-fry. We will use a constant temperature exposure because we do not want to confound the effects of gas exposure. The literature suggests that temperature will not have significant effects on GBD within the short time frame of the exposure and within the range of gas levels we are testing. The use of a four-week exposure is meant to approximate the worst case conditions during spring spill while sac-fry are in the gravel. Finally, we are sampling at two intervals (~2 weeks prior to emergence and immediately at emergence) to determine if there are differences in behavior (moving from egg pocket to surface water) or development (more yolk versus less yolk) that affect the results.

Embryos will be exposed to unsaturated well water until approximately four weeks prior to emergence. We will use an incubation model to determine when emergence is expected to occur but presume it to be around the middle of May, suggesting that exposure to elevated gas levels will begin around the middle of April. At that time, total dissolved gas levels will be adjusted to the four treatment levels and embryos will be exposed to one of these treatment levels for up to four weeks. Following treatment, dissolved gas levels will be returned to unsaturated levels where embryos will be held for an additional 30 days following which the study will be terminated.

We are still trying to locate eggs for this experiment. In FY 2007 we used chum eggs from Minter Creek Hatchery, a WDFW chum salmon hatchery in Gig Harbor, Washington. We will explore other options for egg source, including the Grays River facility, Washougal Hatchery, and collection of eggs from natural spawners in the Ives Island area. Eggs will be transported from the collection site to Richland, and placed within incubation trays where they will be maintained until experimental facilities are prepared. The experiment will be initiated by placing ~300 eyed eggs in an egg tube (or basket); there will be six egg tubes (replicates) in each treatment.

At about 600 accumulated thermal units (ATUs), approximately 100 embryos will be moved from each egg tube into a corresponding emergence tube. The egg tubes and emergence tubes have previously been used to monitor survival and development of fall Chinook salmon embryos (Geist et al. 2006) and the emergence tubes were used successfully in FY 2007 to study TDG effects on emergence of chum alevins. The egg tubes are 6" tall, and 4" in diameter. They are slotted on the sides and screened on the bottom; this allows continuous flow of water to occur around the eggs at all times. Emergence tubes consist of a light and dark chamber connected to each other via a clear tube. Embryos are placed in the dark chamber which also contains gravel. Water flow is directed such that it upwells from the dark chamber, across the clear tube, and into the clear chamber. Fry emergence occurs when they follow the flow of water toward the light and end up in the clear chamber. Fry can easily be counted and observed in the clear chamber, but are not easily monitored in the dark chamber.

Both egg tubes and emergence tubes will be placed within a water table that consists of four troughs. The water table and a Living Stream system will be used to control water temperature and dissolved gas levels. Water with elevated dissolved gas will be created in a dissolved gas chamber, then delivered to separate head tanks that will supply water to the four treatments. Figure 6 shows the set-up that was used in FY 2007. Unsaturated water will be mixed in the head tanks with the gassed water to achieve the desired treatment level. Temperature and dissolved gas will be computer controlled using a Campbell data logger and associated probes.

[2] Specific treatment levels and maximum exposure limits will be set after reviewing results from FY 2007.

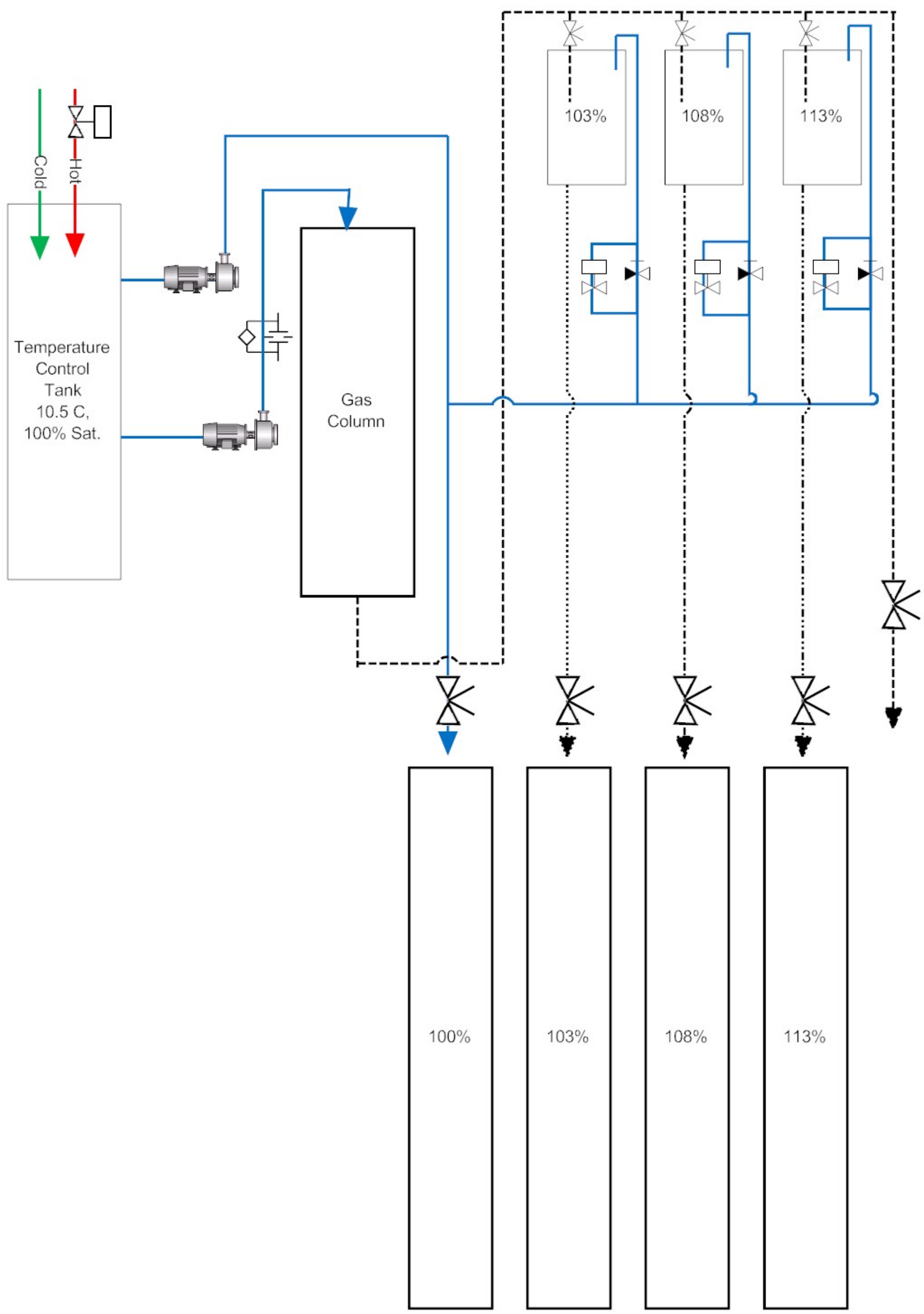

Figure 6. Schematic diagram of FY 2007 analytical apparatus for testing biological effect of four TDG treatments.

Eggs and alevins in the egg tubes will be monitored daily during the entire incubation period. All mortalities will be examined immediately for external GBD signs. On the date of 50% hatch (+/- 1 day), approximately 15 embryos from each egg tube will be weighed and measured for length. During the treatment period, daily samples of up to 10 individuals will be extracted from each treatment level and monitored externally for signs of GBD (including bubbles in the yolk sac, nares, and mouth). A subset of these fish will also be examined for internal GBD signs (including over-inflated swim bladder, air bubbles in the stomach and hindgut). In addition, a sample of about 25 fish per treatment level will be randomly selected and sacrificed at two points during the experiment (e.g., middle and end of treatment). These fish will be preserved and provided to Dr. Ralph Elston, Aqua-Technics, Inc. for histopathological examination. Tissue samples will be examined for damage due to gas bubble disease (GBD).

We will monitor physiological development and abnormal behavior at emergence using the embryos placed in the emergence tubes. A sample of 15 fry from each emergent tube at 50% emergence (+/- 1 day) will be sacrificed and weighed and measured using metrics similar to those used at 50% hatch. The use of emergence tubes will allow us to determine whether timing or size of fish at emergence differs across treatments.

Objective 3 – Conduct in-field TDG monitoring and field analysis of sac-fry in select locations using egg incubation vessels that represent actual redd locations.

In order to assess survival and physiological impacts to chum salmon from TDG, it desirable to employ a technique in the natural environment that can be used in parallel to the laboratory studies. In FY 2007 we sampled natural chum salmon redds in the Ives Island area using a water pump. Live alevins were captured in nets after being washed from natural redds. Fry were examined for signs of GBD using this technique (preliminary data did not reveal signs of GBD), but the technique only enabled a qualitative assessment of the effects of TDG on survival because the number of eggs from each egg pocket was not known. One option to more quantitatively assess mortality is to place fertilized eggs into an incubation vessel buried within artificial redds in the Ives Island area. The artificial redds will be created by hand and will be designed to simulate the hydraulic conditions in a natural redd. The incubation vessels will be placed within an egg pocket that is approximately 20 to 40 cm below the bed of the river. Incubation vessels will be either egg tubes or egg baskets. Egg tubes are usually constructed of perforated PVC pipe that is left in the gravel environment; the egg tubes we used with fall Chinook salmon in the Snake River measured ~30 cm in length by 3.2 cm i.d. (Hanrahan et al. 2004; Hanrahan 2007). Egg baskets are normally larger in diameter (e.g., 10 cm), constructed of fine mesh screen, and filled with gravel representative of the surrounding river bed. Whichever incubation vessel we use, it will be designed so that it is representative of the gravel environment within the Ives Island spawning area; replicates the depth of a natural chum salmon egg pocket; and emulates the vertical distribution of chum salmon as they respond to effects from total dissolved gas encountered during emergence.

During the early spawning period (November – December, 2007), incubation vessels containing 50 to 100 recently fertilized eggs (hatchery to be determined) each will be placed at egg pocket depth within artificial egg pockets created at five sites within the Ives Island study area. One artificial egg pocket will be created at each of the five sites, and each artificial egg pocket will contain 8 incubation vessels (i.e., a total of 40 incubation vessels will be deployed in the Ives Island area). Beginning at the estimated onset of egg hatching, one basket from each artificial redd will be retrieved. At approximately 2-week intervals during the egg incubation period, one basket from each artificial redd will be retrieved until all the baskets have been removed from the redd. Immediately after each egg basket retrieval the fry and dead eggs will be enumerated so that survival can be calculated.

Live and dead fish (embryos, sac-fry or alevins) in each incubation vessel will be enumerated. Fish from the incubation baskets will examined in the field for signs of GBD. Hans et al (1999) suggests that signs of gas bubble trauma in live fish do not change significantly within one hour of removal from a supersaturated environment. Signs of gas bubble disease (GBD) in larval fish may include air bubbles in the yolk sac or between the yolk sac and perivitelline membrane (Shirahata 1966), in the mouth (Peterson 1971), or on the body surface (Shirahata 1966). Therefore, all specimens will be examined for gas bubbles in and associated with the yolk sac, mouth, and external body surface. The degree of severity of GBD will be evaluated by a ranking of percent of tissue surface affected and other metrics as appropriate.

Objective 4 – Facilitate a workshop in the fall of 2008 that will be the first step toward completion of a final synthesis report that combines and evaluates data from FY06-08 studies.

In the fall of 2008 we will have completed three years of study of environmental conditions in the river below Bonneville Dam, and two years of laboratory study on the effects of elevated gas on physiological development of chum salmon sac-fry. We are proposing that a workshop of agency biologists be convened to review and discuss these data. The outcome of the workshop will be a set of recommended actions that will guide the development of a final synthesis document that will be prepared with 2009 funds. The final synthesis report will combine and evaluate data from the three years of the study (FY 2006 through FY 2008) and will include recommendations that managers can use to shape out-year operations such that TDG exposure below Bonneville Dam is minimized.

C.2. JUSTIFICATION

Chum salmon are an ESA listed species, and there are currently two main spawning populations remaining in the lower Columbia River (Grays River and Ives Island Area). The Ives Island site is located approximately 4 rkm downstream from Bonneville Dam, where spring spill operations may be elevating TDG levels and negatively impacting chum salmon sac fry. We will monitor TDG levels in chum salmon spawning gravels utilizing sensors similar to past research evaluating TDG in surface water in the lower Columbia (Tanner and Johnston 2000; Tanner and Bragg 2001; Pickett 2002). Most studies identifying effects at low TDG levels are relatively old and methods used to quantify gas levels and GBD signs have advanced considerably since that time. In addition, most studies conducted on larval fish did not include temperature, exposure duration, and TDG levels relevant to conditions occurring downstream from Bonneville Dam. Toxicity testing will evaluate the range of potential TDG levels from Bonneville Dam spill, and will assess impacts including direct mortality, delayed mortality, abnormal behavior, and sublethal damage on larval chum salmon.

C.3. SAMPLE SIZE CONSIDERATIONS

Hourly TDG and other water quality data will be collected during the 2 month study period. Our sampling rate will match existing USACE data collection efforts monitoring TDG, compensation depth, and tailwater elevation near Bonneville Dam.

Consistent with Backman et al. (2002), a minimum of 100 individuals per treatment replicate will be exposed in each toxicity test. This sample size will provide sufficient statistical power to detect differences if present among treatments and to provide sufficient numbers of individuals for histopathological examination. Four treatments by 6 replicates per treatment by 300 eggs/replicate by 10% contingency is equal to approximately 8,000 eggs for objective 2. We propose exposing eggs to elevated TDG on two different schedules – one that matches the schedule used in 2007 and a second that results in fry being exposed earlier. Therefore, we are proposing to double the number of eggs to 16,000 to enable this parallel exposure treatment.

For Objective 3, we will deploy approximately 2,000 to 4,000 eggs at the five redd sites (50 to 100 eggs/vessel with 8 vessels per redd site).

C.4. LIMITATIONS/EXPECTED DIFFICULTIES

We expect few major difficulties with completing the objectives. We have determined that access to the sensors for repair and calibration purposes will be necessary. Divers will be required to access the sensors because flows can be high during the spring spill period.

Acquisition of eggs for this study has been problematic. The eggs used last year came from a hatchery outside the Columbia River basin. This is acceptable again in 2008 for the second objective, but will not work for objective 3 where out-of-basin disease issues will require us to use either hatchery or natural spawners from the Columbia River basin. We are pursuing this with the management agencies. At the time this proposal was submitted, we had not obtained eggs for either objective 2 or 3.

Several permits will be required to accomplish the proposed project. We expect no difficulties in obtaining these permits:

(1) Fish Transport Application from the Washington Department of Fish and Wildlife; and

(2) Animal Care Use Protocol from PNNL's Institutional Animal Care and Use Committee (IACUC).

(3) State (Oregon and Washington) and Corps of Engineers in-water work permits to install sensors.

C.5. EXPECTED RESULTS AND APPLICABILITY

This project is expected to result in an assessment of the potential effects to chum salmon fry from TDG exposure downstream from Bonneville Dam. This information will assist managers that are faced with deciding between more spill to aid downstream migrants (at the potential expense of elevated intragravel TDG) versus the reduction in TDG with reduced spill (at the potential expense of downstream migrant passage).

C.6. SCHEDULE

Objective	Task	Schedule
1	Monitor TDG (includes bi-weekly site visits)	Mar. 2008-June 2008
2	Permit acquisition	Nov. 2007-Jan. 2008
2	Sac fry toxicity tests	Feb. 2008-Aug. 2008
2	Sac fry histopathological analyses	Mar. 2008-July 2008
3	Construct artificial redds	Early November 2007
3	Deploy egg baskets	Early December 2007
3	Sample incubation vessels from river	Dec. 2007-May 2008
4	Hold workshop	Late Nov/early Dec 2008
1-4	Submit draft report to Corps	November 15, 2008
1-4	Submit final report to Corps	January 31, 2009

D. FACILITIES AND EQUIPMENT

PNNL has extensive experience conducting aquatic research in the hyporheic zone of the Columbia and Snake River systems. We possess all the necessary equipment to successfully install and maintain the equipment that will be used in this study. Our office in North Bonneville is conveniently located near the study site and houses our data telemetry server. The primary investigator and his team have previously published literature summarizing water quality, physicochemical gradients, and groundwater – surface water mixing within the hyporheic zone of the Columbia and Snake rivers (Geist et al, in press; Arntzen et al. 2006; Hanrahan et al. 2005; Moser et al. 2003; Geist et al. 2002; Geist 2000a,b). PNNL also has extensive laboratory capabilities to link empirical field data to simultaneous laboratory work. PNNL operates an aquatic facility that supports a variety of research on fish and other aquatic life, covering topics as diverse as toxicology, bioengineering, and biosensor development. Housed in PNNL's Life Sciences Laboratory 1 in Richland, Washington, the laboratory is operated for the U.S. Department of Energy. Waters from the Columbia River and a groundwater well are delivered to the lab and conditioned to meet specific research needs. The laboratory is capable of producing water for fish exposures that can be supersaturated with dissolved nitrogen, with controlled ratios of dissolved oxygen to dissolved nitrogen.

AquaTechnics Inc. will be used for histological analysis of tissue samples. AquaTechnics specializes in fish and shellfish health management and aquatic environmental assessment. Laboratory capabilities in fish health management include histological assessment of tissues, gross necropsy of fish, stereo, bright field and fluorescence microscopy, photomicroscopy, and virological, bacteriological, polymerase chain reaction (PCR) and other microbiological assays for fish and shellfish pathogens, and physiological assays of fish condition (e.g. plasma evaluation). AquaTechnics has both private and governmental clients in all Pacific coast states as well as in South America, Europe and Asia. AquaTechnics staff are experienced in team management, sample documentation, chain of custody tracking, quality assurance and quality control procedures, project management, and preparation of reports.

E. IMPACTS

1. Other ongoing or proposed research

The on-going BPA project will not be impacted by this study. In fact, there will be a net benefit to both projects through cost-sharing and collaboration.

2. Special operations

There may be need to reduce flow at Bonneville Dam on weekends to accommodate access to the site. This was coordinated with the Corps in 2006 and 2007 and has been coordinated with BPA in the past on BPA Project 1999-003. In both cases the agencies have been extremely cooperative and flow management has worked well to enable short-term access to monitoring stations. The use of SCUBA divers will also be used to reduce this impact.

F. COLLABORATIVE ARRANGEMENTS AND/OR SUB-CONTRACTS

We will subcontract with Dr. Ralph Elston, Aqua-Technics, Inc. for histopathological analyses. Dr. Elston is a recognized expert in the field of histopathology and has considerable experience with gas bubble disease in salmonids (Elston et al. 1997a, b). Mr. Earl Dawley will be consulted for experimental design and data interpretation on field and laboratory studies.

IV. LIST OF KEY PERSONNEL AND PROJECT DUTIES

Dr. David Geist	Project Manager
Mr. Evan Arntzen	Field Lead
Ms. Kris Hand	Laboratory Lead
Dr. Ralph Elston	Sub-contractor, Aqua-Technics, Inc.
Mr. Earl Dawley	Sub-contractor

V. TECHNOLOGY TRANSFER

Information acquired during the proposed work will be transferred in the form of written and oral research reports. A presentation will be made at the Corps' annual Anadromous Fish Evaluation Program Review. Technology transfer activities may also include presentation of research results at regional or national fisheries symposia, or publication of results in scientific journals.

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VII. BUDGET

Detailed budget by PNNL will be provided under separate cover.

FINAL RESEARCH PROPOSAL (COE) (FY08)

TITLE:	Post-passage condition and gatewell retention time of subyearling and yearling Chinook salmon guided from modified Bonneville Dam Second Powerhouse turbine intakes
PROJECT LEADERS:	Lyle G. Gilbreath, Michael H. Gessel, and Dean A. Brege National Marine Fisheries Service Northwest Fisheries Science Center Fish Ecology Division 2725 Montlake Boulevard East Seattle, Washington 98112-2097 (509) 427-8611
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ADMINISTRATIVE:	Doug Dey National Marine Fisheries Service Northwest Fisheries Science Center Fish Ecology Division 2725 Montlake Boulevard East Seattle, Washington 98112 (206) 860-3237
ADMIN. CODE:	SPE-P-08-New-3
DURATION OF PROJECT:	2008
DATE OF SUBMISSION:	October 2007

PROJECT SUMMARY

Juvenile Chinook salmon will be released at three Bonneville Dam Second Powerhouse locations during turbine operation at the high and low ends of the 1% peak efficiency range. The principal study objective is to compare post-passage condition of fish following exposure to the two different operational conditions. Parameters will include descaling, injury, and mortality rates and gatewell retention times (as measured by passage timing). Releases will be made into turbine intakes just downstream from and near the top of trashracks, into gatewells near the top of submersible traveling screens (STS), and into the bypass system collection channel adjacent to turbine unit(s) selected for testing. Each replicate will include releases at the three specified locations during each of the two operational modes; therefore a single replicate test will require six distinct marked groups. All fish used in tests will be tagged with PIT tags and recaptured via separation-by-code (SbyC) at the Second Powerhouse Juvenile Fish Monitoring Facility (JFMF). We will test the following hypotheses:

1. Travel time. H_0: $TT_{Upper}=TT_{Lower}$ and H_1: $TT_{Upper}\neq TT_{Lower}$ where TT=travel time from release to first PIT-tag detection, Upper=release at the upper end of the 1% peak efficiency curve, and Lower=release at the lower end of the 1% peak efficiency curve.

2. Descaling rates. H_0: $DS_{Upper}=DS_{Lower}$ and H_1: $DS_{Upper}\neq DS_{Lower}$ where DS=descaling rate, Upper=release at the upper end of the 1% peak efficiency curve, and Lower=release at the lower end of the 1% peak efficiency curve.

3. Mortality rates. H_0: $MR_{Upper}=MR_{Lower}$ and H_1: $MR_{Upper}\neq Mr_{Lower}$, where MR=mortality rate, Upper=release at the upper end of the 1% peak efficiency curve, and Lower=release at the lower end of the 1% peak efficiency curve.

Test series will be conducted using subyearling Chinook salmon obtained from Spring Creek National Fish Hatchery (NFH) and run-of-river (ROR) yearling and subyearling Chinook salmon captured at the Bonneville or John Day Dam juvenile fish monitoring facilities. Tests using Spring Creek NFH fish will take place in early to mid March, following the first Spring Creek NFH production release. Releases of fish obtained from Spring Creek NFH will also be made in conjunction with the April and May hatchery releases. Releases of ROR yearling Chinook salmon will be conducted during late May and early June in order to assess impacts to this life-history type. A final test series will be conduced during late June and early July with ROR subyearling Chinook salmon.

BACKGROUND

Second Powerhouse Modifications to Improve FGE

The Bonneville Dam Second Powerhouse, completed in 1982, includes a juvenile bypass system (JBS) designed to divert salmonid smolts from turbine intakes into a collection and transport system terminating in the powerhouse tailrace, thereby avoiding turbine passage and improving survival. In 1983, however, the initial evaluation of fish guidance efficiency (FGE) determined that guidance was considerably lower than the 70% design criteria for all species (Krcma et al. 1984). From 1984 to 1989, a variety of structural modifications were installed and tested in attempts to improve Second Powerhouse FGE (Gessel et al. 1991). The results of these tests suggested FGE could be enhanced through structural modifications that would improve flow patterns into and through turbine intakes and increase flow into gatewells.

By 1991, extensive modifications were completed including installation of turbine intake extensions, streamlining trash racks, and lowering submersible traveling screens (STS) by 0.8 m. Continued evaluations of FGE during the 1990s using traditional techniques (Monk et al. 1994, 1995) and hydroacoustic FGE (Ploskey et al. 1998) yielded FGE estimates which were improved, but still well below the 70% design criteria.

Further modification of Second Powerhouse intakes was begun in 2001, with the objective of increasing FGE. These modifications included: 1) increasing the length of vertical barrier screens by removing a portion of the concrete beams located below, 2) installation of a turning vane below the picking beam on STSs, and 3) installation of gap closure devices on the intake ceiling downstream from the top edge of STSs. FGE tests conducted by NOAA Fisheries in 2001 and 2002 (Monk et al. 2002, 2004) determined that there were promising FGE increases in the modified intakes. Also, fish condition (descaling) was not significantly different between modified and unmodified intakes. Based on these evaluations and other considerations, the decision was made to modify intakes across the powerhouse.

Spring Creek NFH Releases – March and April 2007

In 2007, Spring Creek NFH released approximately 15.5 million tule fall Chinook salmon: 6.6 million on 5 March, 1.2 million on 9 March, 4.2 million on 12 April, and 3.5 million in the final production release on 1 May. Average weights of the fish at release were 3.0, 3.5, 5.1, and 6.1 grams for the respective releases. Average daily temperatures at the Second Powerhouse JFMF during passage periods for these fish ranged from 6.0 to 6.6°C in March, 9.1 to 9.6°C in April, and 11.6 to 11.9°C in May. During the 7-13 March passage period for Spring Creek NFH fish, river flow averaged 158,400 cfs, spill plus corner collector flow averaged 6,000 cfs, and Second Powerhouse flow averaged 89,000 cfs. From 13-16 April, river flow averaged 238,400 cfs, spill plus corner collector flow averaged 105,700 cfs, and Second Powerhouse flow averaged 80,400 cfs.

Fish released from Spring Creek NFH in March and early April in 2007 were identified by size (fork lengths 55-70 mm in March and 60-75 mm in April), dark coloration and unsmolted appearance, and high percentage (95-99%) of adipose-fin-clips. Except for small numbers of wild fry, few other subyearling ROR Chinook salmon were present during the March and April passage periods for Spring Creek NFH fish. Average daily Smolt Monitoring Program (SMP) sample rates during Spring Creek NFH releases ranged from 0.5 to 1.5% of bypass system passage during the March passage period and from 0.7 to 25% of passage during April. These sample rates produced catches ranging from 105 to 1,293 fish during the March release period and from 219 to 1,960 fish during the April release.

The SMP data indicate that substantial mortality occurred during Second Powerhouse passage of Spring Creek NFH Chinook salmon released in March and April 2007. Daily mortality rates measured at the sampling facility ranged from 1.6 to 11.7% during passage of the early March releases (7 through 13 March). During passage of the April release, fish began arriving at the monitoring facility about 0645 hours on 13 April and from that time until 0900 hours the mortality rate was 10.1%. The evening of 13 April, Second Powerhouse turbine operation was reduced so that units were run at the lower end of the 1% peak efficiency range. This operational change appeared to reduce the incidence of mortality. Overall mortality from 0900 hours on 13 April to 0700 hours on 14 April was 3.2%. In contrast, SMP data (daily samples ≥100 fish) during the passage of Spring Creek NFH fish during March and April of prior years (2000-2006) showed only one March date (16 March 2002) and 3 April dates (1 April 2002 and 17-18 April 2004) where the mortality rate exceeded 1%.

It is evident from these data that Spring Creek NFH production releases passing the Second Powerhouse in March and April 2007 sustained unusually high mortality rates. Inspection of passage facilities did not identify problems nor did necropsy of post-passage mortalities show evidence of disease. It should be noted that the U.S. Fish and Wildlife Service (FWS) Lower Columbia Fish Health Center conducts extensive fish health monitoring of Spring Creek NFH production fish during rearing and prior to release and no problems were found in the 2007 release groups (S. Gutenberger, FWS, personal communication). In summary, there was no evidence to indicate Second Powerhouse passage facilities were operating out of criteria and no history of preexisting disease problems in the 2007 Spring Creek NFH fish released in March and April. Consequently, we believe that an evaluation of fish condition in relation to operation of modified turbine units at the high and low ends of the 1% peak efficiency range would be an appropriate step in identifying the cause of the mortality observed in 2007.

RELEASE PROCEDURE

Turbine Unit 11 (A slot) at Bonneville Second Powerhouse will be equipped with the necessary release equipment. The releases downstream from and near the top of the trashrack will be made from the intake deck through a 10.2-cm diameter flex hose. The flexible hose will be inserted through a protective metal “sleeve” constructed of 20.3-cm diameter steel pipe. This type of release apparatus was used successfully at McNary Dam in 2005 and 2006.

Gatewell releases will be conducted with a release canister. This system has been used at several COE projects (McNary, John Day, and Little Goose dams) during previous studies (Absolon and Brege, 2003). Releases will be made as deep as possible within the gatewell. Limiting factors include upward flow in the gatewell which tends to “float” the release frame at high turbine operation, and also the different cables, ropes, and power cords present in the gatewell which may hinder the vertical movement of the release frame.

The juvenile bypass releases will be made from a small holding tank directly into the collection channel adjacent to Unit 11. The tank will be placed prior to the start of the field season and test fish will be hand carried in 19-L buckets to the release tank prior to each release.

All releases (trashrack, gatewell, and bypass) will be made on a daily basis for each replicate. The sequence of release will be gatewell, trashrack, and then bypass. It is necessary to make the gatewell release first, so that the frame supporting the release canister can be removed from the gatewell prior to the trashrack fish entering the gatewell. The bypass release will occur approximately 30 minutes after the trashrack release has been completed.

Turbine operation for the test unit (Turbine 11) will need to be continuous for (2-6 hours) for each replicate. At this time the duration of each replicate can only be estimated, but as the test results are obtained we should be able to select a set time period. During any given test day we propose to test both high and low turbine operations. To do this it will be necessary to dip the test gatewell at the end of each replicate. Gatewell dipping will ensure that fish being tested at one turbine operation are not subjected to both.

A standard test day would follow this sequence of events:

1. 0700 hours. Turbine Unit 11 is set at the selected operating load.
2. 0800 hours. Gatewell canister release is completed followed by trashrack release in 11A.
3. 0830 hours. Bypass channel release is made.
4. 1200 hours. Gatewell 11A is dipnetted and all fish removed and examined.
5. 1230 hours. Turbine Unit 11 is set at the second operating load and the prior sequence of events is repeated for the second test.

OBJECTIVES

Objective 1

Conduct fish health sampling to determine status of test subjects prior to release.

The comprehensive fish health monitoring program conducted by the FWS Lower Columbia Fish Health Center will provide suitable documentation for test fish obtained from Spring Creek NFH. For ROR yearling and subyearling Chinook salmon obtained at the Bonneville or John Day Dam juvenile fish monitoring facilities, we suggest that minimal numbers of fish be sacrificed to test for diseases such as bacterial kidney disease (BKD), infectious hematopoietic necrosis (IHN), furunculosis, and columnaris. This work would be completed by personnel of the Lower Columbia Fish Health Center or by NOAA Fisheries personnel from the Northwest Fisheries Science Center.

Objective 2

Calculate and compare travel times within replicates for fish released during high- and low-end turbine operations within the 1% peak efficiency curve. Fish will be released at three test locations: 1) turbine intakes just upstream and near the top of trashracks, 2) gatewells near the top of STSs, and 3) the bypass system collection channel.

The null and alternate hypotheses for Objective 2 are H_0: $TT_{Upper}=TT_{Lower}$ and H_1: $TT_{Upper} \neq TT_{Lower}$, where TT=travel time to first PIT tag detection, Upper=release at the upper end of the 1% peak efficiency curve, and Lower=release at the lower end of the 1% peak efficiency curve.

Calculation of travel times will require that test fish be PIT tagged. Spring Creek NFH subyearling Chinook salmon released in March and April typically include fish as small as 55-60 mm in fork length. The use of standard length (12.5 mm) PIT tags injected with 12-gauge needles can be difficult with fish of this size. We propose to use the shorter 8.5-mm PIT tag which will be inserted manually through a small incision made by a surgical knife such as the BD Micro-Unitome™. These techniques have been used successfully by NOAA Fisheries personnel in other tagging situations (S. Downing, NOAA Fisheries, pers. commun.). Prior to anesthesia, fish will be handled using water-to-water transfer techniques. Fish will be anesthetized with tricaine methanesulfonate at a concentration of about 50 mg/L. Surgical knives will be disinfected prior to reuse in 70% ethanol, following the disinfection protocol used for PIT-tag injection needles. Larger ROR fish used in later releases will be tagged using standard length PIT tags injected with 12-gauge needles.

Travel time will be computed as elapsed time from release to first detection at the JFMF (SbyC Separator Gate Monitor). Passage timing data for individual PIT-tagged fish will be obtained via query of the PTAGIS database. The downloaded CSV data files will be imported into spreadsheet and database programs for calculation of minimum, maximum, and 10^{th}, 50^{th}, and 90^{th} percentile passage times. Since PIT-tag monitors are not installed on gatewell orifices at the Second Powerhouse, gatewell residence time will be computed as the difference between passage times of gatewell and collection channel releases.

We anticipate that median travel time estimates of good precision can be determined with 6 to 8 replicate releases in which each group within a replicate contains about 100 fish. Confidence intervals will be constructed around the median passage times using the empirical standard errors of the replicates and expressed as the mean of median passage times plus or minus “t” standard errors, where “t” is the t-statistic corresponding to $\alpha = 0.05$ and n degrees of freedom.

Objective 3

Calculate and compare between-group descaling rates for fish released during high- and low-end turbine operations within the 1% peak efficiency curve.

The null and alternate hypotheses for Objective 3 are H_0: $DS_{Upper}=DS_{Lower}$ and H_1: $DS_{Upper} \neq DS_{Lower}$, where DS=descaling rate, Upper=release at the upper end of the 1% peak efficiency curve, and Lower=release at the lower end of the 1% peak efficiency curve. If the null hypothesis is rejected, then relative descaling rates will be compared between fish released at the three locations to determine if descaling is occurring during passage through the turbine intake or during residence in gatewells.

Observation of descaling rates will likely be less telling than mortality rates for subyearling Chinook salmon originating at Spring Creek NFH and intercepted at Bonneville Dam within a few days of release in March and April. This is because the Spring Creek NFH fish are essentially parr with non-deciduous scales when they pass Bonneville Dam, and as such, are not as prone to descaling as the more smolted ROR fish. For example, during the April 2007 passage of Spring Creek NFH production fish, mortality rates exceeded descaling rates by factors ranging from 3.6 to 6.3 (D. Ballinger, Pacific States Marine Fisheries Commission, pers. commun.). In contrast, descaling will be the better indicator of passage problems when conducting tests with ROR yearling Chinook salmon in May and ROR subyearling Chinook salmon in late June and July.

Although assessing mortality and injury is straightforward, quantifying descaling can be a difficult, subjective procedure. Prior to 1991, NMFS used a system in which the lateral surface on each side of a fish was divided into five sectors. If a fish was descaled in excess of 40% in two or more sectors on one side, it was classified as descaled. We noted descaling by sector and additional categories were created for overall scattered and patchy descaling. In 1991, the Fish Transportation Oversight Team (FTOT; now defunct) adopted the simplified descaling criteria which is currently in use at all Columbia River system monitoring sites (Ceballos et al. 1993). By these criteria, if cumulative scale loss on one side of a fish equals or exceeds 20%, the fish is classified as descaled. A second category termed “partially descaled” was created for fish with cumulative scale loss on one side that is greater than 3% but less than 20%. The third FTOT category was “non descaled” defined as minor descaling up to 3%.

In this study, fish will be individually identifiable via PIT tags. This, coupled with careful pre- and post-passage observations of fish condition should enable better descaling estimates than were possible with either the historical NMFS or FTOT methods. Although we will note descaling according to FTOT criteria, we will also estimate the extent of descaling on lateral surfaces by using a technique developed during our 2000 post-construction evaluation of the Second Powerhouse JBS. With this method we were able to compare estimated descaling percentages at tagging and after recapture. This yielded an estimate of “new” descaling for each test fish (Gilbreath et al. 2004). With this technique it may be possible to relate descaling to size of test fish and it will be possible to utilize fish with some preexisting descaling as test fish.

Analysis of variance (ANOVA) will be used to identify significant differences in descaling rates between treatment groups released under the two turbine loadings.

Objective 4

Calculate and compare between-group mortality rates for fish released during high- and low-end turbine operations within the 1% peak efficiency curve.

The null and alternate hypotheses for Objective 3 are H_0: $MR_{Upper}=MR_{Lower}$ and H_1: $MR_{Upper} \neq MR_{Lower}$, where MR=mortality rate, Upper=release at the upper end of the 1% peak efficiency curve, and Lower=release at the lower end of the 1% peak efficiency curve. If the null hypothesis is rejected, then relative mortality rates will be compared between fish released at the three locations to determine if mortality is occurring during passage through the turbine intake or during passage into and residence in gatewells.

We will log incidence of mortality during processing of the SbyC recaptures at the JFMF. These data will constitute the primary data set for analysis of passage mortality. We will also hold recaptured fish on fresh water for a 10-d period after examination to determine if latent mortality differs between treatment groups. We acknowledge that freshwater holding could produce overall latent mortality results that are either lower (fish held in a protected environment) or higher (fish stressed by holding) than actual mortality in the natural environment.

Analysis of variance (ANOVA) will be used to identify significant differences in mortality rates between treatment groups released under the two turbine loadings.

FISH REQUIREMENTS

We calculated treatment group sizes necessary to detect an additive difference, d, given a background or control effect, p_1, with $\alpha = 0.05$ and $\beta = 0.20$ by using the following equation from Zar 1999:

$$n \approx \frac{(t_{\alpha/2} + t_{\beta})^2 [p_1(1-p_1) + (p_1+d)(1-p_1-d)]}{d^2} \approx \frac{8[p_1(1-p_1) + (p_1+d)(1-p_1-d)]}{d^2}$$

With the detectable additive difference set at 3% and estimated p_1 values of 0.03, 0.04, and 0.05, estimated group sizes were 846, 1,024, and 1,199 fish per treatment group, respectively. Fish requirements in the following text are based on a conservative group size estimate of 1,199 fish per treatment group; a single test series with six treatment groups would therefore require about 7,200 fish. Should the background effect observed in initial tests be less than 0.05, we will reduce treatment group size accordingly. This will likely be the case in tests using ROR yearling and subyearling Chinook salmon.

In each test, treatment groups (trashrack, gatewell, and collection channel) will be released with the test unit loaded at the upper and lower ends of the 1% peak efficiency range (three groups released with each unit load condition; total of six groups per test). Assuming a 75% recapture rate for fish released at the trashracks and into gatewells and a 100% recapture rate for fish released into the bypass system collection channel, we estimate that a single replicate test would require about 1,100 fish: 400 fish for trashrack releases, 400 fish for gatewell releases, and 300 fish for collection channel releases. If the test is replicated 8 times, a total of 8,800 PIT-tagged fish would be released to ensure recovery of the required 7,200 fish in each test series. If all proposed test series (3 series with Spring Creek NFH fish, 1 series with ROR yearling Chinook salmon, and 1 series with ROR subyearling Chinook salmon) are conducted, then testing would require 26,400 fish obtained directly from Spring Creek NFH, 8,800 ROR yearling chinook salmon (adipose-fin-clipped), and 8,800 ROR subyearling Chinook salmon (clipped and unclipped).

The release group sizes used to evaluate the descaling and mortality objectives will provide adequate numbers for passage timing estimates. As mentioned in the outline of Objective 1 (fish health assessment), we feel it would serve little purpose to sacrifice additional Spring Creek NFH origin fish, given the scope of the existing FWS fish health monitoring program. For ROR groups, we anticipate that fish health surveys would require sacrifice of 58 fish per replicate times 8 replicates, for a total of 480 ROR yearling Chinook salmon and 480 ROR subyearling Chinook salmon. This sample size follows the recommendation of Piper et al. (1982) for minimum numbers required to be 95% confident of detecting a 5% incidence of disease.

SCHEDULE (2008)

10 to 20 March	Obtain, PIT-tag, release, and recapture subyearling Chinook salmon obtained from Spring Creek NFH (first Spring Creek NFH test series).
14 to 25 April	Obtain, PIT-tag, release, and recapture subyearling Chinook salmon obtained from Spring Creek NFH (second Spring Creek NFH test series).
5 to 16 May	Obtain, PIT-tag, release, and recapture subyearling Chinook salmon obtained from Spring Creek NFH (third Spring Creek NFH test series).
19 May to 6 June	Conduct replicate tests using ROR yearling Chinook salmon.
23 June to 11 July	Conduct replicate tests using ROR subyearling Chinook salmon.

IMPACTS TO PROJECTS, FACILITIES, AND EQUIPMENT

We will request COE perform the design, construction, and placement of the steel pipe sleeve required for protection of the trashrack release hose at the Turbine 11 "A" slot. During testing, we will request consistent turbine unit operation within the test criteria (high- or low-end of the 1% peak efficiency range) and hourly recording of operational data.

A fish handling and examination station will need to be located on the intake deck near Turbine 11 and use of the intake deck river water system will be needed to provide life support for fish during pre-release holding and examination of gatewell cleanout catches. Other equipment, including a mobile crane, dipbasket, and release canister frame will need to be stored nearby when not in use.

Acquisition, holding, tagging, and recapture of test fish will require use of JFMF facilities. For these tasks, we anticipate personnel will need to be on the Bonneville Project grounds outside of normal working hours, on weekends, and on holidays.

PROJECT PERSONNEL AND DUTIES

Lyle G. Gilbreath	NOAA Fisheries Principal Investigator
Michael H. Gessel	NOAA Fisheries Principal Investigator
Dean A. Brege	NOAA Fisheries Principal Investigator
Dean Ballinger	PSMFC Principal Investigator
Lila Charlton	PSMFC Tagging Crew Leader
Benjamin P. Sandford	NOAA Fisheries Statistician

TECHNOLOGY TRANSFER

Study findings will be communicated in the form of written or oral research reports. A draft report will be provided to the COE following completion of the work and a final report will be submitted to COE after appropriate review.

RELEVANCE

The Action Agencies document *Final Updated Proposed Action for the FCRPS Biological Opinion Remand*, dated November 24, 2004, provides two references pertinent to this proposal. First, under *Hydrosystem Substrategy 1.4: Project Configuration Research, Monitoring, and Evaluation (RM&E)*, the document calls for post-construction evaluation of new or modified passage facilities. A second applicable reference within the document appears in

Hydrosystem Substrategy 3.4: Operations RM&E, where monitoring and evaluation of fish facilities is mentioned in the context of determining if facilities are operating as intended or to improve performance.

In addition, a recent pre-decisional document prepared by the Action Agencies, *Research Monitoring and Evaluation (RM&E) Proposed Action Summary*, dated May 21, 2007, provides two appropriate references under *RME Strategy 2: Hydrosystem RM&E*. The first, under *Action: Monitor and Evaluate Migration Characteristics and River Conditions*, calls for evaluation of smolt condition, including descaling and injury in order to identify potential problems and evaluate implemented solutions. A second reference is found under *Action: Monitor and Evaluate Effects of Configuration and Operation Actions*, in which smolt passage survival and condition are mentioned in association with evaluation of traditional juvenile bypass systems and modifications to such.

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FINAL RESEARCH PROPOSAL

SUBMITTED TO THE U.S. ARMY CORPS OF ENGINEERS UNDER THE ANADROMOUS FISH EVALUATION PROGRAM 2008 PROJECT YEAR

I. BASIC INFORMATION

A. TITLE OF PROJECT

Acoustic Telemetry Study to Evaluate Juvenile Fish-Passage Efficiency and Survival Associated with Surface-Spill Treatments at John Day Dam in 2008

B. PROJECT LEADERS

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C. STUDY CODES

SPE-P-00-8-new-2: Studies of Surface Spill at John Day Dam

D. DURATION

January 2008 to February 2009 (Draft Report) plus 60 d after receipt of regional comments

E. DATE OF SUBMISSION

October 16, 2007

II. PROJECT SUMMARY

A. GOAL

We propose to evaluate effects of two spill treatments on fish-passage efficiency, spill efficiency, spill effectiveness, project survival, dam survival, and route-specific survival of JSATS-tagged juvenile salmonids at John Day Dam (JDA). We also will evaluate effects of treatments on TSW-specific metrics including discovery, entrance, and passage efficiency. Spill treatments have not been selected by the region, but one likely treatment will involve spill over top-spill weirs (TSW) in spill bays 18 and 19 and associated training spill presented in a randomized 2-day treatment design within 4-day blocks.

The region also has not settled on the species and age classes of juvenile salmonids to study, although it likely will include steelhead (STH) and perhaps yearling Chinook salmon (YC) in spring and subyearling Chinook salmon (SYC) in summer. In this proposal, we describe a study of effects of two generic spill treatments on behavior, passage, and survival metrics for steelhead and yearling Chinook salmon in spring and subyearling Chinook salmon in summer. We recognize that the composition of study fish may change between now and the beginning of the study.

B. OBJECTIVES

1. Estimate route-of-passage for individual YC, STH, and SYC based on forebay tracking of fish on two independent combinations of hydrophones deployed on the dam face at JDA, estimate passage proportions among major passage routes, and calculate efficiency and effectiveness metrics for each of two 2-d spill treatments within 4-d blocks.
2. Estimate route-specific survival and project and dam survival for YC passing JDA in spring using a triple-release study design for each of two spill treatments.
3. Estimate route-specific survival and project and dam survival for STH passing JDA in spring using a triple-release study design for each of two spill treatments.
4. Estimate route-specific survival and project and dam survival for SYC passing JDA in summer using a triple-release study design for each of two spill treatments.
5. Statistically compare metrics estimated in Objectives 1-4 above for each of the two treatments and test a variety of treatment-specific hypotheses.

C. METHODOLOGY

We propose using JSATS acoustic telemetry tags and receivers to conduct a dam and route-specific survival study at JDA in spring and summer 2008. All tags will be programmed to transmit once every 3 s and should last about 20 days, which is more than twice the median travel time from the McNary Dam (MCN) Tailrace to survival arrays below Bonneville Dam each season. We will surgically implant JSATS acoustic tags and PIT tags in at least 2,500 STH and 2,500 YC salmon in spring and 2,500 SYC salmon in summer for release in the MCN Tailrace upstream of JDA to provide treatment-release groups. We will tag and release about 500 each of YC and STH in spring and of SYC in summer in the JDA Tailrace to serve as reference release groups, and also tag and release 500 each of YC, STH, and SYC in the JDA juvenile bypass system to form route-specific releases at JDA. Releases at all locations will be divided among 16 days each season. These release numbers should produce triple-release, treatment-specific estimates of dam survival with one-half 95% confidence limits ranging from 2.3 to 2.5% each season.

An array of five or six autonomous hydrophones will be installed at the JDA forebay entrance, as defined by the hydraulic influence of expected powerhouse and spillway operations. This array would be used to detect the arrival of surviving fish at JDA, assess their lateral distribution across the forebay, and when coupled with downstream survival arrays, will be used to make a virtual release estimate of fish that partitions project survival into pool and dam components. Project and dam survival are expected to be the primary survival metrics for testing treatments because they have higher precision than route-specific survival estimates.

Rectangular configurations of four JSATS hydrophones will be deployed at every turbine and spill bay to allow for tracking (successive hyperbolic positioning or multilateration) of fish as they approach within about 250 ft of JDA. Passage routes will be assigned based on the path of detections on two-dimensional tracking arrays, and we will track each fish twice using two independent combinations of hydrophones. Some of these data could be processed to provide successive positions in three dimensional space for specific volumes of interest (e.g., the forebay upstream of TSWs). We will subdivide powerhouse passage into turbine and JBS passage by examining acoustic and PIT detections of fish in the JBS channel. Fish that pass through the powerhouse but not through the JBS, will be classified as turbine-passed fish.

Autonomous JSATS nodes will be deployed in four arrays downstream of JDA and will sample continuously in spring and summer, except for brief periods required to download data. The first downstream array will be an egress array located about 9.4 km downstream of JDA, and the next three will be arrays for estimating detection and survival probabilities. The use of three detection arrays will allow us to make two estimates of detection probabilities and survival and to test independence assumptions of the single release model using Burnham Tests 2 and 3 (Burnham et al. 1987).

A wide variety of fish-passage metrics will be estimated and used to evaluate effects of spill treatments on fish passage. These include, but may not be limited to, fish-passage efficiency (FPE), spill-passage efficiency (SPY), spill-passage effectiveness (SPS), powerhouse fish guidance efficiency (FGE), TSW discovery efficiency, TSW entrance efficiency, and TSW passage efficiency and effectiveness.

A variety of metrics will be estimated and used to evaluate effects of spill treatments on fish survival, but project-wide estimates have the best hope of detecting significant treatment effects. The best precision will be for JDA project and dam survival estimates because fish numbers will exceed those for route-specific estimates. We also will make route-specific estimates of survival for fish passing through turbines, the JBS, the spillway, TSW bays 18 and 19, and non-TSW bays, although precision, which will be a function of the number of tagged fish passing each route, will be lower than for project and dam-survival estimates. Dr. John Skalski will develop a triple-release model design for this study to overcome some of the potential difficulties of post-pairing treatment fish in the river 3-7 days with newly released control fish.

If both treatments include operational TSWs with different levels of spill, there will be several null hypotheses that will be evaluated as one-tail tests relative to historical measures of performance (Table 1).

1. Estimates of fish-passage efficiency, spill-passage efficiency, spill-passage effectiveness, and FGE for each species and age group tested are not significantly higher than existing benchmarks for each species / age group of juvenile salmonids.
2. Estimates of project and dam survival, as well as route specific survivals, are not significantly higher than historical benchmarks for each species and age group of juvenile salmonids.

If treatments consist of TSW on and off operations, we will compare estimates of passage and survival under the "TSW on" treatment to COMPASS / COP benchmarks, as described above, and also test the null hypothesis that "on treatments" produced estimates that were not significantly higher than "off treatments."

Table 1. Passage and survival benchmarks from COMPASS or the JDA COP

Species	**FPE**	**FGE***	**Spill Passage Efficiency (SPY*)**	**Turbine *Survival***	**Bypass *Survival***	**Spill *Survival***	**Dam *Survival***
YC	0.921	0.640	0.780	0.799	0.965	0.964	0.938
STH	0.926	0.760	0.690	0.799	0.882	0.973	0.913
SYC	0.874	0.320	0.815	0.720	0.920	0.980	0.904

* FGE data are COMPASS average multiple treatment years, whereas SPY data are averages from BiOp 0/60 treatment years (COMPASS). Subyearling Chinook salmon data are from the JDA COP.

D. RELEVANCE TO THE BIOLOGICAL OPINION

As part of the remand process for the 2004 Biological Opinion on Federal Columbia River Power System (FCRPS) operations, the Action Agencies submitted to the U.S. District Court, District of Oregon a draft Proposed Action dated May 21, 2007. Hydrosystem Strategy 2 of the Proposed Action states, "Modify Columbia and Snake river dams to maximize juvenile and adult fish survival." This strategy includes the following measures for juvenile passage and survival at John Day Dam.

- Action 11 – Powerhouse Improvement Actions – "*Providing or enhancing powerhouse surface flow outlets.*"
- Action 12 – Spillway Improvement Actions – "*Providing or enhancing spillway surface flow outlets.*"

III. PROJECT DESCRIPTION

A.1. PROBLEM DESCRIPTION

Non-turbine passage (FPE), FGE, spill efficiency and effectiveness, and project, dam, and route-specific survival estimates for JDA are not as high as the Portland District and region desire, especially for Endangered Species Act (ESA) listed salmonids. Current policy emphasis for operation of Federal Columbia River Power System (FCRPS) projects includes increasing survival rates of ESA-listed Pacific salmon (Oncorhynchus spp.) in part by increasing FPE for juvenile salmonids. Providing a surface flow route of passage in-concert with adequate attraction flows, is currently one accepted means of increasing FPE. Two top spillway weirs (TSW) have been designed and are scheduled to be installed at JDA in spill bays 18 and 19 for the 2008 passage season (Figure 1). The primary goal of the JDA surface bypass program in 2008 will be to reduce turbine passage rates by applying TSW treatments in concert with specific spill and powerhouse operational priorities. Non-turbine passage and survival rates will be evaluated against established passage metrics and survival targets (i.e., COMPASS and the JDA COP – Table 1). Evaluations will either: 1) compare a single powerhouse & spill operation (i.e., TSW and training flow) treatment against these established bench marks, or 2) compare two operational treatments. The hope is that information on TSW performance and project operations from treatment evaluations will help guide further development of surface bypass structures for JDA that can improve fish survival. Further, information on how fish approach and pass the dam is critical in developing and locating future surface-passage structures at JDA.

A.2. BACKGROUND ON METHODS

Baseline biological data on fish distributions were summarized by Giorgi and Stevenson (1995) and Anglea et al. (2001). Telemetry has been used to estimate a variety of passage and survival metrics at JDA. Radio telemetry studies were conducted to evaluate fish movement, travel time, behavior, and route of passage (Sheer et al. 1997; Holmberg et al. 1998; Hansel et al. 1999; Liedtke et al. 1999; Hensleigh et al. 1999; Hansel et al. 2000). The use of radio telemetry to estimate survival of tagged fish at John Day Dam was evaluated and deemed feasible in 1999 (Counihan et al., 2002a) and survival studies were conducted in 2000, 2001, 2002, and 2003 (Counihan et al. 2002b, 2005, 2006a, 2006b). A JSATS acoustic-telemetry survival study was conducted in spring and summer 2006 (Ploskey et al. 2007). Acoustic telemetry studies have become more common in recent years because of advantages such as functionality in both fresh and salt water, no external antenna, detection throughout the water column, and the ability to track in two and even three dimensions. Examples include Faber et al. (2000), Skalski et al. (2002), Skalski et al. (2003), McComas et al. (2004), and Ploskey et al. (2007). The JSATs autonomous nodes were successfully used in the Columbia River estuary to estimate survival of yearling Chinook salmon, steelhead, and sub-yearling Chinook salmon in 2004, 2005, 2006, and 2007. Guidelines and recommended protocols for conducting, analyzing, and reporting juvenile salmonid survival studies were described by Peven et al. 2005.

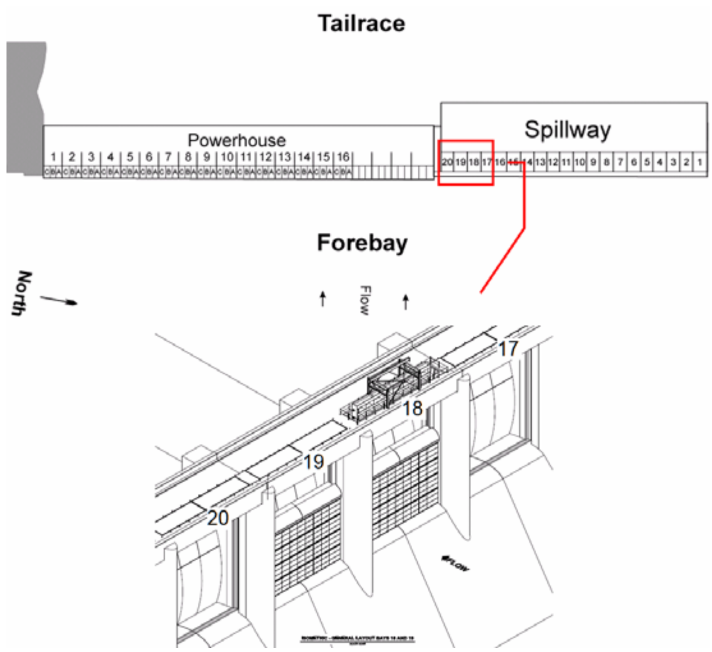

Figure 1. Diagram of John Day Dam (top) and spill bays 17-20, numbered from right to left (bottom). Top-side weirs (TSWs) will be in spill bays 18 and 19.

A.3. SITE DESCRIPTION

This study will involve releasing tagged juvenile salmonids in the MCN Tailrace and JDA Tailrace, and detecting tagged fish in the JDA forebay, JDA Tailrace, JDA Tailwater, and TDA Tailwater down to an array located in the BON Tailwater. Proposed locations of detection arrays will provide estimates of survival at TDA and the TDA Tailwater down to Bonneville Dam for no additional cost. One of the most important findings in the 2006 JDA survival study (Ploskey et al. 2007) was that there was no significant difference in detection nor survival estimates to the primary array below JDA regardless of whether calculations were from three survival arrays in the JDA Tailwater or from one array in the JDA Tailwater and arrays in the TDA Tailwater.

B. OBJECTIVES

1. Estimate route-of-passage for individual YC, STH, and SYC based on forebay tracking of fish on two independent combinations of hydrophones deployed on the dam face at JDA, estimate passage proportions among major passage routes, and calculate efficiency and effectiveness metrics for each of two 2-d spill treatments within 4-d blocks.
2. Estimate route-specific survival and project and dam survival for YC passing JDA in spring using a triple-release study design for each of two spill treatments.
3. Estimate route-specific survival and project and dam survival for STH passing JDA in spring using a triple-release study design for each of two spill treatments.
4. Estimate route-specific survival and project and dam survival for SYC passing JDA in summer using a triple-release study design for each of two spill treatments.
5. Statistically compare metrics estimated in Objectives 1-4 above for each of the two treatments and test a variety of treatment-specific hypotheses.

C.1. METHODS

Tagging and Release

We will surgically implant JSATS acoustic tags and PIT tags in fish collected at the JDA Smolt Monitoring Facility in spring and summer 2008. All fish will be tagged using procedures described in Hockersmith et al. (2007). Any fish that die during the pre-release holding period will be recorded as dead and released to determine whether they travel far enough downstream to be detected by the JDA forebay array or the primary or secondary arrays below JDA. We will tag at least 2,500 STH and 2,500 YC salmon in spring and 2,500 SYC salmon in summer for release in the MCN Tailrace upstream of JDA to provide treatment release groups. We will tag and release about 500 each of YC and STH in spring and of SYC in summer in the JDA Tailrace to serve as reference release groups, and also tag and release 500 each of YC, STH, and SYC in the JDA juvenile bypass system to form one route-specific release at JDA. Releases at all locations will be divided among 16 days and timed so that approximately equal numbers of fish arrive and are paired with JDA releases during each 2-d spill treatment within 4-d blocks each season. One-half of the treatment fish released into the MCN Tailrace will be released in the morning and the other half in the evening. We will lag tagging and release of fish at JDA by the median travel time of fish from MCN to JDA, which is about 3.5 days in spring and 5.2 days in summer. Releases in the JDA bypass channel and the JDA Tailrace will be made in the morning, afternoon, and at sunset so that they pass through the JDA Tailwater during the day, evening, and night and mix with treatment fish that are expected to arrive at JDA during all hours of the day. The Tailrace release location will be slightly downstream of the boat launch at Giles French Park about 4.5 km downstream of JDA where flow from the powerhouse and spillway have mixed.

We estimated the number of fish needed after examining radio telemetry survival studies conducted in 2002 (Counihan et al. 2006a) and 2003 (Counihan et al. 2006b), as well as results about precision in a JSATS acoustic telemetry survival study conducted in 2006 (Ploskey et al. 2007). The radio telemetry studies suggest that it is reasonable to expect at least 1,188 each of YC and STH and 1,063 SYC out of each 1,250 released to survive the trip from MCN to JDA and arrive during one of two spill treatments. Assuming that 2,500 fish of each type were released and one half of the survivors arrived during each spill treatment, Figure 2 indicates that paired-release, dam-survival estimates will have one-half 95% confidence intervals ranging from 2.3% to 2.5%. Based upon spill efficiency in 2002 and 2003, we also expect at least 594 YCS, 594 STH, and 478 SYC to pass at the spillway, so an expected one half 95% CIs would be about 2.7% for yearling Chinook salmon, 3.0% for steelhead, and 3.2 % for subyearling Chinook salmon. Roughly the same range of precision would hold for powerhouse survival estimates, but intervals would be even wider for JBS and turbine fractions, given the number of fish expected to pass through those routes. Precision of estimates for TSW-passed fish also will be lower than that expected for the spillway as a whole.

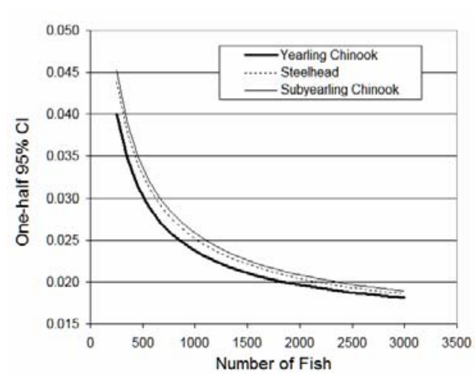

Figure 2. Relation of one-half 95% CIs on paired-release (ratio) estimates of dam survival on the number of fish arriving at JDA Dam.

Tag Life

A tag-life study of 100 randomly sampled JSATS tags of every ping rate will be conducted in 2008, probably by the Tag-Effect Study, like last year, but we will conduct a tag-life study on 100 tags, if no comprehensive JSATs tag-life study is forthcoming. The JSATS micro-acoustic transmitters in this proposed study will weigh no more than 0.63 g in air (0.39 g in water) and will transmit 417 kHz sound once every 3 seconds for about 20 days, which is more than twice the median travel time from MCN Tailrace to survival arrays below Bonneville Dam each season. About 100 tags that transmit once every 3 s will be randomly selected from all available tags, activated, and implanted in hatchery rainbow trout or some other fish surrogate that will be held until all tags are dead. A mobile node will be used to listen for tags daily, and tag-life histories will be reported and used to adjust detection and survival estimates, if necessary.

Forebay Detection and Tracking Arrays

An array of five or six autonomous hydrophones will be installed at the JDA forebay entrance, as defined by the hydraulic influence of expected powerhouse and spillway operations. This array would be used to detect the arrival of surviving fish at JDA, assess their lateral distribution across the forebay, and create virtual releases to partition project survival into pool and dam components. Project and dam survival are expected to be the primary survival metrics for testing spill treatments because they have higher precision than route-specific survival estimates. The location of this array will be determined from runs of the expected range of spill and powerhouse operations using a computational fluid dynamics model. We prefer to define the forebay size and desired array location based upon the upstream influence of dam hydraulics instead of an arbitrary definition based upon the size of the boat restricted zone.

Rectangular configurations of four JSATS hydrophones will be deployed at every turbine (Figure 3) and spill bay (Figure 4) to allow for tracking (successive hyperbolic positioning or multilateration) of tagged fish as they approach within about 250 ft of JDA. Populating the dense tracking array will require 82 hydrophones and associated cables (two on each of 17 main turbine piers, two on each of three skeleton-bay piers between skeleton units 17-18, 18-19, and 19-20, and two on each of 21 spill-bay piers) and 18 spares. Outfitting the skeleton bays is important, because we need to be cautious about putting sufficient detection effort at the ends of powerhouse and spillway arrays to minimize tracking ambiguities.

All hydrophones will be synchronized to a universal global positioning system (GPS) clock, and data will be stored and later processed to calculate tracks within the horizontal plane, as required to assign a route of passage for every fish. Some or all of these data also could be processed to provide successive positions in three dimensional space for specific volumes of interest (e.g., the forebay upstream of TSWs). Careful identification of desired 3-D tracking volumes can save considerable time and expense, since 3-D tracking is not required to assign a route of passage, and detailed 3-D behavior of fish is not necessary for every area of the forebay. The proposed baseline for deployment of JSATS hydrophones at each turbine and spill bay is a rectangular array (Figures 3 and 4), and an example of the resolution pattern of a rectangular array is illustrated in Figure 5.

The proposed deployment will allow us to test the need for two independent forebay tracking arrays to estimate route of passage. The approach involves taking a dense tracking array and decomposing it into two less dense tracking arrays. The position of a fish upstream of any spill bay or TSW bay can be determined by using acoustic receptions on any three out of 10 hydrophones within 250 ft of a tag. Upstream of a turbine, tracking can be done on any three of six hydrophones within 250 ft of a tag. Theoretically, we should be able to track fish on two different sets of hydrophones without duplication. We will use a Lincoln Index mark-recapture approach based on numbers of fish tracked by the first, second, and both arrays to estimate route-specific passage abundance. We will compare the independent estimates of passage probability to determine whether significant differences are observed. We suspect that the proposed array is sufficiently dense that the detection probability should be very close to one and no array replication is needed. In short, we suspect that route-specific relative survivals will be based on passage fates that are unambiguous.

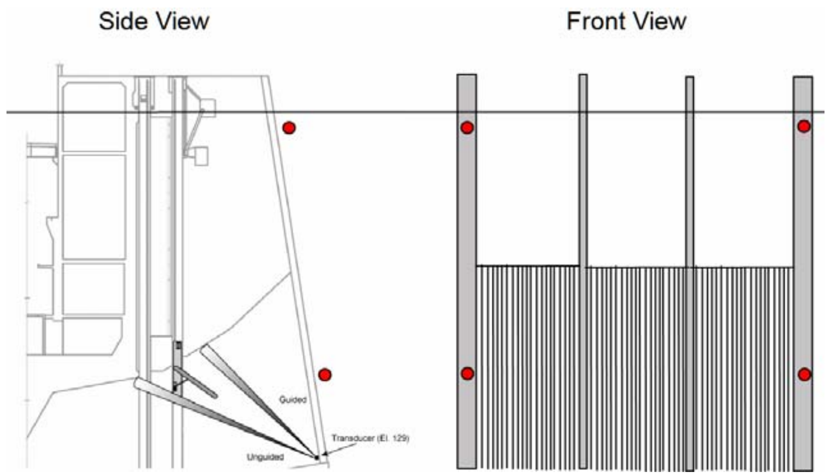

Figure 3. Diagram illustrating the location of JSATS hydrophones (red dots) on main piers in side view (left) and in frontal view (right). Horizontal separation of nodes at the same elevation would be 90 ft. Vertical separation of nodes on the same pier would be about 94 ft.

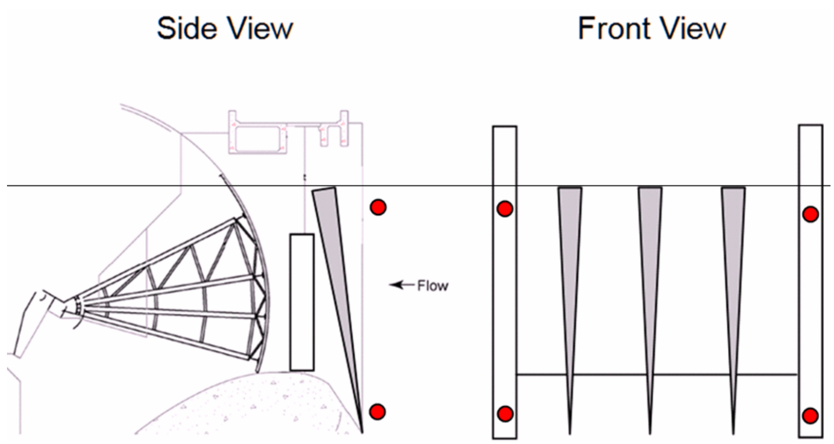

Figure 4. Diagram illustrating the location of JSATS hydrophones (red dots) on spill bay piers in side view (left) and front view (right). Horizontal separation of nodes at the same elevation would be 62 ft. Vertical separation of nodes on the same pier would be about 50 ft.

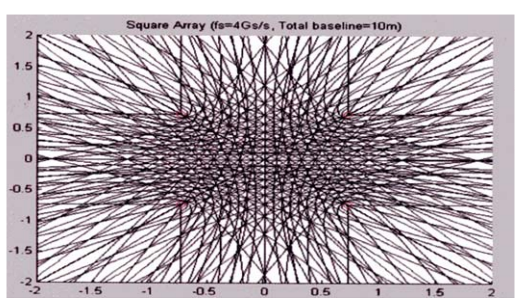

Figure 5. Drawing illustrating the dense resolution pattern within a rectangular array and degradation in resolution outside the tracking baseline. The upper hydrophones would be located just below the minimum expected water level and the lower hydrophones would be located about 1 m below the mid-line depth of turbine intakes and near the bottom of spill bay piers.

The proposed rectangular array at every turbine and spill bay will allow for 2D tracking to assign a route of passage everywhere in the forebay and will provide redundancy to protect the tracking baseline against hydrophone or cable failure. Data from the rectangular array also could be processed to obtain 3D tracks, although it would not be time nor cost effective to process all data to that high level of resolution, except perhaps for the volume upstream of the TSW. By placing a hydrophone slightly below the mid-line depth of each turbine opening and just below the minimum expected water level on every main pier at powerhouse turbines, the rectangular array will allow high resolution 3-D tracking throughout the volume where most fish pass into turbines and out to a range of about 250 ft. The use of any three hydrophones from one turbine and a fourth hydrophone from the next adjacent pier would provide even higher resolution tracking than using any three hydrophones.

Fish Passage

We will subdivide powerhouse passage into turbine and JBS passage by examining acoustic and PIT detections of fish in the JBS channel. We will use a linear array of four small mobile hydrophones spaced 3 s apart in the juvenile bypass channel to acoustically detect tagged fish guided by submerged traveling screens into the juvenile bypass system (JBS). We also will examine PIT-tag records in the PIT Tag Information System (PTAGIS) to obtain independent verification of passage through the JBS. Turbine passage will be assigned for tagged fish known to have passed into the powerhouse without subsequent detection in the JBS channel by mobile nodes or PIT detectors.

A wide variety of fish-passage metrics will be estimated and used to evaluate effects of spill treatments on fish passage. These include, but may not be limited to, fish-passage efficiency (FPE), spill-passage efficiency (SPY), spill-passage effectiveness (SPS), powerhouse fish guidance efficiency (FGE), TSW discovery efficiency, TSW entrance efficiency, and TSW passage efficiency and effectiveness. We also will examine 3D tracks of tagged fish of each species approaching the TSW to try to explain the changes in TSW metrics and any rejection that might be observed. Any consistent differences in approach behavior among types of study fish will be described in detail.

Egress and Survival Arrays

Autonomous JSATS nodes will be deployed in four arrays downstream of John Day Dam and will sample continuously in spring and summer, except for brief periods required to download data. Downloaded data will be stored on two sets of media to provide backup. The time required to service and redeploy an autonomous node is about 20 minutes. The Autonomous nodes in these arrays and in the JDA Forebay entrance array will be checked weekly to synchronize clocks and download data, and they will be serviced every 28 days to install fresh batteries. The first array downstream of JDA will be an egress array at Rkm 339.2 (about 9.4 km below JDA spill and turbine discharge). We will subtract detection times on the egress array from the time of last detection in the forebay to estimate passage time, and rates of passage will be calculated by dividing distance by time. The next three arrays downstream of JDA and the egress array will be survival arrays, as follows: (1) a primary array at The Dalles Dam (TDA) forebay entrance, (2) a secondary array at the Bonneville Dam (BON) forebay entrance and (3) a tertiary array located about 25.6 km downstream of BON. The use of three detection arrays will allow us to make two estimates of detection probabilities and survival and to test independence assumptions of the single release model using Burnham Tests 2 and 3 (Burnham et al. 1987).

The maximum range of detection based upon the receiving sensitivity of JSATs autonomous nodes and the source levels of acoustic micro-tags ranges from about 600 to 800 ft depending upon ambient acoustic conditions in the river. We will space hydrophones ≤ 300 ft (0.183 km) from shore or 500 ft from one another to ensure complete coverage of the intended sample volume at a cross section and provide some redundancy against the loss of a node inside the near-shore nodes. All arrays will be spaced far enough apart to prevent simultaneous detection of tagged fish by two arrays.

Acoustic reception data from arrays downstream of JDA will be processed using TagViz software. Adequate signal-to-noise-level codes detected at least four times in chronological order within a reasonable travel-time window will be considered valid detections and used to develop time-of-detection histories and calculate detection probabilities for primary and secondary arrays. The TagViz data base will contain tag activation and detection histories for all ongoing JSATs studies in 2008, so information about releases and detections for a specific study or all related studies will be readily accessible.

Survival Model Design

A variety of metrics will be estimated and used to evaluate effects of spill treatments on fish survival, but project-wide estimates have the best hope of detecting significant treatment effects. The best precision will be for a single-release estimate of survival through the JDA Pool, Dam, and Tailwater followed by triple release estimates of JDA Dam and Tailwater survival (e.g., Figure 6) because all tagged fish arriving at JDA will contribute. We plan to make route-specific estimates of survival for fish passing through turbines, the JBS, the spillway, TSW bays 18 and 19, and non-TSW spill bays, although precision, which will be a function of the number of tagged fish passing each route, will be lower than for project and dam survival estimates. We encourage managers to select radically different treatments for testing. Inasmuch as changing TSW configuration from open to closed and back again would take the better part of a day, it may be useful to consider treatments that always have the TSWs running, as this would allow for rapid treatment changes.

We will use releases R_3 and R_2 (Figure 6) to estimate absolute survival through the JBS and tailrace, i.e., S_{JBS}. Fish tracked through the routes, i.e., JBS, turbines, TSW, and spill will be used to estimate route-specific passage proportions (P) and relative survivals (R) compared to the JBS. Hence, survival through the dam and tailrace will be estimated as

$$
\begin{aligned}
S_{Dam\ and\ Tailrace} = \quad & P_{JBS} \bullet S_{JBS} + \\
& P_{Spill} \bullet R_{Spill/JBS} \bullet S_{JBS} + \\
& P_{TSW} \bullet R_{TSW/JBS} \bullet S_{JBS} + \\
& P_{Turbines} \bullet R_{Turbines/JBS} \bullet S_{JBS}
\end{aligned}
$$

Spill-Effect Testing

Regardless of the actual treatments specified by the region, we will develop a randomized 2-day treatment design within 4-d blocks. If both treatments include operational TSWs with different levels of spill, there will be several null hypotheses that will be evaluated as one-tail tests relative to historical measures of performance listed in Table 1:

1. Estimates of fish-passage efficiency, spill-passage efficiency, spill-passage effectiveness, and FGE for each species and age group tested are not significantly higher than existing benchmarks for each species / age group of juvenile salmonids.
2. Estimates of project and dam survival, as well as route specific survivals, are not significantly higher than historical benchmarks for each species and age group of juvenile salmonids.

If treatments consist of TSW on and off operations, we will compare estimates of passage and survival under the “TSW on” treatment to COMPASS / COP benchmarks, as described above, and also test the null hypothesis that “on treatments” produced estimates that were not significantly higher than “off treatments.”

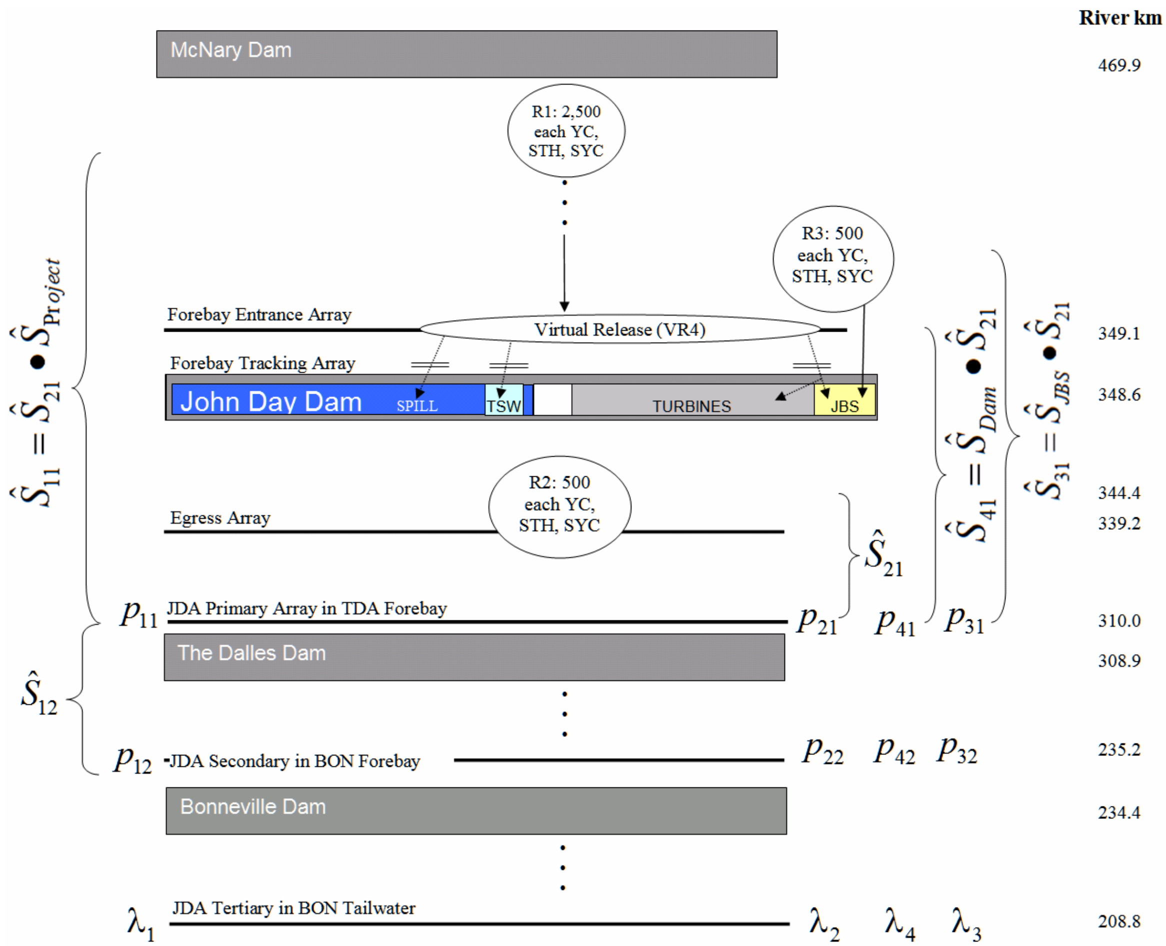

Figure 6. Diagram of the Proposed Triple Release Model. There will be three releases of fish and one virtual release reconstituted from detections of treatment fish on a JDA Forebay Entrance Array. Abbreviations are as follows: YC = yearling Chinook salmon; STH = steelhead; SYC = subyearling Chinook salmon; S = survival estimate; p = detection probability; λ = joint detection and survival probability. Forebay Passage routes will be assigned based on detections on two tracking arrays. Tracking solutions for each fish will be made from detections on two different combinations of hydrophones.

Value Added Research

This proposed study will provide added value above isolated results by being thoroughly integrated with other JSATs studies and with other proposed hydroacoustic and DIDSON studies. When coupled with other possible JSATs fish releases and detection gates, the study can deliver more at reduced cost by leveraging fish released upstream and by allowing estimation of detection and survival on downstream study arrays. For example, fish released for this study also can be detected on JSATS tracking and survival arrays that might be funded at Bonneville Dam. The hydroacoustics and acoustic telemetry studies proposed for JDA are complementary. Telemetry provides species-specific results for the few species or age groups that are tagged, while hydroacoustics non-obtrusively samples a large number of fish to provide composite fish passage metrics for the run-at-large.

C.2. LIMITATIONS/EXPECTED DIFFICULTIES

Dam survival estimates typically can be generated within two weeks after detection data are acquired from autonomous nodes, but tracking to assign route-of-passage has been a much more intensive and slower process. We expect new challenges as we seek to automate and reduce processing times required to turn around forebay tracking data to assign route of passage.

C.3. SCHEDULE

Spring data collection will occur from about May 1 through June 3, 2008.
Summer data collection will occur from June 15 through July 21, 2008.
Verbal or email communication of progress will be provided every 1-2 weeks
A summary of preliminary spring data will be compiled by September 30, 2008.
A summary of preliminary summer data will be compiled by October 31, 2008.
Present results at the Anadromous Fish Evaluation Program (AFEP) in November, 2008
A draft report will be completed by January 31, 2009.
A final report will be submitted within 60 days after receipt of the last comments.

We are aware that the study design will be reviewed by various State and Federal agencies, and is subject to the approval of the NOAA Fisheries, under the Endangered Species Act. We understand that this means that the study design may be modified prior to the start up date. We are prepared to be flexible.

D. FACILITIES AND EQUIPMENT

This study will require at least 2,500 3-s JSATS tags for each species and age class of fish to be studied. All required autonomous nodes are available for this study, but about 100 directional hydrophones and cables will be needed to deploy the forebay tracking array. The cost of similar studies in future years would only include labor and repairs to existing equipment. This study will benefit (without cost) from about 4,000 JSATS-tagged yearling Chinook salmon that are scheduled for release in the Snake River in 2008 and could benefit potential studies at Bonneville Dam.

E. IMPACTS

Fish will be obtained from the JDA SMF. Some small percentage of those fish (typically < 1%) will die from handling and tagging, but those fish will be used to verify that primary arrays are far enough downstream to avoid detecting dead fish. During all tests, every effort will be made to minimize the effects of handling and tagging operations. All necessary permits will be obtained from state and federal agencies for the use of tags with ESA listed species, and the study will follow internal PNNL guidelines for the care and treatment of vertebrate animals. The acoustic frequencies transmitted in this study are above those that can be detected by or injure salmon. Hydrophones are designed without sharp edges and rigging, so they are unlikely to injure fish.

There will be a large effort to install hydrophones and cables in pipes on every main pier at turbine bays and at every spill bay. We will coordinate closely with the JDA Project to minimize our impact on dam maintenance activities and operations.

We plan to coordinate closely with the Estuary Survival and the Tag Effects studies to ensure that JSATS nodes are sampling continuously when Snake River fish with JSATS tags are passing through study area. We also will coordinate with other researchers to avoid conflicts.

We will need hourly data on operations for each turbine unit, spill bay, and TSW, as well as total powerhouse, and spillway discharges and forebay elevations.

F. COLLABORATIVE ARRANGEMENTS AND/OR SUB-CONTRACTS

The PNNL plans to subcontract with Dr. John Skalski, School of Aquatic and Fisheries Sciences, University of Washington for help with the study design, statistical estimation, and reporting. The PNNL also will subcontract with the Pacific States Marine Fisheries Commission.

IV. LIST OF KEY PERSONNEL AND PRIMARY PROJECT DUTIES

Mark Weiland (PNNL)	Senior Scientist and Project Manager, deployment, and JDA Forebay sampling and detections
Gene Ploskey (PNNL)	Senior Scientist, General Management Oversight, deployment, node servicing, survival calculations
Gary Johnson (PNNL)	Senior Scientist, General Manager, hydroacoustic study coordination and management oversight
Zhiqun Deng (PNNL)	2D and 3D tracking
James Hughes (PNNL)	Forebay Deployments and Tagging supervisor
Derrek Faber (PNNL)	Deployment and electronic setup
Shon Zimmerman (PNNL)	Deployment, alternate tagging supervisor (JDA), and JDA release supervisor (JDA)
Robin Durham (PNNL)	Release supervisor (MCN); tagging data entry and management (MCN)
John Skalski (UW) and Rich Townsend	Study Design, statistical oversight, tag-life corrections to survival estimates, independent calculation of survival metrics (QA/QC)
Jina Kim, PSMFC	Deployment, Tagging data entry and management (JDA); forebay data processing, archiving and transmitting tagging and release data
Eric Fischer, PSMFC	Deployment, tagging, release, node servicing, and most other tasks throughout the study.

V. TECHNOLOGY TRANSFER

Information acquired during the proposed work will be transferred in the form of written and oral research reports. A presentation will be made at the Corps' annual Anadromous Fish Evaluation Program Review. Technology transfer activities may also include presentation of research results at regional or national fisheries symposia, or publication of results in a scientific journal.

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VII. BUDGET

A detailed budget will be provided under a separate cover.

DIRECT SURVIVAL AND INJURY EVALUATION OF JUVENILE CHINOOK SALMONIDS PASSING A JOHN DAY DAM SPILLWAY WITH AND WITHOUT A TOP SPILLWAY WEIR

Research Proposal No. SPE-P-08

Prepared for

U.S. ARMY CORPS OF ENGINEERS
PORTLAND DISTRICT
333 Southwest First Avenue
Portland, Oregon 97204

Technical Proposal

August 2007

1.0 INTRODUCTION

This proposal in response to Objective 7 of the U.S. Army Corps of Engineers' Anadromous Fish FY2008 Research Proposal SPE-P-08. Research will undertake and complete the task of obtaining estimates of direct survival and injury rates of juvenile salmon passed through Bay 18, with a Top Spillway Weir (TWS) installed, and Bay 15; a conventional bay at John Day Dam (JDA). Normandeau will utilize the HI-Z Turb'N (HI-Z) tag-recapture methodology (Heisey *et al*. 1892 and Mathur *et al*. 1899). The HI-Z tag recapture technique will facilitate quick retrieval of fish after passage through the spillbays and allows for immediate assessment of fish condition and injury type.

1.1 General Background and Purpose

The primary goal of the Top Spillway Weir (TSW) evaluations at JDA in 2008 is to evaluate the performance of the TSW by estimating and comparing the direct effects of passage through Spillway Bay 18 (with TSW) to Spillway Bay 15 (conventional bay) at two test evaluations (3 and 8 ft above the spillway crest) on immediate 1 hour (h) and 48 h direct survival and injury rates of juvenile salmon.

1.2 Site Description

The JDA Project, Washington, is located on the Columbia River at River Mile 215.6, approximately 24 miles upstream of The Dalles Dam (TDA). The JDA project is the third to last dam encountered by juvenile fish on their journey to the Pacific Ocean and forms a 76-mile slack-water impoundment to McNary Dam. The JDA project includes a powerhouse, spillway, navigation lock, and fish passage facilities. The structure is primarily a concrete gravity dam with a north abutment embankment section. It is a storage project and the dam can be manipulated to provide additional flood control for the lower river. The normal operating pool elevation during fish passage season typically fluctuates from elevation 262 to 265 feet mean sea level (MSL). The operating range of the project varies from elevation 257 to 268 feet MSL. The project is multipurpose and provides hydropower, navigation, flood control, and recreational benefits.

Maintaining high levels of fish passage efficiency (non-turbine passage) is currently being emphasized for the operation of Federal Columbia River Power System (FCRPS) projects. Providing a surface flow route of passage in concert with adequate attraction allows fish the opportunity for discovery and passage, thereby decreasing powerhouse passage rates. By exploiting the natural surface orientation of migrating juvenile salmonids, it is anticipated that the (TSW) installed in Bay 18 could be an effective strategy at JDA, where juvenile migrants have been extensively documented displaying lateral searching and milling behaviors across the powerhouse and spillway.

1.3 Study Objectives

The main objective of this study is to estimate and compare the condition of fish upon passage through JDA's Spillway 18 (configured with a TSW) to Spillway Bay 15 (conventional bay).
Normandeau will collect sufficient data to prepare a report addressing the following objectives:

1. Determine the 1 and 48 h survival and injury rates of juvenile salmon upon passage through the TSW configured Spillway Bay 18 and conventional Spillway Bay 15 at two test elevations (3 and 8 ft above the spillway crest).

2. Estimate and compare direct survival and injury rates for fish passing through Spillbay 18 to those released through Spillbay 15 such that a statistical difference

of ± 5% at a 95% confidence interval is detectable between treatments and precision of survival and injury estimates is within ± 0.025, 95% of the time.

2.0 TASK DETAILS

I. Normandeau will conduct a direct injury and survival HI-Z tag study to determine the effects of passage through two spillbays (one configured with a TSW and one conventional bay) at two test elevations (3 and 8 ft above the spillway crest). Fish releases will be divided among the two spillways to allow adequate statistical precision to discern at least a ± 5% difference between groups 95% of the time.

II. Normandeau will assist Pacific Northwest National Laboratory (PNNL) with the release and recapture of up to 150 HI-Z-tagged 'sensor packages' passed through the two test spillbays (18 and 15) under the same conditions and timing as live fish.

III. Normandeau will collaborate with PNNL staff on constructing a hydraulic, sensor fish, and live test fish database.

2.1 Fish Release System

Treatment fish will be released into Spillbays 18 and 15 and will be accompanied with the release of control fish. Control fish will be released into the tailrace from a pipe on the training wall between Bays 18 and 20 or through the Juvenile Fish Facility bypass release pipe. Normandeau will contract to fabricate and install two fish release pipes each into Spillbay 18 and 15 and one on the training wall between Bays 18 and 20 if this control site is selected. Release hoses will be threaded through a 15.2 cm (6 in) steel support pipe. The terminus of the induction hose will pass through 15.2 cm sweep elbows, and will be positioned and secured with guide wires and/or brackets to ensure each delivery hose remains at the correct depth, is oriented downstream, and is not drawn towards the spill gate.

It is Normandeau's intention to contract Baseline Industrials (Portland, Oregon) to fabricate and install the release pipes and dogging devices (if requested) to the specifications provided by the Corps. Baseline has successfully worked in concert with Normandeau on a number of Columbia and Snake River Projects.

2.2 Source of Fish

Up to 2,500 hatchery-reared juvenile Chinook salmon (approximately 140-200 mm TL) to be used in the study will be acquired by Normandeau from the closest available source. Lots of 150 to 200 fish will be transported in a truck-mounted tank from the hatchery to JDA and held in pools continuously supplied with ambient river water. Holding pools will be equipped with degassing units (if necessary). Fish will be held a minimum of 24 h prior to tagging to allow their acclimation to ambient river conditions at JDA.

2.3 Tagging and Release

Fish handling and HI-Z tagging techniques will follow those used during previous spillway studies (Normandeau Associates, 2006; Normandeau Associates Inc. and Mid Columbia Consulting Inc. 2001; Heisey *et al.* 1892; Mathur *et al.* 1896, 1899; Normandeau Associates *et al.* 1896, 2003). Lots of five to ten fish will be randomly removed from holding tanks to the adjacent tagging site using a water sanctuary equipped net. Fish displaying abnormal behavior, severe injury, fungal infection, or descaling (>20% per side) will not be used. The same fish selection criteria will be applied to all treatment and control groups. Fish will be anesthetized in a 0.5% MS 222 or mild clove oil solution (<5 min) and equipped with two uninflated HI-Z tags and one miniature radio tag.

The tags will be attached via a stainless steel pin inserted through the musculature beneath the dorsal and adipose fins. A uniquely numbered VI tag (Visual Implant), will also be inserted in the postocular tissue for use in tracking 48 h survival of individual recaptured fish. Fish will also receive a fin clip in the event the VI tag becomes dislodged.

Prior to release through an induction apparatus, fish will be allowed to recover from anesthesia. Recovery time generally lasts a minimum of 20 minutes. Fish will be placed individually into the induction system holding tub, tags activated, and fish released. The inflation time of the tags may be adjusted slightly by varying the temperature and amount of water injected into tags prior to release. All procedures used in handling, tagging, release, and recapture of fish for all release groups will be identical. Approximately 150 fish in lots of 10 to 35 will be released throughout the day to evaluate the four treatment conditions (Table 2-1).

If the on-site results indicate that sample size adjustments are necessary to achieve the evaluation objective, the designated Corps' POC will be informed accordingly. All attempts will be made to maximize the use of available fish to increase the understanding of the effects of spillway passage. Increase in the sample size is an authorized item, which can only be exercised by the Contracting Officer or the Contracting Officer's Representative (COR).

2.4 Fish Recapture

Both treatment and control fish will be retrieved from the tailwater by several (three or four) boat crews. Boat crews will be notified of the radio tag frequency of each fish upon its release. Only crew members trained in fish handling will retrieve tagged fish. Normandeau requests hazing of gulls by USDA to minimize the loss of buoyed test fish.

Radio signals will be received on a Yagi antenna coupled to a receiver. The radio signal transmission will enable the boat crew(s) to follow the movement of each fish after spillway passage, and position the boat for quick retrieval when the HI-Z tag buoys the fish to the surface. The boats will maintain a safe distance downstream of the turbulent water in the spillbay. Fish with active radio tags that fail to surface will be tracked for about 30 minutes, and then periodically to ascertain if fish are displaying movement patterns typical of emigrating smolts or that of a predator. Recaptured fish will be placed into an on-board holding facility, and the tag(s) removed. Each fish will be examined for scale loss and injuries and assigned codes relative to descriptions presented in Table 2-2.

Recaptured fish will be transferred in 5 gal pails to an on-shore holding pool for assessment of long-term effects (48 h). Each day's specimens for a given trial will be held in the same or similar pool. Pools will be continuously supplied with ambient river water and shielded to prevent fish escapement and potential avian predation.

2.5 Classification of Recaptured Fish

The immediate status of an individual fish will be designated as alive, dead, predation, dislodged inflated tag(s) recovered, or unknown. The following criteria have been established to clearly define these designations: 1) alive--recaptured alive and remained so for 1 h; 2) alive-- fish does not surface but radio signals indicate movement patterns typical of emigrating juveniles; 3) dead--recaptured dead or dead within 1 h of release; 4) dead--only inflated tag(s) are recovered without the fish and telemetric tracking or the manner in which tags surfaced is not indicative of predation; 5) unknown--neither tags nor fish are recovered and radio signals are not received or only briefly and a more detailed status cannot be ascertained; and 6) predation--fish are either observed being preyed upon, the predator is buoyed to the surface, distinctive bite marks are present, or subsequent radio telemetric tracking and/or dislodged tag recovery indicate predation (*i.e.*, rapid movements of tagged fish in and out of turbulent waters or sudden appearance of fully inflated dislodged tags). In estimation of passage survival, these fish are treated as dead.

Mortalities occurring >1 h post-passage will be considered 48 h mortalities. However, fish will be evaluated at intervals of approximately 12 h. Dead fish will be identified by the numbered VI tag or fin clip (if VI tag is missing), examined for descaling and injury, and necropsied to determine the potential cause of death.

Injuries will be evaluated immediately following recapture, and later during a detailed examination after completion of the 48 h holding period. Injury and descaling will be categorized by type, extent, and area of body. Photographs of injured fish will be taken. Fish without any visible injuries that are not actively swimming will be classified as “loss of equilibrium”. This condition has been noted in past studies and often disappears within 10 to 15 minutes after recapture.

The re-examination of immobilized fish minimizes the need for extensive handling and associated stress upon immediate recapture. The initial examination allows detection of some injuries, such as bleeding and minor bruising that may not be evident after 48 h due to natural healing processes.

A malady category will be established to include fish with visible injuries, scale loss (greater than 20% on either side), or loss of equilibrium. Dead fish without any of these symptoms will not be included in this category. Fish without maladies will be designated “malady free”.

This malady-free metric was established to provide a standard way to present a rate depicting how a specific route affects the condition of passed fish. Malady-free, the absence of maladies was chosen so that this metric may be more comparable to survival; however, the malady-free metric is based solely on fish physically recaptured and examined. Additionally, the malady-free estimate in concert with site-specific hydraulic and physical data can provide insight into what passage conditions may provide safer fish passage.

Visible injuries, scale loss, and loss of equilibrium (LOE) will also be categorized as minor or major, based on laboratory studies by PNNL *et al.* (2001) and Normandeau’s field observations. These are as follows:

- A fish with only LOE is classified as major if the fish dies within 1 hour; if it survives or dies beyond 1 hour, it is classified as minor.
- A fish with no visible internal or external maladies is classified as a passage-related major injury if the fish dies within 1 hour; if it dies beyond 1 hour, it is classified as a non-passage-related minor injury.
- Any minor injury that leads to death within 1 hour is classified as a major injury; if it lives or dies after 1 hour, it remains a minor injury.
- Hemorrhaged eye: minor if less than 50%; major if 50% or more.
- Deformed pupil(s): major.
- Bulged eye: major unless only slightly bulged; minor if slight bulge.
- Bruises (size-dependent): major if 10% or more of fish body per side; otherwise minor.
- Inverted or bleeding gills or gill arches: major.
- Operculum tear at dorsal insertion: major if 5 mm or greater; otherwise minor.

- Operculum folded under or torn off: major.
- Scale loss: major if 20% or more of fish per side; otherwise minor.
- Scraping (damage to epidermis): major if 10% or more per side of fish; otherwise minor.
- Cuts and lacerations: generally classified as major. Small flaps of skin or skinned snouts: minor.
- Internal hemorrhage or rupture of kidney, heart or other internal organs and/or damaged spinal column resulting in death at 1 to 48 hours: major.
- Multiple injuries: use worst injury.

2.6 Sample Size Requirements

Sample size requirements were considered from two perspectives: (1) achievement of prespecified precision (ε) level of $\leq \pm$ 0.025, 95% of the time on the survival (τ) and fish free of passage related maladies; and (2) statistical power (defined as 1-β) to detect prespecified differences (Δ) of 0.05 between two survival or malady free estimates. Beta (β) is the probability that the statistical test fails to reject the null hypothesis where the alternative hypothesis is true; 1-β is the statistical power of the test. In the proposed study, the null hypothesis (H_o) is that the survival or malady free estimates (MF) with the Top Spillway Weir (TSW) is greater than that without the TSW (H_o: τ or MF TSW $\geq$ τ or MF without TSW) versus the alternative (Hα) that survival or malady free estimate is not improved by TSW (Hα: τ or MF TSW $\geq$ τ or MF without TSW).

The sample size requirements per treatment condition are presented in Tables 2-3 and 2-4. In general, the sample size is a function of the recapture rate (P_A), expected passage survival ($\hat{\tau}$) or malady free rate; the survival/malady free rate of control fish (S), and the desired precision of difference (Δ) to be detected at a given probability of significance (α). Sample size requirements decrease with an increase in survival/malady free and recapture rates, or detection of a larger difference (Δ). Only precision (ε), α, and a difference (Δ) to be detected with a given power (β) level can strictly be controlled by an investigator.

Assuming a control survival or malady free rate of 0.99 and a recapture rate of 0.98, approximately 400 fish per treatment condition is needed for detecting difference of 0.05 (τ_1 = 0.97 and τ_2 = 0.92) between two treatment conditions (i.e., Spillbay 15 deep vs. TSW deep) at (α) = 0.05 and power (β) = 0.2 (Table 2-4). Initially, Normandeau will allocate 2,000 fish; 400 for each treatment condition and 400 controls for this study (Table 2-1). These allocations of fish should be construed as guidelines because the embedded flexibility in the HI-Z tag-recapture technique permits adjustment of sample sizes as the investigation progresses. Thus, during the investigation, if the observed results for any of the treatment conditions are contrary to initial expectations, sample sizes can be adjusted with Corps approval to achieve the desired statistical precision level.

2.7 Statistical Analysis

2.7.1 Estimation of Passage Survival

A joint likelihood model will be used to estimate spillbay passage survival both 1 and 48-hour simultaneously for the four treatment releases (i.e., Spillbay 18 with TSW or 15 × 3 or 8 ft) and the common control group. Chi-square tests of homogeneity will be used to compare control releases over time to guide pooling of the release-recapture data. The joint likelihood can be written as follows:

$$L = \binom{R_c}{a_c, d_c} \left(Sp_a\right)^{a_c} \left(\left(1-S\right) p_a\right)^{d_c} \left(1 - Sp_a - \left(1-S\right) p_d\right)^{R_c - a_c - d_c}$$

$$\cdot \prod_{i=1} \binom{R_i}{a_i, d_i} \left(\tau_i S p_a\right)^{a_i} \left(\left(1-\tau_i S\right) p_d\right)^{d_i} \left(1 - \tau_i S p_a - \left(1-\tau_i S\right) p_d\right)^{R_i - a_i - d_i}, \qquad (1)$$

where

S = survival from tailrace to recovery location for all fish;
p_a = probability an alive fish is recovered;
p_d = probability a dead fish is recovered;
R_c = number of control fish released;
a_c = number of control fish recovered alive;
d_c = number of control fish recovered dead;
τ_i = probability a fish from the *i*th treatment survives spillbay passage;
R_i = number of fish released for the *i*th treatment $(i = 1,\ldots,4)$;
a_i = number of fish recovered alive for the *i*th treatment $(i = 1,\ldots,4)$;
d_i = number of fish recovered dead for the *i*th treatment $(i = 1,\ldots,4)$.

Maximum likelihood estimates are

$$\hat{\tau}_i = \frac{a_i}{R_i} \qquad (2)$$

with associated variances

$$\widehat{\text{Var}}\left(\hat{\tau}_i\right) = \frac{\hat{\tau}_i\left(1-\hat{\tau}_i\right)}{R_i}. \qquad (3)$$

The maximum likelihood estimates will be calculated based on a numerical maximization/ minimization algorithm in R software language. Similarly, the variance–covariance matrix will be estimated using numerical methods.

2.7.2 Comparison of Passage Survival

The four treatment conditions (TSW configured, conventional spillway × 3, 8 ft) will not be replicated; therefore, tests of treatment effects will not be based on within-treatment, between-replicate variance. Instead, comparisons of test conditions will be based on linear contrasts using measurement error.

The four treatment conditions will permit three one-degree-of-freedom contrasts as follows:

	Spillbay 18 (TSW)	Spillbay 15

Contrast				
	3 ft	8 ft	3 ft	8 ft
1. TSW vs. Conventional	1	1	–1	–1
2. 3 ft vs. 8 ft	1	–1	1	–1
3. Interaction	1	–1	–1	1

The individual contrasts will be tested, based on the asymptotic Z-test

$$Z_j = \frac{\sum_{i=1}^{n} C_{ij}\hat{\tau}_i}{\sqrt{\sum_{i=1}^{n} C_{ij}^2 \widehat{\text{Var}}\left(\hat{\tau}_i\right)}}, \quad (4)$$

where

C_{ij} = coefficient for the *i*th treatment $\left(i = 1,\ldots,4\right)$ of the *j*th contrast $\left(j = 1,\ldots,3\right)$;

$\hat{\tau}_i$ = estimated survival for the *i*th treatment $\left(i = 1,\ldots,4\right)$.

Overall comparison of the four treatments will be based on a likelihood ratio test with three degrees of freedom at α = 0.10.

2.7.3 Estimation of Being Malady-Free Given Alive at 48-Hours

The conditional probability of a juvenile Chinook salmon being malady-free, (i.e. no injury, scale loss greater than 20% per side or loss of equilibrium) given it passed through the spillbay alive, i.e.,

$$\hat{\Psi} = 1 - \hat{P}\left(I \mid A\right), \quad (5)$$

will be also compared between treatments.

2.7.4 Estimation of Joint Probability of 48-hour Survival and Being Malady Free

In addition to the comparison of 48-hour spillbay passage survival, the probabilities that juvenile Chinook salmon passing through the spillbay malady-free and alive will be compared between the four test conditions. The probability a juvenile chinook salmon passed through the spillbay malady-free and alive will be estimated by

$$\hat{\theta}_i = \hat{\tau}\left(1 - \hat{P}\left(I \mid A\right)\right), \quad (6)$$

where $P\left(I \mid A\right)$ = probability of malady, given a fish is alive. The variance of $\hat{\theta}_i$ will be estimated

$$\widehat{\text{Var}}\left(\hat{\theta}_i\right) = \left(1 - \hat{P}\left(I \mid A\right)\right)^2 \cdot \widehat{\text{Var}}\left(\hat{\tau}\right) + \hat{\tau}^2 \cdot \widehat{\text{Var}}\left(\hat{P}\left(I \mid A\right)\right) - \widehat{\text{Var}}\left(\hat{\tau}\right) \cdot \widehat{\text{Var}}\left(\hat{P}\left(I \mid A\right)\right), \quad (7)$$

where

$$\widehat{\text{Var}}\left(\hat{P}\left(I \mid A\right)\right) = \frac{\hat{P}\left(I \mid A\right)\left(1 - \hat{P}\left(I \mid A\right)\right)}{k} \quad (8)$$

and where k = number of fish alive at 48 hours. The comparison of malady-free rates will be based on the Z-tests (4) analogous to the comparison of passage survival rates.

2.8 Data Analysis

Statistical analysis will be conducted by Dr. John Skalski and Richard Townsend (Normandeau subcontractor) to estimate direct survival and injury through JDA TSW and conventional spillbay.

3.0 ADDITIONAL REQUIREMENTS

Requirements:

- Construct and install two release pipes each into Spillbay 18 (TSW), and Spillbay 15 (conventional) according to the Corps specifications. Control fish will be released through the Juvenile Fish Facility bypass pipe or a control pipe will be constructed and installed at the training wall between Bays 18 and 20.

- Normandeau's sub contractor, Baseline Industrial Construction, Inc., will install schedule 40; 6 inch diameter steel pipe, the length of pipe and bend angle to be determined upon receipt of stamped drawings from a registered Washington State engineer.

- Assist with the release and retrieval of up to 150 HI-Z-tagged 'sensor packages' that are passed through Spillbay 18 and 15 under the same conditions and timing as live fish.

- Construct a hydraulic, sensor fish, and live test fish database in collaboration with PNNL staff.

4.0 GOVERNMENT FURNISHED SERVICES/EQUIPMENT

The Corps will supply the following:

- A crane, operator, and riggers as necessary to open and close TSW and conventional spillbays.

- Precise drawings for the dogging device assembly to Corps specifications (is this applicable?)

- Electronic hourly project operation data during the spill tests.

- "Sensor Fish" for release through Spillbays.

- Provisions to disperse gulls should they pose a threat during the study.

5.0 SUBMITTALS AND REPORTS

Normandeau will communicate daily with the Corps' Point of Contact (Robert.h.wertheimer@usace.army.mil) during all fieldwork discussing progress, problems, needed support, and issues of concern. Daily test results will be provided by fax or email within a day of testing.

5.1 Preliminary Data Summary

The POC will be provided with preliminary data summary of results for the alive fish releases through TSW and Spillbay 15 within 30 days after completion of field tests. This report will include preliminary survival/injury rate estimates for all treatments evaluated.

5.1.2 Draft Report

One electronic, 25 bound copies, and one unbound copy of a Draft Report will be submitted to the Corps POC within 120 days of completion of field tests. The report will include complete analysis, discussion, and biological interpretation of the data for all test conditions.

The Government will review and provide comments to Normandeau. If Normandeau finds any of the Government's review comments are unclear and require clarification and/or amplification to assure compliance, we will furnish a written repose of compliance or non-compliance. An explanation/clarification for each instance of non-compliance will be provided. Exceptions to review comments will be submitted for approval within 10 calendar days after receipt of comments.

5.1.3 Final Report

Twenty-five (25) bound copies, one unbound, and one (1) electronic copy of the Final Report will be submitted within 60 working days of receipt of Corps' comments. The final report will incorporate all the Corps' comments that are within the scope of work.

5.1.4 Report Review

The summary draft and final reports will be reviewed by Normandeau's principal investigators and Dr. John Skalski will conduct the statistical analysis for the draft and final reports.

5.2 Presentations

Normandeau will prepare a Power Point presentation of this research and submit to the Government one week prior to the 2008 Anadromous Fish Evaluation Program Review for the Government's review. Normandeau will give the presentation at the 2008 AFEP Program Review in November 2008.

5.3 Deliverables

The Preliminary Data Summary, Draft Report, and Final Report are classified as "Deliverables" in this Task Order. Failure to deliver the reports within the specified time may result in a non-performance report from the POC to the Contracting Officer, and may subject Normandeau to actions detailed under the Default Clause of the contract.

6.0 WORK SCHEDULE

Normandeau proposes to follow the work schedule outlined in Table 6-1. This is a tentative work schedule and is highly dependent upon installation schedule of the TSW. Pipe installation is planned for early March, 2008. The likely schedule for fish releases is March into early April 2008. The plan is to complete the study and remove fish release pipes before initiation of scheduled spring spill for fish passage in April 2008.

7.0 PROJECT SERVICES/COORDINATION

7.1 Project Support

Normandeau will attend an initial coordination meeting with Portland District office personnel and John Day Dam project personnel within a month of contract award. The purpose of this meeting will be to familiarize Normandeau with the work site and discuss any issues with planning and project personnel to assure that the study goes forward as planned. Potential issues include, but are not limited to, placement of release pipes, holding tanks, electrical supply, boat activity in the tailrace, safety, and study coordination.

The Corps will provide space for equipment storage, and trailer space near or on the spillbay deck. The Corps will also provide a POC to assist Normandeau in gathering John Day Dam operational data. Normandeau should be prepared to be self-sufficient in regard to equipment installation, removal, and all routine activities. Project assistance may be available for emergencies. The extent, timing, and coordination of Project support will be a major agenda item for the Pre-work and Safety Meeting.

7.2 Point of Contact (POC) Coordination

Normandeau's POC for this task order is Joanne Fulmer, 717-548-6429, email: jfulmer@normandeau.com.For the schedule associated with this study to be met, Normandeau will be diligent in maintaining coordination with the designated POC, Robert Wertheimer, 503-808-4777, FAX 503-808-4756, email: robert.h.wertheimer@usace.army.mil. The Corps must coordinate schedules with construction contractors, project activities, and Normandeau's activities. Corps' Project personnel have many conflicting priorities; therefore, Normandeau will coordinate activities that require critical operational changes or other project support with the POC as early as they are known. Normandeau's requests for specific project assistance will be provided to the POC at least 72 hours in advance of the need.

Normandeau will submit drawings and descriptions of all onsite hardware, release pipes and mounting, and work trailers to the designated Corp POC for approval by the Project Engineering staff before installation.

7.3 Expertise and Materials Supplied by the Contractor

Normandeau will supply all HI-Z tags, Advanced Telemetry System radio tags, visual implant tags, and any other materials used in the attachment or implantation of these tags. Normandeau will also supply induction systems, boats for retrieval of fish in JDA tailrace, and nets to recapture fish. Test fish will be obtained and transported to the test site by Normandeau or its subcontractor. Normandeau will secure the services of an engineering firm to modify, and/or fabricate and install four treatment release pipes and one reference release pipe, release platforms and dogging devices (if needed). Normandeau will obtain and install safety railings around the open deck slot where release mechanisms are placed. At the conclusion of the study, Normandeau will remove all pipes, handrails, platforms, and associated equipment for the treatment releases, and replace the concrete deck hatches (if requested). Release pipes, platform and dogging devices will become property of the Government, and will be delivered and stored at the JDA storage yard.

7.4 Personnel

Normandeau will utilize only fully qualified professional biologists with applicable and pertinent expertise and experience in the conduct of this work.

8.0 SAFETY AND SECURITY

For all work on Government installations and all fieldwork at the JDA project, Normandeau and its subcontractors will comply with the requirements of EM-385-1-1 (US Army Corps of Engineers Safety and Health Requirements Manual). EM 385-1-1 and its changes at http://www.hq.usace.army.mil/ceso/cesopub.htm. Normandeau will be responsible for complying with the current edition and all changes posted on the web as of the effective date of this contract action Normandeau will prepare a Job Safety Analysis for every potential hazard that out personnel could be exposed to. This analysis will be submitted to the Corps' designated POC prior to any work being done by Normandeau personnel at the JDA Project. Normandeau will submit required information (names, photographs, etc) for all personnel (ours and subcontractors) that will be working on site during this task order. The Contractor will report the total man-hours expended in field operations monthly by all employees, including Contractor and Subcontractor, supervisor and laborers. The reporting period will end on midnight on the last day of the month. The report will be made by telephone or FAX to Mrs. Eleanor Collins by the 5th of the following month. Mrs. Collins' telephone number is (503) 808-4817 and the FAX number is (503) 808-4805. Her email address is eleanor.v.collins@usace.army.mil.

9.0 ADDITIONAL SERVICES

Normandeau will not perform any services under this Task Order which are considered to be a change in the work or services required by this agreement without the written approval of the Contracting Officer.

10.0 UNSATISFACTORY WORK

The Contracting Officer's Representative maintains the right to reject any work that is found to be in error, incomplete, illegible, or in any way not conforming to the specifications outlined in this task order. Normandeau will be liable for all costs in connection with correcting such errors. Corrective work may be performed by Government forces or by Normandeau forces at the discretion of the Contracting Officer.

11.0 USE OF INFORMATION

The information developed, gathered, assembled, and reproduced by Normandeau, our consultants, our subcontractors, or our associates in fulfillment of the contract requirements as defined in or related to the Statement of Work, will become the property of the Government and will, therefore, not be used by Normandeau for any purpose at any time without the written consent of the Contracting Officer.

12.0 RELEASE OF INFORMATION

Reports and information generated under this contract will become the complete property of the Government and distribution by Normandeau or our subcontractors to any source, at any time, without the written consent of the Contracting Officer is prohibited.

13.0 INVOICING AND FINAL INVOICE WITH RELEASE OF CLAIMS

Normandeau will submit monthly invoices indicating the actual work on services performed to-date for approval by the Government. Payments will be made in accordance with clause 52.232-1, Payments. Normandeau will submit a written "Release of Claims" signed by the corporate officer, with the final invoice for services rendered under the terms of this contract.

14.0 LITERATURE CITED

Heisey, P. G., D. Mathur, and T. Rineer. 1892. A reliable tag-recapture technique for estimating turbine passage survival: application to young-of-the-year American shad (*Alosa sapidissima*). Can. Jour. Fish. Aquat. Sci. 49:1826-1834.

Normandeau Associates, 2006. Direct survival and injury of juvenile salmon passing Ice Harbor Spillway under plunging, skimming, and undular tailwater conditions. Report prepared for U.S. Army Corps of Engineers, Walla Walla District, Walla Walla, WA.

Normandeau Associates and Mid Columbia Consulting, Inc. 2001. Feasibility of estimating direct mortality and injury on juvenile salmonids passing The Dalles Dam spillway during high discharge. Report prepared for U. S. Army Corps of Engineers, Portland District, Portland, OR.

Normandeau Associates, J. R. Skalski, and Mid Columbia Consulting, Inc. 1896. Potential effects of modified spillbays on fish condition and survival at Bonneville Dam, Columbia River. Report prepared for Department of the Army, Portland District COE, Portland, OR.

Normandeau Associates, J. R. Skalski, and Mid Columbia Consulting, Inc. 2003. Estimated direct mortality and injury of juvenile salmonids in passage through The Dalles spillway, Columbia River in spring and summer 2002. Report prepared for U.S. Army Corps of Engineers, Portland District, Portland, OR.

Mathur, D., P. G. Heisey, K. J. McGrath, and T. R. Tatham. 1896. Juvenile blueback herring (*Alosa aestivalis*) survival via turbine and spillway. Water Res. Bull. 32:155-151.

Mathur, D., P. G. Heisey, J. R. Skalski, and D. R. Kenney. 1899. Survival of chinook salmon smolts through the Surface Bypass Collector at Lower Granite Dam, Snake River. Pages 118-127 in M. Odeh (editor), Innovations in fish passage technology. American Fisheries Society, Bethesda, MD.

Pacific Northwest National Laboratory (PNNL), BioAnalysts, ENSR International Inc., and Normandeau Associates, Inc., 2001. Design guidelines for high flow smolt bypass outfalls: Field, laboratory, and modeling studies. Report prepared for U.S. Army Corps of Engineers, Portland District, Portland, OR.

TABLES and FIGURES

(Technical Proposal)

RESEARCH PROPOSAL
SUBMITTED TO THE U.S. ARMY CORPS OF ENGINEERS UNDER THE ANADROMOUS FISH EVALUATION PROGRAM
2008 PROJECT YEAR

I. BASIC INFORMATION

A. TITLE OF PROJECT

Studies of Surface Spill at John Day Dam

B. PROJECT LEADERS

Joanne P. Duncan, Pacific Northwest National Laboratory, P.O. Box 999, Richland, WA 99352, Tel: 509/371-7211. Email: joanne.duncan@pnl.gov
Thomas J. Carlson, Pacific Northwest National Laboratory, P.O. Box 999, Richland, WA 99352, Tel: 503/417-7562, Email: Thomas.Carlson@pnl.gov

C. STUDY CODE

SPE-P-08-new

D. ANTICIPATED DURATION

January 2008 - December 2008

E. DATE OF SUBMISSION

October 2007

II. PROJECT SUMMARY

A. GOALS

Characterize fish passage conditions for Spillbay 19 with a top spillway weir (TSW) installed, and Spillbay 16, a conventional spillbay.

B. OBJECTIVES

1. Evaluate and compare passage conditions that fish may experience during passage in spill through a spillbay with a TSW installed and a conventional, deflector equipped, spillbay
2. Identify potential regions within the passage route that may cause mortality or injury to live fish.

C. METHODOLOGY

We propose to use Sensor Fish Devices to assess the conditions that live fish may be exposed to while passing through John Day spillways. The Sensor Fish Device is a 6 degree-of-freedom sensor with tri-axial acceleration and rotation sensors and an absolute pressure sensor. The pressure, acceleration, and rotation time histories provide a detailed record of the sensor's response to hydraulic and mechanical forces during passage through the fish passage route. Analysis of these data permit detailed assessment of the fish passage route, identification of potential problem areas, and is an important element in understanding biological test results.

Release elevations and other features of experimental design will be determined in collaboration with CE project managers. It is expected that the same release elevations and other features of experimental design will be very similar or the same as those for the live fish balloon tag study that is proposed to take place concurrently with the Sensor Fish study. At this time it is estimated that a minimum of 35 successful sensor releases per treatment (combination of release elevation and spill discharge) will be required to achieve sample size objectives.

Collaboration with Normandeau Associates, Inc. (Normandeau) will be necessary for Sensor Fish release and recapture.

D. RELEVANCE TO THE BIOLOGICAL OPINION

This study addresses Biological Opinion Hydro Sub Strategy 1.1, Mainstem Juvenile Passage Improvements, providing safer and efficient passage of juvenile fish through the hydrosystem complex.

III. PROJECT DESCRIPTION

A. BACKGROUND

Policy emphasis for the operation of federal Columbia River power system (FCRPS) projects includes increasing survival rates by enhancing fish passage efficiency (FPE) via non-turbine specific routes. Strategy to increase FPE and survival rates includes providing a surface flow route utilizing the natural surface-orientation of downstream-migrating juvenile salmonids, and providing adequate attraction flows. Three surface oriented structures have been installed at FCRPS projects: removable spillway weirs (RSW), temporary spillway weirs, and surface bypass channels. All enable fish to pass the spillway using less water volume, improving water quality due to lower total dissolved gases, and are believed to provide a less stressful route due to lower pressures and accelerations, and reductions in passage delay.

The success of management and site improvements are often measured by survival study results. In addition, during the last several years, direct survival rates have been measured using balloon tag studies in conjunction with Sensor Fish at projects on the Columbia and Snake Rivers. This team effort has provided information to identify and locate regions within the hydropower system (i.e. spillways, deflectors, stay vanes, runner, draft tubes, etc.) that may be detrimental to fish survival.

SITE DESCRIPTION

John Day project is the third dam encountered on the Columbia River upstream of the Pacific Ocean at river mile 215.6. Completed in 1971, the project consists of 20 spillbays (bays 2-19 are equipped with deflectors) controlled by 50-ft wide radial spill gates, 16 turbine units capable of producing a total of 2,160 MW of power, four expansion bays for future hydroelectric generation, a navigation lock, and fish passage facilities. It may turn out to be important that the spillway deflectors at JDA are installed much deeper relative to normal tailwater elevations than are those at Snake River Dams. Normal operating pool ranges from 262 ft to 265 ft mean sea level (MSL), with an operating range of 257 to 268 ft MSL.

B. OBJECTIVES

1. Compare the hydraulic conditions for passage (as determined by the Sensor Fish) between Spillbay 16, a conventional spillbay, and Spillbay 19 configured with a TSW. Two release elevations will be evaluated for each spillbay (3 and 8 ft above the spillbay crest).
2. Identify regions of potential fish injury due to hydraulic conditions following passage through a conventional spillway and a spillway configured with a TSW.

