**PRELIMINARY PROPOSAL FOR FY 2007 FUNDING**

Title: Survival and tailrace egress of juvenile salmonids following passage at The Dalles Dam.

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|---|---|
| Study Code: | SPE-P-00-8 |
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## PROJECT SUMMARY

### RESEARCH GOAL

The goal of this study is to evaluate the effects of passing the north spillway (spill bays 1-4) or south spillway (spill bays 5-6) at The Dalles Dam on the survival and tailrace egress of yearling and subyearling Chinook salmon and juvenile steelhead. Radio-tagged fish will be monitored in the tailrace and reservoir following a forebay release and volitional passage via the spillway. We will estimate survival and compare the egress routes of fish passing through the north spillway (spill bays 1-4) with fish passing through the south spillway (bays 5 & 6). We will also estimate and evaluate the route specific survival of yearling and subyearling Chinook salmon and steelhead trout through The Dalles Dam spillway, ice and trash sluiceway, and turbines and provide estimates of dam and project survival. Drift buoys will be used to evaluate juvenile salmonid behavior in respect to general flow conditions in the tailrace. Additionally, Vortex Suppression Devices (VSD) will be attached to the pier nose and stoplog slot in front of the tainter gate in tandem at bay six (potentially, a VSD(s) will be deployed at bay five and/or bay seven). The VSD devices are similar in composition to the structures used to block trash-racks. Recent investigations suggest that a tandem VSD option in which the pier face device (8-foot) is shorter than the stoplog device (12 foot) satisfactorily suppressed the vortex as well as reduced upwelling and surging between the devices. Further, the tandem VSD option enhanced the lateral flow of water to the north, potentially augmenting fish guidance to these bays. Thus, we propose to test and evaluate a configuration that has an 8 ft device at the pier nose in tandem with a 12 ft device at the stoplog slot to assess its' efficacy to enhance fish guidance and survival in FY07.

### STUDY OBJECTIVES

Our study objectives are: 1) Evaluate tailrace egress following north or south spillway passage at The Dalles Dam using fixed-site monitoring of radio-tagged yearling and subyearling Chinook salmon and juvenile steelhead, 2) Estimate survival of yearling and subyearling Chinook salmon and steelhead trout passing spillbays 1-4 or 5-6 at The Dalles Dam spillway using the single and paired release-recapture models, and 3) Estimate the route specific survival of yearling and subyearling Chinook salmon and steelhead trout through the spillway, ice and trash sluiceway, and turbines.

### RELEVANCE TO THE BIOLOGICAL OPINION

This study addresses Hydrosystem substrategy 1.4 and ESU Specific Actions-The Dalles Dam of the Updated Proposed Action for the FCRPS Biological Opinion Remand, November 24, 2004.

## PROJECT DESCRIPTION

## BACKGROUND AND JUSTIFICATION

An objective of the National Marine Fisheries Service (NMFS) Federal Columbia River Power System (FCRPS) Biological Opinion is to increase survival of juvenile salmonid out-migrants through the federal hydrosystem (NMFS 2000). The 2000 Biological Opinion proposed the implementation of a spill program that was expected to provide a safer route of project passage than turbine passage. While there is consensus that survival is greater for fish diverted from turbines, questions regarding the effectiveness of different spill patterns and other passage scenarios remain (Dawley et al. 1998). Normandeau Associates et al. (1996) expressed concerns that spillway survival at The Dalles Dam was lower than other dams. For example, in 2000 the survival through the spillway was estimated to be 0.927 (Counihan et al. 2002) whereas other dams average 0.98 (Ploskey et al. 2001). The lower than expected spill passage survival probabilities under high spill conditions at The Dalles Dam could be due to 1) a short stilling basin and shallow tailrace, resulting in severe turbulence and lateral currents that may cause physical injury to migrant salmon, and 2) predation; spillway-passed water moves through areas where predation on salmonids by gulls (*Larus* spp.), northern pikeminnow (*Ptychocheilus oregonensis*), and smallmouth bass (*Micropterus dolomieu*) likely occurs. In recent years, various spill levels and configurations have been implemented to increase survival.

Survival studies by the NMFS at The Dalles Dam during 1997-2000 and the USGS in 2000 indicated spillway survival at 30% spill and 24 h 40% spill operations was typically higher than spillway survival at 64% spill operations; survival through the sluiceway was similar to the 30% spillway survival (Ploskey et al. 2001). In addition to spill level, the NMFS found that the survival of subyearling Chinook salmon was consistently higher at night than during the day. Previous studies were not able to separate day versus night spill pattern changes; however, the increased night survival was believed to be a result of passage during the juvenile spill pattern used only at night. In 2000, 40% spill operations and the juvenile spill pattern were used 24 h a day. Observed spill passage efficiency values under the 24 h 40% spill pattern were similar to those seen at 64% spill operations in previous years, and even though survival was found to be higher at the lower spill (30–40%) percentages, the survival of juvenile salmonids passing this project was determined to be unacceptably low for a primary passage route.

Results from studies conducted in 2001 – 2003 suggest that juvenile salmon passing through the stilling basin at The Dalles Dam may be susceptible to injury and mortality caused by lateral flow that passes along the stilling basin's length from south to north. During 2001, the USGS continued evaluations of the survival of yearling and subyearling Chinook salmon at The Dalles Dam, however, the emphasis shifted from developing point estimates of survival under varying operating conditions, to identifying the causal mechanisms of mortality. During 2002, evaluations of survival at the spillway suggested that survival was significantly lower for yearling Chinook salmon that passed via spillbay 13 (south) vs. spillbay 4 (north). A similar trend was seen for subyearling Chinook salmon, although the difference was not statistically significant. A concurrent engineering study determined that lateral flow in the stilling basin could be blocked by a longitudinal training wall extending from the downstream spillway pier nose between bays 6 and 7 to the end sill. Balloon-tag studies were conducted in 2003 to determine the amount of spill per bay that can be discharged with minimal fish injury and mortality. Results suggested that for typical summer migrant river conditions, 40% of the total river discharge could safely be passed through bays 1-6 with no measurable increase in fish injury or mortality.

