Preliminary Proposal for FY 2005 funding

Title: Estimating the Survival of migrant Juvenile Salmonids through The Dalles Dam using Radio Telemetry: 2005 evaluations

Study Codes:	SPE-P-00-8
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Contract Period:	January 1, 2005 through September 30, 2005
Date Submitted:	August 3, 2004

PROJECT SUMMARY

RESEARCH GOALS

The goal of this research is to estimate the survival of yearling and sub-yearling Chinook salmon and steelhead trout passing through The Dalles Dam, including dam, project and route specific survival through the ice and trash sluiceway, powerhouse, and spillway.

STUDY OBJECTIVES

During 2005, we propose to use radio-tagged fish releases and radio-telemetry detection schemes to generate survival estimates for juvenile salmonids at The Dalles Dam. All the objectives described below will be evaluated for yearling Chinook salmon, steelhead trout, and sub-yearling Chinook salmon. As part of this study, the USGS will continue to coordinate with the ACOE and regional fish managers to provide the necessary information to them so that the objectives of the studies at The Dalles Dam meet their expectations.

Objective 1. Estimate the route specific, project, and dam survival of juvenile salmonids passing through The Dalles Dam.

Results from studies conducted at The Dalles Dam during 2001-2003 suggest that there is a direct effect on juvenile salmon survival and injury rates and that the causal mechanism for reduced survival and injury is the lateral flow that passes along the stilling basin's length from south to north. Concurrently, an engineering study developed a solution to eliminate lateral flow in the stilling basin and determined that lateral flow could be blocked by constructing a longitudinal training wall that extends 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. Preliminary results suggest that for typical summer migrant river conditions, 40% of the total river discharge could be safely passed through Bays 1-6 with no measurable increase in fish injury or mortality. The training wall at The Dalles Dam spillway will be constructed during 2003 and 2004 and subsequently evaluated in 2004 and 2005. Primary issues to address for the post-construction evaluation include the wall's effect on survival and injury rates for spillway passed fish, spillway and fish passage efficiency, and upstream adult fish passage.

To evaluate survival we will use radio-tagged fish releases of yearling and sub-yearling Chinook salmon and steelhead trout in the tailrace of John Day Dam, in the tailrace of The Dalles Dam and the Route Specific Survival Model (RSSM) (Skalski et al. 1998a) to estimate survival through the ice and trash sluiceway, spillway, and powerhouse, and through all routes collectively at The Dalles Dam after the construction of the longitudinal training wall. Desired precision levels for the RSSM estimates are stated to be ± 4% for the dam and spillway survival estimates.

Objective 2. Evaluate a new survival estimation procedure, the triple release design, to address potential bias in survival estimates generated using the RSSM.

During 2004, the ACOE and the SRWG requested that the USGS employ a survival estimation model that would account for the potential bias in survival estimates generated using the RSSM. As of the submission date of this proposal, the USGS has made the necessary releases to employ this model and are proceeding with the data processing that will allow this model to be evaluated. During 2005, we plan to continue the evaluation of this model at The Dalles Dam.

Objective 3. Evaluate tailrace egress at The Dalles Dam using drogues and fixed-site monitoring of radio-tagged fish.

We propose to use drogues released through the spillway to evaluate tailrace egress within the boat-restricted zone (BRZ). Drogues will be released through the same bays that radio-tagged fish are released.

Objective 4. Estimate the probability of false-positive detection rates for radio-tagged dead fish released below The Dalles Dam.

False positive-detections from radio tags on dead fish may positively bias survival estimates (Skalski et al. 1998a). Thus, we propose to continue to monitor radio-tagged dead fish released below The Dalles Dam to evaluate false positive-detection rates.

RELEVANCE TO THE BIOLOGICAL OPINION

This study addresses the 2000 Biological Opinion RPAs 68, 70, and 83.