C. METHODOLOGY

Sensor Fish releases will be integrated into the direct injury fish study design so that both the Sensor Fish and live test fish experience the same handling methods and exposure conditions. Sensor Fish will be equipped with balloon tags and a radio transmitter tag, supplied by Normandeau, and deployed into Spillbay 16 and Spillbay 19 (configured with a TSW) through release pipes that will be fabricated and installed by another contractor. Release elevations are projected to be 3 and 8 ft above the spillway crest (or equivalent). Normandeau will provide Sensor Fish retrieval utilizing their boat crews and equipment. At least one Sensor Fish will be released with each lot of 10 balloon tagged treatment fish, with a minimum sample size of 35 Sensor Fish per each release location and elevation, for a total of 140 Sensor Fish. In the event that live fish testing meets its confidence limits with a smaller sample size than anticipated, Sensor Fish sample size will be maintained so that a nearly equal number of Sensor Fish data sets are acquired for each study treatment. In addition, several Sensor Fish will be used to evaluate release pipe elevations prior to the start of the study. Therefore, up to 15 Sensor Fish additional releases are required, bringing the total number of Sensor Fish releases to a maximum of 155.

Field Work will include:

- Evaluation of release pipe injection elevations,
- Preparation of Sensor Fish for data acquisition and deployment,
- Assistance with injection of the sensors,
- Retrieval of Sensor Fish following boat crew recovery,
- Downloading acquired data using an infrared modem attached to a laptop computer,
- Evaluation of data for quality and function,
- Preparation of the Sensor Fish for its next deployment.

Data Processing and Analysis:

- Following acquisition, Sensor Fish data sets will be processed to convert acquired data from binary to ASCII format. Quality assurance checks will be performed and each data set will be incorporated into a database with accompanying metadata. Metadata records identify the time, treatment, and provide other information that qualifies the data by describing the conditions under which it was acquired and initially processed.
- Data processing includes standardization of the time base for the pressure and tri-axial linear and angular accelerations, followed by computation of the magnitude and angular arguments for the acceleration vectors and isolation of singular events such as strikes, collisions, and severe turbulence exposures. Analysis is conducted to: (1) compute summary statistics that describe hydraulic exposure conditions for each passage history, (2) quantify (magnitude, duration, location, etc.) and classify significant shear and collision events, (3) qualitatively and quantitatively compare passage conditions by treatment, (4) assess the likely impact on fish of the various passage treatments, and (5) relate exposure metrics to live fish direct mortality and injury test results
- Data integration and collaboration with Normandeau Associates, Inc., and their live fish direct injury/survival study findings are necessary to provide rapid information transfer to Corps personnel. Sensor Fish data, as well as HiZ balloon tag study results, will be incorporated into the new Sensor Fish database to better facilitate data assimilation and conclusions.

D. FACILITIES AND EQUIPMENT

The proposed project will require access to John Day Dam during the period of study. Staff will attend any coordination, planning, and/or safety meetings with Portland District and John Day Dam personnel, as required. The sensor fish required for this study will be provided free of charge by PNNL. However, sensor fish lost or irreparably damaged during the study must be replaced by the Corps.

E. IMPACTS

The proposed project has no expected impacts on other ongoing or proposed research projects at John Day Dam.

F. COLLABORATIVE ARRANGEMENTS AND/OR SUB-CONTRACTS

The proposed project requires collaboration with Normandeau Associates, Inc. for the utilization of their balloon tags, radio tags, and for the retrieval of the Sensor Fish from the tailrace. They are proposing under a separate contract.

Collaboration with Normandeau will also be required to integrate data results into a Sensor Fish database as well as for data examination and discussion. The costs for Normandeau to collaborate with PNNL staff to complete these study elements will be budged separately by Normandeau.

No sub-contracts are expected.

IV. KEY PERSONNEL AND PROJECT DUTIES

The proposed project will utilize only fully qualified professional staff with applicable and pertinent expertise in the conduct of this work.

V. TECHNOLOGY TRANSFER

Management use of the information provided by this project will aid in the decision making for the optimization of spillway passage efficiency to improve survival of juvenile salmonids.

PRELIMINARY RESEARCH PROPOSAL
SUBMITTED TO THE U.S. ARMY CORPS OF ENGINEERS UNDER THE ANADROMOUS FISH EVALUATION PROGRAM
2008 PROJECT YEAR

I. BASIC INFORMATION

A. TITLE OF PROJECT

Hydroacoustic Evaluation of Fish Passage for Surface Flow Outlet Development at John Day Dam, 2008

B. PRINCIPAL INVESTIGATORS

Gary E. Johnson
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C. STUDY CODE

SPE-P-08-new

D. DURATION

January 1, 2008 to March 31, 2009

E. DATE OF SUBMISSION

August 2007

II. PROJECT SUMMARY

A. GOAL

The goal of this study is to provide information on smolt passage to develop surface flow outlet technology and reduce turbine entrainment in order to improve smolt survival at John Day Dam.

B. OBJECTIVES

The objectives of the hydroacoustic evaluation of the run-at-large during separate spring (49-day, April 22 to June 9) and summer (42-day, June 10 to July 21) study periods in 2008 at John Day Dam are to:

1. Estimate spill passage efficiency[1] and effectiveness, top spill weir (TSW) passage efficiency and effectiveness, fish guidance efficiency of the intake screens, and total project fish passage efficiency for the run-at-large.

2. Estimate diel, vertical, and horizontal fish distributions at the powerhouse, spillway, and the two TSWs.

3. Evaluate the effect two treatments for spillway/TSW operations on the fish passage metrics listed in Objective 1. (Treatments are yet to be determined.)

C. METHODOLOGY

The recommended methods will involve state-of-the-science hydroacoustic data collection and analysis methods. Fixed-location hydroacoustic techniques (explained in general by Thorne and Johnson 1993 and in detail by Ploskey et al. 2003) will be used to estimate fish passage rates at the spillway, top spill weirs, and turbines. We plan to conduct hydroacoustic sampling 24 h/d during 49-day spring (April 22 to June 9) and 42-day summer (June 10 to July 21) study periods. Hydroacoustics and telemetry studies are complementary. Telemetry provides species-specific results for the few species or age groups that are tagged, while hydroacoustics non-obtrusively samples a large number of fish to provide composite fish passage metrics for the run-at-large. The results of this study will be thoroughly integrated with those from concurrent acoustic telemetry and acoustic imaging studies also proposed for John Day Dam in 2008.

D. RELEVANCE TO THE BIOLOGICAL OPINION

As part of the remand process for the 2004 Biological Opinion on Federal Columbia River Power System (FCRPS) operations, the Action Agencies submitted to the U.S. District Court, District of Oregon a draft Proposed Action dated May 21, 2007. Hydrosystem Strategy 2 of the Proposed Action states, "*Modify Columbia and Snake river dams to maximize juvenile and adult fish survival.*" This strategy includes the following measures for juvenile passage at John Day Dam that our study pertains to.

- Action 11 – Powerhouse Improvement Actions – "*Providing or enhancing powerhouse surface flow outlets.*"
- Action 12 – Spillway Improvement Actions – "*Providing or enhancing spillway surface flow outlets.*"

III. PROJECT DESCRIPTION

A. BACKGROUND

John Day Dam (JDA), located on the Columbia River at River Mile 216, is a linear dam (Figure 1) with a 322,000-cfs powerhouse capacity. Baseline biological data on fish distributions were summarized by Giorgi and Stevenson (1995) and Anglea et al. (2001). Generally, yearling migrants approach the dam along the Washington side of the forebay and subyearling Chinook salmon approach using migration pathways near both shorelines. Radio telemetry studies indicated that tagged fish were observed traversing the forebay laterally before passing (Anglea et al. 2001). In one of the more recent studies,

[1] By definition, "efficiency" is the proportion of fish passing a given route and "effectiveness" is the fish:flow ratio (proportion fish divided by proportion water through a particular route).

Moursund et al. (2003) studied fish passage distributions and efficiencies.

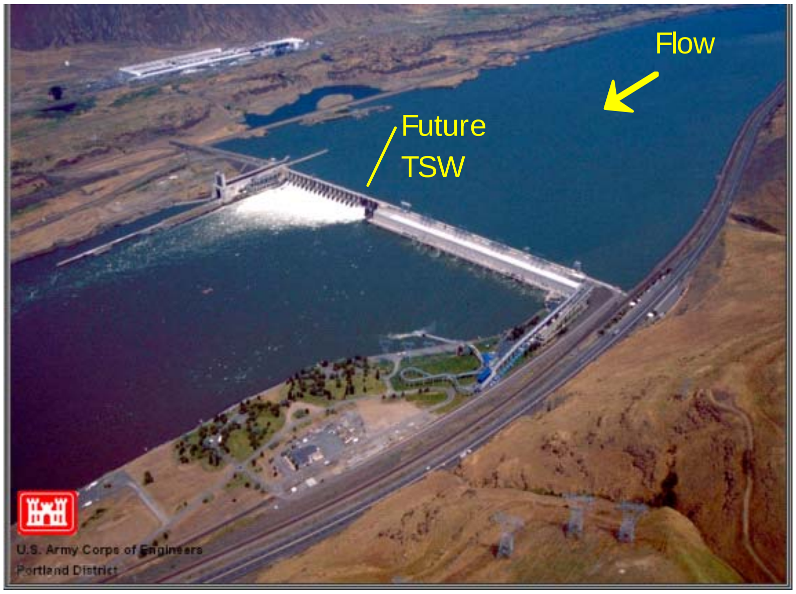


Figure 1. Aerial Photograph of John Day Dam Showing the Location of the Future Top Spill Weirs (TSW).

Surface flow outlet (SFO) development is in its early stages for John Day Dam, although investigations have been undertaken sporadically for over 25 years. In 1981, a prototype surface spill configuration was created using spillway stop logs at Bays 16, 17, and 18; fish were observed visually passing the dam in the shallow spill (Magne et al. 1983). In 1997, field work on a prototype surface spill SFO was conducted with "over/under" weirs that were installed at Bays 18 and 19, the same bays proposed for top spill weirs (TSW) in 2008. Passage at the prototype bays was higher during the spring with the weir out than in; during the summer passage for in and out conditions were comparable (BioSonics 1998). The 1997 test of the prototype surface spill SFO, however, was affected by the large amount of spill in adjacent bays during this abnormally high flow year. Engineering and model studies examining the skeleton bays as potential SFO sites were conducted in the 1990s (Montgomery Watson 1998). At a physical model at ERDC, observations of a 20,000-cfs SFO in a skeleton bay showed strong forebay flow nets; however, because of concerns about cost and tailrace egress caused by a large eddy that formed in the spillway stilling basin adjacent to the SFO outfall plume, this effort was tabled.

Currently, new model investigations (CFD and general physical scale) and engineering design work are underway to develop a prototype SFO for John Day Dam. In 2008, the Portland District plans to install TSWs, which are prototype surface spill SFOs. The device will rest on spillway stop logs. A bulkhead on top of each weir will provide hydraulic control, creating a critical entrance flow regime. The anticipated discharge is about 10,000 cfs per TSW. The weirs are being designed to minimize the angle of SFO jet impact on the ogee. The ongoing SFO work at John Day Dam is part of the project's Configuration and Operation Plan (COP; USACE 2007).

The 2008 evaluation of the John Day TSW will examine whether the prototype SFO moves fish away from the powerhouse, thereby decreasing turbine passage and increasing spill efficiency. Accordingly, the goal of this study is to provide information on smolt passage to develop surface flow outlet technology and reduce turbine entrainment in order to improve smolt survival at John Day Dam.

B. OBJECTIVES

The objectives of the hydroacoustic evaluation of the run-at-large during separate spring (49-day, April 22 to June 9) and summer (42-day, June 10 to July 21) study periods in 2008 at John Day Dam are to:

1. Estimate spill passage efficiency[2] and effectiveness, TSW)passage efficiency and effectiveness, fish guidance efficiency of the intake screens, and total project fish passage efficiency for the run-at-large.

   Efficiency and effectiveness estimates from hydroacoustics are used to summarize fish passage for the run-at-large during the spring and summer migration seasons. Furthermore, the metrics can be compared across years because similar methods were applied in previous studies at John Day Dam (Moursund et al. 2003). This provides fisheries managers with data on trends and patterns in fish passage that they can use to make decisions on project operations and fish protection design efforts.

2. Estimate diel, vertical, and horizontal fish distributions at the powerhouse, spillway, and the two TSWs.

   Fish distribution is fundamental to understanding the fish passage. Distribution data are also used to aid design of project operations and structures intended to increase smolt survival. Hydroacoustics provides detailed distribution data.

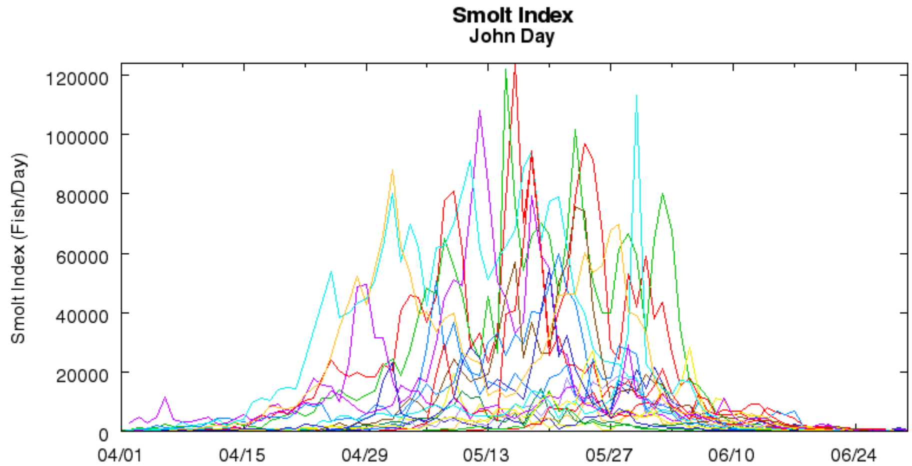
3. Evaluate the effect two treatments for spillway/TSW operations on the fish passage metrics listed in Objective 1. (Treatments are yet to be determined.)

   This objective will take advantage of the sampling intensity of fixed-location hydroacoustics to statistically compare the responses of the listed metrics for the two treatments.

C. STUDY PERIOD

Separate spring and summer study periods were established by examining the recent five-year record of smolt passage indices from John Day Dam (2002-2006; Figure 2). During spring, yearling Chinook, coho, and sockeye salmon and steelhead comprise the downstream migration. During summer, subyearling chinook salmon are prevalent. Based on the previous five years (2002-2006), the emigration generally has started to increase in magnitude by April 22. The demarcation between spring and summer emigrations is around June 5-10. Although the outmigration in summer can be protracted, the peak has usually passed by mid-July when adult shad begin to be present in noticeable numbers. Therefore, the study periods will be: spring = April 22 to June 9 (49 days) and summer = June 10 to July 21 (42 days).

[2] By definition, "efficiency" is the proportion of fish passing a given route and "effectiveness" is the fish:flow ratio (proportion fish divided by proportion water through a particular route).



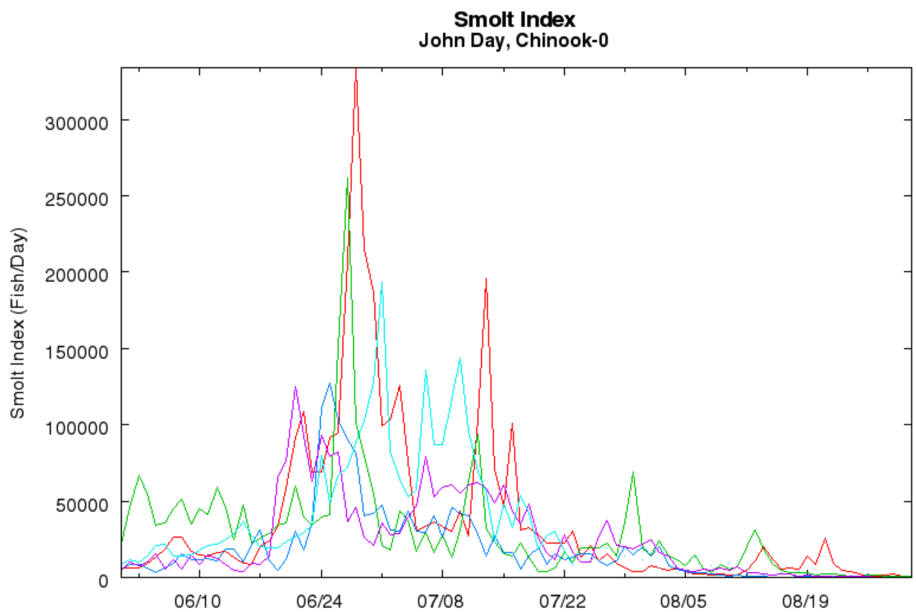


Figure 2. Smolt Index Data for Yearling Salmonid (Top) and Subyearling Chinook Salmon (Bottom) Migrations during 2002-2006 at John Day Dam. Data are courtesy of the Fish Passage Center and were obtained from www.cbr.washington.edu/dart/.

D. METHODS

To estimate fish passage rates and distributions, we propose to use a combination of single- and split-beam transducer deployments. This approach uses the acoustic screen model to determine passage rates (Johnson 2000). Split-beams will be used to provide data to determine weighting factors, assess assumptions of the model, and determine the magnitude of any biases. In accordance with the transducer optimizations developed by Ploskey and Carlson (1999) and Ploskey et al. (2002), single- and split-beam transducers will be deployed to sample fish passage at the spillway, including top spill weirs, and turbines. Transducers will be randomly placed within a passage route. Transducer sampling volumes will be strategically placed to minimize ambiguity in ultimate fish passage routes and potential for multiple detections. Thorne and Johnson (1993) explain fixed-location hydroacoustics. Simmonds and

MacLennan (2005) provide a comprehensive textbook on fisheries acoustics.

In general, a hydroacoustic system consists of an echosounder, cables, transducers, an oscilloscope, and a computer system. Echosounder and computer pairs will be plugged into uninterruptible power supplies. An echosounder generates electric signals of specific frequency and amplitude and at the required pulse durations and repetition rates, and cables conduct those transmit signals from the echosounder to transducers and return data signals from the transducers to the echosounder. Transducers convert voltages into sound on transmission and sound into voltages after echoes return to the transducer. The oscilloscopes will be used to display echo voltages and calibration tones as a function of time, and the computer system will control echosounder activity and record data to a hard disk. The 420 kHz, circular, single- or split-beam Precision Acoustic Systems (PAS) transducers will be controlled by PAS 103 echosounders and Hydroacoustic Assessments' HARP software.

The Corps plans to evaluate the TSWs using fixed-location hydroacoustics (this study), acoustic telemetry (JSATS; Juvenile Salmon Acoustic Telemetry System), and acoustic imaging (DIDSON). Different acoustic systems can cause interference with each other if they are not properly deployed. Because the three acoustic technologies planned for deployment at John Day in 2008 have not been used simultaneously before, we plan to perform field work in fall 2007 to optimize their deployment. Thus, the exact deployment approaches for the various studies will depend on the results of the optimization work to be reported in winter 2007/2008.

Sampling Locations and Orientations

Turbine Intakes. One randomly selected intake (intakes A, B, or C) within each of the 16 turbine units (except any units which may be off-line) will be monitored. We will use 6° circular single-beam and split-beam transducers (first side lobe about -30 dB) for sampling the powerhouse. Single-beam transducers will be deployed at 14 units and split-beam transducers at 2 units. The split-beam data will be used in the detectability calculations and will replace the single-beam at that particular location. A pair of similar transducers will be installed at each unit at elevation 129 feet. To sample fish guided by the submersible traveling screen (STS), one transducer will be aimed above the STS at 35 degrees off of the plane of the trash rack and, to sample unguided fish, the other will be aimed below the STS at 63 degrees off the trashrack plane (Figure 3). The pulse repetition rate for all turbine transducers will be 20 pings/sec.

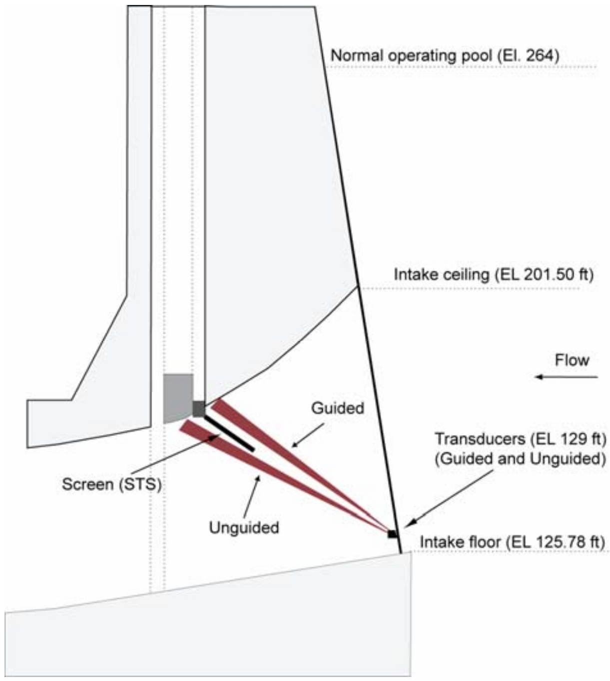
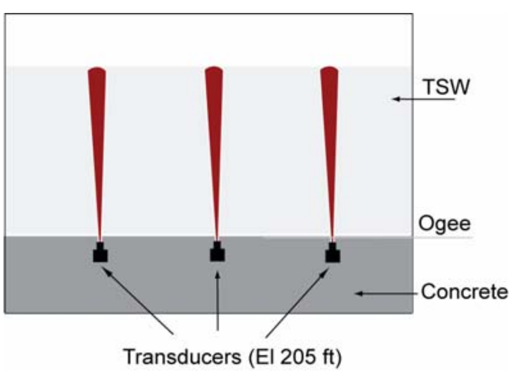


Figure 3. Side View of a Turbine Intake Transducer Deployment.

Top Spill Weirs. To sample fish passage into and over the TSW bays, we plan to deploy three 6° circular, split-beam transducers at each of the two bays. The transducers will be attached to the concrete structure, upstream of the ogee at approximate elevation 205 feet and aimed up in front of the TSW surface flow (Figure 3). Each transducer will sample one-third of the TSW width. The pulse repetition rate at the TSW will be 33 ping/sec.

Front View **Side View**



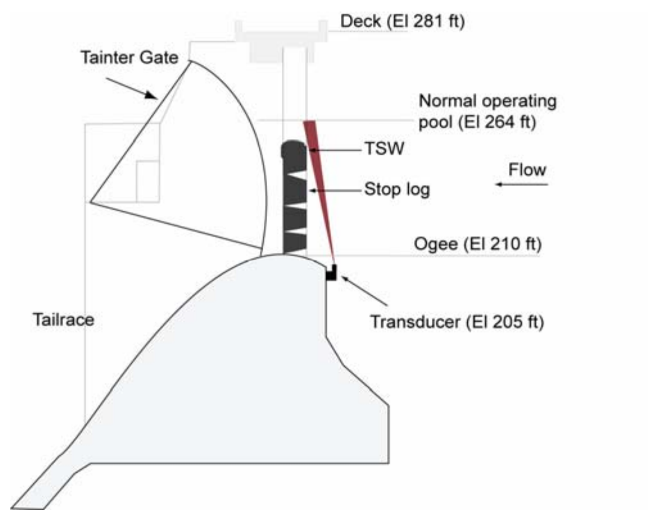


Figure 4. Front and Side Views of TSW Transducer Deployment.

Spillway. We propose to deploy transducers systematically in each of 17 spill bays, unless a bay is not used during the spill season. Note: Spill Bay 1 may not be used depending on the spill plan requirements for 2008 and Bays 18 and 19 will be fitted with TSWs. We will use the spillway pole mounts designed and fabricated in 1999. Thirteen spill bays will be monitored using 10° circular, single-beam transducers (first side lobe -25 dB) and four bays will be monitored using 10° split-beam transducers. The split-beam transducer allows us to collect detectability data under a broader range of spill gate openings. Each transducer will be deployed on a pole mount assembly, installed under the road deck plate, at elevation 258 feet and aimed approximately 2 degrees downstream (Figure 5). The location for each bay will be randomly selected (north, middle, or south) to reduce any bias caused by non-uniform distribution within each bay. The pulse repetition rate at the spillway will be 33 pings/sec.

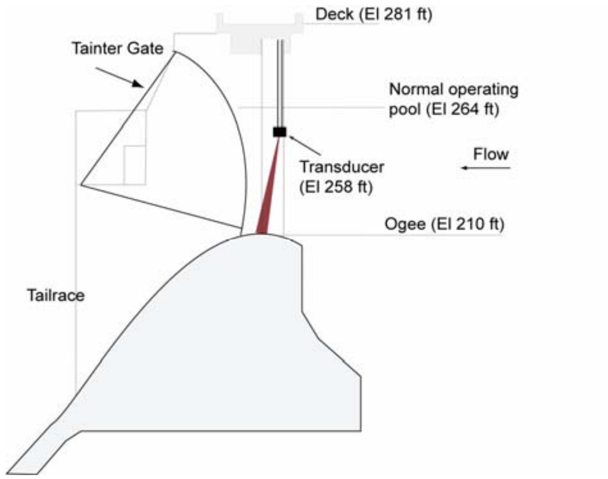


Figure 5. Side View of a Spill Bay Transducer Deployment.

Hydroacoustic Systems

Table 1 summarizes the ten hydroacoustic systems and 55 transducers proposed for this study. Before deployment, all hydroacoustic equipment will be transported to Seattle, Washington, where Precision Acoustic Systems will electronically check the instruments and measure source levels, receiving sensitivities, and beam patterns. After these measurements are obtained, we will calculate receiver gains to equalize the output voltages among transducers for on-axis targets ranging in hydroacoustic size from –56 to –36 dB || 1μPa at 1 m. Lengths of fish corresponding to that acoustic size range would be about 1.3 and 15 inches, respectively, for fish insonified within 21° of dorsal aspect.

Table 1. Hydroacoustic Systems Proposed for John Day Dam, 2008.

System No.	Type	Route	Locations	No. Transducers
1	Single	Turbine Intakes	Units 1, 2, 3, 4(G)	7
2			Units 4(U), 5, 6, 7	7
3			Units 9, 10, 11, 13(G)	7
4			Units 13(U), 14, 15, 16	7
5		Spillway	Bays 2, 3, 4, 6, 7, 8	6
6			Bays 10, 11, 12, 14, 15, 16, 20	7
7	Split	Turbine Intakes	Units 8, 12	4
8		Spillway	Bays 5, 9, 13, 17	4
9		TSWs	Bay 18	3
10			Bays 19	3
Total				55

Sampling Intensity

The proposed sampling intensity minimizes the duration per sample and maximizes the number of samples, as recommended by Skalski et al. (1993). We do not propose to "fast-multiplex" (sample two locations simultaneously) on the same system at the spillway, because it is more important to maximize the pulse repetition rate and, hence, detectability (Table 2).

Table 2. Hydroacoustic Sampling Intensity for Fish Passage Estimation

Route	Sample Intervals per Hour	Minutes Sampled per Hour
Turbine Intakes	16	16
Spillway	8	8
Top Spill Weir	60	60

Experimental Design

A rigorous experimental design will be implemented to compare passage rates and efficiencies for the purpose of investigating TSW performance. Using daily passage data from the sluiceway surface flow outlet at The Dalles Dam in 2002, a calculation[3] was made to determine the relative detectable difference between sample means. The calculation assumed we had two treatments and desired a power of 0.80 for a two-tailed significance level of 0.05. The results of this analysis showed that the difference in passage rates would be on the order of 30% to detect a statistically significant difference.

The comparison of the TSW treatments (Objective 3) will require a randomized block experimental design. Tentatively, a given treatment will be in place for three days and blocks will be six days long. The draft treatment schedule (see the acoustic telemetry pre-proposal by Ploskey et al.) includes a one day transition period between blocks for purposes of the telemetry study. Thus, there will be a total of 13 blocks over the course of a 91-day study period; 7 blocks for spring and 6 blocks for summer. This design will be contingent on requirements of the JDA acoustic telemetry study and is subject to change.

Hydroacoustic Data Processing

All data files acquired during the study will be processed with automated tracking software after the software parameters have been carefully set-up for each transducer. The autotracker tracks almost all linear traces of echoes meeting liberal tracking criteria and then tracked traces are filtered to exclude non-fish using filters derived for every transducer later during the data analysis process.

We will model detectability to determine effective beam widths using fish velocity data by 1-m strata and target strength data from the split-beam transducers. These data and other hydroacoustic-acquisition data (e.g., beam tilt, ping rate, target-strength threshold, number of echoes, and maximum ping gaps) will be entered into a stochastic detectability model. Effective beam angles for every 1-m range strata (EBA in Equation 1) will be used to expand every tracked fish at its range of detection to the width of the turbine intake or spill bay, and to one-third of the width of a TSW bay, because each of three adjacent transducers in a TSW will sample one-third of the opening.

One of the most important factors affecting estimates of effective beam width is the minimum echo-pattern criterion (e.g. a core of 4 echoes in 5 pings), which can only be modeled stochastically. An

[3] As of July 2007, additional sample size calculations may be performed by Dr. Pereira at Oregon State University. Therefore, the number of treatments is subject to change.

effective beam angle for a nominal 7-degree beam may become asymptotic with increasing range at 7 or 8 degrees if an echo-pattern criterion is not modeled. However, modeling detectability for four collinear echoes in five pings (allowing a 1-ping gap) may top out at 6 or 7 degrees. Requiring four collinear echoes in four pings (allowing no gap in the core of a trace) may top out at only 3 degrees. The target strength of fish also has a major effect on detectability and effective beam width. It is deployment dependent because target strength depends in part on the orientation of fish as they pass through a hydroacoustic beam.

Acoustic counts of juvenile salmon acquired at spill bays, TSWs, and turbine intakes will be expanded based upon the ratio of opening width to beam diameter at the range of detection:

Expanded Numbers = OW / (MID_R × TAN(EBA/2) × 2), (1)

where, OW is opening width in m, MID_R is the mid-point range of a trace in m, TAN is the tangent, and EBA is effective beam angle in degrees. Opening width may be the entire width of an intake or spill bay for a single sampling transducer or the width of a zone sampled by one of several transducers sampling a single outlet (e.g., a TSW).

Within-hour counts of fish will be expanded spatially to the width of every passage route and temporally to estimate hourly passage and its variance. Counts and variances also will be expanded to estimate passage for spill bays and turbine intakes that were not sampled. Fixed-aspect hydroacoustic data will be combined with project operations data to estimate passage efficiency and effectiveness, where appropriate. To account for the slot-to-slot variance within turbine units as well as temporal variances, the sampling scheme at each powerhouse will be viewed as a stratified random sampling scheme. Using pairs of consecutive turbine units, we will assume that 2 of 6 intake slots were randomly selected for monitoring within each stratum. The second stage of sampling was the sampling of time intervals within the slot-hour. For example, a conservative variance estimator for unguided fish would be as follows:

$$\hat{Var}\left(\hat{H}U\right)=\sum_{g=1}^{5}\frac{L_g^2\left(1-\frac{l_g}{L_g}\right)s_{\hat{U}_g}^2}{l_g}+\sum_{g=1}^{5}\left[\frac{L_g\sum_{k=1}^{l_g}\hat{Var}\left(\hat{U}_{gk}\right)}{l_g}\right] \qquad (2)$$

where

L_g = number of turbine intake slots in the gth stratum $\left(g=1,\ldots,5\right)$ (here, $l_g=6$);

l_g = number of turbine intake slots sampled in the gth stratum $\left(g=1,\ldots,5\right)$ (here, $l_g=2$);

$$s_{\hat{U}_g}^2=\frac{\sum_{k=1}^{l_g}\left(\hat{U}_{gk}-\hat{\bar{U}}_g\right)^2}{\left(l_g-1\right)};$$

$$\hat{\bar{U}}_g=\frac{\sum_{k=1}^{l_g}\hat{U}_{gk}}{l_g};$$

$$\hat{U}_{gk} = \sum_{i=1}^{d} \sum_{j=1}^{23} \frac{R_{ijgk}}{r_{ijgk}} \sum_{l=1}^{r_{ijgk}} b_{ijkl} \; ;$$

$$V\hat{a}r\left(\hat{U}_{gk}\right) = \sum_{i=1}^{d} \sum_{j=1}^{23} \left[\frac{R_{ijgk}^2 \left(1 - \frac{r_{ijgk}}{R_{ijgk}}\right) s_{b_{ijgk}}^2}{r_{ijgk}} \right];$$

and where

r_{ijgk} = actual number of time intervals sampled in the *j*th hour $\left(j = 1, \ldots, 23\right)$ of the *i*th day $\left(i = 1, \ldots, d\right)$ at the *k*th intake slot $\left(k = 1, \ldots, l_g\right)$ in the *g*th stratum $\left(g = 1, \ldots, 5\right)$ (i.e., nominally 15 1-minute samples);

R_{ijgk} = number of possible time intervals that could be sampled in the *j*th hour $\left(j = 1, \ldots, 23\right)$ of the *i*th day $\left(i = 1, \ldots, d\right)$ at the *k*th intake slot $\left(k = 1, \ldots, l_g\right)$ in the *g*th stratum $\left(g = 1, \ldots, 5\right)$ (i.e., nominally 60 1-minute samples);

b_{ijgkl} = estimated unguided fish passage in the *l*th sample $\left(l = 1, \ldots, r_{ijgk}\right)$ in *j*th hour $\left(j = 1, \ldots, 23\right)$ of the *i*th day $\left(i = 1, \ldots, d\right)$ at the *k*th intake slot $\left(k = 1, \ldots, l_g\right)$ in the *g*th stratum $\left(g = 1, \ldots, 5\right)$;

$$s_{b_{ijgk}}^2 = \frac{\sum_{l=1}^{r_{ijgk}} \left(b_{ijgkl} - \overline{b_{ijgk}}\right)^2}{\left(r_{ijgk} - 1\right)} \; ;$$

$$\overline{b_{ijgk}} = \frac{\sum_{l=1}^{r_{jgk}} b_{ijgkl}}{r_{ijgk}} \; .$$

Hydroacoustic Data and Statistical Analysis

We will calculate fish-passage metrics, including passage proportions relative to passage at other routes (efficiency) and passage proportions relative to flow proportions (effectiveness), and analyze seasonal, diel, and distribution trends. Fish passage sums and variances will be combined to estimate the spring and summer fish-passage efficiency for the entire project and its 95 % confidence interval using the methods of Skalski et al. (1996). Seasonal, diel, and distribution trends in fish passage at the main routes will be plotted graphically, examined, and discussed. We will compare fish passage and TSW efficiencies of the two treatments using a paired t-test on paired treatments (Snedecor and Cochran 1982) within blocks in spring and summer.

E. LIMITATIONS/EXPECTED DIFFICULTIES

We expect few difficulties with completing the planned objectives. However, clear and timely communication between Pacific Northwest National Laboratory (PNNL) and the Corps will be essential.

We have successfully worked with Corps personnel at mainstem hydroelectric projects in the Columbia River Basin and at John Day Dam specifically.

F. EXPECTED RESULTS AND APPLICABILITY

The results from this study and others will provide the region with information to make decisions regarding long-term smolt protection measures at John Day Dam. Currently, spillway surface flow outlets are the top priority. As this work progresses, information on fish passage project-wide can be used to understand the proportion of fish affected by the new structures, and be incorporated into total project survival estimates accordingly. But, even with spillway surface flow outlets, relatively large numbers of fish may still pass through the 16-unit powerhouse. Therefore, the skeleton bay surface flow outlet could also become a critical element of the suite of smolt protection techniques at John Day Dam.

G. FACILITIES AND EQUIPMENT

All of the hydroacoustic equipment necessary for this study is owned by the Corps of Engineers, Portland District, although the replacement of faulty cables or computer parts will be needed.

PNNL will provide the crane services necessary to deploy the spillway mounts.

The Corps would provide the diving services necessary to deploy the trashrack mounts for the turbine intake transducers.

H. IMPACTS

Test Fish: Test fish will not be needed.

Other Research: We plan to coordinate closely to assure that sampling efforts are complementary with the acoustic telemetry (SBE-P-08-new) and smolt responses (SBE-00-06) studies at John Day Dam in 2008. The composite results from these studies will provide a thorough understanding of forebay and nearfield fish movement patterns and fish passage efficiencies.

Hydropower Project: The transducers for monitoring powerhouse passage will be installed and removed by divers. This will involve dive safety coordination and unit outages. Penetration dives will *not* be necessary. The spillway mounts require spillway outages for installation and removal, although we plan to deploy these transducers well before the fish spill season begins. All diving and crane usage will occur only after receiving approval form the Corps regarding the safety of the procedures and equipment.

I. SCHEDULE FOR MILESTONES AND DELIVERABLES

We are aware that the study design will be reviewed by various State and Federal agencies and is subject to the approval of the National Marine Fisheries Service under the Endangered Species Act. We understand this means the study design may be modified before the start up date.

Various technical reports are the deliverables for this study. Given the importance of the comprehensive TSW evaluation at JDA using acoustic telemetry, fixed hydroacoustics, and acoustic imaging, we are proposing to work with colleagues conducting the other studies to produce an Integration Report in addition to the usual study-specific reports. Table 3 shows the milestone and deliverable schedule for FY08 work.

Table 3. Schedule for Milestones and Deliverables

Date	Milestone	Deliverable
January 1, 2008	Start study	
March 1 to April 21	Deploy equipment	
April 22	Deployment complete; start data collection	
June 9	End data collection for spring study	
June 10	Start data collection for summer study	
July 21	End data collection for summer study	
October 31	Preliminary Data Report	✓
November	AFEP presentation	
January 31, 2009	Draft Final Report	✓
March 31	Integration Report	✓
60 days after receipt of comments	Final Report; end study	✓

J. COLLABORATIVE ARRANGEMENTS AND/OR SUB-CONTRACTS

This study would be led by Pacific Northwest National Laboratory (PNNL) and performed with subcontractors (University of Washington, Honald Crane Service, Schlosser Machine Shop). We will collaborate with other researchers performing specific studies as part of the TSW evaluation at JDA in 2008.

K. LIST OF KEY PERSONNEL

Key personnel and their roles are summarized in Table 4.

Table 4. Key Personnel.

Role	Name	Organization
Principal Investigator/Project Manager	Gary Johnson	PNNL
Co-Principal Investigator	Gene Ploskey	PNNL
Project Leader	Fenton Khan	PNNL
Acoustician/Analyst	Kenneth Ham	PNNL
Statistician	John Skalski	UW

L. TECHNOLOGY TRANSFER

Information acquired during the proposed work will be transferred in the form of written and oral research reports. A Preliminary Data Report will be submitted on September 30, 2008. A presentation will be made at the Corps' annual Anadromous Fish Evaluation Program Review in November 2008. A Draft

Final Report will be submitted on January 31, 2009. An Integration Report with colleagues from other JDA studies will be available in March 2009. The hydroacoustic study Final Report will be completed 60 days after review comments are received on the draft. Technology transfer activities may also include presentation of research results at regional or national fisheries symposia and publication of results in scientific journals.

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FINAL PROPOSAL FOR FY 2008 FUNDING

Title:	Monitor tailrace egress and hydraulic conditions during tests of a top spillway weir (TSW) at John Day Dam.
Study Code:	**SPE-P-08-NEW (Objective 8)**
Principal Investigator:	Theresa L. Liedtke U.S. Geological Survey, Biological Resources Discipline Columbia River Research Laboratory 5501A Cook-Underwood Road Cook, Washington 98605 (509) 538-2299; fax (509) 538-2843
Submitted To:	U.S. Army Corps of Engineers Portland District/Planning and Engineering Division Environmental Resources Branch Robert Duncan Plaza 333 SW First Avenue Portland, Oregon 97204-3495 (503) 808-4762; fax (503) 808-4805
Administrative Contacts:	Michele Beeman U.S. Geological Survey, Columbia River Research Laboratory 5501A Cook-Underwood Road Cook, WA 98605 (509) 538-2299; fax (509) 538-2843
Performance Period:	1 January, 2008- 30 September, 2008
Date of Submission:	October 16, 2007

PROJECT SUMMARY

RESEARCH GOAL

The goal of this proposed study is to characterize the flow environment in the tailrace of John Day Dam related to the proposed installation of a top spillway weir (TSW). To accomplish this we will release drogues through the TSW spill bay and adjacent bays, and monitor their movements through the tailrace.

STUDY OBJECTIVE

Our study objective is to characterize the flow environment in the tailrace of John Day Dam, relative to the TSW, by releasing drogues through the TSW spill bay and adjacent bays under a variety of flow and operational conditions.

Objective 1: Characterize the tailrace flow environment at John Day Dam relative to the TSW test configuration through the release of drogues

METHODOLOGY

We propose to release drift buoys (drogues) through the TSW spill bay and adjacent bays to characterize the tailrace flow conditions. A buoy system attached to a drogue will move through the tailrace according to the predominant flows. The drogues will be equipped with GPS units which will allow us to describe the precise position of the buoy during its drift through the tailrace. Drogues will be deployed through several spillbays and under the whole range of flow and operational conditions for the spring and summer outmigration periods. The primary retrieval point for drogues will be the downstream end of the boat restricted zone. A random subset of drogues on each release date will be retrieved at the basin islands to allow visualization further downstream and to best compare with previous drogue data collected at John Day Dam.

RELEVANCE TO THE BIOLOGICAL OPINION: —Hydrosystem substrategy 1: mainstem juvenile passage improvements.

PROJECT DESCRIPTION

BACKGROUND AND JUSTIFICATION

Efforts to improve downriver passage of juvenile salmonids at hydroelectric facilities on the Columbia and Snake rivers have focused on avoiding turbine passage. Juvenile salmonids migrating downriver can be diverted from turbine passage routes by turbine intake bypass systems (such as submerged traveling screens) or by passage over the spillway. The present turbine intake bypass systems at the lower Columbia River dams do not generally guide enough fish to meet the passage goals, therefore spill is used in appropriate volumes to make up the difference (Whitney et al. 1997). Although spill is capable of passing juvenile salmonids over the dam effectively, hydraulic conditions in the tailrace, due to the spill, can render fish vulnerable to predation either directly, or indirectly by extending the amount of time they spend in the immediate tailrace area.

Tailrace conditions are an important factor to consider in the effort to move juvenile salmonids past hydroelectric facilities. Shoals, eddies, flow deflectors, and other physical barriers can have a negative impact on tailrace egress. Even specific routes of passage may influence how effectively or quickly fish are able to exit the immediate tailrace. Characterizing flow conditions in a dam tailrace can help to identify risk areas or operations that lead to egress delay.

The John Day Dam Surface Bypass Program plans to install and test a top spillway weir (TSW) during the 2008 fish passage season. The TSW will be used with appropriate attraction flows to provide a surface route of passage for migrating juvenile salmon. The goal of the bypass program for 2008 is to evaluate the performance of the TSW in combination with appropriate turbine unit operating priorities. The TSW evaluation will compare juvenile salmon passage metrics and survival under the test configuration to an established set of benchmark values or to an alternate set of dam operations.

We propose to release drift buoys into the tailrace to characterize the tailrace flow environments (see Liedtke et al. 2001). A buoy system attached to a drogue will move through the tailrace according to the predominant flows, which will vary based on operating conditions at the dam. Drogues will be equipped with GPS units which will allow us to describe the precise position of the buoy during its drift through the tailrace. These positions can be displayed in a Geographic Information System (GIS) view that allows managers to visualize dominant flow paths in the dam tailrace.

OBJECTIVES AND METHODOLOGY

Objective 1: Characterize the tailrace flow environment at John Day Dam relative to the TSW test configuration through the release of drogues.

Rationale

The test of a TSW at John Day Dam in 2008 is an effort to increase fish passage efficiency and reduce the risk of turbine entrainment for juvenile salmonids. The use of spill to improve fish passage can lead to tailrace hydraulic conditions that may be unfavorable for rapid egress of the immediate tailrace environment. Evaluations of the tailrace flow environment are important when new spill-related passage routes are tested because even small modifications to dam operations can have an influence on the tailrace egress conditions for fish.

We propose to release drogues into the tailrace to evaluate the flow environment. Drogues have previously been used by USGS at John Day Dam, and have been very useful in allowing managers to visualize the movement paths of passive particles following dam passage, and under different operating conditions. We will release drogues into the TSW spill bay and adjacent bays (as available) at the early, middle, and later part of both the spring and summer outmigration periods, and during both day and night conditions. This approach will allow us to capture the variety of flow routines and dam operations for each run and provide the best interpretive power for managers.

The evaluation of the TSW will be either a single operation compared to established fish passage benchmarks or a comparison between two operations. We will release drogues under either one or two test conditions, and make comparisons between conditions as appropriate. The median drogue travel time to the downstream aspect of the boat restricted zone is the appropriate metric for statistical comparisons. If only one operational condition is selected for the TSW test we will present median drogue travel times and GIS views of movement paths, but no statistical comparisons.

The horizontal distribution of fish passage through the TSW may influence the tailrace egress route, timing, and relative risk of predation. For example, if fish passing to the outer edge of the TSW are more likely to be entrained in a lateral eddy, they may be at greater risk for delay or predation in the tailrace. Since the TSW is a new device, and the planned placement of the device is still unknown, there are currently no data that describe the horizontal distribution of fish as they pass through the TSW. Our approach, to meet this challenge, is to release drogues into the TSW bay at the northern edge of the bay, the middle of the bay, and at the southern edge of the bay. By dividing the TSW bay into three horizontal sections we hope to be able to determine if egress conditions are affected by horizontal bay position at passage. If similar data collection efforts are planned for fish, the tailrace flow environment for each bay position can be compared with the percentage of fish passing that part of the bay and their passage metrics.

Task 1.1. Release drogues through the spill bay where the TSW is installed.

For each outmigration period (spring and summer), we propose to release drogues during the early, middle, and late parts of the run. Each of these drogue release periods (early, middle, and late) will be referred to as a drogue effort (see Table 1). For releases at the TSW spill bay, each drogue effort will include releases through the north, middle, and south positions of the TSW spill bay. Multiple horizontal release positions within the bay are planned because the tailrace egress conditions may vary by release position, and the distribution of fish passage across the spill bay with the TSW in place is currently unknown. Splitting the bay into thirds is the best approach, with the current data, to be able to describe the possible egress conditions for these passage routes.

We plan three drogue efforts for each outmigration period. Each drogue effort will release five drogues through each of the three horizontal spill bay positions during periods of daylight and darkness (Table 1). The total number of drogues released through the TSW bay for each effort will be 30, divided between horizontal positions and diel periods. At the end of three efforts for each outmigration period, there will be 90 drogue releases through the TSW bay.

Activity 1.1.1.

Establish drogue release systems at the TSW spill bay to allow north, middle, and south spill bay drogue releases.
Schedule: March 2008

Activity 1.1.2.

Conduct drogue releases at the TSW spill bay during the early, middle, and late parts of the spring and summer outmigration, and during day and night periods. Drogue efforts will follow Table 1 for each outmigration period.
Schedule: April-July, 2008

Activity 1.1.3.

Conduct drogue release efforts during alternate operational conditions if a comparison of two conditions is the final study design.
Schedule: April-July, 2008

Activity 1.1.4.

Monitor drogue movements with a boat, retrieve buoys at the downstream margin of the boat restricted zone, and secure GPS data for the drift. A random subset of drogues for each drogue effort will be retrieved at the dredge islands to allow longer monitoring of tailrace movement.
Schedule: April-July, 2008

Table 1. Description of planned drogue sampling efforts. We define a drogue effort to include both day and night releases of drogues through the spill bay containing the top spillway weir (TSW), in north, middle, and south horizontal positions within the bay, and at adjacent north and south spill bays. We plan three drogue efforts for each outmigration period, one in the early run, one in the middle, and one near the end of the run.

Outmigration Period	**Drogue effort timing**	**Diel period**	**Release spill bay**	**Horizontal position in spill bay**	**Number of drogue releases**
Spring or	Early run	Day	TSW	North	5
Summer				Middle	5
				South	5
			Adjacent North	North	3-5
			Adjacent South	South	3-5
		Night	TSW	North	5
				Middle	5
				South	5
			Adjacent North	North	3-5
			Adjacent South	South	3-5
	Middle run	Day	TSW	North	5
				Middle	5
				South	5
			Adjacent North	North	3-5
			Adjacent South	South	3-5
		Night	TSW	North	5
				Middle	5
				South	5
			Adjacent North	North	3-5
			Adjacent South	South	3-5
	Late run	Day	TSW	North	5
				Middle	5
				South	5
			Adjacent North	North	3-5
			Adjacent South	South	3-5
		Night	TSW	North	5
				Middle	5
				South	5
			Adjacent North	North	3-5
			Adjacent South	South	3-5

Task 1.2. Release drogues through the spill bays adjacent to where the TSW is installed.

The spill bays immediately adjacent to the TSW spill bay will be evaluated for tailrace flow conditions. For releases at these locations each drogue effort will include releases from a single horizontal location within the bay. For the bay adjacent to the TSW bay on the north, we propose a north release location. For the bay adjacent to the TSW bay on the south, we propose a south release location (Table 1). This approach may need to be modified once the appropriate configuration is established for attraction flow.

Activity 1.2.1.

Establish drogue release systems at spill bays adjacent to the TSW spill bay to facilitate drogue releases.
Schedule: March 2008

Activity 1.2.2.

Conduct drogue releases at the adjacent spill bays during the early, middle, and late parts of the spring and summer outmigration, and during day and night periods. Drogue efforts will follow Table 1.
Schedule: April-July, 2008

Activity 1.2.3.

Conduct drogue release efforts during alternate operational conditions if a comparison of two conditions is the final study design.
Schedule: April-July, 2008

Activity 1.2.4.

Monitor drogue movements with a boat, retrieve buoys at the downstream margin of the boat restricted zone, and secure GPS data for the drift. A random subset of drogues for each drogue effort will be retrieved at the dredge islands to allow longer monitoring of tailrace movement.
Schedule: April-July, 2008

Task 1.3. Calculate drogue egress times and generate GIS views of movement paths.

Activity 1.3.1.

Calculate an egress time for drogues released during the early, middle, and late part of the run, and under the different operational conditions. Statistical comparisons will be made if the study design agreed upon is to compare two test conditions.

Schedule: July-December, 2008

Activity 1.3.2.

Use a Geographic Information System (GIS) to display GPS positions of drogue movement paths in the tailrace, correlated with flow data.

Schedule: July-December, 2008

FACILITIES AND EQUIPMENT

No specific facilities or equipment will be required to complete the drogue releases as we have previously established methods and protocols for these activities. The degree to which we may effectively monitor and retrieve drogues will depend on the boating policy within the boat restricted zone. Coordination on recording of dam operating conditions will assist with correlation of drogue movement data with operational data.

LIST OF KEY PERSONNEL AND PROJECT DUTIES

Dennis Rondorf	Section Leader
Theresa Liedtke	Project Leader/Principal Investigator
Collin Smith	Field Team Leader

TECHNOLOGY TRANSFER

Results from this study will be disseminated in the form of annual reports of research, oral presentations and briefings, and peer-reviewed journal publications. The draft annual report of research will be submitted to the COE by December 30, 2008. Comments from the COE will be accepted for 45 d from receipt of the draft final reports, after which the USGS will provide a final report to the COE or any interested parties within 60 d.

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Whitney, R. R., L.D. Calvin. M.W. Erho, Jr., and C.C. Coutant. 1997. Downstream passage for salmon at hydroelectric projects in the Columbia River Basin: development, installation, and evaluation. Prepared for the Northwest Power Planning Council, Portland, Oregon, USA. #97-15.

Full Research Proposal
Anadromous Fish Evaluation Program, 2008

I. BASIC INFORMATION

A. TITLE

Smolt Responses to Hydrodynamic and Physical Characteristics of Forebay Flow Nets Upstream of Surface Flow Outlets

B. PROJECT LEADERS

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C. STUDY CODES

SBC-W-06-01, SBE-P-00-17

D. DURATION

January 1, 2008 to March 31, 2009

E. SUBMISSION DATE

October 16, 2007

II. PROJECT SUMMARY

A. GOAL

The goal of this study is to provide biologists and engineers with general design guidelines for hydraulic and physical conditions that are conducive to passing juvenile salmon at surface flow outlets (SFOs), such as sluiceways and spillway weirs. This information will aid transfer of successful SFO technologies from one site to another. Considerable variety exists in the physical characteristics of existing SFO entrances, and our focus will be to identify entrance characteristics that facilitate or do not facilitate smolt passage. The relationship between entrance conditions and fish responses within about 20 m of SFOs is a critical uncertainty in the ongoing efforts to develop successful SFOs.

B. OBJECTIVES

In the nearfield (< 20 m) of surface flow outlets at the spillways at John Day and McNary dams during spring and summer 2008, we will use empirical data from simultaneous DIDSON (Dual-frequency Identification Sonar) and ADCP (acoustic Doppler current profiler) measurements to:

1. Characterize fish behaviors and water velocities.
2. Examine statistical relationships between juvenile salmonid movements and hydraulic variables immediately upstream of the SFO entrances.
3. Provide recommendations for design guidelines for SFO entrance conditions.

C. METHODOLOGY

The study sites proposed for this research are the prototype top spill weir at John Day Dam (JDA) and a temporary spillway weir at McNary Dam (MCN). Since the first test of the John Day TSW will be in 2008, it will be important to observe fish behaviors and water velocities in the nearfield as part of the evaluation of the prototype's performance. The McNary TSW was installed in 2007. Our six-day feasibility study there during 2007 yielded promising results; therefore, we are proposing a full-scale study for 2008 at a McNary TSW.

We propose to sample 24 h/d during three 3-d periods in spring and three 3-d periods in summer at each dam. This 432-hour sampling effort has produced more than enough data to meet similar objectives in previous studies (Ploskey et al. 2006; Johnson et al. 2006). The sample volume will be a fan about 150° wide and 12° deep emanating about 20 m out from the dam in the surface layer of water. This sample volume should encompass fish approaching and rejecting or entering the respective SFO.

We plan to sample the John Day and McNary TSWs with a DIDSON acoustic camera and a narrow beam-angle ADCP. Fish sampling and tracking methods were developed in previous studies at the Bonneville First Powerhouse sluiceway (Ploskey et al. 2006) and The Dalles Dam (TDA) sluiceway (Johnson et al. 2006). These techniques were refined during the 2007 studies at The Dalles and McNary dams. To obtain simultaneous fish and flow data, both instruments will be mounted on the same plate and moved by a programmable stepper motor. The stepper motor will be programmed to aim the instruments to sample each of five 30° wide, 12° deep zones for 12 minutes every hour. The most important aspect of the 2008 study is that fish and water data will be collected simultaneously in the same volume of water. Our basic strategy is to acquire basic data on fish behavior patterns and average water conditions at the SFO nearfield (Objective 1), then advance to multivariate data analysis (Objective 2) and ultimately interpret the results to recommend design guidelines (Objective 3).

For Objective 1, we propose to identify common dam operations scenarios then analyze the fish and water data from time periods with these operations. Relatively consistent dam operations will reduce the effect of this variable on the analysis. Fish behavior data from the DIDSON will be categorized and the data systematically reviewed by a trained staff member to extract a tally of the behaviors by category. Water velocity data will be analyzed using a running average over time by 0.5-m range bin for each rotator aiming angle. This descriptive fish and water data will be presented using graphs and videos.

For Objective 2, the primary independent variable for the analysis will be the “fish behavior” vector, which is obtained by subtracting the flow vector from the observed fish movement vector. This study will involve statistical methods to examine associations and correlations between fish movements and environmental variables, which will lead to hypotheses for cause and effect. We will merge and analyze fish movement and environmental datasets to determine which variables have the greatest effect on entrance efficiency and characteristics of fish movements at the SFO entrances. These data will be applied in recommendations for general guidelines on SFO entrance conditions for Objective 3.

D. RELEVANCE TO THE BIOLOGICAL OPINION

The Biological Opinion on operation of the Federal Columbia River Power System is in remand. As part of this process, the Action Agencies issued a draft Proposed Action on May 21, 2007. This document contains numerous references to the development of surface flow outlets at the mainstem dams. In fact, Hydrosystem Strategy 2 says, “Modify Columbia and Snake river dams to maximize juvenile and adult fish survival.” Substrategy 2.1 and 2.2 call for powerhouse and spillway improvements, respectively, including development of surface flow outlets as appropriate. The SFO development effort will require supporting biological and hydraulic research. This project would contribute to that research base.

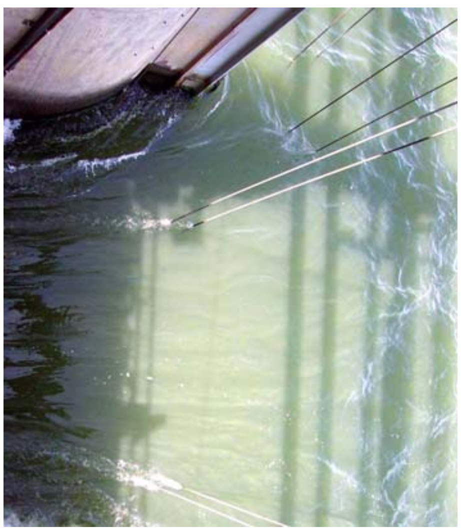
III. PROJECT DESCRIPTION

A. BACKGROUND

Development of surface routes to safely pass juvenile salmon through hydroelectric dams in the Pacific Northwest has been underway for over thirty-five years. In the 1970s and early 1980s, researchers showed that sluiceways at Bonneville, Ice Harbor, and The Dalles dams passed a relatively high proportion of smolts in a relatively low proportion of the flow (Willis and Uremovich 1981; Johnson et al. 1982; Nichols and Ransom 1981, respectively). Sluiceway operations for juvenile fish passage have been employed ever since, although the sluice route is not sufficient as a stand-alone bypass. In 1995, a major Corps program to develop surface flow outlets was initiated. Work in 1995 and subsequent years included prototypes at Bonneville, Ice Harbor, John Day, Lower Granite, and The Dalles dams. Surface flow outlet research was summarized and synthesized by Johnson et al. (1997) and Dauble et al. (1999) for the region as a whole, by Johnson and Giorgi (1999) and Johnson and Carlson (2001) for Bonneville Dam, and by Anglea et al. (2002) for Lower Granite Dam. Recently, Sweeney et al. (2007) completed an exhausting compendium of almost every SFO development efforts in the Pacific Northwest. A common concern expressed in these reviews was, despite many years of research, information was lacking on the relationship between fish behavior and flow-field features, especially in the zone within about 20 m of SFO entrances.

Surface flow outlets are intended to create a flow field in the forebay that juvenile salmon can discover and utilize to move downstream. Although they generally follow the bulk flow downstream through reservoirs, fish sometimes meander when they encounter slow water in the forebays of dams (Adams et al. 1998). Assuming smolts discover the SFO flow net, a key point is whether they will react positively or negatively, i.e., will they enter or avoid the entrance? Discovery of a SFO flow net is only half the battle; the other half is for the fish to actually follow the flow field and pass into the entrance. Efforts to improve SFO passage led to the spillway weir concepts, but there could be other, less expensive approaches. To develop these approaches, we need basic empirical data on fish response to SFO flow fields to help establish engineering design guidelines. Previous relevant work conducted within AFEP is presented in Table 1.

The development of an acoustic camera is what makes this proposed study possible. The Dual-Frequency Identification Sonar (DIDSON) is an ideal assessment tool for this study because it is highly portable, requires minimal site preparation to deploy repeatedly, and does not rely on fish tagging. With the DIDSON, we can distinguish fish from other targets, observe their behavior unobtrusively, and track their movements. The DIDSON was developed by the Applied Physics Laboratory (APL) at the University of Washington for the Space and Naval Warfare Systems Center harbor surveillance program (Belcher et al. 1999). The DIDSON was designed to bridge the gap between existing sonar, which can detect acoustic targets at long ranges but cannot record the shapes or sizes of targets like optical systems, which can videotape fish in clear water but are limited at low light levels or when turbidity is high. The DIDSON has a high resolution and reasonable frame rate designed to allow it to substitute for optical systems in turbid or dark water. The images within about 50 ft of the device are clear enough to reveal fish undulating as they swim and for users to measure fish and to tell the head from the tail. This is important because one of the dependent variables characterizing behavior will be fish orientation throughout their approach and whether they turned and swam downstream at some point.



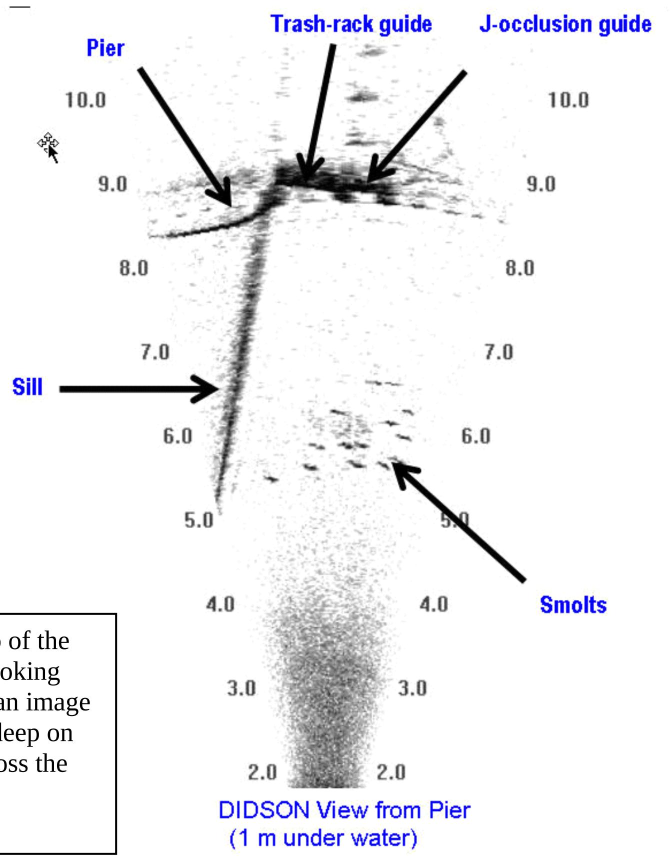


Figure 1. Photograph taken from the top of the pier at Main Unit 1 at The Dalles Dam looking down on a sluiceway entrance (left) and an image from the acoustic camera deployed 1-m deep on the same pier and aimed horizontally across the sluiceway entrance (right).

Table 1. Relevant Work in AFEP on Fish/Flow.

Year(s)	**Location**	**Fish Data**	**Water Data**	**Technical Approach**	**Findings**	**Example Citation**
1995	TDA	Split HA	Physical scale model 1:25	Vector analysis	Difficult to synchronize fish and water data. Presented a method for fish swimming effort vector.	Johnson, R.L. et al. (1995)
1997-1998	Snake R.	Radio telemetry	CFD	FINS model	2D, broad-scale, individual-based particle tracking model had reasonable correlations with observed travel times; not empirical	Scheibe and Richmond (2002)
1998-2000	LGR, B1	Multi-beam HA	CFD	Vector analysis	Difficult to synchronize fish and water data. Short fish tracks were difficult to analyze.	Johnson, R.L. et al. (2001)
2000	B1	Split HA	ADCP	Vector analysis	Good synchrony, although sample volume was small; did not analyze further than vectors	Johnson, R.L. et al. (2001)
2000	TDA	Sonar tracker	CFD	Correlation analysis using Markov data	Reasonably good fish/water synchrony, but variability in fish movement was high, leading to minimal or no correlation between Markov transition probabilities and hydraulic variables.	Johnson, G.E. et al. (unpubl.)
2000-2005	LGR, RRH, WAN	Acoustic telemetry	CFD	NFS model	3D, fine-scale, individual-based particle tracking model using fish behavior algorithms coupled with concurrent flow data; synchrony difficult	Goodwin et al. (2004)
2004	BON B2CC	DIDSON + 2 axis rotator	CFD	Behavior categorization; Fate Analysis	2-D tracking of approach at two depths; Definition of zones of influence and fate in spring and summer.	Ploskey et al. (2005)
2005	BON B1 Sluiceway	DIDSON + 2 axis rotator	CFD	Behavior categorization; Fate Analysis	2-D tracking of approach at one depth; Definition of zones of influence and fate in spring and summer and day and night behavioral description	Ploskey et al. (2006)
2006	TDA	DIDSON+2 axis rotator	CFD	Multivariate analysis	Some significant variables explaining fish displacement, but synchrony poor	Scheibe et al. (unpubl.)
2006	TDA	DIDSON+2 axis rotator	CFD	Artificial neural network	Analysis pending	Hedgepeth et al. (unpubl.)
2007	MCN, TDA	DIDSON	ADCP, CFD	Behavior categorization, multivariate analysis	Analysis pending	

Most of the studies had issues with synchronizing the fish and water data sets. For example, fine-scale fish movement data would be merged with water data from some "average" flow condition – this is not particularly useful for the purpose of understanding fish response to flow fields. There was only one empirical study that simultaneously measured fish and water velocity in the same volume of water (R.L. Johnson et al. 2001); unfortunately, this study only examined fish swimming effort vectors.

Information from our study will be useful to biologists and engineers seeking to transfer SFO technologies from one site to another. We are aware this has been and always will be a difficult proposition because site-specific features can affect fish behavior in unexpected ways. As Mike Erho said in Johnson et al. (1996, p. A-18), "It may be difficult to determine universal biological design criteria for surface flow bypass because of the uniqueness of each site...there is no magic engineering formula for SFB…certainly much can be learned by experience and information from other sites, but ultimately one needs to thoroughly assess each individual project and determine what's best for it." Our study is designed to at least partially transcend this limitation because it will include diverse sites, use standard assessment methods, occur over similar times, and collect data in situ. Thus, while we retain Erho's skepticism about "a magic engineering formula", we are optimistic that the potential exists to discover overarching principles of fish response to flow fields that would lead to guidelines on hydraulic and physical conditions that are conducive to facilitate juvenile salmon passage at surface routes at dams.

Finally, we think that a significant value of this study will be derived from directly and simultaneously observing fish behavior in SFO flow nets. As envisioned, we expect to track thousands of fish at each site, and sample sizes should provide for a robust analysis of effects of physical characteristics. However, from a strictly descriptive viewpoint, the study will provide valuable insight into fish behavior that should also be useful for bioengineers.

B. OBJECTIVES

In the nearfield (< 20 m) of surface flow outlets at the spillways at John Day and McNary dams during spring and summer 2008, we will use empirical data from simultaneous DIDSON (Dual-frequency Identification Sonar) and ADCP (acoustic Doppler current profiler) measurements to:

1. Characterize fish behaviors and water velocities.
2. Examine statistical relationships between juvenile salmonid movements and hydraulic variables immediately upstream of the SFO entrances.
3. Provide recommendations for design guidelines for SFO entrance conditions.

C. METHODOLOGY

The methodology that follows is for study site at the spillway SFOs at John Day and McNary dams in 2008. The methods will be the same for each dam.

<u>Site Preparation</u>

In early spring, we will securely anchor deployment rails on the pier nose between Spill Bays 19 and 20 at John Day Dam and Spill Bays 18 and 19 at McNary Dam. Proper permissions and access procedures will be obtained ahead of time. A motorized winch will be used to deploy and retrieve the trolley apparatus holding the DIDSON/ADCP/rotator at John Day Dam (Figure 2).

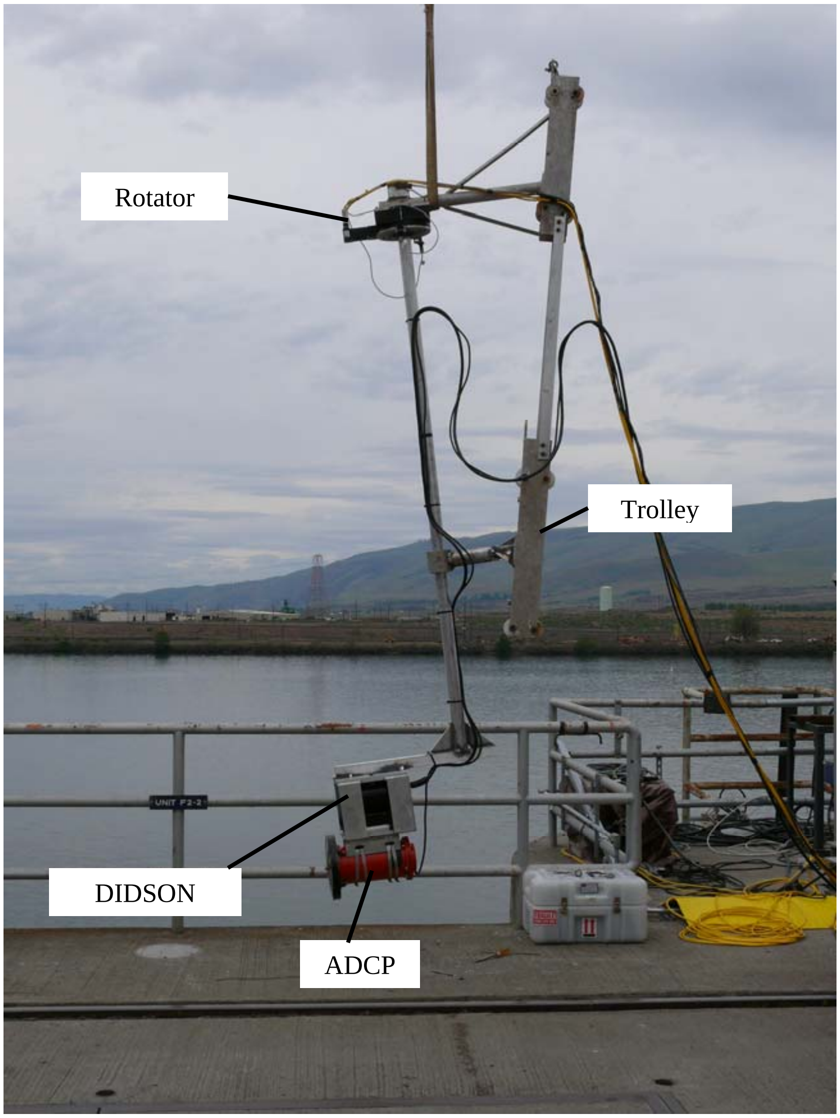


Figure 2. DIDSON/ADCP on a Mounting Plate Attached to a Rotator.

Sampling Schedule

We propose to sample John Day and McNary dam spillway SFOs during three 3-d periods in spring and three 3-d periods in summer. During each 3-d period, movements of fish and flow approaching within about 20 m of each entrance will be sampled for 24-h per day so that about 216 hours of data will be acquired each season. The sample volume will be a fan about 150° wide and 12° deep emanating about 20 m out from the dam in the surface layer of water. This sample volume should encompass fish approaching and rejecting or entering the respective SFO.

Fish Sampling

We will use a DIDSON acoustic camera to sample fish movements. The DIDSON is not as sensitive to entrained air as are the 6–10 degree beams that are typically used for hydroacoustic sampling. The clarity is possible because the field of view is composed of 96 different 0.33 × 8.5-degree beams operating at 1.8 MHz and 48 different 0.6 × 8.5-degree beams operating at 1 MHz. These narrow beams individually have much better signal to noise ratios than does a 6-degree hydroacoustic beam. The DIDSON can sample up to 12 frames per second and has a 29-degree field of view. The multiple beams allow image processing that produces a movie of fish movements. Unlike single and split-beam hydroacoustic transducers, the acoustic camera has multiple narrow beams that allow it to be aimed oblique to a flat surface and still record fish swimming very near the surface. At Bonneville and The Dalles dams during 2001 and 2002, the acoustic camera proved to be a useful tool to evaluate fish movements in turbid water very near structures. Details provided by a single frame from an acoustic-camera file can be seen in Figure 1, but the strength of the method is the ability to record swimming movements of fish.

A DIDSON in low-frequency mode will be used to sample 2D movements of fish and a narrow beam-angle (6-deg) acoustic Doppler Velocimeter (ADCP) will sample average water velocity within 0.5-m strata from the instrument. Both instruments will be mounted on a bracket fastened to a pole below a programmable stepper motor. The stepper motor will be programmed to aim the instruments to sample each of five 30° wide, 12° deep pie-slice shaped volumes for 12 minutes every hour. The zones will overlap slightly in the horizontal plane (~ 3 deg). All zones will be upstream of the SFO so we do not expect structure to interfere with ADCP sampling. Three of the adjacent horizontal zones will be as close to the water's surface as possible and the other three zones will be immediately below the near-surface zones. We propose sampling fixed volumes because previous attempts at actively tracking individual or schools of fish did not result in a large pool of long complete tracks for analysis because most fish were lost even by the most diligent tracker. In addition, tracking and water velocity estimates within the field of view are much more accurate when the instruments are not moving. Every frame of recorded data will include the aiming coordinates of the DIDSON rotator and the lateral position of the fish in the DIDSON field of view. We also will note the number and locations of predators in the vicinity of entrances during sampling so that those observations can be included in the data bases and referenced to flow and smolt behavior.

Species Composition

Although the DIDSON cannot identify species, we will differentiate subyearling Chinook salmon from resident fishes in summer based on size, silhouette, and behavior. We will supplement acquired data with species composition data from the juvenile bypass systems. Measured lengths of targets should allow us to classify many targets as steelhead or yearling Chinook salmon in spring and as subyearling Chinook salmon and other larger fish such as American shad in summer. Pikeminnows often have a distinct image that often can be distinguished from that of other potential predators in the sampling area.

Fish Track Data

Accuracy. The DIDSON detects fish positions accurately in two dimensions, i.e., in range from the device and across the fan of 96 0.3-degree wide beams but can only estimate position in the depth dimension perpendicular to the fan of beams to within 12 degrees. For a deployment with the fan of 48 beams oriented horizontally and the camera aimed across an entrance as proposed in this study, the DIDSON will provide very accurate estimates of fish position (within 50-75 mm) across the opening and in the upstream-downstream direction. However, we will have to estimate depth by assuming that the fish are in the center of the 12° deep beams and calculate fish depth as follows:

$$\text{Fish depth} = CD + (R \times \text{Tan}(RA_{BH}/2)) \times 2,$$

where CD = camera depth, R = range from the acoustic camera, Tan = tangent; and RA_{BH} = rotator angle below horizontal. Therefore, the error in estimates of fish depth will be range dependent (i.e., ± Tan(12º/2) x R). In the low-resolution mode, with a fan of 48 beams oriented horizontally, the DIDSON provides high resolution 2D position information based upon range from the instrument and location among the beams. With the same orientation, the vertical resolution of fish position is less accurate. It is ± 0.52 m at 5 m of range, ± 1.05 m at 10 m, and ± 1.6 m at 15 m.

Processing. Processing of DIDSON fish-image data into a time series of 3D coordinates will be done with a DIDSON manual tracker developed in 2005. The manual tracker will process the data on a frame-by-frame basis for maximum resolution of fish positions through time and will automatically associate time and rotator coordinates with each fish position.

Observation-Specific Metrics. Characteristics of completed tracks will provide a host of metrics for comparing fish behavior at different sites and for relating fish behavior to hydraulic and physical conditions. These include but are not limited to variables listed in Table 2. Because these metrics are fish-specific, the sample size for determining effects of independent variables such as flow or time of day (Table 2) will be much larger than the sample size for comparing entrance efficiencies among sites or times.

Table 2. Dependent and independent variables for the analysis of entrance conditions at surface passage routes.

Type	Variable
Header	Location (field site)
	Julian date
	Time start observation segment
	Time end observation segment
	Day/night
	Zone
	Distance from the entrance that fish are entrained
Primary Metric	Fish behavior vectors (see Data Analysis section)
Observation Metrics	Orientation (rheotaxis)
	Change in orientation
	Behavior category (e.g., swimming d/s, holding, searching)
	Direction of movement
	Fish Length
	Position (X, Y, Z)
	Number of fish in school
	Swim path length relative to the distance to the entrainment point
	Lateral displacement after first detection
	Speed
	Mean track duration (seconds) and variation therein
	Track directivity
Supplemental	Specific composition by date from the juvenile bypass system

Hydraulic Data

Physical data will be primarily hydraulic, although data on entrance dimensions, shape, water temperature, water turbidity, ambient light, wind, and presence of adjacent structures also will be collected. Dam operations data will be obtained from the operations personnel at each site. We will need hourly data on operations for each turbine unit, spill bay, as well as total powerhouse, sluiceway, and spillway discharges and forebay elevations.

A narrow beam-angle (6°) ADCP (RDI, Inc. 600 kHz) will be used to obtain water velocity data while we collect the acoustic camera data. Note that the ADCP provides an averaged velocity over the area encompassed by the four beams and thus is a larger area than occupied by a fish. The ADCP will be mounted on the same plate as the DIDSON and will sample the same zone as the DIDSON at the same time. Standard processing techniques will be used to estimate water velocity by range through time and a common GPS clock of time will ensure that time lines for fish tracks and water velocities are synchronized.

We also propose to assess whether the computational fluid dynamics (CFD) model for the JDA forebay can be used to provide fine-scale (tenths of meters) hydraulic data for the purpose of correlating smolt movements with the hydraulic environment. (The CFD data would be provided by Portland District Hydraulic Design separately through another project.) Past attempts to use CFD data have been limited by the relatively large range of environmental conditions over which fish movement data were collected compared to a few CFD runs for "average" conditions. In our 2007 study at The Dalles Dam, we are identifying specific boundary conditions for individual CFD runs (using a refined version of the Rakowski, et al 2006 model) based on project operations during selected fish sampling episodes. Performing these specific CFD simulations will allow us to generate hydraulic data at finer spatial scales to supplement the ADCP field measurements. This will be especially useful to compute variables such as water acceleration components that are functions of velocity gradients. Following confirmation of the model, the fine-scale CFD data and the capability to calculate multiple hydraulic variables will then be used in the analysis of the smolt response data.

Merging of Biological and Physical Data

The ADCP data on water velocity and associated hydrodynamic characteristics such as acceleration and rate of strain will be merged with the fish data for specific times and three-dimensional positions. The universal coordinate system for this study will be Oregon south referenced to the NAD27 horizontal datum and the NGVD vertical datum. This is the same as for previous studies at Bonneville and The Dalles dams. A reference position at each study site will be established. The measured fish position data and the measured ADCP data will be transformed to the universal coordinate system. Once the master biological and environmental data sets are ready, they will be merged. Merging allows the sequential positions and associated behaviors of ensonified fish obtained by the acoustic camera to be related to hydraulic data for each sequential fish location.

Data Analysis

Data analysis for the three study objectives is interrelated. Fish movement data from the DIDSON samples will be merged with concurrent hydraulic data from the ADCP. These data will be analyzed to determine fish/hydraulic relationships (Objective 1). The fish and hydraulic data sets will also be summarized to compare with other similar data from SFOs at TDA we collected in 2004-2005 and results from the SFO Compendium project (Objective 2). Pertinent data from all sites will be integrated to determine if there is a threshold in water acceleration during approach to a SFO that results in juvenile salmonids rejecting the entrance. This section of the proposal describes data analysis methods for the three study objectives.

Relationships between Fish Movements and Hydrodynamic Conditions.

Observed fish movements are a combination of passive advection and active swimming. The active swimming component reflects fish behavior and is fundamental to the understanding of fish response to hydrodynamic conditions. To extract the active swimming component from the observed fish movement data, we will assume passive advection is represented by the ambient water velocity vector and subtract this vector from the observed fish movement vector. Johnson et al. (1998) and Scheibe and Richmond (2002) used this approach, conceptualized as follows:

$$\vec{Fish}_{behavior} = \vec{Fish}_{observed} - \vec{Water}_{observed}$$

That is, for a given time increment, the vector difference between the displacements of fish and water is the active swimming or fish behavior component (Figure 3).

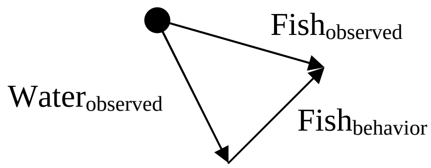


Figure 3. Observed Fish and Water Vectors and the Resulting Fish Behavior Vector.

For the analysis of fish/hydrodynamic relationships, the fish behavior vector will be the basic dependent variable and hydrodynamic and other environmental conditions will be the independent variables. Water acceleration and related variables (e.g., strain) are thought to influence fish behavior (Goodwin 2004), along with other environmental conditions such as the presence of predators, water temperature, and pressure. Thus, independent variables will likely include:

1. Total water velocity
2. Total water acceleration
3. Longitudinal component of water acceleration
4. Transverse vertical component of water acceleration
5. Transverse horizontal component of water acceleration
6. Water temperature
7. Hydrostatic pressure

We will explore the data initially using frequency histograms, bivariate scatterplots, and correlation analyses. Because of the non-linear and complex nature of these types of data sets, we propose to apply multivariate statistical methods (Sokal and Rohlf 1981) to examine relationships between the dependent and independent variables. For example, a Principle Components Analysis will reveal any variables or combinations of variables that explain a majority of the variability (> 50%) in the dependent variable being analyzed. We performed such an analysis on DIDSON fish movement data and CFD hydrodynamic data collected at The Dalles Dam in 2004 (unpublished data). Subsequent analyses revealed the hydrodynamic variables most strongly distinguished by the principle components were those related to acceleration, especially the transverse acceleration variables. We propose analyses similar to this to meet Study Objective 2.

Summary Descriptive Data and Comparison of Fish/Hydraulics among Multiple SFOs

Hydraulic Signatures: The ADCP data we systematically collect at each study site will be analyzed to describe the hydraulic conditions in the forebay of each. The temporal and spatial variability in water velocity, acceleration, and other hydrodynamic variables will also be described. Contour plotting will be used to visualize the hydraulic signatures of the SFOs.

Fish Movement Data: Descriptive results from the DIDSON data sets will be useful to characterize fish movements in general and to foster comparison among sites. Typical descriptive data include the mean and standard deviations of observed fish velocities and computed fish swimming velocities. These data will be partitioned by time season, period within season, and day/night and, if appropriate, region of the forebay. The sampling volume will also be divided into cells to describe fish movements.

SFO Rejection Response Threshold

Null Hypotheses: We eventually plan to statistically test the following null hypotheses, which will be finalized after consultation with the Science Review Work Group, and multiple sites are sampled in future years:

1. At a given distance from the SFO entrance, water acceleration (substitute other independent variables) is not related to entrance efficiency.
2. Water acceleration (substitute other independent variables) is not related to the size of the entrainment zone.
3. Smooth-shaped entrances do not affect entrance efficiency (or zone of entrainment).
4. There is no relationship between hydrodynamic variables (insert variable of interest) and fish behavior in the SFO flow nets.
5. SFO discharge is not related to the extent/size of the SFO zone of entrainment.
6. Fish behavior does not differ among the different SFO entrances.
7. Entrance efficiency does not differ among the different SFO entrances.
8. Zone of entrainment does not differ among the different SFO entrances.

Entrance Efficiency -- OPTIONAL

An absorbing Markov chain (Kemeny and Snell 1960) can be used to capture fish movement to a particular location, i.e., the region where we considered fish were entrained into the surface flow outlet. A Markov chain can model continuous movement in a continuous volume when discrete time steps are chosen and volumetric cells of a sample volume are delineated over which transition movement probabilities can be calculated. We have these with a properly sampled DIDSON dataset. Markov absorbing states (Kemeny and Snell 1960), called "Fates" here, can be assigned on edges of the sample volume. Analytically, movement is not possible through the surface or bottom because of the acoustic imaging technique as proposed herein. Fates can be calculated as probabilities of absorption into cells at a particular portion of the sample volume as follows: TSW, South, North, and Forebay. Movement fates to the faces of the sample volume are simply probabilities for movements within the sample volume. The resulting Markov chain model would allow us to estimate fish movement probabilities from a given cell within the sample volume to each "absorbing" cell on the boundary of the volume – the probabilities can be used to represent the entrance efficiencies described by Sweeney et al. (2007). Using a Markov chain model to estimate entrance efficiency is described by Johnson et al. (2004).

Quality Control and Assurance

Quality control and assurance practices will be used throughout the study. Technicians will be on site at least 10 h per day to verify that all equipment is operating to specifications and that acquired data are useful. After the DIDSON and ADCP data have been processed and analyzed, we will examine the data for anomalies and quality. We plan on the following QA/QC steps:

- Pre- and post-season check of all instruments
- Review of equipment set-up by a manufacturer's representative
- Use silicon rubber or other material to electrically isolate the ADCP and acoustic camera from their mounts

- Identification of detections of big fish and manual examination of those records to identify potential predators or fallback of adult salmonids
- Manual tracking of 1% of the tracked fish data to verify autotracker performance
- Synchronize computer time clocks continuously from a common GPS clock.

Reporting Schedule

A preliminary report will be provided to the Corps of Engineers by 30 September 2008. A formal presentation will be made at the Corps of Engineers Anadromous Fish Evaluation Program review. A draft final report will be delivered by 15 January 2008. The final report will be due 30 days after receipt of the comments on the draft report.

D. FACILITIES AND EQUIPMENT

The following list of equipment will be necessary for this study.

- DIDSON (one owned by the Corps and one owned by PNNL)
- ADCP 600 kHz, narrow footprint (one owned by the Corps and lease one)
- Programmable stepper motor and cables (one owned by the Corps and lease one)
- Vehicle (one leased from GSA and one lease by PNNL)
- Crane support (commercial; obtained by PNNL)
- Equipment mounts (commercial; obtained by PNNL)
- CFD data (optional; provided by Corps)

E. IMPACTS

If available, project assistance in the form of riggers and crane support will be used to deploy the equipment package onto the rail. When unavailable, we will subcontract with a private company for crane support.

F. COLLABORATIVE ARRANGEMENTS AND PROJECT DUTIES

PNNL will subcontract with Drs. John Skalski (University of Washington) and John Hedgepeth (Tenera, Inc.) for assistance with statistical design and analyses.

G. LIST OF KEY PERSONNEL

Staff/Organization	Duty
Gene Ploskey, PNNL	Co-principal Investigator
Gary Johnson, PNNL	Co-principal Investigator
Marshall Richmond, PNNL	Co-principal Investigator
Fenton Khan, PNNL	On-site Project Manager (John Day), data collection and analysis
Bob Mueller, PNNL	On-site Project Manager (McNary), data collection and analysis
Daniel Deng, PNNL	ADCP data analysis
Cindy Rakowski, PNNL	CFD support
John Serkowski, PNNL	Data visualization
Mark Weiland, PNNL	Rotator engineering
John Skalski, UW	Statistical design and oversight
John Hedgepeth, Tenera	Statistical analysis

H. TECHNOLOGY TRANSFER

All results will be formally documented and disseminated to interested parties in the public and private sectors. The principal means of technology transfer will be presentations and reporting. A presentation will be made at the Corps' annual Anadromous Fish Evaluation Program Review. A final report will be published in 2009. Technology transfer activities may also include presentation of research results at regional or national fisheries symposia, or publication of results in a scientific journal.

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FINAL RESEARCH PROPOSAL (COE) (FY08)

TITLE: Fish Passage and Survival at Lower Monumental and Ice Harbor Dams

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STUDY CODES: SPE-W-05-1, SPE-W-07-01

PROJECT DURATION: FY2008

SUBMISSION DATE: October 2007

PROJECT SUMMARY

Research Goals

The goal of this study is to evaluate fish passage behavior including forebay residence time, passage distribution, passage efficiency, passage effectiveness, fish passage efficiency (FPE), fish guidance efficiency (FGE), tailrace egress, and to provide estimates of project survival and route-specific survival for radio-tagged juvenile salmonids (*Oncorhynchus* spp.) passing Lower Monumental and Ice Harbor Dams. Evaluations will focus on passage and survival in conjunction with a removable spillway weir (RSW) at each dam.

Definitions of Passage Behavior Metrics and Survival Estimates

Fish passage behavior performance metrics, project survival, and route-specific survival as used in this proposal are defined as follows:

Immediate Forebay:	Portion of the forebay from the upstream limit of the boat restricted zone (BRZ) to the concrete (approximately 500 m).
Immediate Tailrace:	Portion of the tailrace from the concrete downstream to the downstream limit of the BRZ.
Passage Efficiency:	The number of fish passing the dam through a given passage route (spillway, RSW, bypass system) divided by the total number of fish passing the dam.
Passage Effectiveness:	The proportion of fish passing the dam through a given passage route (spillway, RSW) divided by the proportion of water passing through that route.
Fish Passage Efficiency (FPE):	The number of fish passing the dam through non-turbine routes divided by total project passage.
Fish Guidance Efficiency (FGE):	The number of fish passing the dam through the juvenile bypass system divided by the total number of fish passing the dam through the powerhouse.
Tailrace Egress:	The elapsed time from project passage to exit from the immediate tailrace.
Forebay Residence Time:	The elapsed time from arrival in the immediate forebay of the dam until passage through the spillway, bypass, or turbines.
Pool Survival:	Survival between the immediate tailrace of one dam to the immediate forebay of the next dam downstream.

Relative Dam Survival:	Survival from the upstream limit of the immediate forebay and the release location of reference groups downstream of the dam.
Relative Route-specific Survival:	Survival between detection within a passage route and the release location of reference groups downstream of the dam.

Study Objectives

Specific study objectives may change based on final analysis of 2007 research or changes in 2008 project operations.

Objective 1

Assess passage behavior and estimate survival for yearling Chinook salmon relative to operation of a removable spillway weir at Lower Monumental Dam.

We propose to release radio-tagged yearling Chinook salmon (*O. tshawytscha*) upstream and downstream from Lower Monumental Dam to evaluate passage behavior (forebay residence time, passage distribution, spill efficiency, spill effectiveness, FPE, FGE, tailrace egress) and to estimate dam survival as it relates to operation of the RSW under two operational conditions. In addition, we will also estimate RSW and spillway passage and survival.

Objective 2

Assess passage behavior and estimate survival for juvenile steelhead relative to operation of a removable spillway weir at Lower Monumental Dam.

We propose to release radio-tagged juvenile steelhead (*O. mykiss*) upstream and downstream from Lower Monumental Dam to evaluate passage behavior (forebay residence time, passage distribution, spill efficiency, spill effectiveness, FPE, FGE, tailrace egress) and to estimate dam survival as it relates to operation of the RSW under two operational conditions. In addition, we will also estimate RSW and spillway passage and survival.

Objective 3

Assess passage behavior and estimate survival for subyearling Chinook salmon relative to operation of a removable spillway weir at Lower Monumental Dam.

We propose to release radio-tagged subyearling Chinook salmon upstream and downstream from Lower Monumental Dam to evaluate passage behavior (forebay residence time, passage distribution, spill efficiency, spill effectiveness, FPE, FGE, tailrace egress) and to estimate dam survival as it relates to operation of the RSW under two operational conditions. In addition, we will also estimate RSW and spillway passage and survival.

Objective 4

Assess passage behavior and estimate survival for yearling Chinook salmon relative to operation of a removable spillway weir at Ice Harbor Dam.

We propose to monitor radio-tagged, yearling Chinook salmon released as part of Objective 1 prior to and following passage through Ice Harbor Dam to evaluate passage behavior (forebay residence time, passage distribution, passage efficiency, passage effectiveness, FPE, FGE, and tailrace egress) as it relates to operation of the RSW. In addition, we will estimate pool, dam, RSW, and spillway passage survival for fish released in Objective 1 using a paired-release design.

Objective 5

Assess passage behavior and estimate survival for juvenile steelhead relative to operation of a removable spillway weir at Ice Harbor Dam.

We propose to monitor radio-tagged, juvenile steelhead released as part of Objective 2 prior to and following passage through Ice Harbor Dam to evaluate passage behavior (forebay residence time, passage distribution, passage efficiency, passage effectiveness, FPE, FGE, and tailrace egress) as it relates to operation of the RSW. In addition, we will estimate pool, dam, RSW, and spillway passage survival for fish released in Objective 2 using a paired-release design.

Objective 6

Assess passage behavior and estimate survival for subyearling Chinook salmon relative to operation of a removable spillway weir at Ice Harbor Dam.

We propose to release radio-tagged subyearling Chinook salmon above and below Ice Harbor Dams. We will monitor these fish prior to and following passage through Ice Harbor Dam to evaluate passage behavior (forebay residence time, passage distribution, passage efficiency, passage effectiveness, FPE, FGE, and tailrace egress) as it relates to operation of the RSW. In addition, we will estimate dam, RSW, and spillway passage survival using a paired-release design.

Objective 7

Compare survival over relatively short distances versus longer distances for yearling and subyearling Chinook salmon and juvenile steelhead passing Lower Monumental and Ice Harbor Dams.

The primary array for estimating survival at Ice Harbor Dam has been 16 km downstream of the dam. In regional forums, concern has been raised that survival estimates may be biased high if the primary array is relatively close to the dam. The premise of this bias is that juvenile fish passing a dam that are injured within a passage route may subsequently survive to a primary array if the array is relatively close to the dam. To test whether this bias exists, we will compare survival estimates using primary survival arrays that are relatively close (16 km) and relatively distant (at least 50 km downstream) from the dam. We propose to compare survival estimates derived from these primary survival arrays (16 km and at least 50 km downstream) for radio-tagged yearling and subyearling Chinook salmon and juvenile steelhead passing Lower Monumental and Ice Harbor Dams in 2008.

Relevance to the Biological Opinion

This study addresses needs identified in NOAA's 2004 Biological Opinion (BiOp) "*The Action Agencies will continue to conduct RM&E to provide information on juvenile fish transportation and delayed mortality*", and the 2005-2007 Implementation Plan for the Federal Columbia River Power System Endangered Species Act Updated Proposed Action of the U.S. Army Corps of Engineers, Bureau of Reclamation, and Bonneville Power Administration (dated May 2005). Specifically, the Implementation Plan, under the Hydropower Action Effectiveness Research section (page 40), states "*Advance the understanding of the effectiveness of flow augmentation, spill, transportation, and system configuration changes on fish survival for each ESU*". This study also addresses Question 3 and 7 of the Ten Key Questions for Salmon Recovery in the NMFS-NWFSC Salmon Research Plan (NWFSC 2002).

PROJECT DESCRIPTION

Relevance

The Columbia and Snake River Basins have historically produced some of the largest runs of Pacific salmon and steelhead in the world (Netboy 1980). More recently, however, some stocks have decreased to levels that warrant listing under the U.S. Endangered Species Act of 1973 (NMFS 1991, 1992, 1998, 1999). Anthropogenic factors that have contributed to the decline and loss of some salmonid stocks include overfishing, hatchery practices, logging, mining, agricultural practices, and dam construction and operation (Nehlsen et al. 1991). A primary focus of recovery efforts for depressed stocks has been assessing and improving fish passage conditions at dams.

The spillway has long been considered the safest passage route for migrating juvenile salmonids at Columbia and Snake River dams. Holmes (1952) reported survival estimates of 96 (weighted average) to 97% (pooled) for fish passing Bonneville Dam spillway during the 1940s. A review of 13 estimates of spillway mortality published through 1995 concluded that the most likely mortality rate for fish passing standard spillbays ranges from 0 to 2% (Whitney et al. 1997). Similarly, recent survival studies on juvenile salmonid passage through various routes at dams on the lower Snake River have indicated that survival was highest through spillways, followed by bypass systems, then turbines (Muir et al. 2001). Pursuant to the National Marine Fisheries Service (NMFS) 2000 Biological Opinion (NMFS 2000), project operations at Lower Monumental Dam have relied on a combination of voluntary spill and collection of fish for transportation to improve hydrosystem-passage survival for migrating juvenile salmonids. Efforts to improve juvenile salmonid passage and survival at Ice Harbor Dam have focused on increasing the proportion passing via voluntary spill.

Surface collection and bypass systems have been identified as a viable alternative for increasing survival and FPE for migrating juvenile salmonids at hydroelectric dams on the Snake and Columbia Rivers. At the Wells Dam project on the Columbia River, 90% of the juvenile fish pass through the spillway while spilling just 7% of the total discharge. Studies evaluating a removable spillway weir (RSW) installed at Lower Granite Dam in 2001 have indicated that the RSW is an effective and safe means of passing migrating juvenile salmonids (Anglea et al. 2003; Plumb et al. 2003, 2004). In 2002, the Lower Granite Dam RSW passed 56–62% of radio-tagged fish while discharging only 8.5% of the total discharge. In 2003, passage effectiveness ratios were 8.3-9.9:1 through the RSW. Additionally, survival for radio-tagged fish passing through the RSW was estimated at 98% (95% CI, ±2.3%).

Juvenile anadromous salmonids in the Columbia River Basin generally migrate in the upper 3 to 6 m of the water column (Johnson et al. 2000). However, juvenile fish passage routes at dams on the lower Columbia and Snake Rivers require fish to dive to depths of 15 to 18 m in order to enter a passage route. Engineers and biologists with the USACE have developed the RSW to provide a surface-oriented spillway passage. The RSW uses a traditional spillway and is attached to the upstream face of a spillbay. In the lower Snake River, RSWs have been installed at Lower Granite Dam in 2001 and Ice Harbor Dam in 2005. An RSW is scheduled for installation at Lower Monumental Dam in the fall of 2007.

The proposed study will examine fish passage behavior including forebay delay, passage distribution, passage efficiency, spill effectiveness, FPE, FGE, and tailrace egress as well as project and route-specific survival estimates for juvenile salmonids passing Lower Monumental and Ice Harbor Dams during voluntary spill with an RSW operating at each project. Results of this study will be used to inform management decisions for operation of an RSW at Lower Monumental and Ice Harbor Dams and to optimize survival and passage for juvenile salmonids. This study addressed research needs outlined in SPE-W-05-1 and SPE-W-07-01 of the USACE, Northwestern Division, Anadromous Fish Evaluation Program.

Methods

Numerous research methods have been and are currently being used to evaluate fish passage and/or estimate survival, including PIT tags, balloon tags, hydroacoustics, and radiotelemetry. Each research method has its advantages and disadvantages, but options are limited in some situations because of lack of sampling capabilities downstream or where fish behavior and survival estimates are needed. In these situations, radiotelemetry is an ideal method for evaluating passage behavior and estimating survival. During 1999 studies at Lower Granite Dam, NMFS and United States Geological Survey (USGS) compared the performance of sham radio-tagged yearling Chinook salmon (both gastrically and surgically implanted tags) to PIT-tagged fish (Hockersmith et al. 2003). Results, based on PIT-tag detections, indicated that radio tags did not significantly affect detection probability (approximately equal to FGE in the absence of spill) or survival of yearling Chinook salmon between the tailraces of Lower Granite and Lower Monumental Dams (a 106-km reach that included two dams and two reservoirs).

Study Area

The study area includes a 125-km river reach from about 6 km above Lower Monumental Dam on the lower Snake River to McNary Dam on the lower Columbia River (Figure 1). Lower Monumental Dam, the second dam upstream of the mouth of the Snake River, is located 67 km above the confluence of the Snake and Columbia Rivers in Washington State. Ice Harbor Dam, the first dam upstream of the mouth of the Snake River, is located 16 km above the confluence of the Snake and Columbia Rivers in Washington State.

Fish Collection, Tagging, and Release

Radio tags will have a user-defined shut-off after 10 d, and be pulse-coded for identification of individual fish. In order to accurately assign passage routes to fish passing the project, a 2-3 second tag is required, which limits our tag life with respect to the number of tags needed. A radio tag with a 10-d shut off allows us to release duplicate tag codes if necessary in order to bolster sample sizes. Several years of study under varying flow levels have shown that 10-d transmitters are more than adequate for our study area. Even under low river flows, we have not had problems with our fish passing the project and related survival transects prior to tag shut down, as long as fish were tagged and released before the second week of July. For the objectives of this project, a 10-d tag should provide unbiased results with reasonable measures of precision. Each radio tag will have a 30 cm long external antenna. Spring migrants will be tagged with a transmitter that weighs 0.9 g or less. Summer migrants will be tagged with a transmitter that weighs 0.6 g in air or less.

River-run yearling Chinook salmon, juvenile steelhead, and subyearling Chinook salmon will be collected from the daily smolt monitoring sample at either Lower Monumental or Little Goose Dams from approximately 1 May through 15 July. We will use only fish that have not been previously PIT tagged, and that have no visual signs of disease or injury. The minimum size for tagging will be 115 mm in fork length or 14 g in weight for spring migrants and 100 mm in fork length or 10 g in weight for summer migrants. The minimum fish size criteria used a tag burden of less than 6.5% of the fish weight. Fish will be anesthetized with tricaine methanesulfonate (MS-222) and sorted in a recirculating anesthetic system. Fish for treatment and reference release groups will be randomly selected from the daily smolt-monitoring sample and transferred through a water-filled, 10.2-cm hose to a 935-L holding tank. Following collection and sorting, fish will be maintained via flow-through river water and held a minimum of 18 h prior to radio tagging.

Fish will be surgically tagged with a radio transmitter using techniques described by Adams et al. (1998). A PIT tag will also be inserted with the radio transmitter so that if test fish are collected in the fish collection systems at downstream dams, they will be separated by code and returned to the river (Marsh et al. 1999). Fish handling methods such as water-to-water transfers and pre-anesthesia will minimize injury and stress to fish during the sorting and tagging process. Trained NMFS personnel will supervise all tagging operations

Immediately following tagging, fish will be placed into a 19-L, aerated recovery containers (two fish per container) and held a minimum of 18-h for recovery and determination of post-tagging mortality. All fish will be held in tanks either below the raceways at Lower Monumental or Little Goose Dams. Fish holding containers are perforated with 1.3-cm holes in the top half of the container to allow exchange of water during holding. Recovery containers are closed and transferred to a 1,152-L holding tank designed to accommodate up to 28 containers. All holding tanks will be supplied with flow-through water during tagging and holding and aerated with oxygen during transport to release locations.

We will use a paired-release study design with treatment fish released upstream of the dam and reference fish released into the tailrace. After the post-tagging recovery period, fish will be moved in their recovery containers from the holding area to release locations. For objectives 1, 2, and 3 the treatment fish will be released 7 km upstream from Lower Monumental Dam and the reference groups will be released approximately 4 km downstream from the dam into the tailrace. To provide mixing of treatment and reference groups, treatment groups will be released all at one time twice daily (daytime and nighttime periods), and reference release groups will be released over a 4-h period twice daily (daytime and nighttime periods).

For objectives 4 and 5 the treatment groups at Ice Harbor Dam will be created from fish released for objectives 1 and 2 and subsequently detected on the entrance line at the upstream end of the boat restricted zone (BRZ) in the forebay of Ice Harbor Dam. For objective 6 the treatment fish will be released 7 km upstream from Ice Harbor Dam. The references groups at Ice Harbor Dam will be released over a 4-h period twice daily (daytime and nighttime periods) approximately 4 km downstream from the dam into the tailrace. The specific reference-group release locations were determined from operations testing on 1:55 scale model of Lower Monumental and Ice Harbor Dams at the USACE Engineer Research and Development Center in Vicksburg, MS.

Lower Monumental and Ice Harbor Dams project operations during 2008 have not been finalized at this time. Expectations are that Lower Monumental will operate under two conditions and Ice Harbor Dams will operate under one condition in 2008. It is anticipated that Lower Monumental Dam operations will follow a 4-day randomized block. Each block will comprise of 2-days of operation A and 2-days of operation B. The specifics of operations will be developed by the USACE and regional fish management agencies prior to the 2008 outmigration. Project operation data at Lower Monumental and Ice Harbor Dams will be collected every 5 min by the USACE. Project operations assigned to treatment fish will correspond to conditions closest to time of passage. For treatment fish that pass the dam without a specific passage time, project operations will be assigned based on conditions closest to the time of first detection recorded in the tailrace. For treatment fish that do not pass the dam, project operations corresponding to conditions closest to the time of forebay entry will be used. Operational conditions assigned to reference fish will correspond to conditions closest to time of release. Treatment fish assigned to a specific project operation will be paired with reference fish released during the same project operation.

Data Collection, Processing, and Analysis

The locations of proposed fixed telemetry receiver sites at Lower Monumental Dam are summarized in Table 1 and Figure 2. The locations of proposed fixed telemetry receiver sites at Ice Harbor Dam are summarized in Table 2 and Figure 3. Locations of telemetry transects for estimating survival are presented in Figure 1. Telemetry data will be retrieved through an automated process that downloads networked telemetry receivers up to four times daily. After downloading, individual data files will be compressed by recording the first time a radio-tagged fish was detected and counting the number of detections where the time difference between adjacent detections is less than or equal to 5 minutes. When the difference between adjacent detections becomes greater than 5 minutes, a new line of data is created. All compressed data will be combined and loaded into a database, where automated queries and algorithms will be used to remove erroneous data. On the cleaned data set, detailed detection histories will be created for each radio-tagged fish. These detection histories will be used to calculate arrival time in the forebay, determine forebay approach patterns, passage route and timing, tailrace exit timing, and timing of downstream detections for individual radio-tagged fish.

Forebay Residence Time

A schematic of the model used for forebay delay is presented in Figures 4 and 5. Forebay arrival time will be based on the first time a fish is detected on the forebay entry line at the upstream end of the BRZ. Forebay residence time will be determined for fish that had been released upstream from the dam, detected entering the forebay, detected in a passage route, and detected in the immediate tailrace on either the stilling-basin or tailrace-exit telemetry receivers (Figures 2 and 3). Forebay residence time for individual fish will be measured as the time between the first detection on the forebay entrance line at the upstream end of the BRZ to the last detection in a passage route. Forebay residence data will be partitioned by project operations based on operations at the time individual fish pass the dam. Forebay residence times for fish passing during different conditions will be compared.

Approach and Passage Distribution

A schematic of the model used for passage distribution is presented in Figures 4 and 5. Approach patterns will be based on the first detection at either underwater dipole spillway antennas (Beeman et al. 2004) or on stripped coax underwater antennas (Knight et al. 1977) on the standard-length traveling screens (Figures 2 and 3). Approach distributions will be partitioned by project operations based on operations at the time individual fish pass the dam.

The route of passage through the dam will be based on the location of the last time a fish was detected on a passage-route antenna (Figures 2 and 3). Passage will be confirmed by subsequent detection in the tailrace by stilling-basin, draft tube exit, or tailrace-exit telemetry antennas. Tailrace detections are used to validate passage because it is possible for fish to be detected on a passage-route antenna while still in the forebay. Spillway passage will be assigned to fish that were detected in the tailrace of the dam after last being detected in the forebay on antenna arrays deployed along the pier nose on the sides of individual spillbays. Powerhouse passage will be assigned to fish last detected in a turbine intake prior to detection in the tailrace of the dam.

Powerhouse passed fish will be further partitioned into either turbine or juvenile bypass system (JBS) passage based on the presence or absence of JBS detections (PIT-tag or telemetry detection). Fish that are assigned to powerhouse passage without detections in the JBS will be assigned to turbine passage. Passage distribution will include fish released above a dam, detected in a passage route, and detected in the immediate tailrace on either the stilling-basin, draft tube exit or tailrace-exit telemetry receivers. Approach and passage distributions will be partitioned by project operations and compared.

Fish Passage Performance Metrics

We will evaluate the following fish passage performance metrics; spill efficiency, spill effectiveness, fish passage efficiency (FPE), and fish guidance efficiency (FGE).

Spill efficiency is the number of fish passing the dam via the spillway divided by the total number of fish passing the dam. Spill effectiveness is the proportion of fish passing the dam via the spillway divided by the proportion of water spilled. FPE is the number of fish passing the dam through non-turbine routes divided by total number of fish passing the dam. FGE is the number of fish passing the dam through the JBS divided by the total number of fish passing the dam through the powerhouse (turbines and JBS). Fish passage metrics will be partitioned by project operations and compared.

Tailrace Egress

A schematic of the model used for tailrace egress is presented in Figures 4 and 5. Tailrace egress will include fish detected in a passage route and detected on the tailrace exit array. Tailrace egress will be the elapsed time between last detection on a passage route and last detection on the tailrace exit array. Tailrace egress data will be partitioned by project operations based on operations at the time individual fish pass the dam. Tailrace egress times for fish passing during different conditions will be compared.

Survival Estimates

A schematic of the model used for dam and route specific survival is presented in Figures 6 and 7. Radiotelemetry detection data for all release groups will be compiled and processed as described in Eppard et al. (2000). The "complete capture history" protocol (Burnham et al. 1987) will be used to estimate project survival and detection probabilities by applying a single release-recapture model (Cormack 1964; Jolly 1965; Seber 1965; Skalski et al. 1998; Skalski et al. 2001) independently to the treatment and reference groups. The release-recapture data will be analyzed using the Survival with Proportional Hazards (SURPH) statistical software developed at the University of Washington (Smith et al. 1994). Route-specific survival will be estimated for all passage routes where adequate numbers of fish pass the project to provide estimates with a precision level of at least +/- 0.07. Survival estimates and passage behavior metrics for the two spill patterns will be compared. Correlations between survival, passage behavior, project operations and environmental conditions will be examined by regression analysis to determine how these factors affect project survival, route-specific survival, and fish passage. Survival estimates will be based on detections of individual fish at telemetry transects on the Snake River near Burr Canyon (16 km downstream of Lower Monumental Dam), at Ice Harbor Dam on the Snake River, the Snake River mouth, on the Columbia River near Burbank, WA, and the forebay of McNary Dam (Figure 1). Capture histories of treatment and reference groups will be partitioned into three periods for survival estimation. For evaluations at Lower Monumental Dam these three periods will be detection at Burr Canyon, Ice Harbor Dam, and detection downstream from Ice Harbor Dam. For evaluations at Ice Harbor Dam these three periods will be detection at the Snake River mouth, the Columbia River near Burbank, WA, and the forebay of McNary Dam. Minimum detection probabilities for each transect are expected to be 75%. At Lower Monumental and Ice Harbor Dams, telemetry receivers will utilize underwater and air antennas to monitor the forebay, all routes of passage, and the tailrace to detect radio-tagged fish approaching, passing, and exiting the tailrace of the dam (Figures 2 and 3).

Treatment groups for estimates of survival will be comprised of fish passing during a specific operation. The reference groups of fish for estimates of survival will be grouped by the operations during release. Relative survival estimates will be the ratios of survival estimates of treatment groups over the reference groups. Differences among project operation treatments in forebay residence times, tailrace egress, and survival will be evaluated using ANOVA, likelihood ratio tests, and/or nonparametric methods as appropriate. Chi-square, goodness-of-fit tests will be used to test equal probability of detection (mixing) over time between treatment and control groups.

Survival estimates and passage behavior metrics will be analyzed using appropriate statistical tests. To provide continuity between analysis and interpretation of survival and passage behavior, we will use the same pool of fish for both passage behavior and survival. Assumptions, proposed sample sizes, and estimated precision for the proposed evaluations are presented in Tables 3, 4, and 5. The number of release groups and number of fish per release group were calculated to maximize the ability to provide a dam survival estimate with 95% confidence intervals of +/- 4% at Lower Monumental Dam and +/- 6% at Ice Harbor Dam. Sample sizes for releases were calculated based on data from radio-tagged salmonids released at Lower Monumental and Ice Harbor Dams in 2002 through 2007, and annual PIT-tag survival estimates in the Lower Snake and Columbia Rivers. We used conservative assumptions in calculating sample sizes; our actual precision will likely be greater than shown. To test the assumption that a dead fish carrying an active radio tag could float past a downstream detection line yielding false-positive detections and biasing the survival estimate, any tagging mortalities will be released in conjunction with release groups into the tailrace of Lower Monumental and Ice Harbor Dams. Since 2002, we have been releasing known dead fish bearing active tags in order to determine that the survival array is positioned adequately downstream so that we do not bias our survival estimates. We have not observed any known mortalities at our primary survival transect located 16 km below Ice Harbor Dam. It has been suggested that fish may become injured during passage, but not succumb to their injuries until they proceed further downstream within the Columbia River. For this reason, we have been asked to provide a secondary survival transect, which may indicate whether this is occurring. To test the assumption that juvenile fish passing a dam that are injured within a passage route may subsequently survive to a primary array that is relatively close to the dam, we will compare survival estimates using primary survival arrays that are relatively close (16 km) and relatively distant (at least 50 km downstream) from both Lower Monumental and Ice Harbor Dams. At present, no formal analysis of adult returns of PIT-tagged fish used in this study is anticipated.

Avian Predation

Predation from the Caspian Tern C*aspia hydroprogne* colony on Crescent Island, located 12.9 km downstream from the Snake River mouth (Figure 1), will be evaluated by physical recovery of radio transmitters that are visible on the island and by PIT tag detection. Radio tags and PIT tags will be recovered on the tern colony at Crescent Island during fall 2008 after the birds have left the island. Radio-tag serial numbers will be used to identify individual tagged fish. PIT-tag detections and recovery of radio transmitters at Crescent Island may also be provided by Real Time Research, Inc. (A. Evans, Real Time Research, Inc., personal communication). There is an ongoing monitoring effort to recover PIT tags from active Caspian Tern colonies in the region conducted by NOAA Fisheries and by the Columbia Bird Research group.

Critical Limitations

The degree of success of this study will be contingent upon six primary factors: 1) adequate numbers of fish being collected and radio tagged during the required time frame; 2) the pre-determined replicates and sample sizes providing the necessary precision for the survival estimates; 3) adequate numbers of radio-tagged fish passing through each passage route to estimate route-specific survival with precision and to evaluate passage behavior; 4) radiotelemetry receivers, PIT-tag detectors and bypass systems at downstream dams operating for the duration of the study; 5) the acquisition and availability of detailed operations data in order to correlate passage behavior and survival with project operations; and 6) access to Lower Monumental and Ice Harbor Dams outside normal business hours.

PROJECT IMPACTS

1. Collection, tagging, and fish-holding operations at Little Goose, Lower Monumental and Ice Harbor Dams will be coordinated with the Project Office and Smolt Monitoring Program personnel.
2. All fish for the study will either be collected at Little Goose or Lower Monumental Dams. Changes in the daily smolt monitoring sampling schedule and sample rates may be required to meet daily target numbers for tagging.
3. Activities related to marking and/or releasing fish at Lower Monumental, Little Goose, and Ice Harbor Dams may occur during all hours; therefore, unusual vehicle traffic and activity may occur outside normal COE duty hours during April through July.
4. Installation, deployment, maintenance, downloading, and removal of telemetry equipment by NMFS personnel including receivers, antennas, and cables will occur at Lower Monumental and Ice Harbor Dams from February through July. Temporary spill outages may be required to test and service telemetry antennas.
5. A reliable, uninterruptible power supply will be required at both projects for operation of radiotelemetry receivers.

BIOLOGICAL EFFECTS

These studies will be carried out using an ESA Section 10 Permit issued to the National Marine Fisheries Service.

TECHNOLOGY TRANSFER

Information acquired during the proposed work will be communicated to the fisheries community by presentations at meetings and workshops, by personal contact, by annual and final reports to the U.S. Army Corps of Engineers, and through scientific publications.

KEY PERSONNEL AND DUTIES

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Table 1. Proposed fixed-site telemetry receivers for evaluating passage behavior of radio-tagged juvenile salmonids at Lower Monumental Dam, 2008.

Site description	Type of monitoring	Antenna type
Forebay north shore	Entrance line and residence time	3-element Yagi
Forebay mid channel	Entrance line and residence time	3-element Yagi
Forebay south shore	Entrance line and residence time	3-element Yagi
Turbine unit 1	Approach and passage	Stripped coax
Turbine unit 2	Approach and passage	Stripped coax
Turbine unit 3	Approach and passage	Stripped coax
Turbine unit 4	Approach and passage	Stripped coax
Turbine unit 5	Approach and passage	Stripped coax
Turbine unit 6	Approach and passage	Stripped coax
Draft tube for turbine 1	Project passage	Underwater dipole
Draft tube for turbine 2	Project passage	Underwater dipole
Draft tube for turbine 3	Project passage	Underwater dipole
Draft tube for turbine 4	Project passage	Underwater dipole
Draft tube for turbine 5	Project passage	Underwater dipole
Draft tube for turbine 6	Project passage	Underwater dipole
Spillbay 8 (RSW)	Approach and passage	Underwater dipole
Spillbay 7	Approach and passage	Underwater dipole
Spillbay 6	Approach and passage	Underwater dipole
Spillbay 5	Approach and passage	Underwater dipole
Spillbay 4	Approach and passage	Underwater dipole
Spillbay 3	Approach and passage	Underwater dipole
Spillbay 2	Approach and passage	Underwater dipole
Spillbay 1	Approach and passage	Underwater dipole
Stilling basin south shore	Project passage	Tuned loop
Stilling basin north shore	Project passage	Tuned loop
Juvenile bypass system	Bypass passage	Tuned loop
Tailrace exit north shore	Project passage and tailrace egress	3-element Yagi
Tailrace exit south shore	Project passage and tailrace egress	3-element Yagi

Table 2. Proposed fixed-site telemetry receivers for evaluating passage behavior of juvenile salmonids at Ice Harbor Dam, 2008.

Site description	Type of monitoring	Antenna type
Forebay north shore	Entrance line and residence time	3-element Yagi
Forebay mid channel	Entrance line and residence time	3-element Yagi
Forebay south shore	Entrance line and residence time	3-element Yagi
Turbine unit 1	Approach and passage	Stripped coax
Turbine unit 2	Approach and passage	Stripped coax
Turbine unit 3	Approach and passage	Stripped coax
Turbine unit 4	Approach and passage	Stripped coax
Turbine unit 5	Approach and passage	Stripped coax
Turbine unit 6	Approach and passage	Stripped coax
Draft tube for turbine 1	Project passage	Underwater dipole
Draft tube for turbine 2	Project passage	Underwater dipole
Draft tube for turbine 3	Project passage	Underwater dipole
Draft tube for turbine 4	Project passage	Underwater dipole
Draft tube for turbine 5	Project passage	Underwater dipole
Draft tube for turbine 6	Project passage	Underwater dipole
Spillbay 1	Approach and passage	Underwater dipole
Spillbay 2 (RSW)	Approach and passage	Underwater dipole
Spillbay 3	Approach and passage	Underwater dipole
Spillbay 4	Approach and passage	Underwater dipole
Spillbay 5	Approach and passage	Underwater dipole
Spillbay 6	Approach and passage	Underwater dipole
Spillbay 7	Approach and passage	Underwater dipole
Spillbay 8	Approach and passage	Underwater dipole
Spillbay 9	Approach and passage	Underwater dipole
Spillbay 10	Approach and passage	Underwater dipole
Stilling basin south shore	Project passage	2-element Yagi
Stilling basin north shore	Project passage	2-element Yagi
Juvenile bypass system	Bypass passage	Tuned loop
Tailrace exit north shore	Project passage and tailrace egress	3-element Yagi
Tailrace exit south shore	Project passage and tailrace egress	3-element Yagi

Table 3. Assumptions used for estimating precision for proposed sample sizes for estimating survival and fish passage behavior at Lower Monumental (LMN) and Ice Harbor Dam (IHR) for yearling and subyearling Chinook salmon and juvenile steelhead in 2008.