In response to Action 68 in the 2000 Biological Opinion on operation of the Federal Columbia River Power System (FCRPS; NMFS 2000) the Corps modified the spillway stilling basin and spill pattern at The Dalles Dam during the winter of 2003-04. A training wall was constructed that extends from the pier nose between bays 6 and 7 to the end sill. Spill operations target 40% spill through spill bays 1-6. The intent of these modifications was to increase the survival of juvenile salmonids that pass through the spillway. In order to assess the post-construction performance of these spillway modifications, the USGS conducted a two-year evaluation in 2004 and 2005. Objectives for both years were similar, and include estimating survival, and evaluating fish passage distribution and tailrace egress. The estimated survival of yearling and subyearling Chinook salmon passing via The Dalles Dam during 2004 did not suggest that there was a large survival benefit associated with the new training wall in the spillway. The point estimates of survival for yearling and subyearling Chinook salmon passing through the spillway were slightly higher during 2004 (post-construction) than 2002 (pre-construction) but there was considerable overlap of the 95% confidence intervals. Similarly, following the 2005 evaluation, concerns were raised that tailrace conditions for fish passing through the spillway were contributing to reduced survival of fish. Specifically, fish that passed through bays 5-6 had reduced survival and more extended egress than did fish that passed through bays 1-4. This proposed study is designed to address the concerns identified after the 2005 evaluation of survival and tailrace egress at The Dalles Dam.

During 2007 we propose to 1) evaluate tailrace egress at The Dalles Dam using drogues and fixed-site monitoring of radio-tagged yearling and subyearling Chinook salmon and juvenile steelhead trout, 2) estimate survival through spillbays 1-4 and 5-6 using releases of yearling Chinook salmon immediately above the spillway and the single release model, and 3) survival of juvenile salmonids passing The Dalles Dam using a Route Specific Survival Model (RSSM) approach.

**PROJECT OVERVIEW**

The USGS-BRD has studied juvenile salmonid behavior in dam forebay and tailrace environments since the early 1990's. Our work has primarily focused on assessment of surface bypass/collection concepts at John Day, The Dalles and Bonneville dams. During 1992-1994 and 2002, the USGS-BRD conducted radio-telemetry studies on northern pikeminnow in the tailraces of John Day and The Dalles dams. Radio telemetry has been used by USGS to assess tailrace egress and/or survival at The Dalles Dam since 1999. In this proposal, we offer different approaches to evaluating the survival and egress of juvenile salmonids as they migrate pass The Dalles Dam.

Monitoring tailrace egress of radio-tagged juvenile salmon will enhance management's ability to interpret survival estimates generated for The Dalles Dam and provide a metric that can be compared with previous evaluations, model studies, and dam operating conditions. Drift buoys have proven to be useful tools in evaluations of juvenile salmonid egress from dams in the Columbia River. The USGS has used GPS-equipped drogues in studies at John Day and The Dalles dams for the last few years. Drogues are not a true surrogate for fish, but have been shown to have similar egress paths and times as radio-tagged salmonids at John Day and The Dalles dams. The advantages of using drogues along with fish releases is that drogues collect spatial data more frequently than possible during mobile tracking of fish (about 5 times more data) and, because they are autonomous, can collect data in areas inaccessible by boat. Thus, the use of drogues compliments data collected concurrently from tagged fish.

During 2006 we estimated survival through spillbays 1-4 and 5-6 using releases of yearling Chinook salmon immediately above the spillway and the single release model; we present this methodology as an option to evaluate survival through the spillway during 2006. The advantages of using the single release model include reduced cost compared to other options and control over how many fish go through the spillbay groupings; the disadvantages include not being able to evaluate overall spillway survival and not being able to place spillway survival in the context of the survival through other routes at the project. At the request of ACOE Portland District staff we also propose an evaluation of the survival of juvenile salmonids passing The Dalles Dam using a Route Specific Survival Model (RSSM) approach. In 2004 and 2005 under the RSSM study design we were able to provide evaluations of fish survival through spillbays 1-4 and 5-6 at The Dalles Dam. The disadvantages to this approach include increased cost and lack of control of how many fish go through spillbays 1-4 and 5-6; the advantages include being able to estimate spillway survival using fish that have volitionally distributed themselves across the spillway and being able to assess spillway survival in the context of the survival through the other routes and overall dam and project survival. Given the advantages and disadvantages associated with these approaches, employing both would provide the most complete evaluation of survival through The Dalles Dam spillway. However, employing one or the other will provide useful information about spillway survival at The Dalles Dam.

## OBJECTIVES AND METHODOLOGY

**Objective 1.** Evaluate tailrace egress at The Dalles Dam using drogues and fixed-site monitoring of radio-tagged yearling and subyearling Chinook salmon and juvenile steelhead trout.

*Rationale*

The tailrace at The Dalles Dam is a challenging environment for juvenile salmonids. They are exposed to risk of physical injury, delay and a high risk of predation by northern pikeminnow or smallmouth bass. Based on hydraulic modeling in the 1:80 physical model, the new spillway configuration is expected to influence tailrace egress. Monitoring tailrace egress of radio-tagged juvenile salmon will enhance management's ability to interpret survival estimates generated for The Dalles Dam and provide a metric that can be compared with previous evaluations, model studies, and dam operating conditions.

We propose to monitor the tailrace egress of radio-tagged yearling Chinook salmon passing the north and south spillway. We will make releases of radio-tagged fish in the forebay so that we get approximately equal numbers of fish passing the north spillbays (bays 1-4) and south spillbays (bays 5 & 6). Release locations will be adjusted to try to maximize the number of fish passing through bays 4 and 6 since these bays are of particular interest. We propose to release 1200 radio-tagged yearling and subyearling Chinook salmon and steelhead trout to evaluate egress and survival (see: Objectives 2-3). Study fish will be released at two locations in The Dalles Dam forebay: north (in front of bays 1-4) and south (south of bay 6). We will conduct releases throughout the spring and summer outmigration period during both daylight hours and darkness.

Using the data generated from our previous work at The Dalles Dam, we calculated the sample size required to detect 5-10 min differences in tailrace egress time among the two release sites. For each release date, ten fish at each release site will give us good power (> 0.80) to detect differences in mean residence times among the release groups. Since these releases will be in the forebay and not through pipes mounted on the spillway, we will have to account for some loss of fish on each release. We anticipate that releases of 15 fish at the north spillway and 15 fish at the south spillway will allow us to meet our target of 80% power. Since the egress evaluation will be done concurrently with a survival evaluation (objectives 2-3), sample sizes for each release will be above the required 15 fish per site, and target power levels should be easily reached.

Monitoring will be accomplished by fixed-site receiving stations in the forebay and tailrace of the spillway, on the islands near the Route 197 Bridge (the bridge islands), on the basin islands, and on both riverbanks. The goal of the monitoring array will be to determine specific spillbay of passage and to detect fish in the tailrace so that egress time can be calculated. New arrays of antennas will be designed and implemented near the spillway wall to improve our ability to describe fish movements near the spillway and in front of spillbays to the south of the wall. Fixed-site receiving stations will be established on the basin islands and at a site 6 km downriver of the dam to provide tailrace egress times in zones. Egress times will be determined for the north and south spillbays and they will be compared at each detection location.