	Yearling Chinook salmon		Juvenile steelhead		Subyearling Chinook salmon	
Assumptions	LMN	IHR	LMN	IHR	LMN	IHR
Treatment survival to entry	0.95	0.84	0.95	0.84	0.95	0.95
Entry detection probability	0.95	0.95	0.95	0.95	0.95	0.95
Forebay survival	0.95	0.95	0.95	0.95	0.95	0.95
Spillway passage proportion	0.75	0.75	0.75	0.75	0.80	0.75
RSW passage proportion	0.45	0.45	0.45	0.45	0.60	0.60
Survival tailrace to primary array	0.95	0.95	0.95	0.95	0.95	0.95
Detection probability primary array	0.95	0.95	0.95	0.95	0.95	0.95
Lambda	0.90	0.85	0.90	0.85	0.85	0.85

Table 4. Proposed sample sizes for tagging and release by objective for yearling and subyearling Chinook salmon and juvenile steelhead for evaluating fish passage behavior and survival studies at Lower Monumental and Ice Harbor Dams in 2008.

Release Group	Objective	Yearling Chinook	Juvenile steelhead	Subyearling Chinook
LMN Treatment	1, 2, and 3	1,495	1,495	1,500
LMN Reference	1, 2, and 3	1,100	1,100	1,100
IHR Treatment	4,5, and 6	(2,076[1])	(2,076[1])	400
IHR Reference	4,5, and 6	300	300	300
Total		2,895	2,895	3,300

[1]Treatment groups will be created by regrouping fish released as part of Objective 1 and 2 that subsequently enter into the Ice Harbor Dam study area at the upstream end of the BRZ which is expected to be at least 80%.

Table 5. Estimated precision (95% CI) ($\alpha = 0.05$, $\beta = 0.50$) of survival estimates by project operation and dam (LMN = Lower Monumental Dam, IHR = Ice Harbor Dam) for proposed sample sizes of yearling and subyearling Chinook salmon and juvenile steelhead for evaluating fish passage behavior and survival studies at Lower Monumental and Ice Harbor Dams in 2008.

	Dam survival		Spillway survival		RSW survival	
Species	LMN	IHR	LMN	IHR	LMN	IHR
Yearling Chinook salmon	0.044	0.045	0.048	0.047	0.056	0.050
Juvenile steelhead	0.044	0.045	0.048	0.047	0.056	0.050
Subyearling Chinook salmon	0.044	0.061	0.048	0.065	0.051	0.070

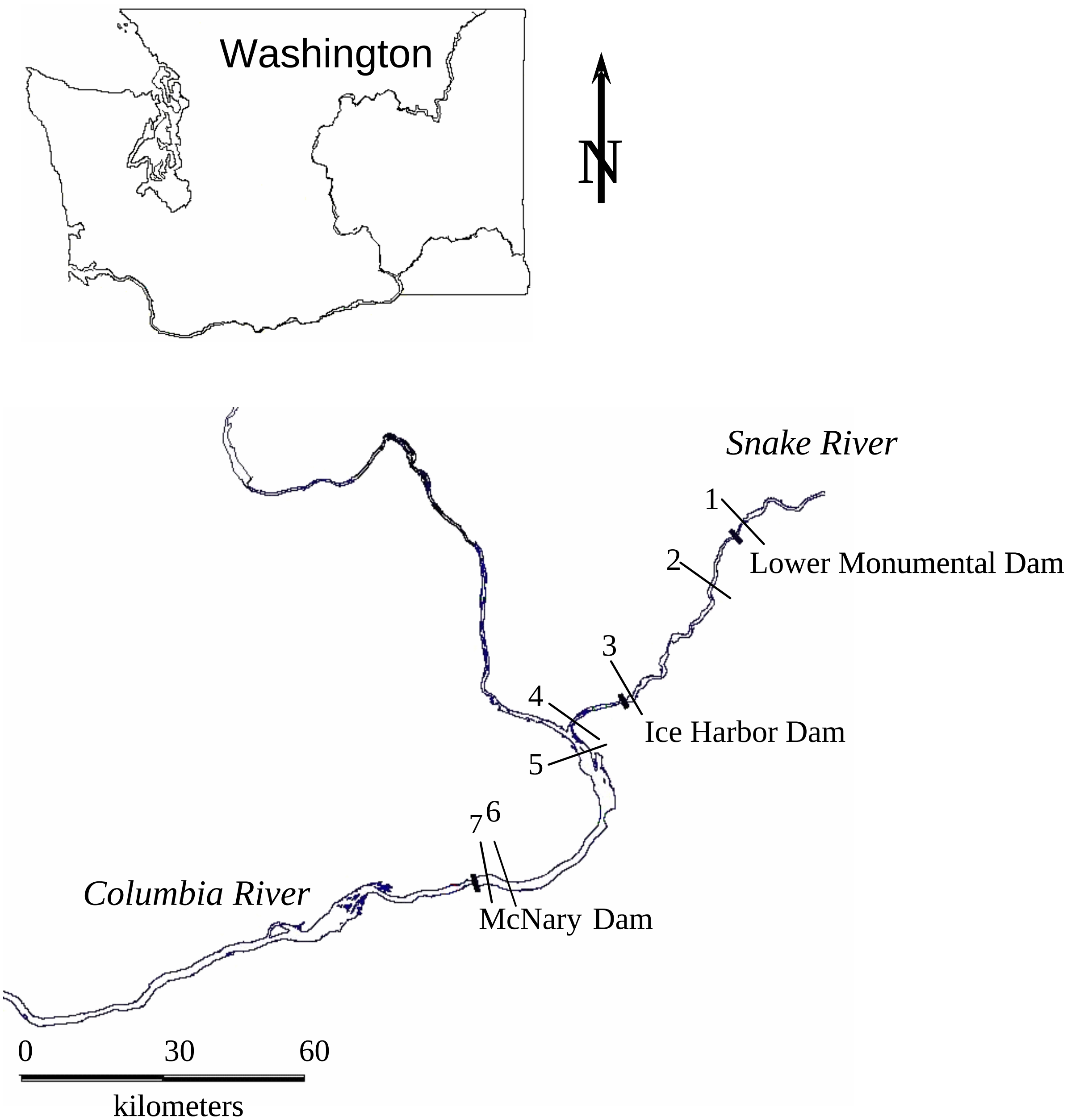

Figure 1. Detail of the study area showing locations of radiotelemetry transects used for estimating survival at Lower Monumental and Ice Harbor Dams in 2008. Transects include: 1 = forebay of Lower Monumental Dam, 2 = Burr Canyon, 3 = forebay of Ice Harbor Dam, 4 = mouth of the Snake River; 5 = Burbank/Finely Railroad Bridge, and 6 and 7 = forebay of McNary Dam. The tailrace, and all routes of passage at Lower Monumental and Ice Harbor Dams will also monitored.

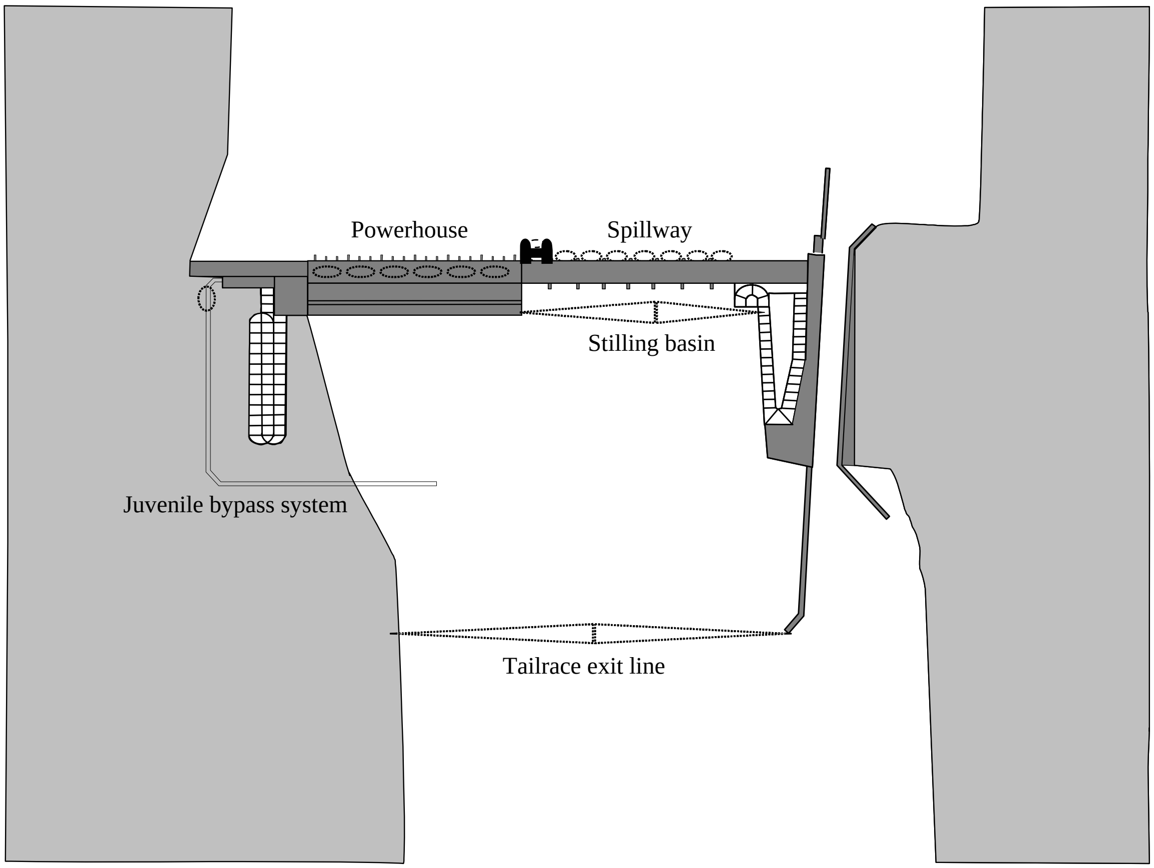

Figure 2. Plan view of Lower Monumental Dam showing proposed radiotelemetry detection zones for 2008 (Note: Dashed ovals represent underwater antennas. Dashed triangles represent aerial antennas).

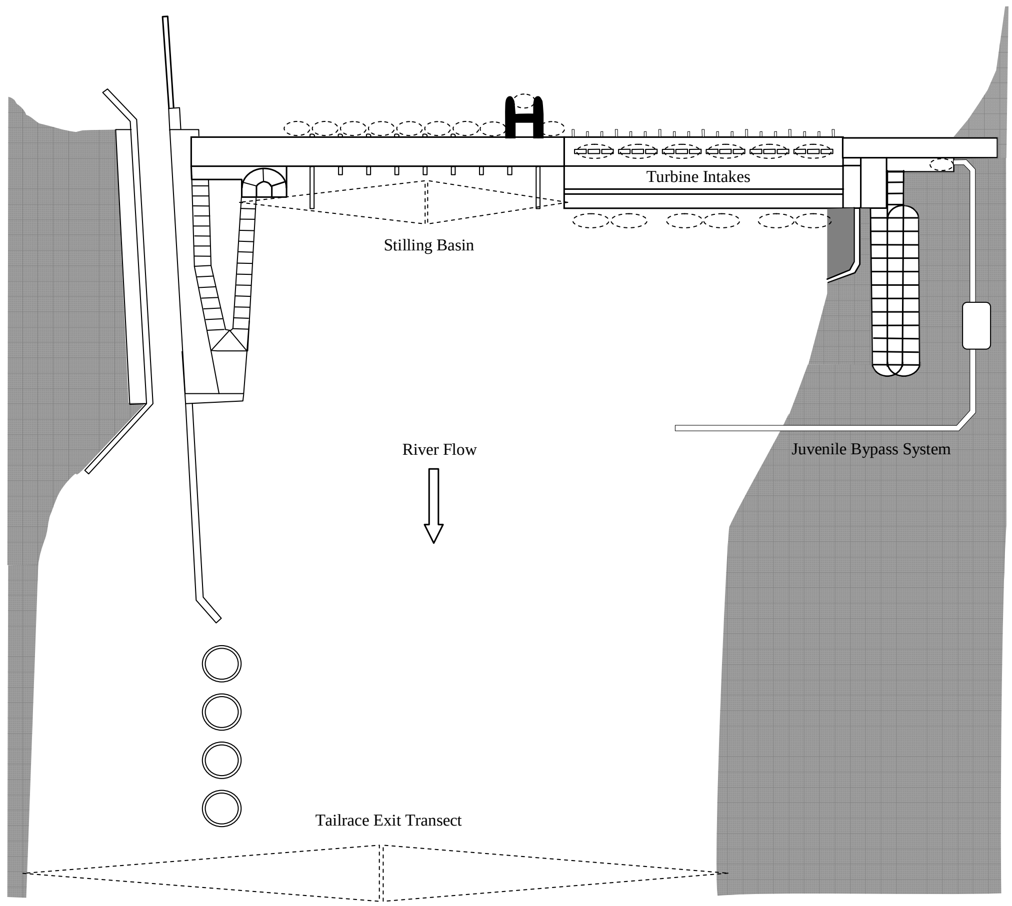

Figure 3. Plan view of Ice Harbor Dam showing approximate radiotelemetry detection zones for proposed evaluation of passage behavior and survival at Ice Harbor Dam in 2008 (Note: Dashed ovals represent underwater antennas. Dashed triangles represent aerial antennas).

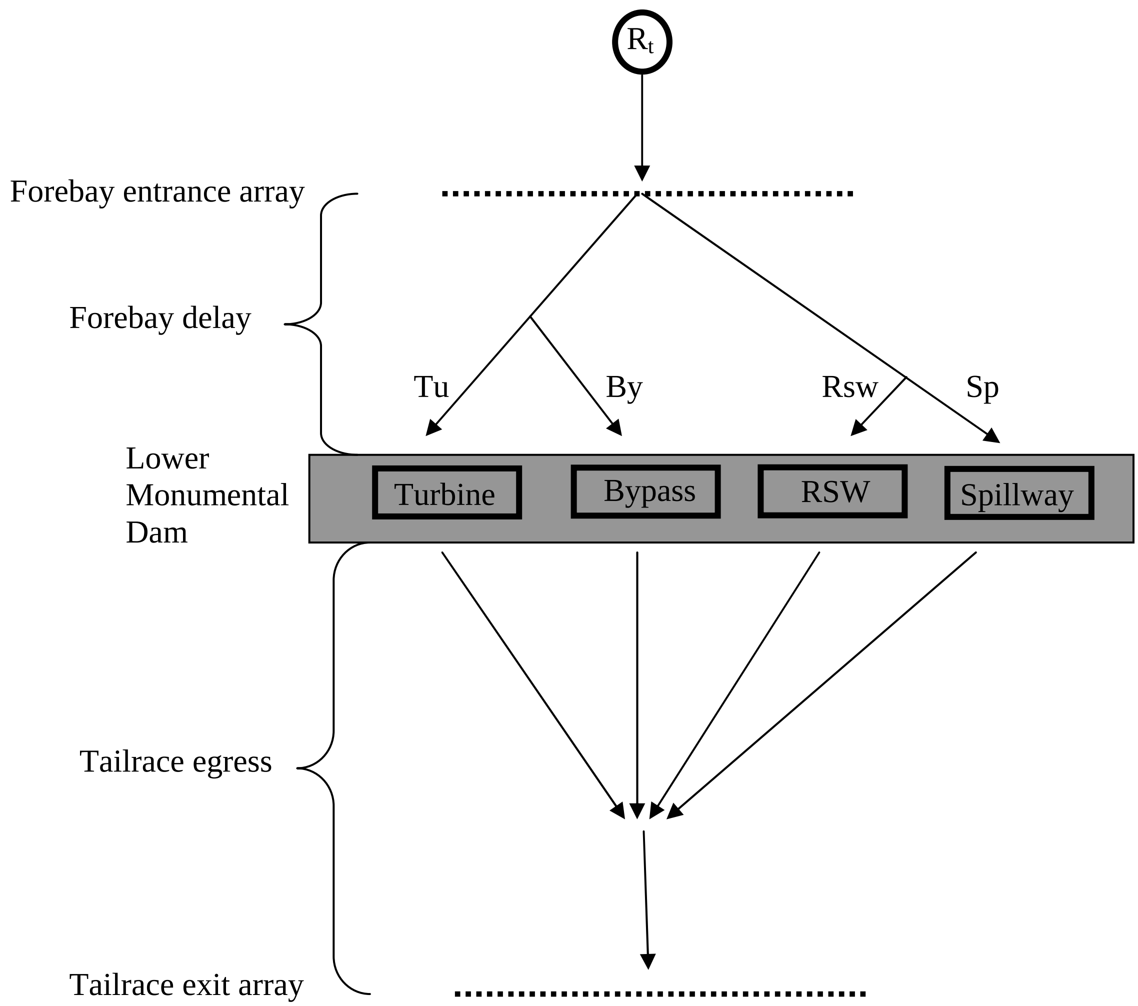

Figure 4. Schematic of passage behavior study design showing release site, passage routes, and parameters used to estimate passage metrics at Lower Monumental Dam. Shown are the treatment releases (R_t) upstream of Lower Monumental Dam and estimable parameters. Estimable parameters include forebay delay, passage routes (Tu = Turbines, By = Juvenile Bypass, Rsw = RSW, and Sp = Spillway), and tailrace egress.

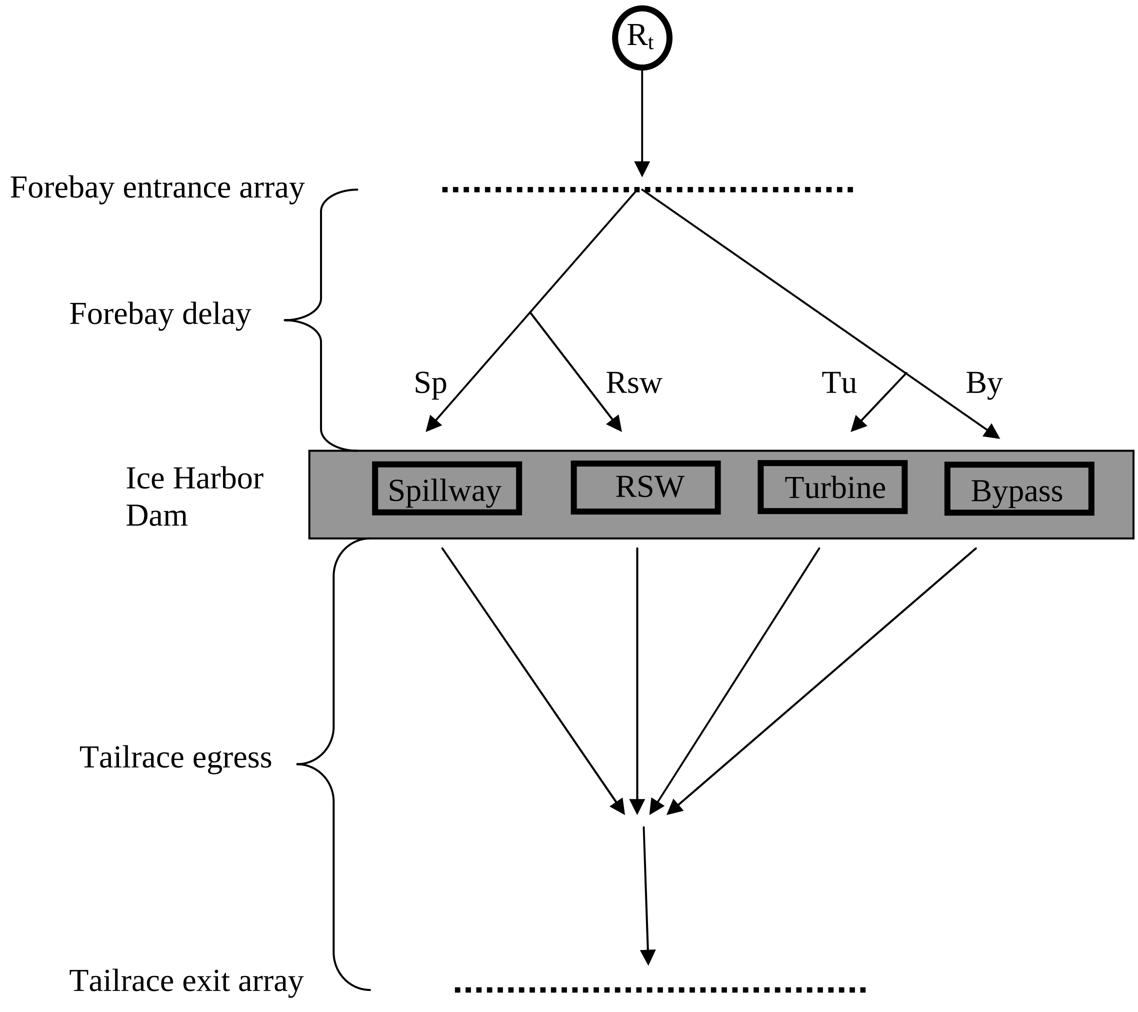

Figure 5. Schematic of passage behavior study design showing release site, passage routes, and parameters used to estimate passage metrics at Ice Harbor Dam. Shown are the treatment releases (R_t) upstream of Ice Harbor Dam and estimable parameters. Estimable parameters include forebay delay, passage routes (Tu = Turbines, By = Juvenile Bypass, Rsw = RSW, and Sp = Spillway), and tailrace egress.

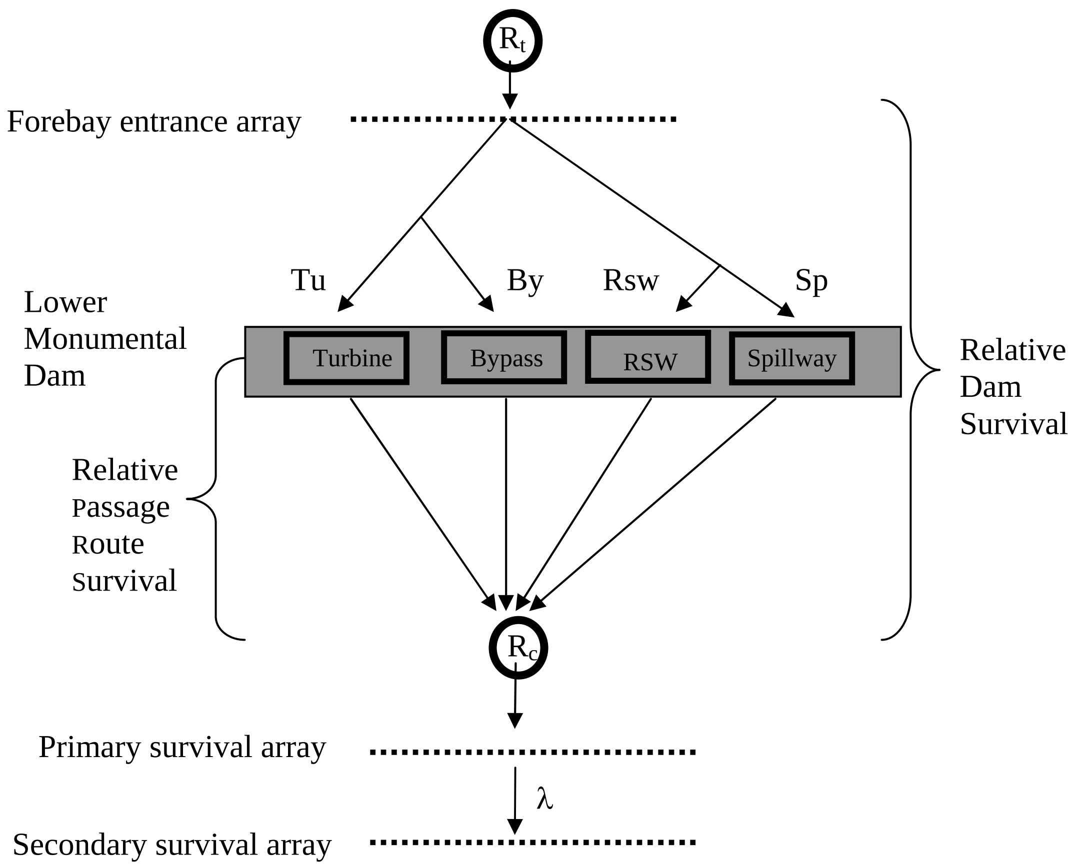

Figure 6. Schematic of relative survival model showing release sites, passage routes, and parameters used to estimate relative survival at Lower Monumental Dam. Shown are the treatment releases (R_t) upstream of Lower Monumental Dam, control releases in the tailrace (R_c), and estimable parameters. Estimable parameters include relative dam survival and relative passage route survival. Lambda (λ) is the joint probability of surviving to and detection at downstream arrays.

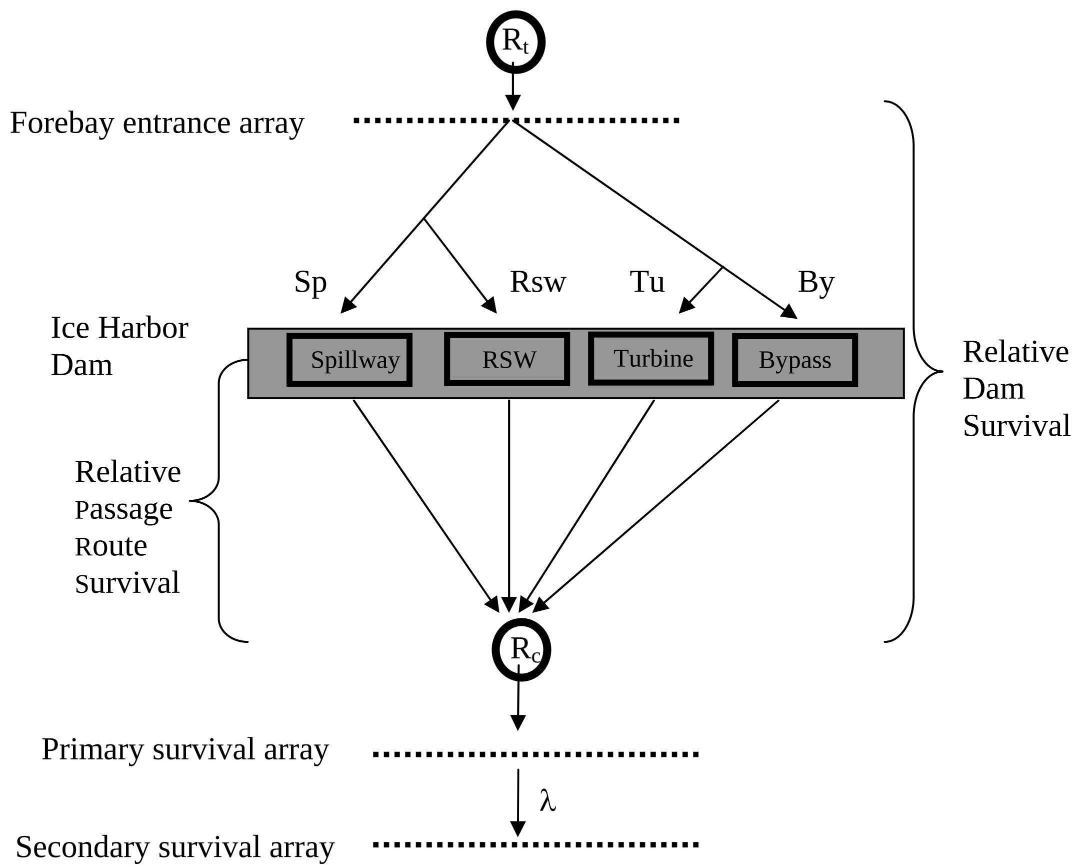

Figure 7. Schematic of relative survival model showing release sites, passage routes, and parameters used to estimate relative survival at Ice Harbor Dam. Shown are the treatment releases (R_t) upstream of Ice Harbor Dam, control releases in the tailrace (R_c), and estimable parameters. Estimable parameters include relative dam survival and relative passage route survival. Lambda (λ) is the joint probability of surviving to and detection at downstream arrays.

FINAL RESEARCH PROPOSAL (COE) (FY08)

TITLE: Comparative performance of acoustic-tagged and PIT-tagged juvenile salmonids.

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STUDY CODE: SPE-06-2

PROJECT DURATION: FY 2008

SUBMISSION DATE: October 2007

PROJECT SUMMARY

Research Goals

The goal of this study is to compare relative performance of juvenile salmonids double-tagged with the Juvenile Salmonid Acoustic Tag System (JSATS) transmitters and passive integrated transponder (PIT) tags to those tagged with PIT tags only. We propose to conduct the study in both laboratory and field settings. The results of this study will aid in determining the suitability of acoustic-telemetry to estimate short- and longer-term (30 to 180 d) juvenile-salmonid survival at Columbia and Snake River dams and through the Snake and Columbia Rivers and estuary.

By including PIT tags along with the acoustic tag, a field comparison will be used to evaluate possible tag effects based on differences in reach and system-wide travel rates and survival among study treatments through detections at dams downstream from the release point. Performance measures will include travel time through Snake and Columbia River reservoirs and dams downstream from the release site, survival and detection probability estimates from the point of release to the tailrace of downstream dams, and susceptibility to avian and piscivorous predation. In addition, the logistics of conducting a survival study using electronic telemetry including tagging, holding, and release procedures will be evaluated. Two groups of fish will be released downstream of Lower Granite Dam each day of the study. The treatments will include fish with surgically-implanted acoustic tags weighing 0.5 g and a PIT tag and fish with only a PIT tag. The PIT tag allows comparisons of downstream performance using passive detections in PIT-tag interrogation systems at Snake and Columbia River dams and using the pair trawl in the lower Columbia River. Run-of-the-river hatchery yearling Chinook captured from the juvenile bypass system at Lower Granite Dam will be used in this evaluation..

We propose to conduct a concurrent laboratory study to examine the effects of acoustic tags on tag retention, growth, disease susceptibility and mortality for run-of-river hatchery yearling Chinook salmon relative to those implanted with PIT tags over a 180-d period. This will enable evaluation of tag effects over a period more commensurate with the use of active tags, variation in out-migration timing, and to estimate survival over a longer period and reach, such as from Lower Granite Dam through the hydropower system and then through the estuary and into the Pacific Ocean. Spring fish held in the laboratory would include a representative portion of the in-river release fish. Appropriate size classes will be based on data collected in the field and the laboratory during the 2007 tag comparison study. Tags used in the lab study will be identical to those used in the field evaluation.

Preliminary results from both the field and laboratory components of the 2007 Tag Comparison study, indicate that the current model of the JSATS transmitter is not yet sufficiently compact for implantation in juvenile fall Chinook of the size class 85-105mm without producing significant adverse effects. Furthermore, observations from the 2007 field and laboratory studies suggest that the procedure for surgical implantation itself may contribute to a ‘tag effect’ in these fish. Subyearling Chinook salmon generally experience significantly warmer water temperatures and lower outflow conditions during summer out-migration than spring Chinook out-migrants. Higher river temperatures and lower flow can contribute to a higher potential for infection at the surgical site as well as enhanced holding stress pre- and post-tagging. Through a series of laboratory experiments, we propose to investigate the degree to which tag burden versus the surgical process itself contributes to the overall 'tag effect' that we witnessed in 2007. In addition, we propose to examine the degree to which the current tag must be reduced in size before one observes 'no effect' in lab fish from the acoustic implant. Finally, we will investigate the efficacy of incorporating various antiseptic agents into the current surgical tagging protocol to prevent infection at the incision site post-tagging. We will utilize run-of-the-river wild and hatchery subyearling fall Chinook of the size 85-105mm, a series of 'dummy' or sham transmitters ranging from PIT-tag size to the size of the current model JSATS transmitter, and several 'fish-friendly' antiseptic agents to accomplish this task.

We propose to utilize the sort-by-code system to recapture a portion of our spring in-river release fish at downstream collection facilities to determine the in-river effects of implantation. These fish will be sacrificed at two or more locations downstream from the release site and full necropsies will be performed on them. Similar necropsies will be performed on a portion of the spring fish collected at Lower Granite Dam for tagging to obtain a baseline index of fish condition by release. Finally, we propose to examine the proportion of acoustically-tagged vs. PIT-tagged fish that are collected from predatory bird colonies through-out the Columbia basin, and we propose to follow through with a pilot project started in 2007 to examine the proportion of acoustically-tagged vs. PIT-tagged fish collected by the northern pike minnow removal program

Relevance

Numerous research methods are currently being used to evaluate fish passage and survival to determine the impacts of the Federal Columbia River Power System (FCRPS) on endangered and threatened salmonids, including PIT tags, balloon tags, hydroacoustic evaluations, radio telemetry, and acoustic telemetry. Each method has advantages and disadvantages, but options are restricted in some situations because of limited capabilities of a specific technology, lack of detection capability downstream, or availability of adequate numbers of fish. In these situations, alternative telemetry technologies have been used to evaluate passage behavior and estimate survival. However, there remains concern about the comparative effects of the tag or tagging procedure on fish performance. Numerous evaluations of the effects of radio tags have been conducted under laboratory conditions, but few have been conducted in the field (Thorsteinsson 2002). Hockersmith et al. (2003) compared relative performance of juvenile salmonids which were either PIT-tagged, radio-tagged gastrically, or radio-tagged surgically. They found that yearling Chinook salmon surgically- and gastrically-tagged with a 1.4 g sham radio transmitter had survival and migration rates similar to PIT-tagged yearling Chinook salmon over 6 d or less and a migration distance of 106 km. However, they further found that regardless of tagging method, the radio-tagged fish had significantly lower survival than PIT-tagged fish when the migration distance was increased to 225 km and the travel time was 10 d. The recently developed JSATS acoustic transmitters (McComas et al. 2005) are approximately 40% smaller than the radio transmitters used by Hockersmith et al. (2003). In addition to being a smaller transmitter, the acoustic tag does not require the trailing antenna associated with radio transmitters, which may affect swimming performance and survival. Determining whether fish tagged with a new acoustic-telemetry tag can provide unbiased estimates of passage behavior and survival within the performance life of the tag is highly important to regional managers.

PROJECT DESCRIPTION

Background

Recent advances in tagging technology (PIT tags and balloon tags) and statistical models to estimate survival have allowed survival estimates to be made at Snake and Columbia River dams through various routes of passage (Mathur et al. 1996; Muir et al. 1994, 1998; Normandeau et al. 1995, 1997, 1998), as well as to estimate reach survival which incorporates both dam- and reservoir-related mortality (Iwamoto et al. 1994; Muir et al. 1995, 1996; Smith et al. 1998, 2004; Zabel et al. 2001). PIT tags have worked well for estimating both route-specific mortality at dams and reach survival. However, PIT-tag evaluations require tagging large numbers of smolts and adequate detection facilities downstream. Balloon and radio tags have worked well for route-specific survival estimates through dams (i.e., turbine or spillway survival), but have not been used for reach survival estimates because of concerns regarding the effects of the tags on fish performance over longer time periods and distances.

In recent years, radio and acoustic transmitters have been miniaturized sufficiently for use in smaller fish such as juvenile salmonids. Telemetry has been used extensively in the Snake and Columbia Rivers to evaluate surface bypass collectors (Adams et al. 1996, 1997; Hensleigh et al. 1997), turbine survival (Absolon et al. 2003), and dam passage behavior and survival (Anglea et al. 2001; Axel et al. 2003, 2004a, 2004b; Eppard et al. 1998, 2002, 2005a, 2205b; Hockersmith et al. 2005; Ploskey et al. 2001). Sample sizes for telemetry survival studies are generally smaller than for other methods because detection probabilities for these tags are usually high (Skalski et al. 1998). As more salmonid stocks in the Columbia River Basin have been listed under the Endangered Species Act, telemetry has become an attractive tool for studies involving juvenile salmonids.

The same models used to estimate survival in PIT-tag studies (SR Model or a Route Specific Survival Model [Skalski et al. 1998]) are used to estimate survival based on radio- and acoustic-tag detections. As with PIT-tag studies, certain assumptions must be met for valid survival estimation using these models. Two of the stated assumptions from Skalski et al. (1998) are: 1) individuals marked for the study are a representative sample from the population of interest, and 2) survival and capture probabilities are not affected by tagging or sampling, i.e., tagged animals should have the same survival probabilities as untagged animals.

Despite recent advances in downsizing of telemetry transmitters, meeting the first assumption is difficult, since a portion of the juvenile Chinook salmon population is smaller than the minimum size recommended for many tags available. Most radio- and acoustic-tag studies have therefore targeted larger smolts (fork lengths [FL] greater than 94 mm for the smaller acoustic tags and 120 mm for larger radio tags) from the overall population.

The second assumption requires that the presence of the tag and the tagging procedure do not significantly affect performance of tagged fish. If the behavior of smolts is altered by the tag, then application of survival estimates or passage timing using tagged smolts to the general (untagged) population would be invalid. For example, a tagged fish might swim at a different depth than non-tagged fish, and therefore could be differentially susceptible to juvenile fish bypass systems, spillway passage, surface bypasses, or predation.

Numerous laboratory studies have been conducted on the effects of externally-attached and gastrically- or surgically-implanted radio and acoustic tags on swimming performance, growth, feeding behavior, predator avoidance, and survival (Mellas and Haynes 1985; Greenstreet and Morgan 1989; Lucas 1989; Adams et al. 1998a, 1998b; Martinelli et al. 1998; Brown et al. 1999; Moore et al. 1990; Anglea et al. 2004; Brown et al. 2006. However, these evaluations were conducted in laboratory tanks, or if conducted in the field, did not compare performance between electronically-tagged and untagged fish.

In evaluations using Chinook salmon, Martinelli et al. (1998) and Adams et al. (1998a) both found that the presence of gastrically-implanted radio tags significantly reduced growth over the long term (21 to 54 days), whereas surgically implanted radio tags had little or no effect on growth rate. Both studies observed “coughing behavior” in gastrically implanted fish, with 5% of the fish successfully expelling tags in the Martinelli et al. (1998) study. Both studies noted abrasions in the mouth near the antenna exit with gastric implantation, and that severity of abrasions increased over time. Adams et al. (1998b) found reduced swimming performance in both gastrically- and surgically-implanted Chinook salmon less than 120 mm FL. For fish greater than 120mm FL, swimming performance in surgically-implanted fish was reduced after 1 day, but not after 21 days. For gastrically-implanted fish the opposite was observed; swimming performance was not effected after 1 day, but was significantly lower after 21 days. Fish with either gastric or surgical implants had significantly reduced predator avoidance capabilities. Adams et al. (1998a, 1998b) and Martinelli et al. (1998) concluded that surgical implantation was the preferred method for most studies, although gastric implantation might be preferred for short duration studies.

Studies which examined the effects of an acoustic transmitter on growth, survival, and swimming performance of juvenile salmonids have been conducted by Anglea et al. 2004 and Brown et al. 2006. The former authors found no significant decrease in the critical swimming speeds of Chinook salmon tagged with an acoustic transmitter which weighed 1.5 g in air and represented 1.6 – 6.7% of the fish’s body weight. Similar results were found by Brown et al. 2006 for Chinook salmon (94-125 mm FL) implanted with a 0.75g acoustic transmitter which represented 3.2 – 10.0% of the fish’s body weight. However, Brown et al. (2005) found the growth rate decreased for acoustic-tagged Chinook salmon compared to control fish.

Hockersmith et al. (1999) compared the performance of surgically-radio-tagged fish with PIT-tagged fish from release at Lookingglass Hatchery on the Grande Ronde River to Lower

Granite Dam on the Snake River, a distance of 238 km. Their results indicated the presence of a radio tag significantly affected growth, travel time, and survival. Radio-tagged fish passed Lower Granite Dam sooner, at a smaller size, and with reduced survival compared to PIT-tagged fish. These results are not surprising since conditions smolts encounter in the wild, such as feeding and predator avoidance, would be expected to be less forgiving than in a laboratory setting. The negative effects of the radio tag on fish performance may have been exaggerated by the great distance over which performance was measured

The 2007 model JSATS acoustic transmitter measures 17 mm long x 5.5-mm wide and tapers from 4- to 2-mm high. The tag weighs 0.62 g, and the coding method provides over 65,000 individual tag codes. We evaluated the performance of this tag in the field (over a 60 day period), and in the laboratory (over a 90 day period) in 2007. Altogether, we evaluated ~50,900 spring migrants (3,900=AT and47,000 =PIT), and ~41,000 Fall Chinook spring/summer migrants (10,600=AT and 30,420=PIT). The effects of this tag in actively migrating fish have not been evaluated previously to this extent. Due to the large flux in river conditions and fish condition from year to year, it is imperative that this study be repeated through time in order to thoroughly evaluate the effects and usefulness of this technology.

Relationship to Other Research

This study will provide critical information on the comparative effects between Chinook tagged with both an acoustic and PIT tag and fish tagged with only a PIT tag using performance in the field over a 60-d period and in the laboratory over a 180-d period. In addition, it is an important follow-up study for work conducted in 2007. If no significant differences exist in performance measures, managers will have more confidence in the results obtained using acoustic transmitters. If significant tag effects are found, knowing what those effects are and over what period and distance the effects occur will aid in designing more robust research and in interpreting existing data. The acoustic-/PIT-tagged fish released for the field component of this study will increase the available samples sizes (by providing additional fish) for USACE juvenile acoustic-telemetry-survival studies at Bonneville Dam (SPE-P-02-01) and for the estuary survival study (EST-02-01).

Objective/Methods

Objective 1

Compare survival and associated detection probabilities of acoustic/PIT-tagged yearling Chinook salmon relative to PIT-tagged fish migrating through the Snake and Columbia Rivers.

***Task 1.A*--During spring 2008, tag two groups of run-of-the-river hatchery yearling Chinook salmon at Lower Granite Dam. One group will be tagged with PIT tags only and the second group will receive a JSATS acoustic tag and a PIT tag.** Fish will be collected at the Lower Granite Dam juvenile collection facility and tagged at the NOAA tagging facility starting in mid to late April, and continuing every Monday, Wednesday, and Friday until 10 releases have been completed. The PIT-tagged only comparison fish will be obtained from another study conducted simultaneously by NOAA Fisheries to evaluate latent mortality associated with passage of yearling Chinook salmon through Snake River dams. The acoustic-tagged fish (~420 per release) will be collected from the same sorting line as the PIT-tagged fish and moved to a holding tank where they will be 'rested' overnight and tagged the following day. Sample sizes will be chosen to evaluate a minimum 5% difference in survival for AT tagged fish versus PIT-only tagged fish (α=0.05) from release at Lower Granite Dam (Rkm 522) to detection at John Day Dam (Rkm 347).

Fish handling methods such as water-to-water transfers and pre-anesthesia will minimize damage and stress to fish during the sorting and tagging process (Matthews et al. 1997). Only non-PIT-tagged animals > 94 mm fork length clearly identifiable as hatchery-reared yearling Chinook salmon will be used as test animals in this study.

The PIT-tagged-only fish will be tagged by hand (Prentice et al. 1990a, b) using individual syringes with a 12-gauge hypodermic needle. The acoustic-/PIT-tagged fish will be implanted with transmitters using methods similar to Anglea et al. (2004). Fish will initially be sedated with 50-80 mg/l MS-222 (depending on ambient conditions and fish sensitivity) then transferred to a custom surgery table. During surgery, anesthesia will be maintained by providing water with 40-50 mg/l MS-222 through rubber tubing from a gravity fed bucket. With the fish facing ventral side up, a 5-7 mm incision will be made 2-5 mm from and parallel to the mid-ventral line anterior of the pelvic girdle. The acoustic tag will then be implanted, while weight, fork length, and tag code are recorded. A PIT tag will also be placed inside the body cavity at this time. The incision will be closed with 2, 5-0 Monocryl sutures. Post surgery, fish will be placed into a recovery bucket with fresh-oxygenated river water and monitored to insure they recover equilibrium.

Following recovery from anesthesia, all tagged fish will be returned to a filter-frame holding tank at the Lower Granite Dam juvenile fish facility. The acoustic-/PIT-tagged fish and the PIT-tagged-only fish will be held together in the filter-frame tank until the following day and released at 0800 hours. All holding tanks will be supplied with flow-through river water during tagging and holding. Fish will then be released through a PVC pipe attached to the top of the bypass pipe into the tailrace of Lower Granite Dam. A subset of the acoustic- and PIT-tagged fish, along with PIT-tagged-only fish, control fish (anesthetized and handled but not tagged), and 'sham-tagged' fish (anesthetized, handled , surgical incision made and closed, but no tag placement) will be held back from each release to evaluate post-tagging mortality, tag retention, and tag life.

***Task 1B.*--Estimate survival and associated detection probabilities of acoustic-tagged yearling Chinook salmon relative to PIT-tagged fish migrating through the Snake and Columbia Rivers.** We propose to use an array of autonomous hydrophone receivers in the Snake and Columbia Rivers to substantially increase the numbers of detected acoustic-tagged fish below primary detection sites to estimate lambda (detection probability downstream of a detection site for PIT-tagged fish). Increasing the number of fish detected below the primary detection site increases the precision of detection-probability and survival estimates to the primary detection site and allows the use of smaller sample sizes to achieve a given level of precision. For this study, we will deploy autonomous hydrophone receiver arrays in the Lower Monumental Dam forebay at the BRZ line, near Windust Park below Lower Monumental Dam and near Irrigon, OR below McNary Dam. We will also use detections from autonomous hydrophone receiver arrays downstream of Bonneville Dam (study code EST-02-01) in our analysis. If other receiver arrays are in place in the Snake River system for other studies, data from these arrays will also be used.

The estimated 80% detection power for treatment fish in 2008 is presented in Table 1. Sample sizes were determined based on detections of yearling Chinook salmon released and detected in the 2007 Tag Comparison Study. Sample size requirements are greatest for detecting significant differences in survival based on estimates from the SR Model. Sample sizes based on the power to detect differences in SR Model survival estimates give even greater power to detect differences in recovery percentages, detection probabilities, and travel times. Sample sizes were estimated to allow us to determine a 5% difference in treatments at α=0.05).

Table 1. Parameters used to develop sample size and associated detectable differences of survival between PIT-tagged and acoustic- tagged hatchery yearling Chinook salmon for 80% detection power. Fish would be tagged at Lower Granite Dam and released through the bypass pipe. Proposed sample sizes are a total of 4200 acoustic-tagged yearling Chinook salmon, and approximately 45000 PIT-tagged yearling Chinook salmon (Obtained from concurrently run NOAA Fisheries Latent Mortality study).

		Yearling Chinook
		John Day Dam
S (Estimated PIT tagged survival from release to detection site)		0.724
p (PIT-tag detection probability at detection site)		0.38
λ (Detection probability downstream of detection site for PIT tagged fish)		0.25
λ (Detection probability downstream of detection site for acoustic tagged fish)		0.9
Estimated detectable difference in survival (Release to detection site, α = 0.05, β = 0.20)		0.05

In 2008, we propose to expand our geographic scope of comparison by approximately 125 Rkm as compared to 2007. Preliminary results from the spring field and laboratory studies conducted in 2007 justify expanding our geographic scope of comparison by approximately 125 Rkm in order to validate a potential 'tag effect' that does not manifest itself until fish have progressed beyond the detection site at McNary Dam (Rkm 470). Although the 2007 data suggest that there is a moderate difference in survival between treatment groups downriver from the detection site at McNary Dam, our sample sizes for 2007 were not constructed to validate moderate differences between treatment groups beyond this detection site. In 2008, the proposed sample sizes (4200 acoustic-tagged yearling Chinook salmon and 45000 PIT-tagged yearling

Chinook salmon will provide 80% power to detect a difference of 5% or more tag-related mortality rate under moderate flows from release to John Day Dam (rkm 347). We will use the significance level of $\alpha = 0.05$ in our tests to detect differences among groups. The rejection rate is justified in light of observed tag effects in previous studies. Our ability to detect differences will be highly dependent on spill and river flow patterns over the course of the study, and detection probabilities for Bonneville Dam will be influenced by detection capability at the Bonneville Dam Second Powerhouse corner collector. With these sample sizes, we will almost certainly be able to detect biologically important differences in survival estimates and travel times.

Detection and survival probabilities will be estimated from PIT-tag-detection histories from individual fish at the juvenile collection/detection facilities at Little Goose, Lower Monumental, McNary, John Day, and Bonneville Dams (Smith et al. 1994). To evaluate mixing of the release groups at downstream dams, we will use contingency table tests for differences between distributions of daily detections at each detection site. If groups are sufficiently mixed, differences in survival will be evaluated using ANOVA on recovery percentages for different release groups. Otherwise, appropriate tests will be based on survival estimates obtained using the SR survival model introduced by Cormack (1964), Jolly (1965), and Seber (1965).

Objective 2

Compare travel times of acoustic/PIT-tagged yearling Chinook salmon to PIT-tagged fish migrating through the Snake and Columbia Rivers. Travel times will be calculated from time of release to time of first detection at each downstream dam (Little Goose, Lower Monumental, McNary, John Day, and Bonneville Dams). Differences in travel times will be evaluated using ANOVA, likelihood ratio tests, and/or nonparametric methods as appropriate.

Objective 3

Compare predation rates of acoustic/PIT-tagged yearling Chinook salmon relative to PIT-tagged fish migrating through the Snake and Columbia Rivers. Ryan et al. (2003) identified substantial rates of avian predation on PIT-tagged juvenile salmonids migrating past Caspian tern *Sterna caspia* and double-crested cormorant *Phalacrocor axrtius* colonies in the Columbia River estuary. Though predation was lowest for Chinook salmon, the effect could be more pronounced for fish tagged with other types of tags. In addition, there has been an ongoing effort to control Northern pikeminnow populations (a known juvenile salmonids predator) through a bounty program administered by the Pacific States Marine Fisheries Commission and funded by Bonneville Power Administration. We will continue to explore this project to see if there are sufficient PIT tags collected from these predators in 2008 to compare predation rates on acoustic/PIT-tagged fish to PIT-tagged only fish. Differences in predation will be evaluated using appropriate statistical tests.

Objective 4

If acoustic tag effects are identified in the field for yearling Chinook salmon, determine the time frame over which the effects are manifested. If there is an effect due to the acoustic tag, it may manifest itself very quickly or over a longer period. To determine the time it takes for a tag effect to take place, we will use PIT-tag detection and acoustic-tag detection to determine this time frame. We will not only use detection at hydroelectric facilities, but detection on bird colonies and on the acoustic arrays ranging from the mouth of the Columbia River to the Snake River.

Objective 5

In a laboratory setting, compare growth, mortality, susceptibility to disease, and tag retention, for run-of-river hatchery yearling Chinook salmon tagged with only a PIT tag to fish tagged with both an acoustic and a PIT tag. These fish will be held in freshwater for 14 d to mimic their migration time to the ocean and then their respective tanks will be infused with saltwater so that they can be held in a more natural ocean-type environment for the duration of the study (180 days).

The recent improvements in the attributes of acoustic tags may enable studies of survival of juvenile salmonids through the Columbia and Snake Rivers, in the estuary, and into the ocean, which would entail longer study periods than typical for this technology. Further, if a 'life cycle' tag is developed, it will be important to determine whether there are biological limitations that may impact studies that would employ this new technology. Prior to such studies, the effects of the tags on fish and assessments of tag loss will be required over longer periods than generally studied. In an effort to answer some of these questions, and to build on data collected from the Tag Comparison Laboratory studies conducted in 2007, we propose to conduct laboratory studies to investigate the effects of acoustic tags on the growth, mortality, susceptibility to disease, and tag retention for run-of- river hatchery yearling Chinook salmon relative to those implanted with PIT tags. We will utilize run-of-river fish tagged in the field at the same time that field study fish will be tagged, and using the same methods and techniques to accomplish this objective

Laboratory fish will be transported to the USACE Juvenile Monitoring Facility at Bonneville dam for holding. Upon arrival at the facility, they will be held in tanks with freshwater for 14 d at ambient river temperatures. After 14 d, the tanks will be infused with saltwater to mimic what these fish would have likely experienced if they had remained in-river. The tanks will be observed daily for mortalities and tag loss. At the end of 180 d, all fish will be assessed for tag loss, growth, mortality, level of BKD, and tissue response based on each treatment. All mortalities collected prior to the 180-d period will also be assessed for these parameters.

***Task 5. A*--Compare growth, mortality, disease susceptibility, and tag retention, for run-of-river spring Chinook salmon belonging to three treatment groups in a laboratory setting.** Four groups of run-of-river spring Chinook will be obtained and tagged at the juvenile bypass facility at Lower Granite Dam at the same time that field study fish are tagged and released. The four groups will be comprised of fish tagged with acoustic and PIT tags, fish tagged with a PIT tag only, fish anesthetized and handled but not tagged (control), and ‘sham-tagged’ fish (anesthetized, handled , surgical incision made and closed, but no tag placement. The four groups will be collected and tagged in proportion to our field tagging. After tagging, the fish will be transported via truck to the laboratory at Bonneville Dam. We will determine sample sizes based on detecting a 5% difference in survival between groups at α=0.05.

Objective 6

In a field setting, compare acoustic tag loss, tag expulsion, growth, and histological response of acoustic-/PIT-tagged run-of-river spring Chinook salmon relative to PIT tagged only subyearling Chinook over their freshwater migratory life.

There have been numerous studies looking at the effects of acoustic tags on juvenile Chinook salmon. These studies have looked at a variety of parameters ranging from physiological to behavioral effects. However, while these studies are a good starting point to evaluate the appropriate use of these tags they do not address what happens to the fish in the field where the tag is intended to be used to make decisions on how we should recover salmonid populations.

In 2008, we have the opportunity to evaluate some of the effects that acoustic tags may have on juvenile salmonids in the field compared to salmonids tagged with only a PIT tag. To evaluate these effects, we would utilize PIT-tag sort-by-code to recover 100 PIT tagged only and 100 acoustic-/PIT- tagged spring Chinook salmon from our sample groups originating at Lower Granite Dam. These fish would be diverted and collected throughout the season at McNary, and Bonneville Dams. Upon collection, a full necropsy would be performed on each fish to look for a suite of potential tag effects (Table 2). With a sample size of 100 fish we would expect that an observed 5% tag explosion rate would be significant at an alpha level of 0.05. Full necropsies will also be performed on approximately 10 fish per release group at Lower Granite Dam to supply us with baseline information on fish condition throughout the tagging season.

Table 2. The following are the some of the effects that we will evaluate for acoustic-/PIT-tagged compared to PIT-tagged only Chinook migrating from Lower Granite Dam to either McNary, Little Goose, or Bonneville Dams. We would expect that throughout the season we will encounter additional signs that we will need to evaluate.

Parameters	Potential Effects
Growth	Length and Weight
Tag Loss/Encapsulation	Are Acoustic Tags still present? If tags are present, are they encapsulated? There is potential for 'double-tagged' fish to expel their acoustic tag while retaining the PIT tag.
Feeding	Sample of Small intestine can be evaluated to determine if fish are actively feeding. The amount of body fat can also be compared between tagging groups to determine comparative feeding.
Disease	As compared between the two groups, relative Levels of BKD and other viruses (such as IPNV, IHN, VHS, & OMV), the presence of parasites, and the presence of bacterial pathogens can be evaluated to determine if 'doubl-tagged fish are more vulnerable to disease than their PIT-tagged counter-parts.
Tissue Damage	Damage to or reabsorption of the liver, kidney, spleen, etc. would be evaluated and compared between tagging groups.
Suture Condition/Wound Healing	Integrity of incision and sutures, presence of fungi on incision or sutures. Fungal infection on suture material and absorption of suture material

Objective 7

In a laboratory setting, investigate the degree to which tag burden versus the surgical process itself contributes to an overall 'tag effect' in run-of-the river subyearling fall Chinook salmon 85-105mm F.L. Examine the degree to which the current tag must be reduced in size before one observes 'no effect' in lab fish from the acoustic implant. Investigate the efficacy of incorporating various antiseptic agents into the current surgical tagging protocol to prevent infection at the incision site post-tagging. Preliminary results from both the field and laboratory components of the 2007 Tag Comparison study, indicate that the current model of the JSATS transmitter is not yet sufficiently compact for implantation in juvenile fall Chinook of the size class 85-105mm without producing significant adverse effects. Furthermore, observations from the 2007 field and laboratory studies suggest that the procedure for surgical implantation itself may contribute to a 'tag effect' in these fish. Subyearling fall Chinook salmon generally experience significantly warmer water temperatures and lower outflow conditions during summer out-migration than spring Chinook out-migrants. Higher river temperatures and lower flow can contribute to a higher potential for infection at the surgical site as well as enhanced holding stress pre- and post-tagging. Through a series of laboratory experiments using run-of-the-river fish, we propose to investigate the degree to which tag burden versus the surgical process itself contributes to the overall 'tag effect' that we witnessed in 2007. In addition, we propose to examine the degree to which the current tag must be reduced in size before one observes 'no effect' in fish from the acoustic implant and will investigate the efficacy of incorporating various antiseptic agents into the current surgical tagging protocol to prevent infection at the incision site post-tagging.

Task 7a. Investigate the degree to which tag burden versus the surgical process itself contributes to an overall 'tag effect' in run-of-the river subyearling fall Chinook salmon. Four groups of run-of-river subyearling fall Chinook salmon will be obtained and tagged at the juvenile bypass facility at Lower Granite Dam on approximately 10 separate occasions throughout the summer out-migration period. The four groups will be comprised of fish tagged with acoustic and PIT tags, fish tagged with a PIT tag only, fish anesthetized and handled but not tagged (control), and 'sham-tagged' fish (anesthetized, handled , surgical incision made and closed, but no tag placement. After tagging, laboratory fish will be transported to the USACE Juvenile Monitoring Facility at Bonneville dam for holding. Upon arrival at the facility, they will be held in tanks with freshwater for 14 d at ambient river temperatures. After 14 d, the tanks will be infused with saltwater to mimic what these fish would have likely experienced if they had remained in-river. The tanks will be observed daily for mortalities and tag loss. At the end of 180 d, all fish will be assessed for tag loss, growth, mortality, level of BKD, and tissue response based on each treatment. All mortalities collected prior to the 180-d period will also be assessed for these parameters.

Task 7b. Examine the degree to which the current tag must be reduced in size before one observes 'no effect' in lab fish from the acoustic implant. Three groups of run-of-river subyearling fall Chinook salmon will be obtained and tagged at the juvenile bypass facility at Lower Granite Dam on approximately 10 separate occasions throughout the summer out-migration period. A series of 'dummy' transmitters ranging from PIT-tag size to the size of the current model JSATS transmitter will be implanted into study fish. After tagging, laboratory fish will be transported to the USACE Juvenile Monitoring Facility at Bonneville dam for holding. Upon arrival at the facility, they will be held in tanks with freshwater for 14 d at ambient river temperatures. After 14 d, the tanks will be infused with saltwater to mimic what these fish would have likely experienced if they had remained in-river. The tanks will be observed daily for mortalities and tag loss. At the end of 180 d, all fish will be assessed for tag loss, growth, mortality, level of BKD, and tissue response based on each treatment. All mortalities collected prior to the 180-d period will also be assessed for these parameters. 'Tag effects' will be evaluated against control fish collected in task 7a. We will determine sample sizes based on detecting a 5% difference in survival between groups at α=0.05 .

Task7c. Investigate the efficacy of incorporating various antiseptic agents into the current surgical tagging protocol to prevent infection at the incision site post-tagging. Five groups of run-of-river subyearling fall Chinook salmon will be obtained and tagged at the juvenile bypass facility at Lower Granite Dam on approximately 10 separate occasions throughout the summer out-migration period. Fish will be surgically implanted with 'dummy' acoustic transmitters and a PIT tag and then subjected to 1 of 4 antiseptic treatments before or during recovery from anesthesia. After tagging, treatment and control fish will be transported to the USACE Juvenile Monitoring Facility at Bonneville dam for holding. Upon arrival at the facility, they will be held in tanks with freshwater for 14 d at ambient river temperatures. After 14 d, the tanks will be infused with saltwater to mimic what these fish would have likely experienced if they had remained in-river. The tanks will be observed daily for mortalities and tag loss. Treatment fish will be evaluated for wound healing intermittently throughout a 180 day holding period. Groups will also be monitored for tag loss and survival throughout the study and growth and level of BKD will be evaluated at the end of a 180 day holding period. We will determine sample sizes based on detecting a 5% difference in survival between groups at α=0.05

STATISTICAL ANALYSES

Field Evaluations

Differences among the acoustic- and PIT- tag treatments in travel time and detection probabilities will be evaluated using ANOVA, likelihood ratio tests, and/or nonparametric methods as appropriate.

The percentage of tagged smolts from each group detected at least once at Little Goose, Lower Monumental, Ice Harbor, McNary, John Day, Bonneville Dams, and from the Jones Beach pair trawl will be calculated. Differences in detection percentages among groups and recoveries from bird-island interrogation sites will also be evaluated using ANOVA. Chi-square, goodness-of-fit tests will be used to test equal probability of detection (mixing) over time. Adult return rates of fish from this study are expected to be too small for formal analysis.

Laboratory Evaluations

Response measures will be evaluated separately for each comparison group. Statistical analysis for the dichotomous response of survival will use a logistic regression model taking the treatment groups as a multi-level factor variable with the control or PIT-tag groups as the reference level. This model will be assessed for ‘goodness-of-fit’ and could possibly include additional independent variables as deemed necessary. Similarly, trend analysis will be performed on survival across studies of the different groups by extending the logistic model. Tag retention analyses will follow a similar approach with designation of the reference treatment level to be determined.

Growth will be assessed by considering changes in length and/or weight as measured on each individual fish from the beginning to end the end of each study. ANOVA modeling will be applied where appropriate for the response distribution on changes in size for each fish. As above, the treatment groups as a 4-level factor variable with the control group as the reference level, and will include assessment of model fit as well as possible inclusion of additional independent variables if deemed necessary. Trend analysis can also be performed by pooling across treatment groups.

Disease susceptibility will be assessed based on results of gross necropsy exam and direct comparison between groups of BKD antigen response as assayed by ELISA tests.

FISH REQUIREMENTS

FY 2008 Field Evaluations

Appoximately 4200 hatchery spring Chinook salmon will be utilized during the spring field portion of this study. These fish will be paired with approximately 45000 hatchery spring Chinook salmon concurrently tagged by NOAA Fisheries Latent Mortality study.

FY 2008 Laboratory Evaluations

To be determined and based on results from tag comparison study 2007, and objective of detecting a 5% difference in survival between groups at α=0.05.
We estimate that the spring laboratory portion of this study will utilize 1600 yearling hatchery spring Chinook (400 pit-only fish, 400 acoustic-pit fish, 400 control fish, 400 'sham' tagged fish).
We estimate that the summer laboratory portion of this study will utilize 4800 subyearling hatchery fall Chinook (400 pit-only fish, 3600 acoustic-pit fish, 400 control fish, 400 'sham' tagged fish).

FYs 2008 and Beyond

Large numbers of fish may be required during future implementation. The numbers of fish required for each target group will be determined dependent on outcomes obtained in 2007/2008 and future years, variability about these estimates, detection probabilities, and requirements of the SR model.

SCHEDULES

Projected timeframe completion of all tagging during 2008 is late-April through July. Laboratory studies should be completed by January 2009, with necropsies and histological examinations completed by March 2009. Preliminary analysis of evaluations in the field including survival, timing, detection probability estimates, and bird predation rates should be available by mid-November.

Outyear work (2009 and beyond) will depend on the results of this study. It is important to consider this work in the context of environmental variability, since river flows, spill scenarios, and detection capability at various sites may vary annually. Therefore, we propose to implement the study over a number of years.

LIMITATIONS AND EXPECTED DIFFICULTIES

The degree of success of this project will be contingent upon five primary factors: 1) whether adequate numbers of fish can be collected for tagging at Lower Granite Dam during the time frame indicated, 2) whether the pre-determined sample sizes will provide the necessary precision for the comparisons of performance, 3) whether detectors and bypass systems at downstream dams will be operational during the duration of the study, 4) whether spill/transport scenarios are in effect during the duration of the study, and 5) whether the assumption of random mixing of the treatment releases will be satisfied.

PROJECT IMPACTS

Collection, tagging, and fish-holding operations at Lower Granite Dam during April through July will be coordinated with the project office and Smolt Monitoring Program personnel.

BIOLOGICAL EFFECTS

These studies will be carried out using an ESA Section 10 Permit issued to the National Marine Fisheries and WDFW permits in 2008.

TECHNOLOGY TRANSFER

Information acquired during the proposed work will be transferred to the fisheries community by presentations at meetings and workshops, by personal contact, by annual and final reports to the U.S. Army Corps of Engineers, and through scientific publications.

KEY PERSONNEL AND DUTIES

A. Michelle Wargo Rub	NOAA Fisheries Principal Investigator
Lynn McComas	NOAA Fisheries Principal Investigator
Eric Hockersmith	NOAA Fisheries Principal Investigator
Doug Marsh	NOAA Fisheries Co investigator
Rich Brown	PNNL Principal Investigator
Geoff McMichael	PNNL Principal Investigator
Steven G. Smith	NOAA Fisheries Statistician
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FY08 RESEARCH PROPOSAL

SUBMITTED TO THE U.S. ARMY CORPS OF ENGINEERS UNDER THE ANADROMOUNS FISH EVALUATION PROGRAM

I. BASIC INFORMATION

I.A. Title of Project	Pressure Investigations to Support Biological Index Testing Synthesis: Objectives 1-4 - Analysis to Derive Pressure Criteria for Turbine Design in Support of FCRPS Turbine Rehab and Replacement
I.B. Project Leaders	Thomas J Carlson Pacific Northwest National Laboratory PO Box 999 Richland, WA 99352 Tel: 503/417-7562 or 503/704-8897 Email: Thomas.Carlson@pnl.gov
Study Code:	TSP-05-1 Objectives 1 through 4
Fish Program Measure:	CRFMP – Turbine Survival Program
UPA Measure:	Hydrosystem Substrategy 1.1; Key Alternatives Under Development – Turbine survival Improvements for The Dalles and John Day dams; Powerhouse Modernization for McNary Dam; Project Configuration RM&E – Turbine Studies; Hydrosystem Studies on Turbine Survival
Management Purpose:	Investigate components of turbine mortality to identify structural and/or design modifications in turbine design that can be integrated into the turbine rehabilitation process to improve juvenile salmonid survival. Identify turbine operations that optimize the survival of turbine passed fish.
I.C. Anticipated Duration:	October 2007 – September 2009
I.D. Date of Submission	Preliminary**:** August 2007; Final: October 2007

II. Project Summary

In FY08 estimation of the probability of mortal injury for depth acclimated yearling Chinook salmon as a function of the nadir in pressure during simulated turbine passage, total dissolved gas concentration, and rate of change in pressure during simulated turbine passage began in FY07 will be completed. Also to be completed in FY08 is testing of the use of hatchery yearling chinook during out of migration season periods as surrogates for run-of-the-river yearling chinook. Tests of the probability of mortal injury and surrogacy were completed for subyearling Chinook salmon during FY07.

The same treatments, experimental designs, and experimental methods developed in FY06-07 to test the assumption of surrogacy of hatchery fish for river run fish will be used to evaluate the effect of various sizes and weights of surgically implanted and neutrally buoyant externally attached acoustic transmitters on the probability of mortal injury for hatchery subyearling and yearling size hatchery Chinook salmon. These tests will include the use of sham transmitters to determine the volume and weight of transmitter that can be implanted in juvenile chinook without significantly increasing the probability of mortal injury beyond that experienced by juvenile chinook not bearing acoustic transmitters. These tests will be extended to include evaluation of external attachment of production and sham acoustic (and RT if desired) transmitters.

Evaluation, including necropsy and histological examinations, of the condition of tagged fish that have passed through turbines and recovered by sort-by-code, initiated in FY07 will be continued in FY08. It was expected at initiation of this study element that more than one year would be required to acquire a large enough sample size to draw conclusions. The effort required to accomplish this study element is minimal.

II.A. Goal

The goals for this project are:

1. Complete acquisition of data needed to assess the response of juvenile Chinook salmon to exposure to low pressure during turbine passage,
2. Initiate identification of acoustic telemetry methods that can be used to obtain unbiased estimates of turbine passage mortality for juvenile salmonids,
3. Continue evaluation of the assumption of depth acclimation by migrating juvenile salmonids.

II.B. Objectives

1. Evaluate the response of depth acclimated juvenile salmonids to simulated turbine passage pressure cycling representative of turbine passage at Bonneville, John Day, and Ice Harbor dams (close out work started in 2006-07).

2. Evaluate the response of depth acclimated juvenile salmonids tagged with various types and sizes of transmitters to simulated turbine passage pressure exposure.
    a. Identify internally implanted tag/fish weight ratio thresholds for yearling
    b. In collaboration with the CE and others finalize a study design to achieve this objective.
    c. Identify internally implanted tag/fish weight ratio thresholds for sub yearling
3. Evaluate the response of depth acclimated juvenile salmonids tagged with external, neutrally buoyant transmitters to simulated turbine passage pressure exposure.
    a. Incorporate external attachment as a treatment factor in the study design developed for objective 2.
4. Collect radio/acoustic-PIT tagged juvenile fish released for project survival studies using sort-by-code at immediate downstream projects and evaluate swim bladder and internal organ condition to estimate the effect of in-river turbine passage.

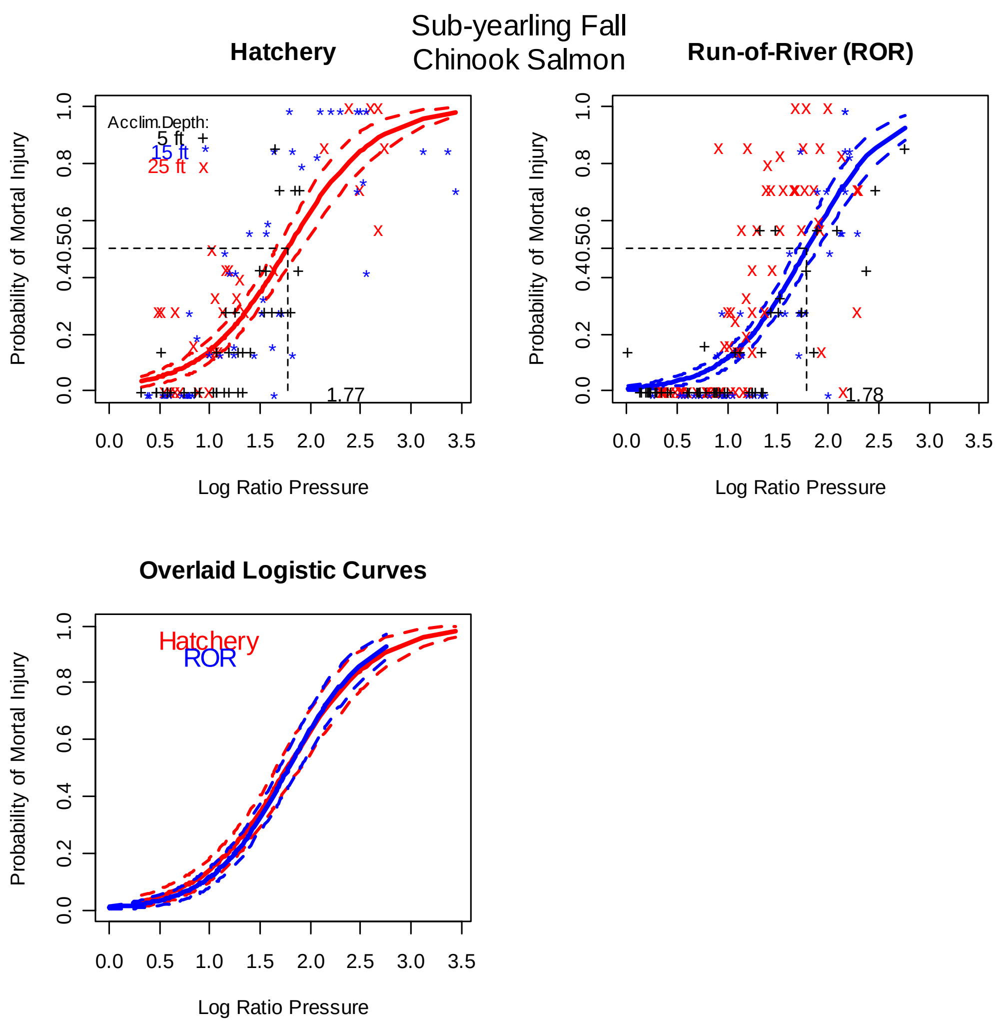
II.C. Methodology

Samples of test fish are held for acclimation in pressure chambers for 18 to 24 hours prior to exposure to changes in pressure that simulate passage through a hydroturbine. During the holding period the test fish are held at a predetermined pressure in water of selected dissolved gas level and permitted access to air so that they can achieve neutral buoyancy and their tissues and blood gas can equilibrate with the surrounding water. Following the holding period the test fish are exposed to a simulated turbine passage pressure time history with selected nadir and rate of change in pressure. Control fish receive the same handling and acclimation treatment as test fish but do not experience simulated turbine passage.

Test fish are observed using video cameras over the acclimation period and during exposure to simulated turbine passage. High speed video recordings are used to make detailed observations of fish response during the most rapid changes in pressure immediately preceding and following the turbine runner passage portion of the simulation. At the end of the simulated turbine passage the behavior and aspects of condition are noted before test and control fish are removed from the pressure chambers. Upon removal from the pressure chambers all fish are necropsied and subsampled for histological examination. Observations of fish condition are made noting the occurrence and severity of approximately 45 types of injury.

Analysis of data from previous studies have identified and defined the metric “mortal injury” which includes fish that immediately die following simulated turbine passage exposure plus those with injuries that have been identified as showing high risk, almost certainty, for delayed mortality. The result is a binary outcome for each test fish that can be used in logistic regression models to recover a function describing the probability of immediate plus delayed mortality as a function of pressure nadir and other test variables. The analysis also permit prorogation of error and estimation of the error associated for the mortality function.

In addition to mortal injury, another metric, log ratio pressure, LRP, has been identified and evaluated to permit more concise presentation of study results. LRP is the natural logarithm of the ratio of acclimation and nadir pressures. Using mortal injury and LRP as dependent and independent variables the response of test fish to rapid decompression can be more succinctly expressed for each age and TDG level treatment combination in the form shown in the figure below.



Data to complete evaluation of yearling hatchery chinook to pressure exposure, to test the assumption of surrogacy of hatchery fish for river-run fish, and extensions to test the effect of the presence of transmitters of various volumes and weights will be acquired for a range of pressure exposure nadirs between 1 and approximately 12 psi. Samples of 21 fish will be acclimated at three pressures equivalent to submergence at 5, 15, and 25 ft and exposed to simulated turbine passage with nadirs 4 biologically meaningful increments between 0 and approximately 12 psi. The biologically meaningful nadir values are obtained by a sequential doubling of pressure beginning with 1.5 psi and progressing to 3.0, 6.0, and 12.0 psi.

The data acquired by executing the 3 (acclimation pressure) by 4 (nadir pressure) experimental matrix constitute the first phase of assessment. Data acquired during this phase are processed and analyzed. In a second phase of data acquisition, additional samples are added where necessary to obtain a more uniform error over the range of nadir values. The end product is a maximum likelihood model that provides a continuous function describing the probability of mortal injury as a function of pressure exposure nadir for each acclimation pressure. It is expected that all acclimation and exposures will be conducted at a single total dissolved gas level of 115%.

The initial phase of investigation for optimization of micro transmitter volume and mass will be examination of response to each factor independently. In addition, tests will be conducted with the model of PIT tags currently in use for survival studies within the hydropower system. The results of fish response to PIT tags when exposed to rapid decompression will be compared to that of fish that have not been implanted with any device. The range of volume and mass investigated will be the volume and mass of the current production JSATS acoustic micro-transmitter. The results of an investigation currently underway to estimate alternatives for further reduction in the volume and mass of JSATS transmitters using current technology will provide intermediate volume and mass values. Finally, consideration of technological advancements that could result in further reductions in transmitter size in combination with transmitter operation alternatives will provide guidelines for the lower end of the volume and mass test range. Those volume and mass values that result in acceptable biological performance by juvenile chinook will be examined to evaluate fish response to both combined. It is possible that all evaluation can be performed at one LRP value for both subyearling and yearling chinook. However, acceptance of this as an adequate test protocol will be evaluated early in the study. In addition to mortal injury the ability of test fish to achieve neutral buoyancy under the same acclimation conditions used in the baseline study will be determined.

II. D Relevance to the Biological Opinion

Investigate components of turbine mortality to identify structural and/or design modifications in turbine design that can be integrated into the turbine rehabilitation process to improve juvenile salmonid survival. Identify turbine operations that optimize the survival of turbine passed fish.

III. Project Description

III.A. Background

Estimates of turbine passage survival for juvenile salmonids passing Corps operated dams on the Snake and Columbia Rivers can vary widely. For example, turbine passage survival for yearling Chinook salmon at Bonneville Dam Powerhouse II has been estimated at approximately 95% while averaging only 84% at John Day Dam. The mechanism for such differences in survival has been poorly described to date. Much of the mortality associated with turbine passage at Snake and Columbia River projects has been attributed to mechanical injury and/or disorientation and subsequent predation in the tailrace immediately following turbine passage, though data confirming these mechanisms are unclear.

Recently, it has been suggested that a component of fish mortality associated with turbine passage may be attributed to the pressure cycle that depth and dissolved gas acclimated juvenile salmonids experience during turbine passage. In 2004, pilot laboratory tests were conducted by subjecting juvenile Chinook salmon to a pressure cycle event similar to what would be experienced during turbine passage. Results from these tests indicated juvenile salmonids that were allowed to acclimate or achieve neutral buoyancy at depths of 15 and 30 feet exhibited a higher incidence of swim bladder rupture, internal injury, and mortality than individuals that were surface acclimated or neutrally buoyant at the surface. The internal injuries observed were presumed to be a result of the instantaneous drop in pressure to near vapor pressure, encountered just downstream of the turbine runner, causing the swim bladder to expand, and in some cases, rupture. Tests in 2004 were conducted with minimal sample sizes and were not conclusive. In 2005, more rigorous testing was conducted with run of river, yearling and subyearling Chinook salmon. Also, testing in 2005 was conducted with both untagged fish and fish tagged with a radio-transmitter, since tagged fish could be more susceptible to the effects of extreme pressure decreases because of the need to compensate for the extra mass of the tag to maintain neutral buoyancy (increasing swim bladder volume). Results from testing in 2005 confirmed results of the 2004 pilot study; that significant injury and mortality occur at the pressures tested and tend to increase with acclimation depth. Many of the mortalities observed in 2005 were caused by ruptured arteries due to expansion of gas in the blood as it comes out of solution during pressure drops. Pressure profile data describing the in-turbine pressure environment is now available for several projects (Bonneville PHI and PHII, John Day, McNary, Ice Harbor, and Wanapum). In-turbine pressure profiles can vary from project to project and may correlate with differences in turbine survival of juvenile salmonids observed across projects. Additional investigations exposing run of the river juvenile salmonids to simulated turbine passage pressure profiles representative of field pressure profile data are underway in 2006 to further evaluate the effects of the simulated pressure cycle associated with turbine passage on juvenile salmonids.

It is becoming increasing clear that exposure to low pressure during turbine passage is a probable significant source of injury and mortality for juvenile salmonids passing through FCRPS hydroturbines. Because of their age and mechanical condition, elements of most FCRPS turbines will be replaced during the next 10 to 20 years. This "rehabilitation" of turbines offers an opportunity to improve their power generating efficiency thereby increasing the electrical power produced from existing civil structures. This process is also an opportunity to change the design of turbine elements to reduce the risk of injury and mortality to turbine passed fish.

While the turbine rehabilitation process takes place existing turbines will continue to be operated. There is evidence that the risk of injury and mortality to turbine passed fish may be less for some operations than others. The same is true for rehabilitated turbines.

Test of the response of fish bearing telemetry devices to rapid decompression implies that previous measures of the survival of fish passing through turbines estimated using telemetry may be biased. Long term evaluation of the biological performance of turbines requires the use of techniques with known or no bias. Preference is for techniques that do not bias survival estimates. An objective of the Turbine Survival Program is investigation of the volume and mass of telemetry devices that do not bias survival estimates of test fish passing through turbines.

Test of the response of juvenile chinook to rapid decompression conducted to date have shown that acclimation depth (pressure) is a significant treatment factor. In spite of decades of observations of the depth range over which juvenile chinook and other juvenile salmonids migrate while moving downstream in the Columbia River, no information exists about the state of buoyancy of fish observed at deeper depths. Because of its significance in juvenile salmonid response to rapid decompression, the buoyancy state of juvenile migrants will continue to be investigated using both direct and indirect techniques as opportunities to do so become available.

III.A.1. Problem Description

Despite considerable efforts to provide bypass alternatives to turbine passage, a portion of downstream migrating juvenile salmonids will continue to pass through turbines. Rehabilitation of turbines is an ongoing process that includes consideration of design alternatives to increase power production and improve conditions for fish passage. The design process requires specifications for physical conditions in the water path for operating turbines that will be safer for fish. Specifications for pressure that have been experimentally derived and verified to provide safer conditions for juvenile salmonids do not exist. The same requirements exist for identification of safer operating conditions for existing turbine units. A goal of this project is to provide elements of these specifications.

Evaluation of the impact of turbine passage on juvenile salmonids is currently hampered by the lack of methods that can be applied to river-run fish and provide information about the direct and indirect mortality of turbine passed fish. Telemetry is a promising technology but only if devices and experimental methods can be identified that can provide data that are not biased by the presence of telemetry devices in or on the body of test fish. A goal of this project is to identify the characteristics of telemetry devices and experimental methods that can provide data for unbiased estimates of turbine passage survival.

Experiments conducted to date clearly show that the physiological state of juvenile salmonids at the time of exposure to low pressure during turbine passage is a significant factor influencing the probability of mortal injury. Of particular importance are physiological factors associated with the buoyancy state of fish permitted to adjust their buoyancy while being held at depth equivalent absolute pressures. While juvenile salmonids are observed to occur during outmigration at depths to 40 ft and greater, no information exists about their state of buoyancy. A goal of this project is to acquire data that can be used to directly or indirectly infer the state of buoyancy of migrating juvenile salmonids.

III.A.3. Relationship of Proposed Research to Other Ongoing or Proposed Research

The research proposed here is in support of ongoing efforts within the Turbine Survival Program to provide design guidance for rehabilitation of FCRPS turbines and for implementation of Biological Index Testing to identify turbine operating conditions that will optimize turbine water path conditions for safer fish passage.

III.B. Objectives

See section II.B.

III.C. Methodology

See section II.C. Additional experimental design detail for assessment of the effect of transmitter volume and weight will be added upon completion of analysis of data acquired for river-run yearling and subyearling Chinook to test the assumption of surrogacy of hatchery fish for river-run fish.

III.D. Facilities and Equipment

The facilities of the wet laboratory and hatchery at PNNL will be used to grow out and hold test fish. Water conditioning and pressure testing equipment are contained in trailers built during FY06 for the CE by subcontractors under the direction of PNNL. All experimental facilities required for the studies proposed here are available and in working order. No major equipment procurements are envisioned however, it will be necessary to continue to maintain and perhaps upgrade and/or modify the existing facilities while they are in use or to satisfy particular test exposure requirements.

III.E. Impacts

At this time no impacts to other projects have been identified.

III.F. Collaborative Arrangements and Sub-Contracts

Collaboration with NOAA Fisheries and other entities conducting fish survival studies using test fish jointly tagged with PIT and telemetry devices will be necessary to accomplish objective 4. The details of these collaborations have not been completed.

A sub-contract with John Skalski at the University of Washington will be needed to obtain assistance with details of experimental design and data analysis.

IV. List of Key Personnel and Project Duties

Thomas Carlson, PNNL. Principal Investigator responsible for project planning, plan execution, data quality oversight, data acquisition, analysis, and reporting.

Rich Brow, PNNL. Project team leader responsible jointly with principal investigator for elements of project planning, project staffing, plan execution, data acquisition, analysis, and reporting.

John Stephenson, PNNL. Experimental apparatus maintenance, test fish maintenance, experiment conduct, data acquisition

V. Technology Transfer.

Technology transfer will be through reporting of study results in regional forums and in written reports.

VI. List of References/Literature Cited

To be provided in final proposal.

FINAL FY08 RESEARCH PROPOSAL

SUBMITTED TO THE U.S. ARMY CORPS OF ENGINEERS UNDER THE ANADROMOUNS FISH EVALUATION PROGRAM

I. BASIC INFORMATION

I.A. Title of Project	Pressure Investigations to Support Biological Index Testing Synthesis: Objective 6 - Assessment of Population Level Risk of Mortal Injury Resulting from Pressure Exposure during Turbine Passage
I.B. Project Leaders	Thomas J Carlson Pacific Northwest National Laboratory PO Box 999 Richland, WA 99352 Tel: 503/417-7562 or 503/704-8897 Email: Thomas.Carlson@pnl.gov
Study Code:	TSP-05-1 Objective 6
Fish Program Measure:	CRFMP – Turbine Survival Program
UPA Measure:	Hydrosystem Substrategy 1.1; Key Alternatives Under Development – Turbine survival Improvements for The Dalles and John Day dams; Powerhouse Modernization for McNary Dam; Project Configuration RM&E – Turbine Studies; Hydrosystem Studies on Turbine Survival
Management Purpose:	Investigate components of turbine mortality to identify structural and/or design modifications in turbine design that can be integrated into the turbine rehabilitation process to improve juvenile salmonid survival. Identify turbine operations that optimize the survival of turbine passed fish.
I.C. Anticipated Duration:	October 2007 – September 2009
I.D. Date of Submission	Preliminary**:** August 2007; Final October 2007

II. Project Summary

Investigation of the potential benefits of changes in exposure to low pressure, shear, and contact with stationary and moving structures for the population of fish passing through turbines is needed to estimate the potential biological benefits of design alternatives for rehabilitation of FCRPS turbines. Similar assessment is needed for implementation of Biological Index Testing to identify operations alternatives for existing turbines that may provide safer passage for fish.

This project will use information already available and information to be developed in a multi-phase effort to assess, as a function of turbine design and operation, the risk of mortal injury for juvenile salmonids passing through turbines. The initial phase will focus on the risk of mortal injury from exposure to low pressure and investigate the basis for extension of the mortal injury metric beyond low pressure to include injuries from mechanical factors: collision, shear, and strike. In a subsequent phase the synthesis model developed for assessment of population level risk of mortal injury from low pressure exposure will be extended to include mechanical injury when adequate data to do so becomes available.

The project is synthesis in nature where the distributions of fish at turbine entry, passage through the turbine runner, and the environmental conditions within the turbine are mathematically related to estimate, in probabilistic terms, the population level exposure of fish to low pressure. The most likely biological outcome of this exposure, again in probabilistic terms, will be estimated using data for the probability of mortal injury for fish exposed to low pressure during turbine passage.

II.A. Goals

The goals for Phase I of this project are:

1. To develop and apply a method to estimate the probable biological benefits of design alternatives for turbines that reduce the probability of exposure to low pressure for fish passing through turbines, and
2. To develop and apply a method for estimation of the probable biological benefits of operation alternatives relative to low pressure exposure for turbines.

II.B. Objectives

Phase I project objectives are:

1. Develop a statistical synthesis model that will provide a bounded estimate of the theoretical population level probability of mortal injury for fish exposed to low pressure during turbine passage given input data sufficient to reliable determine exposure and biological response to low pressure.
2. Provide guidance to projects scoped to obtain fish distribution and pressure distribution data.
3. Investigate extension of the mortal injury metric to include injuries caused by mechanical factors.

4. Estimate the population level probability of mortal injury from pressure exposure for selected operations and turbine designs.
5. Derive pressure exposure turbine design criteria.
6. Derive field testable hypothesis for turbine operations that optimize the survival of fish passing through turbines exposed to low pressure.

II.C. Methodology

An analysis model will be constructed using well understood statistical modeling methods. Development of an analysis model will be a collaborative effort between PNNL, the University of Washington, and the CE Turbine Survival Program Technical Team. Analysis using the model will utilize data for: (1) the vertical distribution of fish at distributor entry, (2) the probable distribution of fish during runner passage (3) the probable distribution of exposure to low (nadir) pressure during runner passage, and (4) the probability of mortal injury for low (nadir) pressure exposure. The error associated with the various data will be propagated through the model and will be reflected in the population level mortal injury probability estimate for each operating condition and turbine design considered.

II. D Relevance to the Biological Opinion

Investigate components of turbine mortality to identify structural and/or design modifications in turbine design that can be integrated into the turbine rehabilitation process to improve juvenile salmonid survival. Identify turbine operations that optimize the survival of turbine passed fish.

III. Project Description

III.A. Background

Estimates of turbine passage survival for juvenile salmonids passing Corps operated dams on the Snake and Columbia Rivers can vary widely. For example, turbine passage survival for yearling Chinook salmon at Bonneville Dam Powerhouse II has been estimated at approximately 95% while averaging only 84% at John Day Dam. The mechanism for such differences in survival has been poorly described to date. Much of the mortality associated with turbine passage at Snake and Columbia River projects has been attributed to mechanical injury and/or disorientation and subsequent predation in the tailrace immediately following turbine passage, though data confirming these mechanisms are unclear.

Recently, it has been suggested that a component of fish mortality associated with turbine passage may be attributed to the pressure cycle that depth and dissolved gas acclimated juvenile salmonids experience during turbine passage. In 2004, pilot laboratory tests were conducted by subjecting juvenile Chinook salmon to a pressure cycle event similar to what would be experienced during turbine passage. Results from these tests indicated juvenile salmonids that were allowed to acclimate or achieve neutral buoyancy at depths of 15 and 30 feet exhibited a higher incidence of swim bladder rupture, internal injury, and mortality than individuals that were surface acclimated or neutrally buoyant at the surface. The internal injuries observed were presumed to be a result of the instantaneous drop in pressure to near vapor pressure, encountered just downstream of the turbine runner, causing the swim bladder to expand, and in some cases, rupture. Tests in 2004 were conducted with minimal sample sizes and were not conclusive. In 2005, more rigorous testing was conducted with run of river, yearling and subyearling Chinook salmon. Also, testing in 2005 was conducted with both untagged fish and fish tagged with a radio-transmitter, since tagged fish could be more susceptible to the effects of extreme pressure decreases because of the need to compensate for the extra mass of the tag to maintain neutral buoyancy (increasing swim bladder volume). Results from testing in 2005 confirmed results of the 2004 pilot study; that significant injury and mortality occur at the pressures tested and tend to increase with acclimation depth. Many of the mortalities observed in 2005 were caused by ruptured arteries due to expansion of gas in the blood as it comes out of solution during pressure drops. Pressure profile data describing the in-turbine pressure environment is now available for several projects (Bonneville PHI and PHII, John Day, McNary, Ice Harbor, and Wanapum). In-turbine pressure profiles can vary from project to project and may correlate with differences in turbine survival of juvenile salmonids observed across projects. Additional investigations exposing run of the river juvenile salmonids to simulated turbine passage pressure profiles representative of field pressure profile data are underway in 2006 to further evaluate the effects of the simulated pressure cycle associated with turbine passage on juvenile salmonids.

It is becoming increasing clear that exposure to low pressure during turbine passage is a probable source of injury and mortality for juvenile salmonids passing through FCRPS hydroturbines. Because of their age and mechanical condition, elements of most FCRPS turbines will be replaced during the next 10 to 20 years. This "rehabilitation" of turbines offers an opportunity to improve their power generating efficiency thereby increasing the electrical power produced from existing civil structures. This process is also an opportunity to change the design of turbine elements to reduce the risk of injury and mortality to turbine passed fish.

While the turbine rehabilitation process takes place, existing turbines will continue to be operated. There is evidence that the risk of injury and mortality to turbine passed fish may be less for some operations than others.

In pressure exposure studies completed to date a new metric, mortal injury, has been identified through analysis of the response of test fish to simulated turbine passage pressure exposure. Mortal injury includes those test fish that are dead at the conclusion of exposure to simulated turbine passage pressure plus those with injuries that are known (based on experimental data) to lead to death. Mortal injury does not include any assumptions about death by predation.

We propose in this project, in addition to the primary objective of synthesis of available fish distribution and pressure exposure biological response data to estimate population level response to low pressure exposure, to investigate extension of the definition of mortal injury to include mechanical factors. Laboratory data for exposure to shear is available from studies conducted by PNNL and it appears almost certain that the definition for mortal injury can be extended to include this mechanical injury mechanism. Data for injury from collision and strike may be available from other sources but investigation is required to identify potential sources and assess the quality and utility of any data.

In the CRFM pressure exposure studies conducted to date, each test fish is identified as being mortally injured or not which leads to a binary outcome for each fish as a function of the ratio of acclimation to nadir (exposure) pressures. The resulting data is analyzed using logistic regression models. An example of the results obtained to date for exposure to low pressure during simulated turbine passage is shown in the figure below for subyearling hatchery Chinook.

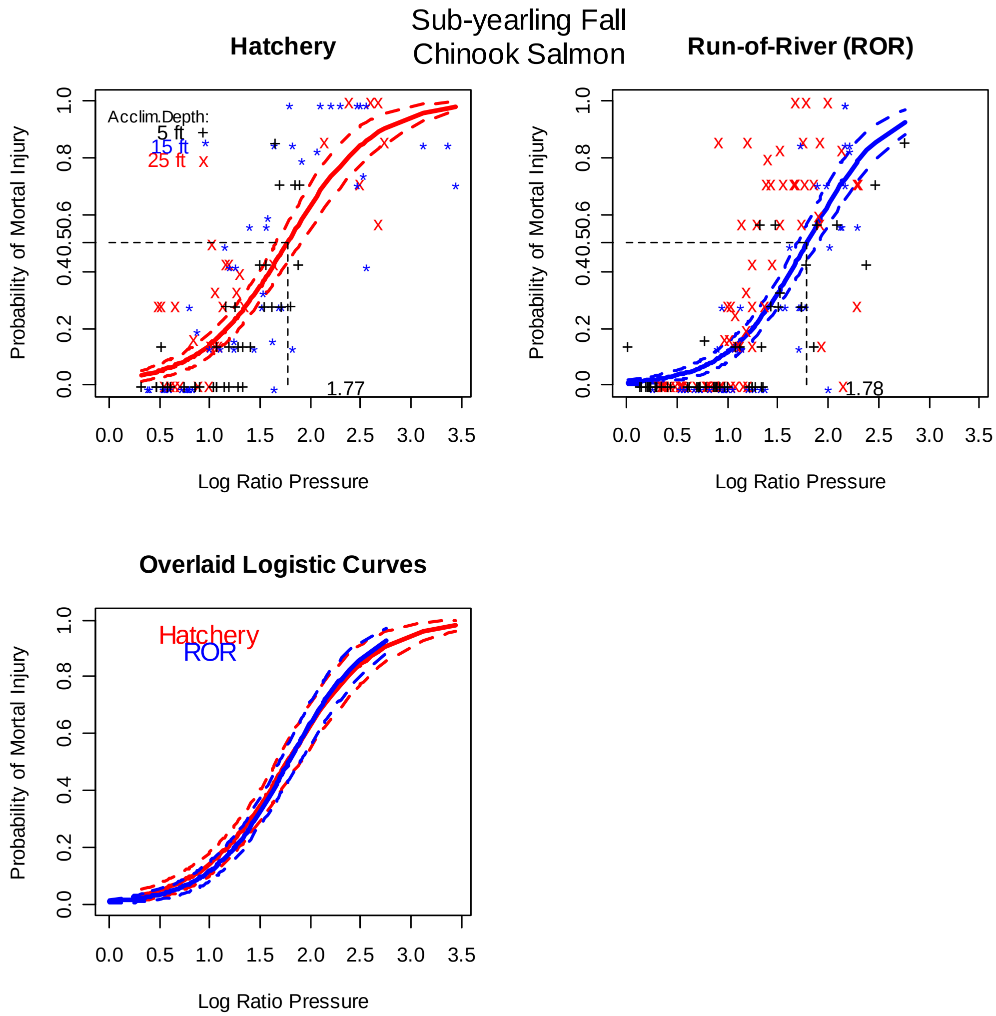


Figure 1: Preliminary data from 2007 study of the effect of simulated turbine passage on hatchery and river-run subyearling Chinook salmon. The figure shows the probability of mortal injury as a function of the natural log of the ratio of acclimation pressure to simulated turbine passage pressure time history nadir pressure.

Research similar to that conducted under the CRFMP has been conducted by PNNL with funding from the DOE Advanced Hydro Turbine System program. This research focused on injury from shear. An example of the results obtained is shown below in Figure 2. Review of this data indicates that it provides an adequate base for extension of the mortal injury metric to include exposure to shear. Similar data for collision and strike is not available from any PNNL studies. At this time it is not clear if suitable data may be available from other sources.

Fig. 6. Fitted probability of four types of injury as a function of acceleration, with 95% predictive confidence intervals (broken lines), as derived from binary logistic regression: (*a*) minor; (*b*) major; (*c*) eye; (*d*) operculum.

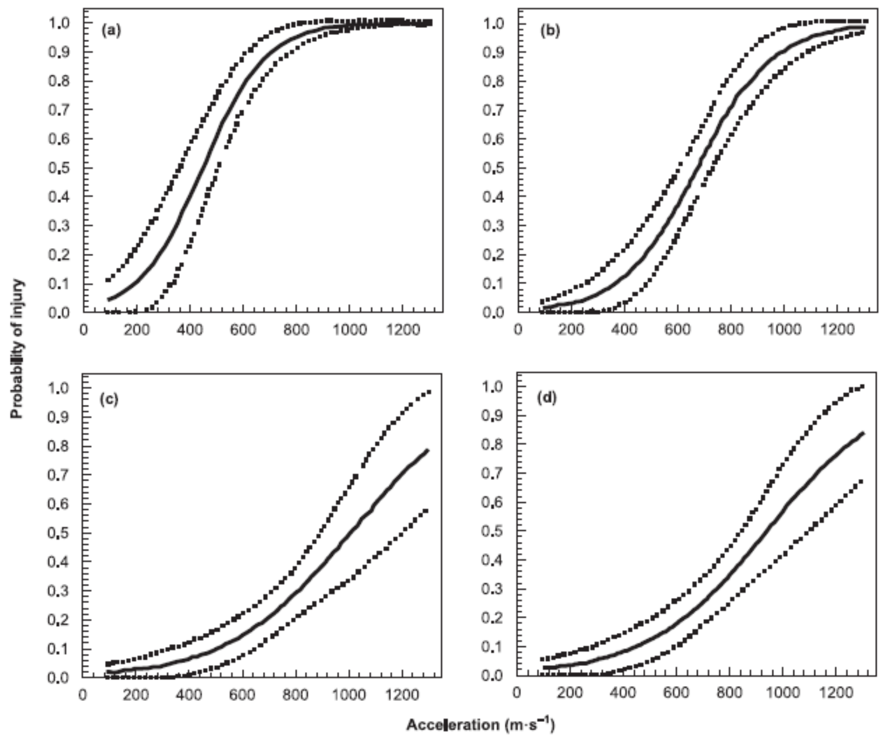


Figure 2: Figure 6 taken from: Z. Deng, G.R. Guensch, C.A. McKinstry, R.P. Mueller, D.D. Dauble, and M.C. Richmond. 2005. Can. J. Fish. Sci. Aquat. 62: 1513-1522. The figure shows the fitted probability of four types of injury as a function of acceleration, with 95% predictive confidence intervals (broken lines), as derived from binary logistic regression: (a) minor, (b) major, (c) eye, (d) operculum.

Initial review of data available for exposure to shear indicates that it is likely sufficient for extension of mortal injury to include shear.

III.A.1. Problem Description

In the general area of turbine passage research, the situation that has evolved is one where data is becoming increasingly available from laboratory studies, physical turbine model studies, sensor fish device studies, and field studies with live balloon tagged, telemetry, and PIT tagged fish. None of the results of these various studies by themselves are sufficient to serve as a basis for either derivation of turbine design criteria or derivation of field testable hypothesis for Biological Index Testing. The synthesis approach proposed here will integrate appropriate data from each source to derive design criteria, initially for pressure exposure and later for mechanical injury, and aid implementation of Biological Index Testing.

III.A.3. Relationship of Proposed Research to Other Ongoing or Proposed Research

Conduct of the synthesis proposed here is dependent upon provision of pressure distribution information from CFD modeling. CFD modeling is to be conducted concurrent with construction of an analysis model and will likely be available piece wise as simulation for the operating conditions selected for each turbine is competed. Completion is also dependent upon provision of data for the vertical distribution of the population of river run fish at entry to a turbine's distributor and completion of pressure cycle testing of yearling Chinook.

III.B. Objectives
See section II.B.

III.C. Methodology
Observations made using physical turbine models, math models, and analysis of field studies of live fish and sensor passage through turbines have clarified the variables most important to assess the exposure to sources of mechanical injury and pressure that a fish may experience during turbine passage. It has been shown that the vertical distribution of fish at entry to the distributor is a primary determinant for the radial location of passage through the turbine runner. Field studies have shown that the risk of mechanical injury is significantly higher for passage near the runner blade tips than at locations nearer the runner hub. Similar trend appear likely for exposure to low pressure. In general, it is clear that passage through a turbine runner near the suction side of runner blades greatly increases the probability of exposure to low pressure. Recently, laboratory studies have provided the link between exposure to low pressure and the consequences of this exposure.

It is now clear that with information about the distribution of fish entering a turbine distributor and the distribution of pressure within the turbine runner, the probability of exposure to low pressure can be estimated for a population of fish passing through the turbine. In turn, with such exposure estimates, the results of laboratory studies of the consequence (probability of mortal injury) of exposure to low pressure can be applied to estimate the probability of mortal injury for the population of fish passing through a particular turbine during a particular operation. Iteration of this analysis process over a range of turbine operations of interest for a particular turbine design will provide a "biological performance" relationship that estimates the population level probability of mortal injury resulting from exposure to low pressure over the turbine's operating range.

The approach to synthesis is straightforward. A statistical analysis model will be constructed that will require input data for: (1) the vertical distribution of fish at distributor entry, (2) the probable distribution of fish relative to runner blades, (3) the distribution of nadir pressures fish with this entry distribution will likely experience, and (4) the probability of mortal injury for nadir pressure exposure. The input data will be analyzed prior to entry so that the error associated with the various estimates is propagated through the model and is reflected in the population level mortal injury probability estimate for each operating condition and turbine design considered.

Development of the synthesis model can begin immediately. Model development will provide insight into requirements for the fish distribution data and pressure exposure estimates to be provided by projects that may be conducted concurrent with this project. The schedule for project completion will be dependent upon the schedules for projects to estimate fish vertical distribution at the turbine distributor and CFD modeling to obtain estimates of probability of exposure to low pressure nadirs.

III.D. Facilities and Equipment

No special facilities and equipment are required for Phase I.

III.E. Impacts

At this time no impacts to other projects have been identified.

III.F. Collaborative Arrangements and Sub-Contracts

A sub-contract with John Skalski at the University of Washington will be needed to obtain assistance with synthesis model construction, operation, and analysis of results.

IV. List of Key Personnel and Project Duties

Thomas Carlson, PNNL. Principal Investigator responsible for project planning, plan execution, analysis model application, and reporting.

Craig McKinstry, PNNL. Statistician responsible for analysis model development.

V. Technology Transfer.

Technology transfer will be through reporting of study results in regional forums and in written reports.

RESEARCH PROPOSAL (COE) (FY08)

TITLE:	Investigation of adult salmon and steelhead straying in the Lower Columbia River
PROJECT LEADERS:	Sandra L. Downing and Eric E. Hockersmith Fish Ecology Division Northwest Fisheries Science Center National Marine Fisheries Service 2725 Montlake Boulevard East Seattle, Washington 98112 (206) 860-5604
ADMIN. OFFICER:	Doug Dey Deputy Director, Fish Ecology Division Northwest Fisheries Science Center National Marine Fisheries Service 2725 Montlake Boulevard East Seattle, Washington 98112 (206) 860-3237
STUDY CODE:	ADS-00-4
PROJECT DURATION:	FY2008
SUBMISSION DATE:	October 2007

II. PROJECT SUMMARY

A. Project goals

The goal of this project is to evaluate the feasibility of using PIT-tag systems to estimate straying in large tributaries. The overarching goal is to establish PIT-tag detection in major tributaries to provide an index of straying for Columbia River Basin anadromous fish populations through the Federal Columbia River Power System (FCRPS).

B. Objectives/Hypotheses

One of the main objectives of this project was accomplished in September 2007. We installed a prototype PIT-tag system into a site near McDonald Ferry on the John Day River. This site is located in the lower reach of the river (around RM 20) and is below all of the major spawning creeks (Figure 1). The antenna configuration for the new John Day River site (JD1) has six antennas, installed in two 3-antenna arrays. The two-array design will provide directional information on the fish detected on both arrays.

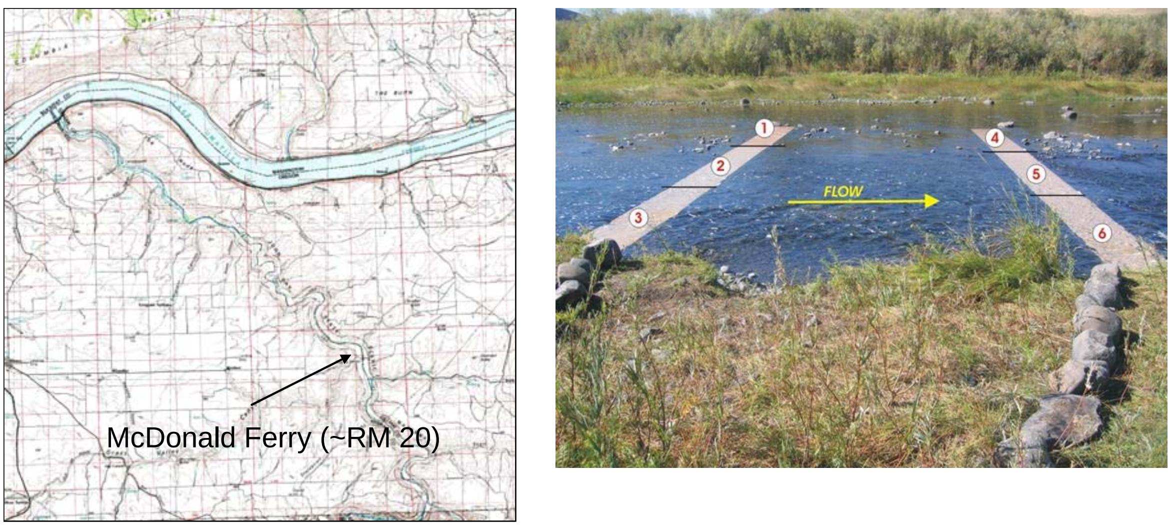


Figure 1. Map showing where the PIT-tag detection system on John Day River was installed. The photo shows the JD1 site with the six antennas marked.

The river is too wide for six antennas to cover it completely when it is full of water and therefore, we designed the system to cover the thalweg portion of the river where most of the salmonids will be migrating. This project is also helping to support the development of a new multiplexing transceiver that will enable more than the current maximum limit of six antennas. This will hopefully enable us to design PIT-tag systems for some of the larger tributaries in the future.

Now that the PIT-tag system is installed, during FY08 we plan to monitor the passage of migrating PIT-tagged adult salmon and steelhead for 1 year. This will help determine how feasible an in-stream PIT-tag system is for monitoring straying salmonids in a large tributary. Then in September 2008, we will set up radiotelemetry equipment in order to determine the detection efficiency of the multiple antenna-array design by using double-tagged steelhead (this objective will mostly be conducted in FY09).

C. Methodology

The first task to be completed in 2008 will be to monitor the passage of any migrating PIT-tagged adult salmon and steelhead. The PIT-tag detection system will be operated and maintained continuously during the whole year. Currently, funding has been obtained for operating this system through September 2008, but if the data collected are encouraging, we will want to maintain the system minimally through November 2009. This duration would enable us to collect data for 3 years on migrating steelhead.

During the fall of 2008, we plan to determine detection efficiency of the multiple antenna-array design using double-tagged (PIT and radio tags) steelhead. To accomplish this, National Marine Fisheries Service (NOAA Fisheries) will need to install the radiotelemetry equipment in September 2008. Radiotelemetry antenna arrays would be installed below the first fishing hole near the mouth of the river, below and above the PIT-tag antennas in order to monitor the double-tagged fish. If possible, we will ascertain whether the radiotelemetry antennas can be set up to confirm that the fish pass in the section of river where the PIT-tag antennas are compared to the section where there are no antennas. This would make the estimate of detection efficiency more accurate.

During FY09, steelhead would be collected in October and November by angling the fish in the John Day River below McDonald Ferry. There are three main fishing holes in this section of the river; we want to capture fish that have definitely chosen to migrate up the river verses capturing fish in the arm near the mouth of the John Day River. This effort would be accomplished with volunteer anglers and assistance from Oregon Department of Fish & Wildlife (ODFW) and hopefully The Confederated Tribes of the Warm Springs Reservation (organizing this effort will start taking place in FY08. We will only be collecting hatchery steelhead; these would then be double tagged with radio and PIT tags. In addition, we will take small tissue sample from a fin (using a hole punch) in order to run genetic analyses on the fish. The double-tagged steelhead will all be potential straying fish because there are no hatchery-reared steelhead smolts released in the John Day River watershed.

Once we have 100-125 double-tagged hatchery steelhead, the fish will be monitored during their migration until at least the end of January. ODFW is also planning on installing some radiotelemetry antennas farther upstream in some of the smaller tributaries to try to identify where the straying steelhead actually spawn.

Investigation of adult salmon and steelhead straying

Besides general administration tasks, the specific tasks for this proposed project in FY2008 are:

1. Operate and maintain the system through September 2008 in order to monitor passage of migrating PIT-tagged adult salmon and steelhead
2. Analyze the fish data to determine the origins of the detected fish and try to make straying estimates
3. Determine if radio tags impact the performance of PIT tags (i.e., impact of double-tagging)
4. Determine detection efficiencies in the field with double-tagged steelhead
    a. Obtain collection permits for the steelhead to be double tagged
    b. Organize with local agencies and clubs for the collection
    c. Set up the radiotelemetry antenna arrays
5. Monitor the progress of the development of the new multiplexing transceiver

The specific tasks for this proposed project in FY2009 are:

1. Operate and maintain the system through November 2009 in order to monitor passage of migrating PIT-tagged adult salmon and steelhead
2. Analyze the fish data to determine the origins of the detected fish and try to make straying estimates
3. Determine detection efficiencies in the field with double-tagged steelhead
    a. Collect the fish
    b. Take genetic samples
    c. Tag the fish
    d. Monitor the double-tagged fish
    e. Determine detection efficiency for the in-stream PIT-tag system
4. Test the genetic samples
5. Continue monitoring the progress of the development of the new multiplexing transceiver
6. Project administration including final report

D. Relevance

In the Final Updated Proposed Action (UPA) for the FCRPS Biological Opinion Remand released in 2004, the Action Agencies discuss needing data from RM&E efforts for determining success in meeting the hydrosystem performance standards (e.g., monitoring adult fallback and delays to help in estimating adult survival rates). Straying is one component in monitoring adult fallback and delays needed to help estimate adult survival rates.

If we go back to the biological opinion (BiOp) developed by NOAA Fisheries in 2000, justification for the development of tributary PIT-tag detection systems is found principally within RAs 192, 193, and 199. These actions address the use of PIT-tagged adult salmon and steelhead to provide critical passage information with minimal adult handling mortality. Research action 193 specifically states:

The Action Agencies shall investigate state-of-the-art, novel fish detection and tagging techniques for use, if warranted, in long-term research, monitoring, and evaluation efforts.

Development of in-stream PIT-tag systems in Columbia River tributaries will provide some of the data necessary to evaluate a range of actions including: transportation effects (RA 48), adult survival (RA 107), and indirect prespawning mortality of adult upstream-migrating fish (RA 118).

III. PROJECT DESCRIPTION

A. Background

NOAA Fisheries in accord with Endangered Species Act (ESA) procedures has developed BiOps for the FCRPS. In 2004, the U.S. Army Corps of Engineers (Corps), Bureau of Reclamation, and Bonneville Power Administration (BPA) released their Final UPA for the FCRPS Biological Opinion Remand where they outlined measures to meet the performance standards described in the NOAA Fisheries 2000 BiOp for the FCRPS and to meet the new jeopardy analyses proscribed by the court.

As part of collecting RM&E data to help the Action Agencies determine whether they are meeting hydrosystem performance standards, the UPA calls for monitoring adult fallback and delays to help in estimating adult survival rates. Straying is a key component in adjusting adult survival estimates. The only straying data collected on known-origin salmonids (fish PIT-tagged as juveniles) was done by the University of Idaho and NOAA Fisheries between 2000 and 2003. Based on around 3,000 double-tagged salmonids, this radiotelemetry study identified the Little White Salmon, White Salmon, Deschutes, and John Day Rivers as the tributaries in the lower Columbia River that have the highest straying rates for salmonids (Keefer et al., 2004).

Currently, models to estimate adult survival rates are using mean straying values derived from the radiotelemetry data as correction factors. However, the statistical strength of these correction factors is weak as data were collected for only a few years and only a low number of radio-tagged fish strayed. Furthermore, set correction factors will not reflect any annual variation that will naturally be occurring. In addition, recent radiotelemetry and PIT-tag data indicate there may be a relationship between being transported as a juvenile smolt and an increased propensity to stray and fallback. Consequently, regional biologists and resource managers are interested in learning more about straying rates of particular salmonid populations.

One approach that would yield annual variability for many different salmonid populations would be to develop a PIT-tag detection system for the identified tributaries with high rates of straying listed above. For the same time period as the above radiotelemetry study (2000-2003), approximately 23,000 PIT-tagged adult Chinook salmon and steelhead were detected at Bonneville Dam; therefore, tributary PIT-tag detection systems could provide information for a broad range of ESUs as every returning PIT-tagged adult would have the potential to be detected compared to the limited number of fish that are radio tagged. Moreover, an annual PIT-tag monitoring program is also cost effective because it utilizes fish tagged previously as juveniles as part of a variety of projects and eliminates the need for collection and tagging of adults during their upstream migration.

Because of advancements in PIT-tag technologies since 2000, the development of a PIT-tag detection system to monitor movement of known-origin adult salmon and steelhead into a large tributary has become a viable solution. The Corps and other agencies agreed to initiate a project in 2006 to evaluate the feasibility of developing a PIT-tag detection system for monitoring straying in a major tributary. During the first year of this project, Biomark and NOAA Fisheries conducted site surveys to evaluate potential installation sites (e.g., thalweg position, land ownership, power access, substrate, etc.) and worked on increasing the size of antennas that could be installed with the FS1001M transceiver manufactured by Digital Angel.

Potential sites on the Deschutes and John Day Rivers were surveyed in June 2006. With its high base flow, an in-stream PIT-tag detection system on the Deschutes River appeared too challenging with the currently available PIT-tag technologies. Three sites on the John Day River were investigated: McDonald Ferry, Cottonwood Bridge, and Clarno Bridge (Fig. 2) (Anglea et al. 2006). In order to be below any tributaries with significant amount of steelhead spawning (based on discussions with the District Fish Biologist, Tim Unterwegner, for ODFW), we decided on a location around 1 mile downstream of the river ford at McDonald Ferry in August 2006.

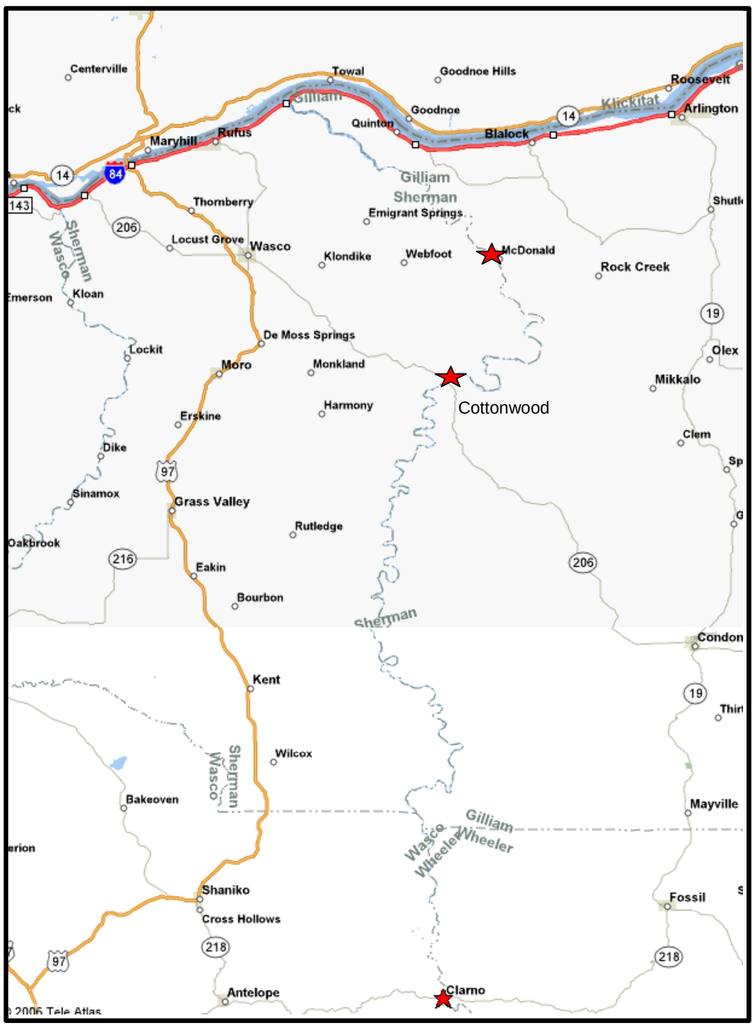


Figure 2. Map showing the sites (red stars) visited on the John Day River.

At this location near McDonald Ferry, the river channel is approximately 120 ft wide at low flow and 200 ft wide at higher flows. The thalweg is around 30 ft. wide. In 2006, we confirmed with a DIDSON camera that the salmonids were mostly using the thalweg at this location. We also hired a hydraulic firm to analyze how much load the different antenna designs could theoretically handle. During February 2007, we installed non-functioning antennas to evaluate if there would be any problems holding the antennas in place in the larger John Day River during the spring runoff. Unfortunately, the spring runoff was minimal this year, but the hydraulic analysis indicated that the antenna housings would be held in place against normal spring flow conditions. Although the nonfunctioning antennas did not get thoroughly tested, the fish managers voted in May to continue with the installation scheduled for late summer (August and September 2007) at the site near McDonald Ferry.

Based on the hydraulic analysis and observation of the nonfunctioning antennas in the river, we decided on using pass-by or flat plate antennas. Research by both Biomark and NOAA Fisheries determined that we could produce antennas that were 25 ft. long, but in order to install them in the thalweg, we chose to fabricate antennas that were 20 ft. long by ~3 ft. wide. We installed two antenna arrays with three antennas each into the thalweg near the right bank (see Figure 1). Therefore, each array will measure approximately 60 ft long and they will be separated from each other by approximately 30 ft. With the 20 ft. antennas, the read range for fish passing over the antennas will be around 18-20" if they are tagged with the latest SST model of 12-mm PIT tags and around 12-15" if they are tagged with the older ST model. USGS maintains a river gauge at McDonald Ferry and the records indicate that water depth during the fall during the steelhead migration is typically ranges from 1.5-3.0 feet (Fig. 3). With these depths and if, as people predict, the fish stay near the bottom of the river and within the thalweg where we installed the equipment, then we think we will be able to detect most of the migrating fish.