We propose to use drogues released through the spillway to evaluate tailrace egress within the boat-restricted zone. Drogues can be used to describe movement paths relative to the new wall and in greater detail than can be collected through radio telemetry. Drogue egress times will be compared with egress times of radio-tagged fish that pass through the tailrace under similar dam operating conditions.

**Task 1.1** Collect, tag, and release yearling and subyearling Chinook salmon and steelhead trout.

Study fish will be collected at the John Day Dam smolt monitoring facility and transported to The Dalles Dam for tagging. Radio transmitter implantation and holding will follow protocols established for USGS survival studies. Fish will be released into the forebay to try to balance the numbers of fish passing the north spillway (bays 1-4) and the south spillway (bays 5-6). Forebay releases will be by boat, approximately 200 m upriver of the spillway. On each release date, there will be two releases into the forebay. For north spillway releases the boat will be positioned in the center of bays 1-4. For south spillway releases the boat will be positioned to the south of bay 6 because the general approach pattern is from the south, and we anticipate that most fish released from this location will pass through bay 6.

Activity 1.1.1

Collect study fish at the John Day Dam smolt monitoring facility, transport them to The Dalles Dam, implant them with radio transmitters, and hold fish for 24 hours to recover.

*Schedule:* April-July, 2007

Activity 1.1.2

Release radio-tagged fish into the forebay of The Dalles Dam by boat. We plan approximately 60 releases (30 day, 30 night) of about 20 fish. On each release date, 10 fish will be released in front of the north spillway (bays 1-4) and 10 fish will be released in front of the south spillway (bays 5-6).

*Schedule:* April-July, 2007

**Task 1.2** Monitor the movements and behavior of radio-tagged juvenile salmonids in The Dalles Dam tailrace using fixed receiving stations located on the face of the dam, along the navigation lock peninsula, on the bridge islands, and on the basin islands. Develop and implement intensive monitoring to the south of the spillway. Establish a study site exit station (6 km downriver of the dam) to be used as a final point of contact within the tailrace.

Activity 1.2.1

Establish fixed receiving equipment in the forebay and tailrace of The Dalles Dam to monitor the movement of radio-tagged fish in the immediate dam tailrace area. The fixed receiving station on the basin islands will serve as the exit station for the immediate tailrace area.

*Schedule:* January-April, 2007

Activity 1.2.2

Establish fixed receiving equipment on the bridge islands, the basin islands and at one point further downriver. Design arrays to be able to detect fish (or consumed fish) that may hold in shallow, low velocity areas of the tailrace.

*Schedule:* January-April, 2007

Activity 1.2.3

Maintain and download fixed monitoring stations to ensure proper operation and secure data.

*Schedule:* April-August, 2007

Activity 1.2.4

Calculate egress times of yearling Chinook salmon to each of the exit station monitoring locations (bridge, basin islands, and 6 km exit station). Compare egress times for fish that passed through the north spillway vs. the south spillway.

*Schedule:* August-December, 2007

Activity 1.2.5

Calculate egress times of subyearling Chinook salmon to each of the exit station monitoring locations (bridge, basin islands, and 6 km exit station). Compare egress times for fish that passed through the north spillway vs. the south spillway.

*Schedule:* August-December, 2007

Activity 1.2.6

Calculate egress times of steelhead trout to each of the exit station monitoring locations (bridge, basin islands, and 6 km exit station). Compare egress times for fish that passed through the north spillway vs. the south spillway.

*Schedule:* August-December, 2007

**Task 1.3** Use drogue releases at the spillway to evaluate tailrace egress times and travel routes.

Data collected from the drift buoy releases will be useful in evaluating the assumption that fish behavior is similar to dye patterns in a physical model. Drift buoys will use a global positioning system (GPS) unit that will record the position of the drift buoy each second. These data can be used to describe the precise path of the buoy/drogue as it moves through the tailrace.

Activity 1.3.1

Release drogues (equipped with GPS units) through the spillway to evaluate egress times and travel routes in the tailrace. Drogue releases will be made on the same dates that radio-tagged fish are released (or pass) so that fish and drogue movements can be compared under similar dam operations.

*Schedule:* April-July, 2007

Activity 1.3.2

Calculate drogue egress times to each study site exit station (bridge, basin islands and 6 km exit station). The egress times of drogues will be compared to the egress times of radio-tagged fish released/passed on the same dates to control for dam operational differences. This product will be useful in evaluating the assumption that fish tend to behave similar to the predominant flows in the tailrace.

*Schedule:* July-December, 2007

Activity 1.3.3

Use a Geographic Information System (GIS) to display GPS positions of drift buoys. Graphic displays will be generated for each release site and dam operation represented.

*Schedule:* July-December, 2007

**Objective 2.** Estimate survival of yearling and subyearling Chinook salmon and steelhead trout passing spillbays 1-4 or 5-6 at The Dalles Dam spillway using the single release-recapture model.

*Rationale*

Recent modifications of the spillway stilling basin (i.e., training wall) and spill pattern at The Dalles Dam were intended to increase the survival of juvenile salmonids that pass through the spillway. Studies using HI-Z tags at The Dalles Dam spillway in 2004 found that survival estimates were higher and passage related maladies were lower for yearling Chinook salmon passing spillbays 2 and 4 than for spillbay 6. Data from a radio-telemetry survival evaluation of yearling Chinook salmon passing the spillway at The Dalles Dam suggest that survival estimates were higher for fish passing bays 1-4 than through bays 5-6. Further evaluation of the survival through spillbays 1-4 and 5-6 at The Dalles Dam spillway will help to better understand where mortality is occurring and thus, focus future efforts to improve survival.

Sample sizes needed to detect a 5% difference in single-release survival estimates between spillbays 1-4 and spillbays 5-6 at The Dalles Dam were estimated. Input parameters to estimate standard errors were based on mean values of single-release survival and detection probabilities from spillbays 1-4 and spillbays 5-6 at The Dalles Dam in 2004 (Table 1). We also assumed 95% of released fish would pass through the intended spillbays and 95% of fish passing spillbays would be detected by underwater antennas.