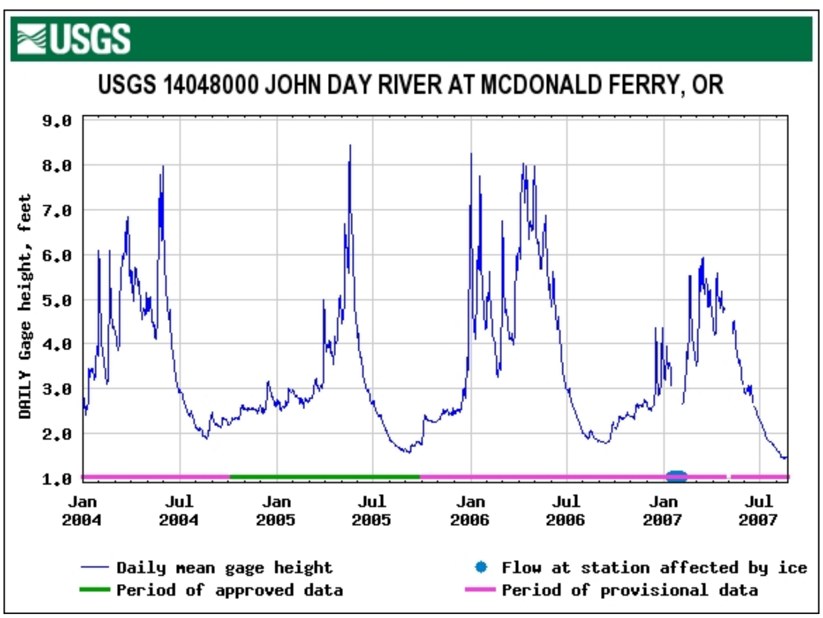


Figure 3. Graphs showing the height of the John Day River as recorded by the gauge system at McDonald Ferry (USGS Station 14048000), 2004-2007.

At the site near McDonald Ferry, we had to install two antenna arrays that only covered the thalweg portion of the river because current PIT-tag technologies prevents us from installing antenna arrays that cover the entire span of the tributary. In order to be able to reach our overarching goal of establishing PIT-tag detection in major tributaries to provide an index of straying for anadromous fish populations through the FCRPS, we need to develop a better multiplexing PIT-tag transceiver. In August 2007, NOAA Fisheries issued a contract to Digital Angel, the manufacturer of the different transceiver models used by the fisheries community, to develop a new multiplexing transceiver. We will monitor the progress of this development; this site may be a good choice for evaluating it if the read range is improved.

The wild population of summer-run steelhead trout from John Day River is a listed population that appears to be negatively impacted by straying. Although no hatchery-reared steelhead smolts are released in the John Day River watershed, ODFW is currently identifying 25-30% of the carcasses in its spawning ground surveys as hatchery fish (Tim Unterwegener, ODFW District Fish Biologist). Obviously, these hatchery strays could potentially impact the genetic integrity and natural production of the wild population by spawning with them (which is another critical management uncertainty that requires investigation). Taking genetic samples from the steelhead we double tag in FY09 will help establish the origin of the straying hatchery fish. In this watershed, there is less concern about strays impacting the Chinook population since it is not listed and the population is increasing.

B. Project objectives

The goal of this project is to evaluate the feasibility of using PIT-tag systems to estimate straying in major tributaries. In 2007, the main objective of this project was to install a prototype PIT-tag system near McDonald Ferry on the John Day River. Then with the system operating, we plan to monitor the passage of migrating PIT-tagged adult salmon and steelhead to observe what type of data gets collected by the system. Then in the fall of 2008, we plan determine detection efficiency of the multiple antenna-array design using double-tagged hatchery steelhead.

C. Methodology

The specific tasks for this proposed project in FY2008 are:

1. Operate and maintain the system through September 2008 in order to monitor passage of migrating PIT-tagged adult salmon and steelhead
2. Analyze the fish data to determine the origins of the detected fish and try to make straying estimates
3. Determine if radio tags impact the performance of PIT tags (i.e., impact of double-tagging)
4. Determine detection efficiencies in the field with double-tagged steelhead
    a. Obtain collection permits for the steelhead to be double tagged
    b. Organize with local agencies and clubs for the collection
    c. Set up the radiotelemetry antenna arrays
5. Monitor the progress of the development of the new multiplexing transceiver
6. Project administration including final report

Task 1 (operate and maintain the site)— As with any PIT-tag system, the site needs to be visited regularly in order to ensure that everything is operating satisfactorily. This is critical for in-stream systems because water levels changes impact the tag-reading performance of the system. This would include checking on the equipment (e.g., transceiver, antennas, antenna cables, computer, satellite equipment, and the camera) and making any necessary adjustments. Biomark will be in charge of maintaining the site; they plan to visit the site monthly. If the site is to be discontinued after November 2009, they will also be contracted to remove the equipment that they installed.

Task 2 (monitoring fish)— Since all of the data will be uploaded into the regional PTAGIS database, we will be able to monitor the origin information of any PIT-tagged fish that are detected by the instream system. If it is statistically possible, we will use the data to estimate straying rates for known source ESU or ESU surrogate fish to help in determining the success at meeting hydrosystem performance standards. This task will start as soon as the site is operational, but it will also continue through the fall of 2009, which is the minimal time we recommend operating this site. The data that are collected will be compared to previous stray estimates developed from radiotelemetry studies to determine if estimates are in the range of previously measured values for the relevant stocks. By the fall of 2009, we should know whether the site is collecting data that aids the fish managers in learning more about straying behavior and making straying estimates for specific fish populations.

Task 3 (impact of double-tagging on PIT-tag performance)—As part of the straying detection systems, we need to be able to evaluate how effective the antennas are at detecting migrating PIT-tagged fish. We propose to investigate antenna performance using double-tagged fish (fish with both radio and PIT tags). Double-tagging fish has been used in the past, but recent evidence suggests that when the two tags are in close proximity, PIT-tag detection efficiency can be reduced. We will be conducting a laboratory investigation to determine the effect of having radio (different types) and PIT tags in close proximity to each other during the fall. We will use a belt system in a screen room and test how well PIT tags are detected when the two tag types are located different distances apart and orientations to each other.

Task 4 (determining detection efficiencies in the field)—A critical part of evaluating the feasibility of straying detection systems is to evaluate how effective the antennas are at detecting migrating PIT-tagged fish. If the above tests show no negative impact, we propose to investigate antenna performance using double-tagged steelhead (fish with both radio and PIT tags). As indicated above, we plan to focus on steelhead because that is the population that appears to be impacted by straying fish entering this river.

There are a number of steps involved in achieving this objective. First we need to obtain the necessary collection permits for capturing and tagging the fish. We will also contact some of the major tagging coordinators in the Snake River to learn whether they would allow us to radio tag their fish if we were to detect them in the John Day River. Then we need to coordinate with the local agencies and clubs to get their support of the project and get them involved; we will need manpower to help with catching the fish. Since fishermen are only allowed to keep hatchery fish, we will be asking fishermen to give up fish that they would normally get to keep for us to tag them. Biologists from ODFW have already indicated that they will be able to supply quite a few volunteer fishermen.

Before any fishing begins, we would set up the radiotelemetry equipment in September 2008. For our purpose of determining the PIT-tag detection efficiency of the in-stream system, we plan to setup three radiotelemetry antenna arrays: downstream of the first fishing hole, downstream of the first PIT-tag antenna array, and then upstream of the second PIT-tag antenna array. ODFW has indicated that they would like to setup some arrays farther upstream in order to try to determine where the straying fish are spawning. We would assist ODFW in setting up their antenna arrays.

[The following subtasks will be conducted in FY09]

We plan to have fish technicians located at the three main fishing holes located in the lower river section. No fishing will occur until the water temperature is below 21 °C. For any hatchery steelhead that is caught, it would first be transferred to an aerated anesthesia tank at the side of the river. The fish technicians would first scan the fish for PIT tags; if the fish has a tag we will need to determine where it was originally tagged and see if we have permission to radio tag it. If we do have permission, they would then radio tag it. If we do not, the fish would be released. If the fish is not PIT tagged, then the technicians would tag it with both PIT and radio tags. For any fish that is radio tagged, we also plan to take genetic samples (a hole punch in one of the fins) since this will help us determine stock information on the test fish. Along with the tag information, each record would contain the fish length, time and date when the fish was caught, and where it was caught.

The test fish would then be held in PVC tubes in the river until they have recovered from the tagging procedure. They would then be released upstream of the fishing hole they were caught in. ODFW has used this approach successfully in the past without any mortalities. We anticipate that it will take approximately 4 weekends to collect the fish we need for the study. Statisticians have estimated that we need a minimum of 100 double-tagged fish to pass the PIT-tag system to determine detection efficiency (John Skalski, personal communication, University of Washington). Since some of the fish will turn around before reaching the PIT-tag in-stream system, we will aim to tag closer to 125 fish.

Once double-tagged fish are released, we would start to closely monitor their passage at both the radiotelemetry and PIT-tag antenna arrays. It is unknown at this time, how long we will need to monitor the fish; obviously ODFW will need to monitor them longer to collect the spawning data they want. Once we have collected data from a minimum of 50 fish passing the PIT-tag system, we will start to make detection estimates. We recognize that river conditions may change that would require us to subdivide the fish into different groups (if water depth significantly varies over the antennas, then there could be a significant difference in how well the system detects the migrating steelhead). To help monitor river conditions, we will use the hydrologic variables collected at McDonald Ferry by USGS.

Task 5 (multiplexing transceiver)— In August 2007, NOAA Fisheries issued a contract to Digital Angel to develop a new multiplexing transceiver for stream applications. This effort is suppose to take 12-18 months to complete. If the transceiver successfully meets the requirements for the transceiver that were developed by a multi-agency team, then it will be very useful for this project. Personnel from this project will monitor the progress of the development and once it is completed, they will help evaluate the new transceiver.

Task 6 (administration)—Proper project administration is necessary to ensure that this project stays on track with its work schedules. Project administration involves planning, issuing contracts, and then monitoring the work and budget to make certain that the milestones are reached and the project stays within budget. It involves attending management, planning, and budgetary meetings on the project. It also includes writing a final report that summarizes the steps taken to complete the individual tasks outlined in this proposal.

Task to be completed in FY09 (genetic samples)— Most of the above tasks will continue in FY09, but the analysis of the genetic samples is unique to FY09 (see the project schedule). The genetic samples collected from the hatchery steelhead will be analyzed by personnel from NWFSC who have experience running such samples. It will be important to learn as much as we can about the fish we tag to help learn about the impact straying individuals are having on the local population.

D. Facilities and equipment

Equipment (trucks, boats, computers, etc.) needed for the proposed work will be provided by research agencies

E. Project impacts and biological effects

Establishing fixed PIT-tag detection systems within the major tributaries will require coordination with county, state, tribal, and federal parties. We will be applying for permits to collect and tag the fish. We do not anticipate needing support from any Corps personnel from any of the hydropower facilities; although we may need some support for the permitting process.

At this time, we do not know of any detrimental biological effects that the project will have since we do not expect mortality from the capturing, tagging, and release operations.

F. Collaborative arrangements or subcontracts

This project brings together the two entities with the most experience in applying PIT-tag technologies to stream applications. By combining forces, Biomark and NOAA Fisheries have been able to develop larger antennas. This collaboration will continue in 2008-2009 as Biomark maintains the site. They have also expressed interest in reviewing the evaluation of the detection efficiency of the installed system.

IV. KEY PERSONNEL AND DUTIES

Sandra Downing and Eric Hockersmith	Principal Investigators
Steve Anglea	Biomark Project Manager
Tim Unterwegener	ODFW District Fish Biologist
Jim Ruzycki	ODFW Supervisory Fish&Wildlife Biologist

Both of the ODFW biologists will be critical to the success of this project. They will help us tremendously in coordinating local assistance. They will be critical in our efforts to collect and tag the fish. They are currently involved with PIT tagging juvenile steelhead in the John Day River and in leading the surveys of the spawning grounds to monitor the impact of straying steelhead.

V. TECHNOLOGY TRANSFER

Information acquired from the proposed work will be transferred to the fisheries community by presentations at meetings and workshops, by personal contact, by annual and final reports to the Corps, and through scientific publications.

VI. REFERENCES CITED

Keefer, M., C. Peery, J. Firehammer, and M. Moser. 2004. Summary of straying rates for known-origin adult Chinook salmon and steelhead in the Columbia/Snake hydrosystem. Letter report to the U.S. Army Corps of Engineers.

Anglea, S., E. Prentice, and S. Downing. 2006. Investigation of straying in adult salmon and steelhead (Study Code: ADS-00-4). Report on Site Visits to the John Day River and Deschutes River. Letter report to the U.S. Army Corps of Engineers.

VII. BUDGET AND SCHEDULE

A detailed budget for FY08 for the tasks that have not been previously funded is attached; this covers the mobilization of the radiotelemetry equipment and establishment of plans for angling the test fish. The amount is roughly $49K. Most of the tasks for FY08 have already been funded (see the schedule on the next page). We are also submitting a budget that covers the rest of the project (~$257K). We will need to receive half of these funds as soon as the fiscal year commences if we are to be able to double tag the steelhead during the fall of 2008. As with other Corps-funded NMFS tagging projects, we indicate that the Corps will furnish the 125 radio tags needed for the system verification task. NMFS will be furnishing the PIT tags at no cost to this project.

Investigation of adult salmon and steelhead straying

SCHEDULE FOR THE DIFFERENT TASKS ASSOCIATED WITH THE DEVELOPMENT OF A PIT-TAG SYSTEM TO ESTIMATE STRAYING RATES

		2007			2008												2009											
Task	**Task description**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
1	Operate and maintain the installed system	P	P	P	P	P	P	P	P	P	P	P	P	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
2	Monitor passage of migrating PIT-tagged adult salmon and steelhead (make straying estimates)	P	P	P	P	P	P	P	P	P	P	P	P	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
3	Tag interference tests					P	P																					
4	Determine detection efficiency in the field with test fish (FY08 subtasks)										P	P	X															
5	Determine detection efficiency in the field with test fish (FY09 subtasks)													X	X	X	X											
6	Monitor the development of the multiplexing transceiver				P	P	P	P	P	P	P	P	P	X	X	X	X	X	X	X	X	X	X					
7	Test the genetic samples																X	X	X	X	X	X	X					
8	Project administration including final report	P	P	P	P	P	P	P	P	P	P	P	P	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

P indicates that the Corps has already provided funding

New Research Proposal

Evaluation of an Instream Passive Integrated Transponder Site to Monitor Adult Steelhead Movements in the John Day River - 2008

Study Code: ADS-00-4

Project Leaders

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Oregon Department of Fish and Wildlife
John Day, OR
541 575-1167

For the period: 1 January 2008 to 31 December 2009

Submitted August 2007

Study Summary

A. Goal

The goal of this study is to evaluate the effectiveness of a newly constructed instream full duplex passive integrated transponder station to accurately detect adult salmon and steelhead migrants in the John Day River.

B. Objectives - 2008

1. Evaluate effectiveness of instream PIT tag station to record adult salmon and steelhead migrants in the John Day River.

2. Incorporate tributary PIT detections to estimate straying rates for known source ESU or surrogate populations.

C. Methods

We propose to use radiotelemetry to determine if adult steelhead, also containing PIT tags, are detected on passing a newly constructed full duplex PIT tag station in the John Day River. Adult fish collect in the John Day River will be double tagged with a radio transmitter (gastric insertion) and PIT tag injected to pelvic girdle and released back to the river downstream from the PIT tag station. Remote radio receivers located near the mouth and just upstream and downstream from the PIT station will be used to determine which individual fish pass the PIT interrogator. These records will be compared to PIT diction records to determine PIT detection efficiencies.

D. Relevance

Development of a reliable instream PIT monitoring system for moderate to large rivers would be used to assess wandering, straying, and escapement of adult salmon and steelhead returning to ESA-listed populations migrating through the Columbia River Federal Power System (FCRPS), including assessing effects of juvenile transport on homing. Straying rates are an essential adjustment factor to adult survival estimates used to evaluate survival goals set in the 2004 FCRPS Biological Opinion Remand. In the NOAA Fisheries 2000 Biological Opinion for operations of the FCRPS, RPAs 48, 50, 107, 118, and 193 deal with accurately assess adult migrant survival and sources of loss of adult salmonid migrants including effects of juvenile transport on homing, accurately assessing tributary turnoff, and development of novel fish detections techniques for long-term research and monitoring efforts.

Project Description

A. Background

Some level of straying behavior is natural in Pacific salmon populations and an important colonization and dispersion mechanism. However, in the current system, salmon staying rates may be affected by operations and management practices. For example, alterations on the lower Columbia River temperature regime may increase straying to cool water refuges during summer. Hatchery rearing, supplementation, juvenile release strategies, and transportations programs may affect homing abilities for returning adults (Keefer et al. 2004). Accurately estimating straying rates is important for adjusting escapement estimates to determine if adult survival goals for ESA listed populations are being met. Upriver (Snake, upper Columbia Rivers) stocks that stray to non-natal tributaries are considered escapement losses from natal streams and will artificially inflate escapement estimates in non-natal populations. Additional concerns regarding straying include documenting harvest of listed stocks that temporarily stray into non-natal tributaries and possible swamping of small wild populations by straying hatchery stocks (e.g., Snake River hatchery steelhead that stray into the John Day River). Out-of-basin spawning by hatchery fish can directly harm local wild populations (e.g., Waples 1991; Chilcote 2003).

Previously, stray rates were determined by monitoring radio-tagged salmon and steelhead from known-source populations. From those studies it was found that some groups, such as Snake River steelhead fall Chinook salmon, will stray temporarily into lower river tributaries (White Salmon, Little White Salmon, Wind, Klickitat, Deschutes, and John Day rivers), when Columbia River water temperatures are warm. Some of those fish will remain in the tributaries or be caught in tributary fisheries. There was also evidence that transport history (barging) may affect straying rates for returning adult salmon (Keefer at al. 2004). This type of information has implications for determining escapement rates, setting harvest levels, improving and evaluating recovery strategies.

Passive integrated transponder tags are widely used within the Columbia River basin to assess survival and movements of anadromous salmonids. With advancements in technology of PIT interrogation stations in adult fishways at dams, smolt-to-adult survival values are also now possible and similar applications are increasing in streams and rivers. In 2006, NOAA Fisheries and Biomark began a project to develop instream PIT interrogator stations in the tributary rivers of the lower Columbia River. From that effort, an initial prototype system is scheduled to be installed fall of 2007 at about river kilometer 32 of the John Day River. Testing the effectiveness of this site is needed to determine detections records should be interpreted and incorporated into salmon survia;l metrics as well as to aide in the continued development of future sites.

Here we propose a study to evaluate the effectiveness of the John Day River instream PIT detection station to accurately detect actively migrating adult salmon and steelhead in the John Day River using radiotelemetry. This study would be a collaborative effort between NOAA Fisheries, Oregon Department of Fish and Wildlife and the University of Idaho and has been developed in consultation with personnel from CORPS.

B. Objectives - 2008

1. Evaluate effectiveness of instream PIT tag station to record adult salmon and steelhead migrants in the John Day River.

2. Incorporate tributary PIT detections to estimate straying rates for known source ESU or surrogate populations.

C. Methods

1. Evaluate effectiveness of instream PIT tag station to record adult salmon and steelhead migrants in the John Day River.

The instream portion of the John Day River PIT station will consist of antenna panels installed along the bottom across the thalweg of the river. This design was selected because it is believed that adult salmon swim close to the substrate in free-flowing rivers and because the low profile reduces the chance for damage from high flows and debris.

We propose to evaluate the detection efficiency of the site by monitoring adult steelhead double tagged with radio transmitter and PIT tag. Records from telemetry receivers to be installed up and downstream from the PIT station will be used to determine the proportion of fish that the site detected. Fish to be used for this evaluation would come from the John Day River. There are several options being considered for collcting fish. Adult steelhead can be collected by angling at several locations downstream from the Tumwater Falls area, at about rkm 16. Optimal timing for this effort is late October or early November. Netting fish using seines or tangle nets would be secondary option. We will work with local biologists and angling groups to enlist local cooperation and approval for these sampling efforts.

Tagging methods will be similar to those we have used in similar studies. Once fish are caught, they will be quickly placed into a soft rubber net and transferred to covered and aerated anesthesia tank at the side of the river. Each fish will be measured, a radio transmitter will be placed into the stomach through the mouth, and a PIT tag will be injected to the pelvic girdle. Fish will then be moved to a netted off area to recover. Once fish are swimming freely, one side of the net will be dropped so the fish can exit. We propose to tag up to 100 steelhead.

Fixed radio receiver sites will be used to monitor tagged fish. We anticipate using at least three sites, one near the mouth of the river, and one each just upstream (within 0.5 km) and downstream from the PIT station. All sites will be solar powered with battery backup. We will test effectiveness of each site to assure that transmitters can be detected and coded across the width of the river. Fish known to have passed the PIT site will be compared to PIT records at the site to estimate detection efficiency. We will block data by operation conditions (flow, temperature, species, swim speed) to evaluate effects on detection probabilities. We propose to extend the study area upstream to spawning areas of the John Day Dam. Using fixed sites, to be determined in consultation with ODFW biologists, and mobile tracking we will determine fates of fish that pass the PIT station. This information will aid in better interpreting data that will be collected from the instream sites in the future.

2. Incorporate tributary PIT detections to estimate straying rates for known source ESU or surrogate populations.

All detections of PIT-tagged at the PIT site will be loaded to the PTAGIS database. These records will be analyzed to determine stream of origin and fish from out-of-basin will be used to identify temporary and permanent strays. Detection probabilities from Objective 1 will be used to estimate actual stray rates. Data will be compared to previous stray estimates developed from radiotelemetry studies to determine if estimates are in the range of previously measured values for the relevant stocks.

D. Facilities and Equipment

Equipment (trucks, boats, computers, etc.) needed for the proposed work will be provided by research agencies on a rental basis. We will contact transmitter manufactures to assure availability of tags prior to start of studies in 2008.

E. Impacts of study on Corps projects and other activities

Division or district Corps personnel will be needed to provide technical review of research proposed for 2008.

Biological Effects

Procedures for trapping and tagging fish in the John Day River will be similar to those we have used in similar studies. Care will be taken to reduce handling and stress. Fish will not be handled if water temperature exceeds 21 °C. All fish will be observed until fully recovered before being released. Some fish may move downstream directly after release, creating some delay in their upstream migration as a result of the We expect little to no mortality from the marking and release operations.

Key Personnel

Project planning, administration, work plan preparation, study protocols:
Project leaders, C. Peery, S. Downing, T. Unterwegner
Permits and data processing software:
M. Jepson, U of I
Equipment specifications and purchase:

K. Tolotti, Uof I

Fish collection, radio and PIT-tagging:

T. Unterwegener ODFW

S. Lee, U of I

S. Downing, NMFS

Analysis of data and preparation of report segments:

C. Peery, S. Downing, T. Unterwegner

Technology Transfer

Information and analyses from this study will be provided regularly to managers via reports and verbal presentations. Information that is appropriate will be published in technical journals. Special efforts will be made to provide information for managers as needed.

References

Keefer, M., C. Peery, J. Firehammer, and M. Moser. 2004. Summary of straying rates for known-origin adult steelhead in the Columbia/Snake hydrosystem. Letter report to the U.S. Army Corps of Engineers

FINAL RESEARCH PROPOSAL

SUBMITTED TO THE U.S. ARMY CORPS OF ENGINEERS UNDER THE ANADROMOUS FISH EVALUATION PROGRAM 2008 PROJECT YEAR

I. BASIC INFORMATION

A. TITLE OF PROJECT

Evaluation of steelhead kelt passage through the Bonneville Dam Second Powerhouse Corner Collector prior to the juvenile migration season

B. PROJECT LEADERS

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C. STUDY CODES

ADS-00-1: Evaluation of adult salmon and steelhead delay and fallback at Snake and Columbia River dams
ADS-P-00-6: Evaluation of steelhead kelt passage through Columbia and Snake River dams

D. DURATION

1 October 2007 through 31 December 2008

E. DATE OF SUBMISSION

September 17, 2007

II. PROJECT SUMMARY

A. GOALS

The goal of this project is to estimate the number of kelt using the B2CC for downstream passage at Bonneville Dam prior to the juvenile spring migration season.

B. OBJECTIVES

We plan to sample 24 h/d from March 1 until the start of operations to pass juvenile salmon at Bonneville Dam in early April, 2008.

1. Sample at the entrance of the B2CC with a Dual-Frequency Identification Sonar (DIDSON) acoustic camera to acquire data of kelt swim paths as they approach and enter, or swim away from, the B2CC during March and early April.
2. Estimate the numbers and distribution of kelt-sized targets that pass at the B2CC using split-beam hydroacoustics during March and early April.
3. Estimate the numbers and distribution of kelt-sized targets passing into Unit 11 at Bonneville Dam PH2 during March and early April.

C. METHODOLOGY

We propose to use split-beam hydroacoustic technology and acoustic camera technology to estimate to what extent kelt use the B2CC prior to the start of operations to pass juvenile salmon at Bonneville Dam in 2008 and to what extent they may be drawn into turbine Unit 11.

<u>DIDSON</u>

We propose to use a DIDSON acoustic camera mounted on a barge located to the southeast of the B2CC entrance to record kelt paths immediately upstream of the B2CC employing methods similar to those used in 2004 to evaluate passage of salmon smolt into the B2CC (Ploskey et al. 2005). The DIDSON will be oriented across the intake just upstream of the weir and a rotator used to adjust the orientation of the DIDSON relative to the B2CC entrance due to changes in forebay water level. We will estimate the proportion of kelt entering the B2CC relative to the proportion that find the B2CC but swim away from the entrance.

<u>HYDROACOUSTICS</u>

We propose to also sample kelt entering the B2CC with hydroacoustic equipment using the same methods used in 2004 and 2005 to monitor smolt passage (Ploskey et al. 2005) and in 2007 (in press) to monitor kelt passage. This will involve locating six split-beam transducers on a vertical pipe about 20 ft to the southeast of the entrance of the B2CC on a barge so that acoustic beams can be aimed across the entrance. Fish will be detected mostly in side aspect, thereby maximizing signal to noise ratios and fish detection. The pipe supporting the vertical array of six transducers will be rotated to aim acoustic beams about 12-15 ft upstream of the entrance where flows are sufficient to capture smolts and possibly kelt (8-10 ft / s) but low enough to allow adequate detectability. With a ping rate of 37 pings / s, a fish moving 10 ft / s through the center of an acoustic beam would provide 7 echoes if it passed into the entrance on the south side and 13 echoes if it passed on the north side of the intake. Four echoes are the minimum required to classify an echo trace as a fish. The upper two split-beams will have nominal 3-degree acoustic beams to minimize volume reverberation, which typically is worst near the surface. The lower four transducers will have nominal 6-degree acoustic beams. The count of every detected fish will be spatially expanded by the ratio of the height of the rectangle it samples to the diameter of the acoustic beam at the range a fish is detected. Whenever forebay elevations range from EL 74.1-76.0 ft, the deployment will provide passage distribution data within 11 1.85 ft vertical strata in the upper 20.35 ft of the water column and within one variable 1.85-3.75 ft strata below that depth. When forebay elevations are between EL 70.5 and 74.1 ft, the deployment will provide passage distribution data within 10 1.85 ft vertical strata in the upper 18.5 ft of the water column and within a 4.5 ft stratum below 18.5 ft. The vertical resolution is possible because tracked fish can be classified as being in the upper or lower one half of the beam. Laterally, the deployment will provide estimates of passage distribution to the nearest 0.5 ft across the 15-ft wide entrance.

A second deployment of hydroacoustic transducers will be mounted on the trash racks of each of the three intakes of Unit 11 to monitor kelt potential passage through the turbine unit for fish that were drawn toward the B2CC but passed into the turbine or were guided by the STS. Transducers will sample the vertical distribution of fish immediately upstream of the STS and will provide hourly estimates of fish passage during March and early April. One transducer of each pair will be mounted at the bottom vertical center of the uppermost trash rack and aimed downward to sample unguided kelt passing below the tip of the STS. The second transducer of each pair will be mounted on the bottom of the fourth trash rack from the top and aimed upward to sample fish passing above the tip of the screen.

D. RELEVANCE TO THE BIOLOGICAL OPINION

The National Marine Fisheries Service (NMFS) recognizes the potential value of kelts for achieving rebuilding goals (NMFS 2000), and has requested that research be conducted to evaluate and reduce dam passage mortality of kelts. This study addresses Reasonable and Prudent Alternative (RPA) 109 states where “The Corps shall initiate an adult steelhead downstream migrant (kelt) assessment program to determine the magnitude of passage, the contribution to population diversity and growth, and potential actions to provide safe passage.”

III. PROJECT DESCRIPTION

A. BACKGROUND

The Corps of Engineers is committed to increasing survival rates for fish passing its projects on the Columbia River. Successful downstream migration of steelhead *Oncorhynchus mykiss* populations may be limited by migration delay and passage events associated with navigating through hydroelectric dams (Wertheimer and Evans 2005). Bonneville Dam (BON) - the lowermost hydroelectric project on the Columbia River - creates the sole FCRPS reservoir affecting both winter (ocean maturing) and summer (stream maturing) steelhead varieties (Busby et al. 1996). Studies indicate that both steelhead varieties spawn in BON pool tributaries from December to April (Howell et al. 1985; CTB et al. 1990; McMillan 2001; Bair and Weiman 1995), prior to the onset of operations at BON to pass juvenile salmon (FPP 2006). Because some steelhead out-migrate immediately after spawning (Shapovalov and Taft 1954) providing optimal migration routes through BON should enhance return rates from these fish. The goal of this study is to quantify the extent of kelt use of the B2CC prior to the onset of operations during the juvenile salmon passage season.

B. OBJECTIVES

We plan to sample 24 h/d from March 1 until the start of operations to pass juvenile salmon at Bonneville Dam in early April.

1. Sample at the entrance of the B2CC with a DIDSON acoustic camera to acquire data of kelt swim paths as they approach and enter, or swim away from, the B2CC during March and early April.
2. Estimate the numbers and distribution of kelt-sized targets that pass at the B2CC using split-beam hydroacoustics during March and early April.
3. Estimate the numbers and distribution of kelt-sized targets passing into Unit 11 at Bonneville Dam PH2 during March and early April.

C. METHODS

We propose to use split-beam hydroacoustic technology and acoustic camera technology to estimate to what extent kelt use the B2CC prior to the start of operations to pass juvenile salmon at Bonneville Dam in 2008 and to what extent they may be drawn into turbine Unit 11.

<u>DIDSON</u>

We propose to use a DIDSON acoustic camera mounted on a barge located to the southeast of the B2CC entrance to record kelt paths immediately upstream of the B2CC employing methods similar to those used in 2004 to evaluate passage of salmon smolt into the B2CC (Ploskey et al. 2005). The DIDSON will be oriented across the intake just upstream of the weir and a rotator used to adjust the orientation of the DIDSON relative to the B2CC entrance due to changes in forebay water level (Figure 1). We will estimate the proportion of kelt entering the B2CC relative to the proportion that find the B2CC but swim away from the entrance.

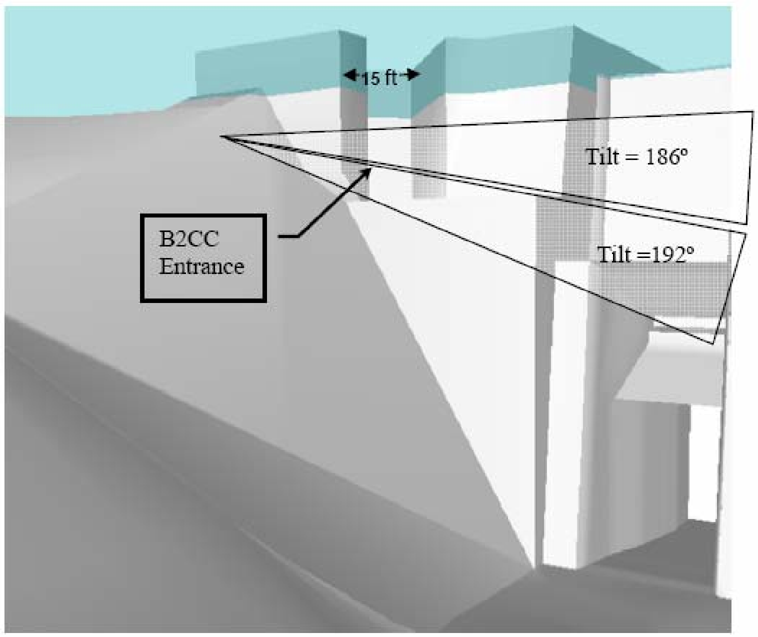


Figure 1. Orientation of the DIDSON relative to the B2CC. The DIDSON will be mounted on a barge as described below for the hydroacoustics.

HYDROACOUSTICS

We propose to also sample kelt entering the B2CC with hydroacoustic equipment using the same methods used in 2004 and 2005 to monitor smolt passage (Ploskey et al. 2005) and in 2007 (in press) to monitor kelt passage. This will involve locating six split-beam transducers on a vertical pipe about 20 ft to the southeast of the entrance of the B2CC on a barge so that acoustic beams can be aimed across the entrance. Fish will be detected mostly in side aspect, thereby maximizing signal to noise ratios and fish detection (Figure 2). The pipe supporting the vertical array of six transducers will be rotated to aim acoustic beams about 12-15 ft upstream of the entrance where flows are sufficient to capture smolts and possibly kelt (8-10 ft / s) but low enough to allow adequate detectability. With a ping rate of 37 pings / s, a fish moving 10 ft / s through the center of an acoustic beam would provide 7 echoes if it passed into the entrance on the south side and 13 echoes if it passed on the north side of the intake. Four echoes are the minimum required to classify an echo trace as a fish. The upper two split-beams will have nominal 3-degree acoustic beams to minimize volume reverberation, which typically is worst near the surface. The lower four transducers will have nominal 6-degree acoustic beams. The count of every detected fish will be spatially expanded by the ratio of the height of the rectangle it samples to the diameter of the acoustic beam at the range a fish is detected. Whenever forebay elevations range from EL 74.1-76.0 ft, the deployment will provide passage distribution data within 11 1.85 ft vertical strata in the upper 20.35 ft of the water column and within one variable 1.85-3.75 ft strata below that depth. When forebay elevations are between EL 70.5 and 74.1 ft, the deployment will provide passage distribution data within 10 1.85 ft vertical strata in the upper 18.5 ft of the water column and within a 4.5 ft stratum below 18.5 ft. The vertical resolution is possible because tracked fish can be classified as being in the upper or lower one half of the beam. Laterally, the deployment will provide estimates of passage distribution to the nearest 0.5 ft across the 15-ft wide entrance.

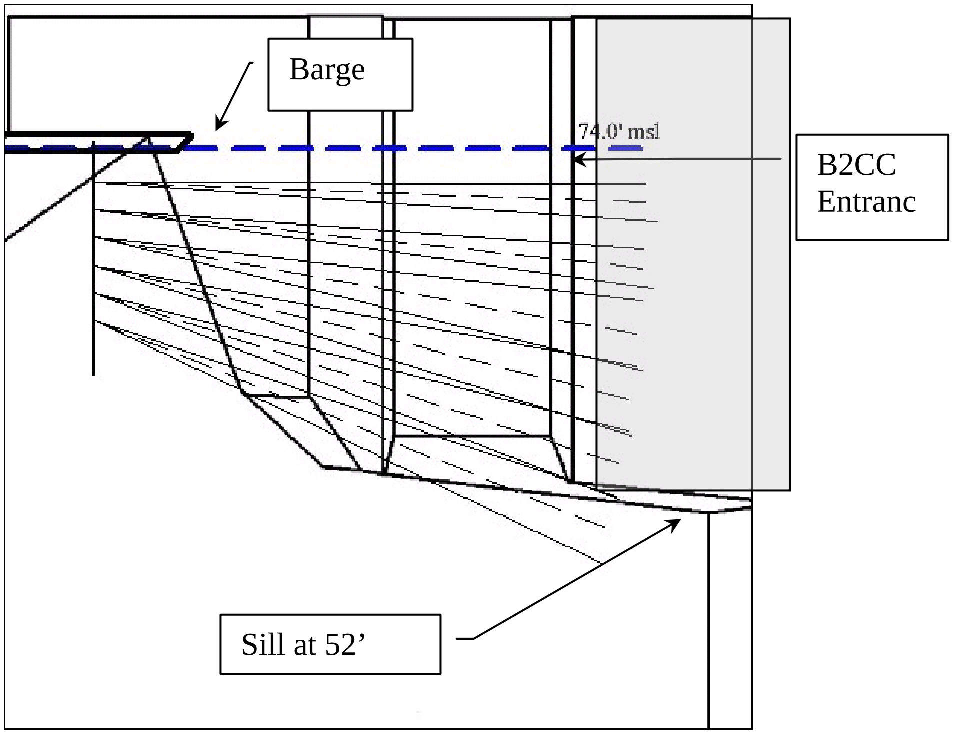


Figure 2. Diagram of a Frontal View of the B2CC Entrance Showing the Acoustic Beams from Six Split-beam Transducers Deployed from a Barge East of the Entrance. Minimum and maximum ranges for tracking fish were 15 and about 29.5-36 ft (depending upon the beam), respectively.

A second deployment of hydroacoustic transducers will be mounted on the trash racks of each of the three intakes of Unit 11 to monitor kelt potential passage through the turbine unit for fish that were drawn toward the B2CC but passed into the turbine or were guided by the STS. Transducers will sample the vertical distribution of fish immediately upstream of the STS and will provide hourly estimates of fish passage during March and early April. One transducer of each pair will be mounted at the bottom vertical center of the uppermost trash rack and aimed downward to sample unguided kelt passing below the tip of the STS. The second transducer of each pair will be mounted on the bottom of the fourth trash rack from the top and aimed upward to sample fish passing above the tip of the screen (Figure 3).

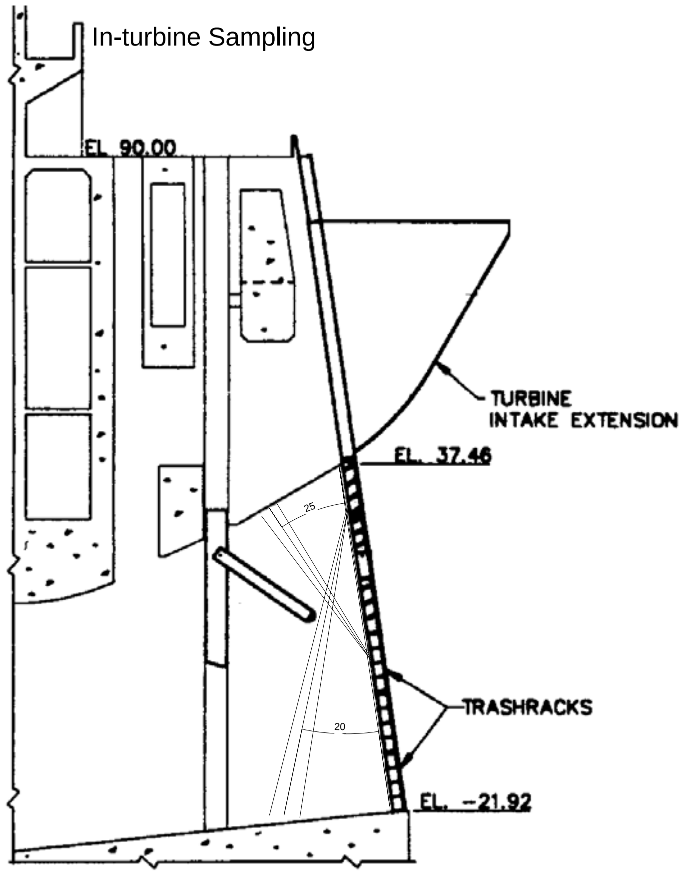


Figure 3. Cross section of a Powerhouse 2 intake showing the deployment of two transducers for sampling the vertical distribution of fish downstream of trash racks and for estimating the fish guidance efficiency of a submerged traveling screen.

D. SAMPLING PERIOD

Kelt passage will be sampled continuously from March 1 until the start of operations to pass juvenile salmon at Bonneville Dam in early April.

E. LIMITATIONS/EXPECTED DIFFICULTIES

We expect few difficulties with completing the planned objectives. Clear and timely communication between Pacific Northwest National Laboratory (PNNL) and the Corps will be essential to minimize difficulties. We have successfully worked with Corps personnel at mainstem hydroelectric projects in the Columbia River basin and at Bonneville Dam specifically.

F. EXPECTED RESULTS AND APPLICABILITY

We expect to accurately estimate numbers of kelt passing at the B2CC and Unit 11 and provide the region with information to make decisions regarding operation of the B2CC for kelt passage. The

DIDSON data will provide additional data on kelt approach and if the fish are entrained by the flow or swim away from the entrance.

G. SCHEDULE

We are aware that the sampling design will be reviewed by various State and Federal agencies and is subject to the approval of the National Marine Fisheries Service under the Endangered Species Act. We understand this means the sampling design may be modified before the start up date. Various technical reports are the deliverables for this study. The table below shows the milestone and deliverable schedule for FY08 work.

Schedule for Milestones and Deliverables

Date	Milestone	Deliverable
January 1, 2008	Start study	
Late January	Deploy and test equipment	
March 1-mid-Apirl	Data collection	
October 31	Preliminary Data Report	✓
November	AFEP presentation	
December 31, 2008	Draft Final Report	✓
60 days after receipt of comments	Final Report; end study	✓

H. FACILITIES AND EQUIPMENT

A DIDSON acoustic sonar, three spilt-beam transceivers, 4 computers and 6 transducers will be used for sampling the B2CC, a barge will also be needed to mount the gear on the sluice entrance. Another split-beam transceiver, computer, and 6 transducers will also be needed for sampling Unit 11 at Powerhouse 2. All required hydroacoustic sounders, transducers, computers, DIDSON and barge are available for the deployment described above.

I. IMPACTS

Project assistance in the form of riggers and crane support will be required to deploy a barge and acoustic equipment at the B2CC and transducer mounts at Unit 11 of Powerhouse 2. Once equipment has been installed, crane support will not be needed unless transducers or cables fail. Deep transducers installed in Powerhouse 2 will require the project to rake trash on those intakes and pull the four upper trash racks. It will take approximately two days to deploy the barge with acoustic gear and mount transducers on the track racks of Unit 11. Very close coordination and advanced planning will be required for this study to assure that all transducers are installed before opening of the B2CC on March 1.

Equipment installation must begin by late-January to assure that all equipment is installed and operational before sampling begins on March 1. A work trailer will have to be located on the south end of Powerhouse 2. All trailers will have to be supplied with electricity. The Project has transformers purchased for the purpose of running power to trailers. Project support also will be required to pull trash racks if any hydroacoustic equipment fails.

J. COLLABORATIVE ARRANGEMENTS AND/OR SUB-CONTRACTS

The PNNL will collaborate with all other researchers performing specific studies at Bonneville Dam in 2008.

IV. LIST OF KEY PERSONNEL AND PROJECT DUTIES

Mark Weiland (PNNL)	Senior Scientist and Co-Leader - all aspects
Fenton Khan (PNNL)	Scientist and Co-Leader - all aspects
Gene R. Ploskey (PNNL)	Senior Scientist and Co-Leader - all aspects
James Hughes (PNNL)	Setup, surveying, and deployment
Shon Zimmerman (PNNL)	Setup, surveying, and deployment
Bill Nagy, FFU, CENWP	Acoustic data processing, DIDSON data processing

V. TECHNOLOGY TRANSFER

Information acquired during the proposed work will be transferred in the form of written and oral research reports. A presentation will be made at the Corps' annual Anadromous Fish Evaluation Program Review. Technology transfer activities may also include presentation of research results at regional or national fisheries symposia, or publication of results in a scientific journal.

VI. LIST OF REFERENCES

National Marine Fisheries Service. 2000. Re-initiation of Consultation on Operation of the Federal Columbia River Power System, including the Juvenile Fish Transportation Program, and 19 Bureau of Reclamation Projects in the Columbia Basin. Biological Opinion. December 21, 2000, National Marine Fisheries Service, Northwest Region, Seattle, Washington.

Ploskey, G.R., C.R. Schilt, J. Kim, C.W. Escher, and J.R. Skalski. 2003. Hydroacoustic evaluation of fish passage through Bonneville Dam in 2002. Report by the Pacific Northwest National Laboratory, Richland, WA, for the U.S. Army Engineer District, Portland, OR.

Ploskey, G.R., M.A. Weiland, C.R. Schilt, P.N. Johnson, M.E. Hanks, D.S. Patterson, J.R. Skalski, J. Hedgepeth. 2005. Hydroacoustic evaluation of fish passage through Bonneville Dam in 2004. PNNL-15249 Pacific Northwest National Laboratory, Richland, WA.

VII. BUDGET

A detailed budget will be provided under a separate cover.

PRELIMINARY RESEARCH PROPOSAL (COE) (FY08)

TITLE:	Migratory pheromones: potential tools to improve performance of adult lamprey passage structures at dams.
PROJECT LEADERS	Mary L. Moser and Andrew Dittman Fish Ecology Division and Resource Enhancement and Utilization Technologies Division Northwest Fisheries Science Center National Marine Fisheries Service 2725 Montlake Blvd. East Seattle, Washington 98112 (206) 860-3351; FAX (206) 860-3267
ADMIN. OFFICER:	Doug Dey Deputy Director, Fish Ecology Division Northwest Fisheries Science Center National Marine Fisheries Service 2725 Montlake Blvd. East Seattle, Washington 98112 (206) 860-3231
STUDY CODE:	ADS-P-00-8
PROJECT DURATION:	FY2008
SUBMISSION DATE:	October 2007

PROJECT SUMMARY

Research Goal

The goal of this work is to improve the efficacy of lamprey passage structures at Columbia River hydropower dams and thereby increase adult lamprey passage at these facilities.

Study Objectives

1). To determine whether adult Pacific lamprey will follow a larval pheromone plume.

2). To determine the feasibility and safety of using larval pheromones to attract lamprey into lamprey passage structures at dams.

Methods

The ability to safely use larval pheromone as a tool to attract lamprey at lamprey passage structures depends on the sensitivity and behavioral responses of adult lamprey to this substance. In addition, it is imperative that lamprey artificially exposed to larval pheromone are able to orient and migrate normally following exposure. We propose conduct Y-maze experiments which offer adult lamprey the opportunity to choose between water with and without larval washings. If lamprey behavior is mediated by the presence of larval washings, we will conduct a second set of experiments to determine if lamprey exhibit the same responses (i.e., can resume normal migratory behavior) after pre-exposure to high concentrations of larval pheromone.

Relevance

The Columbia Basin Pacific Lamprey Technical Workgroup (a subgroup of the CBFWA Anadromous Fish Committee) has identified the need to improve lamprey passage and survival at Columbia River hydropower dams as the highest priority for lamprey recovery. A petition to list both the anadromous Pacific lamprey (*Lampetra tridentata*) and the resident western brook lamprey (*Lampetra richardsoni*) as federally-endangered or threatened species was submitted in 2002 to the U.S. Fish and Wildlife Service. Moreover, concerns about poor lamprey passage at hydropower dams have been raised repeatedly by Columbia River treaty tribes, for which lamprey are an important cultural resource (Close et al. 2002). This project will address concerns raised by tribal agencies, the U. S. Army Corps of Engineers (COE), and the Northwest Power Planning Council in section 7.5F of the 1994 Columbia River Basin Fish and Wildlife Program, related to effects of FCRPS projects on passage of Pacific lamprey in the Columbia and Snake rivers. These concerns have become increasingly urgent as adult lamprey abundance reached a record low in 2007. This project will specifically address the issue of improving adult lamprey passage at lower Columbia River dams by striving to improve the efficacy of lamprey-specific passage structures.

PROJECT DESCRIPTION

Background

Pacific lamprey (*Lampetra tridentata*) are anadromous, spawning in freshwater tributaries to the Columbia River. Radiotelemetry work in 1997 – 2002 indicated that adult Pacific lamprey passage at lower Columbia River dams was low relative to salmonids. For example, passage efficiency (the percentage of lamprey that successfully passed over the dam of those that approached the dam base) at Bonneville Dam was less than 50% in all years (Moser et al. 2005). This occurred in spite of the fact that approximately 90% of the lamprey tagged in all years of study returned to the base of the dam after release downstream, indicating migrational motivation and low tagging effects (Moser et al. 2002). These results indicate that lamprey passage through the hydropower corridor in the Columbia and Snake rivers may be a primary factor contributing to the decline of this species.

In 2002, efforts were begun to develop lamprey-specific passage structures (LPSs). The fishways at hydropower dams were specifically designed to accommodate salmonid behavior. Consequently, many features of these fishways represent obstacles for adult lamprey, as lamprey exhibit very different swimming performance and behaviors. The LPS prototypes were designed to allow for lamprey behaviors, including attraction to seeps and trickling flows, frequent milling and searching in fishways, and the ability to climb steep inclines in very low water volumes (Figure 1). While over 95% of the lamprey that enter these devices are able to pass through them successfully (Moser et al. 2006), attracting lamprey into LPS collectors can be challenging. For example, a prototype lamprey collector at the Washington-shore downstream fishway entrance has exhibited limited collection efficiency due to the relatively small collection area relative to the dimension of this fishway entrance (Figure 2).

Figure 1. Lamprey ascending a lamprey-specific passage structure (LPS) at Bonneville Dam.

Figure 2. Lamprey collector at the Washington-shore downstream fishway entrance.

The highest lamprey collector efficiencies have been recorded when the collectors are positioned in dead-end channels where the fish accumulate and have multiple opportunities to find the collector ramps. In contrast, collectors at fishway entrances must be extremely attractive to effectively collect lamprey over such large areas, which are also characterized by high and turbulent flows (Figure 2). Yet, achieving good collection efficiency at problem fishway entrances is a high priority and could result in large improvements to overall lamprey passage. This is particularly true at fishway entrances like those at the Bonneville Dam spillway, where entrance success has regularly been less than 65% (Moser et al. 2005). While lamprey are clearly attracted to certain flow fields, extensive research on sea lamprey (*Petromyzon marinus*) and pilot work with Pacific lamprey has indicated that these adults also use olfactory cues to orient during spawning migrations. We plan to test whether use of olfactory cues could be used to guide adult Pacific lamprey into LPS structures.

After hatching, juvenile Pacific lamprey (ammocoetes, Figure 3) bury into silty substrate and assume a sedentary life style for up to 7 years (reviewed in Close et al. 2002). A working hypothesis is that during this period, they produce a mixture of bile acids which are attractive to the adults, as is the case with sea lamprey (reviewed in Dittman 2005). Laboratory experiments of olfactory organ activity (measured via electro-olfactogram, EOG) have indicated that Pacific lamprey detect synthesized bile acids (petromyzonol sulfate and 3-keto petromyzonol sulfate (Close et al. 2003). Therefore, it is likely that Pacific lamprey use these and other larval pheromones to localize spawning streams.

Figure 3. Juvenile lamprey prior to metamorphosis (ammocoete) collected in the Snake River drainage. Photo courtesy of J. M. Capurso.

The next step is to determine whether adult Pacific lamprey will alter their migratory behavior in response to an olfactory cue in the form of larval pheromone. If so, is this behavioral modification strong enough to motivate them to move onto an LPS collector? Field and laboratory studies have indicated that larval (migratory) pheromone in sea lamprey guides adult lamprey into spawning streams (reviewed in Sorenson et al. 2003). On the spawning grounds, experiments using male sex pheromones to attract maturing female sea lamprey have indicated that these adults can be guided into traps in tributary streams of the Great Lakes (Johnson et al. 2005). Will the Pacific lamprey migratory pheromone be sufficiently attractive to induce adult lamprey to follow a pheromone plume into an LPS collector? If so, will pre-exposure to this pheromone alter normal upstream migratory behavior of fish that have been thus attracted?

Study Objectives

1). Determine whether adult Pacific lamprey will follow a larval pheromone plume.

2). Assess feasibility and safety of using larval pheromones to attract lamprey into lamprey passage structures at dams.

Methods

Objective 1). Determine whether adult Pacific lamprey will follow a larval pheromone plume.

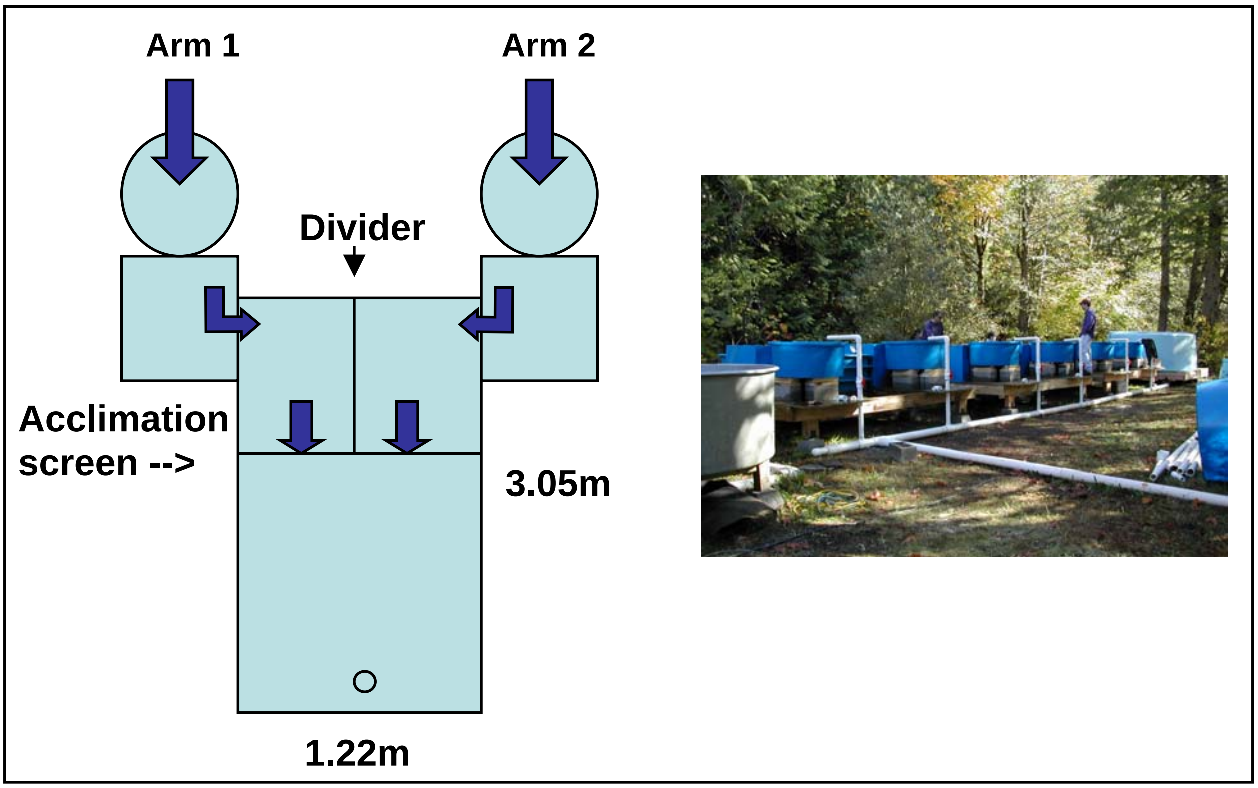
We will use Y-maze experiments to determine the sensitivity and response of adult lamprey to larval washings, following the general approach of sea lamprey researchers (reviewed in Sorenson et al. 2003). Y-maze experiments will be conducted at the existing Y-maze complex at Big Beef Creek field station (Figure 4). Each of the three Y-mazes at this facility can alternatively be supplied with well water and/or water from Big Beef Creek, which harbors larval lamprey populations. For these experiments lamprey will initially be anaesthetized, measured, weighed, and individually tagged by surgically implanting a half duplex passive integrated transponder (HD-PIT) tag in the body cavity following methods of Moser et al. (2006). Adult lamprey will be introduced into each Y-maze downstream from the acclimation screen and allowed to acclimate during the day prior to experimentation. All experiments will be conducted at night. HD-PIT detectors will be installed in the floor and sides of each arm of the Y-maze to allow continuous recording of lamprey behavior. Tests will be conducted to confirm that there is no arm bias (control) and to determine whether lamprey preferentially choose the arm where larval pheromone is introduced (treatment). The number of times lamprey cross each of two HD-PIT antennas in each arm will be used to quantify lamprey entry and residence in each arm. Relative percent time spent in each arm will be computed and compared to the expected value of 50% (no preference) using a one-tailed t-test (as in Vrieze and Sorenson

2001).

Objective 2). Assess feasibility and safety of using larval pheromones to attract lamprey into lamprey passage structures at dams.

If lamprey prove to be responsive to larval pheromone and will follow a pheromone plume (results of Objective 1), a secondary objective of this work is to determine the duration of this response. Will lamprey resume upstream migration after exposure to an artificially high concentration of larval pheromone? This question is critically important to the application of pheromones at dams. While lamprey may be attracted into an LPS using a pheromone signal, this may irrevocably alter the ability of exposed lamprey to orient to normal olfactory signals thereafter. To test this, we propose to conduct the same regime of experiments outlined in Objective 1 on adult lamprey that have been pre-exposed to larval pheromones at levels that elicited behavioral attraction in the Y-maze experiments.

Figure 4. Y-maze complex at the Big Beef Creek field station.



Facilities and Equipment

The Y-maze complex have been used extensively for research on olfactory responses of salmonids by Dr. Dittman and his staff. The Y-maze complex houses three, independent experimental chambers (Y-mazes) to allow multiple trials in a given night. It also features use of either well water (pheromone-free) or ambient Big Beef Creek water (larval lamprey-laced) water in sufficient volumes to run all three chambers at flows exceeding those we plan to use in the lamprey experiments (30 cm/s).

Potential Limitations

The ability to conduct these experiments will depend on the availability of migrating adult Pacific lamprey for testing. We assume that the olfactory responses exhibited by adult Pacific lamprey can be applied across populations. Therefore, access to adult lamprey will not be limited to one specific source (Big Beef Creek) and should allow us enough flexibility in obtaining sufficient numbers of fish for the experiments (n = 60).

Project Impacts

Division or district Corps personnel will be needed to provide technical review of research proposed for 2008. The proposed activities will be coordinated with ongoing projects funded by the Corps of Engineers, the Bonneville Power Administration, and others. We do not anticipate any other project impacts.

Technology Transfer

This study has broad applicability to ongoing efforts by state, federal, and tribal fisheries managers and hydropower operators to recover lamprey populations. The principal investigator will insure that information and analyses from this work are available to resource managers via presentations at professional meetings, workshops, and when otherwise requested. Technical findings may be published in peer-reviewed journals.

Key Personnel and Duties

Drs. Mary Moser and Andrew Dittman will design and oversee experiments, analyze data, and report findings.

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Continuing Research Preliminary Proposal

Improving Adult Pacific Lamprey Passage and Survival at Lower Columbia River Dams - 2008

Study Code: ADS-P-00-8

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For the period: 1 January 2008 to 31 December 2008

Submitted October 2007

Study Summary

A. Goals

The goal of this study is to develop and evaluate aids to passage and survival of adult Pacific lamprey *Lampetra tridentata* at lower Columbia River dams.

B. Objectives - 2008

1. Assess lamprey use of lamprey passage structures (LPSs) at Bonneville Dam auxiliary water supply (AWS) channels and develop aids to lamprey passage at the Cascades Island fishway exit.

2. Evaluate methods to improve passage of adult lamprey at fishway entrances at Bonneville and John Day dams.

3. Determine lamprey passage success and passage times between Bonneville, The Dalles, and John Day dams using radiotelemetry and HD PIT detection systems.

4. Evaluate lamprey behavior in the experimental fishway to develop optimal bottom configurations for lamprey at fishway entrances.

C. Methods

Efforts to aid adult lamprey passage and protect them during dewatering operations have expanded in recent years. They include installation of lamprey passage structures (LPSs) at the Bradford Island and Washington-shore auxiliary water supply (AWS) channels, development of a prototype lamprey collector at the northwestern main entrance to the Washington-shore fishway at Bonneville Dam, and installation of lamprey-friendly diffuser grating material at Pool 16 of the John Day Dam south fishway. In addition, testing of reduced nighttime flow regimes at WA-shore fishway entrances was implemented in 2007. In 2008, we propose to continue these activities and to begin development of lamprey passage aids at the Cascades Island fishway exit, and at John Day Dam (priority sites to be determined based on 2007 radiotelemetry results).

Continued monitoring of adult lamprey movements via both radiotelemetry and passive integrated transponder (PIT) technology is needed to both assess the efficacy of these structures/operations, and to allow effective siting and design of future passage/protection measures. To this end, we propose to tag up to 300 lamprey with radio transmitters and 1700 lamprey with half-duplex (HD) PIT tags. An additional 300 fish will receive both radio and HD-PIT tags to allow evaluation of detection efficiency for each system and determine LPS use by radio-tagged fish. PIT-detectors at fishway entrances and exits, and additional detectors that are integrated into each LPS will allow calculation of overall lamprey passage times, passage efficiency, and route selection.

HD-PIT readers and antennas installed at fishway exits at The Dalles and John Day dams will also be used to estimate lamprey passage times and passage success rates between dams (using fish released downstream from Bonneville Dam). Moreover, intensive monitoring of radio-tagged fish will allow determination of fine-scale spatial movements around fishway entrances, and comprehensive assessment of problem areas, particularly at John Day Dam, where previous radiotelemetry data are extremely limited.

Tests conducted in an experimental fishway have been used to evaluate swimming performance and behavior of adult lamprey, and results have been used to refine the LPS devices at Bonneville Dam. Past studies have focused on effects of velocity, weirs structures, diffuser grating, count windows, and lighting on lamprey performance. More recent tests have been conducted to refine entrance ramp and rest box structures incorporated into LPS devices. In 2008, we propose to use such experiments to identify bottom configurations at fishway entrances that optimize lamprey collection and passage.

D. Relevance

Improving lamprey passage at Columbia River hydropower dams was identified as the highest priority for lamprey recovery by the Columbia Basin Pacific Lamprey Technical Workgroup (a subgroup of the CBFWA Anadromous Fish Committee). A petition to list Pacific lamprey as a federally-endangered or threatened species was submitted in 2002 to the U.S. Fish and Wildlife Service. In 2007, adult lamprey abundance counted at Columbia River dams was the lowest recorded in recent time and lamprey declines have raised concern among tribal agencies throughout the Columbia River basin (Close et al. 2002). This project will address concerns raised by tribal agencies, the U. S. Army Corps of Engineers (COE), and the Northwest Power Planning Council in section 7.5F of the 1994 Columbia River Basin Fish and Wildlife Program, related to effects of FCRPS projects on passage of Pacific lamprey in the Columbia and Snake rivers. This project will specifically address the issue of improving adult lamprey passage at dams which has been raised repeatedly by Columbia River tribes. It will also initiate research to reduce lamprey losses that occur during dewatering operations at lower Columbia River dams.

Project Description

A. Background

Pacific lamprey are anadromous and adults must pass up to eight or nine dams and reservoirs to reach spawning areas historically used by the species: up to four dams in the lower Columbia, five in the mid Columbia, and four in the Snake (Close et al. 1995). This project was initiated to gain information on migration behavior of adult lamprey, and to improve their passage at Columbia and Snake River dams.

Development of this proposal was prompted by requests for preliminary proposals issued by the COE in June of 1994 and subsequent years, and it addresses concerns raised by the COE, the Northwest Power and Conservation Council in section 7.5F of the 1994 Columbia River Basin Fish and Wildlife Program. This proposal was developed via consultation with the COE, and in response to the high priority assigned to adult passage research in the Columbia and Snake rivers by the former Fish Research Needs and Priorities subcommittee of the Fish Passage Development and Evaluation Program, and the current Anadromous Fish Evaluation Program.

Radiotelemetry work in 1997–2002 indicated that adult Pacific lamprey passage efficiency (the percentage of lamprey that successfully passed over the dam of those that approached the dam base) at Bonneville Dam was less than 50% in all years (Moser et al. 2002b, Moser et al. 2005b). This occurred in spite of the fact that approximately 90% of the lamprey tagged in all study years returned to the base of the dam after release downstream, indicating migrational motivation and low tagging effects (Moser et al. 2002a). Passage efficiency for lamprey that approached The Dalles Dam was consistently higher than at Bonneville Dam, while passage efficiency at John Day Dam was usually lower than at Bonneville Dam. These data indicated that lamprey passage is restricted by the dams, particularly Bonneville and John Day, and that these projects may be contributing to declines in basin-wide lamprey abundance.

Models of lamprey passage rates at Bonneville and The Dalles dams further support the observation that lamprey pass more easily at The Dalles Dam than at Bonneville Dam (Moser et al. 2005c). Delay of lamprey below Bonneville Dam may subject them to increased predation pressure from sea lions and sturgeon (R. Stansell, U.S. Army Corps of Engineers, personal communication). Models of lamprey passage rates at both Bonneville and The Dalles dams indicated that lamprey delay decreased with time of year (Moser et al. 2005c). That is, during the course of the summer, lamprey passage rates at these dams increased. These data suggest that lamprey are most delayed during the early part of the season (May-June) when water temperatures are low and sea lion abundance at the base of Bonneville Dam is highest.

Of particular concern is poor performance of lamprey at fishway entrances, through collection channels/transition areas, and past vertical slot fishways at the top of the fishways at Bonneville Dam (Moser et al. 2002b). Tracking results indicated that lamprey pass the count window, but are obstructed in the section of the fishway ladder containing the vertical-slot weirs upstream from the count stations (Moser et al. 2003). Previous years of radiotelemetry indicated that providing lamprey with an alternative route of passage through this area (Figure 1) could increase overall lamprey passage efficiency by approximately 33%.

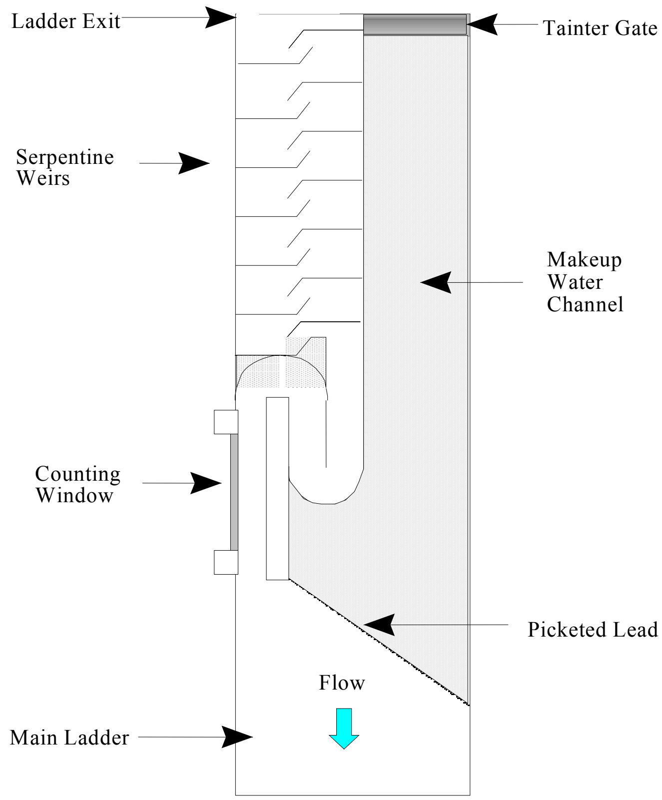

Figure 1. Overhead diagram of the top of the fishway at Bonneville Dam and the auxiliary water supply (AWS) channel referred to here as the makeup water channel.

Radiotelemetry results and visual observations indicated that lamprey obstructed in the serpentine weir section at the top of the fishway can accumulate in the adjacent auxiliary water supply (AWS) channel (Figure 1). Because this area posed a significant threat to lamprey passage, we developed two prototype bypass collectors in 2002 to see if lamprey could be collected from the AWS channel at the top of the Bonneville Dam Bradford Island fishway (Figure 2) (Moser et al. 2005b). Testing of passage alternatives for lamprey at this location was done without impacting salmon passage in the main fishway. Initial testing of the lamprey collectors indicated that lamprey would use them. Further design refinement and testing in 2003 resulted in collector efficiencies of up to 20% and catch rates > 250 lamprey/night (Moser et al. 2005a).

Figure 2. Prototype lamprey collectors tested in the Bradford Island AWS.

Figure 3. Dual ramps of the Bradford Island AWS LPS installed in 2006.

In 2004 we extended the collection device so that it exited directly into the Bonneville Dam forebay. With this extension, lamprey could move directly from the AWS to the forebay. This lamprey passage system (LPS) was used from the day it was installed and the number of lamprey passing through it increased with each year of operation (Table 1). In all years, this represented a significant percentage of the total lamprey count at the Bradford Island count station (Table 1). Consequently a more permanent LPS with dual collection channels was installed in 2006 (Figure 3). In 2007, we monitored lamprey use of this LPS using both a lamprey-activated counter and a HD PIT tag detection system. In addition, we installed a similar LPS at the Washington-shore AWS, and monitored its use using the same methods.

Table 1. The number of lamprey counted at the Bradford Island count station, the estimated total number of lamprey in the flow-control section of the Bradford Island fishway, and the percentage of all fish near the top of the ladder that used the LPS in 2004-2006.

	Count Station Count	Estimated Total	BI AWS LPS Count	%
2004	11,971	35,913	7,490	21
2005	10,257	30,771	9,242	30
2006	14,862	44,586	14,975	34

In 2008, we propose to continue monitoring lamprey use of the LPS structures at both AWS channels and to improve the exit slide design on each structure to reduce lamprey fallback. In addition, we plan to work with Bonneville Project personnel to develop operational changes at the Cascades Island fishway exit to potentially provide a lamprey passage route in that area during periods when this fishway is not operated for salmonid passage (most of the summer).

Radiotelemetry studies and test fishway experiments have demonstrated that lamprey have difficulty entering fishways. Telemetry studies at Bonneville Dam in 1998 through 2002 indicated that lamprey entrance efficiency was particularly low at the northwestern main entrance to the Washington-shore fishway (Moser et al. 2005b). During this period, less than 40% of the lamprey that approached this entrance were able to successfully enter the fishway (Moser et al. 2005b). In addition, over 50% of the radio-tagged lamprey initially approached the Washington-shore fishway entrances during years when PH2 had priority. Consequently, improving passage at this entrance should result in the greatest improvement to lamprey passage while PH2 has priority.

In 2005-07, we installed and evaluated a prototype entrance collector at the northwestern main entrance to the Washington-shore fishway at Bonneville Dam. Design elements were drawn from our experience with the AWS collectors and from behavioral observations in the experimental lamprey fishway. Due to the configuration of the site, it was necessary to install two separate components to this collector. A vertical transition structure was installed for subsurface collection of lamprey and to provide a platform for the ramp collector. The ramp rests on top of the vertical transition and ascends to a trap box for enumeration of collected fish (Figure 4). In 2007, we made further efforts to improve lamprey passage at this entrance by implementing a plan to reduce entrance velocities at night, when lamprey are most active. Performance of tagged lamprey at this entrance was compared during normal and reduced nighttime velocities in a blocked design.

To evaluate the entrance collector and the low flow operations, we used HD PIT tag antennas and readers at the Washington-shore fishway entrance collector, in the fishway and at the fishway exits to monitor tagged fish released downstream of the dam in 2005-07. In 2007, we also used radiotelemetry to assess the finer spatial patterns and timing of lamprey approaches to this entrance. In 2008, we plan to release both radio- and PIT-tagged lamprey below Bonneville Dam to further evaluate lamprey passage performance and use of LPSs under a variety of conditions (i.e., with and without sea lion gates in place, high and low flow conditions, increasing water temperature, etc.).

In 2006-07, HD PIT interrogators were installed at the tops of ladders at The Dalles and John Day dams. By monitoring the fish released at Bonneville Dam, these additional readers provide a measure of passage success and travel times between the three lower Columbia River dams. The effectiveness of both monitoring systems (radio and HD PIT) will be evaluated in 2008 by tagging a group of lamprey with both tag types. This will allow comparison of both detection capability and potential tag effects.

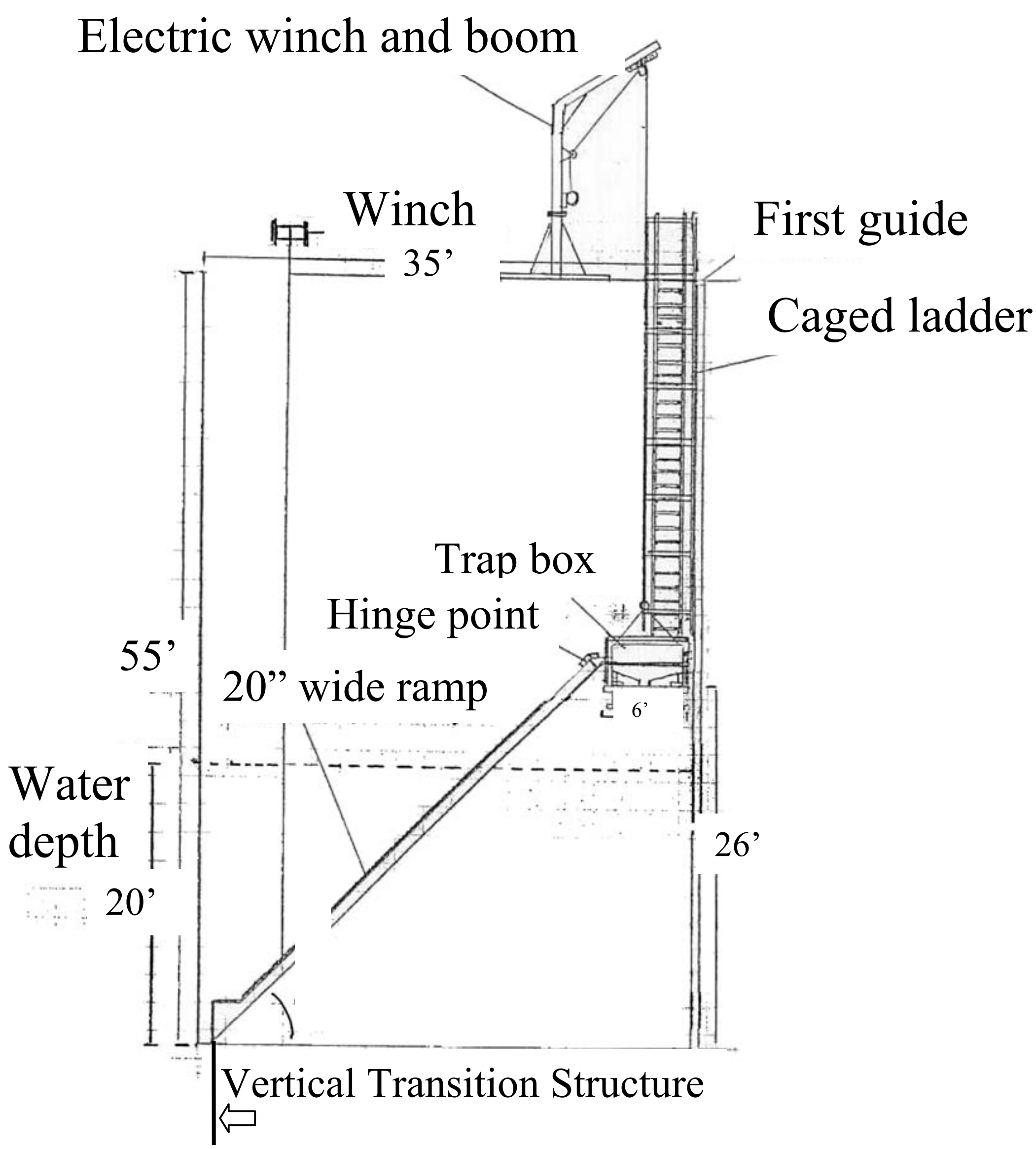

Figure 4. Side view of the collector, trap box, and caged ladder at the northwestern entrance to the Washington-shore fishway. Note that the distal end of the ramp seats seamlessly on top of the vertical transition structure.

In 1998, we initiated controlled tests to evaluate lamprey swimming ability and assess passage performance under various flow conditions. These initial trials led to development of a test flume that allowed more detailed tests on the behavior and swimming performance of lamprey exposed to different structures and flow conditions (Daigle et al. 2005). For example, we documented that lamprey could eventually pass normal weired sections of fishways, but could be delayed by diffuser grating, lips, and other structures with sharp corners under certain flow conditions. However, slight modifications that provided lower velocity corridors or better attachment points could be used to improve passage performance. Later tests were used to evaluate design components that could be incorporated into lamprey-specific structures to augment or even replace existing salmon fishways as lamprey passage alternatives. Studies planned for 2008 will focus on fishway entrance configurations that result in the highest lamprey passage at Bonneville and other FCRPS dams.

B. Objectives - 2007

1. Assess lamprey use of lamprey passage structures (LPSs) at Bonneville Dam auxiliary water supply (AWS) channels and develop aids to lamprey passage at the Cascades Island fishway exit.

2. Evaluate methods to improve passage of adult lamprey at fishway entrances at Bonneville and John Day dams.

    2.1. Monitor lamprey use of the prototype collector at the Bonneville Dam Washington-shore downstream fishway entrance

    2.2. Evaluate efficacy of reduced nighttime entrance velocities to increase passage efficiency at Bonneville Dam Washington shore ladder.

    2.3. Develop and evaluate entrance modifications and aids to lamprey passage at John Day Dam and other locations.

3. Determine lamprey passage success and passage times between Bonneville, The Dalles, and John Day dams using radiotelemetry and HD PIT detection systems.

4. Evaluate lamprey behavior in the experimental fishway to develop optimal bottom configurations for lamprey at fishway entrances.

C. Methods

1. Assess lamprey use of lamprey passage structures (LPSs) at Bonneville Dam auxiliary water supply (AWS) channels and develop aids to lamprey passage at the Cascades Island fishway exit.

Lamprey are able to move directly into the auxiliary water supply (AWS) channel at the top of the Bradford and Washington-shore fishways from the adjacent vertical slot fishways via grates in the wall or via picketed leads at the downstream end of the AWS channel (Figure 1). Lamprey that enter the Bradford Island AWS either fall back downstream or pass through the Tainter gate to reach the forebay of Bonneville Dam. In 2002-05, we designed, built, and installed a lamprey passage system (LPS) to aid adult lamprey passage from the AWS at Bradford Island to the forebay of Bonneville Dam (Figure 5). In 2006, dual ramps were added to the structure (Figure 4) and the lamprey-activated counter at the exit slide (Moser et al. 2006) was modified to incorporate a time stamp for each lamprey passage event.

Due to the success of the first AWS LPS, a second LPS was installed in the Washington-shore AWS channel in 2007. While generally similar in design to the Bradford Island AWS LPS, the Washington-shore structure featured a switchback design to achieve greater vertical elevation over a shorter horizontal distance (Figure 6). Final installation of the Washington-shore AWS LPS was completed in late-June, so it was not operational for the entire lamprey migration in 2007. In 2008, we plan to tag up to 1,700 lampreys with HD PIT tags and release them below Bonneville Dam to further assess use of this and the Bradford Island AWS LPS. These tagged fish may also be detected by LPS PIT antennas and/or antennas positioned in the fishways and at fishway entrances and exits (see Objectives 2 & 3). These detections will allow: 1) evaluation of the percentage of lamprey that use each passage route, 2) computation of total passage efficiency at Bonneville Dam, and 3) assessment of the degree to which the LPSs improve overall passage efficiency. These measures will be compared to those from previous years of LPS work.

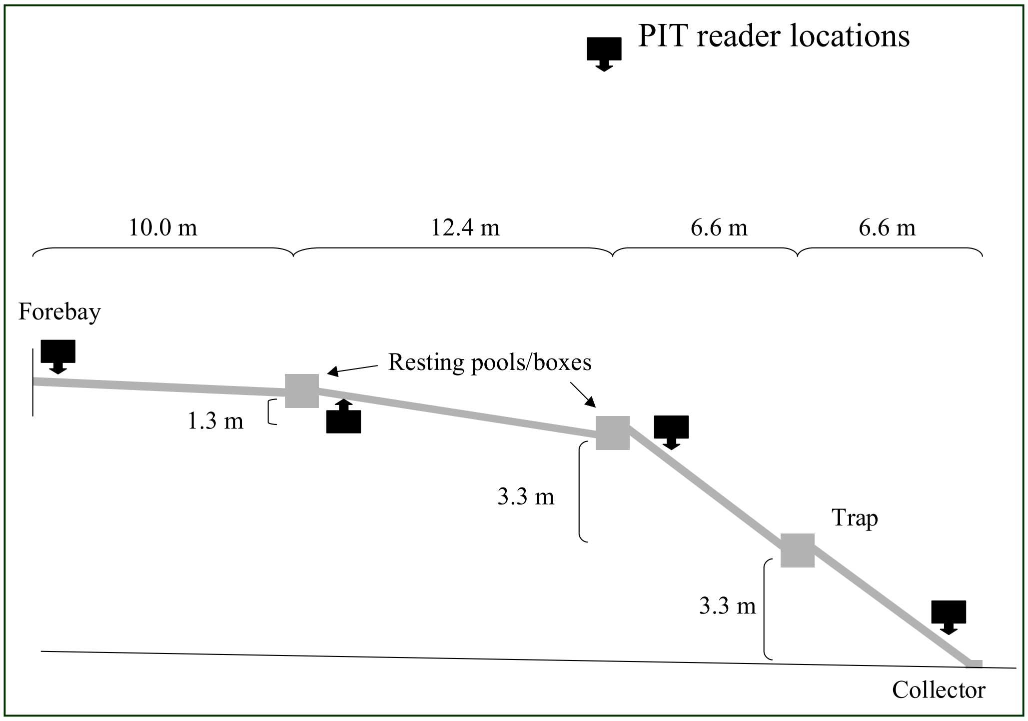

Figure 5. Schematic of the LPS at the Bradford Island AWS channel.

Figure 6. View from above of the Washington-shore AWS LPS collector ramps, and first rest box.

HD-PIT detections in 2006 and 2007 indicated that significant numbers of lamprey entered the Cascades Island fishway and may become trapped in the AWS at the top of this ladder (which is not operated for salmonid passage during most of the lamprey migration period (June-September). Further examination of the Cascades Island fishway exit revealed that it might be possible to operate this area for lamprey passage by diverting some AWS flow into the fishway and providing a passage route for lamprey near the stop logs at the upper end of the fishway (Figure 7). In 2008, we propose to work with project personnel to determine whether minor operational and structural changes to this area could be made to aid lamprey passage in an area that now represents a dead end to lamprey migration.

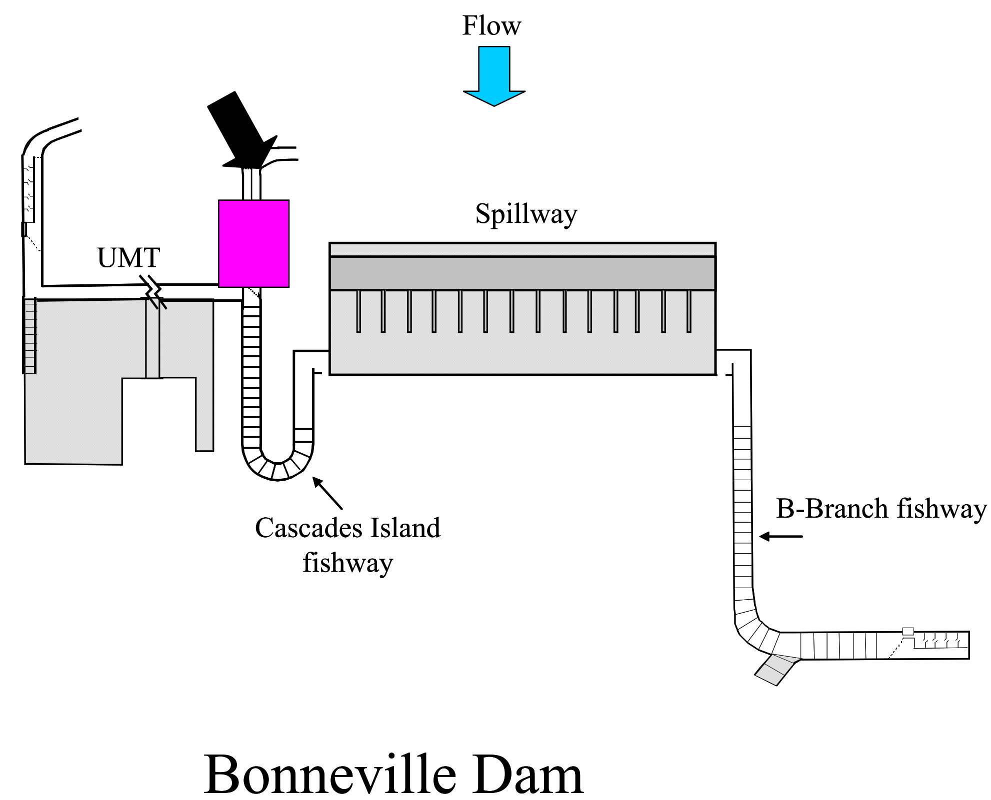

Figure 7. Location of the Cascades Island AWS channel entrance (shaded box) and location of the stop logs at the upper end of the Cascades Island fishway exit (black arrow).

2. Evaluate methods to improve passage of adult lamprey at fishway entrances at Bonneville and John Day dams.

2.1. Monitor lamprey use of the prototype collector at the Bonneville Dam Washington-shore downstream fishway entrance

We installed a prototype entrance collector at the northwestern main entrance to the Washington-shore fishway in 2005 (Figure 4). In 2006 and 2007 we modified the entrance collector configuration to improve lamprey use of this structure. In addition, in 2007, we assessed lamprey use of this structure during both high and low velocity treatments conducted at night (see Objective 2.2). Lamprey use of the entrance collector in 2007 increased substantially relative to previous years of operation. We propose to conduct another year of evaluation of this structure in conjunction with the night time velocity test. This will allow evaluation of relative use of the entrance collector during high and low velocity conditions and will establish whether improvements in 2007 were due to reduced flow or structural changes to the collector (removal of sea lion bars). We will do this by implanting up to 2,000 lamprey: up to 1,700 with HD PIT tags, up to 300 with radio transmitters, and up to 300 with both tag types. These fish will be released below Bonneville Dam (same fish used for Objectives 1 & 3). The trap at the top of the entrance collector will be operated each night and any recaptures of tagged fish will be recorded and used to calculate collector efficiency and provide a basis for comparing results of PIT detections to entrance efficiencies obtained in previous years of radiotelemetry at the same fishway entrance.

In 2007, we radio-tagged adult lamprey to provide more information on both the siting of entrance collectors at Bonneville Dam and to evaluate ways to improve lamprey passage at John Day Dam. At this time, plans are underway to redesign the north fish ladder at John Day Dam and to incorporate lamprey-friendly elements in this design. In 2008 we will use radiotelemetry at John Day Dam to: 1) prioritize problem passage areas, 2) assess the efficacy of lamprey-friendly designs at the north fish ladder, 3) assess the feasibility of LPS installation (or other aids to lamprey passage) at the south ladder.

2.2. Evaluate efficacy of reduced nighttime entrance velocities to increase passage efficiency at Bonneville Dam Washington shore ladder.

Previous telemetry information indicates that adult lamprey do not easily enter fishway entrances. During 2007, we initiated a blocked test at Bonneville Dam to evaluate whether lowered entrance velocities (target of 4 fps; 0.5 ft of head) improve entrance efficiency and rates for radio-tagged adult lamprey at the Washington-shore fishway. In 2008, we propose to replicate this test.

As in the 2007 study (Table 2) , for 2008 we propose to alternate normal nighttime velocities and reduced velocities in two-day blocks from about 1 June through July. The order of treatments within blocks will be randomized. Treatments will be in effect from 2200 to 0600 hrs. The effectiveness of lowering velocities will be evaluated by monitoring performance of radio-tagged lamprey. Adult lamprey will be collected using existing traps in the Washington-shore fishway. Traps are set at night and removed during the day to reduce potential effects on salmonid movements. Each morning, traps will be checked. Lamprey collected will be measured (length, girth, weight), surgically outfitted with radio transmitters, and then released 1 km downstream from the Dam at Hamilton Island and Tanner Creek. Receivers and antennas in the tailrace of the dam and in and near the fishways will be used to assess the number of fish approaching fishway entrances, the proportion that successfully enter, times to enter, and other overall passage metrics relative to the entrance velocity treatment. We propose to tag up to 600 fish, approximately 10 fish per day, with radio transmitters for this evaluation and to facilitate other research objectives. In a preliminary assessment of radio-tagged lamprey during 2007, approximately 1/3rd of the lamprey approached the Washington-shore entrances. If this fraction holds for 2008, we would expect about 200 fish to approach the north entrances during the time treatments were being tested.

Table 2. Potential treatment and tagging schedule for night time velocity test at the Washington-shore fishway entrances in 2008.

		0.5 ft head = reduced velocity	
		Normal = Normal velocity	
Date	Mean lamprey count	Head (ft)	To Tag
1-Jun	216.7	Normal 1	9.0
2-Jun	298.7	0.5	9.0
3-Jun	221.0	Normal 2	9.0
4-Jun	281.3	0.5	9.0
5-Jun	503.1	Normal 3	9.0
6-Jun	665.0	0.5	9.0
7-Jun	605.4	Normal 4	9.0
8-Jun	533.0	0.5	9.0
9-Jun	566.1	0.5	9.0
10-Jun	595.9	Normal 5	9.0
11-Jun	669.3	Normal 6	10.0
12-Jun	774.1	0.5	10.0
13-Jun	634.0	0.5	10.0
14-Jun	707.3	Normal 7	10.0
15-Jun	524.1	0.5	10.0
16-Jun	771.4	Normal 8	10.0
17-Jun	660.7	Normal 9	10.0
18-Jun	729.4	0.5	10.0
19-Jun	751.6	0.5	10.0
20-Jun	679.1	Normal 10	10.0
21-Jun	862.1	0.5	10.0
22-Jun	826.4	Normal 11	10.0
23-Jun	1161.0	0.5	10.0
24-Jun	1021.7	Normal 12	10.0
25-Jun	1054.9	0.5	10.0
26-Jun	1122.7	Normal 13	10.0
27-Jun	1079.1	Normal 14	10.0
28-Jun	1118.4	0.5	10.0
29-Jun	832.1	Normal 15	10.0

30-Jun	948.9	0.5	10.0
1-Jul	1071.7	0.5	10.0
2-Jul	787.6	Normal 16	10.0
3-Jul	650.4	Normal 17	10.0
4-Jul	661.3	0.5	10.0
5-Jul	644.9	0.5	10.0
6-Jul	642.7	Normal 18	10.0
7-Jul	581.9	0.5	10.0
8-Jul	670.9	Normal 19	10.0
9-Jul	538.0	0.5	10.0
10-Jul	828.9	Normal 20	10.0
11-Jul	968.9	0.5	10.0
12-Jul	1039.4	Normal 21	10.0
13-Jul	1422.1	0.5	10.0
14-Jul	1037.7	Normal 22	10.0
15-Jul	919.4	0.5	10.0
16-Jul	723.0	Normal 23	10.0
17-Jul	667.6	0.5	10.0
18-Jul	806.7	Normal 24	10.0
19-Jul	599.1	Normal 25	10.0
20-Jul	777.0	0.5	10.0
21-Jul	580.0	0.5	10.0
22-Jul	723.9	Normal 26	10.0
23-Jul	702.1	Normal 27	10.0
24-Jul	578.7	0.5	10.0
25-Jul	581.1	Normal 28	10.0
26-Jul	502.7	0.5	10.0
27-Jul	413.4	0.5	10.0
28-Jul	507.3	Normal 30	10.0
29-Jul	587.7	Normal 31	10.0
30-Jul	493.4	0.5	10.0
31-Jul	393.7	Normal	10.0

2.3. Develop and evaluate entrance modifications and aids to lamprey passage at John Day Dam and other locations.

Modifications to fishways are continually being made to improve the effectiveness and efficiency of operating fish passage structures. As changes are made it is important that potential effects on lamprey migrations are considered. For example, new grating added to fishways should be of dimensions less likely to allow lamprey access to areas that can lead to loss or delay. New structures should also incorporate rounded surfaces, eliminate lips or abrupt edges, and provide adequate attachment points for lamprey, particularly in areas of fast (> 4 fps) water velocities. One area slated for structural change is at John Day Dam, where a variable width fishway entrance is being considered. The advantage of this structure is that it will simplify operations under changing flow conditions. However lamprey performance at such a structure is unknown. Data collected on lamprey performance at Bonneville, The Dalles and John Day dams during 2008 will be used to inform decisions regarding the effects of structural or operational changes on lamprey passage. We will consult with managers and project biologists on appropriate areas to increase monitoring coverage for PIT and radio-tagged fish to facilitate these evaluations.

3. Determine lamprey passage success and passage times between Bonneville, The Dalles, and John Day dams using radiotelemetry and HD PIT detection systems.

In 2007, we conducted the first comprehensive radiotelemetry-based assessment of lamprey passage in the lower Columbia River since 2002. We released 400 radio-tagged fish downstream from Bonneville Dam. The fish were collected at the Bonneville Adult Fish Facility and tags were surgically-implanted using methods of Moser et al. (2002b). The data obtained from this work were used to assess behavior around fishway entrances during low and high velocity conditions (see Objective 2), and to identify routes and rates of fishway passage at each dam. In 2008 we plan to increase the number of radio-tagged fish to 600 in order to obtain better estimates of passage routes and obstacles to passage at upriver dams (particularly John Day Dam).

A less expensive alternative for long-term monitoring of lamprey passage would be to employ use of half-duplex (HD) PIT tags. We have been investigating this technique by installing HD PIT readers at FCRPS dams to provide estimates of passage success and passage times between these projects. Design features we have evaluated include: antenna configuration (size, location, shielding), use of antenna mutiplexers (which allow differentiation of up to four antennas per reader), power requirements, reader storage, and data retrieval capabilities. In 2006-07, we developed new shielding techniques and antenna installations, evaluated two data logging methods, and explored integration of HD PIT information into the larger PTAGIS database.

Currently HD PIT readers and antennas are operational at multiple locations at Bonneville (Figure 8), and at the ladder exits at The Dalles and John Day dams. Data from HD PIT systems (including those operated at McNary Dam) have been used to determine passage efficiency and passage rates between dams (e.g. Figures 9 and 10). They are also being used to assist evaluation of the relative use of fishways and LPS structures at Bonneville Dam. As antenna performance and placements are improved, we expect this tool to allow better evaluation of specific passage metrics (e.g., entrance approaches, entrance efficiency, passage times through deifferent segments of the fishway structures, etc.). For 2008, the 1,700 lamprey HD PIT-tagged and released below Bonneville Dam for Objectives 1 and 2 can also be used to compute overall passage efficiency (lamprey use of the navigation locks is negligible (Moser et al. 2002b)). These estimates will be compared to those from previous years to determine whether passage improvements for lamprey have resulted in higher overall passage efficiecny at each project. In addition, we plan to tag 300 of the 600 radio-tagged fish with an HD PIT tag to allow more complete evaluation of both detection systems.

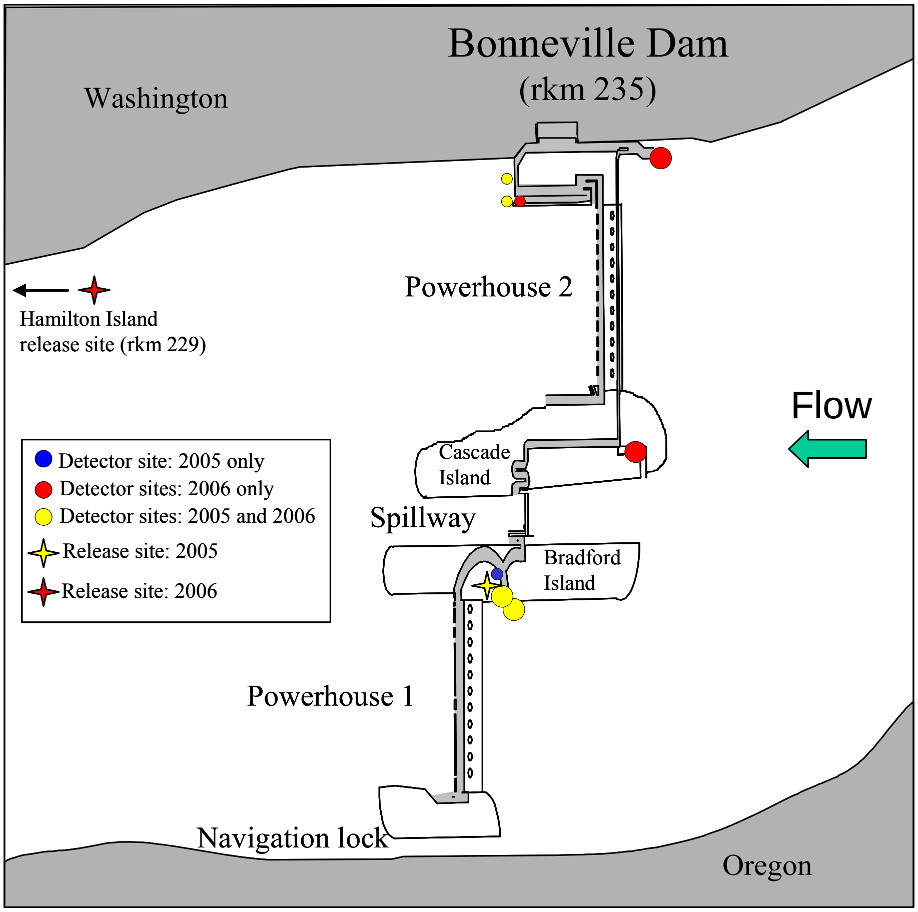

Figure 8. Study area at Bonneville Dam on the Columbia River. Release sites are indicated by yellow stars in 2005 and a red star in 2006. Yellow circles represent half duplex monitoring sites that were operational in 2005 and 2006; blue circles represent sites that were only operational in 2005 and red circles represent sites that were only operational in 2006.

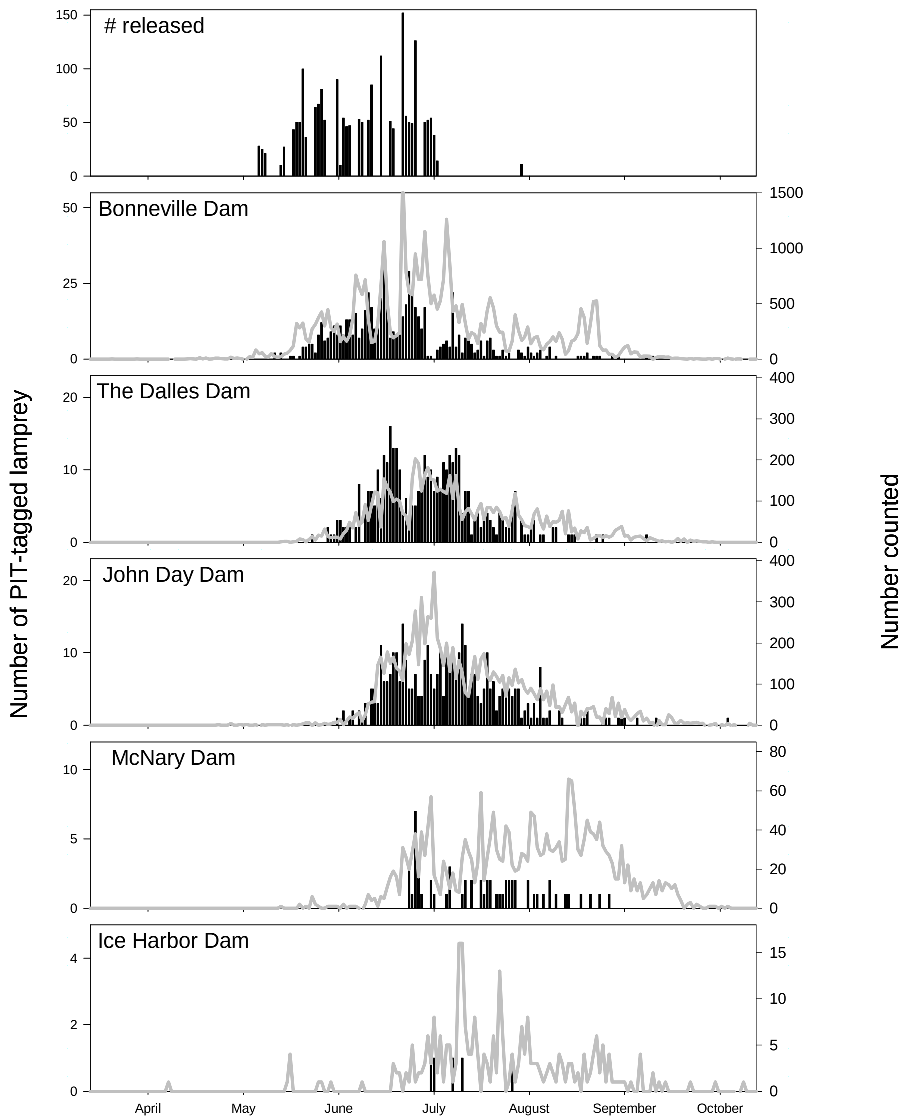

Figure 9. Daily numbers of PIT-tagged lampreys released and first detected at the tops of Bonneville (BO), The Dalles (TD), John Day (JD) and McNary (MN) dams in 2006 and the total number of lampreys tallied at count window stations (solid line).

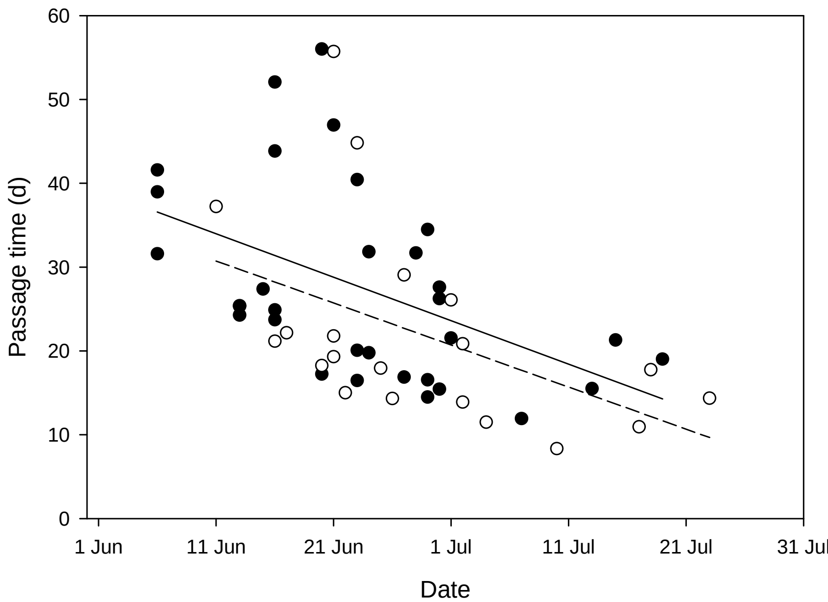

Figure 10. Linear regressions showing the relationship between migration timing and lamprey passage times from Bonneville to McNary dams in 2005. Solid circles (●) are times from release to detection at the top of McNary Dam (*n* = 32; $r^2 = 0.23$). Open circles (○) are from the top of Bonneville Dam to the top of McNary Dam (*n* = 20; $r^2 = 0.23$). Note: reduced monitoring late in the migration may have slightly biased the relationship.

4. Evaluate lamprey behavior in the experimental fishway to develop optimal bottom configurations for lamprey at fishway entrances.

We propose to use the experimental fishway to identify bottom configurations that allow lamprey the greatest attachment and passage opportunities at fishway entrances. To this end, we will simulate flows emanating from fishway entrances and conduct tests with a variety of substrate alternatives that provide attachment surfaces and help to mediate flows. Ultimately, these results will be used to determine the optimal structural configurations of the bottoms and sides of fishway entrances where lamprey encounter rapid current velocity. These results also may be useful in design of fishway bottoms and sides that lead to elevated orifices in weirs (a consequence of proposed full duplex PIT detection equipment installation in some fishways). We will consult with COE and agency managers to prioritize tests in the expected event that numbers of fish available for research will continue to be limiting.

D. Facilities and Equipment

Construction of LPS modifications, repairs to LPS guides, AWS LPS and PIT/radio antenna installation and installation of fishway PIT antennas will be conducted during the winter maintenance periods at dams, and will be completed prior to commencement of lamprey trapping in the spring of 2008.

E. Impacts of study on Corps projects and other activities

Division or district Corps personnel will be needed to provide technical review of research proposed for 2008.

Assistance from project personnel will be required as follows:

1. Provide access to the Adult Fish Facility (AFF) adjacent to the Washington shore ladder at Bonneville Dam during daytime and at night from late May through October for lamprey collection and to conduct laboratory experiments.
2. Provide access to dewatered AFF bypass ladder to allow repairs and alterations to lamprey trap.
3. Provide access at the AWS channel areas for LPS maintenance and to download PIT detection equipment.
4. Provide access at Bonneville, The Dalles and John Day dam fishways for installation and maintenance of LPS, radio receiver, and PIT detection equipment. Some installation work may require crane and/or dive support.
5. Provide AC power to fishway sites for PIT readers and AWS LPS pumps.
6. Relocate and permanently install pumps for the Bradford Island AWS LPS.

Biological Effects

Procedures for trapping and tagging lamprey at Bonneville Dam will be similar to prior years. Fish will be collected using the lamprey traps at the AFF during night only. The trap box is hoisted from the bypass ladder adjacent to the Washington-shore fishway and fish are transferred into a water-filled plastic tank. The fish are then anesthetized, measured, and weighed. Fish used in the PIT and radiotelemetry evaluations will be tagged at this time. We expect little to no mortality from the marking and release operations.

Key Personnel

Project planning, administration, reporting:
Project leaders, M. Moser and C. Peery

Work plan preparation, protocols, computer programs, permits:
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H. Pennington, Jeremy Roos, PSMFC
C. Peery, E. Johnson, C. Boggs, S. Lee, and M. Jepson, U of I

Equipment specifications and purchase:
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Lamprey collection, HD-PIT tagging, construction and evaluation of LPSs:
M. Moser, J. Simonson, and J. Moser, NMFS
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Lamprey radio tagging, experimental flume testing and fishway PIT detection:
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Maintenance and regular downloading of HD PIT recorders and radio receivers at fishways at Bonneville, The Dalles and John Day dams.
K. Tolotti, C. Morat, U of I

Maintenance of radiotelemetry database
K. Frick, NMFS

Analysis of data and preparation of report segments:
M. Moser, C. Peery

Technology Transfer

Information and analyses from this study will be provided regularly to managers via reports and verbal presentations. Information that is appropriate will be published in technical journals. Special efforts will be made to provide information for managers as needed.

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New Research Proposal

An Assessment of Interdam Loss and Fates of Adult Pacific Lamprey in the Lower Columbia River - 2008

Study Code: ADS-P-00-8

Project Leaders

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For the period: 1 January 2008 to 31 December 2008

Submitted August 2007

Study Summary

A. Goal

The goal of this study is to evaluate the use of acoustic telemetry to determine the fates of adult Pacific lamprey *Lampetra tridentata* migrating through reservoirs of the lower Columbia River.

B. Objectives - 2008

1. Evaluate the effectiveness of stationary acoustic receivers to detect actively migrating adult Pacific lamprey in the Bonneville reservoir.

2. Evaluate our ability to mobile track acoustically tagged adult Pacific lamprey in the Bonneville reservoir.

C. Methods

We propose to use a new generation of acoustic telemetry transmitters and receivers and evaluate their effectiveness in tracking migrating adult Pacific lamprey through the lower Columbia River, particularly through reservoirs and into tributaries. Methods will incorporate range testing and efficiency estimation with test tags and a pilot study in which a small sample of up to 50 lamprey outfitted with acoustic transmitters will be released into the Bonneville reservoir. Tagged lamprey would be monitored with static and mobile acoustic receivers. Results from this test will be used to help determine the effectiveness of current acoustic technology to accurately locate and follow lamprey in the reservoir environment and to determine the final fates of unsuccessful migrants.

D. Relevance

A petition to list Pacific lamprey as a federally-endangered or threatened species was submitted in 2002 to the U.S. Fish and Wildlife Service. Although not approved at that time, current downward trends in numbers of lamprey returning the Pacific Northwest, especially lamprey from interior populations, suggest aggressive management is needed to prevent a population collapse. So far in 2007, adult lamprey abundance counted at Columbia River dams was the lowest recorded in recent time. Improving lamprey passage at Columbia River hydropower dams was identified as the highest priority for lamprey recovery by the Columbia Basin Pacific Lamprey Technical Workgroup (a subgroup of the CBFWA Anadromous Fish Committee). This project will address concerns raised by tribal agencies (Close et al. 2002), the U.S. Army Corps of Engineers (COE), and the Northwest Power Planning Council in section 7.5F of the 1994 Columbia River Basin Fish and Wildlife Program which is related to effects of FCRPS projects on passage of Pacific lamprey in the Columbia and Snake rivers. This project will specifically address the issue of determining areas of loss for adult lamprey within the Federal Hydropower System, a concern which has been raised repeatedly by Columbia River tribes.

Project Description

A. Background

Pacific lamprey are anadromous and adults must pass up to eight or nine dams and reservoirs to reach spawning areas historically used by the species: up to four dams in the lower Columbia River, five in the mid Columbia River, and four in the Snake River (Close et al. 1995). While much is not known about the ecology and status of Pacific lamprey in the Columbia River, it is believed that the numbers are in decline. Declines may be most dramatic for interior populations such as in the upper Snake River where only 38 adult lamprey were counted at Lower Granite Dam in 2006.

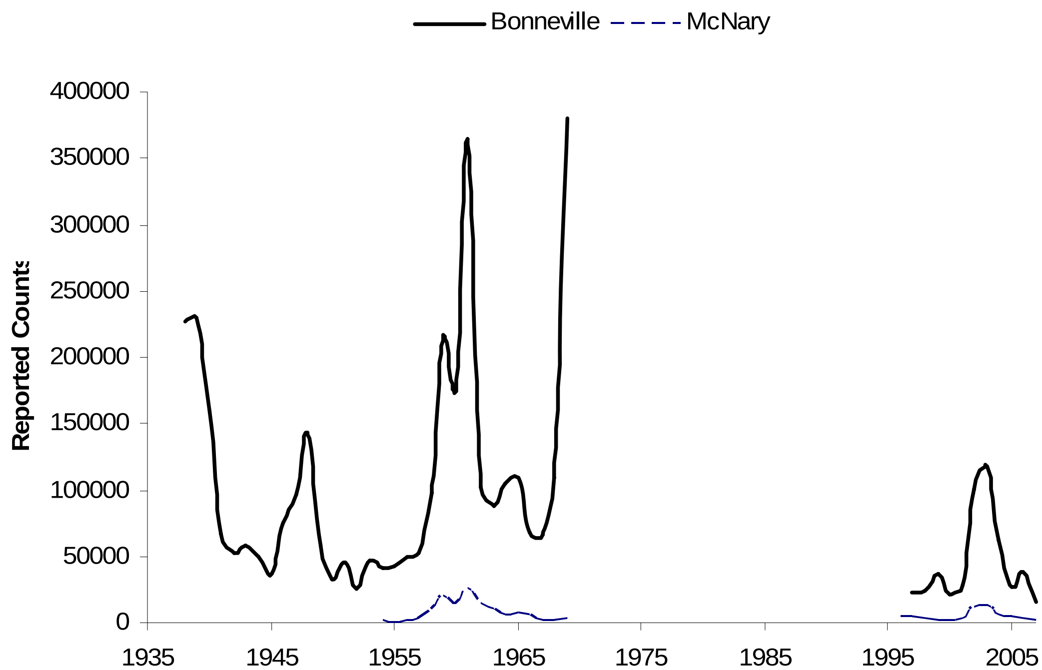

Figure 1. Counts of Pacific lamprey reported for Bonneville and McNary dams. Counts were not made from 1970 to 1995. Source: COE Annual Fish Passage Reports.

Development of this proposal was prompted by requests for preliminary proposals issued by the COE in June of 1994 and subsequent years, and it addresses concerns raised by the COE and the Northwest Power and Conservation Council in section 7.5F of the 1994 Columbia River Basin Fish and Wildlife Program. This proposal was developed via consultation with the COE, and in response to the high priority assigned to adult passage research in the Columbia and Snake rivers by the former Fish Research Needs and Priorities subcommittee of the Fish Passage Development and Evaluation Program, and the current Anadromous Fish Evaluation Program.

From early studies we determined that passage at dams may be a limiting factor in lamprey production within the system (Moser et al. 2002, Moser et al. 2005b).

Information from these early studies was used to guide subsequent efforts to improve passage via a variety of methods (e.g., Moser et al. 2005a; Moser et al. 2006).

Until recently our understanding of movements of lamprey in rivers and reservoirs between dams was based primarily from daytime counts. For example, for the past ten years, conversion of lamprey counts between dams (upstream count divided by downstream count) has been consistently low between Bonneville and The Dalles dams (mean = 0.28) and between John Day and McNary dams (0.38), while counts at John Day Dam are relatively high (mean = 0.95) compared to The Dalles Dam (Figure 2). These conversions may be misleading, however, since counts at John Day Dam can be higher than those at The Dalles Dam during some years. During 2006, using an half duplex passive integrated transponder (HD PIT) system for the first time, conversion of lamprey between the lower Columbia River dams was estimated to be about 68% between Bonneville and The Dalles dams, and between The Dalles and John Day dams, but only 21% between John Day and McNary projects (Daigle et al. *Draft*). There was no information on the fates of fish that dropped out between dams in that study.

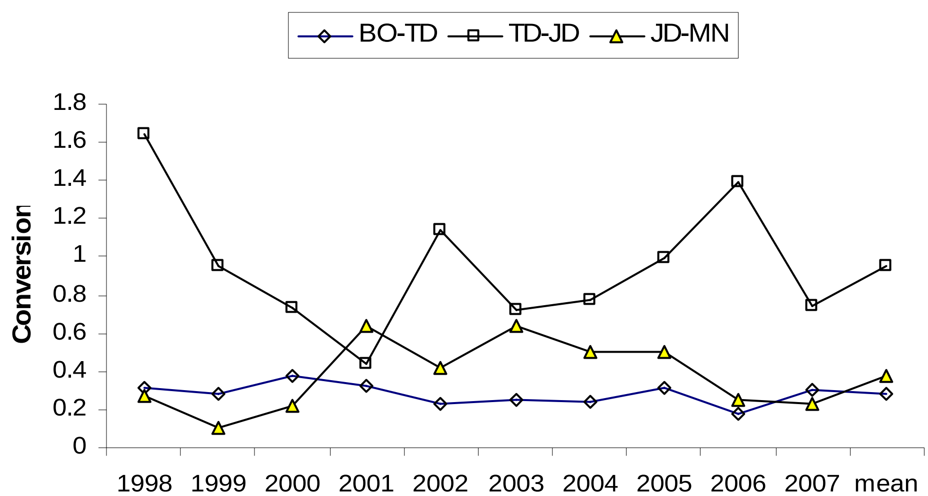

Figure 2. Annual and mean conversions of adult Pacific lamprey between dams of the lower Columbia River, based on daytime counts, for the past ten years. Source: DART.

Early and current lamprey passage evaluations at lower Columbia River hydropower dams were conducted using radio telemetry. While this technology worked well to characterize behavior of lamprey in and near fishways, little information can be collected in reservoirs as fish move between projects. We suspect this is because lamprey likely move near the bottom of rivers, limiting the range of detection for fish outfitted with radio transmitters. Because of this, and because of recent advances in technology, acoustic telemetry appears to be the ideal method to monitor lamprey migrations within reservoirs of the lower Columbia and Snake rivers. In this proposal we describe a pilot study to evaluate the effectiveness of using acoustic telemetry to track movements and fates of adult Pacific lamprey in the lower Columbia River.

B. Objectives - 2007

1. Evaluate the effectiveness of stationary acoustic receivers to detect actively migrating adult Pacific lamprey in the Bonneville reservoir.

2. Evaluate our ability to mobile track acoustically tagged adult Pacific lamprey in the Bonneville reservoir.

C. Methods

The proposed study would have two components, range testing of stationary and mobile receivers and transmitters, and a pilot study in which a sample of acoustically tagged lamprey are released and monitored within the Bonneville reservoir. This will be a collaborative project between the proposal project leaders and their respective agencies.

1. Evaluate the effectiveness of stationary acoustic receivers to detect actively migrating adult Pacific lamprey in the Bonneville reservoir.

Acoustic receivers used for this test are self contained units operating on battery power. Typically in studies of this nature, the receivers can be anchored in place for the duration of monitoring and then retrieved and the stored data downloaded. For this objective, acoustic receivers will be deployed from a moveable platform (pontoon boat) while test tags are moved through the reservoir at various depths, distances, and speeds. Tags will be placed at various depths along weighted cable towed by boat. The tag boat will follow a predetermined course of transects through the river past the receivers. At least two receivers will be used, one near the surface with the hydrophone positioned down and the second near the river bottom positioned up. Receivers could also be placed mid-depth if available. This process will be repeated with receivers positioned at different distances from shore. Both the tag boat and receiver platform will have D-GPS units recording to laptop computers so that tag detections can be superimposed over the boat locations to produce detection probability contours. This information will be used to determine the best location and spacing of acoustic receivers to detect transmitters from fish likely to be moving upstream while deep the water column.

The second phase of this objective would involve releasing 30 to 50 acoustic-tagged adult Pacific lamprey upstream from Bonneville Dam to test the ability of acoustic receivers to detect lamprey migrants. Fish to be used for this test would be collected at Bonneville Dam and surgically outfitted with acoustic transmitters using techniques similar to those used to surgically implant radio transmitters. The main difference is that acoustic tags do not contain an antenna, so a second incision point is not needed. We propose to release fish by boat between Bonneville Dam and Bridge of the Gods. Fish would be detected at acoustic receivers in place for unrelated studies. We would like at a minimum to be able to monitor for test lamprey at the Bridge of the Gods, near Cascade

Locks, Oregon, a natural constriction point at the river, and at one or two other locations within the Bonneville reservoir. HD PIT tags will be inserted into each test fish as well to provide a secondary detection for fish that pass The Dalles Dam.