Table 1. Mean single-release survival and detection probabilities for spillbays 1-4 and spillbays 5-6 at The Dalles Dam in 2004 that were used to estimate standard errors for the power analysis.

| Parameter | Spillbays 1-4 | Spillbays 5-6 |
|---|---|---|
| $S_1$ | 0.909 | 0.871 |
| $S_2$ | 0.991 | 0.981 |
| $P_1$ | 0.797 | 0.784 |
| $P_2$ | 0.679 | 0.658 |
| Lambda | 0.965 | 0.967 |

For given survival and detection probabilities, sample sizes required to detect a 5% difference depend largely on alpha, beta, and whether a 1- or 2-tailed *t*-test is used (Table 2). For example, the sample size for a 2-tailed test when alpha = 0.05 and beta = 0.20 is nearly double that of a 1-tailed test with alpha = 0.10 and beta = 0.20 (Table 2). After conferring with ACOE staff, it was determined that using a 1-tailed test would be appropriate because past data suggests that survival through spillbays 5-6 is consistently lower than through spillbays 1-4. Thus, the null and alternative hypotheses can be stated as:

$$H_0: S_{1\text{-}4} = S_{5\text{-}6}$$
$$H_1: S_{1\text{-}4} > S_{5\text{-}6}$$

However, values for alpha and beta should be chosen based on the allowable risk of committing a Type I or Type II error (Table 3). To examine the effect of varying sample size, we have also provided a plot of the minimum detectable difference in survival versus sample size for different values of alpha, beta, and 1- or two-tailed tests (Figure 1).

Our analyses are based on two assumptions. First, the power analysis conducted here is specific to the set of input parameters used. For example, if observed survival or detection probabilities are lower than those used in our analyses, then larger sample sizes would be needed to detect a 5% difference in survival. Second, standard errors used in the power analysis include only random variation and do not include additional variation that may be caused by environmental factors. For example, widely varying tailrace conditions over the course of the study could introduce additional variation into the survival estimates, which is not accounted for in the power analyses conducted here.

We propose to release 1200 radio-tagged yearling Chinook salmon into the forebay immediately upstream of the spillway at The Dalles Dam, and using the single release-recapture model (Skalski et al. 1998), the series of survival parameters depicted in Figure 2 will be generated. With this sample size we should be able to detect a 5% difference in survival between spillbays 1-4 and 5-6 by evaluating a *t*-test where alpha = 0.05 and beta = 0.20.

Table 2. Sample sizes required to detect a 5% difference in survival between spillbays 1-4 and spillbays 5-6 for alpha = 0.05 or 0.10, beta = 0.20 or 0.30, and a 1- or 2-tailed *t*-test.

| Alpha | Beta (1-Beta = Power) | 1- or 2-tailed *t*-test | Total sample size to detect 5% difference |
|---|---|---|---|
| 0.05 | 0.20 | 2 tails | 1,500 |
| 0.05 | 0.20 | 1 tail | 1,150 |
| 0.10 | 0.20 | 1 tail | 840 |
| 0.10 | 0.30 | 1 tail | 620 |

Table 3. The four possible outcomes of hypothesis testing, that are dependent on whether the statistical test correctly identifies the true state of nature. Also shown are α and β, the probability of committing a Type I and II error, respectively, and examples of commonly chosen values of α and β.

| | **Result of statistical test** | |
|---|---|---|
| **True state of nature** | Significant | Not Significant |
| True difference | Correct decision<br>Power=1-β=0.80 | Type II error<br>β=0.20 |
| No true difference | Type I error<br>α=0.05 | Correct decision<br>1-α=0.95 |

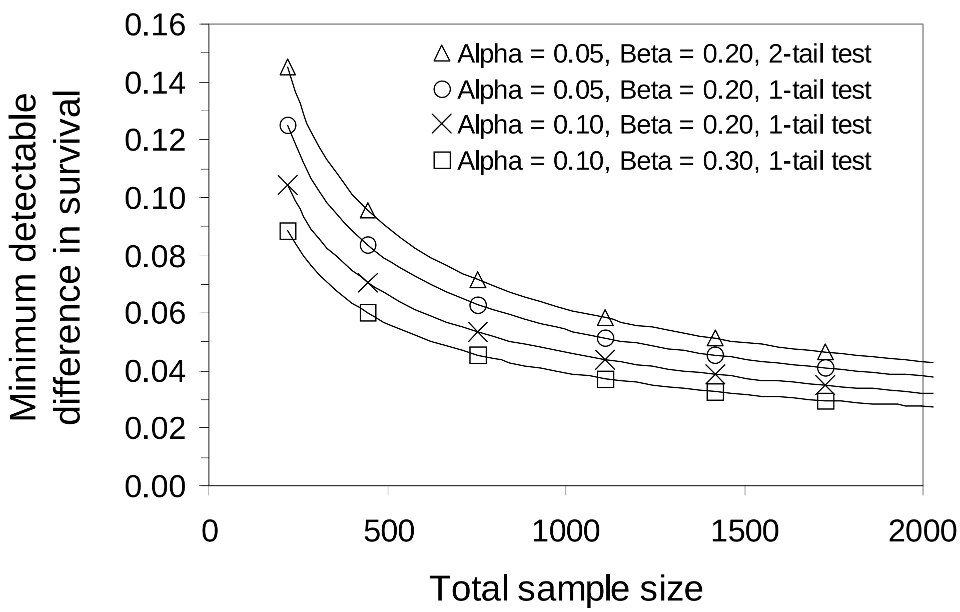


Figure 1. The minimum detectable difference in survival probabilities between spillbays 1-4 and spillbays 5-6 at The Dalles Dam as a function of the total sample size for different values of alpha, beta, and 1- or 2-tailed *t*-tests.