2. Evaluate our ability to mobile track acoustically tagged adult Pacific lamprey in the Bonneville reservoir.

The ability to track movements as fish are actively migrating will significantly aid in understanding how fish react to river environments as well as provide better determinations of fish fates between projects. Important features for a mobile tracking receiver are the ability to easily and accurately detect fish when present, the ability to see data/detection records in real time (while tracking), some indication of proximity of the fish to the boat (i.e.. signal strength indicator and/or directionality as determined from synchronous detection on multiple hydrophones), the ability to simultaneously link and store tag detections and GPS coordinates while tracking, and rugged and compact construction. As with Objective 1, this evaluation would be conducted in two parts, first using test tags, and secondly, using the tagged fish that would be released into the Bonneville reservoir, as described above. For the former, a test tag lowered to set depths (surface, mid-depth, bottom, etc.) will be suspended from a stationary vessel while the tracking boat simulates a searching pattern. Once parameters for locating the test tag have been established, the process will be repeated with the tag boat in motion to determine how best to locate and then remain in contact with a moving transmitter. The operator of the tracking receiver will be blind to the location of the test tag as much as possible, but will use incoming information to guide the movements of the tracking boat. We will again record D-GPS coordinates to document paths of movements by both vessels during this test process.

Tracking tagged lamprey will be conducted using the same group of fish released in the Bonneville reservoir, as for Objective 1. As fish are released by boat, we will attempt to locate and remain in contact with individuals for as long as possible. Movements will be tracked by recording GPS coordinates of the boat at 5 to 10 min intervals, depending on fish movements. We will also conduct several surveys of Bonneville Reservoir to re-locate tagged fish as they migrate upstream to The Dalles Dam. This portion of the evaluation is expected to take place during the lamprey migration, sometime in June through August. Dates of actual work will be determined but should be accomplished within a three week period.

D. Facilities and Equipment

Acoustic receivers will need to be supplied for this evaluation if existing equipment is not available. All other equipment (trucks, boats, computers, etc.) needed for the proposed work will be provided by research agencies on a rental basis. We will contact transmitter manufactures to assure availability of tags prior to start of studies in 2008.

E. Impacts of the Study on Corps Projects and Other Activities

Division or district Corps personnel will be needed to provide technical reviews of research proposed for 2008.

Assistance from project personnel will be required as follows:

1. Provide access to the Adult Fish Facility (AFF) adjacent to the Washington shore ladder at Bonneville Dam during daytime and at night from late May through October for lamprey collection and to conduct laboratory experiments, in conjuncture with other ongoing studies.
2. Boat docking and equipment storage may be needed at Bonneville Dam.
3. Access to Bonneville Dam boat restriction zone may be required during mobile tracking operations.

Biological Effects

Procedures for trapping and tagging lamprey at Bonneville Dam will be similar to prior years. Fish will be collected using the lamprey traps at the AFF during night only. The trap box is hoisted from the bypass ladder adjacent to the Washington-shore fishway and fish are transferred into a water-filled plastic tank. The fish are then anesthetized, measured, and weighed. Fish used in the PIT and radiotelemetry evaluations will be tagged at this time. We expect little to no mortality from the marking and release operations.

Key Personnel

Project planning, administration, work plan preparation, and study protocols:
Project leaders, C. Peery, N. Adams, G. McMichael

Permits and data processing software:
M. Jepson, U of I

Equipment specifications and purchase:
G. McMichael, PNNL
C. Peery, C. Boggs, U of I
N. Adams, USGS

Lamprey collection, HD-PIT, and acoustic tagging:
C. Peery, E. Johnson, S. Lee, U of I

Analysis of data and preparation of report segments:
C. Peery, U of I
N. Adams, USGS
G. McMichael, PNNL

Technology Transfer

Information and analyses from this study will be provided regularly to managers via reports and verbal presentations. Information that is appropriate will be published in technical journals. Special efforts will be made to provide information for managers as needed.

References

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Research Preliminary Proposal

EVALUATION OF ADULT PACIFIC LAMPREY PASSAGE SUCCESS AT MCNARY AND LOWER SNAKE RIVER DAMS - 2008

Study Code: ADS-P-00-8

To
U.S. Army Corps of Engineers

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For the period: 1 January 2008 to 31 March 2009

Project Summary

A. Goal

Evaluate passage success for adult Pacific lamprey *Lampetra tridentata* at McNary Dam, Ice Harbor Dam, and the remaining lower Snake River dams and associated river segments using a combination of radio telemetry and half duplex passive integrated transponder (HD PIT) systems. Identify potential passage problems and recommend potential solutions.

B. Tasks - 2008

Task 1 — Evaluate migratory behavior of adult Pacific lamprey at McNary and the four lower Snake River dams and identify areas where passage improvements are needed.

Task 2 -- Estimate adult lamprey passage success rates and passage times at and between McNary and the lower Snake River dams during upstream migration.

Task 3 – Evaluate use of acoustic telemetry as a method to document movements, behavior, and potential sources of loss of adult Pacific lamprey near and between McNary and the four Lower Snake River dams.

C. Methods

During 2008 we propose to collect additional information on passage performance and behavior of adult lamprey at McNary and the Snake River dams and to further refine use of the HD PIT monitoring systems. Fish will be trapped at McNary Dam, outfitted with HD PIT tags and/or radio transmitters, released in the Columbia and Snake rivers, and monitored as they approach and attempt to pass upstream dams. We also propose to conduct a pilot study to evaluate the effectiveness of using acoustic telemetry to monitor movements and survival of adult lamprey in reservoirs of the FCRPS. Information collected will be used to identify potential obstacles to lamprey passage at federally operated hydropower projects.

D. Relevance

This project will address concerns raised by Tribal agencies, the U. S. Army Corps of Engineers (COE), and the Northwest Power Planning Council in section 7.5F of the 1994 Columbia River Basin Fish and Wildlife Program, which relates to effects of FCRPS Projects on passage of Pacific lamprey in the Columbia and Snake rivers. The loss of Pacific lamprey as a cultural resource has raised concerns among Columbia River tribes (Close et al. 2002). Improving lamprey passage at Columbia River hydropower dams was identified as the highest priority for lamprey recovery by the Columbia Basin Pacific Lamprey Technical Workgroup. In addition, in 2002 the U.S. Fish and Wildlife Service received a petition to list Pacific lamprey as a federally-endangered or threatened species. Lamprey are not currently listed, but numbers continue to decline. Consequently desire of multiple stakeholder is increasing to improve the productivity of this endemic species within the Columbia River system.

Project Description

A. Background

Declining returns of pre-spawning adult Pacific lamprey *Lampetra tridentata* to the Columbia River highlight the need to document juvenile and adult passage at dams (Close et al. 1995; Jackson et al. 1996). Pacific lamprey are anadromous and must pass up to eight or nine dams and reservoirs, four each in the lower Columbia and Snake rivers and five in the mid-Columbia River, to reach upstream spawning areas historically used by the species.

Studies evaluating lamprey passage in the Columbia-Snake hydrosystem and methods to improve passage at dams were initiated in 1997 at Bonneville Dam. We found that passage efficiency of lamprey approaching Bonneville Dam was less than 50% in all years (Moser et al. 2002). Passage efficiency for lamprey that approached The Dalles Dam was consistently higher than at Bonneville Dam, while passage efficiency at John Day Dam was usually lower than at Bonneville Dam. Of particular concern is the poor performance of lamprey at fishway entrances, through collection channels/transition areas, and past vertical slot fishways at the top of the fishways at Bonneville Dam (Moser et al. 2002). From tests conducted in an experimental fishway channel, we determined what conditions were and were not conducive to lamprey passage (Daigle et al. 2005). Information from these studies was incorporated into fishway improvements and the ongoing development and testing of structures to collect and bypass adult lamprey at passage restrictions. Results from efforts to bypass lamprey at fishway obstacles have been encouraging and we believe bypass devices, which to this point have been used only at Bonneville Dam, can be applied at other dams.

Impeding passage of lamprey below dams may subject them to increased predation pressure and other sources of loss. Difficult passage conditions may also decrease recruitment to upstream populations. This project was initiated to gain information on migration behavior of adult lamprey and to determine what factors affect their passage at McNary Dam and the four lower Snake River dams. During 2005, the first year of this study at McNary and Ice Harbor dams, we found that passage efficiency of adult lamprey was only about 61.5% for those fish that reached McNary Dam, but the median passage time for those fish were relatively short, about 1 d. During 2006, passage efficiency at McNary Dam was about 75%. A small number of fish that had not passed McNary Dam directly following release were later recorded at the project during the following year (indicating they had overwintered downstream from the dam). Passage for the small number of lamprey approaching Ice Harbor Dam has been less, 15 to 17% in each year. We are currently monitoring lamprey at McNary and Snake River dams using radiotelemetry and HD PIT systems. A few individuals have also been tracked moving from McNary to Ice Harbor and Lower Monumental dams. Modifications were made to the trapping procedures which appear to have improved our trapping efficiency so far this year. Unfortunately, lamprey research for these studies continues to be limited by the number of fish reaching McNary Dam.

This project was developed in response to a preliminary request for proposals issued by the USACE in June of 2004, and it addresses concerns raised by the USACE and the Northwest Power Planning Council in section 7.5F of the 1994 Columbia River Basin Fish and Wildlife Program. Operational or structural changes at dams intended to improve lamprey passage success must also address RPA 119 of the 2000 NMFS Biological Opinion that “alterations to fish ladders and adult passage facilities to accommodate Pacific lamprey passage do not adversely affect salmonids passage timing and success”. This proposal was developed via consultation with the USACE, and in response to the high priority assigned to adult passage research in the Columbia and Snake rivers by the former Fish Research Needs and Priorities subcommittee of the Fish Passage Development and Evaluation Program and the current Anadromous Fish Evaluation Program.

B. Tasks - 2008

Task 1 *— Evaluate migratory behavior of adult Pacific lamprey at McNary and the four lower Snake River dams and identify areas where passage improvements are needed.*

Task 2 *-- Estimate adult lamprey upstream passage success rates and passage times at and between McNary and the lower Snake River dams.*

Task 3 *– Evaluate use of acoustic telemetry as a method to document movements, behavior, and potential sources of adult Pacific lamprey loss near and between McNary and the four Lower Snake River dams.*

C. Methods

Task 1 *— Evaluate migratory behavior of adult Pacific lamprey at McNary and the four lower Snake River dams and identify areas where passage improvements are needed.*

Fish used in this study will be collected primarily from the Oregon (south) fishway at McNary Dam using traps installed during 2007 and modified during winter 2007-8. We anticipate using up to 300 fish total for 2008 studies, up to 200 at McNary Dam and up to 100 at Ice Harbor Dam. All fish will be tagged with HD PIT tags throughout the period from July to October. Lamprey typically pass McNary Dam between mid-July and mid-October. This is also the period of warmest water temperatures when relatively few salmon are passing the dam. A portion of HD PIT tagged fish will be released near Ice Harbor Dam (see below). Trapping will occur only at night, when lamprey are most active and salmon are relatively inactive. For our 2007 studies, we are using one permanently mounted trap and one movable trap at McNary. We are observing higher catch rates with the permanent trap design and propose to replace the moveable trap with one a permanently mounted trap prior to the 2008 season to maximize catch rates and the number of tagged fish. To eliminate potential impacts on salmonid passage, the traps will be raised out of the water during the day. Any lamprey collected will be transferred to a water-filled and aerated cooler and transported a short distance by truck to the tagging station at the McNary Juvenile Bypass facility. Each morning, collected fish will be anaesthetized, counted, weighed and measured (length, girth, lipid condition). Fish will then receive a half-duplex passive integrated transponder (HD PIT) tag (23 x 4 mm), and or a radio transmitter surgically inserted into the body cavity. Following a recovery period (typically that evening), tagged fish will be released to the tailrace of either McNary or Ice Harbor dams.

A subsample of 60 individuals (30 fish at each dam) of the HD PIT tag group will also be surgically outfitted with radio transmitters in addition to the HD PIT and released along with the fish bearing only HD PIT tags. These radio-tagged fish will allow verification of the detection efficiency of the HD PIT detectors and will provide information on the fates of fish that do not re-appear at the project. Methods to be used to implant transmitters have been developed over several years during passage evaluations at Bonneville Dam (Moser et al. 2002) and will be the same as those used during 2005-2007. Close et al. (2003) found that surgically implanted transmitters had no effects on the physiology (plasma glucose, ventilation rates) and swimming performance for adult Pacific lamprey. However, Moser et al. (In Press) found that the relative size of the transmitter could affect passage efficiency. Therefore, we will take care to insure that the tag size is as low as possible relative to the lamprey body weight and girth. Telemetry monitoring will be conducted using existing telemetry equipment at the dams.

It is expected that a relatively few of the fish (10% or less, based on past counts at the two dams) released at McNary Dam will reach Ice Harbor Dam and can be used to monitor passage at that project in the Snake River. To augment the evaluation, some fish collected at McNary Dam will be transported to Ice Harbor Dam. It will not known which fish collected at McNary Dam would be destined for the Snake River, and so transporting fish to Ice Harbor may potentially bias passage evaluations. However, there has been no conclusive evidence that Pacific lamprey home to natal streams in the Columbia River whereas there is evidence that other lamprey species do not home (Bergstedt and Seelye 1995). While there is no clear evidence of homing in lampreys, we will nonetheless release fish into the tailrace of Ice Harbor Dam and evaluate passage at the project using only fish known to have approached an Ice Harbor entrance based on PIT and/or telemetry detections.

During 2005, 2006, and 2007 we installed HD PIT reader sites at McNary and Ice Harbor dams, within fishways near the base of ladders (transition pools) and at fishway exits (Figures 1 & 2). Multiple antennas were used when possible to determine directionality of movement. We used a variety of antenna configurations: flat-panels with antenna cables imbedded in epoxy and the panels bolted to fishway walls and floors; loops of cable in plastic conduit encircling submerged weir orifices or whole entrance areas; and antennas in rigid frames placed into existing bulkhead slots. During 2005, it was determined that HD and FDX PIT systems can interfere with each other under certain conditions. Because of this, we developed and tested antenna shielding designs to alleviate potential interference problems and these were used effectively in 2006 and 2007. Use of aluminum frames shielded the HD antenna from electrical interference and minimized magnetic coupling with nearby ferrous metals such as the bulkhead slots and rebar reinforced concrete. In 2007, newly available data loggers were incorporated into all HD PIT readers and appear to have improved the reliability of these systems.

Radio telemetry receivers and underwater antennas in and near fishways at the dams installed during previous studies will be used in 2008 to evaluate detailed movement behaviors of adult lamprey. Special attention will be focused in areas associated with HD PIT antennas and in areas that represent passage restrictions for adult lamprey. In particular, we will focus on documentation of fine-scale lamprey movements through the regulatory and tilting weir structures in the flow control section of the Oregon-shore fishway. We will work closely with project personnel to design and implement structural changes in this area to facilitate lamprey movements. HD PIT and radiotelemetry can then be used to assess the efficacy of such changes

HD PIT and radiotelemetry receiver sites will be downloaded at regular intervals by transferring data to a portable computer. Internal times on all receivers and readers will be synchronized to assure comparability between data collected with the two systems and between different sites. HD PIT data will be loaded to a database operated on an SQL server at the University of Idaho and radiotelemetry data will be electronically transferred to a database maintain at the Northwest Fisheries Science Center for pre-processing. Pre-processing will involve screening to remove obvious error (noise) records and detections that occur before fish release. Pre-processed records will be used to identify specific fish behaviors, such as approaches, entrances, and exits to the fishways, using an automated computer program. Coded records will then be inspected for accuracy and imported to spreadsheets for analyses. We will summarize numbers and proportions of fish that successfully navigate segments of the fishways at McNary Dam—those that return to the dam and approach an entrance, enter a fishway, reach and pass through transition pools, ascend the ladders, traverse flow control sections at tops of ladders, and exit to the forebay. Passage times for each segment will be calculated and compared to similar data among projects. Entrance efficiency will be defined as the number of fish that successfully enter divided by the number that approach a given entrance (X 100).

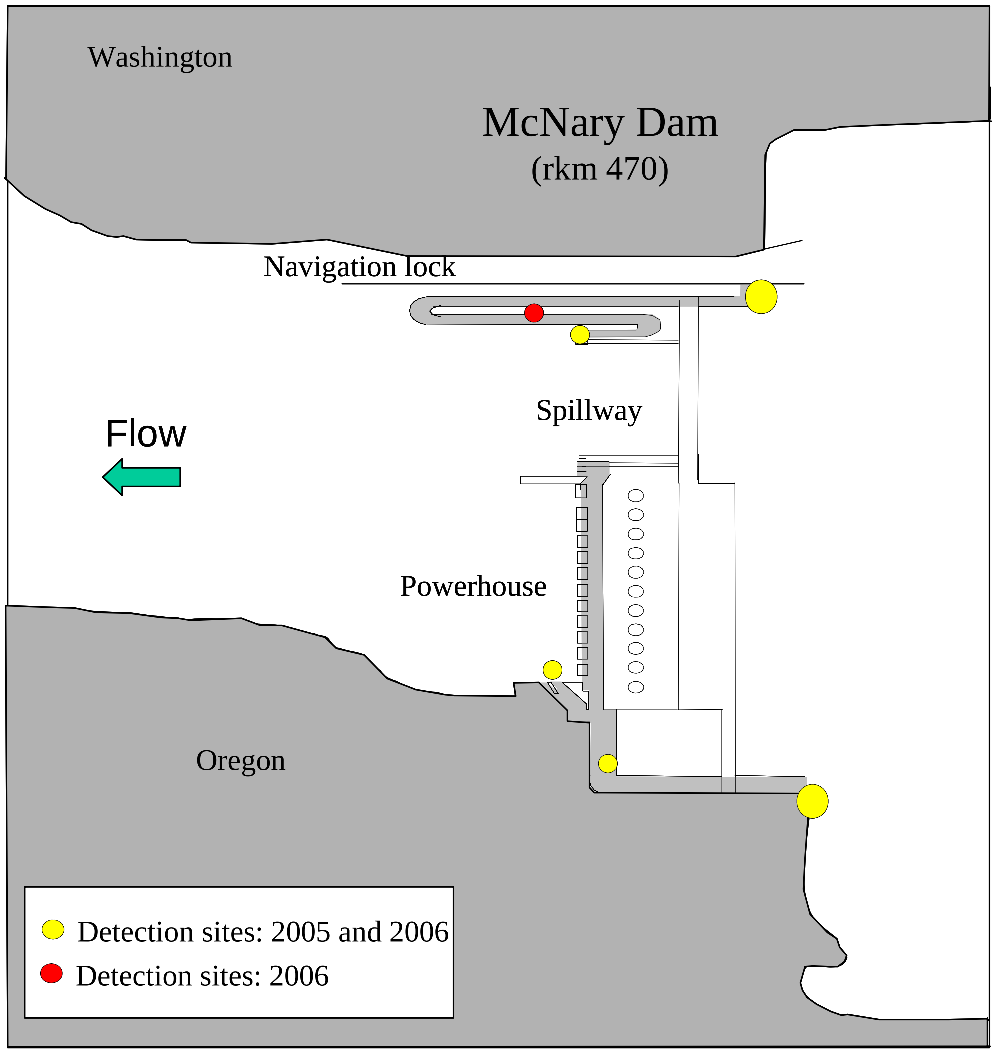

Figure 1. Schematic of radio and half-duplex PIT antenna placement for monitoring passage of adult lamprey at McNary Dam installed during 2005-2006. All six sites will be used in 2008.

Data from HD PIT detectors will be compiled to a separate database so that similar passage summaries can be made. Specifically, we will evaluate the proportion of fish that approach and then successfully enter each fishway entrance, reach and ascend ladders, and exit to the forebay at each dam. Data from the two systems will then be compared to evaluate their effectiveness for characterizing lamprey behavior.

During the course of field work, University of Idaho (UI) personnel will inspect and repair or replace malfunctioning equipment as needed to assure data collection is not interrupted during the 2008 field season. This work will include the purchase of parts (readers, connectors, power supplies, aluminum conduit, antenna cables, etc.) to maintain, repair and upgrade HD PIT systems at McNary and Ice Harbor dams. We will coordinate operations of telemetry and HD PIT systems with other researchers to minimize potential interference. We will consult with managers and the COE to determine the utility of outfitting additional Snake River Dams with HD PIT readers after results of the 2007 evaluation are available.

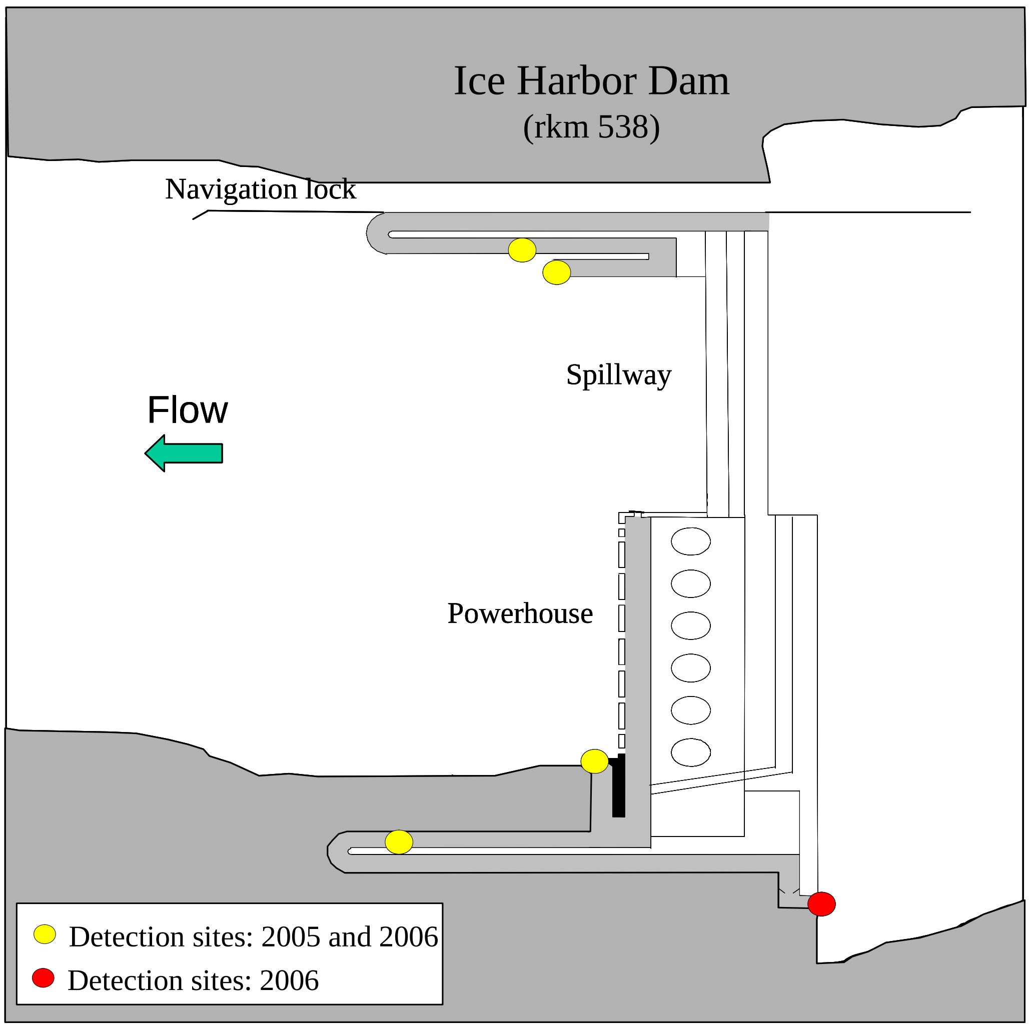

Figure 2. Schematic of radio and half-duplex PIT antenna placement for monitoring passage of adult lamprey at Ice Harbor Dam during 2005-2006. A station was added to the north shore ladder exit in 2007. All five antenna sites will be used in 2008.

***Task 2** -- Estimate adult lamprey upstream passage success rates and passage times at and between McNary and the lower Snake River dams.*

Along with monitoring at dams to identify potential passage restrictions, HD PIT and telemetry monitoring allows us to evaluate passage between projects (e.g. Figure 3). Data will be summarized to determine conversion rates and passage times between dams. Statistical analyses (regression and hazard analysis procedures) will be used to determine the relationships between passage performance and biological (fish size and condition), operational (spill) and environmental (temperature and flow) conditions (e.g., Caudill et al. 2007).

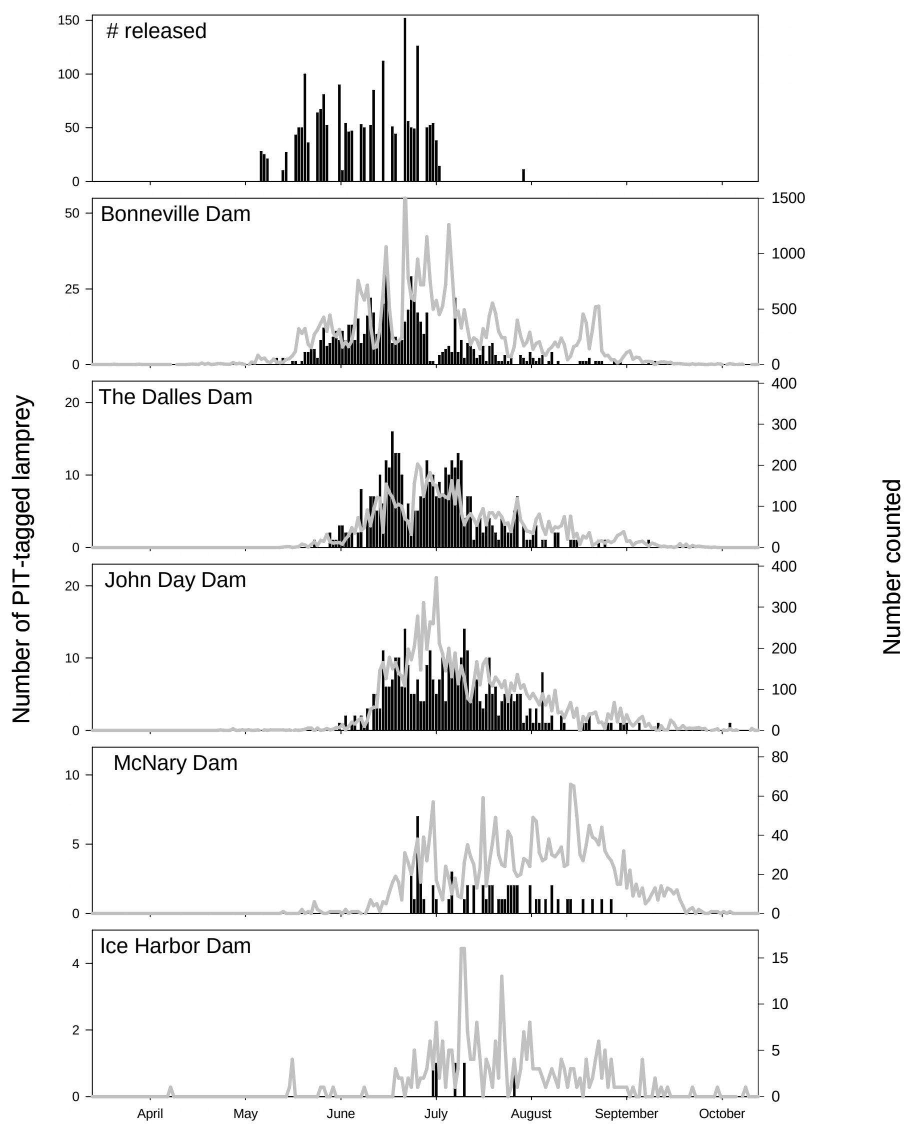

Figure 3. Daily numbers of PIT-tagged lampreys released and first detected at the tops of Bonneville, The Dalles, John Day, and McNary dams in 2006 and the total number of lampreys tallied at count window stations (solid line). Note different y-axis scales used for different projects. From Daigle et al. *Draft*.

***Task 3** – Evaluate use of acoustic telemetry as a method to track movements, behavior, and and potential sources of loss of adult Pacific lamprey near and between McNary Dam and the four lower Snake River dams.*

Based on count data, numbers of adult Pacific lamprey passing Ice Harbor Dam have been just 8 to 14% of the numbers crossing McNary Dam over the past five years. Recent analysis of HD PIT data at the two projects suggest the conversion may be higher, 33 to 36% during 2005 and 2006, respectively (Daigle et al. *Draft*). It is unknown what guides adult lamprey to spawning areas but there is evidence that lamprey as a group may not home to natal streams as do anadromous salmonids (Bergstedt and Seeley 1995). While we do not know what attracts (or repels) lamprey to the Snake River at the Columbia-Snake confluence, one factor could be the temperature difference between the relatively cool Columbia and the warmer Snake River during the lamprey migration. Another contributing factor could be the presence or absence of attractive pheromones from conspecifics in each drainage. Currently fish tagged with radio transmitters or HD PIT tags can be detected at McNary and Ice Harbor dams to determine actual conversion rates between the two projects. However, we lack information on the detailed route-selection behavior that occurs as lamprey approach the Columbia-Snake confluence area and on the fates of fish that do not reach upstream projects. Such information would be useful to discern what factors are associated with selection/rejection of the Snake River by adult lamprey migrants. Because lamprey tend to move close to the substrate, and because of recent advances in receivers and transmitters, acoustic telemetry appears to be an ideal method to collect this information. To test the feasibility of this, we propose to conduct a small-scale trial in 2008 to evaluate the utility of acoustic telemetry for monitoring lamprey movements in the mainstem. This evaluation would primarily involve conducting range and efficiency tests of stationary and mobile tracking equipment from several vendors using test transmitters, and possibly by conducting trial tracking of a small number (5 to 10) of tagged lamprey. For this component, individual tagged fish (each fish would receive one tag type being tested) will be released from a boat and tracked using simultaneously operating telemetry systems to determine which produces the best results. Fish to be used for this test would be collected at McNary Dam including from those that are collected in the juvenile bypass facility.

Equipment from all available acoustic equipment vendors would be tested, including equipment from Lotek Wireless, VEMCO, HTI, and JSATS. All four vendors produce autonomous receivers that can be used as stationary sites. Lotek and VEMCO also produce specialized receivers designed for mobile tracking fish from a boat. Trial versions of mobile tracking units are currently being developed by HTI and JSATS. All receiving equipment needed to conduct this trial is currently available. USGS personnel from the Columbia River Research Laboratory and PNNL personnel (co-PIs listed on title page) have agreed to partner with us to deploy and test the HTI and JSATS systems for this objective. Other acoustic systems can be added to this trial as available. We would coordinate efforts between manufacturers to insure that test equipment is comparable. In particular, transmitters will need to be of similar dimensions. We feel a tag that is 8-9 mm diameter and 2 g in weight or less will be needed for effective lamprey studies. Tag signal strength and battery life will need to be similar between transmitters to conduct a valid test.

D. Facilities and Equipment

HD PIT tag detection equipment will be purchased and assembled by UI personnel prior to the winter de-watering schedule for dams. Maintenance and installation of equipment will occur during the period when fishways are dewatered whenever possible. The required number of PIT tags and transmitters will be ordered by late 2007 after consultation with USACE personnel to insure delivery for the 2008 field season. Computers and vehicles will be supplied by the researchers as needed on a rental basis. Installation of new antennas and repairs to existing antennas will be made during the winter maintenance periods at dams, and will be completed prior to the commencement of tagging in the summer of 2008.

E. Impacts of the Study on USACE Projects and Other Activities

All research activities will be coordinated with USACE project biologists. We do not anticipate that the outlined work will interfere with project operations.

Division or district USACE personnel will be needed to provide technical review of research proposed for 2008.

Assistance from project personnel will be requested as follows:

1. Access to AC power at McNary and Ice Harbor and potentially other Snake River dams for electronics equipment in the fishways and tailrace areas during 2008.
2. Access to fishways to install, repair, and test electronic and trapping equipment. Some dive and crane support may be needed to install antennas in and near fishways.
3. Regular access to tailraces and fishways for downloading of radio and PIT receivers.
4. Access to fishways to trap adult lamprey at McNary Dam.
5. Space at the juvenile facility to process, hold, and tag adult lamprey and access to AC power and a supply of river water to hold lamprey prior to and following tagging.

F. Biological Effects:

Fish for studies outlined here would be collected and tagged at McNary and Ice Harbor dams during 2008. Tagging will take place 6 to 7 days a week. Fish will be trapped at night from the fishway, selected for tagging, anesthetized, fitted with HD PIT tags and/or transmitters, and released approximately 1 km downstream from the dams after a suitable recovery period, typically that evening. Indirect effects on lamprey from tagging are a delay for fish to re-ascend the 1 km of river and reenter a fishway at the two dams. Based on past experience we anticipate few to no mortalities associated with lamprey sampling for this evaluation. In 2006, about 2,500 lamprey were counted passing the McNary Dam. The 200-300 fish proposed for tagging could be up to 12% of the run in 2008.

We will coordinate with other researchers conducting radio telemetry studies with lamprey and salmon to enhance coverage and avoid duplicate use of frequencies and codes of transmitters in the system.

G. Reporting Schedule

Information and analyses from this study will be provided regularly to managers via reports and verbal presentations.

Progress reports and presentations of results will be provided at up to three meetings, as requested by the POC, and an oral presentation summarizing 2008 field effort and providing results from preliminary analyses will be provided at the Annual AFEP Review, November 2008. Additional information, updates, summaries, etc., will be provided for other managers as needed and when time allows.

The draft report of 2008 monitoring results will be provided no later than December 2008. A draft final report should be completed in March 2009. Regular progress reports will be provided during the ongoing research field work. Information that is appropriate will be published in peer-reviewed journals.

H. Key Personnel

Project planning and administration:
Principle investigators, C. A. Peery, M. Moser

Equipment specifications, purchase, construction, and installation:
C. Boggs, T. Dick, UI

Permits, telemetry processing:
M. Jepson, U of I.

K. Frick, NMFS

Fish collection, tagging, data analysis and final reporting:
C. Peery, M. Moser, C. Boggs, C. Caudill

Acoustic evaluation pilot study;
C. Peery, N. Adams, G. McMichael

I. References

Caudill, C.C., W.D. Daigle, M.L. Keefer, M. Jepson, B.L. Burke, T.C. Bjornn, and C.A. Peery. 2007. Slow dam passage in Columbia River salmonids associated with unsuccessful migration: delayed negative effects of passage obstacles or condition-dependent mortality? Canadian Journal of Fisheries and Aquatic Sciences 64: 979-995.

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Moser, M. L., D. A. Ogden and B. P. Sandford. In Press. Effects of surgically-implanted transmitters: lessons from lamprey. Journal of Fish Biology 00:000-000.

CONTINUING RESEARCH PROPOSAL (COE) (FY08)

TITLE:	Developing a separator for juvenile lamprey
PROJECT LEADER:	Mary L. Moser Fish Ecology Division Northwest Fisheries Science Center National Marine Fisheries Service 2725 Montlake Blvd. East Seattle, Washington 98112 (206) 860-3351; FAX (206) 860-3267
ADMIN. OFFICER:	Doug Dey Fish Ecology Division Northwest Fisheries Science Center National Marine Fisheries Service 2725 Montlake Blvd. East Seattle, Washington 98112 (206) 860-3237
STUDY CODE:	ADS-P-00-8
PROJECT DURATION:	FY2008
SUBMISSION DATE:	October 2007

PROJECT SUMMARY

Research Goal

The goal of this work is to increase survival of juvenile lamprey during their seaward migration past hydropower dams in the lower Snake and Columbia Rivers.

Study Objectives

1). Develop a juvenile lamprey separator that separates juvenile lamprey from salmonid fry, subyearling, and yearling juveniles in the bypass systems at Snake and Columbia River Dams.

2). Determine the feasibility of modifying the raceway screens at collector dams to allow juvenile lamprey to pass to the river while retaining juvenile salmonids for transportation.

Relevance

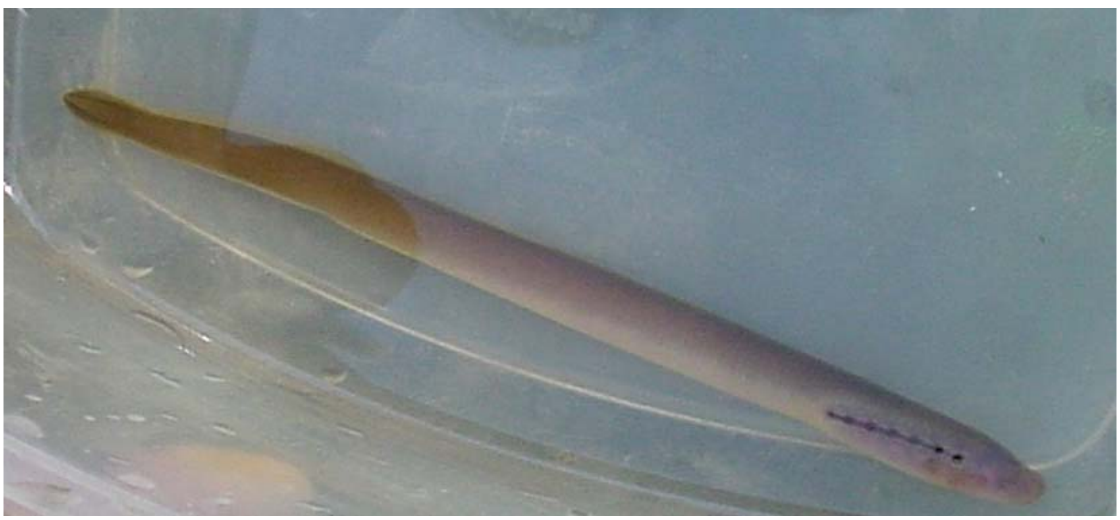
The Columbia Basin Pacific Lamprey Technical Workgroup (a subgroup of the CBFWA Anadromous Fish Committee) has identified the need to improve lamprey passage and survival at Columbia River hydropower dams as the highest priority for lamprey recovery. A petition to list both the anadromous Pacific lamprey (*Lampetra tridentata*) and the resident western brook lamprey (*Lampetra richardsoni*) as federally-endangered or threatened species was submitted in 2002 to the U.S. Fish and Wildlife Service and lamprey declines have raised concern among tribal agencies throughout the Columbia River basin (Close et al. 2002). This project will address concerns raised by tribal agencies, the U. S. Army Corps of Engineers (COE), and the Northwest Power Planning Council in section 7.5F of the 1994 Columbia River Basin Fish and Wildlife Program, related to effects of FCRPS projects on passage and survival of both Pacific and western brook lamprey in the Columbia and Snake rivers. This project will specifically address the issue of improving juvenile lamprey survival at bypass systems designed to divert and transport juvenile salmonids. Concerns about juvenile lamprey mortality at dams have been raised repeatedly by Columbia River treaty tribes, for which lamprey are an important cultural resource.

PROJECT DESCRIPTION

Background

Pacific lamprey (*Lampetra tridentata*) are an anadromous, parasitic lamprey species. Adults spawn in freshwater tributaries to the Columbia River and the juveniles (ammocoetes, Figure 1) bury into silty substrate and assume a sedentary life style for up to 7 years (reviewed in Close et al. 2002). During this period, ammocoetes may move downstream during freshets, however the extent and mechanisms behind freshwater movements are not well understood (Beamish and Levings 1991). After freshwater rearing, ammocoetes metamorphose, developing eyes and mouth parts for their parasitic phase in seawater. The metamorphosed juveniles (macrophthalmia) emigrate from freshwater to the sea, much like juvenile salmonids.

Figure 1. Juvenile lamprey prior to metamorphosis (ammocoete) collected in the Snake River drainage. Photo courtesy of J. M. Capurso.



Western brook lamprey (*L. richardsoni*) are a resident, non-parasitic lamprey form. This species also resides for extended periods in freshwater tributaries to the Columbia River. After the freshwater residence period, Western brook lamprey become sexually mature and spawn in freshwater without making a seaward migration (Pletcher 1963). However, as is the case for Pacific lamprey, Western brook lamprey ammocoetes exhibit downstream movements during freshwater residence that could be extensive (Jennifer Stone, U.S. Fish and Wildlife Service, pers. comm.). The extent and reason for these movements is not known.

During both seaward migration of macropthalmia and downstream movements of ammocoetes, anadromous and resident lampreys may encounter up to 8 or 9 hydropower projects on the Columbia and Snake rivers. Recent research has documented impingement of lamprey at juvenile bypass facilities (Figure 2) and has determined that lamprey are more likely to suffer mortality as a result of screen impingement than from negative effects of passing downstream over dam spillways or through turbines Moursund et al. 2001). Consequently, research has recommended that bar screens be sized to reduce lamprey impingement to improve lamprey survival (Moursund et al. 2002, 2003).

Figure 2. Pacific lamprey macropthalmia impinged on screens at the John Day Juvenile Bypass System. Photo courtesy of the Columbia River Intertribal Fish Commission.

Studies to assess lamprey survival through the juvenile bypass systems (JBSs) at McNary and John Day dams have indicated that lamprey survival after guidance into the JBS is high. An extensive program to PIT (passive integrated transponder) tag juvenile lamprey was undertaken during the past few years (Moursund et al. 2002, 2003, R. Moursund, Pacific Northwest National Laboratory, pers. comm.). This work has determined that juvenile lamprey in the McNary and John Day JBS exhibit high survival and that lamprey show downstream rates of movement that are similar to those of salmonids.

Macropthalmia and ammocoetes collected at the JBS are inadvertently transported downstream during barging and trucking operations to transport juvenile salmonids past dams. It is not known whether barging operations are detrimental to lamprey or not. However, the ability to separate lamprey at these operations would allow release of both anadromous and resident lamprey juveniles back into the river after collection. In addition, developing ways to separate juvenile lamprey from juvenile salmonids may have other important applications. During freshets lamprey can occur in very large numbers and become impinged on screens, resulting in screen blockage and lamprey mortality. Methods to separate lamprey at JBS exit raceways may provide insights into ways to reduce other sources of juvenile lamprey mortality at dams.

There is already some indication that behavioral separation of juvenile lamprey from bypass water is feasible. Some juvenile lamprey are currently separated at the Porosity Control Unit located just upstream from the separator at Lower Monumental Dam. In the past, plates in the Control Unit have been composed of materials with relatively small bar spacing (Jonhson Bar Screen or perforated plate), but recently plates with approximately 0.6 wide by 2.5 cm long oblong holes have been used (K. Fone, U.S. Army Corps of Engineers, pers. comm.)(Figure 3). In addition, raceways screens at this bypass facility are sized at 6.5 x 6.5 mm. Coincident with the use of these plates and raceway screens, there has been apparently greater separation of juvenile lamprey at this location.

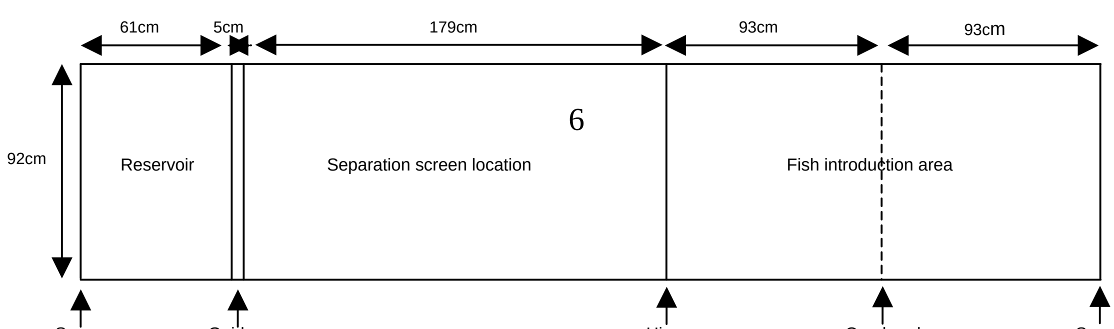
Figure 3. Lamprey macropthalmia moving horizontally over porosity plate material.
In spring 2007, experiments to determine the physical dimensions of separator screens that

juvenile lamprey could negotiate were initiated at McNary Dam. The work was conducted in a 1.5 x 10 m experimental chamber located at the upstream end of bypass facilities for juvenile salmonids. Columbia River water of ambient temperature was diverted into the chamber, and flow rate was controlled via an inlet valve. The entire experimental chamber was covered, allowing accurate control of light levels. Within the experimental chamber, a smaller, self contained flume insert was installed (Figure 4). Fine mesh at both the downstream and upstream ends allowed water to flow freely and evenly through the flume insert (Figure 5).

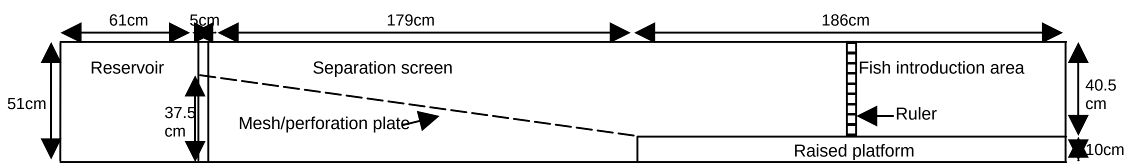
Figure 4. Flume insert within the main flume channel at McNary Dam.

Trials were conducted at night under low water flow (< 30 cm/s) to simulate conditions in JBS exit raceways. Lamprey macroptalmia were introduced into the flume and allowed to acclimate to the chamber in darkness. The trial was initiated by turning on bright lights over the introduction area to stimulate lamprey to move through the separator screens which were positioned either immediately upstream or downstream from the introduction area. The screens could be tested at a variety of angles, from perfectly horizontal to completely vertical. Two screen materials were tested: 6.5 mm square woven stainless steel mesh and 25 mm x 6 mm stainless steel porosity plate. In addition, lamprey were allowed to find their way either vertically (down) or horizontally through a 'sieve' arrangement (Figure 6) over night. In the morning, the macropthalmia were measured, the screen they had passed through was recorded and the fish were released into the JBS.

A)



B)



C)

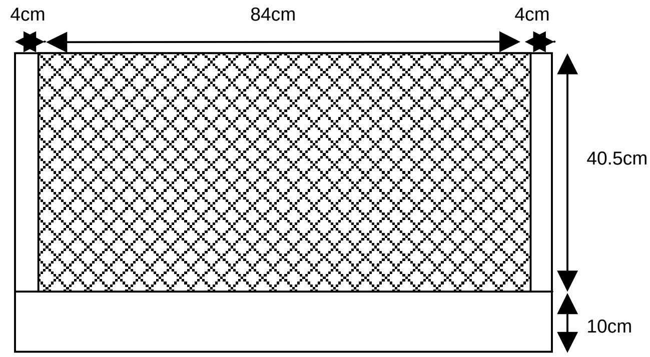
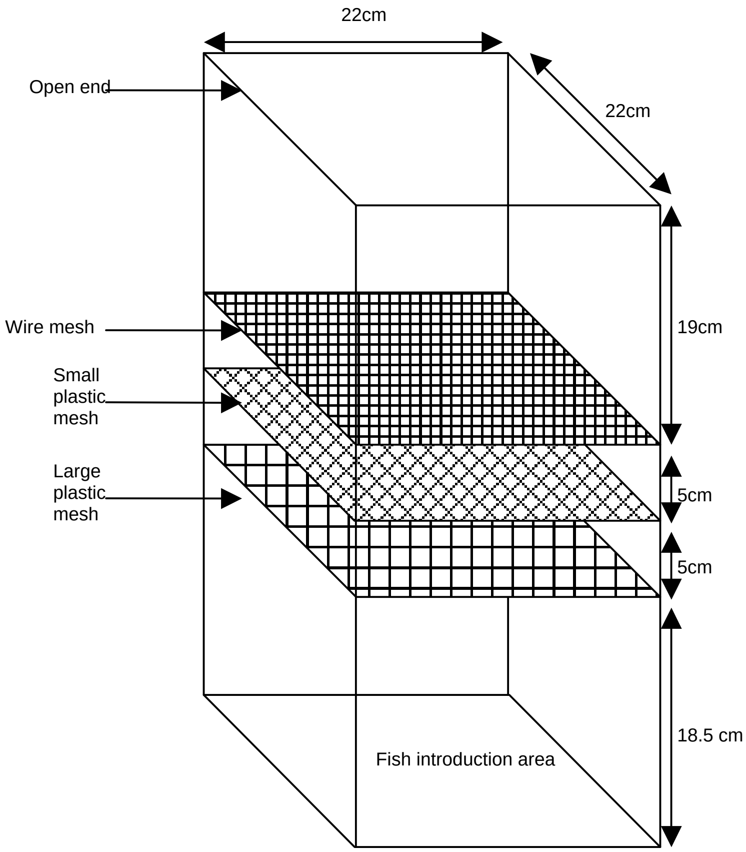


Figure 5. A) Top view of the flume insert; B) Side view of the flume insert, with perforation plate angled at 8.7^o; C) End view of the flume insert (note: both ends had the same dimensions).

Preliminary results of these experiments indicated that lamprey had a greater propensity to move through vertically-oriented screen material than through horizontal or slightly (8.7^o) angled screens. The low numbers of juvenile lamprey collected at the JBS in spring 2007 limited the number of trials that could be conducted with both screen and porosity plate oriented vertically. Therefore, trials in 2008 will focus on vertically-oriented screens and will more thoroughly test macropthalmia movements in both upstream and downstream directions.

A)



B)

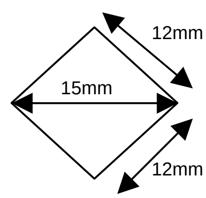


Figure 6. A) Mesh dimensions in the lamprey "sieve" arrangement: stainless steel woven wire mesh = 6.5 x 6.5 mm; Small punched plastic mesh = 9 x 7 mm; Large punched plastic mesh = Diamond shape - 12 x 12 (x 15 at widest point) mm. NOTE: When looking at downward movement of lamprey through sieve, the effective depth of the fish introduction area was 10.5 cm because 8 cm of the chamber was out of the water; B) Large plastic mesh shape and size of mesh.

Objectives

Objective 1. Develop a device to separate juvenile lamprey from juvenile salmonids (fry, subyearlings, and yearlings) in bypass systems at Snake and Columbia River dams.

Objective 2. Determine the feasibility of modifying raceway screens at collector dams to allow juvenile lamprey to return to the river while maintaining criteria for holding fry, subyearling and yearling salmonids prior to transportation.

Methods

Objective 1. Develop a device to separate juvenile lamprey from juvenile salmonids (fry, subyearlings, and yearlings) in bypass systems at Snake and Columbia River dams.

Experiments will be conducted at the McNary Dam covered flume area at the juvenile bypass channel (Figure 4). This area is equipped with a 1.5 × 10-m covered flume. Columbia River water can be diverted into the flume and the amount of flow can be accurately controlled via an inlet valve. The entire experimental area is covered to allow accurate control of lighting and is equipped with an overhead video system (both natural lighting and infrared). This will permit documentation of lamprey behavior during controlled current velocity and light intensity during the night when juvenile lamprey are most active.

Initial experiments tested the ability to separate lamprey by exploiting their negative phototaxis. Juvenile Pacific lamprey are nocturnal and avoid bright lighting (Moursund et al. 2000). Moursund et al. (2001) were able to elicit an avoidance response in both flowing and static water conditions with both constant and strobed white light. In 2007, experiments were conducted under varying flow conditions to determine whether lamprey could be separated using light avoidance. During this work, lamprey exhibited nocturnal behavior, with activity increasing from 1800 h to midnight. Consequently, trials in 2008 will be conducted during this time period under low water flow (< 30 cm/s) to simulate conditions in JBS exit raceways. Lamprey will be introduced into an experimental flume (Figure 5) and allowed to acclimate to the chamber in darkness. Replicated tests will be initiated by turning on bright lights over the introduction area to stimulate lamprey to move through the separator screens positioned either immediately upstream or downstream from the introduction area. In 2008, we will focus on vertically oriented screen materials of two types: 6.5 mm square woven stainless steel mesh and 25 mm x 6 mm stainless porosity plate. The propensity for lamprey to move either upstream against the current or downstream with the current as they pass through the screen material will be tested to determine the best siting for raceway screen replacement (see Objective 2). Also in 2008, we will attempt to conduct trials using ammocoetes collected in bypass facilities in addition to macropthalmia (no ammocoetes were collected during the course of experiments in 2007). After the tests, each fish will be measured (length and interorbital distance) and released into the JBS.

Objective 2. Determine the feasibility of modifying raceway screens at collector dams to allow juvenile lamprey to return to the river while maintaining criteria for holding fry, subyearling and yearling salmonids prior to transportation.

Both objectives require development of a separation system that will not result in impingement or injury to either juvenile lamprey or salmonids. While adhering to the salmonid exit screen criteria, it may be possible to allow lamprey to safely escape through the raceway exit screens (Figure 7) and make their way back into the river at the raceway outflow points. To test this idea, we propose to test use of lamprey-friendly screen material (developed based on 2007 and 2008 laboratory results) during the salmonid transport season at the McNary JBS in 2008. The tests will involve temporary installation of removable lamprey-friendly screen material at the downstream or upstream end of the raceways (depending on results from laboratory studies). The siting and construction of the screens will be closely coordinated with Project personnel to insure that they do not alter operation of the raceways. Sampling of juvenile lamprey in the raceways with and without the new screen material will be conducted in adjacent raceways on a daily basis during the salmonid transport season. At the first sign of any negative impacts to juvenile salmonids, this testing would be terminated.

Figure 7. Raceway exit screen at juvenile bypass system.

Facilities and Equipment

The covered flume facility at the McNary Juvenile Bypass channel (Figure 4) can deliver ambient Columbia River water at controlled velocities under specific lighting conditions during both day and night. In addition, the NMFS Pasco Research Station metal shop is equipped to fabricate custom components for flume experiments and Research Station personnel have extensive experience with development of other separation devices for Columbia River hydropower projects.

Potential Limitations

The ability to conduct these experiments will depend on the availability of migrating juvenile lamprey for testing. In 2007, no de-scaling experiments were conducted at McNary Dam, so there was no access to lamprey collected in the orifice traps at this facility. Lamprey collection rates during sampling for salmonids at the McNary bypass system further downstream were very low (less than 10 fish/day), even during the peak of lamprey migration in 2007. While this is an unusually low sampling rate, it is possible that equally low numbers of juvenile lamprey will be available in 2008. To increase the numbers of lamprey available for this study, we plan to obtain lamprey from existing sampling and also to operate an orifice trap at night for lamprey collection. It may also be necessary to obtain lamprey from the John Day bypass system or from the screw trap in the Umatilla River to obtain ammocoetes in addition to macropthalmia. Fish used in the experiments will be released, unharmed into the Columbia River. It is likely that over 500 juvenile lamprey will be needed for separation tests (5 replicates of 10 treatments with 10 lamprey per replicate). All lamprey will be returned to the Columbia River near the capture location.

Project Impacts

The proposed activities will be coordinated with ongoing projects funded by the Corps of Engineers, the Bonneville Power Administration, and others. Access to the experimental facility will be needed during both day and night to conduct experiments and operate the orifice trap. In addition, project assistance may be needed to obtain lamprey from bypass collection operations. Project assistance may also be required during installation and removal of test screen material in the JBS exit raceways.

Technology Transfer

This study has broad applicability to ongoing efforts by state, federal, and tribal fisheries managers and hydropower operators to recover lamprey populations. The principal investigator will insure that information and analyses from this work are available to resource managers via presentations at professional meetings, workshops, and when otherwise requested. Technical findings may be published in peer-reviewed journals.

Key Personnel and Duties

Dr. Mary Moser, principal investigator will design and oversee experiments, analyze data, and report findings. Iain Russon will conduct experiments and help with data analysis and report writing. Jim Simonson will provide flume modification design and fabrication. Mike Gessel will help with coordination of juvenile lamprey collection.

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FINAL PROPOSAL

For Study Code ADS-P-02-16 to the US Army Corps of Engineers (FY07)

Evaluation of California Sea Lion (*Zalophus californianus*) and Other Pinniped Predation in the Bonneville Dam Tailrace

Project Leader:

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Fish Field Unit
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Anticipated Duration:
January through June 2008 – 2010

August 1, 2007

Project Summary

Goals:

The goal of this evaluation is to determine the impact California sea lions (*Zalophus californianus*) and other pinnipeds, have on salmonid (*Onchorhynchus* sp.), lamprey (*Lampretra tridentata*), and other fish populations migrating through the Bonneville Dam tailrace. The study outlined below will also be used to evaluate the effectiveness of sea lion deterrent management actions employed.

Objectives:

1. Determine seasonal timing and abundance of pinnipeds present at Bonneville Dam.

2. Estimate pinniped predation on adult salmonids, lamprey, and other fish species in the Bonneville Dam tailrace.

3. Identify individual California sea lions at Bonneville Dam, determine whether they return in subsequent years, and their haul out areas.

4. Evaluate impacts that deterrent actions including exclusion gates, acoustics, and harassment on pinnipeds in general at Bonneville Dam may have on predation rates and abundance of pinnipeds in the tailrace. In addition, evaluate the response of individual California sea lions to active, non-lethal or lethal deterrents employed by USDA and state agency personnel.

Methodology

Surface observations for 2007 will occur seven days a week (five days a week between January 1 and February 18) for most daylight hours at all tailraces where sea lions are observed. All observations will be during daylight hours, since that was when all observed feeding activity occurred in previous years. Observations will occur at each of the three tailrace channels below Bonneville Dam. Information recorded will include date, time of day, numbers of sea lions present, location, observed behavior (feeding, swimming, resting, etc), individual pinnipeds present (if known), and number of salmonids, lamprey, and other fish consumed and lost. Acoustics at all main fishway entrances will be turned on and left on from early February through the end of May. If funding permits, active non-lethal hazing may also occur from early February through the end of May during all hours of daylight, 7 days a week, at least at two of the three tailraces. Sea lions typically bring an adult salmon to the surface to rip it apart before eating it, making successful predation visible for large prey. However, exactly where the fish was caught before the sea lion brought it to the surface can only be inferred. We can also estimate the percentage of salmonids caught but subsequently lost. Video-camera recordings will be taken to verify some of these observations. When possible, individual sea lions will be identified, documented (specific markings) and compared to individuals seen in previous years. Video-camera recordings will also be taken to back up the observations of individuals.

If possible, an attempt will be made to coordinate contracted USDA/WS agents to conduct hazing of pinnipeds off of haul out sites and near the dam in conjunction with boat hazing conducted by the states and tribes. However, this is dependant upon available funding and manpower for the states boat hazing as well as for the additional effort from the WS dam hazers. The intent would be to conduct a maximum non-lethal hazing effort at the dam to see if fewer salmonids would be taken near the dam by hazing away all pinnipeds in the tailrace. The goal would be to drive as many pinnipeds as possible out of the tailrace area, and therefore reduce the amount of salmon preyed upon. Predation rates and estimates would have to be compared to previous years observations. No observations of predation below Bonneville Dam tailrace will be conducted other than by volunteers.

Trapping and marking of pinnipeds may also occur again as in 2007, and we will assist in the effort to trap these animals, identify them when possible, and track their behavior once they return to the tailrace.

Although difficult, it is possible to identify individual sea lions by markings (scars, colors, patterns, size, and even behaviors) within year at the dam, and possibly between years, if the marks have not grown over. New marks and healing of older scars may complicate matters. Even branded and tagged sea lions were difficult to identify at times. We did not find any haul out sites for sea lions in 2002 or 2003 from Bonneville Dam down to Ives or Pearce Islands. However, in 2004 several sea lions were seen to haul out on the spillway ogee's before spill began. In 2005, several animals were seen to haul out on several spillway ogees, the rangers' courtesy dock below the new navigation lock, and on the concrete apron to the new corner collector in the powerhouse two tailrace. We will continue to document new haul out sites seen and work with USDA/WS personnel to haze them off when possible. Boat hazers from the states documented sea lions up into Hamilton Creek and in the Ives Island area feeding on salmon. A NMFS technical memo (NMFS, 2001) states that sea lions following fish into fresh water rivers do not always need haul out points during the fish run, and in fact we see them "raft" up at times, resting in the dead water locations such as powerhouse one tailrace. Harassment of these "rafts" will also occur if within distance of our land-based harassment efforts.

Relevance

Marine mammals naturally feed upon salmonids, both in the ocean and in the lower Columbia River. California sea lions have been reported in the tailrace of Bonneville Dam almost every year since at least the 1980's and Lewis and Clark documented hundreds of harbor seals at Celilo Falls in 1805. These pinnipeds are likely taking advantage of the situation imposed by impoundments, which concentrates salmonids as they search for fishway entrances, although we have no data from other sections of the river with which to compare. Salmonids typically take about a day to pass Bonneville Dam once they enter the tailrace area (Bjornn et al., 2000). This concentration and delay of salmonid passage may allow sea lions to inflict higher losses on the salmonid population than would be the case in the free flowing portion of the river below Bonneville Dam. Increasing numbers of California sea lions feeding directly below Bonneville Dam have been estimated to take over 3,500 salmonids of the January 1 to May 31 salmonid run (Stansell, 2004). In 2005, a much smaller spring Chinook run than anticipated presented itself and the sea lions were estimated to have taken 3.4% of that years run. The figure for 2006 was just over 3,000 salmon, which comprised about 2.8 % of the run. Each year the sea lions have been arriving earlier, staying later, eating more fish (until 2005), eating more lamprey, hauling out more, staying for longer periods, and the average number present per day has increased. In 2005 at least eight different sea lions learned to enter the fishways, with one individual being seen at one or both count station windows every day but one from March 11 through March 31. Efforts of active hazing, acoustic deterrents, and Sea Lion Exclusion Devices (SLEDS) in 2006 showed pinniped presence near fishways could be reduced, but overall predation in the tailrace was not affected (in fact, it was actually higher than when no hazing occurred). The SLEDs were 99% effective in keeping sea lions out of the fishways in 2006. Only one animal made it past the SLEDs last spring, and only for a short time. Floating Orifice Gate barriers (FOG's) will be installed by 2008 to prevent sea lions from entering through those structures at the Powerhouse Two. Sea lions likely take endangered and threatened stocks of salmonids in proportion to those passing the dam, and this impact could become significant if left unmanaged.

Project Description

Background

Sea lions in the tailrace of Bonneville Dam in the spring have been documented in fishway inspection reports since the early 1980's. However, increasing numbers of sea lions were observed in 2001, and the 2000 NMFS Biological Opinion for the FCRPS RPA 106 directed agencies to evaluate marine mammal predation in the Bonneville Dam tailrace. The Corps Fisheries Field Unit conducted this work in 2002-2004. Additional observations were made in 2005 after sea lions began entering the fishways and hauling out at multiple locations during daylight hours. The additional year of observation was warranted after it became evident that the predicted 250,000 spring Chinook were not going to show up, the final run being about a third of that estimate. In 2006, active and passive hazing techniques were tested with negative results. In 2007, full time active and passive deterrents were employed with little obvious impact to the predation on salmonids.

Data from 2002 through 2007 (Stansell, 2004; Letter Report, 2005, 2006, Status report 2007) showed the sea lions arrived earlier and stayed later each year, stayed for longer periods, increased in the average number seen per day, increased the percentage of the salmonid run taken, increased the proportion of lamprey in their diet, increased their catch efficiency (decreased percentage of fish caught then lost), increased their predation activity in the spillway tailrace, and an increase in the level of "boldness" concerning haul out sites and entering of fishways. An estimated 3.4% of the salmonid run from January 1 through May 31 was taken by pinnipeds below Bonneville in 2005 (about 3000 salmonids). Fewer total number of salmonids were estimated to be taken in 2005 compared to 2004 (2,920 and 3,533 respectively), however this was more than for 2002 and 2003, all years having much higher salmonid runs than 2005. In 2006, just over 3,000 salmonids were taken, or 2.8% of the run. In 2007, an estimated 3,859 salmonids were taken which amounted to 4.2% of the run.

Over 100 individual pinnipeds were identified in 2003 and 2004, averaging 27 present per day in 2006 with a maximum of 46 at the project in one day. Most fish are caught in the powerhouse two tailrace, followed by powerhouse one and the spillway tailrace. The most salmon any one individual sea lion was seen to consume in one day was 10, and 52 total for the season for the same individual. In 2002, we observed 61 (11%) salmonids being caught and brought to the surface by sea lions then subsequently lost, but this steadily decreased each year to 0.8% in 2005. The percentage of returning individuals ranges from between 42% to 81%.

Pacific Lamprey (*Lampretra tridentate*) made up 18% (by number) of the observed diet consumed by pinnipeds in 2005. Roffe and Mate, (1984) discovered that the most abundant food item in seals and sea lions near the Rogue River were Pacific Lamprey. Since lamprey populations in the Columbia River Basin are in decline (Jackson et al., 1996), it could be that marine mammal predation is increasing on salmonids. In 2006, 264 sturgeon were observed taken in the Bonneville Dam tailrace, all but one caught by Steller sea lions. This made up 7% of all fish observed taken in 2006. In 2007, 360 sturgeon were observed caught and this was about 8% of their diet.

Objectives/Methodology

Objective 1: Determine seasonal timing and abundance of pinnipeds present at Bonneville Dam.

Observations at Bonneville Dam tailrace will begin in February and continue until sea lions are no longer consistently present (last week of May to first week of June). Surface observations will occur during daylight hours only (as 2002-2003 observations revealed no predation at night) on at least five days each week. Observations will occur for several hours (between 8 and 15) at each of the three tailrace channels below Bonneville Dam. Information recorded will include date, time of day, numbers of sea lions present, location, observed behavior (feeding, swimming, resting, etc.), individual pinnipeds present (if known), and number of salmonids and lamprey consumed and lost. Video-camera recordings will be taken to verify some of these observations. When possible, individual sea lions will be identified and markings documented. Video-camera recordings may also be taken to back up the observations of individuals.

Objective 2: Estimate pinniped predation on adult salmonids and lamprey in the Bonneville Dam tailrace.

Observations will occur as for Objective 1 and specifically the number and species of prey observed consumed and lost will be noted. Estimates of the amount of salmonids and lamprey consumed by sea lions across the season will be made by taking actual hourly predation observed and expanding for any daylight hour not observed based upon the hourly distribution of catch at the end of the season. Estimates for days missed will be simply extrapolated for by adding the estimates for the two adjacent days and dividing by the number of days not observed. The period of January 1 to May 31 will be used as the run period for salmonids as the arrival and departure dates for the pinnipeds has been expanding, mostly by arriving earlier, and this makes yearly comparisons consistent. This may change to June 15, as that became the official end of the spring Chinook run season in 2005.

Objective 3: Identify individual sea lions at Bonneville Dam, determine whether they return in subsequent years, and their haul out areas.

The Fisheries Field Unit (FFU) determined that sea lions could be identified to individuals in 2002, albeit with some difficulty, by using scar patterns, marks, color, size, and even behavior for the majority of sea lions observed. This, supported by those marked by ODFW at Astoria, will allow us to determine how many different individual sea lions are present in each tailrace, at the project, and across the season. It will also help us determine how many salmonids and lamprey are consumed by specific individuals, and the frequency and duration of occurrence of these individuals both within year and year-to-year. We will work with ODFW to document movements and sightings between Bonneville and Astoria.

Objective 4: Evaluate impacts that deterrent actions including exclusion gates, acoustics, and harassment on pinnipeds in general at Bonneville Dam may have on predation rates and abundance of pinnipeds in the tailrace. In addition, evaluate the response of individual California sea lions to active, non-lethal or lethal deterrents employed by USDA and state agency personnel.

An evaluation of the average daily numbers of pinnipeds present and predation rates in the Bonneville tailrace with active harassment, acoustics, and exclusion gates will be conducted. This will be with full time hazing and acoustics activity at all tailraces and fishway entrances. This may be conducted in conjunction with hazing from boats by WDFW and ODFW personnel. We will attempt to quantify abundance and predation estimates in the near-dam environment where these measures are assumed to be effective in pushing pinnipeds away, and compare that when these measures are not conducted. Our recommendation is to leave the exclusion gates in at all times (in the spring) at all main entrances and floating orifice gates, and conduct hazing of pinnipeds seven days per week at all tailraces during all hours of daylight from February through the end of May. Comparisons of daily average number of pinnipeds present and daily average number of salmonids taken can then be made to previous years to see if these values have been reduced by all the additional hazing activity. If funding and personnel permit, a single individual branded sea lion will be randomly selected each day and its behaviors tracked and recorded. Behaviors recorded will include resting, traveling, foraging, hauled out, eating, playing, harassment avoidance, and others.

Justification of the proposed study area

Bonneville Dam is the first dam on the Columbia River upstream from the mouth of the estuary. Sea lions tend to congregate in large numbers just below the dam to feed on salmonids, lamprey, and shad (*Alosa sapidissima*) in the tailrace of Bonneville Dam in the spring. Steller sea lions have begun to prey upon sturgeon below Bonneville Dam during the winter in increasing numbers. Observations from 2002 through 2006 showed up to 100 different individual sea lions visiting the tailrace of Bonneville, as many as 46 at one time. An evaluation of marine mammal predation below Bonneville Dam was required by the 2000 Federal Columbia River Power System Biological Opinion (section 9.6.1.5.3 Action Item 106) (2000) and completed in 2002-2004. Management techniques to discourage pinnipeds from entering fishways and preying on fish near the entrances need to be evaluated to determine effectiveness and that there is no adverse impact to fish passage.

Statistical justification of the required sample size, number of tests, and replicates

This evaluation is primarily observational. The sea lion exclusion devices/gates will be installed and remain in place during the spring Chinook run. Comparison of average number of pinnipeds seen daily, predation rates, and total predation estimates will be made to previous years to determine the effectiveness of a full time hazing program. We intend to continue full daylight hours of monitoring and harassement, 7 days per week, but if funding does not permit, a sampling regime of every other day or 3 days per week would put us within +/- 2% or 5% (respectively, 95% confidence interval)of the actual salmonid take based upon 2006 and 2007 years data. Straight exptrapolation for days not observed using adjacent days of observation for an every other day sampling resulted in estimates within 2.2% and 2.5% of the actual take using 2006 and 2007 data respectively. A three day per week sampling resulted in 4.4% and 5.4% for each of the years, respectively.

Numbers and species and source of required fish

Not applicable.

Limitations of proposed methodology and expected difficulties

Sea lions can stay submerged for extended periods of time and this may impact our ability to accurately count, and determine individuals. Documenting individuals with digital video will take a great deal of time and patience as they frequently surface for just a few seconds. There is often insufficient time to aim, zoom, focus, and shoot video that captures an individual's distinguishing characteristics. The reflection of the sun can cause glare that can make it hard to see features on a sea lion and cause an auto-focusing lens to be unable to properly focus, so polarizing filters may be needed. Lighting conditions make coloration appear to change on the same individual. Small prey such as lamprey, jacks, or smolts can be consumed without the sea lion surfacing. If sea lions consume smaller prey while underwater, we may underestimate the total number of those species consumed by sea lions at Bonneville. Individual markings/brands used by ODFW have various degrees of visibility when sea lions are in the water feeding below Bonneville. As always, human error and differing levels of observational skill may play a part in the variability of data collected, but this will likely not be significant.

Expected results and applicability

It is expected that the physical barrier gates will keep all but the smallest or most determined sea lions out of the fishways, but it may increase predation at the fishway entrance if fish hesitate before passing the gates longer than without the gates present. The acoustics may create a safety zone around the entrance gates that will not hinder fish passage but should deter sea lions from hunting within 30-100 feet of the entrances. Harassment of sea lions seen in the tailrace, near the fishways and haul out sights may convince some of the "novice" animals that prey is better hunted for somewhere other than at Bonneville, where they won't be harassed. Better documentation of sea lion numbers and activities (feeding) below Bonneville Dam will allow for a better assessment of their impact to salmonid populations. Individual sea lions that can be identified as problem animals and repeat offenders is necessary for any potential capture or take of marine mammals by NOAA or the states in the future, if those management strategies become necessary.

Schedule

Observations of sea lions at Bonneville Dam will occur from February through June, depending upon when they arrive and leave. Information will be provided to District personnel weekly for summary update reports. A draft summary report will be written by December 31, 2008 with a final by July 31, 2009.

Facilities and Equipment

Binoculars, image stabilizing binoculars, night-vision binoculars, spotting scopes, digital video cameras, polarizing filters, tripods, and video tape will be required to document individuals and predation activities. Observations will occur primarily from the powerhouse tailrace decks and along the fisherman's access shoreline for the spillway for all observers. WS personnel will supply all material for non-lethal hazing, including shotguns, cracker shells, rockets, and rubber bullets. ODFW and WDFW will supply boats for hazing from the tailrace downstream. The states may deploy floating trap barges to begin to see if some animals can be lured into traps for marking, transport, or holding.

Impacts

Active hazing by WS personnel and ODFW/WDFW personnel is not expected to impact fish passage, but the increased level of noise may impact researchers conducting other studies at Bonneville Dam. WS personnel will also likely be hazing avian species in conjunction with this activity and therefore pinnipeds or avian hazing may be compromised for short periods of time. The SLED's and acoustic deterrents have not shown any sign of impacting salmonid passage or passage of any other fish.

Collaborative Arrangements and/or Sub-Contracts

FFU personnel will work with the USDA/WS agents that will be harassing sea lions hauled out and near the dam to identify specific animals being hazed when possible. This also applies to the project for removal of entrance gate barriers.

FFU will contract about six SCA student interns to assist FFU personnel with observations of pinnipeds from February through the end of May.

FFU will continue to work with NMFS and ODFW crews marking and observing sea lions at Astoria to share re-sight data on brands between Bonneville and Astoria.

List of Key Personnel and Project Duties

Robert Stansell – Team Leader - Oversees studies design, data analysis, and report writing, participates in some observations and documentation of individual sea lions.
Biological Technicians – 4 individuals - Data collection, observations.
Student Conservation Corps personnel – 6 individuals - Data collection, observations.
University of Idaho – Sharing data near entrance gates to compare with radio-tagged fish behavior.
Matt Tennis and Robin Brown, ODFW – Providing data on observations of branded sea lions at Astoria that have been at Bonneville Dam.
USDA/WS Agents – Providing hazing of pinnipeds hauled out on the project and near fishway entrances.
ODFW/WDFW/Tribes – May provide hazing from boats below Bonneville Dam.

Technology Transfer

We plan to transfer information obtained from our analysis in the manners listed below. The information will be used by federal and state agencies, Native American Tribes, and the public to make management decisions to reduce salmonid consumption by sea lions below Bonneville Dam. Technologies that may be evaluated include digital video and digital still images to record and document individual sea lion characteristics.

1. Presentations to the Anadromous Fish Passage Evaluation Program (AFEP) in November 2007 and presentations to fisheries agencies, tribes, and the public as requested by the USACE.

2. Expected draft annual reports for 2008 to AFEP by December 2008 and a final report by July 2009.

3. Presentations to the Army Corps of Engineers staff and study review groups.

4. Presentations at professional meetings and publication of information in peer-reviewed journals.

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FINAL RESEARCH PREPROPOSAL (COE) (FY08)

TITLE:	Studies to estimate salmonid survival through the Columbia River estuary using acoustic tags
PROJECT LEADERS:	Lynn McComas National Marine Fisheries Service Northwest Fisheries Science Center 2725 Montlake Boulevard East Seattle, Washington 98112-2097 (509) 547-7518 Geoffrey A. McMichael Battelle Pacific Northwest National Laboratory (PNNL) P.O. Box 999, K6-85 Richland, Washington 99352 Phone: (509) 372-0804 Thomas Carlson Battelle Pacific Northwest National Laboratory (PNNL) 620 SW 5th Ave., Suite 810 Portland, Oregon 97204 (503) 417-7567
ADMINISTRATIVE:	Doug Dey National Marine Fisheries Service Northwest Fisheries Science Center Fish Ecology Division 2725 Montlake Boulevard East Seattle, Washington 98112 (206) 860-3231
ADMIN. CODE:	EST-02-01
DURATION OF PROJECT:	2001 to 2010
DATE OF SUBMISSION:	October 2007

PROJECT SUMMARY

The goal of this study is to continue use of a Juvenile Salmon Acoustic Telemetry System (JSATS) acoustic tag and receiver system to estimate survival, residence behavior, and ocean-entry timing of both stream- and ocean-type juvenile salmonids through the lower Columbia River,and the Columbia River estuary and plume. Statistical basis for this work is the single-release survival model introduced by Cormack (1964), Jolly (1965), and Seber (1965), referred to as the CJS single-release model. Information gained from these efforts will be used to characterize how salmonids utilize estuarine habitats, explore mechanisms of hydropower system latent (BDE) mortality, and evaluate the effect from physical changes to the estuary (flow and habitat) on the recovery of listed salmon stocks. Data collected between 2005 and 2007 indicated that significant portions of the yearling and subyearling Chinook salmon that pass Bonneville Dam on their seaward migration do not survive to ocean entry. In 2008, we propose to implant micro-acoustic tags into non PIT-tagged run-of-the-river (ROR) juvenile salmon obtained at the Bonneville Dam smolt monitoring facility. The Columbia River downstream of Bonneville Dam will be partitioned into up to five distinct reaches to identify areas where fish are ceasing migration and to determine the fate of these fish (e.g., death vs. extended rearing). Sample sizes for this work will be determined based on criteria of the proposed evaluation, single-release survival model requirements, and tag-detection-probability data collected in 2006 and 2007.

Reasonable and Prudent Alternative (RPA) 195 of the NMFS 2000 Federal Columbia River Power System (FCRPS) Biological Opinion required the Corps of Engineers to “evaluate survival of fish passing through the FCRPS below Bonneville Dam, which will include the estuary”. This program began in 2001 due in part to this RPA. The 2004 Updated Proposed Action (UPA) addressing the NMFS FCRPS 2004 BiOp states that “All ESU’s pass through the estuary and utilize it to some extent. In addition, recent findings reported by Marsh et al. (2007), indicated that a large portion (61%) of the returning adult fall Chinook salmon which were transported and released below Bonneville Dam late in the emigration season as juveniles, reared in freshwater for an additional winter before entering seawater. This result emphasizes the importance of understanding the use of habitat in the lower Columbia River and its estuary. Further, increased interest in understanding the effects of passage through the FCRPS on differential delayed mortality (or latent mortality; see ISAB 2007 for a review on this topic), underscore the need to deploy technologies that are capable of providing information to better understand the cumulative effects of dam passage or transport on the survival of juvenile salmonids during seaward migration after they have passed the last dam in the FCRPS.

General objectives for Project EST-02-01 in 2008 are to:

1. Estimate yearling and subyearling Chinook salmon survival from Bonneville Dam through the mouth of the Columbia River.

2. Quantify and compare latent effects of FCRPS passage history on mortality of emigrant juvenile yearling and subyearling Chinook salmon from Bonneville Dam downstream.

3. Monitor and map estuary migration pathway and habitat associations and relative behaviors.

4. Determine the fate of subyearling Chinook salmon that cease their migration in the Columbia River downstream from Bonneville Dam.

5. Estimate survival probabilities for yearling and subyearling Chinook salmon within the plume.

6. Competitively procure prototypes of "rearing Chinook" acoustic micro-transmitters for function and biocompatibility evaluation.

7. Determine the capability and reliability of the JSATS cabled (hard-wired) array.

BACKGROUND

General

Mortality in the estuary and ocean comprises a significant portion of the overall mortality experienced by salmon throughout their life cycle, and seasonal and annual fluctuations in salmonid mortality in these environments are a significant source of recruitment variability (Bradford 1995). In recognition of the potentially important contribution of estuaries to overall survival, recent studies attempted to evaluate effects of estuarine conditions on salmon. Simenstad et al. (1992) suggest that estuaries offer salmonids three primary advantages: productive foraging, relative refuge from predators, and a physically intermediate environment in which the fish can transition from freshwater to marine physiological control systems. Thorpe (1994) reviewed information from three genera of salmonids (*Oncorhynchus, Salmo*, and *Salvelinus*) and concluded that salmonids are characterized by their developmental flexibility and display a number of patterns in estuarine behavior. He found that stream-type salmon migrants (some Chinook, coho, sockeye, and Atlantic salmon) move through estuaries and out to sea quickly, compared to ocean-type salmon migrants.

Most of our knowledge of how salmonids utilize estuaries is limited to smaller systems that can be more readily sampled. For example, Beamer et al. (1999) assessed the potential benefits of different habitat restoration projects on the productivity of ocean-type Chinook salmon in the Skagit River, Washington. They concluded that restoration of freshwater habitats (peak flow and sediment supply) to functioning levels would provide limited benefits unless estuary capacity or whatever factor that limits survival from freshwater smolt to estuary smolt is also increased. They used productivity and capacity parameters to estimate that estuarine habitat restoration could produce up to 21,916 smolts/ha. Reimers (1973) found a diverse number of estuary rearing periods and strategies for fall Chinook salmon in the Sixes River, Oregon.

Columbia River

Little information is available describing historical juvenile salmonid use of the Columbia River estuary. Rich (1920) found that 36% of the juvenile yearling and subyearling Chinook salmon collected from 1914 to 1916 demonstrated extensive rearing in the estuary. In a more recent study, as many as 70% of the fish sampled during July had resided in the estuary from 2 to 6 weeks (Jen Burke, Oregon Department of Fish and Wildlife, Pers. commun., June 2000). Subyearling Chinook salmon attained 20 to 66% of their fork length (FL) while in the estuary. In contrast, in more recent times where hatchery fish dominate the juvenile population, Dawley et al. (1985) noted that movement rates through the estuary were similar to rates from the release site to the estuary, indicating limited use of the estuary by juvenile salmonids originating upstream from Jones Beach (river kilometer, Rkm, 76). Schreck and Stahl (1998) found mean migration speed of radio-tagged yearling Chinook salmon was highly correlated with river discharge, and averaged approximately two mph from Bonneville Dam to near the mouth of the Columbia River. Movement in the lower estuary was influenced by tidal cycles, with individuals moving downstream on an ebb tide and holding or moving upstream during a flood tide. They reported a high proportion of tagged animals were lost to piscivorous bird colonies located on dredge disposal islands. Ledgerwood et al. (1999) also found that travel speed of PIT-tagged fish from Bonneville Dam to Jones Beach was highly correlated with total river flow. They observed significant differences in passages times at Jones Beach for spring/summer Chinook salmon PIT tagged and released at Lower Granite Dam to migrate in-river and fish transported to below Bonneville Dam and released. PIT-tagged fish detected at Bonneville Dam had significantly faster travel speeds than those released from a transportation barge below Bonneville Dam--98 and 73 km/day, respectively. These recent studies provide a cursory assessment of estuarine migration behavior.

Potential Effects of the FCRPS

Physical processes in the estuary and thus estuarine habitat are shaped by two dominant factors; channel bathymetry and flow. River flow is controlled by climate variation and anthropogenic effects such as water storage, irrigation, withdrawals, and flow regulation. The FCRPS has altered the hydrology of the Columbia River estuary through flow regulation, timing of water withdrawals, and irrigation, which have affected the average flow volumes, timing, and sediment discharge (Bottom et al. 2001, NRC 1996; Sherwood et al. 1990; Simenstad et al. 1992; Weitkamp 1994). Annual spring freshet flows are approximately 50% of historical levels, and total sediment discharge is roughly one-third of levels measured in the 19th century. The direct effects of these changes to the estuary from FCRPS operations on salmonids have not been estimated.

The potential for delayed mortality on fish that migrate through the hydropower system is also a concern to fisheries managers and scientists, as well as regional decision makers. Recent quantitative model studies have assessed the importance of survival downstream from Bonneville Dam to the overall life cycle, and sensitivity analyses identified the life stages where management actions have the greatest potential to influence annual rates of population change and priorities for research (NMFS 2000a). A reduction in mortality in the estuary/ocean and during the first year of life had the greatest effect on population growth rates for all spring/summer Chinook salmon stocks when a 10% reduction in mortality in each life stage was modeled. Use of smolt-to-adult ratios (SAR) calculated by the Plan for Testing and Analyzing Hypotheses (PATH) in the sensitivity analysis produced similar results. These analyses suggested that salmonid recovery efforts will require an understanding of the important linkages between physical and biological conditions in the Columbia River estuary and salmonid survival. Kareiva et al. (2000) concluded that modest reductions in estuarine mortality, when combined with reductions in mortality during the first year of life, would reverse current population declines of spring/summer Chinook salmon. Emmett and Schiewe (1997) further concluded that survival must be partitioned between the freshwater, estuarine, and ocean phases in order to answer important management questions. Given the high proportion of mortality occurring below Bonneville Dam, the potential positive response in population growth rates from changes to survival in this area, and the uncertainty over the causal mechanisms of hydropower system delayed mortality, detailed studies of survival and behavior in the estuary are warranted.

Technical Basis

The proposed approach (to mark salmonid smolts with acoustic tags and track them through estuarine environments) has been successfully used in other applications and using the JSATS technology (McMichael et al. 2007; McComas et al. in review). For example, Atlantic salmon marine acoustic-tagging project (MAP) has marked, released, and tracked Atlantic salmon (*Salmo salar)* smolts leaving several rivers in the Passamaquoddy Bay and the Bay of Fundy in southwestern New Brunswick, Canada (Gilles Lacroix, Department of Fisheries and Oceans, St. Andrews New Brusnwick, Canada, Pers. commun., December 2000). Both wild and hatchery-reared smolts were tagged and released. Automated receivers were strategically deployed underwater to form detection arrays or screens that monitored all fish leaving the river, the coastal zone in a 10 km radius of the river mouth, and movement across a 50 km stretch between the inner and outer portions of the Bay of Fundy. All tagged post-smolts were detected, survival was estimated, and the movements of some individuals were monitored for up to 3 months.

In the current application, extensive modeling indicated that acoustic technology is a practical tool for use in making robust survival estimates in the lower Columbia River, estuary and near ocean. Data collected in 2006 indicate that the detection probability of the primary detection array in the estuary (near East Sand Island) averaged between 80 and 90% from early April through July.

Summary

This study will allow assessments of salmonid migrational behavior and survival through the Columbia River estuary under current hydropower system flow management scenarios and the existing physical configuration of the estuary. High detection probabilities for fish implanted with small acoustic tags will allow the methodology to be applied to management questions important to the region. These include determining whether delayed mortality due to passage through the hydropower system can be measured in the reach between Bonneville Dam and the mouth of the Columbia River, characterizing how smolts use the estuary and whether estuarine habitat restoration actions influence habitat selection and survival, how salmonid behavior in the estuary varies between years, dominant environmental conditions (such as river flow), ESU, rearing type, and migration history (e.g., multiple bypassed fish). Further, in 2008 we propose to add new objectives to determine latent mortality effects of different passage histories through the FCRPS, better understand the fate of juvenile salmonids that use the lower Columbia Rvier and/or estuary for extended rearing periods, and initiate activities to determine the possibility of determining the survival of juvenile salmonids beyond the mouth of the Columbia River. Finally, we propose to initiate procurement activities for developing prototype JSATS microtransmitters that would be small enough to implant in very small (e.g., 70 mm) juvenile salmonids that utilize estuary habitat for extended rearing periods.

Estimating reach survival rates for the Columbia River below Bonneville Dam is an important next step toward developing an understanding of whether delayed mortality occurs between Bonneville Dam and the mouth of the Columbia River, and the magnitude and variability of the mortality by specific river reach.

APPROACH

Our general approach has been to integrate the three main components of the program (tag signal specifications, receiver array design, and detection probabilities required by the single-release model) to provide maximum detection capability. In 2001, we contracted systems engineering firms to design the acoustic tag and a primary detection array based on acoustic model simulations and analyses of trade-offs between acoustic tag output characteristics (signal frequency, repetition rate and source amplitude) and probability of detection required by the single-release model, array location, environmental conditions, and constraints from the experimental design (sample sizes available and estimated survival to the mouth).

A prototype tag was produced for coating biocompatibility and acoustic reception trials beginning in September 2002, and more exhaustive biological compatibility evaluations were carried out in 2003. The original prototype has undergone improvement to maximize capabilities of the final product. Though still under development, the current tag is smaller than most electronic transmitter tags, measuring 14 mm long x 5.5 mm wide and tapering from 4 mm to 2 mm high. This is larger than target dimensions; however, weight of the current model is about 0.6 g, which is less than the design goal of 0.7 g dry weight, with a 0.35 g residual. Ergonomic shape of the tag has also been improved to conform to the body cavity. The encoding method currently being used can provide for the possibility of over 32,000 individual tag codes, and this encoding strategy allows for consideration of expanded capabilities, such as the addition of a pressure transducer to encode depth information in the transmitted signal.

From 2002 through 2006, we also tested a functional prototype detection node and demonstrated our capability to physically deploy, anchor, and retrieve fixed and autonomous detection arrays in the lower Columbia River estuary. In 2006 and 2007, autonomous receivers were used in all locations for this project and performed very well (e.g., mean detection probability on the primary array in the estuary was between 80 and 90%). In addition, a prototype mobile tracking system was developed and evaluated in the field. This vessel-mounted, 3-dimensional (3-D) system proved robust, capable of identifying JSATS acoustic tags in real time, and capable of tracking tagged fish for extended periods.

Specific objectives of Project EST-02-01 in 2008 are to:

1. Estimate survival from Bonneville Dam through a minimum of five river reaches to the mouth of the Columbia River for yearling and subyearling Chinook salmon.

2. Quantify the latent effects of FCRPS passage history on mortality of emigrant juvenile yearling and subyearling Chinook salmon downstream of Bonneville Dam; compare survival for fish passing through spill, RSW, and turbines (combined) to passage through juvenile bypass systems.

3. Map estuary migration pathways and assess habitat associations and behavior patterns relative to these pathways to support estuary habitat restoration prioritization.

4. Determine the fate of subyearling Chinook salmon that cease migration in the Columbia River downstream from Bonneville Dam.

5. Initiate feasibility work to enable future estimation of survival probabilities for yearling and subyearling Chinook salmon within the Columbia River plume.

6. Competitively procure prototypes of “rearing Chinook” acoustic micro-transmitters for function and biocompatibility evaluation.

7. Determine the capability and reliability of the JSATS cabled (hard-wired) array to continuously collect and store micro-acoustic transmitter data relative to autonomous-node arrays currently in use.

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Objective 1

Estimate survival from Bonneville Dam through a minimum of five river reaches to the mouth of the Columbia River for yearling and subyearling Chinook salmon.

We propose to estimate yearling and subyearling Chinook salmon survival from release at Bonneville Dam to the mouth of the Columbia River using acoustic telemetry to meet the requirements of the single-release statistical model. For this study, we will estimate survival to a primary detection array located near the mouth of the Columbia River estuary, at river kilometer 8.3.

The most favorable transect for a primary detection array was selected during system design and feasibility studies conducted in 2001, and secondary array locations have been identified to accommodate assumptions of the single-release survival model (Fig 1). Fully-populated detection arrays were deployed along the proposed transect routes in 2005, 2006, and 2007. Both arrays intercepted a substantial portion of the acoustically tagged outmigrant population. Fish from each of the yearling and subyearling Chinook salmon groups released in each of the past three years were detected on nodes in both arrays, and often individual fish were recorded on multiple nodes. Sample sizes (release numbers) will be based on previously measured detection probabilities.

The primary detection array will be comprised of autonomous nodes. These nodes are individual, self-contained acoustic receiver units suspended approximately 4.5 m (15 ft) above the bottom on an anchored tether. Acoustic releases allow periodic recovery for battery replacement and data retrieval. Similar to 2006 and 2007, deployments in 2008 will not use surface buoys.

Since nodes cannot be safely placed in the shipping channel for extended periods, the primary array will be composed of two smaller, independent sub-arrays to cover the line from West Sand Island to Clatsop Spit (Fig. 1). Based on current information for detection ranges for these nodes and reception data from the 2005, 2006, and 2007 deployments, the northern (West Sand Island, WSI) sub-array will consist of nineteen nodes running from West Sand Island

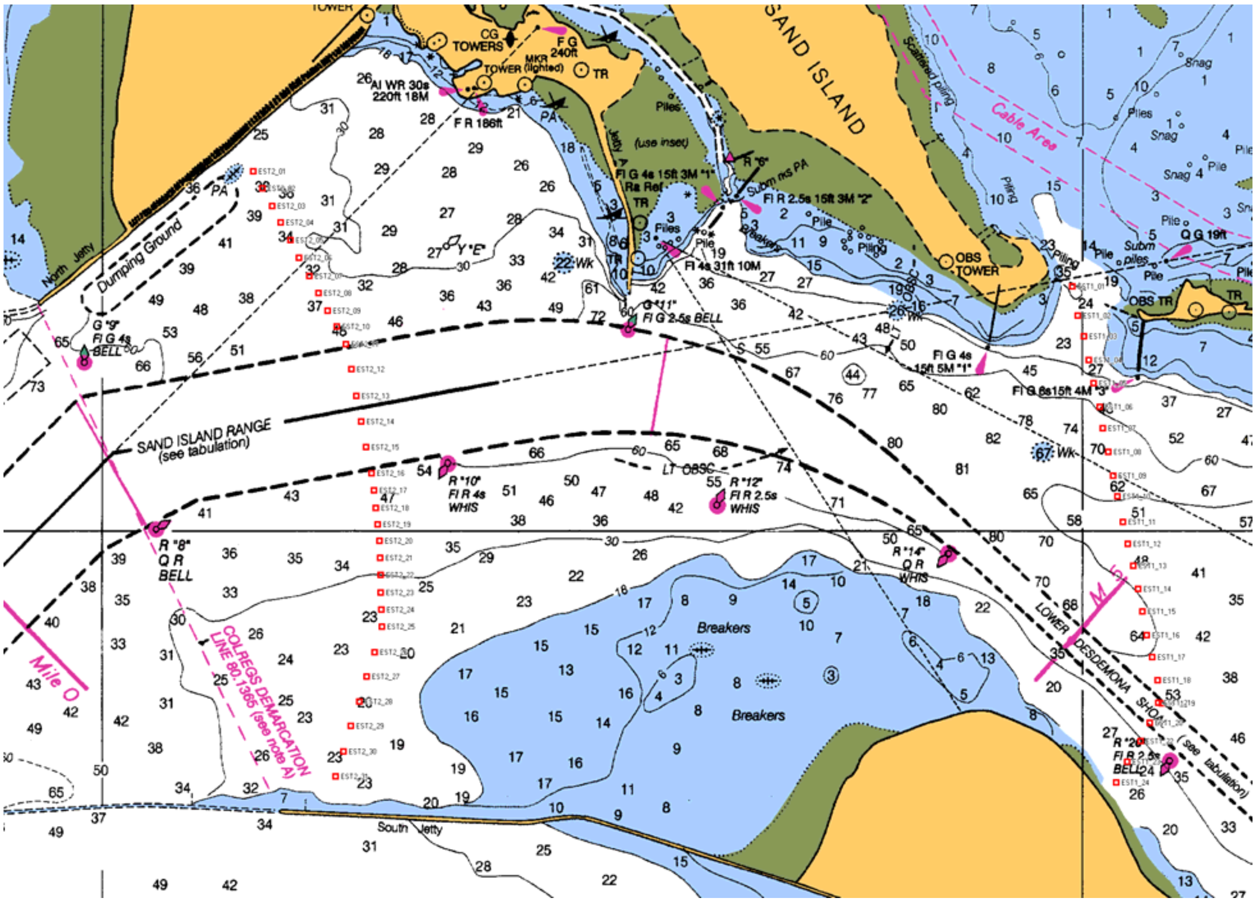

Figure 1. Proposed primary and secondary detection array transects to be used to estimate juvenile salmonid survival through the Columbia River estuary using micro-acoustic transmitter tags. The primary array will consist of 22 autonomous nodes. The secondary array will be comprised of 21 to 31 nodes. All autonomous nodes are suspended approximately between 3 and 6 m from the bottom, depending on total depth at low tide.

(46° 15.889' N, -124° 00.258' W) south to the northeast side of the shipping channel along the Lower Desdemona Shoal Navigation Range (46° 14.310' N, -123° 59.442' W). The second sub-array will be comprised of three nodes extending in a transect east from Clatsop Spit (46° 14.025' N, -123° 59.866' W) to the southwest side of the shipping channel (46° 14.245' N, -123° 59.546' W), terminating directly across from the south end of the northern sub-array. The distance across the shipping channel at this point is approximately 650 ft. This arrangement results in a mean spacing of approximately 137 m between nodes. With a pulse repetition interval (PRI) of 5 seconds between code transmissions, this stationing will allow transmission of at least 9 pulses as the transmitter crosses the detection array reception range in a 11 km/h (6 knot) current. For a 7 second PRI, at least 6 transmissions would occur. Overlap in range of the fixed sub-array end nodes across the navigation channel (198 m, 650 ft), should provide detection of a minimum of 4 pulses for tagged fish migrating along the channel between the two arrays at 11 km/h.

A secondary detection array, downstream from the primary array, will be needed to satisfy the requirements for single-release survival estimation. The secondary array will consist of 21 to 31 autonomous nodes deployed on the Columbia River bar between U.S. Coast Guard Navigation Buoys 8 and 10 (Fig 1).

A total of 11 of the secondary-array nodes will be located on the Washington side of the navigation channel and the remainder on the Oregon side of the channel along a transect from approximately 46° 16.338' N, 124° 04.258' W to 46° 14.454 N, 124° 03.375' W. Equidistant spacing will result in 130- to 137-m intervals between autonomous nodes. This spacing will provide detection capability similar to that for the primary array over the deployed area. Separation between north-south midpoints of the primary and secondary arrays will be approximately 5.3 km. An additional 4 nodes may be deployed in the navigation channel for short (e.g., 72 hour) periods to examine the overall cross-channel distribution of juvenile salmonids as they enter the ocean, in support of O&M data needs of the Portland District of the Corps of Engineers. Also, an additional 6 nodes may be placed between the south end of the secondary array and the South Jetty, for the same support purpose.

Secondary array nodes will be monitored and serviced as necessary to ensure data and power integrity over the tagged fish outmigration interval. We will recover autonomous nodes approximately every 28 days to replace batteries and data cards. Servicing dates will be coordinated with the tagged fish release schedule, anticipated travel times, and tide cycles to minimize omission of tagged fish passing the array during servicing periods. Servicing will require approximately 6 minutes per node.

The geodetic position of each node in both arrays will be recorded at the time of deployment using coordinates obtained through the global positioning system (GPS).

We will install beacon tags within the arrays to serve as system function checks throughout the course of the sampling season.

Deployment of the arrays will occur prior to 25 April 2008, subject to release schedules for this and other JSATS studies as well as weather and sea conditions in the deployment area.

Sample Sizes and Study Design

Building on experience gained during the 2005, 2006, and 2007 spring and summer outmigration seasons, fish to be acoustically tagged will be captured using the Bonneville Dam Second Powerhouse Juvenile Fish Facility (JFF) daily smolt monitoring sample. Only adipose-clipped (presumably hatchery-reared) Chinook salmon will be targeted for the spring outmigration portion of this study. Fish to be tagged will be separated from the daily sample on the day prior to the tagging date and held on river water in the JFF facility until the following day.

All fish will be tagged with acoustic and PIT tags. Tagging will be accomplished in a manner described by McMichael et al. (in review). Fish will be individually anesthetized with tricaine methanesulfonate (MS-222). While immobile, fish will be weighed to the nearest 0.1 g and measured to the nearest millimeter, and the PIT tag code, acoustic tag code, and metrics associated with the fish will be recorded to a database. All recording will be accomplished digitally (including length, weight, tagger ID, PIT and acoustic tag codes) using digitizing tablets, electronic balance, and appropriate tag reading devices. During the recording process, acoustic tag functionality will be verified immediately prior to recording to the database. The subject fish will be placed dorsal surface down on a moist foam operating table, and a rubber tube will be inserted into the animal's mouth to provide a continuous supply of anesthetic water during the procedure. A 10-mm incision will be made approximately 2 mm to the left of the mid-ventral line between the pectoral- and pelvic-fin girdles. The acoustic transmitter and a PIT tag will then be inserted into the abdominal cavity through the incision. The incision will be closed with a minimum of two interrupted sutures, and the fish will be placed in a bucket of fresh water for observation during recovery.

Following recovery from anesthesia after surgery, tagged fish will be placed in 19 L containers and held for up to 24 h (12 h minimum) to evaluate short term tagging effects. Tagged fish will be held in groups of up to 5 fish per container on river water. To best represent the run at large, study fish will be released in temporally and spatially dispersed groups in the Bonneville Dam tailrace. Release location and timing will be closely coordinated with study at Bonneville Dam in 2008, as these fish will serve as a control group in their triple-release survival model. Fish will be released in up to 3 groups each release day, and in two release locations (Bonneville Dam Powerhouse II corner collector and tailrace, based on past hydroacoustics data on time of passage at Bonneville Dam[S1].

Analysis of data from 2006 and 2007 efforts is expected to result in survival and variance estimates for power analysis to empirically refine release group sizes for 2008. For present discussion purposes, nothing in data observations to date indicates that theoretical sample size estimates are invalid. We propose to use the smallest predicted tagged fish group size estimates which will result in approximately ±0.10 precision based on an assumed minimum detection probability at the primary array of 0.60, survival to the primary array of 0.60, secondary array detection probability of 0.60, and survival between the primary and secondary arrays of 0.90 for preliminary planning. Using these parameters, a precision of approximately 0.094 can be realized using release groups of 250 fish. However, since the precision estimate from analysis of the 2007 data set may be different from this target estimate, the 2008 sample size may change to accommodate precision based on that analysis.

Sufficient numbers of fish should be available for tagging from 15 April through 31 May for yearling Chinook salmon. We will begin tagging operations in 2008 on 25 April. The remaining three tagging dates will be spaced with approximately an equal number of days between the start and end dates, providing the greatest possibility for survival comparisons between early- and later-run outmigrants over the time available. We propose to tag up to eight groups of subyearling Chinook salmon over the course of the outmigration from mid-June through mid July, 2008. This will result in one release group per week. This strategy will produce the first reliable estimates of overall subyearling Chinook salmon survival through the lower Columbia River downstream from Bonneville Dam. Successful release of all groups will also provide, at minimum, data for comparing survival and timing among various segments of the subyearling Chinook salmon outmigration.

Objective 2

Quantify the latent effects of FCRPS passage history on mortality of emigrant juvenile yearling and subyearling Chinook salmon downstream of Bonneville Dam; compare survival for fish passing through spill, RSW, and turbines (combined) to passage through juvenile bypass systems

In the coming years, it is likely that many of the FCRPS dams will have semi-permanent deployments of receiving equipment capable of decoding JSATS acoustic transmitters. Data from these deployments will enable assignment of passing fish into passage route categories at each dam (e.g., traditional spill passage versus removable spillway weir passage). With these data and the data on the survival of these groups of fish to the mouth of Columbia River and through the Columbia River Plume, it will be possible to determine the effects of different passage experiences through the FCRPS on latent mortality well after the fish have passed through the FCRPS. For 2008, we propose to analyze survival data for two groups of acoustically-tagged fish; those that pass through bypass systems where their PIT tags are detected (bypass facilities, or the Bonneville Dam corner collector) will be compared to survival of acoustically-tagged fish that were not detected at dams (indicating spill, turbine, or RSW passage). In addition, as some acoustic-tag studies may collect route-specific information for acoustically-tagged fish in 2008, these would allow a more detailed analysis of the effect of FCRPS passage on survival downstream of Bonneville Dam. At this time we are not proposing to tag fish specifically for this objective. Rather, comparison would be between groupings of acoustically-tagged individuals tagged and released for other studies (for example, from Lower

Granite Dam under the tag effects study SPE-06-2). Groupings will be determined for each release and for the total released for both the yearling and subyearling Chinook outmigrations. Statistical comparison of survival for these groups should yield an estimate of whether passage through one or more bypass systems results in a measurable survival burden, relative to non-bypassed fish, through the lower estuary.

Objective 3

Map estuary migration pathways and assess habitat associations and behavior patterns relative to these pathways to support estuary habitat restoration prioritization.

Columbia River Chinook salmon, especially those emigrating as subyearlings, are known to use portions of the estuary as nursery and refuge areas prior to migrating into the ocean (Bottom et al. 2005). Given the relatively large number of juvenile salmon being tagged with microacoustic transmitters for the purposes of survival estimation, we initiated an effort to begin to identify the extent to which outmigrant Chinook salmon may be using habitat or alternative migration corridors other than the main channel of the Columbia River. The 2007 research was focused in the upper Cathlamet Bay area. Preliminary results showed that tagged fish were detected by autonomous nodes in this region. The intent is to use this information to identify habitat types that may be important to the survival of these fish.

To map migration pathways and assess associations with specific estuarine habitat types, we will deploy autonomous acoustic telemetry receiver nodes at selected locations in the lower river and estuary. These nodes will detect acoustic signals from transmitters implanted into outmigrant smolts for other research objectives. We propose a study area (Fig. 2) in the upper estuary (RM 30-50) because of the variety of habitat types (herbaceous and shrub scrub wetlands, sands, etc.) and braided channels (Fig. 2). This area is distinguished from most others in the lower Columbia River estuary because of its deep channels and steep shorelines. The various channels make it conducive to sampling smolt migration pathways and residence times inside and outside the main river channel. Locations for nodes to evaluate tagged-fish movement in 2007 (Fig. 2) may be used during 2008 to maintain continuity among years. The exact node locations for Objective 3 will be selected after the analysis of 2007 data in fall/winter 2007/2008.

The nodes for this objective will be deployed prior to the release of the first tagged fish (~ April 15) to late September. They will be installed along with other nodes as part of the overall effort for this project. Data will be downloaded at least monthly and archived, processed, and filtered at PNNL in Richland, WA.

The following Tasks will be addressed during data analysis:

1. Where and when were the fish detect on the island nodes released? (by node)
2. Which fish were detected on the island nodes? (by species, life history stage and node)
3. When (time periods) were the fish detected on the island nodes? (by node)
4. What was the average residence time, defined as time from first to last detection? (by species, life history stage)

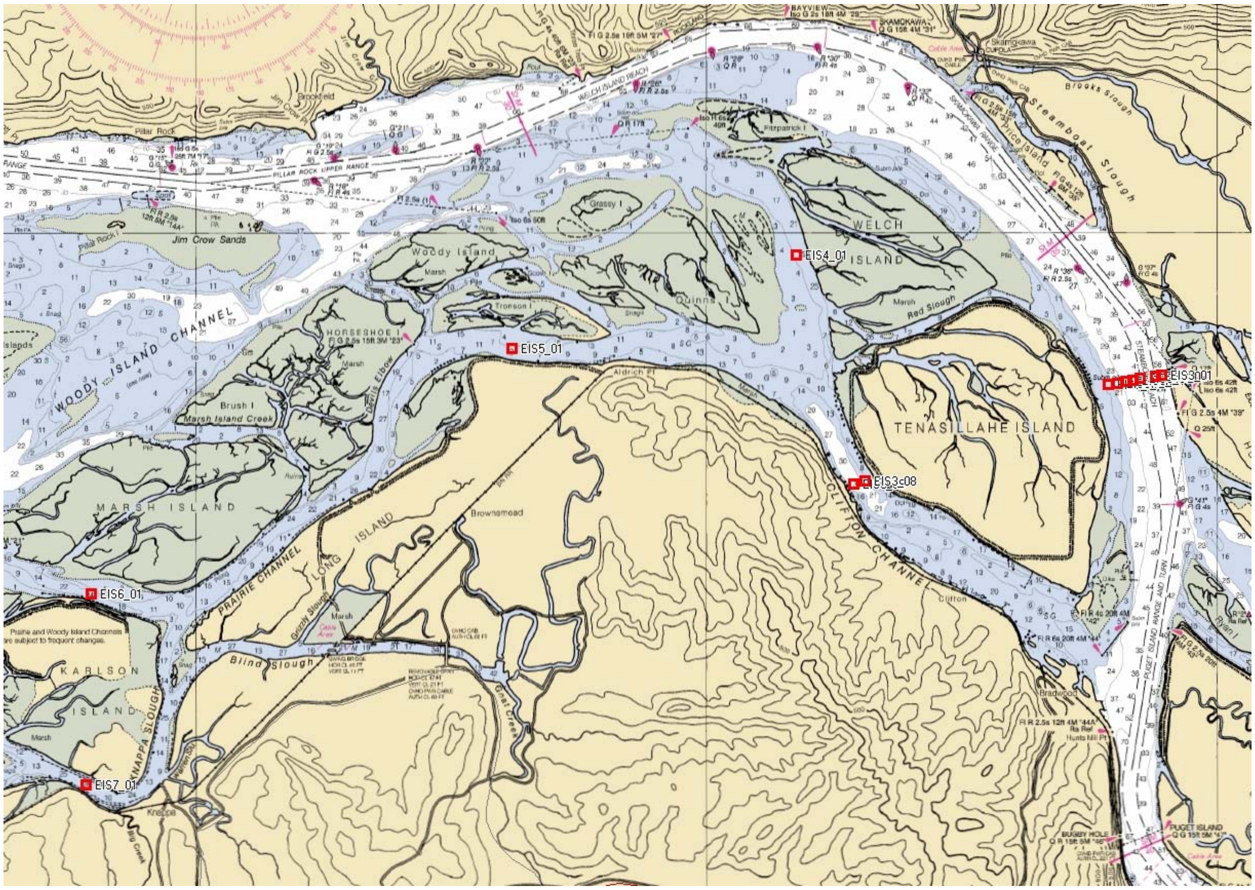

Figure 2. Upper Columbia River estuary study area for evaluation of smolt migration behavior. Red squares indicate locations of autonomous node locations used during 2007 for work under this objective. We propose to repeat these node locations in 2008, and possibly add a few more downstream in Cathlamet Bay. The exact location for migration pathway nodes will be based on forthcoming 2007 results.

5. What were the migration pathways, as determined by the sequence of detections on different nodes, and their frequencies? (by species, life history stage)
6. What were the average travel times between the upstream Puget Island array to the first island detection to the last island detection to the primary/secondary arrays? (by species, life history stage)
7. Of the total number of fish passing the array upstream of Puget Island, what proportion was detected on the island nodes? (by species, life history stage)
8. What proportion of fish detected on the island nodes was not detected on either the primary or econdary arrays? (by species, life history stage). Survival estimates will be also calculated for groups of fish using the island pathways versus groups using main channel routes.

The results from Task 3, Migration Pathways, will be integrated as appropriate with those from Objective 4, Fate of Fish Ceasing Migration. For example, we will compare data from the fixed nodes in Cathlamet Bay with those from mobile tracking in the same area. Tasks 3 and 4 are complementary.

Objective 4

Determine the fate of subyearling Chinook salmon that cease their migration in the Columbia River downstream from Bonneville Dam.

Fate determination is aimed at identifying mortality or behaviors which impact survival estimates, and determining portions of the lower river where, particularly, subyearling Chinook salmon may be overwintering. We will attempt to determine the fate of fish which fail to pass through specific reaches by locating areas of high predation and by attempting to identify habitat or reaches selected by tagged fish which do not outmigrate before their tag expires. In addition to fate determination, we will use resulting data to map specific migration routes through the lower river and estuary. Fate determination will involve two strategies, partitioning the lower river into smaller reaches using fixed arrays, and mobile tracking. Working these strategies in concert, we will attempt to identify specific areas of concern for both yearling and subyearling Chinook salmon.

In 2007, the lower river was partitioned into five sections, the lower estuary (approximate river kilometer, Rkm, 8.3) to Tenasillahe Island (Rkm 57), Tenasillahe to Oak Point, (Rkm, 87) Oak Point to Cottonwood Island (Rkm, 113), Cottonwood I. to Candiana Cliff (Rkm 212), and Candiana Cliff to the release point at Bonneville Dam (Rkm 232). Preliminary survival estimates for each reach are being processed. In 2008, pending outcome of those analyses, we propose to maintain at least these partitions to identify reaches of apparent mortality. To do this, we will complete single release (CJS) survival estimates for individual reaches following data retrieval.

Since program inception, mobile tracking has been recognized as a necessary component of survival estimation as a means to provide information difficult to obtain using stationary receivers. For example, some cohorts of fall Chinook salmon have been shown to reside in estuarine habitats for extended periods before completing their emigration to the ocean environment (Reimers 1973, Levy and Northcote 1982). If this residence period exceeds the life of the micro-acoustic tag, survival estimates will overestimate mortality. Marsh et al. (2007) concluded that a considerable percentage of subyearling Chinook salmon tagged at Lower Granite Dam and transported below Bonneville Dam spent their first winter in fresh or estuarine habitats before migrating to the ocean. In those data, they found that the propensity to remain in fresh/estuary residence appeared to be greater for late (fall) migrants (61%) than for early (summer) migrants (35%). Mobile tracking could be used to monitor the selection and extent of estuarine habitat utilization for acoustically-tagged fish under these transport strategies. For all acoustically-tagged smolts, the mobile unit can identify migration routes through the lower river and estuary, document evidence of predation events, and define migration timing through selected reaches.

A mobile tracking unit for use with the JSATS transmitter was developed for preliminary testing and use in 2007. This vessel-mounted unit computes range, bearing (relative to the vessel), and depth vectors for JSATS-tagged targets within the reception range of receiver hydrophones based on differences in time of target signal arrival at four pylon-mounted hydrophones. Operator displays are updated in near real time, with target ID (tag code), range, relative bearing, and depth estimates, to allow simultaneous tracking of up to four (operator selected) targets of interest. Reception data for incidental targets (those not being actively tracked) are continuously recorded during the tracking episode. In addition to vector information, target and incidental-target data recorded includes observation time and date, GPS position of the vessel, acoustic signal strength, and time-of-arrival by hydrophone. Displaying reception data with successive transmitter pulses allows the operator to follow targets through time and later map these tracks.

Data from mobile tracking efforts in 2007 are being analyzed. However, it appears that this work has identified migration corridors in the lower river that had previously not been documented and specific sections of the river where mortality may be higher relative to the entire system. One surprising development was the capability to identify individual sites which appear to be indications of mortality or tags rejected by the host. We are currently engaged in mapping these sites and migration routes.

In 2008, we propose to continue to refine mobile tracking protocols to track individual target migration routes, identify and document high-risk predation areas, and attempt to determine areas and identify habitats where fish may be slowing migration to the extent that survival estimates are impacted. We will locate and track targets with implanted acoustic micro-transmitters using the mobile tracking unit. Initial tracking operations will begin just downstream from the release point, and continue through the estuary as tagged smolts migrate following release. Based on travel-time data, experience gained in 2007, and information obtained by in-season analysis of data from fixed arrays, targets in subsequent areas will be identified and tracked using protocols developed to establish specific behavior or evidence of mortality events that may result in survival impacts. We will establish tracks and identify selected targets for as long as practicable over the Chinook salmon spring and summer outmigration seasons. Physical data (surface water temperature, gross vessel movement, and weather conditions) will also be collected for correlation to tracking data[S2].

Objective 5

Initiate feasibility work to enable future estimation of survival probabilities for yearling and subyearling Chinook salmon within the Columbia River plume.

In 2008, we propose to initiate a feasibility approach to make progress toward being able to estimate the survival of acoustically-tagged fish that pass out of the Columbia River plume area (for simplicity defined as a 20-km square out to the 49 fathom curve; Fig. 3). To do this, we propose to deploy up to 20 acoustic receivers which will be designed to detect JSATS microtransmitters in the water column while withstanding most contacts by commercial trawlers that fish in this area. Initial proof-of-principal work in 2007 showed that existing autonomous receivers could be successfully deployed and recovered in over 100 m of water in the plume and that, once deployed, the receiver successfully detected and decoded a beacon transmitter drifted over the receiver at a depth of approximately 6 m. However, information available on the commercial bottom trawl fisheries from both Oregon and Washington indicate a fair amount of commercial fishing activity in this area, necessitating the design and deployment of trawl resistant mounts.

The focus of this effort in 2008 will be to design and test trawl-proof mounts for up to 20 acoustic receivers that would be deployed around the perimeter of the plume. Range tests would be performed in conjunction with these deployments/recoveries. The sensor package would be designed to allow for 120-day deployments, requiring only two trips out during the season to deploy and recover equipment. Interim surveys would be conducted at two other times during the summer to determine (through transponders) the presence of the equipment in the deployed locations.

Data from this feasibility effort would be used to extend the reach of survival estimation for fish exiting the Columbia River from the primary array near West Sand Island (River km 8.3; current) down to the location of the secondary array (rkm 2.8). More importantly, this effort would yield the information necessary to design a survival study that would be capable of estimating survival of fish out of the Columbia River plume and into the Pacific Ocean. The plume survival information would be very useful in determining the delayed and latent mortality effects of passage through the FCRPS for both in-river and transported fish.

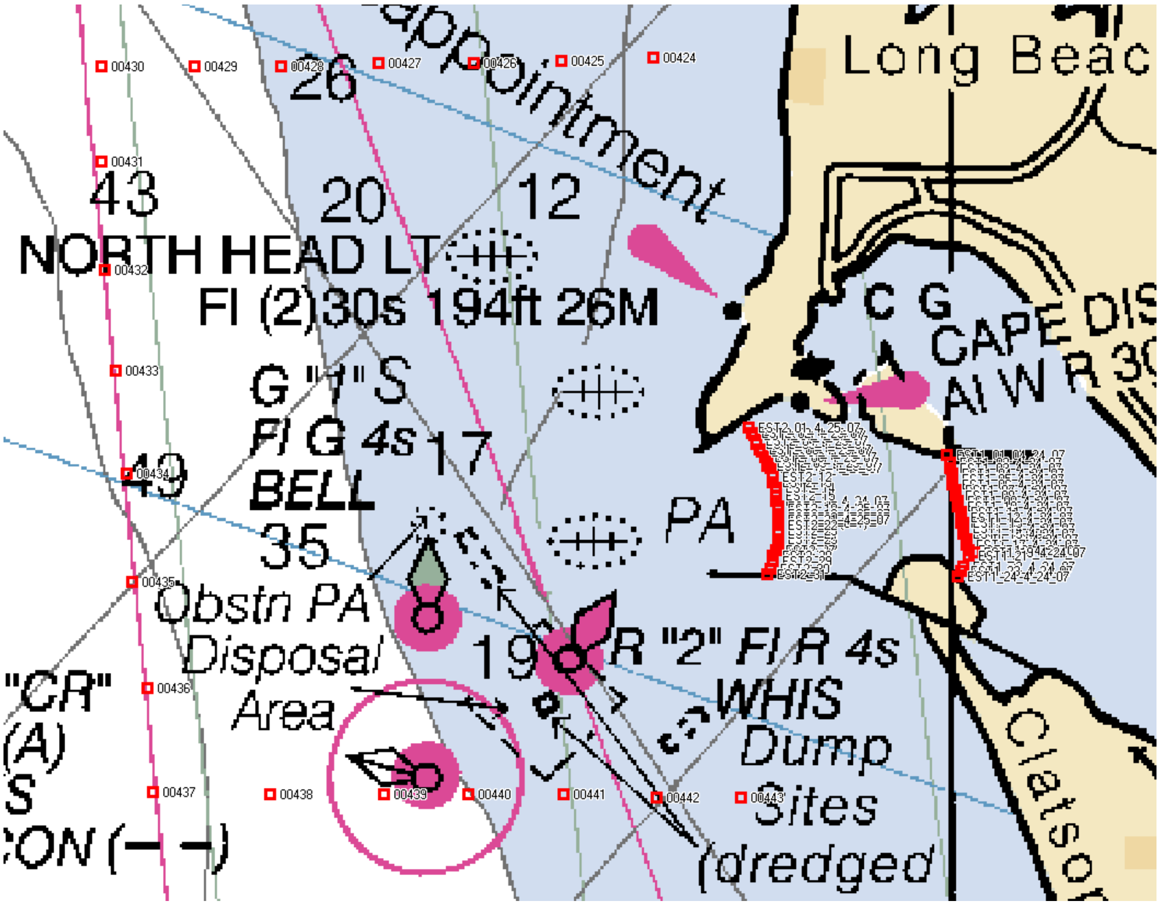

Figure 3. Proposed plume array (labeled red squares)and relative position in comparison to current (through 2007) primary and secondary arrays in the mouth of the Columbia River. The plume array will be comprised of 20 bottom-mounted receivers.