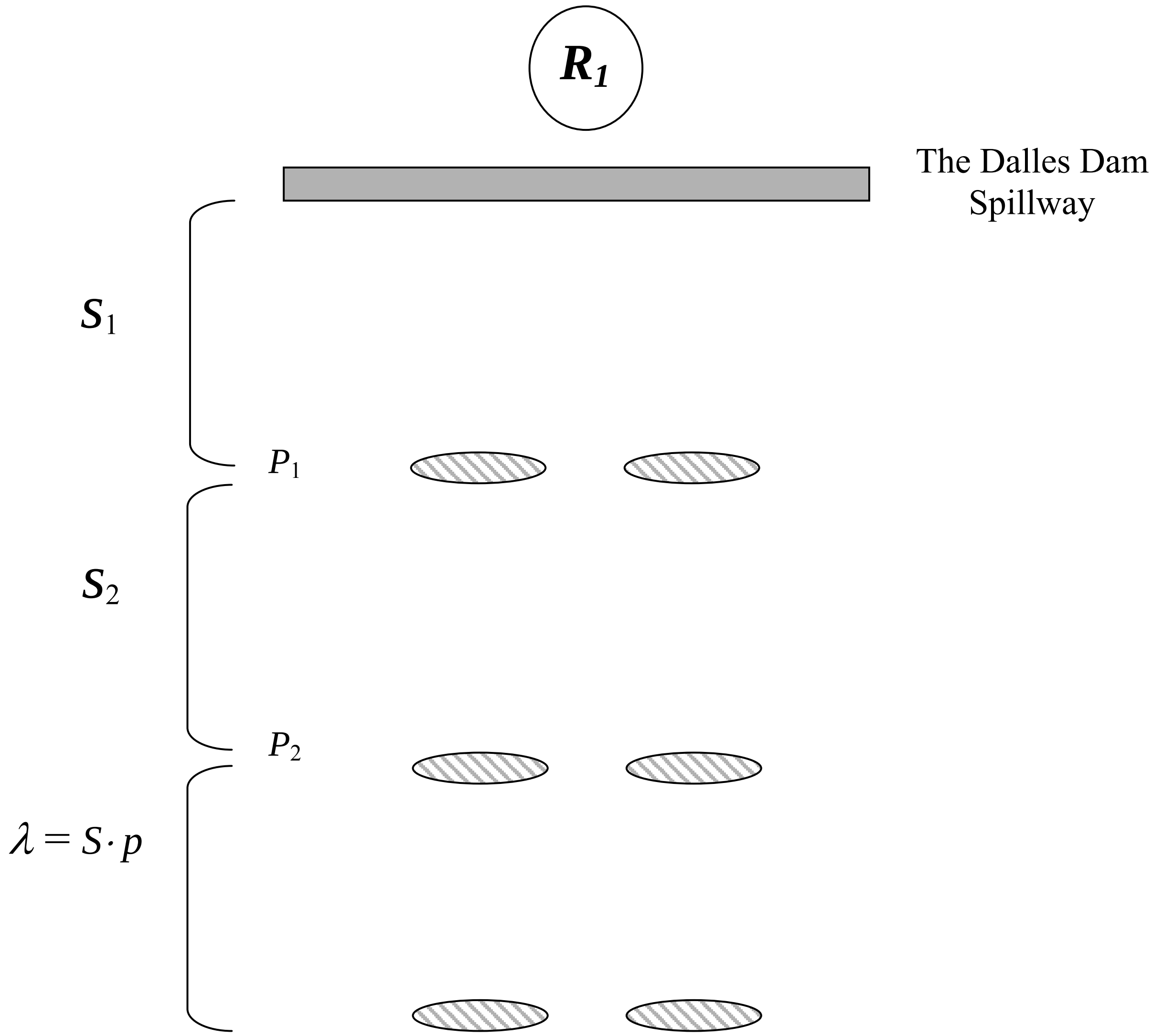


Figure 2. Schematic of release, possible detection sites, and estimated survival parameters ($S$ = survival estimate, $p$ = capture probability, and $\lambda = S \cdot p$) generated in a single release-recapture design to estimate migrant juvenile salmonid survival through the spillway at The Dalles Dam.

**Task 2.1** Set up and test radio telemetry fixed receiving equipment at The Dalles Dam, and in Bonneville Reservoir.

Activity 2.1.1.

Configure aerial and underwater detection arrays.

*Schedule*: January-April, 2007.

Activity 2.1.2.

Test system performance by drifting transmitters through antenna arrays to assess and improve antenna coverage. This will be done to ensure proper system operation.

*Schedule*: January-April, 2007.

**Task 2.2** Release radio-tagged yearling Chinook salmon and steelhead trout in the forebay of The Dalles Dam during the spring of 2007.

*Schedule:* April-June, *2007.*

**Task 2.3** Release radio-tagged subyearling Chinook salmon in the forebay of The Dalles Dam during the summer of 2007.

*Schedule:* June – July, 2007.

**Task 2.4** Monitor the performance of receiving equipment with diagnostic checks and download equipment at least twice weekly.

Activity 2.4.1.

Perform diagnostic checks on receiving equipment 2 to 7 times per week.

*Schedule*: April-July, 2007.

Activity 2.4.2.

Download telemetry receivers and MITAS system 2 to 7 times per week.

*Schedule*: April-July, 2007.

**Task 2.5** Proof and apply quality assurance and control protocols to radio-telemetry data.

Activity 2.5.1

Proof database of contacted radio-tagged fish for accuracy by applying established protocols for determining the validity of records.

*Schedule:* June through September 2007

Activity 2.5.2

Generate capture-history matrices from the proofed database.

*Schedule:* September 2007

Activity 2.5.3

Conduct QA/QC on radio-telemetry data.

*Schedule:* June – September 2007

**Task 2.6** Estimate false-positive detection rates for radio-tagged dead fish at The Dalles Dam.

Activity 2.6.1

Juvenile salmonids will be implanted with radio transmitters and then euthanized and released in The Dalles Dam tailrace.

*Schedule:* April - July 2007

Activity 2.6.2

Verify the validity of contacts of dead radio-tagged fish detected at arrays downstream of release sites.

*Schedule:* June through September 2007

Activity 2.6.3

Estimate the rate of false-positive detections for all areas of interest.

*Schedule:* September 2007

**Task 2.7** Perform tag life evaluation.

Activity 2.7.1

Randomly sub-sample 50 tags from those used for the survival study. Activate radio tags in three batches (beginning, middle, and end) during the study period, and hold in tanks at The Dalles Dam at ambient conditions. Monitor radio tag output with a Lotek SRX-400 telemetry receiver and download the data collected weekly.

*Schedule:* April - July 2007

Activity 2.7.2

Estimate the probability a radio tag is operational over time, model the probability a radio tag is operational, and estimate the probability radio tags are operational at detection arrays.

*Schedule:* June through August 2007

**Task 2.8** Estimate the survival of yearling and subyearling Chinook salmon and steelhead trout.

Activity 2.8.1.

Assess conformance to survival model assumptions.

*Schedule:* September 2007

Activity 2.8.2.

Model the downstream survival and capture processes of each release.

*Schedule:* September 2007

**Objective 3.** Estimate the project, dam, and route specific survival of juvenile yearling and subyearling Chinook salmon and steelhead trout passing through The Dalles Dam.

*Rationale*

During 1994, spill patterns were developed for The Dalles Dam to promote tailrace egress. Evaluations of conditions in the tailrace of The Dalles Dam suggested that spill in excess of 30-40% would cause a large percentage of migrating salmonids to use a route near the shallow water area along the Oregon shore and increase the probability of predation. Survival estimates generated by the National Marine Fisheries Service using PIT tags indicate that survival was lower for test groups at The Dalles Dam for 64% spill than for fish at other projects (Dawley et al. 1998). Consequently, the effects of spill levels lower than 64% on the survival of juvenile salmonids were investigated during FY98 and FY99. During 2000, the USGS participated in a joint study with the NMFS at The Dalles Dam to compare survival estimates generated with PIT and radio tags. During 2001, releases of radio-tagged fish were made through north and south spillbays (evaluation was constrained by the low water year) at The Dalles Dam. Recent modifications of the spillway stilling basin (i.e., training wall) and spill pattern at The Dalles Dam were intended to increase the survival of juvenile salmonids that pass through the spillway.