Objective 6

Competitively procure prototypes of "rearing Chinook" acoustic micro-transmitters for function and biocompatibility evaluation.

To address research needs related to habitat use of rearing juvenile salmonids in the Columbia River Estuary (and elsewhere within the Columbia River Basin), we propose to develop specifications for a microacoustic transmitter that could be used to investigate behavior and survival of small (e.g., 70 mm) salmonids in fresh and marine waters. Specifications for the transmitter will focus on dimensions and weight of the transmitter as well as transmission characteristics. Specifications would be published by the USACE and vendors wishing to compete for the prototype procurement would be evaluated by a selection board appointed by the USACE. Prototype transmitters would be evaluated in the laboratory and field settings to determine acceptability.

Objective 7

Determine the capability and reliability of the JSATS cabled (hard-wired) array to continuously collect and store micro-acoustic transmitter data relative to autonomous-node arrays currently in use.

The original JSATS receiver design was a 22-node cabled system bottom mounted as the primary array along a transect between East Sand Island and Clatsop Spit. This system was composed of two independent arrays, one (3-node) array from Clatsop Spit to the south edge of the ship channel, and the other a 19-node array from East Sand Island to the north side of the ship channel. While the Clatsop Spit array ran continuously from deployment in April through mid August without problem, the longer array was inoperable for the spring outmigration, requiring repair before functioning through the subyearling outmigration. An inordinate amount of effort has been expended by concerned parties to determine the cause for the failure, and in using that knowledge to correct the problem. The result of those efforts was a submerged test of remaining functional components of the system to determine whether remedial actions would alleviate the problem. As a component of that test, current draw by the system was monitored continuously for over 4 months. That test ran for over 6 months with no problems reported from the cabled-array system. On the assumption that corrective actions undertaken (careful cleaning of mating connector surfaces and a clean power supply source) have indeed had the desired effect, that system is now ready for in-river evaluation.

For convenience and access, the test of the cabled system was carried out in a large tank filled with salt water. This provided proximity for monitoring and allowed evaluation of commercial power to run the system. However, the tank environment did not allow collection of acoustic data, and anchors used during the original deployment were too large to be accommodated.

Prior to depending on the cabled array as a reliable tool to collect survival and timing data, we propose to evaluate whether the fully functional and properly assembled and deployed JSATS cabled array can function as designed over sufficiently long periods in the river environment. To accomplish this, we propose to deploy the cabled array at the mouth of the Snake River near autonomous-node arrays. As the standard for acoustic data collection using JSATS transmitters, we will use data from autonomous nodes to ground-truth cabled-array performance by post-season comparison the two data sets.

We propose to deploy 4 – 8 nodes of the cabled array beginning April 1, 2008. This timeframe will allow a suitable 2-week period for in-water evaluation prior to the beginning of yearling Chinook salmon acoustic tagging efforts at Lower Granite Dam. New node anchors will be fabricated suitable to in-river deployment and light enough to be deployed from smaller vessels. During the in-water test period, we will continue to monitor current draw to assess irregularities in power consumption as was done in the test tank. Results of that monitoring will be continuously archived for later analysis should that be necessary or prudent.

One major problem with the test-tank evaluation was that the original power system used in 2005 proved too unstable to be depended upon to provide continuous power for the array. Shore power supplied through commercial grid was substituted for that test. Evaluation of the original system is underway and may result in a redesign of independent power generation capability for use in remote locations. If that system is available, it can be used during the 2008 field season. However, deploying the array at the Snake River mouth will permit use of commercial power should the independent system not be completed in time. In addition, this location will allow ready access for monitoring and maintenance.

A detailed test and evaluation plan will be formulated to compare acoustic data (transmitter receptions and timing at a minimum) to similar autonomous-node data collected from the same area. Output from both arrays will be downloaded to the PNNL database for analysis and comparison both periodically during and at the conclusion of 2008 field season data gathering operations. If the cabled array can be found to be a reasonably reliable tool compared to autonomous nodes, regional managers can begin to consider study designs to incorporate this tool into data gathering efforts to augment information gathering for inclusion in a regional database.

FISH REQUIREMENTS

FY 2008

Objective 1 - Up to 1,500 hatchery propagated river-run yearling Chinook salmon from the Columbia River watershed will be collected and acoustically tagged at Bonneville Dam.
Objective 2 - Up to 2,800 river-run subyearling Chinook salmon from the Columbia River watershed will be collected and acoustically tagged at Bonneville Dam.
Objective 3 - None required
Objective 4 – None required
Objective 5 - None required
Objective 6 – None required
Objective 7 - None required
Objective 8 – None required

FYs 2009-2010

Large numbers of fish may be required during future implementation. The numbers of fish required for each target group will be determined dependent on estimated survival to the Columbia River mouth obtained in 2005, 2006, 2007, and 2008 variability about these estimates, detection probabilities, and requirements of the single-release model. Existing populations of PIT-tagged stream- and ocean-type migrants passing Bonneville Dam will be used to the fullest extent possible. The need for additional PIT tagging will be determined during annual planning stages, and will depend on which groups are selected for study, the number of PIT-tagged fish estimated to pass Bonneville Dam, and the numbers of those fish available for acoustic tagging.

SCHEDULES

During 2008, we will continue full implementation by securing baseline survival and timing estimates for generalized yearling and subyearling Chinook salmon. In future years, we will continue this effort by refining target groups to begin addressing specific management-related concerns.

It is important to consider this work in the context of environmental conditions, since the importance of the estuarine environment may vary among years. Therefore, we will propose to implement the study over a number of years.

IMPACTS TO PROJECTS, FACILITIES, AND EQUIPMENT

In 2008, use of existing space and facilities at the Bonneville Second Powerhouse JFF will be required for capture, tagging, and holding of acoustically-tagged fish. Access to river water and a commercial electrical power supply will also be needed. We will coordinate with

Bonneville Project Smolt Monitoring Facility personnel and other researchers to ensure our requirements for space and water fit within the needs of other user groups.

PROJECT PERSONNEL AND DUTIES

1. Project Leader:	Lynn McComas, NOAA Fisheries
2. Project Leader:	Geoffery McMichael, Battelle Pacific Northwest NationalLaboratory
3. Project Leader and Tag design:	Thomas Carlson, Battelle Pacific Northwest National Laboratory
4. Survival estimates:	Steven G. Smith, NOAA Fisheries

TECHNOLOGY TRANSFER

Technology transfer will be in the form of written and oral research reports as required. Draft reports will be provided to the COE. Results will also be published in appropriate scientific journals and presented at scientific forums.

RELEVANCE

The NOAA Fisheries 2000 FCRPS Biological Opinion (NMFS 2000b) Research Action 47 stipulates that delayed mortality of transported versus non-transported fish be estimated. In Research Actions 158 through 160, the 2000 Biological Opinion also includes provisions to identify, catalogue, mitigate, and restore factors in the Columbia River estuary that are limiting to salmonid survival. Research Actions 161 through 164 include provision for development and funding of a monitoring program aimed at evaluating the dynamics among the hydropower system, the estuarine environment, and fish response to changing conditions. Information from this study can be used to directly or indirectly address these actions.

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RESEARCH PROPOSAL

SUBMITTED TO THE U.S. ARMY CORPS OF ENGINEERS ANADROMOUS FISH EVALUATION PROGRAM 2008 PROJECT YEAR

I. BASIC INFORMATION

A. TITLE

Evaluating Cumulative Ecosystem Response to Habitat Restoration Projects in the Lower Columbia River and Estuary

B. PRINCIPAL INVESTIGATORS

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C. STUDY CODE

EST-02-P-04

D. DURATION

Entire Study: January 1, 2004 to December 31, 2010

Current Study Period: January 1, 2008 to February 28, 2009

E. DATE PROPOSAL SUBMITTED

October 15, 2007

II. SUMMARY

A. GOALS AND BACKGROUND

The primary goal of this study is to develop and employ science-based methods to quantify cumulative effects[1] on ecosystem function from salmonid habitat restoration in the Columbia River estuary (CRE[2]). A secondary goal is to standardize restoration[3] project monitoring protocols to support the cumulative effects analysis and ensure comparable data sets across multiple restoration monitoring efforts estuary-wide. The management implications from this work are wide-ranging and include: 1) decision support for estuarine restoration project prioritization; 2) evaluation of the ecological performance of collective estuarine restoration actions; 3) methods and data for Corps authorities under various Water Resources Development Acts (Sections 206, 306, 536, 1135); 4) protocols to sample juvenile fish and environmental metrics in estuarine wetlands; 5) database for assessment of relative benefit of investments in tributary versus estuarine wetland habitats; and 6) a collaborative approach for a multi-stakeholder environment.

Measurement of the effects of multiple habitat restoration projects on selected ecosystem structures, processes, and functions in the Columbia River estuary is a challenge similar in magnitude to other large scale monitoring efforts such as those associated with the Colorado River system and the Mississippi River delta. Assessing cumulative ecosystem effects of habitat restoration projects in the CRE may be even more difficult in practice because of the complexity of spatial and temporal scales associated with measuring ecosystem responses in the CRE. Despite the challenges, developing and implementing appropriate indicators and measurement methods is the best way to enable estuary managers to track the effectiveness of their large investments in estuary habitat restoration projects and to improve conservation and restoration measures over time.

Because ecosystem restoration projects are difficult and fraught with uncertainties, this study is providing information that can be used to better design restoration projects to maximize the probability of success. One aspect of this work is development of an adaptive management framework. The adaptive management framework is the mechanism for incorporating changes in the monitoring protocols developed as part of the study. Further, the data being collected provides refinement of metrics most likely to be key indicators of site development, which further can be used in an adaptive way to improve design and predictions.

The types of estuarine restoration being implemented in the CRE by the Corps and others include activities to: 1) reconnect backwater channels, sloughs and oxbows and recover estuarine wetlands through dike removal and tide gate replacement; 2) reconnect upland drainages and freshwater inflow through removal of armored channels, culverts, diversions, and other channeling structures; 3) remove intertidal fills and piling fields; 4) allow natural accumulation of large woody debris; 5) place fill material; and, 6) remove armor from shorelines. Such ecological restoration requires that detrimental

[1] By "cumulative effects" we mean the collective effects on the CRE ecosystem as a result of implementation of multiple habitat restoration projects.

[2] The Columbia River Estuary is defined as the region of the river under tidal influence (i.e., from the mouth to Bonneville Dam at river mile 146).

[3] In this document, the term "restoration" generally refers to any or all of the five fundamental restoration approaches commonly reported in the literature: creation, enhancement, restoration, conservation, and protection (NRC 1992).

changes be reversed to a measurable degree. However, existing data collection and analytical methods are insufficient to evaluate the cumulative benefits to the ecosystem or salmon populations.

B. OBJECTIVES

Overall Multi-Year Study Period (2004-2010)

The overall objectives of this multi-year study are to:

1. Develop standard monitoring protocols and methods to prioritize monitoring activities that can be applied to CRE habitat restoration activities for listed salmon.

2. Develop the empirical basis for a cumulative assessment methodology, together with a set of metrics and a conceptual model depicting the cumulative effects of CRE restoration projects on key major ecosystem functions supporting listed salmon.

3. Design and implement field evaluations of the cumulative effects methodologies by applying standard methods, a COE geographic information system (GIS) database[4] of habitat types and land ownership (private, federal, state, local), hydrodynamic model, and meta-analyses to assess through-ecosystem response of the cumulative effects of multiple habitat restoration projects.

4. Develop an adaptive management framework that coordinates and compares the diverse restoration efforts in the CRE, including data management and dissemination, to support decisions by the Corps and others regarding CRE habitat restoration activities.

Current Annual Study Period (2008)

The objectives of the 2008 study are to:

1. Issue final monitoring protocols for habitat restoration evaluations, including examples of data analysis and presentation.

2. Collect and analyze limited field data to support the 2008 cumulative effects pilot scale study (Objective 3) and the final estuary-wide cumulative effects analysis by continuing existing time series and assessing larger spatial and temporal scales.

3. Implement the weight-of-evidence cumulative effects analysis methodology at a pilot scale, including GIS assessments, hydrodynamic modeling, and meta-analyses, and develop management recommendations for estuary-wide assessment based on the results.

4. Support the Corps to implement an adaptive management framework developed in FY06-07 to support decisions by the Corps and others regarding CRE habitat restoration activities.

C. APPROACH

The recommended methods combine state-of-the-science synthesis, innovative indicator development and field-testing, and the creation and implementation of ecosystem-specific monitoring

[4] The GIS database is a collaborative, coordinated effort among multiple parties, including the Columbia River Estuary Study Taskforce, the Lower Columbia River Estuary Partnership, the Pacific Northwest National Laboratory, the University of Washington, and the U.S. Geological Survey.

protocols and data analysis methods to produce estimates of ecosystem responses to cumulative restoration actions. Future management actions, thus, can be supported by a robust adaptive management decision framework. Theory on cumulative *impact* assessment will be applied in reverse to assess what cumulative *gains* to the ecosystem and selected resources are achieved by the multiple restoration projects planned in the CRE. The adaptive management system is being designed to incorporate project-specific, salmon-specific, and ecosystem measures and efficiently integrate existing and planned monitoring efforts. Stakeholders, including the Federal Columbia River Power System action agencies, fisheries management agencies, restoration project managers, and the interested public, may share data and reporting systems designed to facilitate communication and partnering, negotiation, and management decision-making.

D. RELEVANCE TO THE PROPOSED ACTION

Habitat restoration actions in the CRE were included in the 2000 and 2004 Biological Opinions on FCRPS operations, the Action Agencies' draft Implementation Plan for the Updated Proposed Action in 2005, and the Proposed Action in 2007. Habitat restoration in the estuary will likely be an important component in the next Biological Opinion on FCRPS operations.

III. RESEARCH PLAN

A. BACKGROUND

Under Congressional authorities in various Water Resource Development Acts and mandates in Biological Opinions, the Corps of Engineers and others are working to restore estuarine habitats in the Columbia River Estuary. The number of restoration projects being planned and implemented in the CRE has increased in recent years through the coordinated efforts of state, federal, and local organizations. For example, the types of estuarine restoration being implemented in the CRE by the Corps and others include activities to: (1) reconnect backwater channels, sloughs and oxbows and recover estuarine wetlands through dike removal and tide gate replacement; (2) reconnect upland drainages and freshwater inflow through removal of armored channels, culverts, diversions, and other channeling structures; (3) remove intertidal fills and piling fields; (4) allow natural accumulation of large woody debris; (5) place dredged material; and, (6) remove armor from shorelines. The vision is to improve CRE ecosystem functionality through habitat restoration efforts to aid in rebuilding listed salmon stocks in the Columbia Basin.

As the salmon habitat restoration effort grows, projects being implemented will require some level of monitoring and evaluation to determine their effectiveness. It will not, however, be practical to intensively monitor the results of every project. Ecological restoration at this scale requires that detrimental changes be reversed to a *measurable degree*. Therefore, methods must be established to prioritize and manage limited monitoring budgets while determining whether the proposed restoration actions will have a net cumulative benefit to CRE ecosystem health and functionality. In addition, data from numerous restoration monitoring efforts should be as comparable as possible to aid decision-makers as they learn from the collective project-specific monitoring data. Standardized monitoring protocols are necessary to compare restoration effectiveness through time at a given project site and through space among multiple projects. Focused, prioritized, and standardized monitoring at the project scale will support monitoring and evaluations at the estuary scale that will ultimately help to measure the success of the CRE salmon habitat restoration.

Although it is relatively straightforward to measure the area of habitat restored, it is difficult to assess the cumulative effects of individual restoration projects on ecosystem function. Currently, a formal method for quantifying whether restoration of habitats will have a measurable effect on the health and functionality of the ecosystem or on the viability of salmon populations does not exist in the literature. Small projects may result in local improvements, which are confined to a relatively short distance from the restoration site. Many small projects may only improve conditions within a small area, and not have any significant effect on the larger ecosystem. In contrast, a mix of large and small projects, placed strategically within the system, and containing the appropriate mix of habitats, and managed in a way to maximize success, may provide highly significant improvements. The availability of land in the CRE for habitat restoration, however, will be an important factor affecting the size of projects to be implemented. Implementation of the methodology developed in this study will likely be affected by the types and sizes of potential projects and, therefore, the methodology must allow for objectively incorporating this variable. Most importantly, restoration actions in the CRE represent a unique opportunity to develop and employ science-based, defensible methods to evaluate the potential cumulative gains in restored ecosystem function provided by a suite of restoration projects in the system.

Accounting for the total effect of multiple restoration actions on the functioning of the system is both one of the most important and challenging topics in restoration science. In theory, it is assumed that any improvement to a component (e.g., enhancement of a selected habitat attribute; Shreffler and Thom 1993) will contribute to overall ecosystem improvement. However, the size, number, and type of projects that will have the greatest benefit varies with the ecosystem and is difficult to ascertain. In a situation where the state of the system has been altered, such as in the CRE, knowing how many and what type, and the location of projects that result in a reversal of degradation and a measurable switch back to a former (and less disturbed) system state would help guide restoration programs and justify the expenditures of funds directed toward restoration. The development of methods to detect and assess the cumulative net improvement toward a former system state is the focus of this research. Relevant to the proposed research, we paraphrase the definitions of cumulative impacts and cumulative effects in Leibowitz et al. (1992) as follows:

- *Cumulative restoration impacts* are the net sum of all changes in selected habitat metrics of all restoration projects occurring over time and space, including those in the foreseeable future of the development of these projects.

- *Cumulative restoration effects* are the net change in ecosystem-wide metrics and ecosystem state resulting from cumulative restoration impacts.

The challenge of balancing the need for coastal economic development with enhancement of coastal ecosystems is among the top priorities for coastal planners and researchers this century (Thom et al. 2005). In this context, we introduced the concept of "*net ecosystem improvement*", which is defined as "following development, there is an increase in the size and natural functions of an ecosystem or natural components of the ecosystem" (Thom et al. 2005). We argue that this concept is critical to meeting sustainability of coastal systems as defined by the World Commission on Environment and Development (1987). The present study will provide much needed data and guidance on the effects of habitat restoration intended ameliorate development in the Columbia River.

This project is addressing the above issues and providing information that can be used to make management decisions primarily regarding cumulative effects of mitigation and estuarine restoration that are designed to enhance ecological functions benefiting the estuarine ecosystem and its juvenile salmon inhabitants. The work is intended to provide means to assess and quantify the cumulative improvements associated with restoration projects and to lay the foundation for the evaluation of the effectiveness of the restoration activities undertaken. Thus, this project is intended to examine the effects of habitat restoration in the CRE in a comprehensive, ecosystem basis. As such, the central premises guiding this work are as follows:

- Standardization of monitoring methods will result in comparable data sets
- Monitoring efforts can be prioritized and designed strategically while maintaining statistical robustness
- Cumulative effects on the CRE ecosystem designed to benefit salmon must be viewed at a landscape scale
- A conceptual model[5] of the CRE ecosystem, including the food web, provides organization and focus to the research and assessment
- Key attributes indicating ecosystem response to restoration will be assessed and used
- A framework can be developed and applied to assess the cumulative effects for all restoration actions
- An adaptive management system based on project and ecosystem monitoring data will aid decision-makers implementing salmon habitat restoration in the CRE

B. PROJECT PROGRESS

The project has mostly completed the first of the four overall objectives (see p. 3) and made significant progress on the remaining three, as detailed here, in chronological order. In the first year of this project (FY04), the cumulative effects project team reviewed applicable monitoring protocols, conducted outreach, and participated in a forum (June 2004) with restoration project managers and the Estuary Partnership to discuss monitoring needs relevant to tracking the success of restoration projects. Interfacing this effort with its analysis of the state-of-the-science via existing restoration literature, the team produced a set of draft monitoring recommendations – supported by many restoration project managers – that is to serve as a template for ongoing and future effectiveness monitoring for the region. This was a critical component of the draft monitoring manual, a Year 1 deliverable by the project. Restoration project managers will be able to apply this set of measurable parameters at most, if not all, restoration project sites. The Year 1 literature review demonstrated the need for research to increase the scientific defensibility of restoration, and has uncovered few comparable efforts in restoration science (e.g., Steyer et al. 2003). Indicators and cumulative effects methodologies from disciplines including forestry, fisheries, ocean sciences, wetlands, physics for complex systems, and watershed sciences were assessed during the Year 1 literature review for their applicability to the CRE. The potential indicators evaluated included organic matter production and flux; nutrient processing; sedimentation; macroinvertebrate production; food web/stable isotope method; salmon habitat usage; salmon habitat opportunity/connectivity; and bioenergetic modeling. This review (Diefenderfer et al. 2005) formed the basis of the sampling design for field monitoring that was developed and implemented in Year 2.

In Year 2 (FY05), the project team continued to develop and test indicators, methods and a sampling design for estuary-wide cumulative effects analysis. This tiered approach incorporates a short list of minimum ("core") indicators and appropriate protocols for project-specific implementation monitoring, the results of which can be rolled up into estuary-wide analyses. This approach also includes ecosystem indicators ("cumulative effects indicators") that require intensive monitoring, which can be evaluated at specific study sites in order to limit overall monitoring program costs. Both the core and ecosystem indicators were field tested at paired restoration and reference sites, producing baseline datasets from the brackish marsh and tidal freshwater forest habitat types. A statistical sampling design for cumulative effects analysis was developed and released in the 2005 Annual Report (Diefenderfer et al.

[5] This project will consolidate existing conceptual models for the CRE (Bottom et al. 2001; Thom et al. 2001).

2006). This sampling design and meta-analysis require field sampling and data collection from sites additional to the paired sites to achieve adequate power.

In Year 3 (FY06), the results of 2005 field studies analyzed were used to validate and improve the monitoring protocols, which were released in a revised draft in April of 2006 (Roegner et al. 2006). Over 100 copies of the field-tested and revised version of "Monitoring Protocols for Salmon Habitat Restoration Projects in the Lower Columbia River and Estuary" were requested by individuals with agencies and non-governmental organizations. Post-restoration data on both core and cumulative effects metrics were collected creating a data set for cumulative effects analyses that encompasses both baseline and post-restoration time frames. This data set was designed to represent the habitat types that have sustained the most loss – marshes and forested wetlands – as well as three of the most typical restoration actions in the estuary: dike breaches, culvert replacements, and tidegate replacements. Additionally, intensive studies evaluating aspects of ecosystem processes and the food web that are critical to cumulative effects assessment were initiated in restored and reference sites of the two key habitat types, i.e. material flux (organic matter, nutrients); structural controls on hydraulic geometry, channel morphology, and restoration site development; and salmon diets and prey production. Year 3 work is documented by Johnson (ed.) (2007).

In Year 4 (FY07), the project conducted a workshop with regional monitoring practitioners and managers (February 2007) to solicit feedback on the monitoring protocols, continued field work on post-restoration monitoring to support cumulative effects analyses and finalize monitoring methods for the protocols, and initiated GIS analysis and hydrodynamic modeling method development. A suite of tidegate-installation sites (Julia Butler Hansen) was added to the study area to complement and compare to the suite of dike breach restoration sites already under study (lower Grays River watershed) in order to permit quantitative contrast (through modeling and statistics) of the potential cumulative effects of the two most commonly used methods for restoring lateral connectivity between the floodplain and mainstem; baseline data on vegetation, elevation, and channel morphology was collected at these sites following the protocols. Uncertainties reduction on the tidal floodplain forests including water temperatures and riparian plant community productivity continued with the latter being completed. Regarding cumulative effects metrics, material flux sampling was expanded to include these sites while geomorphology and salmon diet studies were concluded and analyzed helping to establish functional linkages between marsh and floodplain forest habitats and the riverscape on which to base predictions of cumulative effects in FY08 GIS modeling.

C. TASKS AND METHODS

The tasks and associated methods below for FY 2008 are organized by study objective.

Objective 1. Issue final monitoring protocols for habitat restoration evaluations, including examples of data analysis and presentation.

Development of standard protocols serves a number of needs relative to the cumulative effects program and other related programs in the CRE. First, the protocols establish a standard set of methods and metrics that should be utilized in the evaluation of restoration projects conducted within the system. By having a standard set of methods and metrics, the data acquired is comparable among projects, and allows a systematic assessment of the effects of each of these projects. Second, the database developed allows for broader assessments of system-wide changes (i.e., improvements) in habitats and functions supportive of salmonid populations. Third, programs funded by other entities can use information generated by these systematic studies to understand the rates and patterns of development of various habitat types, and to refine the metrics required to assess their performance. Fourth, the data set provides the critical element to an adaptive management framework. Systematic data taken at a growing number of sites, when evaluated annually by planners and managers, is extremely valuable in determining whether changes in the projects or programs are needed to better meet project and program goals.

Task 1.1. Finalize the monitoring protocols manual.

A draft standard protocol manual was be developed in FY04 and revised in FY06. It will be finalized based on the material developed in the 2007 workshop and field experience in 2005-2007. The manual will be a stand-alone document, in addition to being included in the annual report for this study. The Corps of Engineers will apply the results of this effort to ongoing and planned restoration work. Since it is important and well recognized that monitoring results must be comparable within and across individual projects on an estuary-wide basis, we have been assured that entities monitoring restoration projects find the manual to be beneficial and are thus using it on a variety of conservation and restoration projects (e.g., Columbia River Estuary Study Taskforce, Lower Columbia River Estuary Partnership, and Columbia Land Trust).

Task 1.2. Present the monitoring protocols manual at the Conference on Research, Monitoring, and Restoration in the Lower Columbia River and Estuary; April 2008, Astoria, Oregon.

The final monitoring protocols manual will be demonstrated in an oral presentation or workshop format, with invitations to all project managers, monitoring practitioners, restoration funding agencies, and interested parties who have previously requested or received copies of the draft document.

Objective 2. Collect and analyze limited field data to support the 2008 cumulative effects pilot scale study (Objective 3) and the final estuary-wide cumulative effects analysis by continuing existing time series and assessing larger spatial and temporal scales; develop measurement methods for channel network metrics.

Task 2.1. At existing cumulative effects study sites, continue to sample hydrology. At Kandoll, sample hydrology, fish abundance, and habitat use.

At Kandoll, Vera, and the swamp reference sites, continue automated hourly data logging of water level and temperature, with one download and relaunch of the HOBO sensors. Water level data are critical to the measurement of the extent of juvenile salmon habitat area for the cumulative effects analysis (i.e. habitat opportunity), and temperature data are critical to measurement of habitat suitability (i.e. habitat capacity.) Standard hydrological measurements (temperature, salinity, water level) will be collected to assess the continued evolution of Vera Slough and Kandoll Farm habitat conditions. Additional final biological and landscape features measurements including fish presence and vegetation development relative to elevation are scheduled for FY09. Data-logging temperature sensors will remain deployed at the suite of three reference spruce swamps to establish intra-annual temporal extent of suitability as juvenile salmon habitat and support predictions regarding swamps' suitability as refugia for outmigrating salmon throughout the range of *P. sitchensis* on the Columbia floodplain for the upcoming cumulative effects meta-analysis. In collaboration with the LCREP reference sites project, data on additional metrics from these sites will also become available, including water elevations, vegetation, and land elevation and temperature data will be quality-control checked, analyzed, and summarized.

Post-restoration time series of salmon habitat use from a single monitoring location within the Kandoll Farm restoration site has demonstrated species-specific patterns of salmonid abundance and diet. We propose to expand this data set to two additional channel locations to improve the spatial-temporal resolution of salmon habitat use. With an improved trap net design, we can now simultaneously sample three channel environments at the same level of effort. We propose to continue a bimonthly trap net sampling schedule at three sites from late January through June, which previous data indicate is the period when Chinook, chum, and coho salmon are present in the system. Genetics samples from a subset of fish to determine stock of origin. This level of effort will greatly increase estimates of total salmon habitat use in the restored landscape. Hydrological measurements (temperature, water level) will provide comparative inundation rates and temperature regimes across the Grays River system. These fish abundance and physical data will provide input parameters for hydrological modeling and salmon habitat use scenarios described below. Additional biological and landscape features measurements including vegetation and elevation are scheduled for FY09.

Task 2.2. Develop and ground-truth methods to quantify wetted area and channel density at Kandoll using LiDAR and geographic information systems analyses.

Channel density and wetted area have been identified in the 2007 annual report as critical descriptors of salmon habitat opportunity that will be used in the meta-analysis of cumulative effects of habitat restoration projects in the estuary. However, straightforward and cost-effective methods for measuring these metrics are not available; this study's LiDAR analyses in 2007 indicated that this dataset can be used to develop indices of wetted area and channel density, which will require ground-truthing.

Task 2.3. At Julia Butler Hanson, sample vegetation, elevation, cross-sections, water levels, and flux, and collaborate with USACE to model wetted-area.

The Julia Butler Hanson reserve provides a unique opportunity to examine the comparative and cumulative effects of tide gate installation/replacement on key ecosystem functions within a small spatial scale. Like the suite of dike breaches under study on the Grays River, this suite of projects represents multiple actions in space and time and thus presents an excellent case study for assessing the cumulative effects of multiple restoration projects (i.e. additive and synergistic). Hydrographic and material flux measurements will be made before and after tidal reconnection/improvement, with the targeted flux components to include water properties (temperature, salinity, oxygen concentration, fluorescence), dissolved nutrients (N, P, C, Si), chlorophyll, as a function of stage of tide, and marsh macrodetritus on a semiannual basis. During flux sampling, we measure these constituents as time series of water properties through tide gates as well as along a spatial gradient by transect sampling. Proposed flux sampling in 2008 includes before replacement seasonal samples in Winter and Spring, and after tide gate replacement sampling in Summer. Three tidal sloughs are being sampled, Ellison Slough, Duck Lake Slough, and a reference tidal swamp. In addition, pre-construction data on plant community, land elevation, and channel morphology will be collected on the reference swamp and three sloughs slated for 2009 construction: Indian Jack, Hampson, and Unnamed 50. The intent is that this baseline data, together with FY07 baseline data on Ellison Slough and Duck Lake Slough, will be compared to 2009 post-construction data to assess the extent of plant community, land elevation, and channel morphological changes relative to baseline data following the suite of tidegate replacements; this will provide a valuable comparison and contrast to changes following the suite of dike breaches studied by this project in the lower Grays River watershed, i.e. the effectiveness of tide gates versus dike breaches in salmon habitat restoration. Through collaborative efforts with USACE and the USFWS, time series of hydrology (water elevation) and fish will be sampled and wetted area will be modeled using the Corps' existing HEC-RES model since wetted area is a critical indicator of salmon habitat.

Task 2.4. At selected natural breach sites, sample hydrology, morphology, vegetation, and fish abundance.

Natural breach sites allow for an appraisal of time-dependant factors affecting the evolution of wetland restoration trajectories on timescales outside the period of this project. Their assessment will therefore provide a basis for the prediction of the cumulative effects of multiple restoration projects throughout the estuary, by providing information on the condition of restoration sites decades after breaching, i.e. of the restoration trajectory of salmon habitat functions of sites. Through reconnaissance surveys in 2007, we identified five naturally reconnected wetlands that span a suitable time period to evaluate restoration trajectories. Sites include Karlson Island, Svensen Island, Fort Clatsop, Miller Sands, and Goat Island. A rapid survey sampling design is proposed examine fish presence, hydrology, vegetation patterns and landscape features (elevation, channel morphology) at select sites using methods in the Monitoring Protocols manual. Sampling for fish presence will entail beach seines within reconnected areas during May, June and July 2008, and the other metrics will be sampled with a 2-day effort per site in summer 2008. Genetics samples will be acquired from a subset of animals. Additional archived literature and data is available from some sites (e.g., the original Miller Sands restoration project, university theses, and other concurrent studies) and will be acquired and assessed. Resulting data will be used in the final project GIS projection of the cumulative effects of restoration projects estuary-wide as it will permit reasoned estimates of the outcomes of existing projects in terms of salmon habitat opportunity and capacity to be made.

Objective 3. Implement the weight-of-evidence cumulative effects analysis methodology at a pilot scale, including GIS assessments, hydrodynamic modeling, and meta-analyses, and develop management recommendations for estuary-wide assessment based on the results.

Task 3.1: Review any new (2007) literature, evaluate methods applied previously in other systems, and assess models employed for the purpose of cumulative ecosystem effects.

Key major ecosystem functions to be considered are the production and flux of marsh macrodetritus, sediment trapping, nutrient processing, floodwater storage, and macroinvertebrate production. The relative roles of macro- and micro-detritus in the CRE ecosystem will be investigated.

Task 3.2: Based on any new information, revise the set of metrics for a cumulative assessment methodology developed in previous years.

The set of draft metrics was developed from published information, discussions with knowledgeable individuals, and analysis of our field data. It will be revised as necessary based on any new information prior to the pilot analyses. Our bases for judging cumulative effects are two: 1) what are the quantifiable changes in selected system metrics with each project; and 2) at what point can incremental restoration be detected by a response variable in the CRE ecosystem. The answers to these questions are directly applicable to addressing the amount of restoration required to move the ecosystem toward goals established for restoration of salmonids and other species, and what types of projects produce the best gain in ecosystem function according to the metrics chosen. This statistically sound approach will lead directly to project design considerations. It is intended to illustrate whether individual restoration projects are making a difference in the health of the ecosystem and to selected ecosystem components.

In FY08 we will develop a set of “report cards” for the indicator metrics that are based on the data we have been collecting. The purpose is to define quantitatively what we have learned is changing or not changing following restoration actions. These indicators provide the basic information upon which performance can be assessed. Examples of these report cards are as follows:

- *percentage cover of native tidal wetland herbs*
- *percent similarity in species composition between restored and reference sites*
- *presence of juvenile salmonids*
- *length of productive marsh-channel edge opportunity for salmonids*
- *marsh macrodetritus mass flux*
- *sedimentation rate*
- *nutrient concentration and flux rate*
- *total organic carbon matter flux rate.*

We will display the metrics using simple bar graphs where comparisons of results from before and after hydraulic reconnection can be made. Where appropriate we will use similar bar graphs to compare results from the restored site with reference sites.

The time-series sites we will initiate sampling at in FY08 will provide information on the conditions of a selected number of metrics over extended periods. For these sites we will devlop simple bar graphs of values for the following metrics (as examples):

- *percentage cover of native tidal wetland herbs*
- *percent similarity in species composition between restored and reference sites*
- *presence of juvenile salmonids*
- *length of productive marsh-channel edge opportunity for salmonids.*

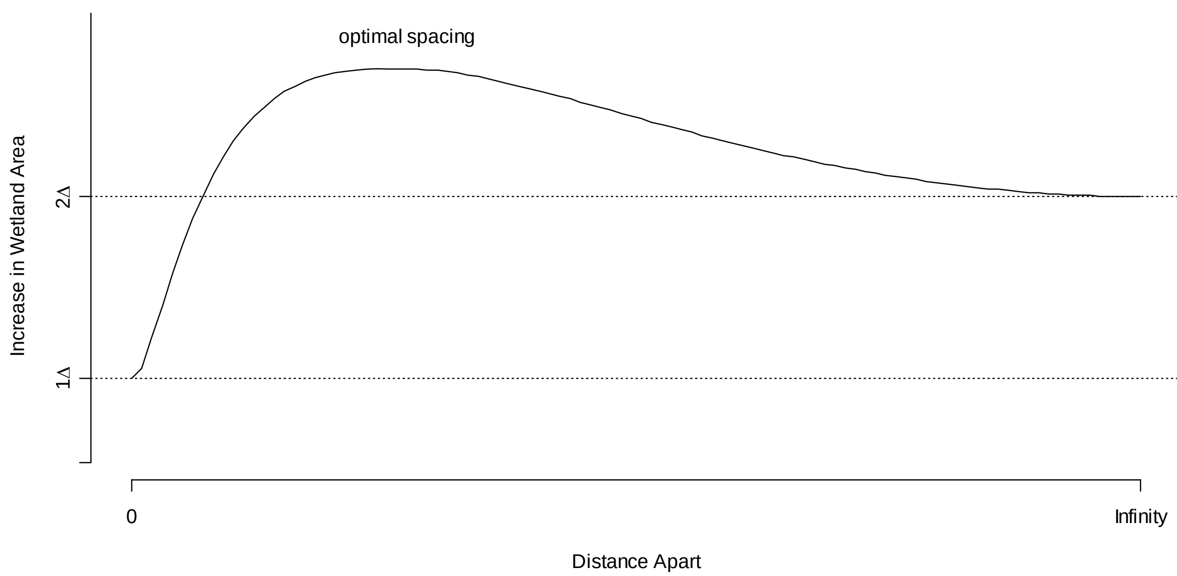
Task 3.3: Update a geographic information system (GIS) database of habitat types and land ownership (private, federal, state, local) on the 235-km historical estuary floodplain and use it to conduct a pilot-scale additive assessment of the effects of multiple project-scale restorations on the riverscape of one estuary tributary.

GIS assessment is one of the three lines of evidence in the cumulative effects weight-of-evidence approach proposed in the project 2007 annual report, and will be used to assess the additive effects of habitat restoration projects throughout the estuary in the final cumulative effects assessment. This complements assessment of synergistic effects using hydrodynamic modeling in Task 3.4. This GIS effort will be coordinated with ongoing efforts to develop GIS platforms at the Columbia River Estuary Study Taskforce, the Lower Columbia River Estuary Partnership, the University of Washington, and the U.S. Geological Survey. Specifically, it is proposed that the Estuary Partnership prioritization database be updated with additional currently available layers including LiDAR if feasible. This database includes layers for property ownership, land use, and other physical features for the historical floodplain. In 2007, it is proposed that testing at the subwatershed scale will be conducted to “scale up” restoration project monitoring results using the field data collected 2005-2007 on the lower Grays River restoration sites. Recommendations generated by this effort would be made in the summary annual report in order to scale up to the estuary-wide analysis in the following year.

Task 3.4. Perform pilot scale test of synergistic cumulative effects of multiple habitat restoration projects using existing hydrodynamic model.

Use of an existing hydrodynamic model is proposed, to assess the potential for synergistic cumulative effects to occur from a suite of restoration projects; this is one of the three lines of evidence proposed in the weight-of-evidence approach in the 2007 annual report. The model is for the lower Grays River but this analysis is intended as a generic pilot study the results of which can be used to characterize the potential for synergistic effects to occur from suites of projects in other areas of the estuary. No new model development will be conducted in this task. The aim is to evaluate whether any set of restoration efforts might provide a cumulative, non-linear increment in benefits to the system or whether additive effects of dike breaching and tidegate replacement on floodplain habitat are the norm. Monte Carlo simulations will be used to examine the relationship between the spacing of estuary mitigations (dike breaches, culverts) and the resulting area of wetland or rechannelization. It is anticipated that spatially disparate actions will have only additive effects while coincident mitigation actions will be no better than a single effort. In between these extremes is the probability that optimally spaced projects may benefit from the synergistic effects of neighboring habitat mitigation projects. Using the existing hydro model, two randomly located mitigations at a fixed distance apart would be repeatedly sampled and average area of resulting wetlands calculated. These simulations will be repeated at alternative distances, and average area plotted against distance apart (Figure 1). If synergistic effects are present, there should be a project spacing where the area1 effect is more than twice (2Δ) the size of a single project effect (1Δ) (Figure 1). A minimum of 50 simulations per distance class and at least 10 different distance classes will be examined in the simulation study. If cumulative effects are observed, the simulations would be repeated, examining the relationship between the density of projects (#/km shoreline) and area of wetlands. Thus through Monte-Carlo methods, numerous simulations from initial conditions can be used to produce input for the cumulative effects statistical sampling tests developed in FY05 virtually, i.e. without investment in large-scale on-the-ground restoration and monitoring.

Figure 1. Plot of the conceptual relationship between the spacing of two mitigation projects and the resulting area of wetlands produced. An individual project will produce, on average, a change in area of size 1Δ. Two very disparate sites would be expected to produce, on average, 2Δ in new wetlands. More than 2Δ would suggest synergistic effects of the hydrology.



Task 3.5. Perform pilot-scale meta-analysis of previously collected field data.

Meta-analysis is the third line of evidence supporting the weight-of-evidence approach proposed in the 2007 annual report. The meta-analysis task involves analysis of all data sets for the purpose of developing the weight of evidence approach to cumulative effects assessment and predicting the cumulative effects of various sets of projects in various sequences throughout the lower river floodplain. In 2007, it is proposed that the data previously collected for a suite of dike breach projets on the lower Grays River be analyzed to develop and refine these methods and make management recommendations for estuary-wide metaanalysis in the following year. We will develop the framework and refined pathway leading to the final assessment of cumulative effects on a pilot scale (watershed); the role of each data set will be defined and preliminary analysis of cumulative effects will be produced to evaluate the framework. Results will be integrated with the results of Monte Carlo simulations with a hydrodynamic model and the additive assessment of effects using GIS as a pilot-scale analyses (e.g. the tidal floodplain portion of one CR estuary floodplain tributary).

Task 3.6: Summarize the cumulative effects methodology.

A summary will be prepared for the metrics, protocols, and sampling design to assess cumulative effects and will include methods to analyze data. This will result in improved monitoring of future projects. In addition, the methods summary will provide guidance for existing projects by specifying how new project information can be fed into the adaptive management program described below. We will evaluate and prescribe the approach to determine the appropriate sampling design for monitoring cumulative effects. This includes ecosystem stratification, sample site selection, replication, sample unit size, etc. The sampling design work will be conducted with guidance of a statistician familiar with the system and the intent of this project. All of this information will be included in an annual project report (see Deliverables and Schedule).

Objective 4. Support the Corps to implement an adaptive management framework developed in FY06-07 to support decisions by the Corps and others regarding CRE habitat restoration activities.

The following three subtasks will meet the fourth objective by synthesizing the outcomes of Objectives 1-3 as follows: information gathered from individual restoration project monitoring according to the protocols developed in Objective 1, will be synthesized with cumulative effects data gathered in Objective 2 according to the methods developed in Objective 3, in order to derive recommended management actions for existing and proposed restoration projects in the CRE.

Task 4.1: Prioritize COE monitoring activities for adaptive management at the landscape scale.

A system such as that developed in the Estuarine Habitat Assessment Protocol (Simenstad et al. 1991), which classifies projects for minimum, recommended and preferred monitoring approaches, will be developed for the CRE, drawing on published methods as well as information specific to the CRE.

Task 4.2: Develop guidelines for data production, archiving, and dissemination for individual restoration project monitoring.

Detailed procedures including, for example, appropriate units and appropriate spreadsheet formats, will be developed and disseminated to local restoration project managers to ensure the standardization of data and make landscape-level synthesis, analysis and evaluation possible. It is anticipated that guidelines for database development will be developed in the following project year.

Task 4.3: Develop a landscape-scale adaptive management system for CRE restoration projects.

The adaptive management system, as described in Thom (2000), will detail the analyses of data from the CRE restoration database and cumulative effects monitoring that will be required to assess project results against performance standards for listed salmon and required habitats. It will provide a decision framework to produce management recommendations if performance standards for the cumulative effects of CRE restoration projects on listed salmon are not met. It will be consistent with the conceptual models currently developed for the CRE (Bottom et al. 2001; Thom et al. 2001). The adaptive management plan will take its goal from the 2000 FCRPS BiOp: that habitat restoration in the CRE contribute to the increased annual population growth of listed Columbia River Basin salmon species. The adaptive management plan will provide an integrative decision framework to enable managers to incorporate the results of the status monitoring and action effectiveness research described in the Estuary and Ocean Subgroup Research, Monitoring and Evaluation Plan that is currently under development. We recognize, however, that the CRE is part of a larger, interconnected landscape supporting salmon in the Columbia Basin. Actions or conditions outside the CRE, e.g., ocean productivity, hatchery practices, will affect ecological conditions inside the CRE. Thus, elements beyond the CRE must be considered to provide context for the landscape-scale adaptive management system for CRE restoration projects.

D. FACILITIES AND EQUIPMENT

No unusual facilities or equipment are anticipated at this time.

E. IMPACTS

Test Fish: An ESA Incidental Take permit and State of Oregon and Washington collection permits will be required to sample fish. Fish will be sampled in 2008 by CREST under subcontract to PNNL. CREST will have the required fish collection permits.

Other Research: We plan to coordinate closely to assure that sampling efforts are complementary. We also will coordinate with other researchers to avoid conflicts. In addition, this project is consistent with Action Effectiveness Research (AER) prescribed for the CRE in the federal RME plan for BiOp implementation. We will coordinate with others researching the effectiveness of individual restoration actions, i.e., projects. Furthermore, this AER work proposed here complements other studies performing Status Monitoring for federal RME, such as NOAA's monitoring efforts for the COE and the Estuary Partnership's habitat monitoring for the BPA. Other closely related monitoring and research projects in the CRE include "Estuarine Habitat and Juvenile Salmon – Current and Historical Linkages" by NMFS and others (BPA 2003-010-00), "Post FCRPS Survival Estimates Using Acoustic Telemetry" by NMFS and PNNL (EST-P-02-01), "Habitat Monitoring in the Lower Columbia River and Estuary" by the Lower Columbia River Estuary Partnership (BPA 2003-007-00), and "Research, Monitoring, and Evaluation Plan for the Columbia River Estuary and Plume" by the Action Agencies and others (BPA 2002-077-00).

Hydropower Project: Not applicable.

F. SCHEDULE AND DELIVERABLES

This is a multi-year project that started in FY04 and is scheduled to end in FY10. To date, the project is meeting its schedule of tasks and deliverables. In general, Year 1 and Year 2 entailed the development of methods and tools that the Corps of Engineers and others can apply immediately to restoration monitoring efforts. Years 3-7 will finalize the monitoring protocols including methods and evaluation of cumulative effects of restoration projects. The level of effort anticipated for each study-year by objective is depicted in the following table. (Key: dark shade = high level of effort; intermediate shade = medium effort; and light shade = low effort.)

Objective	2004	2005	2006	2007	2008	2009	2010
Objective 1: Project monitoring protocols							
Objective 2: Field evaluations							
Objective 3: Cumulative effects methods/assessment							
Objective 4: Adaptive management system							

The overall intent is to annually provide information on CRE habitat restoration monitoring and evaluation to decision-makers. Understand, however, that any cumulative effects of habitat restoration are not likely to be evident in the short-term. Annual reports will be delivered documenting the work to-date and providing feedback and recommendations to decision-makers on the CRE habitat restoration effort. A generic format for the annual report will be: 1) what was done this year; 2) what was learned; 3) actions planned for next year based on experience to-date; and 4) summary of progress and its management implications. We plan to publish much of the material developed in this study in the peer-reviewed literature. The following table shows the annual schedule and deliverables, along with management implications, for each year.

Year	Deliverables	Management Application
1	Annual report with draft monitoring manual, including site-specific monitoring protocols, cumulative effects literature review, and monitoring program strategy. Paper suitable for publication: "A review of cumulative effects research methods in ecological restoration"	Comparable data sets and prioritized monitoring
2	Annual report with results of any field research for site-specific monitoring protocols and further development of cumulative effects methodology. Paper suitable for publication: "Cumulative effects assessment strategy and adaptive management plan for the Columbia River estuary"	Method to assess the success of habitat restoration efforts at the ecosystem level in the CRE. Methods, information, and recommendations for restoration decision-makers
3	Annual report with final manual for monitoring protocols and field research. Paper suitable for publication: "Techniques for monitoring restoration projects in the Columbia River estuary"	Ditto
4	Annual report of field research.	Ditto

Year	Deliverables	Management Application
5	Annual report of field research Paper suitable for publication: "Synthesis of field research related to monitoring and evaluation in the CRE."	Data to feed the adaptive management system designed to aid decision-makers regarding habitat restoration projects
6	Annual report of field research	Method to assess the success of habitat restoration efforts at the ecosystem level in the CRE. Methods, information, and recommendations for restoration decision-makers
7	Annual report synthesizing seven years of research. Paper suitable for publication: "Columbia River estuary adaptive management restoration and research program: 7-year review and recommendations."	Proven methods for M&E of habitat restoration projects and program effectiveness.

G. COLLABORATIVE ARRANGEMENTS AND/OR SUB-CONTRACTS

This study would be led by Pacific Northwest National Laboratory (PNNL) and performed in collaboration with the NOAA Fisheries (NOAA), the Columbia River Estuary Study Taskforce (CREST), the Columbia Land Trust (CLT), and the University of Washington (UW). PNNL has nationally recognized expertise in coastal ecosystem monitoring and restoration. NMFS/Northwest Science Center is the leading research agency studying salmon ecology in the Columbia River Estuary, among many other locales. CREST is a council of local governments based in Astoria, Oregon that is heavily involved in monitoring and restoration in the CRE. CLT is heavily involved in the protection and restoration of CRE habitats. UW's Columbia Basin Research Center is at the leading edge in environmental statistics.

H. LIST OF KEY PERSONNEL

Role	Name	Organization
Principal Investigator	Ron Thom	PNNL
Co-Principal Investigator	Curtis Roegner	NOAA
Restoration Ecologist	Heida Diefenderfer	PNNL
Fisheries Biologist	Earl Dawley	Retired-NOAA
Fisheries Biologist	Blaine Ebberts	COE
Project Manager	Gary Johnson	PNNL
Fisheries Biologist	Micah Russell	CREST
Statistician	John Skalski	UW

I. TECHNOLOGY TRANSFER

Information acquired during the proposed work will be transferred in the form of written and oral research reports and scientific publications. Each year a presentation will be made at the Corps' annual Anadromous Fish Evaluation Program Review. A draft annual report will be provided to the COE by

February 28 following each study-year, and after appropriate review final reports will be completed in a timely manner each year. Technology transfer activities may also include presentation of research results at regional or national fisheries symposia.

As mentioned above under Deliverables, the proposed work should generate at least five articles submitted to the COE and suitable for peer-reviewed scientific journals: 1) "A review of cumulative effects research methods in ecological restoration”; 2) "Cumulative effects assessment strategy and adaptive management plan for the Columbia River estuary;" 3) "Techniques for monitoring restoration projects in the Columbia River estuary;" 4) “Synthesis of field research related to monitoring and evaluation in the CRE;” and 5) "Columbia River estuary adaptive management restoration and research program: 6-year review and recommendations." Also, the annual report series will provide an opportunity for collaborators at various agencies and other entities to analyze the results of restoration project monitoring and directed research on cumulative effects and submit short papers to the COE; where warranted, elements of these reports would be submitted for peer-reviewed publication to disseminate information more widely. The annual reports would, in turn, be relied on in developing the synthesis paper in Year 7, which would provide management recommendations for the estuary and related systems based on all information generated through this cumulative effects research program. Each year, the pertinent articles and research reports will be packaged in the annual reports described above in Deliverables and Schedule.

Oral presentations at the National Conference on Ecosystem Restoration (2004 and 2007), and poster presentations at Pacific Estuarine Research Society (2005, 2006); Society of Wetland Scientists/Society for Ecological Restoration Northwest (2006); and the Conference on Research, Monitoring, and Restoration in the Lower Columbia River, Estuary and Nearshore Ocean (2006); were made to communicate the project outcomes to date to the interested technical and management community. Further oral presentations are planned at the biennial meeting of the Estuarine Research Federation in 2007.

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IV. BUDGET

To be submitted separately.

FINAL RESEARCH PROPOSAL (COE)(FY08)

Title:	Alternative barging strategies to improve survival of transported juvenile salmonids
Project Leader:	William Muir and Douglas Marsh NOAA Fisheries Northwest Fisheries Science Center Fish Ecology Division 2725 Montlake Boulevard East Seattle, Washington 98112-2097 (509) 538-2626
COLLABORATOR:	Diane Elliott, USGS Western Fisheries Research Center 6505 N.E. 65th Street Seattle, WA 98115 (206) 526-6591
ADMIN. OFFICER:	Doug Dey National Marine Fisheries Service Northwest Fisheries Science Center Fish Ecology Division 2725 Montlake Boulevard East Seattle, Washington 98112-2097 (206) 860-3270
STUDY CODE:	TPE-W-06-02
PROJECT DURATION:	March 1, 2008 to February 28, 2009
SUBMISSION DATE:	October 2007

PROJECT SUMMARY

The goal of the 2008 alternate barge release site study is to determine whether releasing barged fish at River kilometer (Rkm) 10 (approximately 10 km downstream of the Astoria Bridge) will improve the smolt to adult return (SAR) rate of spring Chinook salmon *Oncorhynchus tshawytscha* and steelhead *O. mykiss*. The strategy is to minimize the time spent moving into and through the estuary and to document fish condition,

which will provide insight into the vulnerability of smolts to predators. The general approach is to tag transported smolts with passive integrated transponders, collect samples for pathogen analysis, release fish at the current barge release site downstream of Bonneville Dam (Skamania Landing) and at Rkm 10, and compare the SARs of the two groups. This (2008) will be the third year of juvenile releases for this study.

There are two objectives for this study. The first objective is to compare SARs of spring Chinook salmon and steelhead released at Skamania Landing to their cohorts transported downstream and released at Rkm 10. Allowing for fish availability, we will PIT tag sufficient numbers of juvenile spring Chinook salmon and steelhead smolts at Lower Granite Dam (LGR) to test a 1.3 transport-Rkm 10-release-to-transport-Skamania release ratio (T_A /T_S) based on an expected SAR of 1.0 for adults returning to LGR. If the SARs of Astoria released fish are improved by 30% or more, this would be a considerable increase in adult returns that might warrant a change in the transportation program.

The second objective provides ancillary data that can be provided at minimal logistical and financial cost. This objective is to determine *Renibacterium salmoninarum* prevalence and infection severity for each release group along with the presence of *Nucleospora salmonis.* The prevalence and severity of *R. salmoninarum* and *N. salmonis* will then be correlated with avian predation rates and SARs.

A concern that this barging strategy could have unintended consequences, including the potential to shift the magnitude of avian predation to in-river migrants, has been noted on a regional level. We believe, however, that the potential impact on any one specific stock would be minimal.

Relevance

This study addresses needs identified in NOAA's 2004 Biological Opinion (BiOp) "*The Action Agencies will continue to conduct RM&E to provide information on juvenile fish transportation and delayed mortality*", and the 2005-2007 Implementation Plan for the Federal Columbia River Power System Endangered Species Act Updated Proposed Action of the U.S. Army Corps of Engineers, Bureau of Reclamation, and Bonneville Power Administration (dated May 2005). Specifically, the Implementation Plan, under the Hydropower Action Effectiveness Research section (page 40), they state "*Advance the understanding of the effectiveness of flow augmentation, spill,* ***transportation****, and system configuration changes on fish survival for each ESU*".

BACKGROUND

To avoid the mortality caused by downstream passage through the Snake and Columbia River hydropower system, salmonid smolts are guided from turbine intakes by screens at Snake River Dams and transported either by truck or barge to a release site downstream of Bonneville Dam. The benefit provided by transport has been shown to vary for different fish stocks and/or time of year (Williams et al. 2005, Muir et al. 2006).

Since about 50% of Snake River smolts migrating in-river typically survive to below Bonneville Dam (Williams et al. 2005), while about 98% of transported smolts survive (Budy et al. 2002), one would expect about twice as many adults that were transported to return as those that migrated in-river. On an annual basis, the transport to in-river migrant ratio of returning adults is usually lower than expected, indicating that higher post-Bonneville Dam mortality occurs for transported smolts. The difference between post-Bonneville Dam survival of in-river migrants and transported fish has been termed differential delayed mortality or "*D*", and reducing delayed mortality for transported fish is the purpose of this study. Fish condition and health have been assessed prior to and after transport in previous studies (Pascho and Elliott 1989; Elliott and Pascho 1991, 1992, 1993, 1994; Elliott et al., 1997; Congleton et al. 2000, 2005; Kelsey et al. 2002; Schreck et al., 2005). Although stress and stressors have been examined in detail in these studies, and modification to the collection and transportation system have been made to reduce stress (Williams and Matthews 1995), transportation has not provided the benefit expected, particularly for wild Chinook salmon (Williams et al. 2005). This research continues an ongoing effort by the Anadromous Fish Evaluation Program (AFEP) to evaluate modifications to the existing fish transportation program to improve post-Bonneville Dam release survival.

Studies conducted with Coho salmon *O. kisutch* found that smolts transported to a release point near Tongue Point in the Columbia River returned at 1.6 times greater rate than those released upriver (Solazzi et al. 1991). Similarly, Gunnerod et al. (1988) found that Atlantic salmon *Salmo salar* released in salt water returned at a higher rate. Marsh et al. (1996, 1998, 2000) compared the Skamania Landing release site with a Tongue Point (RKm 29) release site in the Columbia River estuary, but too few adult steelhead returned from either release point for a meaningful evaluation.

The goal of our 2008 study is to determine whether releasing barged fish at Rkm 10 (approximately 10 km downstream of the Astoria Bridge) will improve the smolt to adult return (SAR) rate of spring Chinook salmon and steelhead (Figure 1). The strategy is to minimize the time spent moving into and thru the estuary and to document fish condition, which will provide insight into the vulnerability of smolts to predators. The general approach is to tag transported smolts with passive integrated transponders, collect

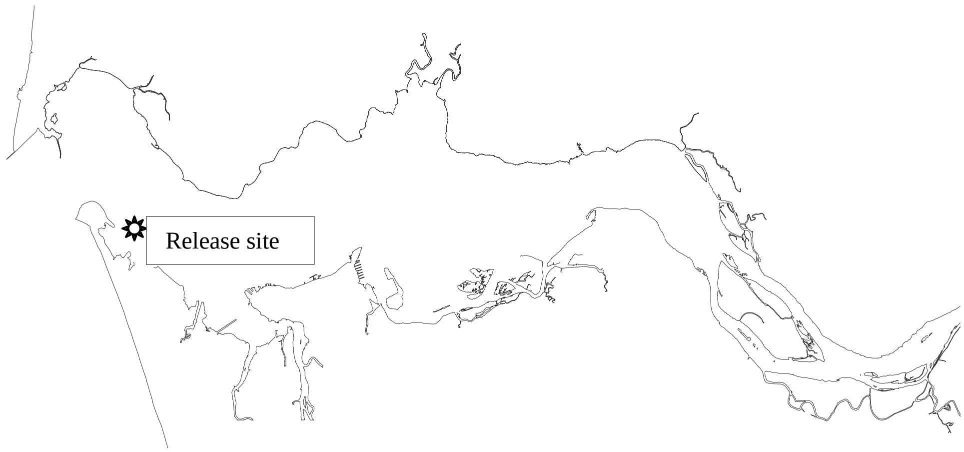

Figure 1. Proposed alternate site (Rkm 10) in the lower Columbia River estuary.

samples for pathogen analysis, and release fish at the current barge release site downstream of Bonneville Dam (Skamania Landing) and at Rkm 10. This (2008) will be the third year of releases for this study.

While the primary focus of this study is the difference in SARs, we are also interested in examining mechanisms that may cause the observed differences in SARs. The first area we are looking at is the presence of pathogens and second is vulnerability to avian predation. We intend to document the prevalence of the pathogens *Renibacterium salmoninarum and Nucleospora salmonis*, both of which have been shown to have a negative affect of salmonid health. In addition, we are using data from a COE funded project, that recovers juvenile salmonids tags from the world's largest Caspian tern *Hydroprogne* c*aspia* and double-crested cormorant *Phalacrocorax auritas* colonies in the Columbia River Estuary (Ryan et al. 2003). The recovery of PIT tags from these colonies will allow us to compare the number of salmonids preyed upon from the Skamania Landing release site to the Rkm 10 release site.

APPROACH

Objective 1

Compare SARs of spring Chinook salmon and steelhead released at Skamania Landing to their cohorts transported downstream and released at Rkm 10

Task 1.1

During spring 2008, PIT tag two groups of spring Chinook salmon smolts at Lower Granite Dam, one group will be loaded on the normal transportation barge to be released at Skamania Landing while the second group will be loaded on an alternate barge and released at Rkm 10. This effort will be repeated for steelhead smolts.

In spring 2008, we will PIT tag sufficient numbers of spring Chinook salmon smolts at Lower Granite Dam (LGR) to test a 1.3 transport-Rkm 10-release-to-transport-Skamania release ratio (T_A / T_S) for adults returning to LGR. The sample size to detect a 1.3 T_A / T_S ratio (two-tailed, alpha 0.05) is based on an expected SAR of 1.0 for the Rkm 10 release group (Table 1). Concurrently, we will conduct the same comparisons for steelhead smolts. For both spring Chinook salmon and steelhead, we will tag both hatchery and wild fish in the same proportions that they enter the juvenile bypass facility. While the 1.3 ratio sets our tagging number at 53,000 for each species, we will request extra tags to increase tagging numbers if fish supplies and logistics permit so that in the event of a lower SAR we might still realize a meaningful comparison. The extra tagging would primarily be focused on Chinook salmon since the expected SARs are generally lower for them than for steelhead.

Table 1. Predicted sample sizes based on expected smolt-to-adult return (SAR) and transport-Rkm10 release to transport Skamania release ratio (T_A / T_S).

T_A/T_S Ratio	Expected Astoria SAR	Number PIT tagged at Lower Granite: Astoria Release	Skamania Release
1.2	1.00	48,000	57,000
1.2	0.75	64,000	76,000
1.2	0.50	95,000	114,000
1.3	1.00	23,000	30,000
1.3	0.75	31,000	40,000
1.3	0.50	46,000	58,000

Since the releases at Rkm 10 will require an extra barge and transport vessel, tagging will be conducted on six Sundays throughout the migration season. Additional tagging will be conducted on Saturdays possibly during the first and final two weeks, which will facilitate reaching our weekly target numbers. Both the Rkm 10 and Skamania releases will be tagged on Sundays, and on Mondays the Skamania releases will be loaded on a normal transportation barge and the Rkm 10 releases will be loaded on a 2000 series barge. Loading densities and water volume replacement times will be targeted to match the specifications of the two newer versions of the transport program barges (Table 2; Series 4000 and Series 8000). The Skamania release groups will be transported and released with the normal transportation fish.

Table 2. Loading density data for U.S. Army Corps barges used in the alternate barge release location study in 2008.

Barge series	Pounds	Gallons	Inflow	lbs/gal	Replacement rate
2000	23,000	85,000	4,600	0.27	18.48
4000	50,000	100,000	10,000	0.50	10.00
8000	75,000	150,000	15,000	0.50	10.00

The 2000 series barge will be towed with a separate vessel mirroring the path of the normal barge. Once passed Bonneville Dam, the 2000 series barge will continue downstream to Rkm 10. The releases at Rkm 10 will be coordinated to occur on the ebb tide at night to help avoid avian predation in the Columbia River estuary (Tables 3 & 4).

Table 3. Proposed schedule for tagging and transport of Skamania and Rkm 10 release groups for 2008

Release 1	20 Apr	21 Apr	22 Apr	23-25 Apr
	Tag at LGR	Load Barges	Skamania Release; transfer 2000 series barge.	Release at Rkm 10
Release 2	27 Apr	28 Apr	29 Apr	30 Apr-2 May
	Tag at LGR	Load Barges	Skamania Release; Transfer 2000 series barge.	Release at Rkm 10
Release 3	4 May	5 May	6 May	7-9 May
	Tag at LGR	Load Barges	Skamania Release; Transfer 2000 series barge.	Release at Rkm 10
Release 4	11 May	12 May	13 May	14-16 May
	Tag at LGR	Load Barges	Skamania Release; Transfer 2000 series barge.	Release at Rkm 10
Release 5	18 May	19 May	20 May	21-23 May
	Tag at LGR	Load Barges	Skamania Release; Transfer 2000 series barge.	Release at Rkm 10
Release 6	25 May	26 May	27 May	28-30 May
	Tag at LGR	Load Barges	Skamania Release; Transfer 2000 series barge.	Release at Rkm 10

Recover study adults utilizing the PIT-tag detection system in the fish ladder at Lower Granite Dam and analyze adult return data.

Lower Granite Dam will serve as the principal recovery site for adults. Data acquired from other areas will be considered ancillary. To analyze results, statistical tests will be applied when adult returns for the study are complete. The CIs for the T_A/T_S will be calculated using the ratio (survival) estimate (Burnham et al. 1987) and its associated empirical variance. The study will produce an overall, statistically-bound T_A/T_S estimate at Lower Granite Dam.

Table 4. Proposed release schedule for Rkm 10 release groups.

Tagging Date	Load Date	Release Date	High Tide	Release Times Between
20-Apr	21-Apr	23-Apr	2:52am	3:15am to 5:15am
		24-Apr	3:20am	3:35am to 5:35am
		25-Apr	6:06pm	8:00pm to 9:00pm
27-Apr	28-Apr	30-Apr	10:26pm	11:30pm to 1:30am
		1-May	11:05pm	12:05am to 2:05am
		2-May	11:42pm	12:42am to 2:42am
4-May	5-May	7-May	2:23am	3:23am to 5:00am
		8-May	3:11am	4:00am to 5:15am
		9-May	6:06pm	8:30pm to 10:30pm
11-May	12-May	14-May	10:30pm	11:30pm to 1:30am
		15-May	11:10pm	12:10am to 2:10am
		16-May	11:46pm	1:45am to 3:45am
18-May	19-May	21-May	1:51am	2:50am to 4:50am
		22-May	2:22am	3:15am to 5:15am
		23-May	2:56am	3:30am to 5:15am
25-May	26-May	28-May	8:41pm	9:40pm to 11:40pm
		29-May	9:25pm	10:25pm to 12:25am
		30-May	10:10pm	11:10pm to 1:10am

Objective 2

Determine *Renibacterium salmoninarum* prevalence and infection severity profile for each release group and document relationships between SARs and prevalence and levels of *R. salmoninarum* infection. Determine the prevalence of *Nucleospora salmonis* for each release group and document relationships between SARs and prevalence of *N. salmonis* infection

Task 2.1:

Compare data on *Renibacterium salmoninarum* prevalence and levels, and data on *Nucleospora salmonis* prevalence and levels to fish performance measures**.**

Diane Elliott, USGS, will lead this task. Data on *R. salmoninarum* and *N. salmonis* prevalence and levels will be compared to SARs for sampled groups. Gill filament samples for determining the presence and levels of *R. salmoninarum* in tagged fish will be collected from fish representing each of the release groups throughout the migration season. Sample collection methodology will follow the protocol for non-lethal detection outlined Schrock et al. (1994). Samples will be placed in individual labeled tubes on dry ice and forwarded to the USGS Western Fishery Research Center for analysis. Data on which microacoustic tag ID associated with each gill sample will be collected and reported.

This task will provide fish condition data for evaluating potential risks to survival of smolts. Salmonids in the Columbia River are very susceptible and routinely exposed to bacterial kidney disease (BKD). Infected fish can survive or perish depending on their overall condition and levels of other stressors they encounter. The influence of BKD on survival, migration route, and timing has been ignored recently due to the inability to acquire information non-lethally. This work will utilize newly available polymerase chain reaction (PCR) technology to provide information on percent incidence and levels of *R. salmoninarum* infections in smolts at the time of tagging. A sub-sample of PIT-tagged smolts will be tested to provide the estimate of percent prevalence of *R. salmoninarum* infection and the distribution of infection levels for each particular release group. The sub-sample will include about 150 steelhead and 150 Chinook salmon per release group. Gill samples will be tested for *R. salmoninarum* by quantitative PCR (qPCR; Chase et al. 2006) and nested PCR (Chase and Pascho 1998). Both techniques have been used successfully to detect active (moderate level or greater) infections in gill samples from Chinook salmon (Elliott and Pascho 2004). Testing a single sample by both PCR techniques is desirable to provide the most information. This information can then be used during data analysis as a factor that may influence fish behavior or survival.

In addition to gill tissue samples, water samples will be taken from the containers in which fish are held before tagging, and tested for *R. salmoninarum*. Preliminary results from testing the 2005 samples suggested a higher prevalence of *R. salmoninarum* in gill samples than in kidney samples. It is possible that some of the gill samples may have become contaminated by high numbers of *R. salmoninarum* being shed into the water of the holding containers by infected fish. Furthermore, the presence of high numbers of *R. salmoninarum* in the water may enhance the transmission of this pathogen during the tagging procedures (Elliott and Pascho 2004). Water samples will be taken periodically from the fish holding containers throughout each tagging day and tested for *R. salmoninarum* by solid phase laser scanning cytometry. This technology provides rapid and sensitive detection and quantification of bacteria in water samples (Lemarchand et al. 2001, Lisle et al. 2004).

This task will also provide a measure of the prevalence and levels of *N. salmonis*, an intranuclear microsporidian parasite that has been reported from several salmonid species, including Chinook salmon and steelhead, in the western U.S. and Canada (Giorgiardis et al. 1998), and occurs in the Columbia River and Snake River basins. This parasite primarily infects lymphoblast cells resulting in a chronic, severe lymphoblastosis and a leukemic-like condition. Natural infections have been associated with acute or chronic mortality in Chinook salmon (Elston et al. 1987; Hedrick et al. 1990; Morrison et al. 1990) and with chronic mortality in steelhead (K. Clemens, U.S. Fish and Wildlife Service, Idaho Fish Health Center, Ahsahka, Idaho). Chronic disease can result in poor growth, secondary infections, and low-grade mortality (Hedrick et al. 1990). A sensitive nested PCR procedure has been developed for detection of *N. salmonis* genomic DNA in fish (Barlough et al. 1995; Georgiadis et al. 1998). Although anterior kidney is the principal tissue sampled for *N. salmonis,* the parasite has been detected in gill tissue (Barlough et al. 1995). Gill samples taken from fish in this study for *R. salmoninarum* analysis will also be tested for *N. salmonis* by the nested PCR procedure of Barlough et al. (1995) and a newly developed qPCR (J.R. Foltz et al., University of Idaho).

FISH REQUIREMENTS FOR FY 2008

We plan to PIT tag 53,000 yearling Chinook salmon and steelhead each throughout the spring of 2008. We will tag both hatchery and wild fish proportionate to what is collected at the juvenile fish facility. Handling and tagged numbers from previous years will be used to calculate the proportion of wild fish that we will handle to apply for ESA permits.

SCHEDULE

Activity	FY08	Outyears
Task 1.1		
Fish marking and release	Apr-Jun	Same
Task 1.2		
Recover study adults	Mar-Jul	Same
Task 2.1		
Collect samples for pathogen analysis	April-June	Same

PROJECT IMPACTS, FACILITIES, AND EQUIPMENT

At Lower Granite Dam, tagging for this study will require the use of an additional raceway on Sundays and Mondays for the releases at Rkm 10 (Table 4). In addition it will require the use of the NOAA tagging facility adjacent to the juvenile fish facility. For the Rkm 10 released fish, it will require the use of a 2000 series barge as well as a separate tow vessel. The tow vessel and barge will be required for six trips between April 21 and June 10.

PROJECT PERSONNEL AND DUTIES

Wiliam D. Muir, NMFS—biologist and principal investigator working on Objective 1.
Douglas M. Marsh, NMFS--biologist and principal investigator working on Objective 1.
Steven Smith, NMFS–statistician working on Objective 1.
Benjamin Sandford, NMF--statistician working on Objective 1.
Dianne Elliott, USGS—pathologist working on Objective 2.

Table 4. Raceway usage for 2008 at Lower Granite Dam on tagging dates (April 20; April 27; May 4, 11, 18, & 26) for alternate barge release site study.

East (Upstream) Raceways at LGR				
Raceway 10	**Raceway 9**	**Raceway 8**	**Raceway 7**	**Raceway 6**
	Tagged Astoria bridge release fish **Load on 2000 series barge Monday** After tagging these fish would be top-loaded to bring up density	**Rejects and tagged control fish** **Load on normal transport barge Monday**		**(General collection)** Send rejects and tagged controls to Raceway 8 and tagged Astoria bridge fish to Raceway 9

TECHNOLOGY TRANSFER

Technology transfer will be in the form of written and oral research reports as required. A draft report will be provided to the COE by 15 November each year, with a final report provided by 15 March the following spring. Results will also be published in appropriate scientific journals.

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FINAL RESEARCH PROPOSAL (FY08)

TITLE:	Evaluate the effectiveness of transporting Subyearling Chinook Salmon from McNary Dam
PROJECT LEADERS:	Douglas M. Marsh National Marine Fisheries Service Northwest Fisheries Science Center Fish Ecology Division 2725 Montlake Boulevard East Seattle, Washington 98112 (206) 860-3235
ADMINISTRATIVE:	Doug Dey National Marine Fisheries Service Northwest Fisheries Science Center Fish Ecology Division 2725 Montlake Boulevard East Seattle, Washington 98112 (206) 860-3237
ADMIN. CODE:	TPE-W-04-03
DURATION OF PROJECT:	2002 to 2008
DATE OF SUBMISSION:	October 2007

PROJECT SUMMARY

The goal of this project is to compare smolt-to-adult return rates (SAR) of wild and hatchery-reared subyearling Chinook salmon (*Oncorhynchus tshawytscha*) that migrate in-river compared to those transported from McNary Dam to below Bonneville Dam, and determine if statistical differences in return rates exist for different juvenile migration histories.

The most recent evaluations of transportation from McNary Dam for subyearling Chinook salmon began in 2001. During the summers of 2001 and 2002, we PIT-tagged river-run subyearling Chinook salmon at McNary Dam. In 2008, we propose to conduct additional studies using hatchery subyearling Chinook salmon PIT-tagged and released from Columbia River

hatcheries above McNary Dam as well as river-run subyearlings collected and tagged at McNary Dam.

In addition to overall SAR comparisons on an annual basis, we will examine the effects of transportation on a seasonal basis and determine if transportation alters homing of adults.

Relevance

This study addresses needs identified in NOAA's 2004 Biological Opinion (BiOp) "*The Action Agencies will continue to conduct RM&E to provide information on juvenile fish transportation and delayed mortality*", and the 2005-2007 Implementation Plan for the Federal Columbia River Power System Endangered Species Act Updated Proposed Action of the U.S. Army Corps of Engineers, Bureau of Reclamation, and Bonneville Power Administration (dated May 2005). Specifically, the Implementation Plan, under the Hydropower Action Effectiveness Research section (page 40), they state "*Advance the understanding of the effectiveness of flow augmentation, spill,* ***transportation****, and system configuration changes on fish survival for each ESU*".

BACKGROUND

Research to evaluate the effects of transporting juvenile salmonids around dams began over 30 years ago and the results have varied depending on the species evaluated, the time of year, and the transport site (Ward et al. 1997, Williams et al. 2005). Transportation of subyearling Chinook salmon from McNary Dam on the Columbia River was evaluated from 1978 through 1983. Results indicated that more marked/transported fish returned to the point of release than did marked fish released to migrate in-river, while initial studies conducted after re-building the juvenile facilities at the dam in 1995-1996 were less conclusive (Williams et al. 2005).

The 1995-96 studies used CWT fish as adult PIT-tag detection facilities did not exist at the dam. Return rates depended on expansion of CWT tag recoveries and were weighed toward recoveries at hatcheries above McNary Dam. In 2002, the adult fishways at Bonneville and McNary Dams were equipped with PIT-tag interrogation systems. In anticipation, we PIT-tagged subyearling Chinook salmon migrating through McNary Dam beginning in summer 2001 and continuing in summer 2002. The third year of tagging was not done in 2003 partly due to a cutback in funding for research activities. For 2008, we propose tagging at McNary Dam to complete the third year of the study. Although the ideal study design would capture, PIT tag, and release natural subyearling fall Chinook salmon in the Hanford Reach rather than at McNary Dam, logistical restraints (capturing enough subyearlings of taggable size and their survival to McNary Dam) prevent conducting the study in this manner (McMichael et al. 2005). In 2002, we also proposed to PIT tag and release subyearling Chinook salmon from Columbia River hatcheries above McNary Dam, but this portion of the study was also not done. In 2008, we again propose conducting this part of the study. This evaluation will provide new data to assess the efficacy of transportation from McNary Dam to increase adult returns of anadromous salmonids to the Columbia River.

APPROACH

Objective 1

Compare SARs of subyearling Chinook salmon juveniles PIT tagged at and either transported from McNary Dam to below Bonneville Dam or released into the tailrace to migrate in-river.

Because the majority of subyearling migrants originate from natural spawning above the dam and we cannot tag enough of these fish to provide adequate sample sizes at McNary dam, as in 2001 and 2002, we propose to PIT tag fish arriving at the dam. The majority of these fish will represent the natural migrants. This year will provide the third year of a planned 3-year study.

Task 1.1:

PIT tag two groups of subyearling Chinook salmon at McNary Dam in summer 2008. Transport one group for release below Bonneville Dam and release the other group into the McNary Dam tailrace to continue its in-river migration through the remaining three dams and reservoirs.

We recommend testing a minimum 1.3 T/I for subyearling Chinook salmon transported from McNary Dam vs. those that migrate in-river from the tailrace of the dam through three additional dams and reservoirs. The SARs of transported PIT-tagged fish from the the 2001 and 2002 subyearling Chinook salmon studies were 0.3% and 1.0%, respectively. Given that 2001 was a record low flow year, we used the SAR of 1.0% for subyearlings transported in 2002 to determine sample sizes for our 2008 studies.

Sample Size Calculations

Sample size calculations for a transport study using transport SARs relative to in-river SARs can be based on determining precision around the estimated T/I such that the ½ width of a confidence interval on the true T/I will not contain the value 1, or the confidence interval on the true natural-log-transformed T/I, LN(T/I), will not contain 0. Therefore, for a desired α and β and specified true T/I, the number of fish needed can be determined in the following manner.

T/I is needed such that:

$$LN(T/I) - (t_{\alpha/2} + t_{\beta})*SE(LN(T/I)) \approx 0$$

and $SE(LN(T/I)) \approx SQRT(1/n_T + 1/n_I) = SQRT(2/n)$, where $n_T = n_I = n$ is the number of adult returns per treatment (n for transport and in-river groups set equal for simplicity). The previous two statements imply that the sample of adults needed is:

$$n \approx 2*(t_{\alpha/2} + t_{\beta})^2 / [LN(T/I)]^2.$$

Set α = 0.05, β = 0.20, and an expected transport SAR of at least 1.0%. Sample sizes needed at McNary Dam are listed as follows (N denotes the number of juveniles):

T/I	n	N_T	N_I ($=N_T$*T/I)	N_{Total}
1.3	229	22,900	29,770	52,670

Therefore, we will tag a total of 52,670 river-run subyearling Chinook salmon at McNary Dam in 2008.

While our proposal is to test if the T/I is equal to or greater than 1.3, the table below shows the number of fish needed to test T/Is of 1.1 to 1.5.

Alpha	Beta	Transport SAR	T/I	n	N_T	N_I (= N_T*T/I)	N_{Total}
0.05	0.20	1.0	1.1	1,729	172,900	190,190	363,090
0.05	0.20	1.0	1.2	473	47,300	56,760	104,060
0.05	**0.20**	**1.0**	**1.3**	**229**	**22,900**	**29,770**	**52,670**
0.05	0.20	1.0	1.4	139	13,900	19,460	33,360
0.05	0.20	1.0	1.5	96	9,600	14,400	24,000

We will attempt to sample the population collected at McNary Dam at levels that will permit marking a constant rate of fish throughout the outmigration. The percentage of the daily collection we handle will depend upon the number of fish collected. Marked study fish will be held an average of 12 hours before transport or release into the McNary Dam tailrace.

As in the past, all handling/marking will be done using pre-anesthesia techniques (Matthews et al. 1997). After the fish are anesthetized, they will be gravity-transferred in water into the sorting building. Fish for marking will be sorted out and sent to one of several marking stations to receive a PIT tag.

This basic study design can be executed under any hydropower system operation scenario. The proportion sampled daily for marking will be established when river operation scenarios are known. This will provide a total adult-return estimate for marked/transported fish that represents the number of fish collected and transported.

Objective 2

Compare SARs of subyearling Chinook salmon PIT tagged and released from hatcheries in the Columbia River upstream of and subsequently transported from McNary Dam to below Bonneville Dam with the SARs of groups of the same fish estimated to have arrived in the tailrace of the dam and to have migrated in-river through the remaining three dams and reservoirs.

Evaluations of transportation from McNary Dam are complicated because the populations of fish arriving at the dam originate from two major river systems--the Snake River and the

Columbia River upstream of McNary Dam, and from natural and hatchery production that exhibit different migrational timing. Objective 1 addresses an evaluation of transportation for the composite populations of anadromous fish arriving at McNary Dam. Objective 2 addresses an evaluation of transport from McNary Dam for hatchery fish originating only in the Columbia River.

Task 2.1:

PIT tag and release subyearling Chinook salmon from Columbia River hatcheries upstream of McNary Dam to establish transport and in-river-migrating test groups at the dam in 2008.

To provide a holistic approach to evaluations of SARs and T/Is for fish originating only in the Columbia River upstream of McNary Dam, we propose to tag and release three groups of fish that originate in hatcheries in this area. Transport and in-river-migrating groups will be established when the fish pass through McNary Dam. The numbers of fish transported will be a known value, while the numbers of fish arriving in the dam's tailrace will be estimated using the methods of Sandford and Smith (2002).

Sample Size Calculations

The method used to calculate sample sizes for a transport study at McNary Dam is the same as described under Objective 1. Setting $\alpha = 0.05$, $\beta = 0.20$ and an expected transport SAR of at least 1.0% for each hatchery, sample sizes needed to detect a 1.2 T/I at McNary Dam are listed below (N denotes the number of juveniles):

T/I	n	N_T	N_I (=N_T*T/I)	Ntotal
1.2	229	22,900	29,770	52,670

While we propose to test for a 1.3 T/I value, the table in Objective 1 shows the number of fish needed to test T/Is of 1.1 to 1.5.

The above numbers are required at McNary Dam. Releasing tagged fish from hatcheries upstream of the dam will require increasing the numbers of fish tagged to provide sufficient numbers collected for transport at the dam. To determine the numbers required for tagging at the hatcheries, we examined the estimated survival to the dam and detection probabilities for fish released previously in the Columbia River above the dam.

For subyearling fish released from Wells Hatchery, survival to McNary Dam has averaged about 0.3 to 0.4 (pers. commun., Larry Basham, Fish passage Center, 2001). Using this value and a detection probability of 0.585, about 130,000 (22,900/0.300/0.585) PIT-tagged subyearling hatchery fish would be required for release in the Columbia River upstream of McNary Dam. However, during 2007, temporary spillway weirs were tested at McNary dam, resulting in detection probabilities in the range of 0.3 to 0.4. If the same project operation and configuration occurs in 2008, it will require marking approximately 254,000 fish.

We propose to tag fish at three hatcheries upstream of McNary Dam and in numbers roughly proportional to each hatchery's contribution to the total number of fish released. The following table provides numbers of fish proposed for tagging at each hatchery (assuming a detection probability of 0.3):

Population	Hatchery	Number tagged
Subyearling Chinook salmon		
	Priest Rapids	151,000
	Ringold	75,000
	Eastbank complex	28,000
		254,000

FISH REQUIREMENTS FOR FY 2008

1. We will need to coordinate with WDFW, COE, and other researchers at McNary Dam to obtain 52,440 subyearling Chinook salmon and the facilities for marking them.

2. We will coordinate with the proposed Columbia River hatcheries as to the best time for tagging fish at each location. We will work with the COE and whoever is chosen for the actual tagging of these fish.

SCHEDULE

Activity	FY08	Outyears
Task 1.1		
Fish marking and release	Jun-Aug	Same
Task 2.1		
Fish marking and release	Oct-April	Same

PROJECT IMPACTS, FACILITIES, AND EQUIPMENT

We will need use of a part of the Smolt Monitoring Laboratory at McNary Dam for our marking stations. If no space is available, we will need a location close to the lab where we can set up a tagging trailer for our use.

PROJECT PERSONNEL AND DUTIES

Douglas M. Marsh--biologist and principal investigator working on Objectives 1-2.
Steven Smith–statistician working on Objectives 1-2.
Benjamin Sandford–statistician working on Objectives 1-2.

TECHNOLOGY TRANSFER

Technology transfer will be in the form of written and oral research reports as required. A draft report for fall Chinook salmon will be provided to the COE by 15 August each year, with a final report provided by 15 December. In this way, complete returns for each age class of adults can be included in the final report for each study year. Results will also be published in appropriate scientific journals.

REFERENCES

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FINAL RESEARCH PROPOSAL (FY08)

TITLE:	**A Study to Determine Seasonal Effects of Transporting Fish from the Snake River to Optimize a Transportation Strategy**
PROJECT LEADERS:	Douglas M. Marsh and Robert L. Emmett National Marine Fisheries Service Northwest Fisheries Science Center Fish Ecology Division 2725 Montlake Boulevard East Seattle, Washington 98112 (206) 860-3251
ADMINISTRATIVE:	Doug Dey National Marine Fisheries Service Northwest Fisheries Science Center Fish Ecology Division 2725 Montlake Boulevard East Seattle, Washington 98112 (206) 860-3237
ADMIN. CODE:	**TPE-W-00-04-1**, **TPE-W-05**
DURATION OF PROJECT:	2000 to 2010
DATE OF SUBMISSION:	October 2007

PROJECT SUMMARY

The goal of this project is to determine if smolt-to-adult return rate (SAR), transport/in-river-adult-return-ratio (*T/I*), and post-hydropower system mortality (*D*) of transported and in-river yearling Chinook salmon *Oncorhynchus tshawytscha* and steelhead *O. mykiss* is related to their size and timing of arrival in the estuary/nearshore ocean. Recent transportation studies using PIT tags have found that transported yearling Chinook salmon returned at rates that were lower than were expected based on estimated survival through the hydropower system (to below Bonneville Dam) (Williams et al. 2005). This indicates that transported fish had a lower survival

rate between leaving the hydropower system as juveniles and returning as adults than did fish migrating in-river. This differential post-hydropower system survival is referred to as "*D*"; *D* is less than one when post-hydropower system survival is lower for transported fish than for in-river fish. Several hypotheses to explain $D < 1$ have been proposed: Budy et al. (2002) proposed stress and disease; Muir et al. (2006) proposed size and timing of release of transported fish. Stress and disease hypotheses are being investigated through other research proposals. Here we will investigate seasonal effects of differences in size and timing of fish from the two groups upon arrival below Bonneville Dam. Fish-tagging efforts for this portion of the study will be combined with concurrent in-river smolt survival study tagging funded by BPA (Project # 199302900).

A secondary goal of this project is to provide valid statistical comparisons between the SAR of Snake River juvenile salmonids that migrate in-river and the SAR of those transported around dams of the Federal Columbia River Power System (FCRPS) from returning adults from past studies. Beginning in 2004 and continuing through 2007, we marked a barge index group with no corresponding in-river group. We will compare the SARs of the transported fish with those of fish PIT tagged concurrently and released in the tailrace of Lower Granite Dam for juvenile reach survival studies. Adult returns from this marking will continue through 2010. Based on SARs to Lower Granite Dam, we will calculate a 95% confidence interval (CI) for the overall transport/in-river-adult-return-ratio (*T/I*). We will compare results from our studies (wild fish marked at the dam) to results from hatchery fish PIT tagged above the dam (Berggren et al. 2005).

A third goal is to correlate estuary/ocean bio-physical indicators with the weekly timing of barge releases. If strong correlations are found, these data will eventually be used to develop the best time (week) within a year that estuarine/ocean entry will maximize SARs for transported and in-river yearling Chinook salmon and steelhead. Recent studies using PIT tags have shown that yearling Chinook salmon and steelhead show large within year variations in their SARs. For example, juvenile Chinook salmon that arrive and enter into the estuary/ocean early in the year generally have relatively low SARs compared to individuals that migrate only a week or two later (Muir et al. 2006). However, the actual week that SARs are highest varies annually. The annual fluctuation in the best time of ocean entry (highest SAR) appears associated with fluctuations in estuary/ocean biological and physical conditions. Unfortunately, a detailed long-term database of estuary/ocean conditions that could be used to statistically relate ocean entry timing of Chinook salmon and steelhead SARs with oceanographic conditions does not presently exist. This proposal addresses this issue. Ultimately the results of this research will lead to the ability to: 1) identify the estuary/ocean biological/physical conditions that most influence SARs, and 2) develop models that will predict the annual, within-year optimal time (week) for juvenile salmon to enter the ocean to maximize SARs. As a consequence of this research, salmon managers could adjust juvenile salmon release/transportation/river passage strategies to maximize the number of smolts entering the ocean at the predicted time to maximize ocean survival.

Analyses of data from this and other research conducted under various contracts will provide critical information to examine potential seasonal effects of transportation, compare overall SARs of transported and in-river-migrating or bypassed anadromous salmonids, to evaluate the effects of transportation on homing of adults, to estimate *D* of transported and in-river fish, and mechanisms to explain *D*. The studies will be conducted using state-of-the-art facilities and technologies and under environmental conditions known to provide in-river passage conditions as favorable as possible through the FCRPS as it is currently configured and operated.

Relevance

This study addresses needs identified in NOAA's 2004 Biological Opinion (BiOp) "*The Action Agencies will continue to conduct RM&E to provide information on juvenile fish transportation and delayed mortality*", and the 2005-2007 Implementation Plan for the Federal Columbia River Power System Endangered Species Act Updated Proposed Action of the U.S. Army Corps of Engineers, Bureau of Reclamation, and Bonneville Power Administration (dated May 2005). Specifically, the Implementation Plan, under the Hydropower Action Effectiveness Research section (page 40), states "*Advance the understanding of the effectiveness of flow augmentation, spill, **transportation**, and system configuration changes on fish survival for each ESU*".

In 1996, the Northwest Power Act Amendment called on the NWPCC to consider the impacts of ocean conditions on salmon populations rather than focus efforts exclusively upriver of Bonneville Dam (US Government 1996). This view was adopted in the 2000 Fish and Wildlife Program Plan, which recognizes the "North Pacific Ocean as a geographic unit (of the Columbia River basin) that should be considered in research, monitoring, and evaluation actions". In the 2003 Mainstem Amendments to the Columbia River Basin Fish and Wildlife Plan (NWPCC 2003), one of the important biological objectives was to understand the relationship between the Columbia River estuary and nearshore ocean, and salmon marine survival. In 1996, the National Resource Council concluded that scientists/managers should find ways to reduce sources of Pacific Northwest salmon mortalities and find ways to compensate for them (NRC 1996).

BACKGROUND

Research to evaluate the effects of transporting juvenile salmonids around dams began over 30 years ago (Ebel et al. 1973, Ebel 1980, Park 1985, Ward et al. 1997). The benefits of transportation (based on annual averages) have been shown to vary by species and dam with hatchery spring/summer Chinook salmon and wild and hatchery steelhead generally showing a benefit, while wild spring/summer Chinook salmon and fall Chinook salmon have generally shown little or no benefit (CSS 2007, Williams et al. 2005). However, more recent studies and analysis have shown the efficacy of transportation to vary seasonally, with early transported smolts generally having lower SARs than in-river migrants, but the reverse of this later in the migration (Williams et al. 2005, Muir et al. 2006, CSS 2007).

Results from our latest tagging efforts provide new data to assess in-river migration and transportation to determine what strategies will provide the highest adult returns of anadromous salmonids to the Snake and Columbia Rivers. We will integrate results with concurrent in-river-smolt-survival studies (Muir et al. 2001), and using the results from these combinations of studies, provide estimates of *T:I* and *D* for the various groups of study fish. Furthermore, as *T:I* and *D* has been shown to vary temporally within the migration season (Williams et al. 2005, Muir et al. 2006, CSS 2007), we will estimate *T:I* and *D* on a weekly basis, as data allows.

Smolts that are not transported typically take from 2 to 4 weeks to migrate from Lower Granite to Bonneville Dam, while barged fish take < 2 days (Muir et al. 2006). Thus, fish from the two groups that leave Lower Granite Dam on the same day likely face considerably different conditions upon ocean entry, a critical time in their life cycle (Pearcy 1992). Data from hatchery yearling Chinook salmon PIT tagged above Lower Granite Dam and wild yearling Chinook salmon tagged at Lower Granite Dam, and either transported from Lower Granite Dam or returned to the river, suggest that *D* varies widely within a season as well as from year to year (Fig. 1) (Muir et al. 2006). However, data on wild fish are limited, particularly for steelhead.

Congleton et al (2005) reported that during migration from Lower Granite to Bonneville Dam (typically 2 to 4 weeks) average growth of wild yearling Chinook salmon that migrated in-river was 6 mm in 2002 and 8 mm in 2003 (Fig. 2). Hatchery yearling Chinook salmon were found to exhibit similar growth during their migration. Thus, in-river-migrating smolts are larger upon arrival below Bonneville dam than their transported counterparts that left Lower Granite Dam on the same day, making in-river-migrating smolts potentially less vulnerable than transported smolts to size-selective predation (Muir et al. 2006). Northern pikeminnow (*Ptychocheilus oregonensis*), the most abundant smolt predator in the Columbia River, particularly below Bonneville Dam (Ward et al. 1995), have been shown to be size selective predators (Poe et al.1 1991, Shively et al. 1996).

In summary, transported smolts arrive below Bonneville Dam at a different time and size than fish that migrate in-river and this likely affects their survival from below Bonneville Dam to return as adult (*D*). It is clear that estuary/ocean conditions are very important to salmon marine survival and stock abundance (Kareiva et al. 2000; Logerwell et al. 2003; Peterson and Schwing 2003; Wilson 2003; Emmett 2006; Emmett et al. 2006; Emmett and Sampson, *In press*) and that measures of ocean conditions can be used to predict annual SARs (Scheuerell and Williams 2005). Ocean temperatures appear to be particularly important to spring/summer Chinook salmon survival (Emmett and Sampson, *In press*).

To begin to address the issue of timing of smolt ocean entry and SARs, Muir and Emmett (2007), released marked (CWT) spring Chinook salmon in the Columbia River estuary at 10-day intervals from April-June 2002-2006. They will be correlating estuary/ocean conditions and SARs as adult return data becomes available. The Muir and Emmett (2007) study is obtaining much of their oceanographic information from a NOAA/BPA funded study of plume conditions (Emmett 2006; Emmett et al. 2006). Unfortunately, oceanographic measurements have been taken only at approximately 2-week intervals, and many biological measurements, such as zooplankton abundance and turbidity, have not been measured. Furthermore, the 6 years of the Muir and Emmett (2007) study will provide only limited information on time of ocean entry and ocean survival as the statistical power of their analysis will be relatively low because of limited sample size (6 years with 6 releases/yr). The current proposal will build on their work and have greater statistical power.

Substantial efforts and funds have been expended upstream of the Columbia River estuary to rear hatchery salmon, improve dam and reservoir survival, and enhance salmon habitat. Although all salmon stocks within the Snake/Columbia River Basin must pass through the Columbia River estuary and near-shore ocean, we presently have little knowledge of what conditions they will encounter upon ocean entry. By providing this information, the results of this study will support and enhance these upstream efforts at relatively little cost. This project is linked to another COE proposal that will be PIT tagging and releasing relatively large numbers of smolts that will provide seasonal Snake River salmon and steelhead SARs for this project: Alternative Barging Strategies to Improve the Survival of Transported Juveniles Salmonids (TPE-W-06-02).

APPROACH

Objective 1

PIT tag transport and in-river groups of wild yearling Chinook salmon and wild steelhead smolts at Lower Granite Dam to provide temporal and seasonal estimates of T/I.

In 2008, we propose to PIT tag wild Snake River yearling Chinook salmon and wild steelhead for release into transport barges. The fish PIT tagged for transport will be paired with those PIT tagged for BPA Project 199302900 for in-river survival estimation to provide temporal and seasonal *T/Is* and temporal and seasonal estimates of *D*.

Task 1.1:

<u>PIT tag wild yearling Chinook salmon and wild steelhead smolts in spring 2008 to establish seasonal transport groups at Lower Granite Dam.</u>

Sample Size Calculation

For seasonal transport groups at Lower Granite Dam, the number of PIT-tagged fish required to estimate the SAR of the group with a desired level of precision can be determined from the following equation:

$$N = (z_{\alpha/2})^2 * SAR * (1-SAR)/w^2$$

where:

N = the number of PIT-tagged juveniles required in the transport group at Lower Granite Dam.

SAR = the expected smolt-to-adult return rate.

w = desired precision of the estimate, expressed as ½ the width of a (1- α) x 95% confidence interval.

Thus, with α = 0.05 and expected SAR for the transport group of 0.01 (1.0%), the following table gives the number of PIT-tagged fish required to achieve various levels of precision on the estimate of SAR for the seasonal transport groups:

Half-width of 95% confidence interval on estimated SAR	Number of PIT-tagged fish required in release group
0.0020 (i.e., interval of 0.8% to 1.2%)	9,508
0.0025 (i.e., interval of 0.75% to 1.25%)	6,085
0.0030 (.i.e, interval of 0.7% to 1.3%)	4,226
0.0035 (i.e., interval of 0.65% to 1.35%)	3,105

Similarly, if the same numbers of fish are tagged for seasonal in-river groups, the following table shows the expected precision of the estimated SAR, assuming that the expected SAR for the in-river groups is 0.007 (0.7%):

Number of PIT-tagged fish	Half-width of 95% confidence interval on estimated SAR
9,508	0.0017 (i.e., interval of 0.53% to 0.87%)
6,085	0.0021 (i.e., interval of 0.49% to 0.91%)
4,226	0.0025 (.i.e., interval of 0.45% to 0.95%)
3,105	0.0029 (i.e., interval of 0.41% to 0.99%)

We will PIT tag and release a transport group (COE) and an in-river group (under BPA Project 199302900) of each species each week at Lower Granite Dam in spring 2008 as long as sufficient numbers of fish are available. Based on availability of fish passing Lower Granite Dam in past years, we anticipate that we can tag 6,000-fish groups of wild Chinook salmon for 5 or 6 weeks during the migration, beginning the second week of April. Wild steelhead migration patterns are more variable from year to year, but barring a very large spike in the migration corresponding to a large runoff event, we anticipate tagging a similar number of weekly groups of 4,000-6,000 wild steelhead. For Chinook salmon, nearly 100% of hatchery-released fish are fin clipped or have an elastomer (visual implant) tag. Additionally hatchery fish are significantly larger than wild fish. Using size and marked criteria, we believe that nearly all Chinook salmon designated as wild fish are, in fact, wild. Wild steelhead are easily identifiable from hatchery steelhead.

The population collected at Lower Granite Dam will be sampled at varying rates from week to week to permit marking a constant number of fish each week throughout the entire outmigration. Smolts will be collected in the upstream raceways used for transportation research. The first week of tagging in April, smolts will likely have to be collected for multiple days to reach the target number. The percentage of the daily collection we handle will depend on the number of fish collected. Hatchery smolts of both species will be sorted and returned to the Lower Granite Dam raceways for transport or returned to the river.

We propose to begin collecting fish on 6 April, with marking beginning on 7 April 2008. Depending on the number of fish available, we will collect fish for 1-2 days with tagging occurring on the day following collection. During sorting in our tagging facility, targeted fish will be randomly distributed between transport index marking and BPA Project 199302900 marking. A barge will leave each Thursday morning with all fish collected during the previous

1-3 days (excluding fish tagged for in-river survival, which will be released into Lower Granite Dam tailrace). By barging all fish collected (minus the in-river migration group) during 1 to 3 days of collection, barge densities will be maintained at a level similar to what would occur under normal transport operations that time of year. This pattern will occur in the weeks preceding general transportation, currently set to begin between 20 April and 1 May. Depending on the number of fish available, we will adjust our collection and tagging days to minimize the amount of time fish need to be held at the dam before transporting. That is, if sufficient fish can be collected and tagged in two days, collection will begin on Monday; if three days are needed, collection will begin on Sunday.

Generally, very few hatchery fish arrive at Lower Granite Dam prior to the third week of April, so non-target fish numbers should be at a minimum during the first two weeks of tagging. Depending on the number of fish being collected each day, we may collect all fish bypassed within a 24-hour period (on days when few fish are collected), or we will focus our collection during periods of the day when we are most likely to encounter target species/rear types (on days when large numbers of fish are being collected).

As in the past, all handling and marking will be done using pre-anesthesia techniques (Matthews et al. 1997). After the fish are anesthetized, they will be gravity-transferred in water into the sorting building, as is done at the primary fish-sampling facilities at dams.

Objective 2

Estimate growth during migration between Lower Granite and Bonneville Dams

During 2008, studies funded by BPA will include wild and hatchery yearling Chinook salmon and steelhead tagged and measured at Lower Granite Dam and released into the tailrace (i.e., “in-river”, not transported). We will enter the PIT-tag codes of these fish into the sort-by-code system (Marsh et al. 1999) at Bonneville Dam for recapture. We will record the date of recapture and the fork length (mm) for each recaptured fish and compare these with date and length at Lower Granite Dam to calculate growth (mm) and travel time (days) between Lower Granite Dam and Bonneville Dam. Mean growth and mean travel time will be calculated for the season as a whole and for segments of the season (at least early/middle/late and probably weekly).

Sample sizes

We anticipate that around 15,000 PIT-tagged wild Chinook salmon and 40,000 PIT-tagged hatchery Chinook salmon will be released into the tailrace of Lower Granite Dam in 2008. Based on detection rates in 2005, we anticipate that 5% of these fish (750 wild and 2,000 hatchery fish) will encounter the sort-by-code system at Bonneville Dam. Based on growth data for wild Chinook salmon sampled in 2002 and 2003, we anticipate that a sample of 100 fish will provide a mean growth estimate with a 95% confidence interval of +/- 1 mm. Thus, by sampling every wild Chinook salmon (from above) that encounters the sort-by-code system and one of every four hatchery Chinook salmon, we anticipate that we can make estimates of mean growth with this precision for five temporal groups within the migration season.

Objective 3

Monitor SARs of PIT-tagged wild yearling Chinook salmon and wild steelhead smolts barged from Lower Granite Dam to below Bonneville Dam from past marking.

From 2004-2007, we marked wild yearling Chinook salmon and wild steelhead smolts for an index group of smolts transported from Lower Granite Dam with no in-river comparison group. However, concurrent with tagging the transport index groups, wild Chinook salmon and wild steelhead were PIT tagged and returned to the river to estimate in-river survival for BPA study 199302900. SARs from the fish returned to the river to migrate will be paired with the transport index groups to provide *T/I*s on a seasonal and annual basis. Adults from these marking years will continue returning through 2010.

Task 3.1:

Monitor PIT-tag detections of wild adult Chinook salmon and steelhead and analyze adult return data.

Lower Granite Dam will serve as the primary detection site for adults. Data acquired from other areas will be considered ancillary. To analyze results, statistical tests will be applied when adult returns for the study are complete. We will calculate confidence intervals for the *T/I* using the ratio of SAR estimates (Burnham et al. 1987) and their associated empirical variance. The study will also produce seasonal trends in SARs and *T/Is* and an overall, statistically-bound *T/I* estimate for both wild species at Lower Granite Dam. Additionally, we will use regression analyses to correlate *T/Is* with a number of variables related to hydropower system operation and time of ocean-entry (see objective 5). We will integrate our SAR data with in-river survival estimates from BPA-funded studies (using the Single-Release Model (Muir et al. 2001)) and use the information from this combination of studies to estimate *D*, on a weekly basis if data allow.

Task 3.2:

Examine PIT-tag detection histories of adults as they migrate upstream through the hydropower system.

Currently, Bonneville, McNary, Priest Rapids, Ice Harbor, and Lower Granite Dams are equipped with adult PIT-tag detection systems (Harmon et al. 2003) and detection systems are planned for installation in other dams in the future. At these dams, all PIT-tagged fish passing through the fish ladders will likely be detected. Detection systems are also in place at many hatcheries in the Columbia River Basin.

To evaluate whether transportation affects the homing of returning adults, we will compare the PIT-tag detection histories of transported and non-transported adult study fish as they pass upstream through PIT-tag detection systems in the basin.

Objective 4

PIT-tag transport and in-river groups of juvenile fall Chinook salmon at Lower Granite Dam during the fall migration period.

In 2008, we propose to continue the program of PIT-tagging juvenile fall Chinook salmon at Lower Granite Dam in September and October and monitoring their adult returns. This study began in 2002. From incomplete adult returns to date, we already have determined that fish tagged in the fall return at much higher rates than fish transported earlier in the migration. In addition, recent studies looking at scale patterns from returning adults have indicated that a large percentage of these fish do not enter the ocean immediately following release below Bonneville Dam, but instead over-winter in the freshwater/estuary area between Bonneville Dam and the ocean. We propose tagging both transport and in-river components under this marking effort.

Sample sizes

Sample size is limited to the number of fish available in the collection system at Lower Granite Dam during September and October. Based on the numbers of fish collected in previous years, our goal will be to tag between 5,000 and 6,000 fish (with marking split equally between transported and in-river migrant fish).

Objective 5

Explore relationships among temporal SARs and biotic and abiotic conditions that spring-run smolts encounter during migration and ocean entry

Changes in direct survival during migration through fresh water do not appear to explain observed changes in SARs for groups of fish within or between years. Characterization of the conditions that smolts encounter in the estuary and nearshore ocean and of SARs on a temporal basis might allow us to identify which estuarine or ocean biological/physical conditions are correlated with high or low levels of salmon ocean survival. Managers can potentially use this information to determine whether to transport smolts from collector dams or allow them to migrate naturally to synchronize their arrival to the estuary and nearshore ocean during optimal conditions. Adult returns from our temporal releases (when complete) will be evaluated and correlated with the biotic and abiotic conditions smolts encountered in the Columbia River, the estuary, and nearshore ocean environment. The biotic and abiotic conditions smolts encounter will be obtained from other research programs in the basin currently collecting this type of data.

Task 5.1

<u>Continue and Enhance the Database of Columbia River Estuary/ocean Physical and Biological Conditions and Snake River SARs from 1998 Through the Present.</u>

A database of estuary/ocean biological and physical conditions including information from 1998-2006 has been developed by Muir and Emmett (2007). We will continue to add information to this database, including field information collected from **Tasks 5.2** described below**.** Information included in the database will include at a minimum; Snake River spring/summer Chinook and steelhead estimated time of ocean entry and SARs, weekly (or daily if possible) ocean temperatures, salinities, and turbidities; zooplankton species composition and densities; forage fish densities, upwelling indices, and river flows, turbidities, and temperatures. We are also currently investigating the use of satellite imagery data to characterize near-shore ocean conditions (Bessey and Palacious 2007). Based on data collected in the estuary by Dawley et al. (1985), we will assign ocean entry timing as 5 days after fish pass Bonneville Dam.

The two COE funded studies described above (Objective 1 from this study and TPE-W-06-02) will PIT tag, barge, and release substantial numbers of smolts on a weekly basis. Fish from barge releases are preferable for this research since their approximate time of ocean entry is known (Muir et al. 2006). This study (objective 1) will PIT tag, barge, and release groups of from 5,000 to 6,000 wild yearling Chinook salmon and from 4,000 to 6,000 wild steelhead each week of the migration. The study "Alternative Barging Strategies to Improve the Survival of Transported Juveniles Salmonids" will PIT tag and release groups of the composite population of hatchery and wild yearling Chinook salmon and steelhead collected each week at Lower Granite Dam, with about 57% released at the traditional barge release site at Skamania Landing and the other 43% released downstream of Astoria. This study will provide a minimum of 53,000 PIT tagged smolts for analysis.

Task 5.2

Collect and Quantify Weekly Zooplankton Samples and Acoustic Measures of Forage Fishes and Bio-Physical Oceanographic Conditions from April through June.

Task 5.2a. Make weekly collections of zooplankton.

A direct correlation between copepod abundance (an index of salmon food), ocean conditions (Hoof and Peterson 2006), and salmon marine survival has been demonstrated (Peterson and Schwing 2003). Weekly zooplankton samples will be collected by vertical towing a ½-m plankton net from 60 m (or bottom) to the surface. Samples will be collected at the same two stations that have been sampled regularly off the Columbia River since 1998. Zooplankton will be identified and counted. Recent studies (Emmett et al. 2006) have collected zooplankton samples in the Columbia River plume approximately every two weeks from late-April through July since 1998. However, these samples have never been processed and quantified. We will process and quantify these samples for species composition and abundance, and enter this data into the database.

Task 5.2b. Make weekly acoustic measures of forage fish abundance off the Columbia River.

Forage fishes appear to be important "alternative prey" for juvenile salmonid predators, and their abundance appears to influence salmon marine survival (Emmett 2006; Emmett and Sampson In press). However, because of their patchy distribution within the large ocean environment, quantifying forage fish abundance using traditional sampling methods is difficult and costly. Fisheries acoustics provide an alternative cost effective method to monitor the abundance of forage fishes (Simmonds and MacLennan 2005). At least two transects will be surveyed in the ocean off the Columbia River. Relative abundance estimates for forage fishes will be made for each weekly period. Species composition will be identified from ongoing NOAA/Plume forage fish studies, which are using net tows to measure forage fish abundance.

Methods: A Simrad EK 60 system with 38 kHz split beam operations will be towed near the surface from a contracted vessel. Backscatter information collected by the Simrad system will be downloaded to a computer for later laboratory analysis. Estimates of the abundance of forage fish will be made each week from April to mid-June. Acoustic data will be analyzed using SonarData Echoview Software.

Task 5.2c Take weekly measurements of ocean temperatures, salinities, conductivity, chlorophyll, and turbidity

Method: A Seabird CTD (conductivity/temperature/depth) meter with be used to measure the physical conditions of estuary/ocean waters. The CTD will also have sensors to measure Chlorophyll (flurometer) and turbidity. Measurements will be taken from surface to depth at zooplankton collection stations and other designated stations in the estuary/ocean.

Task 5.3

Identify the Statistical Relationship Between Salmon and Steelhead SAR, Time of Ocean Entry, and Ocean Conditions.

Logistic regression similar to that used by Scheuerell and Williams (2005) and time series analysis will be used to identify the relationships between weekly SARs, time of ocean entry and ocean conditions at the time of ocean entry. Initial analysis of explanatory variables versus SAR will be conducted (using linear and nonlinear regression) and then a full model incorporating important variables will be built using a GAM. We will first build and test a model using data from earlier studies (1999-2003 PIT-tagged Snake River transported fish) and make predictions about survival of 2008 releases. Once final SAR data from 2008 are available, we will incorporate these data into the model and test the model against future returns. We will continue to fine tune the model throughout the study period as more adults return. Correlations among explanatory variables will be checked; a variable will not be added to the model if it is too highly correlated with another variable already in the model.

FISH REQUIREMENTS FOR FY 2008

Lower Granite Dam

We will PIT tag 4,000 to 6,000 wild yearling Chinook salmon and wild steelhead smolts each week for as long as sufficient numbers are available, to monitor the temporal smolt-to-adult return rates of transported fish (Objective 2). A similar number of fish will be tagged under BPA Project 199302900 for in-river survival estimation and for comparison to the transported groups.

For the fall Chinook salmon marking under Objective 4, we anticipate tagging between 5,000 and 6,000 fish for the season.

SCHEDULE

Activity	FY08	Outyears
Objective 1		
Juvenile fish tagging and release	April-June	Same
Objective 2		
Recapture fish at Bonneville Dam	April-June	Same
Objective 3		
Adult detection monitoring	Mar-Dec	Same
Objective 4		
Juvenile fish tagging and release	Sept-Oct	Same
Objective 5		
Plume sampling	April-June	Same
Analysis	Ongoing	

PROJECT IMPACTS, FACILITIES, AND EQUIPMENT

1. COE shall provide maintenance and repair of the adult collection facility at Lower Granite Dam.
2. Coordination with operations for smolt marking will be required at Lower Granite.
3. We will require exclusive use of at least three (possibly four) of the upstream raceways at Lower Granite Dam to collect and hold study fish.
4. A barge and tug will be required for one trip per week in the weeks prior to the beginning of general transportation (currently, we expect two such trips).

5. Space will be needed in the smolt monitoring facility's lab for Objective 4.
6. Use of the sort-by-code system at Bonneville Dam will be required.
7. NMFS presently has the equipment (transducers and receivers) to conduct acoustical survey of fishes, but will need to purchase computers and software.
8. Contract vessels will be used to conduct weekly ocean collections.

PROJECT PERSONNEL AND DUTIES

1. Douglas M. Marsh--biologist and principal investigator.
2. Robert Emmett-- biologist and co-principal investigator.
3. Neil Paasch--biological technician.
4. Kenneth McIntyre--biological technician.
5. Paul Bentley -- biologist in charge of all ocean field duties.
6. New Hire--zooplankton biologist and database technician
7. New Hire--acoustic technician/biologist

TECHNOLOGY TRANSFER

Technology transfer will be in the form of written and oral research reports as required. A draft report for spring/summer Chinook salmon will be provided to the COE by 15 November each year, with a final report provided by 15 March the following spring. A draft report for steelhead will be provided to the COE by 15 August each year, with a final report provided by 15 December. In this way, complete returns for each age class of adults can be included in the final report for each study year. Results will also be published in appropriate scientific journals.

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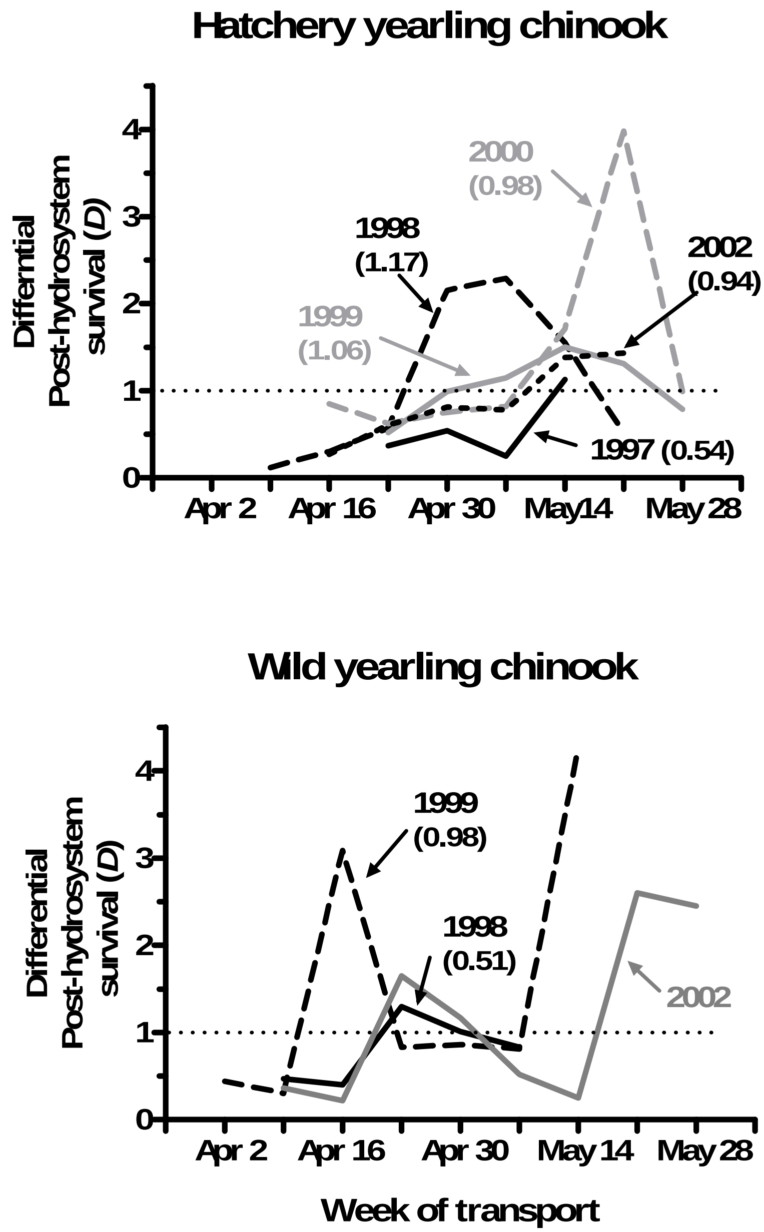

Figure 1. Weekly estimates of differential post-hydropower system survival for hatchery (tagged above Lower Granite Dam) and wild (tagged at Lower Granite Dam) yearling Chinook salmon. "D" is the ratio of estimated post-hydropower system survival for transported smolts to that for in-river migrant smolts. Annual pooled estimates of *D* in parentheses.

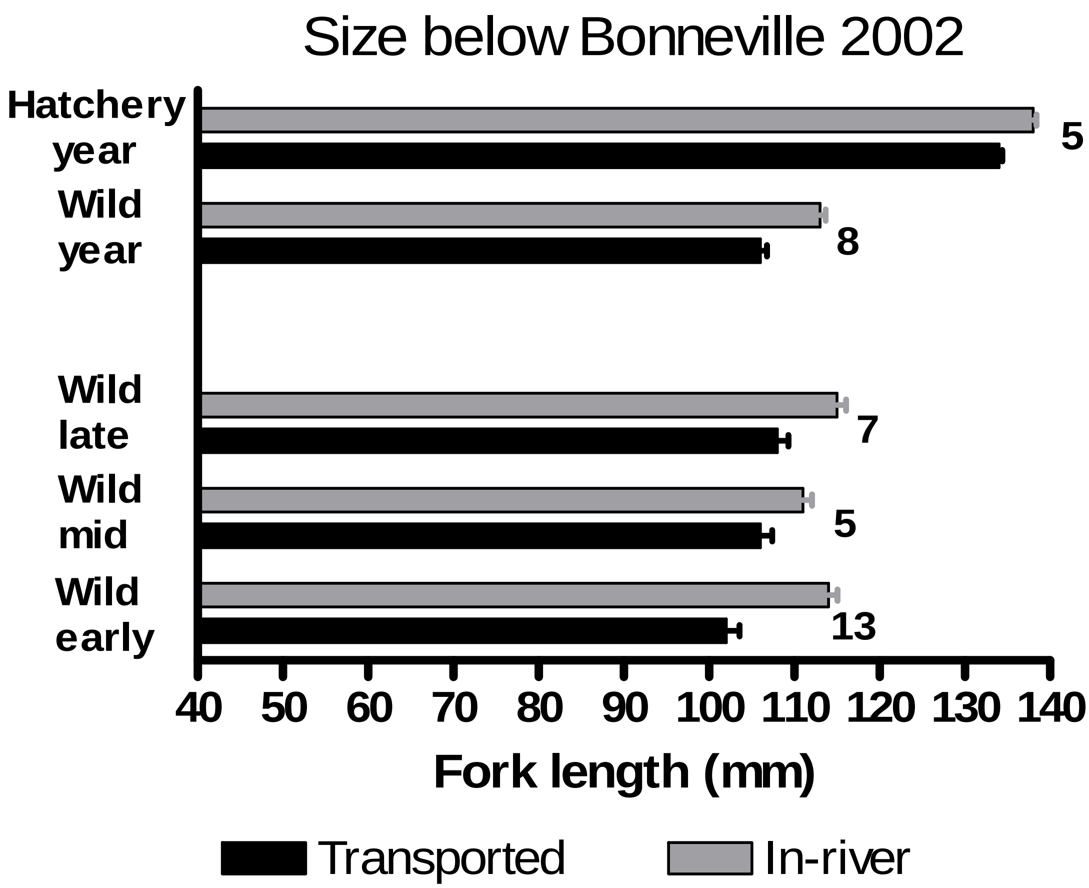

Figure 2. Fork length (mm) of wild yearling Chinook salmon on arrival below Bonneville Dam in 2002 that were transported or migrated in-river. The yearly average (top of graph), seasonal average (bottom), and difference in length (number next to bars) are shown. Data provided by J. Congleton, U of I.

FINAL RESEARCH PROPOSAL (COE) (FY08)

TITLE: Sampling PIT-tagged juvenile salmonids migrating in the Columbia River estuary

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STUDY CODES: BPS-00-10, TPE-W-00-3, TPE-W-04-01,
TPE-W-06-02, TPE-W-03, and TPE-W-00-06

PROJECT DURATION: 2007-2009

CURRENT PROPOSAL: 1 January through 31 December 2008

SUBMISSION DATE: October 2007

PROJECT SUMMARY

Detection of passive-integrated-transponder (PIT) tagged juvenile salmon in the estuary will allow survival to be partitioned between river and ocean environments and facilitate a more complete understanding of survival and timing differences between transported and in-river-migrant groups. The information will provide system survival estimates which, when combined with smolt-to-adult-return rates (SAR) of all groups of transportation study fish, can be used to estimate differential delayed mortality or 'D' as called for in the 2000 and 2004 Federal Columbia River Power System (FCRPS) Biological Opinions (BiOp). These data may also lead to management actions that increase survival by adjusting ocean entry timing or changing the proportions of fish transported or left to migrate in-river.

The goal of this project is to partition survival of juvenile salmonids between river and ocean environments and provide survival estimates between transported and in-river out migrating groups. Additional information on travel time, diel migration patterns, and migration behavior in response to flow and water temperature will also be collected by species and compared to similar data collected in the upper estuary from 1998 to 2007. The objectives for 2008 are first, to estimate survival through the Columbia River hydropower system for PIT-tagged salmonids during March-July; second, to contribute data to a multi-year analysis for survival through the Columbia River hydropower system of PIT-tagged salmonids; third, to continue development of a magnitude larger and more efficient detection antenna system, eventually replacing the existing system and finally, to extend sampling during summer and fall for subyearling salmonids. Estuarine detections of PIT-tagged fish will also provide an index of PIT-tagged salmonids known to be in the upper end of the estuary for use by researchers to assess how avian predators in the lower river select prey by comparing difference in prey selectivity by species and rear type or migration history. Further, if appropriately marked fish are available during the spring, we will compare migration timing of radio-, acoustic-, and PIT-tagged fish to and through the estuary.

We propose to assess migration timing to the estuary for yearling Chinook salmon and steelhead from a variety of tagging studies proposed on the Snake and Columbia Rivers in 2008. Several major studies proposed will contribute fish for these specific goals and there appears to be amble groups planned for tagging in 2008 for the evaluation. We provide preliminary numbers for several proposed tagging studies in the methods section of this proposal.

Sampling for run-of-river fish will be conducted from as early as mid-March through June (yearling migrants) and continue in summer and fall (subyearling migrants). The duration of research will depend on the presence of PIT-tagged fish from the studies mentioned above and possibly other major release groups of PIT-tagged fish. To obtain these data we will utilize a surface pair-trawl and detection electronics similar to those used in previous years (Ledgerwood et al. 2004; Ledgerwood et al. 2003; Ledgerwood et al. 1997). In 2007, we successfully deployed a proto-type 'Matrix' antenna system consisting of 2 front coils and 3 rear coils. The overall fish passage opening measured 2.6m wide by 3m tall and the reduced drag resulting from the enlarged opening and elimination of the Electric Barge allowed for tow speeds approximately double that of the standard 0.9-m diameter, 2-coil system used for sampling through most of 2007. There are still logistical details to work out for full utilization of the Matrix system but the potential increase in sample efficiency (perhaps doubling the detection rate) causes us to propose to utilize both systems simultaneously during the early part of the migration season and compare performance. Once we are satisfied the Matrix is reliable and consistently outperforms the standard system during periods of relatively high PIT-tagged fish density (early May) we would switch

to the Matrix exclusively. Towards that end, we expect to construct 2 additional sets of 3-coil antenna components (replace the 2-coil component tested in 2007 and have one 3-coil component for backup) and deploy a 6-coil antenna composed of 3 front coils and 3 rear coils separated by about 1.5 m of webbing.

BACKGROUND

Migration behavior and survival of juvenile salmonids passing through the lower Columbia River from Bonneville Dam to the mouth is poorly documented. Reasons include concern for impacts from physically handling large numbers of fish, inaccuracies in mark application and identification (brands and fin clips), and difficulties with sampling logistics which lead to inconsistent and biased results. However, precise estimates of migration timing and survival among juvenile salmonid populations traveling through the hydropower system and estuary would help evaluate factors affecting survival and the contribution of various enhancement activities to adult returns. In particular, timing and post-release survival of fish released from transportation barges could be compared to those for fish migrating in-river. These data would enable segregation of the effects of immediate mortality following barge-release from potential differential mortality associated with ocean entry or longer term effects on adults in the estimation of 'D' associated with transportation as called for in the 2000 and 2004 FCRPS BiOps.

In 1966, NOAA Fisheries researchers began evaluating migrational characteristics and relative survival differences between marked groups of juvenile salmonids released throughout the Columbia River Basin. Sampling was conducted in the estuary and occasionally in the nearshore ocean (Miller et al. 1983; Dawley et al. 1986; Johnsen and Sims 1973; Ledgerwood et al. 1990; Ledgerwood et al. 1991; Ledgerwood et al. 1994; Miller 1992). Purse and beach seines were selected as the primary sampling gear because of greater catch efficiency and less injury to the intercepted salmonids. Coded-wire tags (CWT) proved a useful marking technique for relative survival comparisons, compared to the uncertainty associated with poor mark application or retention using fin clip and cold brand methodologies. However, because of the large number of recoveries necessary to detect statistically significant differences among treatment groups using CWTs, it was necessary to sample as many as 367,000 fish. Concern over handling such large numbers of juvenile fish led us to seek alternative methodologies that greatly reduce impacts to fish when assessing migrational behavior and survival such as benignly detecting PIT-tagged juvenile salmonids. Detecting PIT-tagged fish in the estuary would also provide a means to evaluate juvenile salmon migrations independent of and downstream of hydroelectric facilities.

Therefore, in 1995, we began testing a PIT-tag detection system for use in the freshwater portion of the estuary. Between 1995 and 1999, we detected over 17,000 juvenile salmonids tagged with 400 kHz PIT-tags at the entrance to the Columbia River estuary at Jones Beach (RKm 75). In 2000, our electronic equipment was adapted to interrogate the 134.2 kHz PIT-tag used in the Columbia River Basin, and, through 2007, we have detected over 108,000 juvenile salmonids implanted with these tags.

In 2007, we continued evaluation of specialized pair-trawls and shoreline samplers using PIT-tag detectors for estuarine interception of PIT-tagged juvenile salmonids. Target fish were PIT-tagged juvenile spring/summer Chinook salmon *Onchorynchus tshawytscha* and steelhead *O. mykiss* released from April through early July each year to compare SARs between in-river migrating and barge-transported fish. We compared migrational behavior, timing and relative survival of fish groups transported and released downstream from Bonneville Dam with groups that migrated in-river. We provided dates of estuarine passage that allowed comparison of SARs for groups with similar ocean-entry timing and made estimates of survival for in-river migrants to below Bonneville Dam. We also provided observations on the diel behavior of juvenile salmonids in the estuary, on differences in migration timing between radio- , acoustic-, and PIT-tagged fish, and documented the presence of tagged smolts at the entrance to the estuary for use in assessing the relative vulnerability of juveniles to birds nesting in the lower estuary[1].

Our studies have suggested that the temporal distributions of transported PIT-tagged yearling fish at Jones Beach compared to in-river migrants were significantly different for fish tagged at Lower Granite Dam on the same date. We detected transport fish from each release for only a few days, whereas in-river migrants from each release at Lower Granite Dam were available for 2 to 3 weeks. We concluded that the longer, more uniform period of availability for fish released at Lower Granite Dam (in-river migrants) accounted for the increased number of detections for these fish compared to transported fish. Travel time for yearling fish to the estuary from Lower Granite Dam was correlated with available river flow. In normal flow conditions, the medians ranged from 13 to 18 days but in the low-flow drought year of 2001, the median travel time was 33 days. We also compared the daily differences in travel speed of fish to the estuary for fish released from barges or detected at Bonneville Dam and river flow. Fish released from barges generally traveled to the estuary slower than those detected at Bonneville Dam on the same date (i.e., compared with fish thought to have migrated to the estuary from Bonneville Dam under similar conditions). For example, in 2003, the median travel speed to Jones Beach for yearling Chinook salmon released from barges averaged 69 km/day compared to 87 km/day for in-river migrants detected at the dam, whereas for steelhead the median travels speeds were 81 and 88 km/day for barged and in-river migrants, respectively.

The PIT-tag detection system in our trawl operates independently from hydroelectric facilities and provides a unique opportunity to compare migration timing between fish detected or not detected at Bonneville Dam. For example, for fish released at The Dalles Dam in 1999 and 2000, the average travel times to Jones Beach for yearling Chinook salmon detected at Bonneville Dam were 6 and 9 hours longer than for those not detected at the dam, respectively; for coho salmon *O. kisutch* the travel times were 4 and 5 hours longer for detected fish in 1999 and 2000, respectively.

Daily trawl sampling was consistent, and detections of PIT-tagged fish were sufficient during the spring to provide survival estimates for in-river migrating yearling Chinook salmon to Bonneville Dam from 1999 to 2007 and steelhead from 1998 to 2007, using a modified single-release model (Williams et al. 2001; Steven G. Smith, NOAA Fisheries, NWFSC, Seattle, WA, Pers. commun., July 2001).

Beginning 2004, we modified our trawls by extending the floors 9.2 m forward of the foot-rope rather than 4.5 m as in previous designs. The extended-floor design was apparently effective at decreasing the escape rate of yearling Chinook salmon from the trawl. This helped increase our detection rates of those fish previously detected at Bonneville Dam during the date period of our 2-crew daily sample from about 2% in previous years to over 3% in both 2004 and 2005. In 2006, sample efficiency dropped to 1.9% of fish previously detected at Bonneville Dam and the lower efficiency was assumed to be primarily associated with the higher than average spring river flows that year. However,

[1]Large colonies of Caspian terns and double-crested Cormorants nest on dredge disposal and other islands located in the lower estuary downstream from Jones Beach.

it may also have been related to a lower detection efficiency of the enlarged antenna (1.4 m diameter), particularly during high-density periods, due to electronic collision of multiple-codes. In 2007, this larger 2-coil antenna leaked and we reverted to the 0.9 m diameter antenna. Detection rate of the 69,644 fish previously detected at Bonneville Dam during the period of our 2-crew sampling in 2007 was 3.5% using the smaller antenna in near average spring-time flows.

These gross estimates of sample efficiency are conservative in that we assume 100% survival to the estuarine sample site of fish detected at Bonneville Dam. The front to back antenna design provides improved efficiency using two opportunities to decode passing fish and we believe the properly tuned 0.9-m diameter antenna read over 95% of PIT-tagged fish passing from the trawl through the antenna. Our standard empirical testing of antenna systems using PIT-tags placed at known spacing and orientations on a flexible tape measure and passed through the center of the antenna coils shows the relative detection performance. The increased water volume passing through the enlarged antennas improved the natural alignment of antenna with the trawl body and the 1.4-m inside diameter antenna used in 2006 and early 2007, until it leaked, was the maximum allowed given the restriction in the basic foot print of the *RV* Electric Barge. To go to a larger fish passage opening would require elimination of the *RV* Electric Barge and utilization of the wireless data relay and video system developed and used previously with a 1.5-m outside diameter salt-water antenna in the lower estuary (Ledgerwood et al. 2006; 2007).

Construction of much larger freshwater antenna coil was also theoretically possible (perhaps as large as 1.0-m wide by 3-m tall, E. Prentice, June 2005, pers. commun.). In 2006, we constructed and tested a proto-type 'Matrix' antenna with a fish passage opening measuring 2.6-m wide by 3.05-m tall powered by a MUX transceiver. The antenna itself was constructed of 10-cm diameter PVC pipe using a parallel-pair of 3.05-m long detection coils, each coil having an inside opening of 102 cm. Including the 15-cm gap between adjacent coils, the overall fish passage opening width was 3.05 m. We tested this proto-type Matrix system attached to a small trawl for a few days in the water at Jones Beach using a charter vessel and a 26-foot NOAA vessel (*RV* Barracuda). The antenna required 111 kg of attached lead to sink it and overall weighed over 180 kg in air. Electronically, the system initially tested with good read rates in the center of each coil and in the gap, but developed unexplained environmental interference problems and poor read rates after a few days of sampling[2]. Early tests in 2007 showed low interference levels with the 'Matrix' antenna. However, as testing continued, interference levels increased and detection efficiency dropped.

In May, we incorporated the 2-coil 'Matrix' antenna with one of our large surface pair-trawls. About 6 m of the trawl body was removed to accommodate the larger antenna opening; otherwise the trawl design was the same. The Matrix system, with similar towing power applied, moved nearly twice as fast through the water as the standard system (5.5 knots vs. 3.0 knots, respectively). When towed in conjunction with the standard large-trawl and antenna system, we found that detection rates were lower overall, but when interference levels dropped, detection rates were similar or improved over the standard system (standard system was not affected by this interference). In response to high levels of interference, we began construction of another 'Matrix' component with the same outside dimensions, but consisted of three inner coils, each having a 70 cm width (compared to the earlier 102 cm width).

[2] In 2007, the probable source of the intermittent electronic interference was attributed to operations by the Canadian Navy on Vancouver Island. This signal also affected other western Washington PIT-tag detection systems using large in-stream antenna coils (Bruce Jonnason, NOAA Fisheries, Seattle, WA, pers. commun).

We theorized that the smaller inter coil configuration would reduce the effects of interference and reduce collision of codes (not having to read so far to the middle of the coils also reduced read range front and back, a source of code-collision). This 3-coil component tested well and was attached 1.5m behind with the 2-coil component to complete a 5-coil front to back Matrix antenna. Unavailable for testing until mid-July when fish densities were low, and with only a single shift of simultaneous testing with the standard trawl system due to vessel failures, it never-the-less detected over twice the number of PIT-tagged salmonids as did the large pair trawl system during a 4 day period of testing.

In 2008, we propose to continue testing of the Matrix system prior to the peak of the spring migration period and gain side-by-side evaluation of detection efficiency while supplementing our overall detection numbers. The goal is to eventually replace the *RV* Electric Barge and the required generator and AC power system computer with this magnitude larger antenna system and proven wireless mobile battery-powered system. This summer and fall, we will verify relative read performance of the 2- and 3-coil designs with test tags and adapt the best design for in situ testing in 2008. If the 3-coil design is selected, we would build a 2nd matching component and fabricate a 6-coil antenna; 3 coils front and 3 coils rear for redundant reading of passing fish. By use of the multiplex transceivers now available, we can power six antenna coils simultaneously. By eliminating a major part of the trawl body and *RV* Electric Barge, the resulting net-system has reduced drag and this enabled faster trawl speed without increasing impacts to fish. If adapted to operational use, this large-sized Matrix antenna grid could further increase detection efficiency (filter more water in less time) and perhaps facilitate development of a separation-by-code mechanism similar to those currently used at dams. Fish passage concerns and associated antenna handling logistics would be fully evaluated prior to making these major changes in configuration of the large trawl system. We anticipate using contract SCUBA divers to evaluate these changes prior to full implementation.

Conducting these developmental steps with a separate research system (the ‘Matrix’ system) would avoid any disruption of the consistent sampling effort required by the large trawl for survival and timing estimates in 2008. By sampling intermittently in the same river reach as the large trawl system, experimental results can be compared using the hourly PIT-tag detection rate and relative species composition. If the hourly detection rates are improved using the Matrix system and performs consistently without outside electronic interference, we would switch to the new system exclusively at some point. The enlarged antenna design and associated electronic components could also potentially be utilized in on-going habitat investigations in tidal side channels of the estuary as well.

OBJECTIVES

Objective 1. Estimate survival through the Columbia River hydropower system for PIT-tagged yearling salmonids during March-July 2008.

In 2008, we propose to repeat previous PIT-tag detection efforts using a pair-trawl to estimate survival of major in-river migrating release groups to the tailrace of Bonneville Dam. Furthermore, if a transportation study is conducted for fish PIT-tagged on the Snake River, estuarine detection rates will be used to compare seasonal trends in relative survival of transported fish released just downstream from Bonneville Dam to those in-river migrants detected in the juvenile bypass system at Bonneville Dam. We will also collect specific migration timing information for many other PIT-tagged groups. These data will provide supplemental information on transport benefits by comparing ocean-entry timing for barged versus in-river groups, form a basis to evaluate relative effects of bird predation on PIT-tagged salmonids, enable completion of survival estimates through the entire hydropower system, provide the ability to estimate differential delayed mortality or 'D' for different transport groups and will provide the first post-release detection data on transported fish. Our goal is to detect 2% of PIT-tagged fish previously detected at Bonneville Dam. Detection results from both Matrix and standard detection systems will be pooled for these evaluations which should increase our overall detection efficiency during the period when simultaneous sampling occurs, and increase sensitivity of the results.

Objective 2. Provide a multi-year analysis for survival through the Columbia River hydropower system of PIT-tagged salmonids for years 1998 through 2008.

Beginning in 1998, we have sampled annually during the peak of the spring/summer migration period with two daily sample crews at Jones Beach (rkm 75). Consistent sampling with the large surface pair trawl and antenna system from April to June has yielded a comprehensive multi-year relational database. These data provide an opportunity to compare estuarine run timing, species composition, travel time, diel migration patterns and survival through the Columbia and Snake River hydropower systems during these years. We will also compare these data to annual river flow and temperature trends. These data may also lead to management actions that increase survival by adjusting ocean entry timing or changing the proportions of fish transported or left to migrate in-river.

Objective 3. Test and sample with new larger antennas and related equipment intermittently using a proto-type experimental system in the upper estuary in 2008.

During the early season and into the peak of the yearling salmonid migration season, an experimental pair-trawl with a 5 to 6 coil 'Matrix' antenna system will be deployed for about 20 test days to evaluate the feasibility and efficiency of a large multiplex antenna system. As part of these developmental efforts, we will consider the design and logistical requirements for a future separation-by-code mechanism for diverting detected PIT-tagged fish of known migration history or treatment into a "live capture" holding container. Detections with this system will supplement fish numbers needed to accomplish Objective 1.

Objective 4. Extend sampling during summer and fall for subyearling salmonids.

Evaluation of transportation of PIT-tagged subyearling Chinook salmon is a new endeavor, and little information on behavior and timing for these fish following release is available. Sampling in mid-river at Jones Beach during late June and July in 2002, 2004, 2005, 2006 and 2007 indicated that detection rates of subyearling salmonids were adequate to determine timing and behavioral differences with a single sampling crew. In those previous sampling efforts, numbers of detections declined in mid- to late-July and increased with cooler water temperatures during September and October. We will match our sampling effort to this migration timing associated with numbers of PIT-tagged fish entering the estuary as indicated by detections at Lower Granite and Bonneville Dams and our detections. Intermittent sampling (from 0 to 6 d per week), will occur in response to fish availability and possible management actions (spill volume and fish-transportation options as implemented). Our goal is to detect 0.75% of the fish previously detected at Bonneville Dam and to document the duration of availability of transported fish in the estuary at this time of year (hypothesis is that some Snake River fall Chinook salmon fish may residualize even following transport). In addition, during March and April 2009, we will sample along the shoreline at Jones Beach to document possible migration in shallower waters of the estuary and reveal possible residency of Snake River subyearling Chinook salmon in these areas. Shoreline sampling is essential to document the early season migration of subyearling Chinook salmon thought to reside over winter in the Columbia River Basin. These early migrants would possibly include a portion of PIT-tagged fish that had been transported from collector dams during the summer of 2008 as subyearling fish. Their subsequent detection in the estuary would provide positive evidence that at least a portion of those transported fish over-winter downstream from Bonneville Dam and migrate to sea the following year.

METHODS

Sampling with the large trawl PIT-tag detection system for run-of-river fish will be conducted from March through June (yearling migrants) and continue in the summer and fall (subyearling migrants) 2008. The duration of research will depend on the presence of PIT-tagged fish from the studies mentioned above and possibly other major release groups of PIT-tagged fish. We do not anticipate sampling in the shoreline area in 2008, as results in 2007 were disappointing (no hold-over Snake River fall Chinook salmon were detected during March-April deployments) and fewer of these fish were tagged this past summer to potentially contribute to an over-winter life history with possible shoreline migration in 2008. To observe the behavior of fish as they move through the nets and PIT-tag detector tunnels, we will continue to use underwater video cameras and divers as available to evaluate fish and net interactions. Bi-weekly reports of preliminary research results will be provided to interested parties, and raw detection data will be available through the Columbia Basin PIT-tag Information System (PTAGIS) database (recovery site code is TWX--towed array experimental, large trawl).

Migration year 2008 PIT-tag Releases

Roughly 755,500 Chinook salmon, 226,000 steelhead, 27,000 Coho and 5,300 sockeye are to be tagged and released on the Snake River in 2008. About 120,000 Snake River hatchery spring/summer yearling Chinook salmon will be tagged for the ‘extra mortality’ study; 91,000 released into the tailrace at Lower Granite Dam and the remainder released into the tailrace at Ice Harbor Dam (E. Hockersmith, NOAA Fisheries, Pasco, WA, pers. commun., July 2007). As many as 30,000 wild yearling Chinook salmon and 30,000 wild steelhead, and another 20,000 hatchery steelhead will be tagged and released into the tailrace at Lower Granite Dam on the Snake River for a survival study of these groups (D. Marsh, NOAA Fisheries, Seattle, WA, pers. commun., July 2007). Another 30,000 wild yearling Chinook salmon and 30,000 steelhead at Lower Granite Dam will be tagged for an index barging and release-site study. The alternative barge release-site study will tag and release 30,000 hatchery/wild yearling Chinook salmon and 30,000 hatchery/wild steelhead on the Columbia River downstream from Bonneville Dam, to compare to an addition, 23,000 hatchery/wild yearling Chinook salmon and 23,000 hatchery/wild steelhead tagged and released at an alternative barge release site near Astoria in the lower estuary (B. Muir, NOAA Fisheries,Cook, WA, pers. commun. July 2007). We will also evaluate migration timing and survival of more than 522,500 spring/summer Chinook salmon, 27,000 Coho, 5,300 sockeye and 93,000 steelhead to be PIT-tagged and released by various hatcheries throughout the Snake River basin (B. Chockley, Fish Passage Center, pers. commun., July 2007). Additional tagging will occur to document movement and migration of subyearling fall Chinook salmon from the Snake and Clearwater Rivers. These studies potentially include as many as 800,000 PIT-tagged fish (S. Dunmire, COE, Walla Walla District, pers. commun., May 2007).

Approximately 122,500 Chinook salmon, 30,000 steelhead, 40,000 Coho, 15,000 sockeye and another 29,000 juvenile salmonids are to be tagged for release into the middle and upper Columbia River in 2008, not including unknown source totals. Grant County PUD will tag about 30,000 Chinook salmon for release on the Little White River (C. Dotson, Grant Co. PUD, pers. commun., July 2007). Chelan county PUD will tag and release 15,000 sockeye from Lake Wenatchee, 10,000 spring Chinook salmon from Chiwawa River rearing ponds, plus 30,000 steelhead, and perhaps 2,500 naturally produced spring Chinook salmon and steelhead, on the Wenatchee and Entiat Rivers (C. Jordan, NMFS, NWFSC, Seattle, WA, pers. commun., July 2007). Douglas County PUD will tag and release 10,000 juvenile salmonids, primarily Chinook salmon, from the Methow River, and potentially 5,000 summer/fall Chinook salmon from the Wenatchee Reservoir. Together with USFWS and WDFW, they will also tag and release another 12,000 summer Chinook subyearlings from Wells Hatchery plus another 9,000 juvenile salmonids from screw traps for Wells and Methow Hatcheries (T. Kahler, Douglas County PUD, East Wenatchee, WA, pers. commun., July 2007). The Yakama Nation plans to tag approximately 143,000 fish next year for their entrainment study on the Yakama River, as they have since 1999. A total of 40,000 hatchery spring Chinook salmon from the Cle Elum Juvenile Fish Facility, 13,000 hatchery/wild spring Chinook salmon from the Rosa Dam, and 10,000 hatchery/wild spring/fall Chinook salmon and Coho from the Chandler Juvenile Fish Facility, are to be tagged and released on the Yakima River. Another 40,000 Coho and 40,000 fall Chinook salmon will be tagged and released as well (M. Johnston, Yakima Nation Fisheries Resource Management, Toppenish, WA, pers. commun., July 2007).

Trawl Designs

Large Pair-Trawl Detection System

We will utilize a surface pair-trawl similar to those used in previous years (Ledgerwood et al. 2004; Ledgerwood et al. 2003; Ledgerwood et al. 1997). The operational procedures include towing the surface pair-trawl upstream with the wings open while juvenile salmonids pass downstream into the trawl and exit through the detector tunnels. PIT-tag decoding is accomplished electronically and requires no handling or removal of juvenile salmon from the net.

The pair-trawl consists of a 91.5m wing attached to each side of the 14m body of the trawl containing the PIT-tag detector located where the cod end is normally positioned. Two vessels are used for towing, thus the name pair-trawl. We will use, at least initially, the 86-cm diameter, two-coil PIT-tag antenna powered by a multiplex Digital-Angel transceiver as used in 2007. We may elect to switch to the Matrix system (see below) following additional testing comparing simultaneous sampling. GPS positions will be recorded every 15 minutes and with each detected fish, as in previous years.

Matrix Pair-Trawl Detection System

In 2007, we modified a large surface pair-trawl net used previously to sample juvenile PIT-tagged salmonids at river km 75 to fit the outside dimension of a proto-type ‘Matrix’ antenna system. The antenna has a fish passage opening 259cm wide by 305cm deep and consists of two components. The front component utilized two coils side by side (115cm x 319cm each) and the rear component utilized three coils side by side (83cm x 319cm each). These two components, connected by 1.5 m of net, comprised the 5-coil antenna and further increased detection rates through redundant interrogation of passing fish (like the two in series coils positioned in our 86 cm diameter by 210 cm long antenna).

Detections are transmitted to a data collection computer via wireless mobile battery-powered system mounted on a small raft as developed and used in the lower estuary in 2005 with the small trawl system (Ledgerwood et al. 2005). The body of this trawl extends ahead of the antenna 11m. Two 91.5m wings are attached to each side of the trawl body for a total length of 108 m. Like the large pair-trawl system, the 'Matrix' system was towed by two vessels. However, because the larger antenna passes much more water and does not require the RV Electric Barge to house the electronics, it was towed almost twice as fast. In 2008, we anticipate assembly of another 3-coil component to replace the 2-coil component resulting in a 6-coil antenna having a 3 front to rear coil arrangement and redundant reads for passing fish.

Detector Design and Efficiency

From 2000 to 2005, we used 86cm diameter PIT-tag detector antenna powered by Whit-Paten transceivers. A single-coil antenna was used in 2000, and a 2-coil version by 2.1 m long was used during the other years. In 2006, we used a larger diameter (118cm) but shorter (1.2 m) 2-coil antenna system powered with a Digital-Angel MUX transceiver. That antenna leaked in early 2007, thus we reverted to the 2005 antenna powered by a MUX transceiver. In 2008, we will begin the season using the 2005 antenna and MUX transceiver. We devised a test procedure to verify detector performance by positioning a 2.5-cm PVC pipe through the exact center of the antenna and passing a series of PIT-tags attached to a vinyl tape measure through the pipe. On each end of the PVC pipe, we used a plastic funnel to guide the tags smoothly into the pipe, (i.e., "funnel tests"). There were 50 PIT-tags positioned along the test tape at various densities (lengths) and orientations (in-line with the coils or at 45 degree angles). The tape was designed such that not all tags could be read. Generally, high density (0.3 m spacing) and poorly oriented tags (45 degrees to the coils) would disappear from the data records when the electronic systems were not working properly. We tested each antenna about once a week by passing the tape through the antenna six times (300 tags). About 80% of the test tags are read during these evaluations. Since the funnel-pipe was positioned in the center of the antennas, the procedure was conservative in that most fish pass closer to the antenna walls where read rates are higher. When the test funnel was mounted within 20-cm of the antenna wall, 98% of the same test tags were decoded. We believe that *in situ*, over 95% of all PIT-tagged fish passing through the 2-coil antenna system were detected in 2007. In 2008, we propose to continue "funnel tests" on a weekly basis or more frequently if needed to verify electronic system and detector performances. Similar testing will be used to validate performance of experimental proto-type antennas and the shoreline sampler equipment.

Detection Rates

In 1996, a relatively high flow year (flood conditions at Jones Beach), detection rates for 400 kHz PIT-tagged fish using the detector/trawl were 0.64% for in-river migrants previously detected at Bonneville Dam. This detection efficiency was similar to that attained at Jones Beach using a purse seine (Ledgerwood et al. 1994). In 1998, 1999 (400 kHz), and 2000-2003 (134.2 kHz PIT tags), we improved our detection efficiency by sampling 7 instead of 5 days per week and by extending our sampling effort using two daily sampling crews during the peak of the yearling salmonid migration each season. During the extended sampling periods, we detected over 2% of the in-river migrant salmonids previously detected at Bonneville Dam. Since 2004, we increased the detection rate of yearling Chinook salmon through use of a trawl with an extended floor (double previous floor length). We expect to again sample about 2 to 3% of the available PIT-tagged fish during the peak of the yearling Chinook salmon migration (April-June). At the beginnings and ends of migration periods, sampling occurs two or three days per week to determine timing and abundance. Net cleaning and maintenance, river conditions, personnel, vessel considerations and PIT-tag-detector operation should be the only impediments to continuous operation of the PIT-tag detector equipped pair-trawl.

Efforts to refine the net configuration, antennae and operational procedures to increase detection percentages and stimulate rapid passage through the net and detector systems, will continue. To do this without compromising the detection efficiency of the large trawl system, we have utilized the equipment developed for use in the more restricted and fast-flowing areas of the lower estuary. We will continue to test antenna design at sizes and configurations that will push the technology further. As the new equipment and procedures developed prove reliable, safe, and demonstrate low impacts on fish, we will modify the standard large trawl system accordingly.

Physical Impacts to Intercepted Fish

Passage of intercepted fish through the net and detector tunnel will be visually assessed using video cameras, and we will periodically use divers (as available) to assess net configuration and impacts to fish in areas not readily monitored by cameras. In addition, we will occasionally inspect areas of the net using a video camera mounted on a pole and adjust operations as needed. For example, when debris accumulations or other problems are observed, we reduce tow speed and pull the detection antenna to the surface to access the cod end of the net. When necessary, we disconnect the electronics and invert the entire net to clear debris.

SCHEDULE

In 2008, we propose to sample PIT-tagged juvenile salmon beginning in March and continue into July. At the beginning and end of the yearling salmonid migration a single crew will sample 2 to 6 days/week, depending on PIT-tagged fish abundance. During the peak of the yearling salmonid migration, mid-April to mid-June, we will utilize two daily sampling crews, 7 days/week. During this period of intensive sampling, catches are sufficient to enable calculations of survival probabilities for yearling Chinook salmon and steelhead to Bonneville Dam for in-river migrants and provide relative survival comparisons to the estuary among transported fish and in-river migrants detected at Bonneville Dam. Sampling in the for subyearling Chinook salmon will continue with a single daily crew in mid-June and July, most likely halt (with a decline in fish numbers) in mid-July through early September, then resume and continue into December. Actual daily sample schedule for subyearling fall Chinook salmon will depend in part on numbers of fish tagged, observed detection rates at Lower Granite and Bonneville Dams, fish transportation, and spill strategies implemented for management of these fish.

During April and into early May, we will also intermittently deploy the Matrix system simultaneous with the standard large-trawl system. If detection rates of the two systems are similar, and we expect the Matrix system to have significantly higher detection rates based on increased sample volume associated with higher tow speed, we would continue through the remainder of the season using the Matrix system. However, until fully evaluated in situ, particularly during time periods with high densities of PIT-tagged fish that might reduce detection rates due to collision of codes, we can not assume increased speed of sample will result in increase detections. When multiple tagged fish are in the electronic field simultaneously, as happens during net flushing actions, it can result in missed reads. We have not fully tested the Matrix front to back coil detection efficiency and have little previous experience with it during high fish density time periods. Data collected with the Matrix system will supplement data used in the above mentioned survival calculations. During periods with lower tag densities, like during summer and fall sample periods for fall Chinook salmon, we believe the Matrix system would be the preferred sample tool, due to higher sample volume.

Beginning in 2003, we emphasized sampling at dawn and dusk (typical periods of increased detection rates) by running our evening shift through the night until relieved by a morning shift while leaving the trawl deployed. The period of decreased daily sampling was generally from about 1400 to 1700 hours, a period characterized by high winds and difficult sampling conditions. We propose to repeat this strategy in 2008 during the 2-crew sample period.

FACILITIES AND EQUIPMENT

Facilities are located at the NOAA Fisheries Point Adams Field Station at Hammond, OR and at Jones Beach near Clatskanie, OR. Vessels are moored at Kerry West Marina near Westport, OR. A new large trawl with an extended floor was constructed in 2003, and we extended the floor of our 1999 net in 2005. New trawls were constructed in 2006 and 2007. In 2008, interchangeable trawl bodies will be constructed to adapt these trawls to the larger-sized Matrix antenna. In 2006, we switched from older-style Whit-Paten transceivers to newer 'multiplex' Digital-Angle Model FS1000M (MUX) transceivers and will continue their use in 2008 with both standard and Matrix systems. Both systems are now powered using 24-volt DC powered transceiver. The *Electric Barge* standard system operates using redundant battery banks recharged using a gas powered AC generator system which also powers the recording computers and video system. The MUX transceiver for the Matrix system rides in a small Hobe-cat pontoon raft with battery power is towed attached to the antenna. A wireless radio-link to a computer in a tow vessel is used for real time transceiver diagnostic and detection recording. A separate wireless system relays signals from the underwater video system to a monitor in the tow vessel. The multiplex transceiver makes it possible to operate up to six detection coils simultaneously (we use two to six coils in the two systems).

DATA ANALYSIS AND STATISTICS

PIT-tag interrogations of run-of-the-river yearling Chinook salmon and steelhead from various studies throughout the Columbia River Basin will constitute the primary sources of PIT-tagged fish. Secondary sources will include PIT-tagged fish previously detected at Bonneville Dam and PIT-tagged fish diverted at upstream collector dams to transportation barges and released downstream of Bonneville Dam. Also, we will compare the detection patterns of PIT-, radio- and acoustic- tagged fish released from transportation barges with those from radio- or acoustic-tagged run-of-the-river fish released at Bonneville Dam. If sufficient numbers of in-river migrating fish are detected, we will also evaluate detection rates associated with passage through multiple bypass systems.

Diel-catch patterns (number of fish detected per hour during daylight compared to dark hours) of yearling Chinook salmon and steelhead are evaluated using one-way ANOVA (Zar 1999). The number of detections and the minutes within each hour that the detector was energized each day are separated into daylight- and darkness-hour categories, and mean hourly detection rates for wild and hatchery rearing types of each species are used as the source for the ANOVA. Diel detection curves are generally prepared for yearling Chinook salmon and steelhead based on the average number of fish detected each hour weighted by the minutes within each hour that the detectors were energized. For the other species, the numbers detected are generally too few for meaningful analyses.

Multiple linear regression will be used to evaluate differences in travel speed to Jones Beach between in-river migrants and transported fish. Factors used in the regression models of travel speed included Julian date, flow, “treatment” (in-river migrant vs. transported), and two-way interaction terms for the three main effects. Flow data will be daily average discharge rates at Bonneville Dam ($ft^3 sec^{-1}$).

Binary logistical regression analyses will be used to compare daily detection rates among in-river migrants previously detected at Bonneville Dam to those released from transportation barges on the same dates as detection at Bonneville Dam. The daily groupings are treated as “cohorts” in the analysis (Hosmer and Lemeshow 2001). The daily in-river groups will be paired to barged-released fish on date of barge-release and selected to include only those PIT-tagged fish released at sites from McNary Dam upstream. Components of the logistic regression model are treatment as a factor and date as a covariate. The model estimates the log odds of the detection rate of the daily cohorts (i.e., ln[p/(1-p)]) as a linear function of the components, assuming a binomial distribution for the errors.

Detection data from the estuary are essential to estimate survival of juvenile salmonids to Bonneville Dam, the last dam encountered by seaward migrants (Muir et al. 2001, Williams et al. 2001, Zabel et al. 2001). The probability of survival through an individual reach of river is estimated from PIT-tag-detection data using a multiple-recapture model for single release groups (Cormack 1964, Seber 1965, Skalski et al. 1998). Seasonal average survival probabilities are estimated for yearling Chinook salmon and steelhead migrating in-river from the Snake and mid-Columbia Rivers (dependant on release numbers). Estimates are obtained using component reach survival probabilities for migration from Lower Granite Dam reservoir to McNary Dam and from McNary Dam to Bonneville Dam (Iwamoto et al. 1994, Williams et al. 2001). PIT-tag detection data from the estuary provided a minor contribution to estimates of survival probability from Lower Granite to McNary Dam. However, they were essential to estimates of survival to Bonneville Dam from any upstream release site.

EXPECTED RESULTS AND APPLICABILITY

It is important to assess fish migrational behavior and reach survival with the PIT-tag detector/trawl using a multi-year research approach to incorporate flow and the environmental variability into the analyses. The need for a multi-year repetition was demonstrated in 2001 and again in 2004, when, based upon preliminary analyses, low-flow conditions appeared to dramatically change migrational timing and survival for in-river and transport groups. Application of 134.2 kHz PIT-tag equipment has improved reliability and increased tag read ranges, particularly with the advent of ‘Super’ tags (ST) and ‘SST’ tags. Larger antennas have lessened impacts to fish. Migration timing data from PIT-, radio- and acoustic-tagged fish allow comparison of these methodologies. Information gained on timing of PIT-tagged fish from various locations within the watershed to the estuary and the variability in timing between different groups, will help managers define future release strategies. These analyses now include data on transported fish, an addition that is essential to access recovery efforts for depressed salmonid stocks in the Columbia River Basin.

Little is understood regarding the behavior, utilization, and distribution of Snake River subyearling fall Chinook salmon. These are ESA-listed fish generally presumed to migrate to sea during the summer. Recent evidence suggests that a large portion of the adults returning to Lower Granite Dam entered the ocean as yearlings. Further, scale sample analyses of adults returning from the

2002 tagging study indicated that some adults that had been transported to downstream from Bonneville Dam as subyearlings delayed, presumably in the lower river, and entered the ocean as yearlings the following spring (D. Marsh, NMFS, NWFSC, Seattle, WA, pers. commun., June 2006). Currently hydropower operations are being legally challenged, but in recent years have included the use of transportation without spill to maximize SARs. In 2005, a judicial decision mandated spill and fewer fish were transported. An evaluation using PIT-tagged fish comparing transport to bypass and spill options for Snake River subyearling Chinook salmon is under consideration, and some PIT-tagged fish were released in 2005, 2006, and 2007. The scope of study scheduled for 2007 was much reduced from originally planned and thus we cancelled scheduled fall 2007 sampling and shoreline sampling in 2008. Plans for tagging fish in 2008 are as yet uncertain but potentially may include as many as 800,000 PIT-tagged fish (S. Dunmire, COE, Walla Walla District, pers. commun., May 2007) which would be sufficient to re-institute fall and early spring sampling in the estuary in 2008-09. It is possible that a portion of these subyearling migrants over-wintered downstream of Bonneville Dam, perhaps even in the upper or lower estuary. Detections of PIT-tagged fish in the estuary during early spring, summer, and into the fall would help identify and correctly characterize their life history patterns.

COLLABORATIVE ARRANGEMENTS

Collaboration with Oregon State University, U.S. Fish and Wildlife Service, and other researchers involved with the radio- and acoustic-tracking studies in the Columbia River will continue. PIT-tag interrogation data from the Jones Beach sampling efforts (site code TWX) will be uploaded in batches to the PTAGIS database thus providing regional access to estuarine passage of PIT-tagged fish. PIT-tag detector/trawl interrogation data will be used by NOAA Fisheries and other researchers to assess differential predation on juvenile salmonids by Caspian terns and double-crested cormorants. .

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CONSENSUS RESEARCH PROPOSAL

Evaluating the Responses of Snake and Columbia River Basin fall Chinook Salmon to Dam Passage Strategies and Experiences

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Preface

This proposal was developed collaboratively and represents the consensus of the principal investigators and collaborating parties. These are Idaho Department of Fish and Game, Nez Perce Tribe, National Marine Fisheries, Oregon Department of Fish and Wildlife, and U.S. Fish and Wildlife Service. The Columbia River Inter-tribal Fish Commission, Umatilla Tribe, U. S. Army Corps of Engineers, and the Washington Department of Fish and Wildlife provided comments that were incorporated into the proposal. This proposal is built upon and consistent with the Long-Term Framework for Evaluating the Responses of Snake and Columbia River Fall Chinook Salmon to Dam Passage Strategies and Experiences (AHG 2007; Appendix A). In some cases, alternative funding currently exists to support portions of this proposed work. These cases are identified throughout this document and in Appendix B. We are seeking U.S. Army Corps of Engineers funding for work identified as needing additional funding support.

Executive Summary

Purpose: Snake River juvenile fall Chinook Salmon utilize the mainstem Snake and Columbia rivers for both migration and rearing. As such, hydrosystem operations and transportation strategies affect the behavior and survival of this ESA listed species. Numerous policy and management decisions take into consideration impacts to Snake River fall Chinook salmon. Various study design requirements and management decisions that could be made yielded disagreement between entities, even when working towards the common goal of establishing acceptable hydro-system operations and fish passage strategies that support both recovery and maintain harvest of Snake River fall Chinook salmon. A long-term goal of the region is to determine a hydrosystem operation and fish passage strategy for Snake River Fall Chinook that will meet the recovery needs of this ESU, through a regionally developed approach.

Agreed To Study Design: To facilitate agreement on a long-term study design for evaluating the responses of Snake River Basin fall Chinook salmon to dam passage strategies and experiences, an AD HOC group has drafted three documents. The first is an executive summary (this document). The second is an agreed to “living” proposal. The third is an appendix that functions as a long-term framework that effectively memorializes original expectations that will hold parties to this study accountable over the 10 plus years it will take to realize study results.

Study Products: An important part of any research plan is the development of the key management questions. In general, the overall broad scale management questions expected to be answered by this evaluation are:

- Would bypassing or transporting individuals collected in the bypass systems result in a higher SAR for the Snake River fall Chinook population?
- What is the relative performance of in-river fish (i.e. spilled and passed via surface bypass) versus transported fish?
- What are the corresponding smolt to adult return rates under various conditions, various FCRPS entry points, and various routes of passage?
- How do various juvenile migration life history approaches contribute to population level status and trends?

Study Groups and Sample Size: The diversity of life history strategies exhibited by naturally-produced fall Chinook salmon and differences between hatchery and natural production requires this study to utilize multiple treatment groups with various samples sizes (Table 1). Two general analytical approaches are proposed. The first approach involves comparing two groups of fish that are released upstream of Lower Granite Reservoir, but whose treatment at collector dams differs in an effort to represent two different management strategies:

- transportation with summer spill/surface bypass (TWS); and
- screen bypass with summer spill/surface bypass (BWS).

The second general analytical approach compares groups of juvenile migrants based on their passage experience at the dams. The three possible passage experiences for these fish are:

- transportation from a collector dam ("T_0" group);
- passage undetected through spillways and turbines but not through juvenile collection and bypass systems at all four collector dams ("C_0" group); and
- collection and bypass back to the river at one or more juvenile fish bypass systems at collector dams ("C_1" group).

Table 1. Proposed sample sizes of PIT-tagged fish for the study.

Study Groups	Definition	Sample Size
Snake Basin surrogate subyearlings	Surrogate subyearlings would be reared to 70–75 mm and released from mid-May to early July to approximate the behavior and life history diversity of natural subyearlings.	328,000 or 417,000
Snake Basin production subyearlings	Production subyearlings are typically grown rapidly to a target fork length of approximately 85–90 mm fork length and then released in April–May.	250,000
Snake Basin production yearlings	Production yearlings are reared at Lyons Ferry Hatchery for approximately one year after emergence to a target release size of approximately 150–160-mm fork length.	57,000
Snake Basin natural subyearlings	Includes Snake and Clearwater production areas: 40 to 80 mm, captured and released late March to early August.	20,000 target
Hanford Reach natural subyearlings	Hanford Reach natural subyearlings: 55-78 mm, captured and released during late May to early June.	20,000 target
Deschutes River natural subyearlings	Deschutes River natural subyearlings: 50-68 mm, captured and released in mid-May.	20,000 target
Little White Salmon production subyearlings	Little White Salmon production subyearlings: 81-85 mm, released during third week of June.	25,000
Lyons Ferry Hatchery on-station yearlings[1]	Production yearlings are reared at Lyons Ferry Hatchery for approximately one year after emergence to a target release size of approximately 150–160-mm fork length.	30,000
Lyons Ferry hatchery on-station subyearlings[1]	Production subyearlings are typically grown rapidly to a target fork length of approximately 85–90 mm fork length, released in April–May.	45,000

[1]Seperate proposal - Evaluation of yearling and subyearling fall Chinook survival from Lyons Ferry Hatchery to be funded by the Lower Snake River Compensation Program

Study Duration: Fish production and marking should be implemented for five years (release groups). Since low numbers of returning adults may, in some years, preclude the production of study fish, these years may not occur consecutively. After five years of marking, further discussion/justification for continuation could be considered at that time. There may be good reason(s) to continue producing/marking fish for study or monitoring purposes, however that decision should be considered near the end of the 5 years of marking.

Study Tasks/Activities:

- Production and PIT tagging of surrogate subyearling in the Snake and Clearwater rivers.
- PIT tagging of Snake River general production subyearlings.
- PIT tagging of Snake River general production yearlings.
- PIT tagging of Lyons Ferry on-station releases (subyearlings and yearlings (sister proposal).
- PIT tagging of Snake and Clearwater River natural production.
- PIT tagging of Hanford Reach natural production.
- PIT tagging of Deschutes natural production.
- PIT tagging of Little White Salmon production subyearlings.
- Subsampling of juveniles at Snake River dams for growth.
- Subsampling of returning adults for scale collection and assessment of juvenile life history.
- Genetic analysis of juveniles for partitioning spring/summer or fall Chinook salmon.
- Data analysis methods workshops.
- Data interpretation and reporting workshops.
- Estuary trawling for PIT tag detection.

Remaining Uncertainties: While this proposed study will provide key information for improving understanding of fall Chinook from the Columbia and Snake Rivers, it is unlikely to provide resolution to all unresolved issues or answers to all possible management questions. Several high priority issues and critical uncertainties would be difficult to address via this study, including:

- What specific operations provide optimal in-river and transport conditions for fish?
- What is the relative survival of fish that migrate undetected during periods of summer spill to transported and bypassed fish?
- By route of passage at dams (e.g., spillway, turbine, and bypass),, what is the direct juvenile survival of smolts through the FCRPS under various conditions?

Collaboration Approach: The study will be conducted in three phases. A joint effort of tribal, state, and federal staff worked as an ad hoc group during Phase I to identify the components of the Columbia River Basin fall Chinook salmon populations to be studied and the sample sizes of PIT-tagged fish required for adequate statistical power (attached proposal). Phase II includes a series of workshops that will be open to federal, state, and tribal researchers to explore and identify analytical techniques. Phase III ensures federal, state and tribal co-managers opportunities for involvement during data analysis and reporting. The U.S. Army Corps of Engineers will sponsor the workshops by providing a meeting place and a facilitator.

Introduction

Like other Columbia Basin salmonids, understanding the responses of fall Chinook salmon (*Oncorhynchus tshawytscha*) over their life-cycle to environmental and management conditions within and outside the Federal Columbia River Power System (FCRPS; Figure 1) requires a consistent and comprehensive monitoring and evaluation program (Muir et al. 2001; Smith et al. 2002; Smith et al. 2003; Williams et al. 2005; Muir et al. 2006; Schaller et al. 2007). Passive integrated transponder (PIT) technology within the FCRPS (Prentice et al. 1990a; 1990b) and techniques for analyzing PIT-tag data (Skalski et al. 1998; Sandford and Smith 2002; Williams et al. 2005; Schaller et al. 2007) provide an opportunity for developing a comprehensive understanding of fall Chinook salmon demographic rates and how those rates vary over their life-cycle in response to environmental and management conditions.

Key demographic rates that can be obtained using PIT-tag analytical techniques include; juvenile migration and survival rates within the FCRPS, ocean survival rates (i.e., post-FCRPS), adult upstream migration and survival rates, and overall smolt-to-adult survival rates (SARs), although estimation of juvenile salmonid survival through the hydropower system is complicated by the tendency of some fall Chinook salmon to migrate during times of the year when juvenile fish bypass and PIT tag detections systems are not watered up (Connor et al 2005; Buchanan and Connor 2007). Methods are available for partitioning these rates based on migration experience (e.g., transportation, bypass or undetected in-river migration routes), rearing type (e.g., hatchery or wild), and points above and within the FCRPS (e.g., from release points and from detection sites).

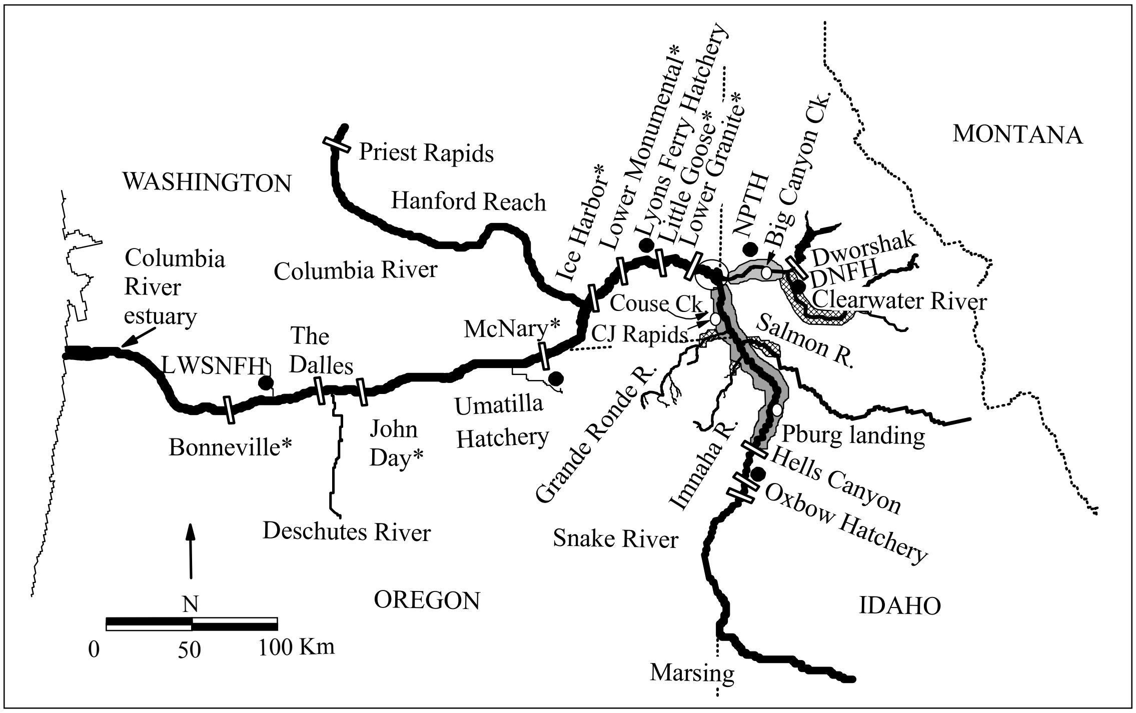

Figure 1.–The Federal Columbia River Power System (Dworshak Dam to Bonneville Dam) and the Snake and Columbia River basins including the contemporary primary (shaded areas) and secondary (cross-hatched areas) areas of fall Chinook salmon spawning in the Snake River Basin upstream of Lower Granite Reservoir (large white circle). Surrogate subyearlings reared at Dworshak National Fish Hatchery (DNFH; black circle) are directly released at Couse and Big Canyon creeks (arrows). Some of the hatchery fall Chinook salmon produced at Lyons Ferry Hatchery are transferred to Oxbow and Umatilla hatcheries (black circles) before release at the following locations. Production subyearlings and yearlings are acclimated and released at Pittsburg Landing, Captain John Rapids, and Big Canyon Creek (small white circles). Some production subyearlings are released directly into the Snake River without acclimation at Hells Canyon Dam and Couse Creek. Some production subyearlings are also released directly into the Grande Ronde River without acclimation. Lower Granite, Little Goose, Lower Monumental and McNary dams are collector dams, from which collected fish are transported for release downstream of Bonneville Dam. Dams equipped with PIT-tag detection systems are indicated by an asterisk. The Columbia River portion of this proposal focuses on fall Chinook salmon from the Hanford Reach, Deschutes River, and Little White Salmon National Fish Hatchery (LWSNFH).

For monitoring and evaluating Snake River Basin fall Chinook salmon, two analytical approaches are proposed. Each approach has its merits and limitations. The first approach was developed specifically for Snake River Basin fall Chinook salmon (Marsh and Connor 2004).

This approach involves comparing two groups of fish that are released upstream of Lower Granite Reservoir (Figure 1), but whose treatment at collector dams differs in an effort to represent two different management strategies; transportation with summer spill (TWS) and bypass with summer spill (BWS). Fish from the TWS group will be transported if they are detected at a collector project (Lower Granite, Little Goose, Lower Monumental and McNary dams; Figure 1) and fish from the BWS group will be bypassed if they are detected at a collector project. For both the TWS and BWS release groups, roughly half the fish in each group will not be detected at any of the four collector projects due to low collection efficiencies associated with summer spill and/or undetected passage during the winter or spring. Fish pass undetected because spillways and turbines are not equipped with PIT-tag detection systems and the juvenile fish bypass and PIT-tag detection systems are not watered up from late fall to early spring. This analytical approach is attractive because it requires few assumptions and the resulting SARs reflect two management strategies of interest. However, because both groups will have adults from undetected migrants returning, detecting a significant difference between the TWS and BWS groups will be more difficult.

The second analytical approach proposed for monitoring and evaluating Snake River Basin fall Chinook salmon was developed by Schaller et al. (2007) for spring/summer Chinook salmon and steelhead (*O. mykiss*). This approach also involves tagged fish released upstream of Lower Granite Reservoir, but compares groups of juvenile migrants based on their passage experience at the dams. The three possible passage experiences for these fish are: transportation from a collector dam ("T_0" group), passage undetected through spillways and turbines, but not through juvenile collection and bypass systems at all four collector dams ("C_0" group), and collection and bypass back to the river at one or more juvenile fish bypass systems at collector dams ("C_1" group). The analytical approach is attractive because it provides unbiased estimates of the number of first-year migrant smolts in the C_1, and T_0 study groups. The methods are also capable of estimating the number of first-year migrant smolts in the C_0 study group for populations of fall Chinook that exhibit low incidence of winter passage or overwintering behaviors above Lower Granite Dam. However, methods to estimate the number of smolts in the C_0 study group for populations of fall Chinook exhibit greater incidence of winter passage or overwintering are not presently applicable and are to be discussed and/or developed through upcoming technical workshops.

For both analytical approaches, a key demographic metric derived is the smolt-to-adult survival rate (SAR), measuring life-cycle survival from the smolt life stage to the adult life stage. Based on their group designation (for the first approach) or their migration experience at the four collector projects (for the second approach), returning adults are tabulated and divided by the corresponding number of smolts to determine the SAR. Comparing these SARs over time provides key information needed to improve understanding of the effects of environmental conditions and management strategies within and outside the FCRPS on life-cycle survival rates of salmonids (Williams et al. 2005; Muir et al. 2006; Schaller et al. 2007). However, it should be noted that estimates of SAR based on PIT tags may or may not be lower than SARs for the untagged population (Williams et al. 2005. Schaller et al. 2007).

Similar approaches can be used to monitor and evaluate the SARs of other Columbia River Basin fall Chinook populations. In addition to Snake River fall Chinook salmon, three other fall Chinook salmon stocks are proposed for monitoring and evaluation using PIT-tag analytical techniques including Hanford Reach wild, Deschutes River wild, and Little White Salmon National Fish Hatchery fall Chinook salmon (Figure 1). Each of these fall Chinook salmon populations experiences a different portion of the FCRPS and may respond differently to the environmental and management factors experienced within the FCRPS. Similarly, the responses of these populations may vary following their exit from the FCRPS. Comparing the SARs over time for other Columbia River Basin fall Chinook salmon groups may provide key information needed to improve understanding of the effects of environmental conditions and management strategies within and outside the FCRPS on life-cycle survival rates of Snake River Basin and Columbia River fall Chinook salmon.

In addition to SARs, PIT-tag data allow for the monitoring and evaluation of several other key demographic rates (Muir et al. 2001; Smith et al. 2002, 2003; Connor et al. 2003, 2004; Williams et al. 2005; Muir et al. 2006; Schaller et al. 2007). Within the FCRPS, these include fish travel time between release and all detection sites and survival rates between release and most detection sites, although estimation of juvenile survival is complicated by passage of reservoir-type fall Chinook salmon during late fall, winter, and spring. With a consistent tagging effort over time, functional relationships between these demographic rates and the environmental and management factors that are associated with the variability in those rates can be derived (Smith et al. 2002, 2003; Connor et al. 2004; Williams et al. 2005; Schaller et al. 2007). PIT-tag data also provide the unique opportunity to separate survival rates within the FCRPS from survival rates post-FCRPS. A key example of this type of analysis is evaluating the effects of arrival date at Bonneville Dam on ocean survival rates (Scheuerell and Zabel, *draft manuscript*). With tagged wild and hatchery groups released in the lower Columbia River, the amount of data available for this type of analysis is greatly expanded beyond the data available from tagging efforts in the Snake River Basin. Combining the data from the different release groups or rearing types may or may not be appropriate, but each tagging effort would substantially improve the understanding of the effects of Bonneville Dam arrival timing on ocean survival rates for each release group.

Ongoing efforts to evaluate the responses of Snake and Columbia River Basin fall Chinook salmon to passage strategies and experiences within the FCRPS have been hindered by several issues of disagreement (See Framework Document). One issue that has been partially resolved was the lack of spill at Lower Granite, Little Goose, and Lower Monumental Dams from June through August (hereafter, "summer spill"). In 2005, plaintiffs in the NWF vs. NMFS case regarding the remanded 2004 Biological Opinion requested summer spill to provide what they presumed would be better inriver migration conditions for migrating Snake River Basin fall Chinook salmon subyearlings. A preliminary injunction was granted and spill was provided from June 20th to August 31st, 2005. Summer spill was again provided in 2006 and 2007 with a slight reduction in volume. Volume and duration of summer spill in future years will vary in accordance with that prescribed in the new Biological Opinion and through policy level decisions and will not invalidate our consensus study design.

A second issue that has been partially resolved involves the seasonal dewatering of the PIT-tag detection systems stationed within the juvenile fish bypass systems at lower Snake River dams. Before 2006, the juvenile PIT-tag detection systems were dewatered at Lower Granite, Little Goose, and Lower Monumental dams prior to 2 November and they were not watered up until late March. The juvenile bypass systems of the Snake River dams are the only passage routes that can be monitored for the passage of PIT–tagged fish. Dewatering of the bypass system meant that passage that occurred during late fall and winter was not monitored. In 2006, the U.S. Army Corps of Engineers (COE) operated the juvenile fish bypass at Lower Granite Dam for an extended period compared to earlier years, continuing operation from 1 November to 16 December. Substantial numbers of PIT-tagged natural and hatchery fall Chinook salmon from the Clearwater River were detected between 1 November and 15 December. Modifications were made to the juvenile fish bypass system at Lower Granite Dam in 2006 that will facilitate late-fall and winter operation in the future. Furthermore, the COE is planning on structural modifications at Little Goose and Lower Monumental dams that will allow extended operation of the PIT-tag detection systems at these two dams by spring 2008.

The remainder of this proposal describes how federal, state, and tribal co-managers can help to facilitate evaluation of the response of Snake and Columbia River Basin fall Chinook salmon to management strategies (TWS and BWS), passage experience (T_0, C_0, C_1) at Snake River dams, and environmental conditions within and outside the FCRPS. The proposed study will not provide resolution to all unresolved issues or answers to all possible management questions (see Framework Document). If implemented, however, the study will help to inform federal, state, and tribal co-managers and facilitate long-needed analyses. The proposal is intended as a "living" document, to be modified with co-manager input and as new biological and technical information becomes available. It is structured in three phases.

Phase I offers resolution to the issue of identifying the components of the Snake and Columbia River Basin fall Chinook salmon population to be studied and the sample sizes of PIT-tagged fish required for adequate statistical power. Phase I also includes a series of supplemental evaluations. Phase II is intended to help resolve the issue of how best to analyze the data by establishing an agreed upon set of methods for data analysis. Phase II includes a series of workshops that will be open to federal, state, and tribal researchers to explore and identify analytical techniques. Phase III will help resolve the issue of collaboration by ensuring federal, state and tribal co-managers opportunities for involvement during data analysis and reporting. During Phase III, the principle investigators for each objective will preliminarily analyze the data based on input received during Phase II. Phase III will then proceed with a series of workshops open to federal, state, and tribal researchers to interactively analyze and interpret the data, as well as provide formal peer-review. This review will be used to refine the study results prior to preparation of a Final Report by the principal investigators for public release. The COE will sponsor the workshops by providing a meeting place, facilitator, and may support travel expenses for a select group of participants.

Phase I: A Plan for Tagging, Release, and Evaluations Needed for Phase II

Tagging Summary

We propose to tag fish representatively from major components of the Snake and Columbia Basin upriver bright fall Chinook salmon populations upstream of Bonneville Dam, with the exception of subyearlings released from the Nez Perce Tribal Hatchery (NPTH; Figure 1). We will tag natural subyearlings from the Snake River and Clearwater River drainages, Lyons Ferry Hatchery-origin subyearlings specially cultured and released as surrogates for natural subyearlings (hereafter, “surrogate subyearlings” or “surrogates”), Lyons Ferry Hatchery-origin subyearlings and yearlings (hereafter, “production subyearlings” and “production yearlings”), natural subyearlings from the Hanford Reach and Deschutes River, and hatchery subyearlings from Little White Salmon NFH (LWS) released from the locations described in Figure 1. The proposed sample sizes are shown in Table 1 with the methods used to derive them given under each objective.

Table 1. Proposed sample sizes of PIT-tagged fish for the study. The surrogate subyearling sample size will depend on fish availability.

Component	Sample Size
Snake Basin surrogate subyearlings	328,000 or 417,000
Snake Basin production subyearlings	250,000
Snake Basin production yearlings	57,000
Snake Basin natural subyearlings	20,000 target
Hanford Reach natural subyearlings	20,000 target
Deschutes River natural subyearlings	10,000 target
LWS[1] production subyearlings	25,000
LFH on-station yearlings[2]	30,000
LFH on-station subyearlings[2]	45,000

[1]Little White Salmon Hatchery
[2]Seperate proposal - Evaluation of yearling and subyearling fall Chinook survival from Lyons Ferry Hatchery to be funded by the Lower Snake River Compensation Program.

Objective 1.—Tagging and releasing Snake River Basin surrogate subyearlings (NMFS lead)

Sample Sizes for Surrogate Subyearlings

We are proposing to rear surrogate subyearlings to 70–75 mm and release them from mid-May to early July with the intent of approximating the average size and migration timing of PIT-tagged natural subyearlings including those that exhibit a reservoir-type juvenile life history. The variables we propose to analyze are given in Table 2.

Evaluation of the two management strategies will be based on the ratio of SARs for the TWS and BWS groups (hereafter "T/I ratio"). The SARs will be measured from the point of release as juveniles to return as adults to Lower Granite Dam. Assuming an SAR from release of 0.3% for the higher of the two groups, a two-sided test with significance level (α=0.1) and statistical power of 80% (β=0.2), an 18% difference in the SARs could be detected with a release of 328,000 fish. Under the same assumptions, a difference of 16% could be detected with a

Table 2. Variables that can be estimated by PIT tagging and releasing natural (target of 20,000) and surrogate subyearlings (*N* = 328,000 to 417,000) upstream of Lower Granite Reservoir. The Snake River Basin population of natural subyearlings includes natural fish from both the Snake River and Clearwater River drainages, whereas the Snake River Basin population of surrogate subyearlings includes releases made into the Snake and Clearwater rivers. An "X" indicates a high precision estimate. An "x" indicates lower precision estimate resulting from the division of the population into smaller subpopulations. An "A" indicates a high precision estimate that will require adjustments to the estimated number of smolts due to migration during winter or the following spring. An "a" indicates a lower precision estimate that will require adjustments to the estimated number of smolts due to migration during winter or the following spring. The adjustment method is presently unknown. Without adjustment estimates will be biased. A "0" indicates sample sizes of fish tagged with 12 mm tags are expected to be too small to make meaningful estimates. Application of the 8 mm tags might make it possible to calculate precise SARs (See Objective 6).

Variable evaluated	Snake River Basin population		Snake River subpopulation		Clearwater River subpopulation	
	Surrogates	Natural	Surrogates	Natural	Surrogates	Natural
SARs for passage strategies and passage-experience groups (can also be analyzed by dam)						
TWS[a]	X	0	x	0	x	0
BWS	X	0	x	0	x	0
Transported (T_0)	X	0	x	0	x	0
Undetected (C_0)	A	0	a	0	a	0
Bypassed (C_1)	X	0	x	0	x	0
Jun to Aug (T_0, C_1)	x	0	x	0	x	0
Sep to Dec (T_0, C_1)	x	0	0	0	x	0
Ratios of SARs						
T/I	X	0	x	0	x	0
T0/C0	A	0	a	0	a	0
T0/C1	X	0	x	0	x	0
C0/C1	A	0	a	0	a	0
Post-release attributes						
Passage timing	X	X	X	X	X	X
Travel time	X	X	X	X	X	X
Reservoir overwintering	X	X	X	X	X	X
Exposure to spill	X	X	X	X	X	X
Migrant size	X	X	X	X	X	X
Migration and survival[b]	X	X	X	X	X	X
Surivival	A	A	A	A	A	A

[a] Fish designated to the transport group will be bypassed back to the river if the decision is made to terminate transport operations (a.k.a., routing will be determined by monitor mode).
[b] Joint probability of active migration and survival.

release of 417,000 fish. Using the second proposed analytical approach and defining the T_0 and C_1 groups as the first-year migrants in those groups, assuming a SAR from Lower Granite Dam of 0.6% for the lower of the two groups, and a survival from release to Lower Granite Dam of 0.30, a 31% difference could be detected between the T_0 and C_1 groups with a release of 328,000 fish. Under the same assumptions, a 28% difference could be detected with a release of 417,000 fish.

For evaluation of the two management strategies groups, calculations were based on a two-sided test of the difference between two proportions (i.e., SARs). Sample sizes are based on the following formula:

$$n = (Z_{\alpha/2} + Z_{\beta})^2 (p_1 q_1 + p_2 q_2)/(p_2 - p_1)^2$$

where n is the size of each sample (i.e., the number of juvenile fish to release in each group), $Z_{\alpha/2}$ is the normal deviate corresponding to the significance level used in the test, Z_{β} is the normal deviate corresponding to the desired statistical power $(1-\beta)$ to detect the difference, p_1 is the proportion for group 1 ($q_1 = 1 - p_1$), and p_2 is the proportion for group 2 ($q_2 = 1 - p_2$).

Assuming that p_2 is the higher proportion and that it is equal to 0.0030 (0.3% SAR), an 18% difference would result in $p_1 = 0.00254$ (0.254% SAR). (If p_2=0.0030 were the SAR for the TWS, then T/I=1.18; if p_2=0.0030 were the SAR for the BWS, then T/I=0.85). Under these specifications, n = 163,097 ($2n$ = total juvenile release for two groups = 326,195). Figure 2 depicts alternative total release sizes and the associated detectable differences for the two-tailed test, given $\alpha = 0.10$, $\beta = 0.20$, and the higher of the two proportions is equal to 0.0030. Arrows denote the total release sizes of 250,000, 328,000 and 417,000, with the associated detectable differences plotted above the arrows.

We propose to represent natural fall Chinook salmon subyearlings by releasing surrogate subyearlings into both the Snake and Clearwater Rivers in proportion to redds counted in each respective drainage (Snake River drainage, 70% of all redds; Clearwater River drainage 30% of all redds; hereafter the "70:30 rule"). For example, 229,600 surrogate subyearlings will be tagged and released into the Snake River and 98,400 surrogate subyearlings will be tagged and released into the Clearwater River if 328,000 surrogate subyearlings are provided for the study.

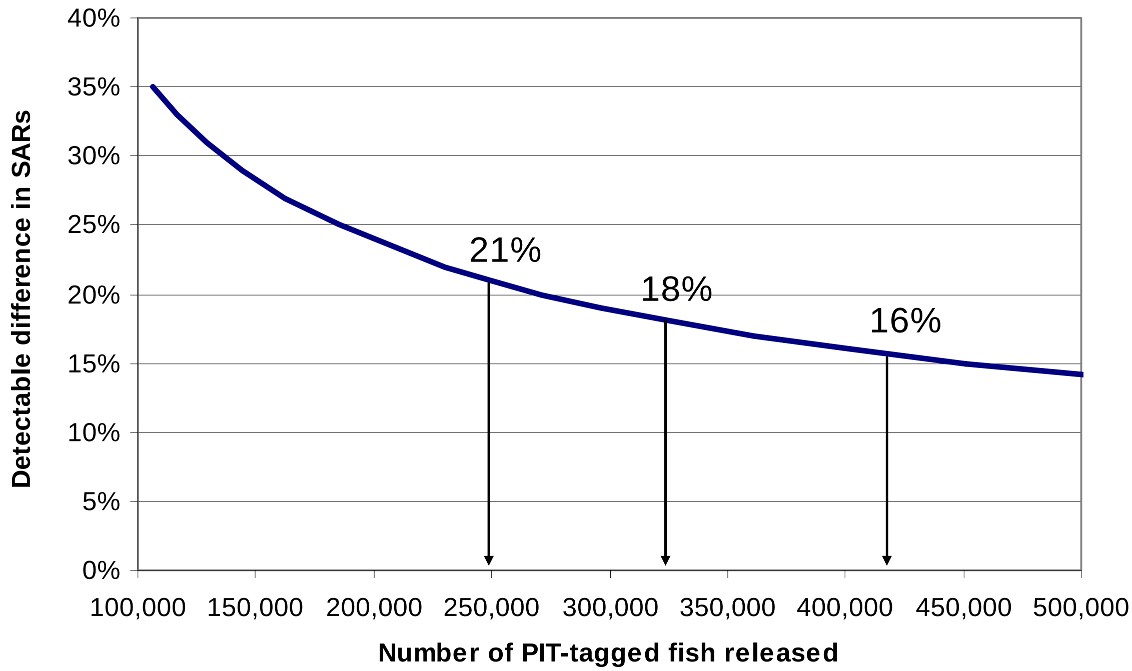

Figure 2.—The detectable difference in smolt-to-adult return rates (SARS) plotted against the number of PIT-tagged surrogate subyearlings released.

Task 1.1 Request fish through U.S. v. OR

The U.S. v. OR holds monthly meetings. During the October 2007 meeting, representatives of the principal researchers will formally request provision of 417,000 surrogate subyearlings. A sample size of 328,000 surrogate subyearlings is acceptable. Sample sizes less than 328,000 could also be used for the study, but will result in an increase in the detectable difference between SARs (Figure 2). Without revision of Table B.4 in the Snake River fall Chinook salmon production plan, surrogate production of 328,000 would be provided under priorities 12 and 14 and the remaining 89,000 would be made available only after all other approved production groups are met (assumes approval of study achieved). Modification of Table B.4 to increase the priority of surrogate subyearling releases would increase the likelihood of comparisons key to this proposal would be made with five consecutive release years.

Task 1.2 Surrogate subyearling transfer and rearing

During January–February, roughly 100,000 (for 328,000 sample size) eyed eggs or fry from Lyons Ferry Hatchery will be transferred to Umatilla Hatchery (Figure 1) for incubation in cold water to delay hatching. In April, after button-up, 60 randomly selected fry will be examined for *Renibacterium salmoninarum* antigen by ELISA. In addition, gill/kidney/spleen tissue will be examined for viruses associated with infectious pancreatic necrosis, infectious hematopoietic necrosis, and viral hemorrhagic septicemia. After disease testing is complete and state transportation permits are obtained, staff will transport the fry to Dworhsak National Fish Hatchery (Figure 1) where they will be reared to control growth to provide surrogate subyearlings for release into the Clearwater River.

In March, 60 randomly selected fish will be randomly tested from the roughly 230,000 subyearlings (for 328,000 sample size) set aside at Lyons Ferry Hatchery for surrogate subyearling releases into the Snake River. After disease testing is completed and state transportation permits are obtained, the fish will be transported to Dworshak National Fish Hatchery where growth will be controlled to provide surrogate fish of suitable size for release into the Snake River.

Task 1.3 Separation-by-Code designation, tagging, and release for surrogate subyearlings

Prior to release, we will randomly divide the tag codes into two equal sized groups to represent the TWS and BWS groups. We will coordinate with the Pacific States Marine Fisheries Commission to program the separation-by-code systems ("SbyC"; e.g., Marsh et al. 1999, Downing et al. 2001) at Lower Granite, Little Goose, Lower Monumental, and McNary Dams to route TWS designated codes to the raceways and BWS designated codes back to the river. In the case of the TWS group (and all other T groups in this proposal), SbyC will be run in monitor mode. Monitor mode insures representative SARs by routing TWS designated fish back to the river on the rare occasion when run-of-the-river fish entering the juvenile fish bypass system are not routed to the raceways. A total of 500–1,500 tag codes will also be pre-designated for SbyC diversion to net pens at Lower Granite Dam to provide sample fish for task 7.1 of objective 7. These fish will be excluded from further SAR analyses.

Tagging of the Snake River surrogate subyearlings will begin at Dworshak National Fish Hatchery in mid-May and will occur five days a week for three weeks. Tagging of the Clearwater River surrogate subyearlings will begin in mid-June and will occur five days a week for three weeks. These periods coincide with the historical period of peak beach seine catch of natural parr in the Snake and Clearwater rivers. The tagged fish will be transported, tempered, and released daily. Snake River and Clearwater surrogate subyearlings will be released at Couse Creek and Big Canyon Creeks, respectively (Figure 1).

Objective 2.—Tagging and releasing Snake River Basin production subyearlings (NPT lead).

Sample Sizes for Production Subyearlings

We are proposing to tag production subyearlings, which are typically grown to a target fork length of approximately 85–90 mm fork length and then released in April–May. Currently, 18,000 fish are PIT tagged under BPA funding, with the intent of characterizing the survival and life history diversity of production subyearlings. The production subyearling rearing strategy typically results in relatively high rates of seaward movement and survival, passage through the lower Snake River dams by late July, and very low incidence of migration during fall, winter, or the following spring (e.g., Rocklage 1999; Connor et al. 2004).

Valid SAR estimates from release to adult return at Lower Granite Dam can be calculated for the TWS and BWS groups of production subyearlings (Table 3). Using the first analytical approach and assuming an SAR from release of 0.3% for the higher of the two groups, an alpha of 0.1, and a beta of 0.2, a 21% difference in the SARs could be detected with a release of 250,000 fish. Using the second proposed analytical approach and defining the T_0 and C_1 groups as the first-year migrants in those groups, assuming an SAR from Lower Granite of 0.6% for the lower of the two groups, and a survival from release to Lower Granite of 0.41, a 31% difference could be detected between the T_0 and C_1 groups with a release of 250,000. Table 3 indicates the parameters that can be estimated if a full C_1 group of production subyearlings is tagged.

Table 3. Variables that can be estimated by PIT tagging and releasing production subyearlings (Age-0; *N* = 250,000 to 328,000) and production yearlings (Age-1; *N* = 56,000) upstream of Lower Granite Reservoir, provided that production subyearlings are larger than 85-mm fork length and released in May. The Snake River Basin population includes subyearlings and yearlings released into both Snake and Clearwater rivers. An "X" indicates a high precision estimate. An "x" indicates lower precision estimate resulting from the division of the population into smaller subpopulations. A "0" indicates sample sizes of PIT-tagged fish that are expected to be too small to make meaningful estimates.

	Snake River Basin population		Snake River subpopulation		Clearwater River subpopulation	
Variable	Age-1	Age-0	Age-1	Age-0	Age-1	Age-0
SARs for passage strategies and passage-experience groups (can also be analyzed by dam)						
TWS[a]	X	X	x	x	x	x
BWS	x	X	x	x	x	x
Transported (T_0)	X	X	x	x	x	x
Undetected (C_0)	X	X	x	x	x	x
Bypassed (C_1)	x	X	x	x	x	x
April and May (T_0,C_1)	x	x	x	x	x	x
June–July (T_0, C_1)	0	x	0	x	0	x
Ratios of SARs						
T/I	x	X	x	x	x	x
T_0/C_0	x	X	x	x	x	x
T_0/C_1	x	X	x	x	x	x
C_0/C_1	x	X	x	x	x	x
Post-release attributes						
Passage timing	X	X	X	X	X	X
Travel time	X	X	X	X	X	X
Reservoir overwintering	X	X	X	X	X	X
Exposure to spill	X	X	X	X	X	X
Migrant size	X	X	X	X	X	X
Survival	X	X	X	X	X	X

[a] Fish designated to the transport group will be bypassed back to the river if the decision is made to terminate transport operations (a.k.a., routing will be determined by monitor mode).

We propose to release tagged production subyearlings in proportion to the number of production subyearlings released at Pittsburg Landing, Captain John Rapids, and Big Canyon Creek acclimation facilities (Figure 1). For example, 41,666 (16.7% of the 250,000 tagging level) of the 500,000 Captain John Rapids subyearlings (U.S. v OR priority 7) (16.7% of the production total) will released at Captain John Rapids if full production of 3,200,000 subyearlings upstream of Lower Granite is achieved.

Task 2.1 Request fish through U.S. v. OR

Representatives of the principal investigators will request 250,000 production subyearlings for this proposed study at their October 2007 meeting.

Task 2.2 Separation-by-Code designation, tagging, and release for production subyearlings

For Snake Basin releases, the percentages of tagged fish placed in the T and I groups is 46% designated to the T group and 54% would be designated for I group. Based on recent detection efficiency estimates, these percentage designations are expected to result in even numbers of smolts in the C_1 and T_0 categories. Setting the SbyC system to monitor mode insures that the PIT-tagged fish follow the route of run-at-large fish; thus, very few of the detected PIT-tagged fish in the T group would be bypassed back to the river. A total of 500–1,500 tag codes will also be pre-designated for SbyC diversion to net pens at Lower Granite Dam to provide sample fish for task 2.1 of objective 2. These fish will be excluded from further SAR analyses.

The PIT-tagging will occur at primary rearing facilities (i.e., Lyons Ferry, Oxbow, Umatilla hatcheries) before transfer to acclimation facilities in May. In some years, fish may not reach a size sufficient to marking before transfer to acclimation facilities. If that occurs, tagging fish at the Pittsburg Landing and Big Canyon acclimation facilities will be considered; however, representative or full tagging may not be possible.

Objective 3.—Tagging and releasing Snake River Basin production yearlings (NPT lead)

Sample Sizes for Production Yearlings

Production yearlings are reared at Lyons Ferry Hatchery for approximately one year after emergence to a target release size of approximately 150–160-mm fork length. A total of about 450,000 production yearlings are transferred from Lyons Ferry Hatchery during March in equal lots of 150,000 to Pittsburg Landing, Captain John Rapids, and Big Canyon Creek acclimation facilities. The production yearlings are released in mid-to-late April. Production yearlings migrate seaward rapidly and survive passage in the lower Snake River hydrosystem at relatively high rates (Rocklage 1999). Production yearlings do not exhibit the reservoir-type life history.

In 2008, however, we only propose to collect pilot data and calculate a SAR under the TWS strategy (represents the unmarked subpopulation performance) to characterize the 450,000 production yearlings released from the three acclimation facilities. Funding for this pilot analysis limited the number of production yearlings tagged to 45,000 (15,000 from each acclimation facility). We estimated the expected precision of a SAR from a sample size of 45,000 by using the equation for the expected half-width of a 95% error bound (B^): 2(SQRT((*p*^*q*^/(*n* – 1))(*N* – *n*/*N*))) where; *p*^ was set at 0.6% (the mean release to Lower Granite Dam SAR observed for coded-wire tag groups of production yearlings in the late 1990s); *q*^ = 1-p = 99.4%; *N* = 450,000, and n was varied in increments of 1,000. We plotted the values of B^ against *n* to examine the effect of sample size on estimated precision. The expected 95% error bound for the release of 45,000 production yearlings was 0.07% (Figure 3).

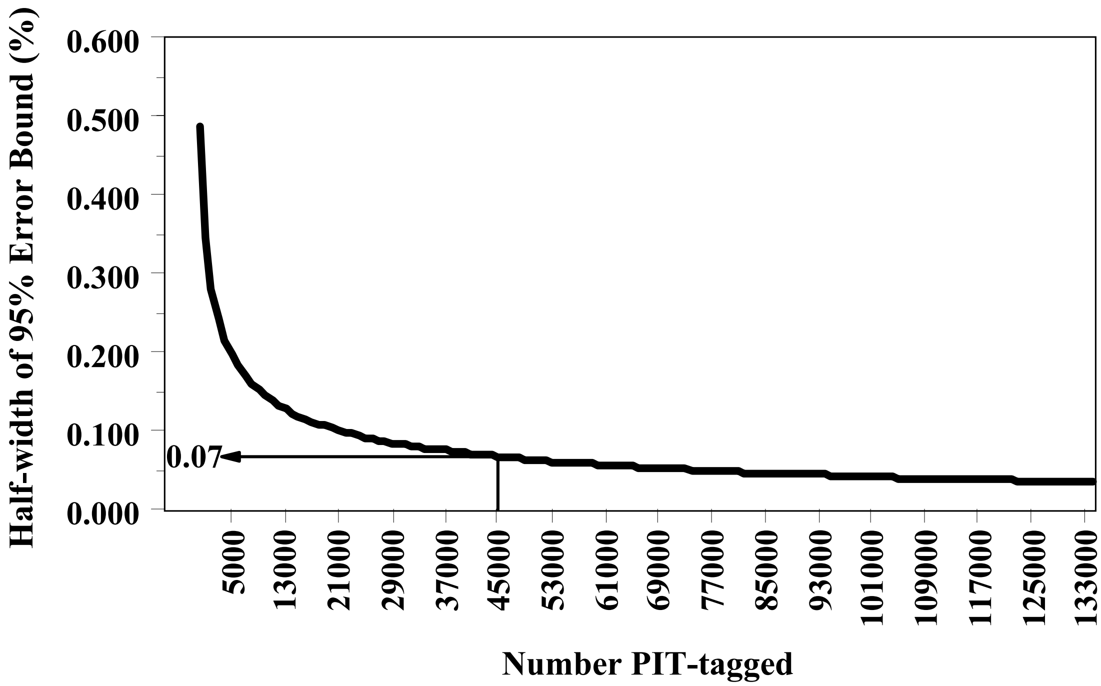

Figure 3. Expected half-width of a 95% error bound for a smolt-to-adult return rate of 0.6% plotted against sample size (*n*) of PIT-tagged production yearling fall Chinook salmon released from Pittsburg Landing, Captain John Rapids, and Big Canyon Creek acclimation facilities.

An additional 12,000 production yearlings will be released by NPT Fisheries as part of their long-term monitoring and evaluation program of post release juvenile survival and migration timing. These production yearlings will be designated for bypass bringing the total sample size of PIT-tagged yearlings up to 57,000. Thus, there is the potential for calculating a variety of SARs and comparing a variety of ratios (Table 3).

Task 3.1 Request fish through U.S. v. OR

The COE and representatives of the principal investigators will request 57,000 production yearlings for this proposed study at their October 2007 meeting.

Task 3.2 Separation-by-Code designation, tagging and release for production yearlings

All 45,000 of the production yearlings tagged as part of this study will be designated for monitor mode (i.e., transport, unless run-of-the river fish are being routed back to the river). The additional 12,000 fish tagged as part of long-term monitoring by NPT Fisheries will be designated for bypass. Tagging of the monitor mode fish will occur at Lyons Ferry Hatchery before transfer to the Pittsburg Landing, Captain John Rapids and Big Canyon Creek acclimation facilities in March.

Objective 4.—Tagging and releasing Snake River natural subyearlings (IFRO lead).

Sample sizes for Snake River natural subyearlings

Logistic and feasibility constraints limit the number of Snake River natural subyearlings that can be tagged, and thus target sample sizes reflect the expected number of fish that could be sampled and the resulting precision on the release to adult return SARs (Figure 4).

Task 4.1 Separation-by-Code designation, tagging and release for natural subyearlings

IFRO is presently funded by the Bonneville Power Administration to capture natural fall Chinook salmon subyearlings at sites in the free-flowing Snake River. Sampling will begin at the onset of fry emergence in late March and be conducted 3 d/week. A total of 15 permanent stations between rkm 227 and rkm 366 (rkm 0 = Snake River mouth) will be sampled every week of the study. During the release of Snake River surrogate subyearlings, supplemental sampling will increase the number of natural subyearlings that are PIT tagged. Sampling will be discontinued after the first week in July, when catch approaches or equals zero.

Origin (hatchery vs. natural) of fish with no mark (i.e., adipose fin not clipped) and no tag (i.e., no coded-wire or PIT tag) will be determined primarily from pupil diameter and body shape. Natural fish have smaller pupils and more robust body shapes than their hatchery counterparts (85–100% accurate; IFRO unpublished data). Each natural subyearling fall Chinook salmon captured will be anesthetized in a 3 ml MS-222 stock solution (100 g/L) per 19 L of water buffered with a sodium bicarbonate solution, measured (fork length in mm). Random tissue samples will be collected for future genetic analyses (e.g., to determine run). Natural subyearlings 60-mm fork length and longer will be implanted with a 12-mm PIT tag. A sample (approximately 10,000) of the natural subyearlings between 45 and 59-mm fork length will be implanted with 8-mm PIT-tags. Tagged fish will be released at the collection site after a 15-min recovery period.

Prior to release, we will randomly divide the tag codes into two equal sized groups to represent the TWS and BWS groups. We will coordinate with the Pacific States Marine Fisheries Commission to program the separation-by-code systems at Lower Granite, Little Goose, Lower Monumental, and McNary Dams to route TWS designated codes to the raceways and BWS designated codes back to the river. In the case of the TWS group (and all other T groups in this proposal), SbyC will be run in monitor mode. Monitor mode insures representative SARs by routing TWS designated fish back to the river on the rare occasion when run-of-the-river fish entering the juvenile fish bypass system are not routed to the raceways. A total of 500–1,500 tag codes will also be pre-designated for SbyC diversion to net pens at Lower Granite Dam to provide sample fish for task 7.1 of objective 7. These fish will be excluded from further SAR analyses.

Objective 5.—Tagging and releasing Clearwater River natural subyearlings (NPT lead).

Sample sizes for Clearwater River natural subyearlings

Logistic and feasibility constraints limit the number of Clearwater River natural subyearlings that can be tagged, and thus target sample sizes reflect the expected number of fish that could be sampled and the resulting precision on the release to adult return SARs (Figure 4).

Task 5.1 Separation-by-Code designation, tagging and release for natural subyearlings

NPT Fisheries is presently funded by Bonneville Power Administration to sample natural fall Chinook salmon subyearlings in the Clearwater River. Supplemental funding would be used to increase sampling effort throughout the season. NPT Fisheries will use beach seines, fyke nets, and rotary screw traps to capture natural fall Chinook salmon subyearlings in the lower Clearwater River. Seining will be conducted during May–August along the lower Clearwater River from rkm 7 to rkm 65 (rkm 0 = Clearwater River mouth). Permanent sites will be seined 5 days a week when flow allows. Supplemental sites will be seined when time and flow allow. Two sizes of beach seines fitted with 0.48 cm diameter mesh will be used (30.5 m x 1.8 m and 15.2 m x 1.2 m). Both will be fitted with weighted multi-stranded mud lines. The larger seine will be set from a jet boat. The smaller seine will be set by hand at less accessible and smaller beach seining sites. Four fyke nets and two 2.4 m diameter rotary screw smolt traps will be deployed and operated 5 days a week during beach seining. Beach seining and screw trapping will be discontinued the first week in August, when catch approaches or equals zero. Sampling will continue in August with a tow net and continue into October.

Origin will be determined as described for the Snake River. All salmonids captured by all methods will be placed in 18.9 L buckets and then placed in larger aerated 114 L plastic holding bins. Salmonids will be anesthetized in a 3 ml MS-222 stock solution (100 g/L) per 19 L of water buffered with a sodium bicarbonate solution. All natural fall Chinook will be measured to the nearest 1.0 mm fork length and weighed to the nearest 0.1 gm. A random subsample of natural fish (non-lethal upper caudal fin clip) will be collected for future genetic analyses. Natural subyearlings 60-mm fork length and longer will be implanted with a 12-mm PIT tag. A subsample (approximately 10,000) of natural subyearlings between 45 and 59-mm fork length will be implanted with 8-mm PIT-tags. Tagged fish will be released at the collection site after a 15-min recovery period.

Prior to release, we will randomly divide the tag codes into two equal sized groups to represent the TWS and BWS groups. We will coordinate with the Pacific States Marine Fisheries Commission to program the separation-by-code systems at Lower Granite, Little Goose, Lower Monumental, and McNary Dams to route TWS designated codes to the raceways and BWS designated codes back to the river. In the case of the TWS group (and all other T groups in this proposal), SbyC will be run in monitor mode. Monitor mode insures representative SARs by routing TWS designated fish back to the river on the rare occasion when run-of-the-river fish entering the juvenile fish bypass system are not routed to the raceways. A total of 500–1,500 tag codes will also be pre-designated for SbyC diversion to net pens at Lower Granite Dam to provide sample fish for task 7.1 of objective 7.

Objective 6.—Tagging and releasing Columbia River Basin subyearlings (CRFPO lead).

Sample sizes for other Columbia Basin subyearling groups

We are proposing to tag natural subyearlings from the Hanford Reach and the Deschutes River, and hatchery subyearlings from Little White Salmon NFH. Each of these groups is classified as upriver bright fall Chinook salmon. Logistic and feasibility constraints limit the number of subyearlings that can be tagged in each of these groups, and thus target sample sizes reflect the expected number of fish that could be sampled and the resulting precision on the release to adult return SARs.

Because of the limitation on the number of fish that can be tagged, most analyses for these groups will focus on demographic rates that can be monitored within the FCRPS. These include passage timing, travel time, the proportion overwintering, exposure to spill, migrant size, detection probabilities, and the probability of migrating and surviving. In addition to these metrics, the proposed sample sizes will be capable of providing estimates of the SAR from release to adult return (Figure 4). Assuming an SAR of 0.6% for Snake Basin releases (the average SAR for PIT-tagged natural subyearlings from the Snake River, brood years 1992–2001) a target release of 20,000 fish would result in an SAR with a coefficient of variation of 9%. Assuming a SAR of 0.7% for Hanford Reach natural releases (Jeffry Fryer, *personal communication*); a target release of 20,000 would result in a coefficient of variation of 8%. Assuming a SAR of 0.8% for Deschutes River natural releases, a target release of 10,000 would result in a coefficient of variation of 11%. Finally, assuming a SAR of 0.5% for Little White Salmon NFH (Tim Roth, *personal communication*), a release of 25,000 would result in a coefficient of variation of 9%.

In addition to the within-FCRPS metrics and SARs, these releases will increase the number of natural and hatchery upriver bright fall Chinook salmon detected at Bonneville Dam for evaluating the effects of Bonneville arrival timing on ocean survival rates (Scheuerell and Zabel, *draft manuscript*). A target release of 20,000 Snake Basin fall Chinook salmon would provide approximately 180 detections at Bonneville (based on a 0.9% average proportion of detections, 2003–2007). A target release of 20,000 Hanford.

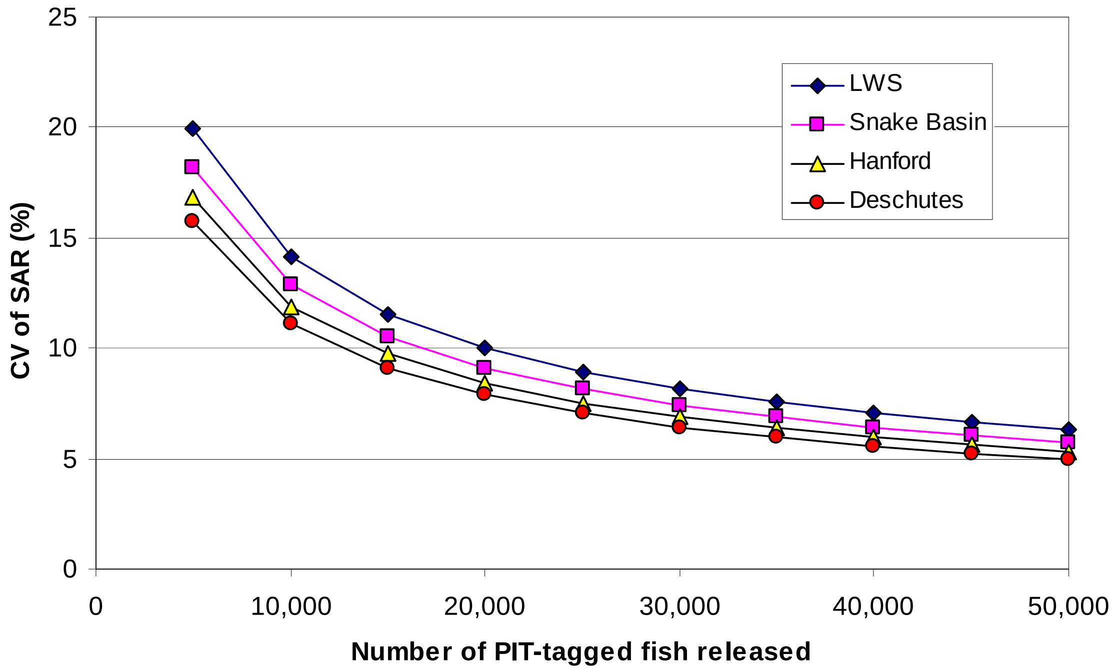

Figure 4. Coefficient of variation in SAR from release to adult return for natural (Snake Basin, Hanford, and Deschutes) and hatchery (Little White Salmon [LWS]) releases for various numbers of PIT-tagged fish released (assumed SARs are: LGR=0.6%, MCN=0.7%, Deschutes River=0.8%, and LWS NFH=0.5%).

Reach natural fall Chinook salmon would provide approximately 400 detections at Bonneville (based on a 2% average proportion of detections, 2003–2007). A target release of 10,000 Deschutes River natural fall Chinook salmon and 25,000 LWS NFH fall Chinook salmon would provide approximately 1,000 and 2,500 detections at Bonneville (based on a 10% average proportion of detections from JDA and TDA tailrace releases of hatchery fall Chinook salmon, 2006-2007). In total with these releases, approximately 1,600 natural fall Chinook salmon detections at Bonneville would be available for examining the effects of Bonneville arrival timing on ocean survival rates. Because fish from some of these rearing areas have known different ocean distributions, it remains to be determined whether all or some of the natural groups could be combined for these analyses, or whether ocean survival rates are different enough that combining groups may not be appropriate.

Task 6.1 Tagging and release of Columbia River Basin natural subyearlings

Dr. Jeffrey Fryer (CRITFC) has one year of funding from the State of Alaska to PIT-tag 20,000 natural Hanford Reach fall Chinook in 2008. The onset of the tagging activities is dependent on fish maturation rates. The PIT-tagging effort will begin when the percentage of fish greater than 48 mm in length has risen to 70–80% and the mean size has increased to about 53 mm. Tagging will end prior to the release of juvenile fall Chinook salmon from Priest Rapids Hatchery to ensure that hatchery fish are not tagged. Typically, tagging will begin on or near June 2 and will take place over four days.

Pre-smolt salmon will be collected by three crews of 3 to 4 persons working out of two 5.8 m to 6.4 m jet sleds. Fish will be collected primarily between the Hanford town site boat ramp and upstream of the White Bluffs town site boat ramp. Fish will be captured with stick seines 11.0 m to 18.3 m long and 1.8 m deep with a mesh size of 4.8 mm. The captured juvenile Chinook salmon will be temporarily placed into 19 liter plastic buckets and then transferred to the holding tanks equipped with oxygen aeration systems in each boat. When crews have a full load of fish they are transported to the tagging area and transferred into three 0.9 m x 0.9 m x 4.9m fiberglass tanks with a pump providing a continuous water flow. The tagging area will be located at the Hanford townsite boat ramp which has been used for this project since 1999.

Fish are graded by the tagging crew. The 60–80 mm and >80 mm groups will be placed in a holding tank for tagging with the 8 or 12.5mm tag, while the 48-59mm fish will be placed in a second additional holding tank for tagging with the 8 mm tag. PIT Tags will be inserted using standard techniques. Fish will be tagged in a trailer equipped with a recirculating anesthetic system and flow-through fish holding tanks. One person will tag the fish while another enters data and three to four others disinfect, load tag injectors, and support the operation. Subsequent to tagging, fish will be held for a minimum of 2 hours prior to release back into the river. We will hold groups up to 100 fish with the standard 12.5 mm tag. We will hold fish with the new 8.5 mm tag for longer periods to assure there is minimal to no impact of the tag on fish behavior or survival.

Task 6.2 Tagging and release of Columbia River Basin hatchery subyearlings

The Warm Springs Tribe has ongoing funding to sample natural fall Chinook salmon for coded-wire tagging. Up to 10,000 of these fish could be PIT-tagged each year from 2008–2012 with sufficient funding. Similar protocols to those used in the Hanford Reach and Snake River Basin would be used for handling, tagging, and releasing fish.

For Little White Salmon NFH releases, PIT-tagging will be conducted by CRFPO crews at the hatchery after fish are greater than 60 mm. CRFPO presently has funding to PIT-tag 15,000 fish per year, beginning in 2008. Additional funding would be required for supplementing these efforts with an additional 10,000 tags/year for three years (and 25,000 tags/year during 2011-2012). As transportation does not occur below McNary Dam, no tag designation will be required for LWS NFH releases.

Objective 7.— Comparisons among PIT-tag release groups and migration experiences

Task 7.1 Evaluation of surrogate performance (IFRO lead)

We will conduct comparisons and present results on the three PIT-tag groups of Snake Basin subyearlings four different ways. First, we will summarize tagging and release results. Second, we will pool the data collected from Snake and Clearwater River natural subyearlings to depict passage timing at Lower Granite, Little Goose, and Lower Monumental Dams to represent the natural population. We will do the same for the Snake and Clearwater River surrogate subyearlings and production subyearlings. We will not make statistical comparisons at the population level. We will weight the population-level analyses according to 70:30 rule in the instance of the surrogate releases when 70% of all natural fish tagged are not tagged in the Snake River and 30% of all the natural fish tagged are not tagged in the Clearwater River (or when the production subyearlings are not tagged in proportion to the actual numbers of untagged subyearlings released upstream of Lower Granite Reservoir). The third way we will analyze data and present results will be with statistical comparisons of the post-release attributes among the three PIT-tag groups (surrogate, production, natural) released into the Snake River. Fourth, we will make statistical comparisons among the three PIT-tag groups of subyearlings released into the Clearwater River. All statistical tests of differences among and between groups will use a significance level $\alpha = 0.05$. Tests will be done separately by dam except in the cases of travel time and the joint probability of active migration and survival. These two variables will be estimated and compared among the three PIT-tag groups of Snake River subyearlings at Lower Monumental Dam and the three PIT-tagged groups of Clearwater River subyearlings at Lower Granite Dam.

Analysis on passage timing at dams, level of exposure to spill, and travel time to Lower Monumental Dam will depend on estimated daily passage distributions at the dams. We will estimate the number of subyearlings from each of the three PIT-tag groups that passed a dam on a particular day as the counted number of PIT-tag detections for the group (or the expanded number in the instance of the Clearwater River fish during population-level analyses) divided by the estimated proportion of fish from the group that was detected as they passed that day. We will estimate the daily detection proportion at each dam using the methods of Sandford and Smith (2002). We will treat the estimated daily passage distributions as observations in statistical tests.

We will use a three-sample Kolmogorov-Smirnov test (hereafter "K-S" test) (Kiefer 1959) to test for differences among the 2008 cumulative passage distributions of the three PIT-tag groups. We will use two-sample K-S tests to evaluate pair-wise differences in the cumulative passage distributions between each pair of groups. We will report "Dmax" test statistics from the K-S tests in percentage points calculated as the maximum daily difference between the cumulative passage distributions of natural and surrogate subyearlings and natural and production subyearlings.

We will estimate the monthly percentage of each PIT-tag group of subyearlings that passed each dam by dividing estimated monthly passage by estimated total passage in 2008 and multiplying by 100. We will use a chi-square test to determine if there was a difference in monthly passage among the three PIT-tag groups of subyearlings. We will identify the peak month of passage for PIT-tagged natural subyearlings and use simple chi-square tests to compare daily passage during this month between natural and surrogate subyearlings and natural and production subyearlings.

For each of the three PIT-tag groups of subyearlings released in 2008, we will also calculate the percentage of the total detections (i.e., 2008 and 2009 combined) that were made in 2009 (i.e., fish that overwintered in a reservoir and completed migration in 2009). This percentage will provide an index of the relative proportion of reservoir-type juveniles in each group's migration histories, noting that PIT-tag detection systems will be dewatered at the dams during winter and passage that occurs during this period will be unmonitored. We will use a chi-square test to determine if there was a difference in the percentage of each group that passed in 2009 and then use simple chi-square tests to make pair-wise comparisons between all pairs of groups.

We will use the estimated 2008 passage distributions to estimate the percentage of each PIT-tag group of subyearlings that was exposed to summer spill. For statistical tests, we will transform these percentages to meet normality assumptions. We will use a two-way analysis of variance (factors: release group and dam) to test for differences in the level of exposure to spill. We will use Fisher's protected least significant difference (LSD) test to evaluate pair-wise differences in the level of exposure to spill between all pairs of groups.

For each PIT-tagged fish detected at Lower Monumental Dam (or Lower Granite Dam in the case of Clearwater River fish), we will calculate travel time as the number of days that elapsed between release and detection. Then, for each detection date, we will calculate the mean travel time of all fish that were detected that day from each of the three PIT-tagged groups of subyearlings. Finally, the average travel time for all fish from a group will be estimated as the weighted mean of estimates for each detection date, with the number of fish estimated to have passed Lower Monumental Dam on that date as the weight. We will use a one-way analysis of variance to test for differences in weighted mean travel time to Lower Monumental Dam among the three PIT-tag groups of subyearlings. We will use Fisher's protected LSD test to evaluate pair-wise differences in weighted mean travel time between two groups.

We will recapture subsamples of fish from each of the three PIT-tag groups of subyearlings at Lower Granite Dam, Bonneville Dam, and by hook-and-line sampling in Lower Granite Reservoir to characterize size during seaward migration as mean fork length (mm), mean weight (g), and mean condition factor K (weight divided by the cube of fork length multiplied by 100). Statistical analyses will depend on sample size.

Because of the reservoir-type juvenile life history, the detection data will not always conform to the classic single-release-recapture model described by Cormack (1964) and Skalski et al. (1998). Lowther and Skalski (1998) attempted to develop a model to deal with data of this nature. However, de-watering of the PIT-tag detection systems at the dams during late winter, and consequent unmonitored passage, will violate a critical assumption of both the single-release-recapture model and the model of Lowther and Skalski (1998).

One option for dealing with this situation is to use only detections during the year of release. This results in data more likely to fit assumptions of the single-release-recapture model, but requires re-interpretation of the model parameters. By ignoring detections of reservoir-type juveniles the year following release, there is no distinction in the resulting truncated data between cessation of active migration during the year of release and mortality. Consequently, the parameter that is usually interpreted as the probability of survival must instead be interpreted as the joint probability of actively migrating and surviving.

Natural fall Chinook salmon from the Snake River upstream of the Salmon River confluence rarely exhibit the reservoir-type juvenile life history (2% and less; Connor et al. 2002). Thus, we can assume that few of these fish pass dams unmonitored from late fall to winter when the PIT-tag detection systems are dewatered. Ignoring detections of reservoir-type juveniles the following year, after the PIT-tag detection systems are watered up, a typical single-release-model "survival" estimate to the tailrace of Lower Granite Dam for upper Snake River reach fish from the single release-recapture model might be 69%. In reality, this estimate is the product of the probability of migrating as a subyearling smolt and passing the Lower Granite Dam when the PIT-tag detection system is watered up (e.g., 98%) and the probability of surviving to the tailrace of Lower Granite Dam as a subyearling (e.g., 70%). That is, 69% = 98% x 70%. In this example, the estimate of the joint probability is only one percentage point lower than the actual survival probability. Therefore, the joint estimate is a relatively unbiased estimate of actual survival probability alone.

Natural fall Chinook salmon produced in the Clearwater River exhibit the reservoir-type juvenile life history more frequently (e.g., 6–85%; Connor et al. 2002) than natural fall Chinook salmon from the Snake River upstream of the Salmon River confluence. The prevalence of late fall passage, as well as empirical observations (Tiffan and Connor 2005; B. Arnsberg, NPT Fisheries, unpublished data), suggest that reservoir-type juveniles commonly pass dams unmonitored during the winter when the PIT-tag detection systems are dewatered. Ignoring detections of reservoir-type juveniles that occur in the spring following release, a typical single-release-model “survival” estimate to the tailrace of Lower Granite Dam for Clearwater fish might be 16%. Again, this quantity actually estimates the product of the probability of migrating as a subyearling smolt when the PIT-tag detection system at Lower Granite Dam is watered up (e.g., 40%) and the probability of surviving to the tailrace of Lower Granite Dam as a subyearling (e.g., 40%). That is, 16% = 40% x 40%. The joint probability estimate in this example is 24 percentage points lower than the actual survival probability.

In the first step of analysis of the data from this study, we will divide the natural subyearlings from each river into two intra-annual groups referred to as “cohorts” (Connor et al. 2003). For Snake and Clearwater River surrogate subyearlings, we will divide the data into intra-annual release groups based on week of tagging and release (n = 3 in the Snake River; n = 3 in the Clearwater River). The production subyearlings and yearlings will be kept in their original release groups by location. We will calculate SEs as described by Zar (1984) with the exception of the Clearwater River production subyearlings and yearlings in which case we will use the methods described by Cormack (1964) and Skalski et al. (1998).

To test for differences among the estimates of the joint probability of migration and survival for the PIT-tagged groups, we will square-root transform the joint probability estimates, and then used one-way analysis of variance, with group as the factor. We will use Fisher's protected LSD test to evaluate differences in the estimates between two groups.

The final step in the analyses will be to compile river-specific summaries. We will calculate a standardized index of attribute similarity between natural and surrogate subyearlings and between natural and production subyearlings. We will also tabulate the outcome of the hypothesis tests (i.e., yes, rejected Ho; no, failed to reject Ho) made during the analyses.

To calculate each index of attribute similarity, the higher value of the attribute will always be divided by the lower value of the attribute as shown in the following examples for travel time to Lower Monumental Dam. If travel time was 41 days for natural subyearlings and 45 days for surrogate subyearlings, the index for travel time of surrogate subyearlings would be

1.1 (45/41). If travel time was 41 days for natural subyearlings and 20 days for production subyearlings, the index for production subyearlings would be 2.0 (41/20). From this example, we would conclude there was a 1.1-fold difference between the mean travel times of natural and surrogate subyearlings and there was 2-fold difference between the mean travel times of natural and production subyearlings.

To calculate the indices for cumulative passage, we will use the cumulative percent passage values observed at Dmax. For peak monthly passage, we will use the percentages of the groups that passed during the peak month of passage observed for natural subyearlings. For passage in 2009, we will use the percentages of total detections (i.e., 2008 and 2009 combined) that occurred in 2009. For exposure to spill, we will calculate the indices from the estimated percentage that passed during the spill period in 2008. An example for travel time to Lower Monumental Dam was given previously. We will calculate the indices for size during seaward movement and the joint probability of active migration and survival to the tailrace of Lower Monumental Dam using means.

<u>Task 7.2 Evaluation of migration of Snake River subyearlings through the FCRPS (IFRO lead)</u>

In addition to the comparisons described under Task 7.1, IFRO will compile the existing journal articles on the effect of fork length, release date, release location, and environmental conditions following release on the variables compared among Snake River subyearlings. Additional analyses of the factors affecting some of these variables are presently funded by the Bonneville Power Administration (Project 199102900).

Task 7.3 Evaluation of migration of Columbia River subyearlings through the FCRPS (CRFPO lead)

Principle investigators will conduct preliminary comparisons and present results on the each of the PIT-tag groups of Columbia River subyearlings in three general steps. First, we will summarize tagging and release results. Second, we will summarize passage timing, fish travel time, proportion overwintering, spill exposure, detection probabilities, and migration and survival rates within the FCRPS. Third, we will make preliminary comparisons between the release groups documenting the similarities and differences in the demographic rates based on length, release date, release location, and environmental conditions following release.

Task 7.4 Scale pattern analyses for understanding life-history diversity (NOAA lead)

We PIT-tagged subyearling fall Chinook salmon from 2001–2006 as part of transportation evaluations as a baseline against which to compare SARs during years with and without summer spill (Marsh et al. 2003, 2004a, 2004b, 2005). Returning adults from these studies will be collected at Lower Granite Dam's adult fish trap using SbyC (Marsh et al. 2007). The numbers of adult fish collected will vary each year depending on the numbers of fish tagged as juveniles that form the various age-classes of returning adults, and the overall return rate for each age-class of outmigrants. Depending on SARs, the number of adults sampled could range from 100 to over 1,000. During fall 2006, we sampled approximately 140 adults.

Before the return of adult fall Chinook salmon in 2008, we will add the PIT-tag codes of all fish we PIT tagged as juveniles to the SbyC database. We will then collect each fish that is detected passing through the adult facility at Lower Granite Dam. Scales will be taken and associated with the PIT-tag code of the fish. Fork lengths will also be recorded. The scale envelope will be marked with a sequential sample number. The sample number and the PIT-tag code will then be recorded onto a log sheet. The scales will be analyzed to determine origin (natural or hatchery) and whether the first annulus was formed in seawater (seawater annulus) or in freshwater (freshwater annulus; see Connor et al. 2005). A seawater annulus indicates first-year wintering in seawater and age-0 ocean entry, whereas a freshwater annulus indicates first-year wintering in freshwater or the estuary and age-1 ocean entry (i.e., reservoir-type life-history). We will determine year of ocean entry from age at ocean entry. For example, if a juvenile was released in 1998 and entered seawater as a subyearling, then year of ocean entry was 1998. Scale pattern analysis prior to 2005 preceded the compilation of juvenile PIT-tag histories and was conducted without the knowledge of gender or fork length to ensure blind analysis of scale patterns.

The adults that will be sampled for scales passed Bonneville Dam that had the T_0, C_0, or C_1 passage experiences as juveniles. We will divide the T_0 group into summer (21 Jun–31 Aug) and fall (1 Sep–13 Dec) subgroups based on PIT-tag detection history. Membership in the C_0 and C_1 groups will also be determined based on PIT-tag detection history. The C_1 group will be divided into summer and fall groups as described for the T_0 group. The C_0 group cannot be divided because time of passage for these fish is unknown.

We will be able to conclusively identify first year wintering locale of some of the returning fall Chinook salmon recaptured at the trap based on the results of scale-pattern analysis and PIT-tag detection histories. The scale will have a saltwater annulus if the returning fall Chinook salmon had spent its first winter in saltwater. The scale will have a fresh-water annulus, and potentially a PIT-tag detection history indicating tagging in year *t* and detection at a dam in year *t*+1, when the returning fall Chinook salmon had spent its first winter as a juvenile in reservoir. A returning fall Chinook salmon that had spent its first winter as a juvenile in freshwater downstream of Bonneville Dam will also have scales with freshwater annuli, but conclusive identification of this first-year wintering history will require either a detection (1) when the fish was routed to a raceway and transported as a subyearling, or (2) when the fish passed Bonneville Dam via the juvenile fish bypass system as a subyearling. Using our present methods it is not possible to conclusively determine first-year wintering locale for a returning fall Chinook salmon that possess scales with freshwater annuli, but (1) is last detected upstream of Bonneville Dam as a subyearling (C_1 group) or (2) is never detected as a subyearling or as a yearling (C_0 group). We will continue to explore methods to confirm first-year wintering locale of these fish.

We will calculate time spent in seawater for each returning fall Chinook salmon by subtracting the year of ocean entry from the return year. For example, a subyearling that was released in 1998, entered seawater in 1998, and returned to freshwater in 1999 will be classed as a “I-salt” (Chinook salmon with this life history are males called jacks). A subyearling that was released in 1998, entered seawater as a yearling in 1999, and returned in 2000 will also be a “I-salt” (and also a jack). Fall Chinook salmon males that enter seawater as yearlings may also return to freshwater as "mini-jacks" (“0-salt”) after residing at sea for only a few months (Zimmerman et al. 2003). These fish mature and return to spawn in the same year of seawater entry. We will consider only II-salt and older adults to be "full-term" adults.

Until adequate sample sizes are available, we will pool results for fall Chinook salmon from the Snake and Clearwater rivers to increase sample sizes for analysis of percentages by ocean age (I-, II-, III-, etc. salt).

In most instances, fork length (cm) will be measured on adult fish recaptured at the trap. To evaluate the effect of age at ocean entry on size at return, we will calculate mean fork length by ocean age. For this analysis, we will pool the data for hatchery fall Chinook salmon from the Snake and Clearwater Rivers across all return years to increase sample sizes. In some instances, gender will have been assigned to adult fish recaptured at the trap. We will calculate mean fork length by age at ocean entry and gender for comparison.

Task 7.5 Scale pattern analyses on Columbia River fish (CRFPO lead)

For comparative purposes, we propose to sample scales from returning adults from the Hanford Reach, Deschutes River and LWS NFH releases to determine age-at-ocean-entry.

Phase II: Exploring Methods for Analysis

The COE will host a workshop on potential analytical approaches to evaluate Snake and Columbia Basin fall Chinook passage, consistent with the study design agreed upon by the US v Oregon parties. Federal, state, or tribal researchers (or their representatives) interested in participating in the workshops and providing input to the development of the analytical methodologies will be given the opportunity to share their ideas, concerns, and candidate approaches. The workshops will provide an opportunity for participants to collaboratively develop and review a systematic analytical approach that fully considers uncertainties, evaluates evidence for and against each key assumption, and allows for adjustments in methods to account for critical uncertainties. Workshop results will advise and guide analysis, interpretation, and reporting of results using accepted scientific methods for analyzing data,. The COE will provide a professional facilitator responsible for summarizing the workshop products submitted by attendees, along with any additional supporting information developed during and after the meeting (within a reasonably short deadline) into a Phase II Workshop Report. The Workshop Report and results of any independent scientific review (e.g. ISRP or ISAB) will then be used by the principle investigators to prepare a Final Report of Methods for Analysis of Snake and Columbia Basin Fall Chinook Salmon Passage Strategies for use during Phase III. The principal investigators will work with workshop participants to ensure the analytical approach described in the Final Report of Methods for Analysis reflects, at best, a regional scientific agreement, and at least, the range of scientific opinion.

Phase III: Final Data Analyses and Reporting

During Phase III, principle investigators will analyze the data as described in the Phase II Final Report of Methods for Analysis of Snake and Columbia Basin Fall Chinook Salmon Passage Strategies. The principal investigators will share the data collected during the study with the managers in preparation for a series of workshops open to federal, state, and tribal researchers. The intent of the workshops is to provide an opportunity for the principal investigators to work interactively with other managers to analyze and interpret the data, as well as provide formal peer-review. Workshop participants can discuss and develop alternative analysis and interpretations of results during the workshops. The input received during the workshops will be included in a Final Draft Report that summarizes the analyses, study results and conclusions, prior to public release. The workshop facilitator will summarize the workshop products and supporting information provided into a Phase III Workshop Report. The Phase III

Workshop Report and the Final Draft Report summarizing study results may be sent out for independent scientific review (e.g. ISRP or ISAB). A Final Report of research results will then be prepared incorporating comments received during the public COE review process and the ISRP/ISAB review. Data will be made available for alternative analysis and publication.

The number of workshops required during Phase III will likely depend on the outcome of Phase II, but would likely be one or two workshops (or perhaps two the first year, and one per year thereafter).

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APPENDIX A

Long-term Framework for Evaluating the Responses of Snake and Columbia River Fall Chinook Salmon to Dam Passage Strategies and Experiences

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Introduction

Snake River juvenile fall Chinook Salmon utilize the mainstem Snake and Columbia rivers for both migration and rearing. As such, hydrosystem operations and transportation strategies affect the behavior and survival of this ESA listed species. Numerous policy and management decisions take into consideration impacts to Snake River fall Chinook salmon. Various study design requirements and management decisions that could be made yielded disagreement between entities, even when working towards the common goal of establishing acceptable hydro-system operations and fish passage strategies that support both recovery and maintain harvest of Snake River fall Chinook salmon. A long-term goal of the region is to determine a hydrosystem operation and fish passage strategy for Snake River Fall Chinook that will meet the recovery needs of this ESU, through a regionally developed approach.

To facilitate agreement on a long-term study design for evaluating the responses of Snake River Basin fall Chinook salmon to dam passage strategies and experiences, an AD HOC group has drafted three guiding documents. The first document is an executive summary. The second document is an agreed to proposal. The third document is an appendix (this document) that functions as a long-term framework to effectively memorialize original expectations and will hold parties accountable over the 10 plus years it will take to realize study results. The documents represent “will live with” approaches. These agreed to approaches may not be the best, or the ultimate desire of all individuals but each individual has a common understanding of what agreement was obtained and was acceptable to all.