Studies using HI-Z tags at The Dalles Dam spillway in 2004 found that survival estimates were higher and passage related maladies were lower for yearling Chinook salmon passing spillbays 2 and 4 than for spillbay 6. Similarly, data from radio-telemetry survival evaluations of yearling and subyearling Chinook salmon during 2004 and 2005 at The Dalles Dam suggest that survival estimates were higher for fish passing bays 1-4 than through bays 5-6.

Since modifications continue to be made to the spillway at The Dalles Dam, continued evaluation of the survival through spillbays 1-4 and 5-6 at the spillway and through other routes at The Dalles Dam will help to better understand where mortality is occurring and thus, focus future efforts to improve survival. Evaluating spillway survival using the RSSM will allow the estimation of spillway survival using fish that have volitionally distributed themselves across the spillway and allow spillway survival to be placed in the context of the survival through the other routes and overall dam and project survival. During 2007, we propose to estimate the dam, project and route specific survival through The Dalles Dam. Using releases of radio-tagged fish below or at John Day Dam and releases in the tailrace of The Dalles Dam and the RSSM (Skalski 1998), we will estimate survival through The Dalles Dam. Using the release and detection schemes depicted in Figure 3, the parameters in Figure 3 will be estimable.

**Task 3.1** Collect, tag, and release yearling and subyearling Chinook salmon and steelhead trout.

Study fish will be collected at the John Day Dam smolt monitoring facility. Fish to be released in the tailrace of John Day Dam will be tagged at John Day Dam. Fish to be release at The Dalles Dam will be transported from John Day Dam shortly after collection to The Dalles Dam for tagging. Radio transmitter implantation and holding will follow protocols established for USGS survival studies. Fish will be released from boats into the tailrace of John Day Dam and in the tailrace of The Dalles Dam.

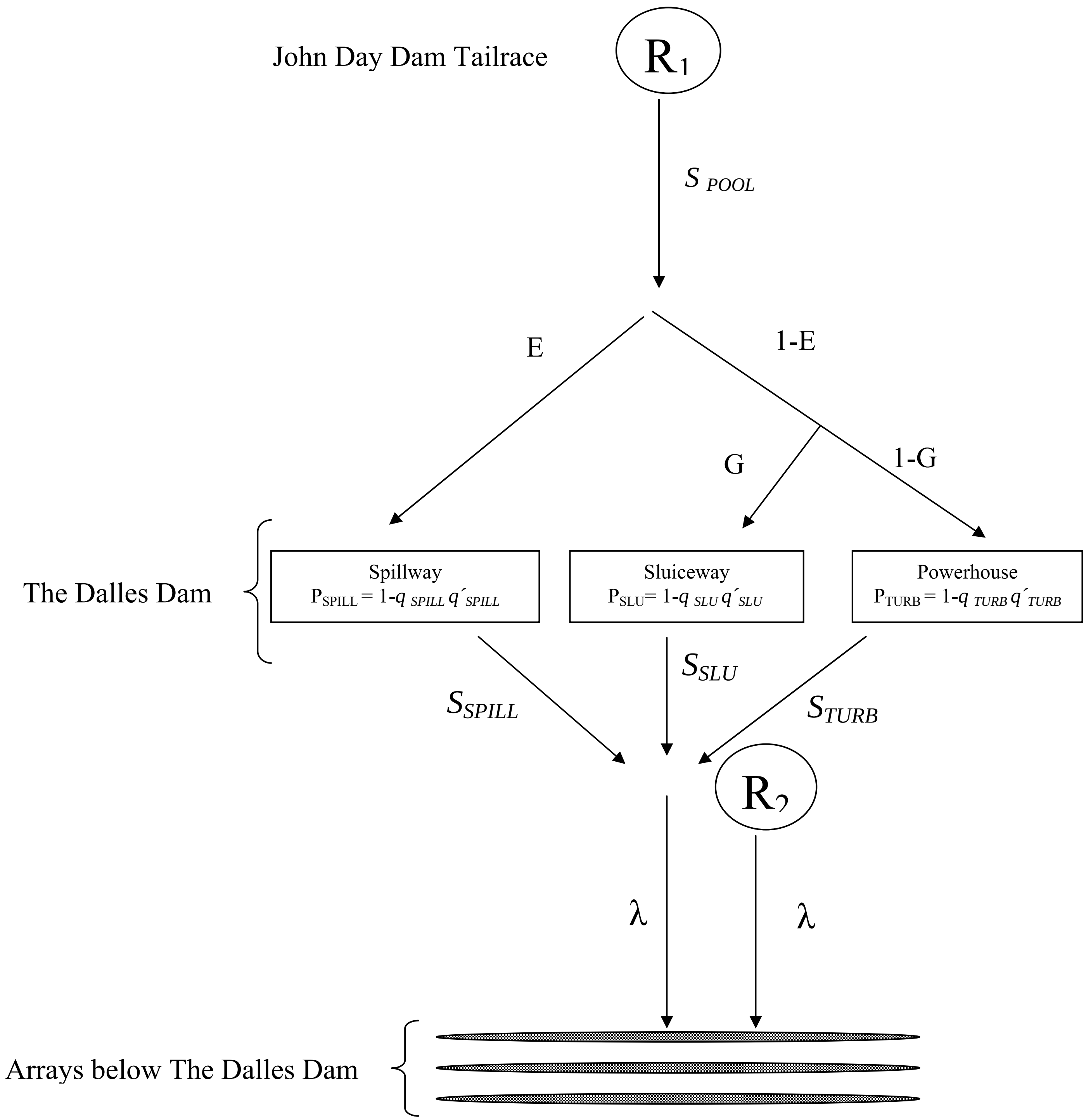


Figure 3. Description of estimable parameters using the route specific survival model (RSSM) given release and detection schemes in place during 2007. Included in the detection scheme is a double radio-telemetry array at The Dalles Dam that is necessary to use the RSSM.

**Task 3.2** Prepare data for input into USER 1.0 software.

Activity 3.2.1

Proof database of contacted radio-tagged fish for accuracy by applying established protocols for determining the validity of records.

*Schedule:* June through September 2007

Activity 3.2.2

Generate capture-history matrices from the proofed database using the Statistical Analysis System (SAS).

*Schedule:* September 2007

**Task 3.3** Generate dam and route-specific survival estimates using the RSSM and the USER 1.0 software

*Schedule:* September through November 2007

## Methods

### Study area and Radio Telemetry system antenna configuration

The study area (e.g., zone of inference; Peven et al. 2005) will include the forebay of The Dalles Dam and Bonneville Reservoir. Antenna arrays on the Dalles Dam spillway will be set up so that passage route can be determined (Hansel et al. 2005). Three antenna arrays, spanning the breadth of the river channel, will be set up downstream of The Dalles Dam in Bonneville Reservoir.

### Fish tagging and release

Study fish will be collected at the John Day Dam smolt monitoring facility. Fish to be released in the tailrace of John Day Dam will be tagged at John Day Dam. Fish to be release at The Dalles Dam will be transported from John Day Dam shortly after collection to The Dalles Dam for tagging. Radio transmitter implantation and holding will follow protocols established for USGS survival studies. Fish will be released from boats into the tailrace of John Day Dam and in the tailrace of The Dalles Dam. To represent the full range of passage conditions, releases will be planned during daytime and nighttime conditions throughout the spring and summer outmigration periods.

### Converting radio signals into detection histories

After data collection, radio signals have to be interpreted and converted into detection histories. Aerial and underwater antennas attached to data logging equipment will often record spurious radio signals or “noise” and designate them as such, or misinterpret other radio signals (e.g., from cars or trucks) and label them with fish channel and code designations.

We performed automated data processing using Statistical Analysis System (SAS) software to separate spurious radio signals from true radio signals and assign passage and location designators. The following criteria were used to classify data records as noise:

1. Records composed of invalid channel and code combinations, typically a result of erroneous radio transmissions (noise) that overlap with the radio frequencies that we are monitoring.
2. Records logged before a fish's release.
3. Records below an empirically determined signal strength threshold for each aerial and underwater array at the dam.
4. Fewer than two records recorded within a 20 min period for an individual fish.
5. Fewer than 5 records in a 60-min interval on the MITAS underwater antenna array for an individual fish.
6. Fewer than 5 records in a 60-min interval on a single aerial receiver unsupported by at least one record on the corresponding forebay aerial or underwater array during the same hour.
7. Fewer than 5 records in a 60-min interval unsupported by a minimum of two other records recorded on one receiver at the entrance, tailrace, or exit stations during the hour interval before or after the detections.

Once all times and locations of interest (events) are electronically assigned, individual fish histories are verified using criteria derived from manually-proofed radio-telemetry data obtained in past years for the same species. A fish's event history is considered potentially suspect if 1) the travel time between release and first forebay, tailrace, or exit detection, or travel time between sequential events is less than the $5^{th}$ or greater than the $95^{th}$ percentiles of past data from a similar flow year, 2) forebay, tailrace, and exit residence times exceeded the $95^{th}$ percentile of similar past year's metrics, or 3) a fish's events are chronologically or geographically out of order. Fish whose event histories are suspect because of one or more of the above criteria are flagged to be manually proofed and reconciled with the electronic proof prior to further analyses. In addition to the flagged files, a random 10% of the fish from non-flagged files are manually examined by separate proofing staff and then reconciled by another staff member if any disagreements in either the time of passage or passage location are noted between the electronically assigned events and the manually assigned events.

### Generating survival estimates using the single release-recapture model (SRM) design

The SRM design requires as a minimum the following design elements: that tagged fish are uniquely identifiable, at least two downstream detection sites below the release locations, the re-release of all or some of the marked fish recaptured at each detection location, and the recording of the identity of the marked fish recaptured at each location (Peven et al. 2005). John Skalski (University of Washington) in Peven et al (2005) provides a discussion of the potential bias associated with this methodology. We encourage reviewers of this proposal to review this document if they have not done so.

Survival can be estimated from the release point to the next detection array and from then on, survival is estimated from the detection zone of one detection array to the next (Figure 2). Unique recapture probabilities can be estimated at each detection arrays except the farthest downstream. In the last reach, only the joint probability of survival to and being detected at the last detection array can be estimated (i.e., $\lambda = S \cdot p$). Thus, the minimal study design must consist of at least two downstream detection locations. The assumptions of the SRM are the following:

A1. Individuals marked for the study are a representative sample from the population of interest.

A2. Survival and recapture probabilities are not affected by tagging or sampling. That is, tagged animals have the same probabilities as untagged animals.

A3. All sampling events are "instantaneous." That is, sampling occurs over a negligible distance relative to the length of the intervals between sampling locations.

A4. The fate of each tagged individual is independent of the fate of all others.

A5. All tagged individuals alive at a sampling location have the same probability of surviving to the next sampling location.

A6. All tagged individuals alive at a sampling location have the same probability of being detected at that location.

A7. All tags are correctly identified and the status of each smolt (i.e., alive or dead), is correctly assessed.

The first assumption (A1) involves inferences from the sample taken to the target population. For example, if inferences are desired for yearling Chinook salmon, then the sample of tagged fish should be drawn from that population. This assumption could also be violated if the fish selected for tagging were on average larger than the target population.

Assumption A2 again concerns making inferences to the target population (i.e., untagged fish). If tagging has a detrimental effect on survival, then survival estimates from the single release-recapture design will tend to be negatively biased.

The third assumption (A3) stipulates that mortality is negligible immediately near the sampling stations, so that the estimated mortality is associated with the river reaches and not the sampling event. For migrant salmonids, the time spent near detection equipment is typically brief relative to the time spent in the river reaches.

The assumption of independence (A4) suggests that the survival or death of one smolt has no effect on the fates of others. In the Columbia River where many thousands of migrants can be found, this is likely true. Violations of assumption (A4) may bias the variance estimate (true variability would be greater than estimated).

Assumption (A5) specifies that the prior detection history of the tagged fish does not affect subsequent survival. This assumption could be violated if fish were trained to go through turbine or spill routes or alternatively to avoid routes because of prior experience. The lack of handling following initial release of radio-tagged fish minimizes the risk that subsequent detections influence survival. Similarly, assumption (A6) could be violated if downstream detections were influenced by upstream passage routes taken by tagged fish. Violation of this assumption is minimized by placing radio telemetry arrays across the breadth of the river and below the mixing zones for fish using different passage routes. Burnham et al. (1987) Tests 2 and 3 can be used to assess overall goodness-of-fit to single release-recapture assumptions, in particular whether upstream capture histories are independent of downstream histories.

Assumption (A6) states that all live tagged individuals should have the same probability of being detected at downstream detection arrays. However, radio-tags have a limited and varied battery life. Radio-tag battery life may be affected by water temperature and may vary among years or production batches. Survival estimates may be biased if radio-tags expire prior to fish exiting all the detection arrays. To address the probability of tag failure at detection arrays a tag-life study will be performed. Information obtained from a tag-life study can be used to adjust survival estimates if necessary.

Assumption (A7) implies that fish do not lose their tags and are subsequently misidentified as non-detected, or dead fish are falsely recorded as alive at detection locations. Tag loss would result in a negative bias (i.e., underestimation) of fish survival rates. Typically, the retention rate of active transmitters is high suggesting that the effects of tag loss on survival estimates would be minimal. Dead fish drifting downstream could result in false-positive detections and upwardly bias survival estimates. Tailrace antenna arrays are therefore not recommended because they are too close to locations of potential mortality. In addition dead radio-tagged fish will be released during the season along with live radio-tagged fish to determine the potential for detecting dead fish.