Snake and Columbia River fall Chinook salmon have experienced many anthropogenic challenges to their existence. A program of maximized transportation around the Federal Columbia River Power System (FCRPS) was instituted beginning in the 1980’s as the primary hydrosystem management strategy for the Snake River ESU. Despite this operation, abundance of this stock seriously diminished and in 1992 this stock was listed under the ESA. In 2005, the District Court of Oregon determined that spill operations should be implemented to better protect this ESU and this operation was codified in a court order for 2007. There is substantial regional disagreement as to the appropriate passage route that would result in achieving Viable Salmonid Population (VSP) and other management goals for the Snake River ESU: in-river migration through spill/surface bypass or collection and transportation. Regional parties are keenly interested in how to operate the hydropower system to meet the needs for the persistence, sustainability, and broad sense recovery of SRFC, therefore, in 2004, discussions were initiated to identify key management questions and to develop an evaluation plan. This document captures some of the details of those discussions, the plan that was developed, and a way forward for areas of disagreement.

Overall, the direction of this framework is two-fold. The first priority was to develop a study design that would meet the needs of the federal action agencies and cooperative parties to answer the needs of how to configure and operate the hydropower system relative to juvenile fall Chinook salmon survival. The issue of adult fall Chinook passage and survival under different operations also needs to be addressed (i.e. fallback and delay), but that is not addressed in this plan. The second purpose was to document points of agreement and disagreement identified and resolved during the development of the study design. If outstanding issues can be resolved or information gathered over the course of the evaluation indicates a need to change the study design, this plan may be modified towards that end. It is important to move ahead with a process and plan development that is acceptable to fishery managers and the Action Agencies.

Goal, Purpose and Need

A long term goal of the region is to determine a hydrosystem operation and fish passage strategy for Snake and Columbia River Fall Chinook that will meet the recovery and other management needs, through a regionally developed approach. Towards that goal, this plan was developed towards evaluating the performance of transportation of SRFC relative to inriver migration under the current court ordered spill operation.

The purpose of this framework is to:

1) Establish a collaborative approach;
2) Document key management questions regarding transportation and inriver migration of SRFC and Columbia River upriver bright fall Chinook salmon;
3) Document key management decisions with a focus on fish passage routes;
4) Document monitoring and evaluation objectives;
5) Describe general experimental design;
6) Points of agreement; and
7) Points of disagreement and decisions to move forward.

The regional managers have agreed that it is desirable to have agreement on the key management questions, study designs, data analysis and decision making at the outset of this evaluation, such that agreed to management decisions will be acceptable to participating parties and are as transparent and sound as possible. Thus, an overall plan for evaluating SRFC migration strategies is desired. This framework along with the consensus research proposal for evaluating the responses of Snake and Columbia River basin fall Chinook salmon to dam passage strategies and experiences is meant to satisfy that need.

Collaborating partners

Towards developing this evaluation plan (framework and proposal), federal, state and tribal agencies came together and worked in three primary groups including policy, planning and technical groups. The role of the technical group was to establish the biological issues and study design, the planning group was meant to develop the overall plan and to act as a liaison between the technical and policy group, and the policy group was meant to be the final decision making body. The primary participants are listed in the following table.

	BPA	CORPS	CRITFC	CTWS	IDFG	NOAA	NPT	ODFW	USFWS	WDFW
Policy	X	X	X	X	X	X	X[1]	X	X[2]	X
Planning	X	X	X		X	X	X	X	X	X
Technical	X	X	X		X	X	X	X	X	X

Other interested parties included technical staff from the Fish Passage Center, Pacific Northwest National Lab, Idaho Power Company, University of Washington and the US Geological Survey. In addition, to better coordinate the logistical aspects of the study, the *Snake River Fall Chinook Ad Hoc Group* was engaged at the technical level to facilitate coordination of the rearing and release groups from which the research fish were designated, and to facilitate technical discussion prior to submission to the *US v. Oregon* Policy Group. At the recommendation of the *US v. Oregon* parties (NPT and ODFW Feb 8th, 2006 letter to ACOE; Attachment 1), the fall Chinook research planning was brought into the FCRPS Biological Opinion Remand research, monitoring, and evaluation (RME) work group process. Finalization of this plan was not achieved during the collaboration portion of the Remand process, as such, this Ad Hoc Group has identified the USvOR and AFEP processes as the targeted forums for approval and implementation of this plan. However, this may not be acceptable to other basin fishery management parties that are not part of the ad-hoc group.

Historic Summer Operations (Pre-2005)

Prior to 2005, the Lower Snake River collector projects (LGR, LGO, LMN, McN) were operated without voluntary spill in an effort to maximize transportation during the summer in accordance with the 1995 and 2000 NOAA Biological Opinions. At that time, NOAA's concern was that high temperatures and low flow conditions would cause poor inriver survival for migrating SRFC; therefore fish collected at transportation dams should be transported to minimize mortality. However, recent analyses have indicated that transportation (under non-spill conditions) appears to neither greatly harm nor help these fish and that a combination of transportation and good inriver conditions for fish not collected and transported would be consistent with a “spread the risk” strategy until more is known. In the 2000 FCRPS BiOp and the Updated Proposed Action for the 2004 FCRPS BiOp, an evaluation of Snake River fall Chinook transportation and inriver migration was planned.

Recent and Future Summer Operations

In 2005, plaintiffs in the *NWF vs. NMFS* case regarding the remanded 2004 Biological Opinion, requested spill during the summer at the collector projects to provide what they believed to be better inriver migration conditions for these fish. Judge James Redden granted the Preliminary Injunction and spill was provided from June 20th to August 31st, 2005. In 2006, spill

[1] While some Nez Perce Policy personnel have been involved at various stages, whether the key policy personnel were involved in the design of the study may not have been well defined.
[2] While initially USFWS were within the policy group, moving to the remand group has made an unclear connection to the policy level where USFWS did not participate.

operations were laid out in the spill implementation plan which again included summer spill, however at volumes less than that provided in 2005. Variability in operations including spill levels, timing, and duration are anticipated and do not invalidate the study design; however realized operations are expected to maintain "good in-river conditions."

Management Questions, Decisions, and Research

Management Question and Policy Input

An important part of any research plan is the development of the key management questions. These questions help shape the overall research and planning efforts, allow the various interests to be addressed, and help to establish the operations that are needed for evaluation purposes. In general, the overall broad scale management question expected to be answered by this evaluation is:

- How should the FCRPS be operated to provide conditions for Fall Chinook during the migration and early rearing habitat phase within the FCRPS to achieve overall life cycle survival needed to support: recovery, other authorized purposes of the FCRPS, and sustainable harvest?

As subcomponents of this question, there were additional key questions that were raised at the Policy and Planning Groups including:

- What specific operations provide optimal in-river and transport conditions for fish?
- At what component of Snake River Fall Chinook should our management actions be directed to facilitate recovery?
- What is the relative performance of true in-river fish (i.e. spilled or passed via surface bypass) versus transported fish?
- What is the appropriate monitoring program to evaluate overall Snake River fall Chinook performance relative to the hydrosystem experience?
- Within and between years, what is the direct survival of smolts through the FCRPS under various conditions and routes of passage? What are the corresponding smolt to adult return rates under various conditions and various routes of passage?
- Do the marked fish used in the study represent the key component of Snake River Fall Chinook? If not, what changes are needed?

In an effort to answer these questions, the Policy group guidance was**:**

- Subject to logistical and financial constraints, mark enough wild fish (a good sample without mortalities), hatchery fish to size (surrogates); and hatchery fish to judge the effectiveness and survival over the long term.
- Design a transport study to have minimal (or no) impact on US v. Oregon release strategies and locations. If there is a change, be clear how and why so the US v. Oregon table can address this.
- When considering life cycle survival, figure in harvest rates from Canada and Alaska.

Management Decisions

Many management decisions could be informed by the evaluation outlined in this plan. These management decisions could include management of the hydropower system, management of harvest, or management of hatcheries. While the primary intent is to assess the management of the hydropower system, this evaluation could also yield additional information to these other H's to assist in the persistence, sustainability, and broad sense recovery of SRFC.

The management decisions which are the primary focus of this evaluation include whether:

- To transport or bypass SRFC back to the river at collector projects
- To spread the risk, maximize transport, maximize bypass or maximize spillway/surface bypass for migrants
- To use hatchery surrogate fish for research purposes to represent wild fish
    - Additional management decisions that <u>would likely be informed</u> because of this evaluation, but requiring additional analysis, include:
- When to transport SRFC from collector projects and when they should be bypassed back to the river
- To apply identifying marks to hatchery reared and natural origin fish.
    - Type of mark.
    - Number of fish marked.
    - Rearing location at time of marking.
    - Implement technical improvements for fish passage
- Tailor hydrosystem operations to address life history strategies
- How to monitor adult fish movement/passage.

Further management decisions that <u>may be informed</u> because of this evaluation, but requiring separate analysis could include:

- Need for additional flow augmentation and temperature modification
- Provide PIT tag information for harvest management
- To operate Lower Granite Dam trap to representative sample across fall Chinook run and remove identified "strays".
- How to prioritize energy generation and fish survival
- When to spill for fall Chinook
- How to operate hatchery mitigation programs
- How much spill to provide for fall Chinook at each dam

In addition to this evaluation, many additional studies are being performed for SRFC to determine direct passage survival at dams, habitat effects, behavior, and spawning success.

Monitoring and Evaluation Objectives

Members of the Policy workshop brought forward some basic tenets to follow regarding performing this type of evaluation. These tenets included that we should design a study to have minimal (or no) impact on *US v. Oregon* release strategies and locations, that we should look for opportunities to overlap efforts, and when considering life-cycle survival, we should figure in harvest rates from Canada and Alaska. In addition, discussions within the collaborative process identified the following as key technical information to make informed decisions.

- **Evaluate the SAR rates of SRFC by route (i.e. bypass, undetected and transport) across multiple years**

  The collaborating partners agree that by releasing fish upstream of the dams, collecting and transporting some, bypassing others, and allowing some to migrate inriver undetected, that a reasonable number of adults would return to compare SARs for assessing passage effectiveness by route for the years studied. This information should be obtainable from PIT-tagged fish.

- **Make direct estimates of survival & guidance efficiency for individual projects by route of passage, including in-season variations**

  Information on specific routes of passage (e.g., spillway, turbine, or bypass) will be gathered through radiotelemetry or acoustic tagging studies conducted as an additional component of the AFEP on an as needed basis.

- **Within and between years, determine the direct survival of juvenile SRFC migrating through the FCRPS under various conditions and routes of passage**

  The intent would be to examine the development of methods to assess fall Chinook survival based on what was learned from the tagging juvenile fish for multiple years, and the information on passage and run timing. Although the information gained from adult returns is believed to be of higher value.

- **Determine how well tagged fish used in the study represent their respective components of Snake River fall Chinook and assess what changes may be needed**

  Because there were three primary components of fish (hatchery, naturally produced and hatchery surrogate) tagged in 3 different river segments (lower Hells Canyon, upper Hells Canyon and the Clearwater River), with varying migrational behaviors and characteristics, the concern was that insufficient tagging of groups of fish would be occurring or that some fish tagged as representatives of others, would actually not be representative. In addition there is concern that surrogate fish may or may not represent the naturally produced fish that they were intended to.

In that large numbers of fish tagged as juveniles from each group would be tagged (2006 numbers of 183,000 production, 328,000 surrogates, and ~ 3,700 naturally produced fish) across various (close to representative) locations, it was thought that sufficient fish would be available from each group to assess if these fish are comparable, and representative of each other.

- **Estimate the proportion of fish migrating in river vs. transported**

  This should be informed in season and across years through the use of counts at dams, and evaluations being conducted concurrently. Radiotelemetry evaluations will provide estimates of fish guidance and passage through various routes. Monitoring at the fish facilities will allow for estimates of fish passing through bypass systems, and the proposed evaluation will provide substantial numbers of PIT tags passing through bypass systems to estimate the proportion of fish transported. Assessments of inriver abundance and survival towards developing these estimates are presently in the unresolved category.

- **Determine SARs for subyearling-type migrants vs. holdover yearling-type migrants**

  Recent information has indicated that fish that tend to over-winter in fresh water tend to return at higher rates than those that out migrated as subyearlings. Operating with and without spill may change the ratio of fish that holdover versus those that out migrate in the same year, potentially affecting the number of adult returns. This will be informed through this evaluation by monitoring for PIT tag codes at the adult fish facilities. If fish were detected as passing through detection systems as a juvenile, a comparison between life history of fish through the hydrosystem would be possible. In addition, scale readings on all PIT-tagged fish captured at the Lower Granite Adult Trap should provide an estimate of time of entry into salt water for all groups of fish. The proposed evaluation will provide substantial numbers of PIT tags to inform this question and appropriate sample numbers of adult fish would be worked through as to avoid any conflicts with run reconstruction efforts.

  Assessing survival in the mainstem river for those fish that hold over will be very challenging. Technology will be pursued for answering these questions; however, the Action Agencies believe that this is not presently possible.

- **Evaluate the comparative life cycle survival performance between Snake River and downriver fall Chinook salmon**

  Some of the collaborative participants would like to tag downriver populations of fall Chinook and use upstream/downstream comparisons to provide information on the latent effects of the FCRPS on fall Chinook. In their assessment of latent effects on spring/summer yearling Chinook, the ISAB recommended "the continuation of PIT tagging with a monitoring and evaluation program designed to reduce the current levels of uncertainty" and that "future monitoring and research is needed to further quantify biological factors that contribute to variability in estimated post-Bonneville mortality." The federal Action Agencies believe that there are too many differences between upstream and downstream stocks to provide reasonable comparisons. In addition, the ISAB reported, “the hydrosystem causes some fish to experience latent mortality, but strongly advises against continuing to try to measure absolute latent mortality. Latent mortality relative to a dam-less reference is not measurable. Instead, the focus should be on the total mortality of in-river migrants and transported fish, which is the critical issue for recovery of listed salmonids. Efforts would be better expended on estimation of processes, such as in-river versus transport mortality that can be measured directly.” While the Action Agencies are in line with this opinion, this does not preclude the need to discuss these issues at a workshop in the future.

- **Determine the harvest rates of Snake River Fall Chinook**

  While harvest rates on fall Chinook may provide valuable information to the management of fall Chinook stocks, and this management question may be informed by this and other research. While data on harvest rates of Columbia and Snake Basin fall Chinook are currently being collected through coded-wire tagging (CWT) efforts, the assessment of transport to inriver migration does not rely on the assessment of harvest. This component lies outside the scope of this evaluation, but may be answerable through other RM&E efforts.

- **Spawner to spawner recruits ratio**

  This component lies outside the scope of this evaluation, however may be informed through the use of counts at dams, and research being conducted under the NPCC's program.

- **Hatchery effects**

  While hatchery effects on fall Chinook may provide valuable information to the management of fall Chinook stocks, and this may be informed by this research, this component presently lies outside the scope of this evaluation. Consideration of how to complement hatchery RME will be considered at a Workshop.

- **Dam operation effects on habitat**

  While effects of dam operations on habitat used for spawning, rearing and migration may be informed by this evaluation, this component lies outside the scope of this evaluation.

With a basic goal to develop a consistent and comprehensive monitoring and evaluation program to understanding the responses of fall Chinook salmon over their life-cycle to environmental and management conditions within and outside the Federal Columbia River Power System. The diverse nature of information described above goes beyond five primary objectives for evaluating the responses of Snake and Columbia River Basin fall Chinook salmon to dam passage strategies and experiences:

1. Estimate juvenile migration and survival rates within the FCRPS,
2. Estimate ocean survival rates (i.e., post-FCRPS),
3. Estimate adult upstream migration and survival rates,
4. Estimate overall smolt-to-adult survival rates (SARs) by management strategy and migration experience, and
5. Compare and contrast the above demographic rates, examining the effects of rearing type (hatchery, natural, surrogate), release and detection points above and within the FCRPS, release date, length at release, management strategy (TWS, BWS), migration experience (T_0, C_1), and environmental conditions following release (temperature, flow, water transit time, turbidity, spill).

General Experimental Design

What operations should be provided for the evaluation?

In general, there were two primary components at issue, one was the overall condition of whether to spill or not to spill, and the second was what volume to spill at the Snake River and McNary dams.

As far as overall operations, there were two general schools of thought on testing operations. One included a "max spill versus no spill (max transport) regime", while the other would be a test of a "spread the risk" operation. For the purposes of bringing forward one discussion topic in a short time period for discussion at the *US v. Oregon* forum, the spread the risk operation was brought forward. This was advised based on the 2005 court decision and discussions held in the remand forum. However, the understanding was that the no spill versus max spill operation would be revisited, but not necessarily within the primary scope of this evaluation. (This is in the unresolved issues section.) If one operation versus another is determined to be the better migrational strategy, the spill versus no spill may be a moot point. For example, if inriver migrating fish perform better than transported fish during a spill operation, a no-spill operation may not be warranted for testing in the future.

As far as specifics, the spill level for the 2005 operation was determined in the preliminary injunction as all flow other than one turbine operation at each project, with the exception of Little Goose Dam, which was changed to a 30% daytime operation in order to not affect adult migration, and McNary dam, which was to spill all flows over 50kcfs. For the 2006 operation, planned spill levels were 18kcfs at LGR, 30% LGO, 17kcfs at LMN, ICH 45kcfs day, cap night (30% testing purposes), McNary 40%/60% spill operation 24 hrs. These or similar operations are likely to continue through the course of the evaluation.

Marking Numbers and Design for 2005 and 2006

An initial tagging effort began in 2005 whereby 176,000 hatchery surrogate fish were released.

For 2006, a study was outlined using targets of 250,000 and 330,000 PIT-tagged hatchery production and hatchery surrogate fish (see attachments 1 & 2). Additionally, 10-20,000 naturally produced fish would be targeted for PIT tagging from the Snake and Clearwater rivers for comparing to the large numbers of hatchery PIT-tagged fish. This marking level was agreed to for the 2006 study based on the number of fish available through the *US v. OR* process. Actual fish numbers released in 2006 were roughly 185,000 production fish, 328,000 surrogate fish, and about 4,000 naturally produced fish.

In 2006, the hatchery surrogate fish were released in groups of which 50% were destined for transport if collected and 50% destined for bypass. The hatchery production fish were released in groups of which 65% were destined for transport and 35% destined for bypass. There were concerns by some of the partners that bypassed fish survive at lower rates; therefore this route was not preferable for the production group. The 35% of fish destined for bypass in this group was meant to allow for the potential of producing inriver survival estimates; although not all parties (primarily the Action Agencies) agreed that this was feasible. At the time, the Corps believed that in addition to their stewardship responsibilities for production fish, that tagging these fish provided a reasonable comparison between hatchery, surrogate and wild fish, and a certain level of transport analysis could still be performed.

Numbers of Fish and Statistical Precision

While the numbers of fish released in 2006 may provide enough information to assess the various migration strategies, they may not be acceptable to all parties in the region with regard to statistical precision.

Timeline

The exact number of years that will be required for the primary transportation evaluation depends on: 1) the number of fish that are marked, 2) the desired detectable difference between transported and in-river-migrating fish, 3) the number of years required for people/agencies to develop a level of confidence and comfort with the results, 4) the lag-times spent waiting for adult returns and 5) the decision criteria. With the marking levels proposed for this study in 2006, sample size calculations expected that differences of 25-50% between the transported and in-river-migrating groups could be detected with one year of marking. Although summer operations do not typically vary widely, the effects of transportation are likely to vary with differences in between year environmental conditions and thus this evaluation will require more than one year of tagging. Because of lag-times spent waiting for adult returns, the full returns from fish released in 2005 and 2006 will not be realized until 2009 and 2010 respectively. In the interim, jacks and mini-jacks will return in 2007 and the first egg bearing females will return in 2008. These initial returns will provide important information on whether the marking levels were appropriate for the initial sample size calculations, and should allow for modifications to the numbers of fish as necessary.

At a meeting on January 19, 2006 and at subsequent meetings, the number of years of tagging and targeted operations (spill) was discussed, ranging from a minimum of three years up to 10 years. In general, the technical group supported a target of 5 years of study for marking and operations which would be representative of one brood (one full cycle of smolt to spawners). This would require marking fish in 2006 and from 2008 through 2011. The full return for the

2011 releases would return by 2015, indicating that final assessment duration of nine years would be required for five years of operations. What operations and evaluations would occur in the interim (i.e. between the last year of tagging and the last year of adult returns) is in the unresolved issues section. This target duration would encompass five years of marking (with the possibility that the release numbers in the last two years could be altered based on the first adult returns in the fall of 2008), and five years of natural variation in the in-river environmental conditions. If the regional parties had the desire to evaluate additional operational scenarios or if extremely low flow years occurred at some time during the study period, additional years of marking and alternative operations would likely be required. Marking levels would need to be informed by the targeted operations.

It must be understood that this number of years (5) was not determined analytically or derived statistically because there is presently not sufficient information available to make that assessment. It is likely that several years of tagging will be required to develop a strong understanding of how operations and environmental conditions affect these fall Chinook metrics.

Although a general target of 5 years was supported, the regional parties believe that annual check in points would be prudent. An assessment of the returns of fish tagged from 2005-2006, and 2008, all years in which large numbers of PIT-tagged fish would be released and for which some level of adult returns with spill occurring will be in hand, may yield early clues as to whether one migration strategy was favorable over another. If differences in some migratory routes were drastically different than others, a reassessment of that operation and the evaluation (including duration) would be made. The potential is that a lesser number of years may be needed to assess these operations.

For the purposes of this, and potential subsequent operations planned for evaluation, the maximum number of years for planning to tag Snake River Fall Chinook is ten (with 2006 being year 1). This is not to say that tagging or specific operations would necessarily be required in all ten years or that fish would be requested in every year, however, based on check ins, decisional criteria, and certainty with the data, ten years provides sufficient flexibility for adaptive management purposes, while providing a solid end date for fish requests for members within the Policy Workgroup.

Points of Agreement

Overall, the level of agreement was quite high within the group regarding the mechanics of the evaluation. In general, it was agreed that:

- Hatchery-surrogate, naturally produced, and production fish would be used, with hatchery surrogates used in an attempt to mimic naturally produced fish. However, comparisons would be required to determine how well the hatchery surrogate fish mimicked the naturally produced fish.

- For the release groups, it would be best to have fish in pre-determined treatment groups for Bypass-if-collected and Transport-if-collected with sort by code occurring at each dam.

- When tagging the production fish, groups should come from a proportional tagging effort across the release sites.

- Hatchery surrogate fish would be released into the Clearwater and Snake rivers in roughly a 30%/70% ratio to mimic the proportions of redds in each river, meant to emulate the naturally produced fish proportions, size and timing.

- Performing adult fish scale reading would yield valuable information for the evaluation including an assessment of yearling and subyearling life history and over wintering behavior.

- It was agreed that jacks and mini jacks would be reported on, with the various analyses brought forward including all of the different groups of treatment fish. While the reporting of jacks was thought to be important, it was not agreed as to the management framework, as to whether or not jacks would be included in the management decision.

Points of Disagreement and Decisions to Move Forward

While the collaborating groups were in agreement on most of the issues regarding the research, there were still some unresolved issues. These issues ranged from minor technical differences to major policy issues. The following italicized text is the August 24th memo to USvOR small work group from the Snake Basin Fall Chinook Salmon Ad Hoc Group and subsequent small work group decisions. The USvOR small work group with representatives from Confederated Tribes of Umatilla Indian Reservation, Confederated Tribes of the Warm Springs Indian Reservation, Idaho Department of Fish and Game, National Oceanic and Atmospheric Administration – Fisheries, Nez Perce Tribe, Oregon Department of Fish and Wildlife, U.S. Fish and Wildlife Service, and Washington Department of Fish and Wildlife met on September 25th, 2007. The achieved consensus decisions on all eight points of disagreement.

To facilitate agreement[3] on a long-term study design for evaluating the relative performance of Snake River Basin fall Chinook salmon (SRFC) using different passage routes at dams, an AD HOC group has been drafting a "living" document made up of three parts. The first part is an executive summary. The second part is a an agreed to proposal. The third part is an Appendix that functions as a long-term framework that effectively memorializes original expectations that will hold parties accountable over the 10 years it will take to realize study results. This memorandum describes areas of disagreement which need resolution in order to complete an agreed upon long-term Snake River fall Chinook salmon passage route study design. The issues identified here represent aspects identified by at least one entity as either essential to include or exclude in order to fund the study or for them to participate. If left unresolved, these issues

[3] USvOR parties and COE.

would likely jeopardize conduct of all or part of the study either through lack of fish production/marking approval by USvOR and/or withdrawal of study funding by COE.

The memorandum was prepared for a small work group of USvOR, formed to help reach agreement on near-term and long-term topics in need of resolution. Results of discussions by the small work group will be included in the Appendix. As of August 22nd, 2007, there remain three general topics of disagreement[4]; (1) groups of fish to be marked, (2) collaborative approach for study conduct, and (3) management process for applying results. Each one of these topics has 2 or 3 associated decisions; resulting in eight total decisions needing to be made. Three of the points of disagreement may be resolved, but are included here in order to confirm the identified approaches. The decisions requiring resolution by September 14th, 2007 are:

Topic 1: Groups of fish to marked.

- *Should the study include a downstream (below Ice Harbor Dam) mark group that would serve as a reference against which smolt-to-adult returns (SAR's) of SRFC could be compared to assess latent and delayed mortality? (resolution pending)*
- *Should the production of surrogate SRFC for the study be assigned a higher priority than it is presently given in the USvOR fall Chinook salmon production priority agreement?*
- *Should general production be marked to enable inclusion of a bypass SAR group in the study?*

Topic 2: Collaborative approach for study conduct.

- *Should a weight of evidence approach, using a series of interactive workshops whose intent is to ensure the experimental design, data collection and analysis, and interpretation and reporting of study results reflect, at best, a regional scientific agreement, and at least, the range of scientific opinion that best informs policy choices be used)? (resolution pending)*
- *Should the US Army Corps of Engineers fund the participation of additional scientists in the collaborative process to conduct and/or participate in the SRFC evaluation, data analysis, and reporting? (resolution pending)*
- *Should the ISAB, ISRP, or some other independent scientific group perform a scientific review of the study design, workshops, and or results?*

Topic 3: Management process for applying results

- *Should fish marking as prescribed in this study be discontinued after 5 years of marking before adult returns/results are complete?*
- *Should hydro-system operation adaptive management related to Snake River fall Chinook salmon follow a pre-established decision tree, applying a standardized suite of primary metrics and precision targets?*

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[4] In November of 2006, six points of disagreement were communicated to US v OR, two of which (#2 and #5) have been resolved. The points of disagreement described in this memo are similar with remaining issues identified in 2006. 1) Should survival of other fall Chinook stocks be compared to survival of Snake River fall Chinook stocks as part of this study? 2) How many years should fish be tagged? 3) What would the interim FCRPS operations be during the period after the last year of tagging and before final results are available? 4) Should a bypass group be included in the analysis as a management alternative? 5) How much certainty do we need in the study results? 6) Who should be involved in and responsible for collecting, analyzing and reporting on evaluation results?

The reminder of this memorandum is structured to provide a description of:

1) Topic of disagreement;
A) decision required, including background; and
i) statements of opposing and supporting positions.

Topic 1: <u>Groups of fish to be marked</u>.

Decision 1.A) Should the study include downstream (below Ice Harbor Dam) mark groups that would serve as a references against which smolt-to-adult returns (SAR's) of SRFC could be compared to assess latent and delayed mortality? (resolution pending)

Background 1.A) Many regional salmon managers believe that an assessment of fall Chinook in the Columbia Basin in its entirety is important. This approach, to address latent mortality and differential delayed mortality between transport and in-river groups ("D"), follows that used in PATH and CSS studies of Snake River Basin spring/summer Chinook salmon. The ISAB reported, "the hydrosystem causes some fish to experience latent mortality, but strongly advises against continuing to try to measure absolute latent mortality. Latent mortality relative to a dam-less reference is not measurable. Presently it is not clear how decisions would be made regarding the operations for fall Chinook. For example if SARs are the primary metric for the evaluation, what difference between SARs is acceptable to salmon managers to choose one migration strategy over another? Instead, the focus should be on the total mortality of in-river migrants and transported fish, which is the critical issue for recovery of listed salmonids. Efforts would be better expended on estimation of processes, such as in-river versus transport mortality that can be measured directly." However, the ISAB clarified their position on this issue and recommended that data from downstream marked groups was indeed valuable and should be obtained (Implementation Team meeting June 7, 2007). A key element of the debate is whether fall Chinook stocks originating downstream from Ice Harbor Dam share the same ocean experiences to serve as legitimate "controls" for evaluating how passing the four Snake River dams or being transported from Snake River collector projects affects survival of Snake River fall Chinook.

Ad Hoc group members have recently discussed the following potential resolution. Inclusion of a downstream mark group will continue to be negotiated following description of downstream treatment groups, analysis of their suitability, and summary of ongoing tagging. Pending the identification of a suitable group, a stand-alone proposal will be prepared and considered for funding within AFEP and/or NPCC forums, or directly from BPA.

Support 1.A.i) Comparing the performance of upstream stocks versus those that have not migrated through the Lower Snake River hydro projects enables the consideration of whether and to what degree differential mortality related to migration through the Lower Snake River exists. To estimate the magnitude of latent mortality and "D" comparisons of SARs between Snake River Basin fish experiencing exposure to transport, bypass, and in-river passage to downriver stocks with no exposure is needed. (ODFW, CRITFC, USFWS-CRO)

Opposition 1.A.ii) With respect to tagging downstream stocks of fall Chinook we continue to have concerns with the underlying purpose and objectives. In discussions with salmon managers over the past several months, we have identified the need for an overall study proposal including underlying basis and rationale, and study design. Such information is important for us to determine if the research is properly within the Corps area of responsibility and what application it might have to Corps programs and projects. Among others, specific questions about this study of "downstream" fall Chinook include:

- *What tagging of lower river stocks is presently being done, whether coded wire or PIT tags that might be useful in looking at downstream stock performance?*
- *Why are the proposed stocks considered to be appropriate downstream controls considering the differences in their characteristics and life histories?*
- *Have the basic scientific principles been outlined and addressed in a proposal for using downstream stocks as a comparison to Snake River fall Chinook? These would include: the hypothesis, rationale for tagging, justification for numbers of fish, analysis to be performed and comparisons to be made, etc…. This is especially important in that the Corps would need to regionally vet this through its AFEP process in addition to determining our role as noted above.*

In considering the operation of the Corps projects on the Snake River, how would tagging downstream stocks inform the operational decisions at the collector projects? Lacking resolution of these issues we can not fund marking downstream stocks. (COE)

Opposition 1.A.iii) The federal Action Agencies have expressed concerns with tagging downstream stocks as comparisons to upstream stocks. To determine whether these comparisons are valid, they've called for more discussion about what is presently being tagged, what stocks might be appropriate for tagging, the hypothesis and rationale for tagging those fish, and the applicability to Snake River dams and McNary Dam operations. Their support would be conditioned on demonstration that the stocks are comparable in all aspects except their experience through the hydro-power system. (NOAA, USFWS-IFRO, COE, NPT)

Small-work Group Consensus Decision 1.A: Include implementation of downriver marking groups in the long-term framework for the study with a recommendation to have the COE fund or at least support funding in other forums. Justification should also include a description of how inclusion of downstream groups is consistent with and will contribute toward to the implementation of basic diagnostic regional monitoring and evaluation for the ESUs. Include rationale and design for downriver marking in a single proposal package with the Snake River basin (upriver) component. Provide responses to questions raised about the merits and appropriateness of including downstream mark groups as part of the study proposal.

Decision 1.B) Should the production of surrogate SRFC for the study be assigned a higher priority than it is presently given in the USvOR fall Chinook salmon production priority agreement?

Background 1.B) Revision of the existing production priority table is not required to enable study implementation. The current agreement includes surrogate production of 328,000 *as priorities 12 and 14. Rearing of surrogate production does not limit rearing capacity for general production fish. Rearing surrogate production does require eggs from the same brood as general production. Duration of surrogate production is not currently limited in the agreement. Surrogate production does not reduce or supplant general production if sufficient broodstock is available (i.e. under unlimited broodstock conditions surrogate production is above and beyond USvOR general production agreement). Lower production priority increases the chance/ frequency of years when surrogate groups would not be implemented due to shortages in broodstock.*

Opposition 1.B.i) The tribes believe that surrogate production profiles may result in fish with reduced survival rates, and possible other negative changes in productivity from modifications in sex ratios and age class structure relative to general production profiles. As such, programming of eggs to surrogate production, when broodstock is limited, could result in reduced adult returns. (NPT, CTUIR, CRITFC)

Support 1.B.ii) Given broodstock is most likely limited in some/most years, failing to assign a high priority to surrogate production may result in years without treatment fish. Although surrogate releases do not have to occur in consecutive years, the proposed duration of the study is based on achieving 5 years of surrogate releases, however, skipping years would delay the point when final data is obtained and available to inform adaptive management decisions. Annual uncertainty in whether the study will proceed increases uncertainty in annual management processes, effort, and staffing. (COE, NOAA, USFWS-IFRO)

Small-work Group Consensus Decision 1.B: Support reconsideration of priorities after agreement on a final study design is reached among US v Oregon parties, with final production priorities informed by COE funding decisions.

Decision 1.C) Should general production be marked to enable inclusion of a bypass SAR group in the study?

Background 1.C) Some general production (yearling and subyearling) fish need to be bypassed (i.e. collected at the projects and returned back to the river) to monitor in-river survival rates. However the number of fish that must be tagged is substantially higher if the objective is to evaluate the SARof bypassed fish as a treatment group. Some members of the collaborative process would prefer that a bypass group only be included in the study as a means to get an estimate of in-river survival (C0). Others believe that each migratory management option should be evaluated as a potential management tool for the future. The debate centers around the costs, risks, and priority of marking the additional fish necessary to evaluate the SAR of bypassed fish, given disagreements on its appropriateness as a long-term management alternative. Performance of bypassed fish relative to transported fish will occur with surrogate fish. One purpose of including a production bypass group is to better enable a comparison among surrogate, natural, and production fish using different passage routes. An additional consideration for having a bypass group is to allow for maintaining a 50:50, split between in-river and transport migration, with an early bypass and late transport approach. However, policy level discussions are ongoing about what is meant by a spread the risk strategy and 50:50. The COE position is that the 50% inriver component can be comprised of either bypass or *spilled/surface bypass fish. The fishery managers' position is that the 50% in-river component needs to pass the dams via spill/surface bypass.*

Support 1.C.i) COE desires to answer the question of what to do with juvenile migrating fish once collected. It's conceivable that fish that are collected and bypassed will have higher SARs than transported fish. Without evaluating the bypass route, we wouldn't know what to do with collected fish (transport or put back in the river). As some fish will always be collected, even with passage improvements (RSWs, TSWs, etc.), this management option needs evaluation. When making management decisions based on the results of this study, it will be important to know if surrogates and general production fish responded similarly to transportation. Would an operation benefit one group at the detriment of the other? Therefore, the COE feels if general production fish are included in the study; it needs to be with the same study design as the surrogates (i.e. bypass and transport treatments).

Bypass is a viable management option. It is not clear that bypassed production subyearling Chinook would have lower return rates. Hatchery yearling Chinook bypassed (PIT return to river) at Lower Granite in 6 of 11 years had higher SAR than their undetected cohort (NWFSC, 16 Aug 2007).

Data available for "bypassed" fish represents sort-by-code return to river system that in some cases were in poor locations and with low flows, not operation bypass. Also, bypassed fish tend to be smaller and perhaps more diseased then the general population and may have lower SAR regardless of their route of passage. Nevertheless, the COE is changing the bypass outfalls to avoid the secondary dewatering, separators, etc and adding PIT detectors to these "full flow" outfalls. This has been completed at all project expect Little Goose (2008) and Lower Granite (2012). Therefore, future bypass operations may perform better, do to reduced stress and increased discharge, than the PIT return river and facility bypass. (COE, NOAA)

Opposition 1.C.ii) Yearling juvenile spring Chinook and steelhead that have been bypassed at dams consistently show lower SARs than fish passing in other routes, including transportation. Because the emphasis is on comparing transportation to in-river passage with good conditions (i.e. spill/surface bypass) and due to the fact that fish available for marking likely will be limited, a comparison of bypass fish to fish passing other routes is likely logistically infeasible and not defensible. Given the existing data on low SARs for bypass fish and the limited amount of fish available for marking, it is not a prudent method for managing fall Chinook. (CRITFC, NPT)

Small-work Group Consensus Decision 1.C: Include marking of an additional 65,000 (250,000 fish total) general production subyearlings for evaluation of a bypass study group under the following conditions: inclusion of the bypass treatment should not limit the ability to mark 185,000 production fish needed to evaluate the transport and in-river comparisons; as many fish are marked as possible before transfer to acclimation sites, and, for all study groups, marking should be done without adding undue risk to fish health, especially if tagging done post transfer to acclimation sites. Tagging constraints assessed annually based on site specific rearing conditions.

Topic 2: <u>Collaborative approach for study conduct</u>

Decision 2.A) Should a weight of evidence approach, using a series of interactive workshops whose intent is to ensure the experimental design, data collection and analysis, and interpretation and reporting of study results reflect, at best, a regional scientific consensus, and at least, the range of scientific opinion that best informs policy choices be used)? (resolution pending)

Background 2.A) In response to a one-page request for proposals by the COE, two proposals on the efficacy of transportation and spill were submitted to the COE in 2005. A series of SRWG meetings were held to discuss the proposals. Existing data on topics such as life history diversity and SARs were presented by a small number of experts. Audience participation was limited to comments and questions. A proposal prepared by NOAA and IFRO was selected by the COE, based on these meetings and a review of the proposals by three independent contractors funded by the COE, BPA, and BOR. However, based upon their own evaluations of the proposal, several of the fisheries managers opposed the study and emphasized that a weight-of-evidence workshop was first necessary to move forward on a consensus proposal. The proposal that was selected by the COE specified that workshops would be held to share data, preliminary results, and provide the opportunity for peer-review.

The ad hoc group feels that agreement on this issue simply requires clarification. It is clear that shared confidence in the results of the evaluation will require some level of ownership by all the parties. Collaboration, defined as joint contribution to intellectual projects or process, is probably the most important factor affecting ownership. The ad hoc group discussed the following.

The COE will commit in writing to sponsor a series of facilitated interactive workshops, as special SRWG meetings, open to federal, state, and tribal researchers. The first series will explore and identify valid analytical techniques to be used in the evaluation. A report written by the facilitator and reviewed by all participants will describe the data analyses and techniques to be used when the adult returns from the first year of releases are complete (2009–2010). Then, the COE will sponsor a second series of facilitated interactive workshops. The workshop attendees will be provided the raw data and draft analyses from the principle investigators. The attendees will have the opportunity to analyze and interpret the data independently, and then provide oral and written feedback on their results. The results will be revised accordingly and draft report written. The draft report will not be distributed until it is reviewed by federal, state, and tribal co-managers. This will produce results that at best reflect a regional scientific understanding; and at least, the range of scientific opinion.

Support 2.A.i) Some co-managers supported the proposal selection process and the concept of a workshop.

Opposition 2.A.ii) The process of proposal selection and the plans for future data analyses did not meet the expectations of some co-managers who felt that: (a) the floor should have been open for presentation of data by others in addition to the experts, (b) the interaction during the meeting was not truly collaborative, (c) the independent review provided by the *contractors was biased, and (d) the COE was not fully committed to sponsoring the workshop. They proposed that the study design and analyses should follow the "weight of evidence approach."*

Small-work Group Consensus Decision 2.A: A collaborative effort should continue, using interactive workshops.

The COE will host a workshop on potential analytical approaches to evaluate Snake River fall Chinook passage, consistent with the study design agreed upon by the US v Oregon parties. Federal, state, or tribal researchers (or their representatives) interested in participating in the workshops and providing input to the development of the analytical methodologies will be given the opportunity to share their ideas, concerns, and candidate approaches. During the workshop, participants will have the opportunity to discuss and debate the alternative approaches presented. The COE will provide a professional facilitator responsible for summarizing the workshop products submitted by attendees, along with any additional supporting information developed during and after the meeting (within a reasonably short deadline) into a Phase II Workshop Report. The Workshop Report and results of any independent scientific review (e.g. ISRP or ISAB) will then be used by the principle investigators to prepare a Final Report of Methods for Analysis of Snake River Basin Fall Chinook Salmon Passage Strategies for use during Phase III. The principal investigators will work with workshop participants to ensure the Final Report reflects, at best, a regional scientific agreement, and at least, the range of scientific opinion.

During Phase III, principle investigators will analyze the data as described in the Phase II Final Report of Methods for Analysis of Snake River Basin Fall Chinook Salmon Passage Strategies. The principal investigators will share the data collected during the study with the managers in preparation for a series of workshops open to federal, state, and tribal researchers. The intent of the workshops is to provide an opportunity for the principal investigators to work interactively with other managers to analyze and interpret the data, as well as provide formal peer-review. Workshop participants can discuss and develop alternative analysis and interpretations of results during the workshops. The input received during the workshops will be included in a Final Draft Report that summarizes the analyses, study results and conclusions, prior to public release. The workshop facilitator will summarize the workshop products and supporting information provided into a Phase III Workshop Report. The Phase III Workshop Report and the Final Draft Report summarizing study results may be sent out for independent scientific review (e.g. ISRP or ISAB). A Final Report of research results will then be prepared incorporating comments received during the public COE review process and the ISRP/ISAB review. Data will be made available for alternative analysis and publication.

Decision 2.B) Should the US Army Corps of Engineers fund the participation of additional scientists in the collaborative process to conduct and/or participate in the SRFC evaluation, data analysis, and reporting? (resolution pending)

Background 2.B) Collaborative processes are most successful when all parties are represented and contribute to project direction and product development. This creates a sense of ownership and helps assure the project is consistent with and supportive of each entities *goals/mandates. Even when authority and/or desire to participate in a collaborative process exist, participation can be constrained by staff availably. Funding some level of staff participation by all parties demonstrates a real commitment to collaboration and holds participants accountable for contributions. To date, the various ad hoc and individual efforts to develop study designs, data anaylses, and write/review reports has been done without COE funding beyond the Principle Investigators (NOAA, USFWS-IFRO, NPT). Some co-managers had the expectation that the COE would fund their staff to be involved with this effort. Others supported the approach regardless of funding status. Further, some parties feel the researchers conducting the study can adequately implement, analyze, and report the results, with guidance from collaborators provided through the workshop process described above and the peer-review process.*

Ad Hoc group members have recently discussed the following potential resolution. The COE will fund a series of workshops to discuss and incorporate concerns, suggestions, and contributions from all interested parties (see Decision 2.A background for scope of workshop details). Funding will be provided to cover; meeting independent facilitation including reports, room costs, and participants travel/per diem/lodging.

Support 2.B.i) Funding of non-principle investigator staff to enable/ensure participation in design, implementation, analysis, and report writing will significantly contribute to the quality of the end products (tribes, Oregon, Idaho)

Opposition 2.B.ii) The COE encourages and welcomes broad agency participation in development of objectives, and review of proposals and reports through the Anadromous Fish Evaluation Program. However, we do not provide funding for this participation. COE lacks authority to fund general process participation and has some contacting constraints with certain types of entities. (COE)

Small-work Group Consensus Decision 2.B: The COE will fund a series of workshops to discuss and incorporate concerns, suggestions, and contributions from managers and related collaborators. Funding could be provided to cover; meeting independent facilitation including reports, room costs, and participants travel/per diem/lodging (number of participants may be limited).

Decision 2.C) Should the ISAB, ISRP, or some other independent scientific group perform a scientific review of the study design, workshops, and or results?

Background 2.C) Review of the study proposal, participation in workshops, and review of results by an independent scientific group has been suggested as a way to resolve points of disagreement by some parties. Not all parties agree that review of this plan or the research efforts should be conducted by the ISAB or ISRP without a clear and useful purpose. However, other agencies believe that a review by an independent scientific source is a prudent way to proceed, given that this issue is surrounded in controversy. The Northwest Power and Conservation Council has had this study as an agenda topic at their monthly meetings for the past 4-5 months. They have expressed their intent to have an ISRP review conducted.

This is a decision that the USvOR parties may not have authority to make/influence. However, unless the study is funded through the Council process or is expressively included in the Council Fish and Wildlife Program, the Council has no jurisdiction in this issue.

Opposition 2.C.i) The Ad Hoc Group participants are the regional experts on Snake River fall Chinook salmon and hydro-system operation. The ISAB, ISRP, or other group of independent scientist would need to be "educated" by the ad hoc group members in order to perform a review. Independence does not mean unbiased (we all have biases). As such, adding one more technical opinion to an issue that already has different technical opinions does not move us forward. Their participation essentially becomes one of arbitrator (not the intended purpose for independent review). The AFEP process for selecting projects and reviewing draft reports is open to all entities. However, the AFEP process is a COE process and the COE has the authority to override fishery managers' project selection priorities in the AFEP process- this has often been a serious point of contention and a significant reason why the AFEP process will not be acceptable to many of the fisheries managers for this issue.

Opposition 2.C.ii) The content of the pending agreed to study design will be technically sound. However, aspects of the study will represent inclusion and/or exclusion of aspects resulting from the collaborative effort at the technical, management, and policy levels. Alteration of the agreed to study design based on a post hoc review becomes problematic.

Support 2.C.iii) The NPCC process requires an independent review for scientific adequacy. This is the type of issue for which the ISRP and ISAB were created. They have conducted several reviews on related topics in recent years, and their input is likely to improve this study. (NPCC, NOAA)

Small-work Group Consensus Decision 2.C: The workshop reports from Phase II and III could be sent for independent scientific review (eg ISRP or ISAB) for their review.

Topic 3: <u>Management process for applying results</u>

Decision 3.A) Should fish marking as prescribed in this study be discontinued after 5 years of marking before adult returns/results are complete?

Background 3.A) After the initial years of study are performed and the agreed-to number of years of marking and operations have been achieved, final results from the research will not be obtained until 4 years after the evaluation. Ie. We have done the study but don't have the results yet, what should we do while we wait for results? Other questions include "should changes to major operations be made after the evaluation based on preliminary results?" And "should additional requiring research surrogate production and marking for evaluation of alternative operations or new questions arise, should they proceed?" An additional debate centers around whether interim FCRPS operations should remain unchanged from those that occurred during the evaluation, should be changed based on preliminary results from the evaluation, or should be changed to either maximize the proportion of juvenile fish transported or left in-river.

Support 3.A.i) Continued production of surrogate fish and marking of general production to address alternative operational strategies or address new management questions might be desired prior to obtaining final results from this study. (NOAA)

Opposition 3.A.ii) General production of surrogate fish and marking of general production is costly, unwarranted, or not worth the risk prior to final results being obtained. Dam operations should remain the same as conducted during the study until all of the adults return back to the Lower Snake River (COE, tribes)

Small-work Group Consensus Decision 3.A: Fish production and marking as prescribed in the long-term framework and study design should be implemented for five years (release groups). Since low numbers of returning adults may, in some years, preclude the production of study fish, these years may not occur consecutively. After five years of marking, further discussion/justification for continuation could be considered at that time. There may good reason(s) to continue producing/marking fish for study or monitoring purposes, however that decision should be considered near the end of the 5 years of marking.

Decision 3.B) Should hydrosystem operation adaptive management related to Snake River fall Chinook salmon follow a pre-established decision tree, applying a standardized suite of primary metrics and precision targets?

Background 3.B) Hydrosystem operations in terms of flow and juvenile fish passage route, have been and continue to be very contentious. Presently, it is not clear how, what, or when hydro-system operation adaptive management decisions would be made regarding fall Chinook salmon based on the results of this and other studies. Attempts to control and constrain data collection, analysis, and recommendations has become an unfortunate reality due to ineffective communications, mistrust, and limited resources (money and fish). As such, a need exists to formally establish how decisions are to be made, who will be involved, how conflicts would be resolved, and what type of feed back loops would be used to communicate between groups and agencies.

This issue is primarily a management process problem, only indirectly related to the scope of research study designs. For example if SARs are the primary metric for the evaluation, what difference between SARs is acceptable to salmon managers to choose one migration strategy over another? What level of statistical precision is required to justify a change in transport operations for SRFC from current status quo? This helps communicate what level of risk each entity is willing to assume.

It does have overlap with study design content by guiding the magnitude of samples sizes and replication required, however approaches for these technical aspects have been decided upon. Development of future study design would benefit from a pre-established decision tree.

Support 3.B.i) Developing and implementing a pre-established decision tree/matrix is desired. This approach would help identify/collect the specific data types needed for management decisions, and avoid collection of data not appropriate or insufficient for guiding decisions. (CBFWA/FPC, CRITFC, NPT).

Opposition 3.B.ii) Identification of all the detailed considerations used in management decisions years in advance is not feasible. Many aspects are intangible, and similar data may result in different management recommendations depending on agency goals. As such, adaptive management should not be hard wired, but should attempt to follow a transparent, but flexible process. (NPT, CRITFC, COE)

Small-work Group Consensus Decision 3.B: No. However, efforts should continue to better understand and communicate management decisions to be made and the level of precision needed to inform those decisions.

Conclusion

This plan is intended to be a living document that will be updated as necessary in accordance with regional technical input and ongoing discussions associated with the development and implementation of the FCRPS BiOp. It must be understood that as discussions occur in the remand process, as FCRPS BiOp activities occur, and other regional efforts continue forward, that this plan will be modified accordingly. However, the intent is to follow this plan as closely as possible, in a regional commitment to provide both sufficient fish and sufficient years of study to develop an acceptable management strategy for this species. Therefore, the baseline duration, marking levels and design are expected to change very little.

Attachment 1

Copy for Betty, Ed + Jay

Oregon

Theodore R. Kulongoski, Governor

MAR 23 2006

Nez Perce

March 9, 2006

Brigadier General Gregg F. Martin,
Commander and Division Engineer
U. S. Army Corps of Engineers,
Northwestern Division
P.O. Box 2870
Portland, OR 97208-2870

Dear Brigadier General Martin:

On February 8, 2006, *the United States v Oregon* parties discussed the request by the U.S. Army Corps of Engineers (ACOE) to PIT-tag hatchery-produced Snake River fall Chinook as part of an evaluation of passage alternatives through the Federal Columbia River Power System. The 2005-2007 Interim Management Agreement (Section III.E.1 (b)) directs the *U.S. vs. Oregon* parties to review and approve research designs involving hatchery-origin Snake River fall Chinook "in order to protect the integrity of the parties' production commitments." Artificial production of Snake River fall Chinook salmon occurs at facilities in the Clearwater and Snake rivers as part of the Lower Snake River Compensation Program at Lyons Ferry Hatchery, the Fall Chinook Acclimation Program, the Idaho Power Program, and the Nez Perce Tribal Hatchery.

On behalf of the *U.S. v Oregon* parties, we are writing to inform you about agreements the parties made regarding conditions and recommendations for the use in 2006 of Snake River fall Chinook hatchery sub-yearlings in an evaluation of how hydropower system operations, including transportation, affect the survival of hatchery fish. There are two "groups" of hatchery fish involved in the ACOE study proposal: 1) surrogate sub-yearlings reared to represent the size of wild fish, and 2) general production sub-yearlings.

Surrogate Sub-yearlings

The ACOE study proposal called for the PIT-tagging and release of up to 328,000 surrogate-sized fish (30% in the Clearwater and 70% in the Snake). Surrogate fish would be released between late-May to early-July and, based on emigration observations in 2005, are expected to experience summer spill conditions. In 2006, the surrogate fish would include a designated "transportation group" and a designated "bypass group".

The *U.S. vs. Oregon* parties support PIT-tagging up to 328,000 surrogate-sized fish in 2006, as described in the ACOE study proposal. Any future commitments will be based upon agreement by the *U.S. v Oregon* parties on a long-term evaluation plan.

General Production Sub-yearlings

The ACOE study proposal called for the PIT-tagging and release of up to 328,000 general-production fish. Because of the lack of an agreed-to long-term study design, the *U.S. v Oregon* parties, instead, agree to PIT-tag and release up to 185,000 "general production" group fish in 2006, as described in the attached Table 1. This number includes 19,500 fish already ear-marked for PIT-tagging under existing marking programs, and up to an additional 165,500 fish PIT-tagged for the evaluation. The *U.S. v Oregon* parties agree to this marking in 2006 under the following assumptions (which do not necessarily reflect a technical consensus among the parties, but interim agreement on the terms necessary to implement marking this year):

1. The commitments described in this letter are in effect for 2006 only. Any future commitments would be conditioned upon agreement by the *U.S. v Oregon* parties on a long-term evaluation plan.
2. The long-term evaluation will be included as part of a "regional" research, monitoring and evaluation plan developed in the remand process for the Biological Opinion on the Federal Columbia River Power System.
3. In 2006, the U.S. Army Corps of Engineers and/or Bonneville Power Administration will work cooperatively with appropriate *U.S. v Oregon* parties to fund the PIT-tagging of fall Chinook from the Little White Salmon Hatchery and, if feasible, from the Deschutes River and Hanford Reach of the Columbia River. *U.S. v Oregon* scientists will provide numbers to be PIT-tagged from each location.
4. The evaluation in 2006 will not include a "bypass treatment" group for Snake River "general production" hatchery fish, except as necessary to estimate reservoir-reach in-river survival of juvenile salmon. Except as mandated by existing agreements, fall Chinook collected at Snake River projects will be transported and not returned to the river.
5. The PIT-tagging of the "general production" hatchery group will be representative of the group at-large, and will be consistent with the programs described in Table B5 of the *U.S. v Oregon* "2005-2007 Interim Management Agreement for Upriver Chinook, Sockeye, Steelhead, Coho, and White Sturgeon". Production fish will be PIT-tagged as described in the attached Table 1.
6. The study sample procedures and statistical designs for adult scale sampling will be coordinated with the existing run reconstruction analysis.

Brigadier General Gregg F. Martin
March 9, 2006
Page Three

The parties of *U.S. v Oregon* recognize that planned hydropower operations and potentially good water conditions in 2006 may provide a unique opportunity for learning. It is in this spirit that the Parties support efforts this year to PIT-tag representative numbers of naturally- and hatchery-produced fall Chinook in the Snake River basin and lower Columbia River to evaluate their survival.

Sincerely,

Edward C Bowles

Ed Bowles
Fish Division Administrator
Oregon Department of Fish and Wildlife

Rebecca Miles
Chairman, Tribal Executive Committee
Nez Perce Tribe

cc: US v Oregon Parties
Steve Wright, Bonneville Power Administration

Attachment

APPENDIX B

Appendix B. Funding status for proposed tasks and associated activities by study year. Funding sources include ongoing Bonneville Power Administration (BPA) projects, Pacific Salmon Commission (PSC), and U.S. Fish and Wildlife Service (FWS). An X indicates funding is needed for a listed activity.

Tasks and activities	2008	2009	2010	2011	2012
Objective 1.—Tagging and releasing Snake River Basin surrogate subyearlings (NMFS lead)					
Task 1.1 Request fish through U.S. v. OR	X	X	X	X	X
Task 1.2 Surrogate subyearling transfer and rearing					
Snake Basin surrogate subyearlings					
Hatchery transfers	X	X	X	X	X
Rearing	X	X	X	X	X
Disease testing	X	X	X	X	X
Task 1.3 Separation-by-Code designation, tagging, and release for surrogate subyearlings					
Snake Basin surrogate subyearlings					
PIT tags and tagging	X	X	X	X	X
Transport & release	X	X	X	X	X
Objective 2.—Tagging and releasing Snake River Basin production subyearlings (NPT lead)					
Task 2.1 Request fish through U.S. v. OR	X	X	X	X	X
Task 2.2 Separation-by-Code designation, tagging, and release for production subyearlings					
Snake Basin production subyearlings					
PIT tags and tagging	BPA	BPA	X	X	X
Supplemental PIT tags and tagging	X	X	X	X	X
Transport, acclimation & release	FWS	FWS	FWS	FWS	FWS
Objective 3.—Tagging and releasing Snake River Basin production yearlings (NPT lead)					
Task 3.1 Request fish through U.S. v. OR	X	X	X	X	X
Task 3.2 Separation-by-Code designation, tagging and release for production yearlings					
Snake Basin production yearlings					
PIT tags and tagging	BPA	BPA	X	X	X
Supplemental PIT tags and tagging	X	X	X	X	X
transport, acclimation & release	FWS	FWS	FWS	FWS	FWS

Objective 4.—Tagging and releasing Snake River natural subyearlings (IFRO lead).					
Task 4.1 Separation-by-Code designation, tagging & release for natural/wild subyearlings					
Snake River natural subyearlings					
Capture	BPA	BPA	X	X	X
supplemental sampling and PIT tags and tagging	X	X	X	X	X
genetic sampling / DNA analysis of natural fish	X	X	X	X	X
Objective 5.—Tagging and releasing Clearwater River natural subyearlings (NPT lead).					
Task 5.1 Separation-by-Code designation, tagging & release for natural/wild subyearlings					
Clearwater River natural subyearlings					
capture	BPA	BPA	X	X	X
supplemental sampling and PIT tags and tagging	X	X	X	X	X
genetic sampling / DNA analysis of natural fish	BPA	BPA	X	X	X
Objective 6.—Tagging and releasing Columbia River Basin subyearlings (CRFPO lead).					
Task 6.1 Tagging and release of subyearlings					
Hanford Reach natural subyearlings					
capture & CWT	PSC	PSC	PSC	PSC	PSC
supplemental sampling and PIT tagging	PSC	X	X	X	X
Deschutes River natural subyearlings					
capture & CWT	PSC	PSC	PSC	PSC	PSC
supplemental sampling and PIT tags and tagging	X	X	X	X	X
genetic sampling / DNA analysis of natural fish	X	X	if needed	if needed	if needed
Task 6.2 Tagging and release of subyearlings					
Little White Salmon production subyearlings					
PIT tags and tagging	FWS	FWS	X	X	X
Objective 7.—Conduct supplemental evaluations					
Task 7.1 Evaluation of surrogate performance (IFRO lead)	X	X	X	X	X
Task 7.2 Evaluation of migration of Snake River subyearlings through the FCRPS (IFRO lead)	BPA	BPA	X	X	X
Task 7.3 Evaluation of migration of Columbia River subyearlings through the FCRPS (CRFPO lead)	X	X	X	X	X
Task 7.4 Scale pattern analyses for understanding life-history diversity (NMFS lead)	X	X	X	X	X
Task 7.5 Scale pattern analyses on Columbia River fish (CRFPO lead)	X	X	X	X	X

Additional tasks for improving study reliability					
Evaluate the use of 8.5 mm PIT-tags to represent smaller fish					
Hanford Reach	PSC	X	X	X	X
Deschutes River	X	X	X	X	X
Phase II: Exploring Methods for Analysis					
Travel support for participants	X	X	X	X	X
Facilitator	X	X	X	X	X
Workshop results	X	X	X	X	X
Phase III: Final Data Analyses and Reporting					
Travel support for participants	X	X	X	X	X
Facilitator	X	X	X	X	X
Workshop results	X	X	X	X	X

2008 PRELIMINARY RESEARCH PROPOSAL

Submitted to:

U.S. Army Corps of Engineers
Walla Walla District
Anadromous Fish Evaluation Program

by

Department of Fisheries and Wildlife
Oregon State University
Corvallis, OR 97331-3803

Title: **Evaluate the Impacts of Avian Predation on Salmonid Smolts from the Columbia and Snake Rivers**

Study Code: AVS-W-03

Project Leaders:

Daniel D. Roby, Professor
Principal Investigator
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Project Duration: 2004 - 2010 (with 2009 - 2010 as optional years)

Original Submission Date: August 2007

Revision and Resubmission Date: October 16, 2007

SUMMARY

This study is designed to help determine the extent to which avian predation on ESA-listed salmonids reduces survival and limits recovery of these stocks on the Columbia River Plateau. We will investigate the distribution, colony size, productivity, and diet of piscivorous waterbirds at breeding colonies on or near the mid-Columbia River and lower Snake River to determine which waterbird colonies pose the greatest risk to smolt survival. Our proposed research will focus on colonial waterbirds, primarily Caspian terns (*Hydroprogne caspia*) and double-crested cormorants (*Phalacrocorax auritus*), and to a lesser extent gulls (*Larus* spp.), American white pelicans (*Pelecanus erythrorhyncus*), and perhaps other avian predators. The primary objectives of this study are to determine (1) the fish species comprising the primary prey for piscivorous waterbirds nesting at selected colonies on the Columbia Plateau and, in particular, the proportion of the diet that consists of juvenile salmonids; (2) the size of each waterbird colony (number of breeding pairs); (3) nesting success at each colony (average number of young fledged per breeding pair); and (4) factors limiting the size and productivity of each colony, to the extent possible. Bioenergetics modeling and smolt PIT tag recoveries will be used to assess the relative impacts of piscivorous waterbirds on different species and stocks of juvenile salmonids from the Columbia River basin. Data will also be collected to assess the biotic and abiotic factors that account for differences in smolt vulnerability to avian predators on the Columbia Plateau. Finally, we will evaluate to what extent piscivorous waterbird management elsewhere (e.g., in the Columbia River estuary) affects the distribution and abundance of piscivorous waterbirds and their impacts on the survival of salmonid smolts on the Columbia Plateau. Data collected as part of this study will help guide managers in developing management initiatives for reducing smolt losses to avian predators along the mid-Columbia and lower Snake rivers, initiatives that are science-based, defensible, cost-effective, and have a high probability of success.

BACKGROUND AND RATIONALE

Previous research has measured population trends, diet composition, and consumption of salmonid smolts by piscivorous waterbirds nesting at colonies along the lower and mid-Columbia River (Collis et al. 2001; Collis et al. 2002; Roby et al. 2002; Roby et al. 2003; Ryan et al. 2003; Anderson et al. 2004; Suryan et al. 2004; Antolos et al. 2005). A system-wide assessment of avian predation using the available data suggests that the most significant impact of avian predation on survival of juvenile salmonids occurs in the Columbia River estuary, followed by McNary Pool (Collis et al. 2001; Collis et al. 2004). Although the overall annual consumption of juvenile salmonids by avian predators is an order of magnitude greater at bird colonies in the Columbia River estuary compared to colonies on the mid-Columbia River (*ca.* 10 million versus *ca.* 1 million, respectively), predation rates on some in-river migrant fish from the Snake River are as high or higher in the mid-Columbia as in the estuary (Ryan et al. 2003; Collis et al. 2004; Antolos et al. 2005; Roby et al. 2005). For example, predation rates by Caspian terns (*Hydroprogne caspia*) on in-river migrating, PIT-tagged smolts from the threatened Snake River

Steelhead ESU were quite similar for terns nesting at the East Sand Island colony (river km 8) and those nesting at the Crescent Island colony (river km 510) (10.8% and 13.9%, respectively; averaged over 2004-2005; A. Evans, RTR, unpublished data). This result is surprising because the Crescent Island tern colony is roughly 1/20th the size of the East Sand Island tern colony in the Columbia River estuary (Roby et al. 2005). The reasons for the high vulnerability of Snake River steelhead to predation by Crescent Island terns (and perhaps other avian predators on the mid-Columbia River) is not clearly understood, and will be one of the major research tasks addressed in this study.

Caspian terns and double-crested cormorants (*Phalacrocorax auritus*) are the two species of piscivorous waterbirds responsible for the vast majority of losses of salmonid smolts to avian predators in the Columbia River basin (Collis et al. 2002; Collis et al. 2004; Roby et al. 2005). The Caspian tern colony on Crescent Island, just below the confluence of the Snake and Columbia rivers, is the largest of its kind on the Columbia Plateau at about 500 breeding pairs (Collis et al. 2004; Roby et al. 2005). Also near the confluence, on Foundation Island (river km 519), is the largest double-crested cormorant colony on the mid-Columbia River at more than 300 nesting pairs (Collis et al. 2004; Roby et al. 2005). Annual smolt consumption by the Crescent Island tern colony has ranged from 400,000 to 680,000 smolts during 2000-2005 (Roby et al. 2005). Annual smolt consumption by the Foundation Island cormorant colony is currently unknown, but is likely to be somewhat less than for Crescent Island terns due to the smaller size of the colony and the lower percentage of salmonids in the diet (Roby et al. 2005).

It should be noted, however, that unlike the Crescent Island tern colony, which has remained relatively stable in size, the Foundation Island cormorant colony has been growing steadily (20% increase over the past three years; Roby et al. 2006). The prospects for further growth in numbers of double-crested cormorants nesting along the mid-Columbia and lower Snake rivers is good because double-crested cormorants are not as constrained by the availability of suitable nesting habitat as are Caspian terns; cormorants commonly nest in trees, on navigational structures, on bridges, and on the ground on islands, both on bare substrate and amidst vegetation. Furthermore, unlike terns, which migrate out of the region following the breeding season, a sizable but unknown number of cormorants spend most or part of the non-breeding season on the mid-Columbia and lower Snake rivers. The impacts of these post-breeding birds on smolt survival, particularly late migrating and over-wintering fall Chinook salmon, are unknown. Based on all these considerations, plus the much higher food requirements of cormorants compared to terns, it is possible that the impact of cormorant predation on smolt survival may soon eclipse that of tern predation in the region, just as has been the case for terns and cormorants nesting in the Columbia River estuary (Collis et al. 2004; Roby et al. 2005; Roby et al. 2006). Another major task of this study is to quantify the effects on salmonid smolt survival of the growing numbers of double-crested cormorants on the mid-Columbia and lower Snake rivers, both during and after the breeding season, and to determine what salmonid stocks are most vulnerable to cormorant predation and why.

A number of large breeding colonies of other piscivorous waterbirds (i.e., California gulls [*Larus californicus*], ring-billed gulls [*L. delawarensis*], American white pelicans [*Pelecanus erythrorhyncus*]) currently exist along the mid-Columbia River (Roby et al. 2006). Previous research (Collis et al. 2002; B. Ryan, NOAA Fisheries, unpublished data) indicated that smolt losses to gulls and pelicans on the Columbia Plateau were insignificant compared to those caused by Caspian terns and double-crested cormorants nesting on the lower and mid-Columbia River. Recent data, however, suggest that gull and white pelican colonies along the mid-Columbia River may be growing (Collis et al. 2004; Roby et al. 2005; Roby et al. 2006), and that predation on juvenile salmonids may be increasing, potentially reaching levels that are of concern to fisheries managers. For example, the American white pelican colony on Badger Island (river km 511) has increased four-fold from 2001-2005 to more than 1,000 adults counted on-colony in 2005. Recent evidence also suggests that California gulls nesting at Miller Rocks near the mouth of the Deschutes River may also be preying upon a substantial number of juvenile salmonids (N. Hostetter, OSU, unpublished data). As part of this study, we will determine the population trajectories and diet (when feasible) of piscivorous waterbirds other than Caspian terns and double-crested cormorants in order to determine the magnitude and trend for total losses of juvenile salmonids to avian predators on the mid-Columbia and lower Snake rivers.

Further management of Caspian terns to reduce predation on juvenile salmonids in the Columbia River estuary is imminent; the Caspian Tern Management Plan for the Columbia River Estuary has the management goal of redistributing approximately half of the East Sand Island colony to alternative colony sites in Oregon and California (USFWS 2005; N. Seto, USFWS, personal communication). Management to reduce or limit smolt losses to the expanding double-crested cormorant colony in the estuary is under consideration and may also involve relocation of nesting cormorants to alternative sites. We know that Caspian terns readily move between nesting colonies in the Columbia River estuary and colonies on the mid-Columbia River, based on re-sightings of banded individuals (Collis et al. 2004; Roby et al. 2005; Y. Suzuki, OSU, unpublished data); this is also probably the case for double-crested cormorants. It is likely that at least some of the birds displaced from existing colonies in the Columbia River estuary will relocate to colonies on the Columbia Plateau. As part of this study we will assess the inter-colony movements of banded individuals to determine how bird management in the Columbia River estuary and elsewhere affects the distribution, numbers, and smolt predation rates of piscivorous waterbirds on the Columbia Plateau. These data are crucial in order to confirm that increases in smolt survival associated with piscivorous waterbird management in the estuary and elsewhere are not offset by increased avian predation on juvenile salmonids along the mid-Columbia and lower Snake rivers.

Beginning in 2007, the U.S. Army Corps of Engineers committed to decrease the proportion of juvenile salmonids that are transported around the hydro-system, thereby increasing the proportion that migrate in-river, as well as delay the initiation of the program to transport smolts around the hydrosystem. These changes will result in more salmonid smolts being available to avian predators on the mid-Columbia River. Our research will evaluate how changes in hydrosystem operation and configuration (e.g., delay in the onset of transportation from early April to early May and overall reduction in the number of smolts transported) affect avian predation rates and overall salmonid consumption.

PROGRAM FUNDING

This proposal is for funding of research, monitoring, and evaluation of avian predation on the Columbia Plateau during 2007-2010. Many of the research objectives and tasks proposed here for the Columbia Plateau are also proposed for the Columbia River estuary with funding from the Bonneville Power Administration as part of their Fish and Wildlife Program. The proposal submitted to BPA also advocates a comprehensive look at avian predation throughout the Columbia River basin during 2007-2009, in addition to the focused investigation of avian predation in the estuary. Funding from the BPA in 2008 and beyond looks favorable; however, the Mainstem Systemwide Review Team has recommended level funding from BPA during 2006-2009, which would preclude support from BPA for RM&E along the mid-Columbia (i.e., would provide funding for estuary studies only). As was the case in 2007, there is no overlap in funding of research proposed here with that proposed to BPA in 2008; BPA would fund the estuary work and the Walla Walla District, USACE would fund the work on the mid-Columbia and lower Snake rivers. In the event that funding from BPA is significantly cut or eliminated during 2008-2009, we would like to request additional funding from the Walla Walla District, USACE as part of this contract in order to collect the necessary information to assess the over-all impact of avian predators in the Columbia River Basin). Finally, we would like to point out that future RM&E on the Columbia Plateau will depend on results from our studies during 2004-2007, results that are not yet available in their entirety. Thus, some flexibility with regard to the details of research objectives, tasks, and funding for this project in out-years may be warranted.

OBJECTIVES AND METHODOLOGY

Objective 1. Research, monitor, and evaluate predation on salmonid smolts by Caspian terns on the Columbia Plateau.

Task 1.1. Determine colony size, habitat use, nesting success, and factors limiting colony size and nesting success of the Caspian tern colony on Crescent Island (**on-going**).

Prior to the arrival of breeding terns at Crescent Island, a grid will be placed on the colony to facilitate colony counts and monitoring of nesting success. Direct counts of adult terns on the colony will be conducted at frequent intervals from an observation blind at the edge of the colony and averaged over 2-week periods throughout the nesting season. Counts of incubating adult terns late in the incubation period will be used to estimate the size of the Crescent Island tern colony (see Roby et al. 2002). Multiple counts will be conducted in order to calculate 95% confidence limits for the estimate of the number of breeding pairs. An aerial photo of the colony will also be taken late in the incubation period to determine habitat use and total colony area occupied by nesting terns. Colony size and habitat use will be compared with previous years and among colony sites.

Nesting success at the Crescent Island colony will be measured using ground counts of young terns near fledging age (see Roby et al. 2002). Multiple counts will be conducted in order to calculate 95% confidence limits for the estimate of the number of fledglings produced at the colony. We will determine average clutch size, hatching success, and nestling survival rate for a sample of nests on the colony. Nesting success (i.e., productivity) will be compared with previous years and among tern colony sites.

Data will also be collected on gull kleptoparasitism rates on terns, disturbance rates to the tern colony, predation rates on tern nests, and other causes of tern nesting failure in order to evaluate those factors that limit nesting success at the Crescent Island Caspian tern colony.

Task 1.2. Determine diet composition and consumption of juvenile salmonids by Caspian terns nesting on Crescent Island (**on-going**).

The taxonomic composition of the diet of Caspian terns nesting on Crescent Island will be determined by direct observation of adults as they return to the colony with fish (i.e., bill load observations). The target sample size will be 150 bill load identifications per week at Crescent Island. Prey items will be identified to the taxonomic level of family. We will identify prey to species, where possible, and salmonids will be identified as either steelhead or 'other salmonids' (i.e., Chinook salmon, coho salmon, or sockeye salmon). Steelhead will be distinguished from 'other salmonids' by the shape of the anal and caudal fins, body shape and size, coloration and speckling patterns, or a combination of these characteristics. The percentage of each prey type among the identifiable prey items in tern diets will be calculated for each 2-week period throughout the nesting season. The diet composition of terns over the entire breeding season will be based on the percentage of each prey type during each 2-week period, adjusted for the average colony size during that 2-week period. Samples of fish transported by terns to the colony will not be collected at the Crescent Island tern colony due to the potential impact of this type of sampling on such a small colony.

Estimates of annual smolt consumption for the Crescent Island Caspian tern colony will be calculated using a bioenergetics modeling approach (see Antolos et al. [2005] for a detailed description of model structure and input variables). We will use a Monte Carlo simulation procedure to calculate 95% confidence intervals for estimates of smolt consumption by terns.

Some salmonid smolts that are captured by terns and transported back to the colony are pirated by gulls; at the Crescent Island tern colony these rates of kleptoparasitism by resident California gulls can be high. Bioenergetics models do not include estimates of these kleptoparasitized smolts. We will measure kleptoparasitism rates (i.e., stealing of fish carried in the bills of terns by gulls) at the Crescent Island tern colony. We will use focal observations of terns carrying fish to the colony and record the fate of each fish observed. Fish fate will be classified as either a kleptoparasitism, courtship feed, chick feed, self feed, gull chase/no feed, tern chase/no feed, or left colony/no feed. These data will be used to estimate the proportion of fish captured by terns that are consumed by terns relative to the proportion captured by terns that are kleptoparasitized by gulls. These data will then be used to adjust estimates of smolt consumption by terns (see above) to account for fish kleptoparasitized by gulls.

Task 1.3. Determine species-specific and stock-specific (where feasible) predation rates on juvenile salmonids from the Snake and Columbia rivers by Caspian terns nesting on Crescent Island (**on-going and completed**).

We will assess species and stock-specific predation rates using salmonid PIT tags recovered at the Crescent Island tern colony (see Ryan et al. 2001a, 2001b; Collis et al. 2001; Glabek et al. 2003; Ryan et al. 2003; Antolos et al. 2005). This approach will allow us to use two independently-derived estimates of predation – those derived from PIT tags and those derived from bioenergetics modeling (see Task 1.2.) – to evaluate the impact of Crescent Island terns on juvenile salmonids.

Each year millions of juvenile salmonids in the Columbia River basin are implanted with PIT tags to gather information on downstream survival and behavior. These tags provide data on the species of fish, run of fish (when known), release date, release location, and other information. Thousands of these tagged fish are consumed annually by avian predators, and the tags deposited on nesting colonies throughout the Columbia River basin (Collis et al. 2001; Ryan et al. 2001a; Ryan et al. 2003; Antolos et al. 2005). On-colony recoveries of PIT tags, along with releases and detections of PIT-tagged smolts migrating in-river, can be used to estimate minimum stock-specific predation rates and to evaluate the relative vulnerability of salmonid stocks to avian predators (Collis et al. 2001; Ryan et al. 2003; Roby et al. 2003; Glabek et al. 2003; Antolos et al. 2005).

We will measure predation rates on different salmonid species, run types, and stocks (as defined by NOAA Fisheries' Evolutionarily Significant Units or ESUs) for those groups of fish where a sufficient sample is tagged. For Caspian terns nesting on Crescent Island, stock-specific predation rates will be generated for PIT-tagged fish migrating in-river past Crescent Island (i.e., excludes all PIT-tagged smolts captured at dams on the lower Snake River and transported past Crescent Island). Predation rate estimates do not account for mortality that takes place between the fish's release location and the detection site (i.e., Crescent Island) and, as such, are minimum estimates of tern predation rates because the numbers of smolts susceptible to tern predation are inflated.

A more direct or reach-specific measure of tern predation rates will be calculated by limiting the analysis to actively-migrating smolts that were last detected within the foraging range of Crescent Island terns. For Snake River stocks, PIT tags used in analyses will be from smolts that have been tagged and released into the river above Crescent Island and interrogated passing Lower Monumental and/or Ice Harbor Dam (lowest PIT tag interrogation points on the Snake River). Similarly for Upper Columbia River stocks, PIT tags will be from smolts that have been interrogated or tagged at Rock Island Dam (lowest PIT tag interrogation point on the mid-Columbia River above Crescent Island). On-colony detection rates will be calculated by simply dividing the total number of tags detected on the Crescent Island tern colony (sorted by location, species, and stock) by the corresponding number of interrogated PIT-tagged fish. Temporal trends for reach-specific predation rates will be investigated based on the passage date of interrogated smolts. Again these predation rate estimates are minimums because we are unable to account for mortality that takes place between the fish's release/tagging location and the detection site.

To more accurately assess the impact of Crescent Island terns on salmonid stocks from the Snake River, tern predation rates will be corrected to account for the proportion of those stocks that were collected for transportation and bypassed the federal hydro-system in barges or trucks (NMFS 2000). These transported fish are not available as prey for Crescent Island terns. This correction is not necessary for Upper Columbia River stocks because there is no smolt transportation program at Columbia River dams above Crescent Island (i.e., all Upper Columbia River smolts must migrate in-river past Crescent Island).

Accurate data on the abundance of smolts within a given river segment are needed to derive consumption estimates based on predation rates calculated from PIT tag recoveries (i.e., by multiplying the total number of available smolts by the corresponding predation rate estimate), thereby calculating predation rates as a proportion of smolts available to Crescent Island terns. In cooperation with NOAA Fisheries (POC: Ben Sandford), we will estimate absolute abundance of Snake River smolts downstream of Lower Monumental Dam so that the predation rate estimates based on PIT tag detections on bird colonies can be used to generate estimates of bird consumption of various salmonid species and stocks from the Snake River. Predation rate estimates for bypassed and non-bypassed smolts combined will be used in cases where groups of non-bypassed PIT-tagged fish can be identified. Estimates of absolute smolt abundance will be generated by dividing daily smolt passage counts at the dam by daily PIT tag detection probabilities (see Sandford and Smith 2002), using a bootstrap method to calculate variance.

Predation rate estimates based on PIT tag recoveries are minimums because (1) an unknown proportion of consumed tags are deposited off-colony, (2) wind and water erosion removes an unknown number of tags from the colony, and (3) on-colony detection efficiency is < 100% for various reasons (Collis et al. 2004; Roby et al. 2005; Ryan et al. 2003). To address these uncertainties, we will collect data to estimate the magnitude of these biases, and correction factors will then be used to adjust all predation rate estimates derived from PIT tag recoveries (see below for more explanation) .

PIT Tag Recovery (**on-going**): As was previously accomplished by NOAA Fisheries, we will detect and recover PIT tags from the Crescent Island tern colony in August of each study year using previously established methods. Physical or hand removal of PIT tags will be used to minimize PIT tag collision (a phenomenon whereby high tag densities render PIT tags unreadable using electronic equipment). We will physically remove tags from the colony site by breaking up the surface layer of soil with rakes equipped with magnets and then remove tags by rolling large sweeper magnets over the colony surface. To ensure that tags are removed efficiently, 60-cm wide transects will be spread across the colony surface and used to guide removal efforts. Each transect will be swept for tags at least twice. During hand removal of PIT tags, other fish tags (i.e., radio tags, acoustic tags, and floy tags) will also be collected from the colony site and returned to the appropriate project sponsor, if possible.

Following hand-removal efforts, collaborators from NOAA Fisheries will systematically scan the Crescent Island tern colony site for PIT tags using a flat-plate detector/transceiver mounted on a four-wheel-drive vehicle. We will use hand-held, pole-mounted transceivers to detect tags in areas inaccessible to the flat-plate detector (see Ryan et al. 2003 for detailed methods). All PIT tags detected/recovered using hand and electronic methods will be submitted to PTAGIS for integration into the regional PIT tag database.

PIT Tag Detection Efficiency (**on-going**): Not all smolt PIT tags that Caspian terns egest on their nesting colony are subsequently detected on-colony after the nesting season. To address this, we will continue to measure PIT tag detection efficiency by sowing 800 PIT tags on the Crescent Island tern colony in four discrete plots on four different occasions: (1) prior to the birds' arrival on colony, (2) during egg incubation, (3) just prior to chick fledging, and (4) following the nesting season once the birds have left the colony. Each discrete plot will measure 5 m x 10 m and plots will be located within the core colony area. Detection efficiency estimates will be calculated relative to the sowing date and plot, thereby describing both temporal and spatial variation in detection efficiency.

PIT Tag Deposition Rates (**completed sub-task**): Not all smolt PIT tags consumed by terns are deposited on the nesting colony. Some proportion of consumed PIT tags are regurgitated by terns while they are not on-colony; for example, at off-colony loafing areas. Therefore, predation rate estimates based on on-colony PIT tag recoveries are still minimums, even after accounting for detection efficiency. In 2004-2006 we conducted two experiments to measure on-colony deposition rates of PIT tags ingested by terns nesting on Crescent Island. First, we allowed terns to forage on PIT-tagged fish confined to net pen enclosures and then scanned for those tag codes at the colony following the nesting season. Second, we captured nesting terns on colony and force fed them PIT-tagged fish and then scanned for those tag codes following the nesting season. We believe we now have sufficient data to accurately estimate PIT tag deposition rates for Crescent Island terns, and recommend that PIT tag deposition studies on terns be discontinued in 2008.

Task 1.4. Determine how various biotic and abiotic factors are associated with differences in smolt vulnerability to predation by Crescent Island terns (**on-going, expanded, and new**).

Avian predation rates vary by salmonid species, run-type, stock, and rearing type (Collis et al. 2001; Ryan et al. 2003). Furthermore, predation rates for specific groups of fish can vary greatly from one year to the next (Antolos et al. 2005; Collis et al. 2004). Despite this well-documented variation, limited data are available to determine what biotic and abiotic factors account for differences in smolt vulnerability to avian predators. Previous research suggested that low river flows may be associated with higher avian predation rates (Antolos et al. 2005), that high prey densities may reduce smolt susceptibility to predation (Roby et al. 2005), and that smolt origin (i.e., hatchery versus wild: Collis et al. 2001; Ryan et al. 2003) and "quality" (Mesa 1994; Schreck and Stahl 1998; Schreck et al. 2006) may be associated with differences in vulnerability to avian predation.

In 2008, we will continue our investigations of the relative importance of biotic and abiotic factors for explaining differences in tern predation rates on juvenile salmonids. Based on the initial success of the pilot study conducted this year[1], we propose to (1) continue the PIT-tagging and release of steelhead at the juvenile fish facilities of Lower Monumental and Ice Harbor dams, and

[1] A total of 7,093 steelhead smolts were PIT-tagged at either Lower Monumental or Ice Harbor dam during the 2007 smolt migration year as part of this study. Thus far, 539 of those tagged fish have been recovered on 6 different piscivorous waterbird colonies on the Columbia Plateau. Analysis of these data is ongoing and the results will be made available in a subsequent report.

(2) expand our steelhead PIT-tagging efforts to include steelhead at Rock Island Dam (upper Columbia ESU). This work is designed to improve the precision of our estimates of predation on steelhead from the Snake and Upper Columbia rivers, based on PIT tag recoveries at various piscivorous waterbird colonies on the Columbia Plateau (see Task 1.3). Additionally, by quantifying the physical condition of the PIT-tagged steelhead used in this study, we will determine which biotic factors (e.g., size, physical injuries, pathogen prevalence, disease incidence, whole body chemistry) affect steelhead smolt vulnerability to avian predation.

Steelhead have been selected as the target species for this task because prior research has shown that they are the most vulnerable to predation by birds nesting on the Columbia River (Ryan et al. 2003; Antolos et al. 2005; Collis et al. 2004). The benefits of using steelhead for this study are four fold: (1) we are likely to recover sufficient numbers of PIT tags from steelhead on bird colonies on the Columbia River to address a multiplicity of predation-related questions (more so than any other salmonid species or stock), (2) the incidence of morphological abnormalities (e.g., fungal infections, de-scaling, parasites, body injuries, etc.) is greater in steelhead than in other salmonid species (USACE, unpublished data), (3) a better understanding of those factors responsible for the higher vulnerability of steelhead to avian predation will help resource managers implement measures to reduce avian predation on steelhead, if warranted and feasible, and (4) steelhead from both the Snake and Upper Columbia rivers are listed under the Endangered Species Act, and data to evaluate the impact of avian predation on these stocks are needed to evaluate recovery options.

PIT Tag Studies (**expanded**): In 2008, we propose to continue to PIT-tag and quantify the condition of run-of-the-river steelhead smolts encountered at the juvenile fish facilities of Lower Monumental (LMN) and Ice Harbor (ICH) dams. Sampling and tagging steelhead smolts will allow us to test hypotheses concerning how differences in smolt morphology, condition, abundance, origin, river conditions, and dam operations are associated with differences in smolt vulnerability to avian predation. Lower Monumental Dam represents the edge of the foraging range of Caspian terns nesting at Crescent Island (Collis et al. 2003), making the dam an excellent location to release study fish. Ice Harbor dam (50 Rkm downstream of LMN) is also well within the foraging range of Crescent Island terns and is in close proximity to the Foundation Island colony of double-crested cormorants (*see* Task 2.4).

In addition to PIT-tagging steelhead from the Snake River, we propose a pilot study to PIT-tag run-of-the-river juvenile steelhead encountered at Rock Island Dam (located on the mid-Columbia River at Rkm 730) for purposes of evaluating avian predation on Upper Columbia Steelhead. Presently, very few empirical data exist to determine the impact of avian predators in the McNary pool on this critically endangered ESU. This is because very few run-of-the-river steelhead smolts from this region are PIT-tagged, and those that are PIT-tagged are often not representative of the entire ESU (e.g., tagged at hatcheries). In order to assess the impacts of avian predators on the Upper Columbia Steelhead ESU, we propose PIT-tagging run-of-the-river steelhead, both hatchery and wild fish, throughout the 2008 smolt out-migration. Rock Island Dam has been selected for this task because it is the lowest dam on the mid-Columbia River where run-of-river fish from each of the four stocks of the endangered Upper Columbia Steelhead ESU (Okanogan, Methow, Entiat and Wenatchee) can be collected.

The tagging of steelhead on the lower Snake and mid-Columbia rivers will be carried out by personnel from this project, in cooperation with the Smolt Monitoring Program (SMP), the Washington Department of Fish and Wildlife, and the Chelan County PUD (PUD) at Rock Island Dam. Sampling will be conducted during normal activities at the dams, unless additional samples are needed to achieve sample size targets (primarily a concern during the month of April). At Ice Harbor and Lower Monumental dams, juvenile steelhead will be collected for PIT-tagging from a random sample of fish collected at the juvenile bypass facility. At Rock Island Dam, fish will be collected 24-hours a day as they volitionally pass and are entrained in the dam's gatewells and randomly PIT-tagged. Sampling will take place weekly throughout the 2008 steelhead smolt migration (early April to 30 June or until steelhead numbers are too low for productive sampling). Using existing protocols developed in 2007, data will be collected on fork length, weight, origin (based on presence/absence and/or erosion of fins), and morphological condition of steelhead smolts. Physical condition will be scored based on external criteria, including (1) de-scaling; (2) injuries to head, body, or operculum; (3) fungal infections; (4) bacterial infections; (5) parasite infestation; (6) predator marks (i.e., scars left from a failed predation attempt); and (7) other abnormalities of each fish. Following inspection, each fish will be PIT-tagged (Biomark model TX1400SST) and a digital photo will be taken of each side of the fish for later referencing and data validation. PIT-tagged smolts will then be placed in a temporary holding tank for recovery.

Following the recovery period, the tank will be inspected for mortalities and fish released into the dam's tailrace at LMN and ICH to resume their downstream migration. Steelhead PIT-tagged at Rock Island Dam will be transported and released below Priest Rapids Dam (Rkm 639; the lowest dam on the mid-Columbia River). Transportation is needed for upper Columbia River steelhead to control for in-river smolt mortality that occurs between Rock Island and Priest Rapids dams (91 Rkm, including two mainstem dams, Wanapum and Priest Rapids dams). Following PIT-tagging at Rock Island

Dam[2], smolts will be loaded into a USACE fish transportation truck for transportation and release below Priest Rapids Dam. Trucks will be outfitted with 1,100-liter, aerated fish tanks capable of transporting up to 68 kg of fish. Fish will be released under the cover of darkness (to minimize avian predation at the release site) and at two different times; just before sunrise or just after sunset. We have tentatively identified the I-24 Bridge (Rkm 624) as the release site below Priest Rapids Dam.

The target sample sizes for this study will be (1) 500 steelhead per week over a 13-week season (or 6,500 fish total) from the lower Snake River, and (2) 900 steelhead per week over an 8-week season (or 7,200 fish total) from the mid-Columbia River. On the lower Snake River, a sample of 500 steelhead per week (week = Sunday through Saturday) would be adequate for statistical comparisons between various subgroups or proportions of sampled steelhead (e.g., proportion of hatchery fish versus wild fish recovered) in cases where at least 6% of one subgroup is detected on-colony, with a minimum difference of 5% between subgroup proportions. For the mid-Columbia River, a sample of 900 steelhead per week would be adequate in cases where at least 2% of one subgroup is detected on-colony, with a minimum difference of 3% between subgroups. All sample size calculations provide statistical power of 80% (beta) at the 0.05 level (alpha). Ultimately, however, the sample size needed to detect a statistical difference in proportions or means within different subgroups of sampled fish will depend on the magnitude of difference between the subgroups and the prevalence of the variable(s) of interest in the sample[3]. Predation rate estimates generated from PIT-tagged steelhead will be bound by 95% confidence intervals based on weekly releases of fish from each listed ESU (Snake and Upper Columbia) and release location.

Histopathology Screening (**new**): In order to validate our scoring of fish condition based on physical anomalies in external appearance, we propose a pilot study whereby a sub-sample of the steelhead used in this study are screened to evaluate fish pathology and whole body chemistry as a measure of fish health. Such tests will help determine whether a fish's external condition – as determined at the time of examination at the dams – is correlated with disease pathogenicity or other indices of fish health. Such screening will also assist our investigation of how vulnerability to predation is related to internal indicators of fish health. Both lethal and non-lethal screening techniques will

[2] Logistics regarding holding times and conditions at the dam (e.g., separate tank or within the transport-hold of the truck) need to be worked out and will depend on space availability and other factors currently under discussion.

[3] The sample size estimates provided here will be updated once empirical data from our 2007 pilot study on Snake River steelhead are available (tentatively late October 2007). As of August 17, 2007 7.6% (n = 539) of the steelhead tagged and released at LMN and ICH as part of this study had been detected at bird colonies in McNary Pool. Empirical data from upper Columbia River steelhead do not currently exist and will therefore not be available until results from the pilot study are completed.

be investigated through our collaboration with U.C. Davis/NOAA Fisheries (POC: Frank Loge) and USGS (POC: Diane Elliot). Lethal screening of fish will be used to estimate the prevalence of a large suite of common salmonid pathogens in our study fish, which will then be related to our scoring of fish condition based on external anomalies. Non-lethal screening (if feasible in 2008) of fish for selected pathogens will enable tracking of individual fish with known presence/intensity of pathogen infection for correlation with subsequent vulnerability to avian predation. Screening will be conducted using established protocols developed by our collaborators as part of on-going studies that are funded by the USACE, Walla Walla District. Further details regarding this pilot study (e.g., sample sizes) will be provided in the near future and will depend on the outcome of our discussions with our collaborators, USACE, and the permitting agencies.

In addition to biotic factors, we will also investigate how abiotic factors (i.e., river conditions and dam operations) are associated with differences in smolt vulnerability to predation by piscivorous waterbirds. We will investigate such abiotic factors as water temperature (ºC), inflow (kcfs), outflow (kcfs), spill levels, spill duration, and turbidity, as well as other abiotic variables measured at lower Snake River and mid-Columbia River dams. In addition to data collected at the dams, we will supplement dam-specific measurements by taking similar measurements from in-river water quality monitoring stations located within a 15 Rkm-radius of Crescent Island. These data will be used to assess water quality parameters in close proximity to Crescent Island and assess whether substantial differences exist between dam-specific and in-river monitoring sites.

PIT tag recoveries at the Crescent Island tern colony (and other piscivorous waterbird colonies, see Tasks 2.4 and 3.3) will be compared within and among subgroups of PIT-tagged steelhead to investigate whether there are differences in predation rates associated with fish length, weight, condition, origin (hatchery vs. wild), abundance, and release date. Furthermore, differences in recovery rates of PIT-tagged steelhead will be determined to investigate relationships between avian predation rates and river flows, spill regimes, river temperatures, turbidity, and other environmental factors. Finally, the tagging and condition data collected from run-of-the-river steelhead smolts will benefit other USACE-sponsored analyses in the region, such as in-river smolt and smolt-to-adult survival models generated annually by NOAA Fisheries (B. Sandford, NOAA Fisheries, personal communication).

Telemetry Studies (**on-going**): Data acquired from steelhead examined and PIT-tagged as part of this study may not be sufficient to determine whether smolt travel times, migration behavior, and passage histories (e.g., bypass, spillway, etc.) are associated with vulnerability to predation by Crescent Island terns. Data acquired from radio-tagged fish released in the lower Snake River, however, may offer some insight into these factors. In 2008, we will continue to work collaboratively with NOAA Fisheries (POC: Gordon Axel and Eric Hockersmith) to utilize existing and future smolt telemetry data for these purposes. As part of this on-going task, we will continue to compile and analyze radio telemetry data collected on the Crescent Island tern colony (2003-2007), as well as facilitate telemetry data collection during the 2008 field season by helping NOAA Fisheries to place and maintain telemetry equipment on both Crescent and Foundation islands (see Task 2.4). Receivers will be placed on-colony prior to the arrival of breeding birds on the colony to minimize disturbance to nesting birds.

Task 1.5. Detect the formation of new Caspian tern colonies on the Columbia Plateau and investigate colony size, habitat use, nesting success, and factors limiting colony size and nesting success of incipient tern colonies (**on-going**).

We will conduct surveys of the distribution and size of Caspian tern colonies on the mid-Columbia River (from The Dalles Dam to the head of Wanapum Pool) and on the lower Snake River (from the mouth of the Clearwater River to the confluence with the Columbia River), as well as at sites off the Columbia and Snake rivers that are within tern foraging range (e.g., Potholes Reservoir). Aerial, boat, and land-based surveys will be conducted to identify all tern colony sites within the study area. Once a new tern colony has been identified, we will periodically monitor (i.e., bimonthly) the colony to determine tern colony size, productivity, and factors limiting colony size and productivity, when feasible. Once incipient tern colonies become established (i.e., > 50 nesting pairs with some active nests), we will increase our monitoring efforts at that colony (i.e., periodic to weekly) and collect data on diet composition.

Task 1.6. Assess inter-colony movements, survival, and average age at first reproduction of Caspian terns banded at breeding colonies throughout the western United States (**on-going**).

Available evidence from band recoveries indicates that all Caspian tern colonies west of the Continental Divide in North America constitute one panmictic population (Suryan et al. 2004). Consequently, changes in the size and productivity of Caspian tern colonies outside the Columbia Plateau may have profound effects on the numbers of terns nesting on or within foraging distance of the mid-Columbia and lower Snake rivers and, consequently, on predation rates on juvenile salmonids from the Columbia and Snake rivers. Also, we do not currently understand some of the fundamental components of Caspian tern demography in the Pacific Coast population, such as sub-adult survival rates, average age at first reproduction, and minimum levels of colony productivity needed to ensure sufficient intrinsic recruitment to balance adult mortality. The latter is critical for identifying minimum levels of nesting success to assure a stable colony size in the absence of immigration and emigration.

We will continue to band cohorts of fledgling Caspian terns each year with field-readable plastic leg bands engraved with unique alphanumeric codes in order to collect information on sub-adult survival and dispersal, and maintain sample sizes of banded adults for measurement of adult survival to be used as input for demographic models. Re-sightings of banded terns will allow us to measure adult survivorship, average age at first reproduction, and juvenile recruitment, three essential parameters for modeling the demography and assessing the status of the tern population. The model, combined with colony size and productivity data, will allow us to reliably predict changes in population size into the future.

Re-sightings of color-banded adult terns will also be used to study dispersal patterns and recruitment of terns formerly banded at colonies in the lower Columbia River and along the coast (see Suryan et al. 2004). By monitoring the size and productivity of unmanaged Caspian tern colonies on the Columbia Plateau, we will assess the relationship between management-related changes in the size and productivity of colonies in the Columbia River estuary and changes in recruitment and reproductive success at colonies on the Columbia Plateau. This will help determine the potential for future impacts of unmanaged Columbia Plateau Caspian tern colonies on the survival of salmonids from the Columbia River basin.

Objective 2. Research, monitor, and evaluate predation on salmonid smolts by double-crested cormorants on the Columbia Plateau.

Task 2.1. Determine the size, habitat use, nesting success, and factors limiting colony size and nesting success of the double-crested cormorant colony on Foundation Island (**on-going**).

The number of double-crested cormorants breeding on Foundation Island will be estimated using aerial, ground, and boat-based counts of occupied nests on the island. These counts are minimum estimates of the number of breeding pairs because some nests may be obscured from view by dense vegetation. A sub-sample of nests visible from an observation blind located at the periphery of the colony will be monitored for nesting success throughout the nesting season. The ground beneath nesting trees will be searched for signs of nest predation and all potential nest predators observed in the vicinity of the colony will be recorded.

Task 2.2. Determine diet composition and consumption of juvenile salmonids by double-crested cormorants nesting on Foundation Island (**on-going**).

During the 16-week nesting period, we will collect diet samples that are spontaneously regurgitated by nesting adults and their young and by the lethal sampling of adults for stomach contents analysis, if permitted by the USFWS. We will attempt to collect between 150 and 200 regurgitations from the ground underneath trees where cormorants are nesting. If permitted, we will lethally collect adult cormorants with full stomachs during each of three discrete stages of the nesting cycle: (1) egg-laying and early incubation, (2) late incubation/early chick-rearing, and (3) late chick-rearing. These samples will be analyzed in our laboratory at Oregon State University to determine the diet composition of cormorants nesting on Foundation Island. These data will be used to (1) determine the proportion of the diet that consists of juvenile salmonids, (2) estimate the total number of juvenile salmonids consumed based on calculations using a bioenergetics model (see Roby et al. 2003), and (3) estimate predation rates on smolts based on numbers of juvenile salmonids available as potential prey in each migration year from the Snake River (in cooperation with NOAA Fisheries). Species-specific genetic markers will also be used to identify salmonid smolts collected from cormorant diet samples. Genetic analysis will be conducted by our collaborators at the Northwest Fisheries Science Center (POC: David Teel). Diet composition and smolt consumption will be compared with previous years and among colony sites.

Task 2.3. Determine species and stock-specific (where feasible) predation rates on juvenile salmonids from the Snake and Columbia rivers by double-crested cormorants nesting on Foundation Island (**on-going with modification**).

The same methods and analytical approach used to determine species and stock-specific predation rates on juvenile salmonids by Crescent Island terns (*see* Task 1.3) will be used for Foundation Island cormorants. For example, PIT tags detected on-colony will be used to assess the relative vulnerability of various salmonid species, ESU's, run-types, and stocks to cormorant predation (based on the proportion of available PIT-tagged smolts subsequently recovered on the cormorant colony; see Task 1.3 for details on general methods and analytical approach). Predation rates derived from PIT tag evaluations will then be compared to consumption estimates independently-derived from bioenergetics modeling, to the extent that sample sizes allow.

Similar to smolt predation rates estimated from PIT tag recoveries on tern colonies, PIT tag recoveries from cormorant colonies must be corrected for sources of potential bias. The breeding behavior of cormorants, however, differs from that of terns; consequently, some alternative data collection techniques are needed to calibrate estimates of smolt predation rates by cormorants based on PIT tag detections.

PIT Tag Recovery (**on-going**): We will recover PIT tags from the Foundation Island cormorant colony during August of each study year using hand-held electronic equipment (see Ryan et al. 2003 for detailed methods). Due to the thick underbrush on Foundation Island, however, it will not be possible to physically remove PIT tags after the nesting season using magnetic rakes and sweepers.

Nesting Platform (**modified**): Unlike Crescent Island Caspian terns, which nest on bare ground, Foundation Island double-crested cormorants nest in trees. This poses significant challenges for the recovery and detection of PIT tags egested on-colony by nesting cormorants. To enhance our ability to detect PIT tags at the cormorant colony on Foundation Island, we will construct a nesting platform near the colony and use social attraction techniques (i.e., decoys and audio playback systems) to encourage cormorants to nest on the platform (see Roby et al. 2002, 2005 for more detailed methods). We hypothesize that if we successfully attract cormorants to nest on the platform, detection efficiency for smolt PIT tags would be markedly enhanced. Furthermore, by monitoring the number of cormorant breeding pairs nesting on the platform, we could calculate a per-capita PIT tag consumption rate for this sample of cormorants, which could be used, along with our estimate of colony size, to estimate total consumption of PIT-tagged smolts by cormorants nesting on Foundation Island.

Although efforts to attract cormorants to nest on a platform on Foundation Island were not successful in 2007, we propose to repeat this experiment with some modification in 2008. Our previous experiments using habitat modification and social attraction to encourage cormorants to nest at sites in the Columbia River estuary have demonstrated that, unlike Caspian terns which readily move to new nest sites using these techniques, double-crested cormorants take longer (i.e., more than a year) to colonize experimental sites (Roby et al. 2005; Collis et al. 2004). We suspect that by increasing the elevation of the platform and by placing the platform closer to the Foundation Island cormorant colony, we may be successful in enticing cormorants to nest there in 2008. Prior to the 2008 nesting season, we will once again construct an elevated platform (measuring 6 m x 6 m) adjacent to the Foundation Island cormorant colony. The platform will be top-dressed with sand and an array of 30 truck tires will be placed on the platform. Sticks will then be placed in the center of each truck tire to simulate cormorant nests, providing nest sites for up to 30 nesting pairs on the platform. Cormorant decoys and two speakers broadcasting audio playbacks of a cormorant colony will be used to attract nesting pairs to the platform. If fully successful, cormorants nesting on the platform would represent ~10% of the over-all Foundation Island cormorant population (ca. ~300 breeding pairs in 2005; Roby et al. 2005). The nesting chronology, number of breeding pairs, and nesting success of cormorants on the platform will be recorded throughout the nesting season.

PIT Tag Detection Efficiency (**on-going**): Similar to the Crescent Island tern colony, PIT tags will be systematically sowed on the Foundation Island cormorant colony to calculate detection efficiency. A total of 400 PIT tags will be distributed evenly under nesting trees at the main colony during four discrete time periods: (1) prior to the birds' arrival at the colony, (2) during egg incubation, (3) during fledging, and (4) following the nesting season once all cormorants have left the colony.

Detection efficiency for PIT tags on the nesting platform will also be measured by sowing 50 PIT tags on the platform during each of the same four discrete time periods (if this can be accomplished without severe disturbance to cormorants nesting on the platform). Detection efficiency will then be analyzed relative to release date at the main colony and on the platform. We hypothesize that detection efficiency on the main colony will be much less than on the platform colony; the difference will be used to further calibrate estimates of smolt predation rates at each nesting location.

Task 2.4. Determine how various biotic and abiotic factors are associated with differences in smolt vulnerability to predation by Foundation Island double-crested cormorants (**on-going and expanded**).

The same methods and analytical approach described for the Crescent Island tern colony (see Task 1.4) will be used for the Foundation Island cormorant colony in 2008. Results from Foundation Island cormorants will be compared to those from terns to evaluate differences between these two species of avian predators, and to evaluate the combined impact of both bird colonies on survival of steelhead smolts PIT-tagged and released on the Snake and mid-Columbia rivers. Based on PIT tag recoveries from the Foundation Island cormorant colony in 2005-2007, we anticipate fewer steelhead tags will be deposited and detected on the cormorant colony compared to the tern colony (Roby et al. 2005; Roby et al. 2006), which may limit what questions can be addressed with the available PIT tag data from the Foundation Island colony due to sample size constraints.

Similar to Task 1.4, smolt telemetry data will also be compiled and evaluated for Foundation Island cormorants (for years when data exist), in collaboration with NOAA Fisheries (*see* Task 1.4, "Smolt Telemetry Data" for more details).

Task 2.5. Detect the formation of new double-crested cormorant colonies on the Columbia Plateau and investigate colony size, habitat use, nesting success, and factors limiting colony size and nesting success of incipient cormorant colonies (**on-going and expanded**).

We will conduct surveys of the distribution and size of double-crested cormorant colonies on the mid-Columbia River (from The Dalles Dam to the head of Wanapum pool) and on the lower Snake River (from the mouth of the Clearwater River to the confluence with the Columbia River), as well as at sites off the Columbia and Snake rivers that are within foraging range of cormorants (e.g., Potholes Reservoir; see Task 1.5). Aerial, boat, and land-based surveys will be conducted to identify all colony sites within the study area. Once new cormorant colonies have been identified, we will periodically monitor (i.e., bi-monthly) the colony to estimate colony size, productivity, and factors limiting colony size and productivity. More frequent monitoring of these colonies may occur in subsequent years, if the colony becomes established, and data on diet composition will be collected.

In 2004, a relatively large nesting colony of double-crested cormorants (> 500 breeding pairs) was identified in northern Potholes Reservoir (located between the Snake and Columbia rivers, WA). Additional research on this colony in 2006 revealed that this colony is growing (ca. 1,200 nesting pairs in 2006), making the Potholes cormorant colony the largest known double-crested cormorant colony on the Columbia Plateau, and the second largest double-crested cormorant colony in the Pacific Northwest (second only to the world's largest on East Sand Island at the mouth of the Columbia River). Little is known about the Potholes cormorant colony (e.g., trends in colony size, diet composition of birds nesting at the colony, impact of the colony on survival of out-migrating salmonid smolts from the Columbia River). In 2008, we propose to visit this colony bi-monthly to monitor colony size, nesting success, and diet composition of the cormorants nesting at this colony. Diet composition will be based on chick regurgitations collected on-colony during the nesting season, when feasible. We also propose to search for smolt PIT tags on the ground beneath this colony to assess predation rates on juvenile salmonids from the Columbia and Snake rivers by cormorants nesting at this colony.

Task 2.6. Determine the distribution, relative abundance, and diet composition of double-crested cormorants at selected dams on the lower Snake River during the post-breeding season to assess the impacts of predation by over-wintering cormorants on residualized fall Chinook salmon (**on-going and modified**).

In 2008, we will work with Corps project staff to count the number of double-crested cormorants foraging and roosting near Lower Granite and Little Goose dams during the post-breeding season (i.e., September – January). We will work with project staff to coordinate the counts so that the results collected at each dam are comparable, both among dams and across years. The methodology used and frequency of the counts will take into account what is currently being done by project staff and what is feasible at each dam.

If significant numbers of foraging cormorants are found at sites where fall Chinook smolts might be vulnerable to cormorant predation (e.g., dam forebays) in 2008, we propose lethal sampling of up to 45 adults for stomach contents analysis, if permitted by the USFWS. We will contract with USDA – Wildlife services to lethally collect 10 adult cormorants with full stomachs during each of four months that follow the end of the breeding season (i.e., September – January). Collections will occur at one or more locations from the confluence of the Clearwater and Snake rivers downstream to Little Goose Dam. These samples will be analyzed in our laboratory at Oregon State University to determine the diet composition of post-breeding cormorants on the lower Snake River, with emphasis on understanding the impacts of cormorant predation on survival of juvenile fall Chinook salmon. Species-specific genetic markers will be used to identify salmonid smolts collected from cormorant stomach samples. Genetic analysis of salmonid tissues will be conducted by our collaborators at the Northwest Fisheries Science Center (POC: David Teel)

Objective 3. Research, monitor, and evaluate predation on salmonid smolts by other piscivorous waterbirds on the Columbia Plateau[4].

Task 3.1. Investigate the distribution and size of other piscivorous waterbird colonies on the mid-Columbia and lower Snake rivers (**on-going**).

We will conduct surveys to assess the distribution and approximate size of other piscivorous waterbird colonies (i.e., American white pelicans, California gulls, ring-billed gulls, Forster's terns, great blue herons, black-crowned night-herons, great egrets) on the mid-Columbia River (from The Dalles Dam to the head of Wanapum pool), on the lower Snake River (from the confluence with the Columbia River to the mouth of the Clearwater River), and on other bodies of water within foraging distance of the Snake and Columbia rivers (e.g., Potholes Reservoir). Aerial, boat, and land-based surveys will be conducted to identify all major colony sites within the study area. Once waterbird colonies have been identified, we will periodically (i.e., at least monthly) monitor the colony to determine the approximate colony size and to assess productivity, if feasible. More frequent monitoring of these colonies may be conducted in subsequent years, if warranted by the results.

Task 3.2. Determine species and stock-specific (where feasible) predation rates on juvenile salmonids from the Snake and Columbia rivers by other piscivorous waterbird colonies on the Columbia Plateau (**on-going**).

We propose to detect PIT tags at selected gull colonies on the Columbia River and at the Badger Island colony of American white pelicans as a means to evaluate relative predation rates on juvenile salmonids. Due to the size and number of gull colonies in the region (> 40,000 breeding pairs on at least 8 different islands; Roby et al. 2006), efforts to estimate smolt predation rates by gulls will be limited to three or four selected colonies and derived from a sub-sample of breeding pairs at each colony. To capture potential spatial

[4] There is not a significant incremental cost associated with this objective because these data will be collected while collecting similar data outlined in the objectives and tasks listed above.

differences in predation rates on salmonids by gulls, gull colonies from The Dalles Pool (Miller Rocks), John Day Pool (Three Mile Canyon Island), and McNary Pool (Crescent Island and possibly Island 18, if permitted) will be investigated. Sub-sampling will be accomplished by placing several 10 m x 10 m plots on-colony and then monitoring the number and general productivity of birds within the plots during the nesting season. PIT tags recovered from each plot will then be used to generate estimates of per-capita PIT tag consumption and determine species- and stock-specific predation rates, when adequate samples exist (see Task 1.3 for further details on general methods and analysis).

A combination of PIT tag recovery and detection efficiency studies will be used to calibrate estimates of predation rates by gull and pelican colonies.

PIT Tag Recovery (**on-going**): Following the nesting season, we will recover PIT tags from each study plot using a combination of hand-held electronic scanners and magnets (see Task 1.3 for details). In cases where a relatively large number of PIT tags are discovered within experimental plots, the entire colony may be scanned to maximize data collection for that particular colony (e.g., as was done at Miller Rocks in 2007).

PIT Tag Detection Efficiency (**on-going**): We propose to sow equal numbers of PIT tags on separate plots during four discrete time periods on each selected gull colony on the Columbia Plateau: (1) prior to the nesting season (n = 50 tags per plot), (2) during egg incubation (n = 50 tags per plot), (3) during chick-rearing (n = 50 tags per plot), and (4) after the nesting season (n = 50 tags per plot). Due to access retrictions, however, we will not be able to sow test tags on the Badger Island pelican colony during the nesting season, but instead will sow PIT tags on the colony prior to and following the nesting season.

Task 3.3. Determine how various biotic and abiotic factors are associated with differences in smolt vulnerability to other avian predators nesting on the Columbia Plateau (**on-going and expanded**).

The same methods and analytical approach described for Crescent Island terns (see Task 1.4) will be used for other species of piscivorous waterbirds (i.e., selected gull colonies and the Badger Island white pelican colony) nesting on the Columbia Plateau. It is likely, however, that the number of PIT tags recovered from these colonies will be relatively small compared to the Crescent Island tern colony due to differences in (1) smolt predation rates by these bird species (i.e., tern predation rates tend to be much higher than those of gulls and pelicans), (2) sampling methods (i.e., whole colony tag recovery for terns versus plot-restricted tag recovery for gulls and pelicans), and (3) detection efficiencies (i.e., detection efficiencies on tern colonies are often higher than on gull and pelican colonies). The comparatively low numbers of

PIT tags recovered from gull and pelican colonies may further limit the questions that can be addressed with the available PIT tag data due to sample size constraints.

REPORTING

We will provide weekly updates of field activities and results (if available) directly to the Corps' appointed POC. Weekly reports will summarize laboratory and field activities, along with any general comments and suggestions associated with specific project objectives and tasks. In-season updates and results will also be made available weekly on the project's website www.columbiabirdresearch.org. We will prepare the necessary reports required by permitting agencies and give presentations to regional resource management agencies, as requested by the funding agency (e.g., Annual AFEP Review meeting).

A draft 2008 annual report describing results of this project will be submitted to the funding agency by January 31, 2009. A final annual report, which will incorporate comments from AFEP reviewers, will be submitted by March 31, 2009. Deliverables in optional years (i.e., 50 printed copies of annual reports for regional distribution, presentations to regional managers, etc.) of this study will follow the schedule outlined above, to include a final project completion report due one year after the completion of field work.

COLLABORATION AND COORDINATION

This project will be conducted cooperatively by the USGS-Oregon Cooperative Fish and Wildlife Research Unit at Oregon State University and Real Time Research (via a sub-contract with Oregon State University). Research methods used in this study will be similar to those used in related avian predation research in the Columbia River estuary and elsewhere (e.g., San Francisco Bay and Dungeness Spit). Data collected as part of this study will be compared and contrasted with data collected throughout the Western States to get a better understanding of the population dynamics and impacts of avian predation on a larger geographic scale. Collaborations on this project include; NOAA Fisheries (PIT tag studies, telemetry studies, Potholes Reservoir tern studies, steelhead transport from Rock Island Dam to below Priest Rapids Dam, and genetic analysis of salmonid soft tissue), USGS (non-lethal fish pathology screening), U.C. Davis (lethal fish pathology screening), WDFW's Smolt Monitoring Program (steelhead PIT-tagging), Chelan County PUD (steelhead PIT-tagging at Rock Island Dam), USDA – Wildlife Services (cormorant collections at Snake River Dams), and perhaps others. Our work is closely coordinated with many resource management agencies, which includes representatives from Bonneville Power Administration (POC: Dorothy Welch); U.S. Army Corps of Engineers, Walla Walla District (POCs: Rebecca Kalamasz, Scott Dunmire); U.S. Army Corps of Engineers, Portland District (POCs: Bob Willis, Geoff Dorsey); Northwest Power and Conservation Council (POCs: Peter Paquet, Patty

O'Toole, Doug Marker); NOAA Fisheries (POCs: Ben Meyer, Cathy Tortorici, John Ferguson, Ed Casillas, Tom Good, Dick Ledgerwood, Gordon Axel, Ben Sandford); U.S. Fish and Wildlife Service (POCs: Tara Zimmerman, Nanette Seto, Howard Browers); Oregon Department of Fish and Wildlife (POC: Charlie Bruce); Washington Department of Fish and Wildlife (POC: Rocky Beach, Jim Taber); and the Columbia River Inter-Tribal Fish Commission (POC: Dale McCullough). We anticipate that additional collaborative and cooperative arrangements will be forged with other agencies and research organizations currently engaged in or planning work on the Columbia River.

FACILITIES AND EQUIPMENT

Fieldwork will be focused along the Columbia River between The Dalles Dam and the head of the McNary Dam pool, with additional survey fieldwork on the lower Snake River, the mid-Columbia River from Hanford Reach to Rock Island Dam, and other sites on the Columbia Plateau. This work will be conducted out of field stations in Pasco, WA and Wenatchee, WA (for the Rock Island steelhead PIT tagging task). USGS-Oregon Cooperative Fish and Wildlife Research Unit will provide two skiffs capable of handling conditions encountered on the mid-Columbia River. The Unit will provide boats for use on the project in return for maintenance, repair, and/or replacement in the event of normal wear and tear, damage, or loss of these watercraft and associated equipment (outboard motors, trailers, etc.).

Since the project was initiated in 1997, it has acquired a considerable quantity of reusable field supplies and equipment that are dedicated to this project. These include several sturdy plywood blinds for colony observations, optical equipment for colony observations, computers, and a wide variety of other miscellaneous field supplies.

The Department of Fisheries and Wildlife, Oregon State University will provide lab facilities. This laboratory is fully equipped to conduct analyses of diet and proximate composition and energy content of fish prey for piscivorous birds.

Much of the research associated with Tasks 1.4, 2.4, and 3.3 will rely on the infrastructure and basic facilities already present at the juvenile fish facilities at Lower Monumental, Ice Harbor, and Rock Island dams. Most of the equipment needed to complete this work was purchased in 2007; however, we will need to purchase one new Destron PIT tag reader and additional water quality monitoring probes as part of our expanded work PIT-tagging and releasing steelhead on the mid-Columbia River. A fish tagging trailer and use of one or more of the Corp's mini fish tankers (transport trucks) may be needed for research at Rock Island Dam in 2008; pending the results of on-going discussions with Chelan County PUD and NOAA Fisheries. Telemetry equipment (two receivers and antennas) for installation at Foundation Island and Crescent Island colonies will be supplied by NOAA Fisheries (Pasco Field Station). Finally, the project will need ~15,000 PIT tags for tasks 1.3, 1.4, 2.3, 2.4, 3.2, and 3.3.

IMPACTS

The capture and handling of juvenile steelhead at Lower Monumental, Ice Harbor, and Rock Island dams requires ESA-permits, which will be obtained prior to the commencement of that work in 2008. We will work with USACE, WDFW, and NOAA Fisheries to adjust estimated "take" to account for PIT-tagging and sub-sampling of steelhead for pathology screening at the dams in 2008. Other activities associated with this research project should not impact or otherwise interfere with other Corps activities in the region. Our research does, however, require permitting from the U.S. Fish and Wildlife Service and the Washington Department of Fish and Wildlife to access islands where bird colonies are located, collect birds for diet composition analysis, and to occasionally handle specimens (e.g., bird banding). We believe these activities pose minimal risk to native wildlife and vegetation.

TECHNOLOGY TRANSFER

Information obtained from this study will be made available to regional resource managers in a variety of formats. As previously mentioned, research results will be presented in annual reports to the U.S. Army Corps of Engineers (see section entitled "Reporting"), made available in weekly summary reports during the field season via the project's website (www.columbiabirdresearch.org), and presented at professional meetings throughout the Pacific Northwest and elsewhere. In 2008, we are planning on presenting results at five different meetings: the AFEP Technical Studies Review Work Group meeting, the Annual AFEP Review Meeting, the Annual Meeting of the Oregon Chapter of The Wildlife Society (Corvallis, OR), the Annual Meeting of the Pacific Seabird Group (Blaine, WA), and the Annual Meeting of the Oregon Chapter of the American Fisheries Society (Corvallis, OR). The funding support of the U.S. Army Corp of Engineers, Walla Walla District will be gratefully acknowledged as part of each presentation and/or scientific paper resulting from this project.

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