**Route Specific Survival Model**

**Model Assumptions**

The assumptions associated with the Route Specific Survival Model (RSSM) are described in detail in Skalski et. al. (2002).

A1. Individuals marked for the study are a representative sample from the population of interest.

A2. Survival and capture probabilities are not affected by tagging or sampling (i.e., tagged animals have the same probabilities as untagged animals).

A3. All sampling events are “instantaneous” (i.e., sampling occurs over a short time relative to the length of the intervals between sampling events).

A4. The fate of each tagged individual is independent of the fate of all others.

A5. All tagged individuals alive at a sampling location have the same probability of surviving until the end of that event.

A6. All tagged individuals alive at a sampling location have the same probability of being detected.

A7. All tags are correctly identified and the status of fish (i.e., alive or dead) is correctly identified.

A8. Survival in the upriver segment (*S*) is conditionally independent of survival in the lower river segment.

A9. Both the upstream and downstream release groups within a paired release experience the same survival probability in the segment of the river that they travel together.

Skalski et. al. (2002) identified two additional assumptions are associated with the RSSM:

A10. Routes taken by the radio-tagged fish are known without error.

A11. Detections in the primary and secondary antenna arrays within a passage route are independent.

Skalski et al. (2002) suggest that assumption A10 can be qualitatively assessed by examining radio telemetry detection histories to determine whether inconsistencies in individual fish detection histories exist. Skalski et al. (2002) use an example of a situation where a radio-tagged fish is detected in the upstream array of a route and then in the downstream array of another route, resulting in uncertainty in the route taken. That is, they used aerial antennas that monitored the tailrace area to help determine passage. Similar to the radio-telemetry system used in Skalski et al. (2002), the double array we will deploy at The Dalles Dam will consist of aerial and underwater telemetry systems that interrogate fish in the immediate forebay area of each particular route, with the exception of the ice and trash sluiceway where underwater antennas will be placed at two locations within the structure. However, while we will have a radio-telemetry system monitoring the tailrace area of each route, we do not consider detections in the tailrace when determining passage routes.

Skalski et al. (2002) determined that while assumption A11 is necessary for valid estimation of in-route detection probabilities, the assumption cannot be empirically assessed with the data collected with this type of study. Rather, they suggest that the detection fields of the primary and secondary arrays should be located in a way that fish detected in one array does not have a higher or lower probability of being detected in the secondary array than the primary array. Further, they suggest that this is best accomplished by having independent receivers for each antenna array and by having the detection field of at least one array encompass the entire passage route. The arrays we will deploy at the ice and trash sluiceway, spillway and powerhouse will conform to these requirements.

## Parameter Estimation

The double radio-telemetry array systems that we will deploy at The Dalles Dam will allow us to estimate route specific detection probabilities. In turn, these route specific detection probabilities can be incorporated into a statistical analysis that will extract route specific passage and survival (Skalski et. al. 2002). The following parameters are defined for the construction of the RSSM used at The Dalles Dam: $S_{POOL}$, survival from the release location at John Day Dam; G, conditional probability of passing via the ice and trash sluiceway, given that fish were going to the powerhouse; $P_{TURB}$, the powerhouse primary array detection probability; ($q_{TURB} = 1 - P_{TURB}$); $P'_{TURB}$, the powerhouse secondary array detection probability; ( $q'_{TURB} = 1 - P'_{TURB}$); $P_{SPILL}$, spillway primary array detection probability; ($q_{SPILL} = 1 - P_{SPILL}$); $P'_{SPILL}$, spillway secondary array detection probability; ($q'_{SPILL} = 1 - P'_{SPILL}$); $P_{SLU}$, the ice and trash sluiceway primary array detection probability; ($q_{SLU} = 1 - P_{SLU}$); $P'_{SLU}$, the ice and trash sluiceway secondary array detection probability; ($q'_{SLU} = 1 - P'_{SLU}$); $S_{SLU}$ , the ice and trash sluiceway survival probability; $S_{SPILL}$, spillway survival probability, $S_{TURB}$, the powerhouse survival probability, $\lambda$, joint probability of surviving and being detected at the arrays below The Dalles Dam. The releases made at John Day Dam ($R_1$) and the releases made in the tailrace of The Dalles Dam ($R_2$) will be interrogated at three arrays below The Dalles Dam, the furthest downriver being an array deployed on Bonneville Dam. A branching process will be used to model the migration and survival of releases $R_1$ and $R_2$ (Figure 3). Additional details regarding the methodology used in the formulation of the RSSM and the estimation of the associated parameters can be found in Skalski et al. (2002). For the RSSM survival probabilities, both standard errors and profile likelihood 95% confidence intervals are reported (Skalski et al. 2002).

The route specific survival and passage probabilities can be combined using maximum likelihood estimation to estimate survival through the dam. The survival through The Dalles Dam will be estimated from the expression

$$\hat{S}_{DAM\cdots} = (1-\hat{E})(1-\hat{G})\ \hat{S}_{TURB} + (1-\hat{E})\hat{G}\ \hat{S}_{SLU} + \hat{E}\,\hat{S}_{SPILL}$$

The variance for the dam survival estimate will be estimated using the delta method (Seber 1982, pp 7-9). All of the route specific survival and passage probabilities will be estimated using the USER (User Specified Estimation Routine) developed at the University of Washington (Lady et al. 2003; see: http://www.cqs.washington.edu/paramEst/USER/).

## FACILITIES AND EQUIPMENT

No specific facilities or equipment will be required to complete the fixed monitoring component of this study as we have previously established methods and protocols for these activities. Fish collection activities at John Day Dam will be coordinated with other research groups that may need juvenile salmon for research projects.

## IMPACTS

We will coordinate radio frequencies used with other researchers to minimize conflicts with other projects.

## COLLABORATIVE ARRANGEMENTS AND SUBCONTRACTS

None

## LIST OF KEY PERSONNEL AND PROJECT DUTIES

| | |
|---|---|
| Dennis Rondorf, USGS | Section Leader |
| Theresa Liedtke, USGS | Principal Investigator |
| Tim Counihan, USGS | Principal Investigator |
| Chris Peery, University of Idaho | Principal Investigator |
| Jill Hardiman, USGS | Analysis |
| Amy Puls, USGS | Analysis, QA/QC |
| Philip Haner, USGS | Fixed Receiving Equipment Coordinator |
| Collin Smith, USGS | Field Team Coordinator |

## TECHNOLOGY TRANSFER

Results from this study will be disseminated in the form of preliminary reports, 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 31, 2007. 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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