PROJECT DESCRIPTION

BACKGROUND AND JUSTIFICATION

Decreases in Pacific salmon populations throughout the Columbia and Snake rivers have led to the federal listing of certain runs as endangered species. Hydroelectric development in the Columbia River Basin has been shown to be one of the causal mechanisms contributing to the declines in Pacific salmon populations. As anadromous juvenile salmonids migrate from freshwater rearing habitats to the ocean, they are vulnerable to a host of factors that affect their survival. Direct effects associated with dam passage (e.g., instantaneous mortality, injury, loss of equilibrium, etc.) and indirect effects (e.g., predation, disease, and physiological stress) contribute to the total mortality of seaward migrating salmonids. Many studies have been conducted to determine the effects of hydroelectric dams on the survival of salmonid migrants (Raymond 1979, Stier and Kynard 1986, Iwamato et al. 1994, Muir et al. 1995, Smith et al. 1998, Bickford and

Skalski 2000). Giorgi et al (2002) noted that survival of salmonid migrants is variable among projects and across species. Thus, tagging studies designed to estimate project specific survival and route specific survival (i.e. through turbines, bypass areas, and spillways) of juvenile salmon are needed to identify the potential sources of mortality. Based on current research and past studies examining migrant salmonid behavior at dams in the Columbia River Basin, management actions are implemented to improve the survival of juvenile salmonid migrants.

New fish marking techniques and the development and acceptance of new statistical methodologies (see Lebreton et al. 1992) have led scientists to reevaluate past techniques used to assess survival of migrant salmonids in the Columbia River Basin. The development of the passive integrated transponder (PIT) tag, allowed for the unique identification of fish (Prentice et al. 1990), and recent technological advancements in radio-telemetry equipment have decreased the size and increased the life of transmitters allowing for use with juvenile fish passage behavior and survival studies (Skalski et al. 2001 and 2002, Counihan et al. 2001 and 2002). Consequently, PIT-tag recoveries, radio telemetry capture histories, and release-recapture models (Burnham et al. 1987, Smith et al. 1996) have been used to assess the survival of migrant salmonid smolts through various reaches of the Columbia and Snake rivers (Muir et al. 1995, Skalski et al. 1998b, Smith et al. 1998, Dawley et al. 1998, Skalski et al. 2001 and 2002). Results from studies examining simultaneous releases of PIT-tagged and radio-tagged fish in the Snake River and mid Columbia River suggest similar trends in survival between the two groups (Hockersmith et al. 2003). Further, concurrent releases of radio- and PIT-tagged yearling Chinook salmon at The Dalles Dam also indicate that estimates from the two tagging techniques provide comparable estimates (Counihan et al. 2001) for yearling Chinook salmon. Estimates of survival generated from radio-tagged sub-yearling Chinook salmon were less comparable. However, the large confidence intervals associated with both PIT- and radio-tagged fish were not conducive to a meaningful evaluation of the comparability of the estimates.

While the PIT-tag and radio telemetry techniques have been shown to produce similar results, there are important logistic considerations associated with each method. The use of the PIT-tag technique relies on the availability of PIT-tag detectors at hydroelectric dams, which are not present at all locations in the Columbia River Basin (e.g., The Dalles Dam). The absence of PIT-tag detectors at certain projects and areas below Bonneville Dam has precluded or confounded survival estimation in some specific reaches of the Columbia River and limited the spatial scale over which survival estimates can be made. Further, the low detection probabilities associated with this technique requires that large numbers of fish be handled (although minimally) to obtain desired levels of precision in survival estimates (Skalski 1999b). Detection rates of marked fish affect the sample size required for a given level of precision and thus, the reliability of survival estimates (Skalski 1992). The radio-telemetry technique offers high detection rates, observed in migrant salmonid studies at specific project sites and in-river sites in the lower Columbia River; suggesting that the numbers of fish necessary to generate survival estimates with similar or greater precision could be reduced using radio-tagged fish. Further, the flexibility of radio-telemetry system deployment at hydroelectric projects and in-river locations can increase the geographic area over which estimates are generated (e.g. areas below Bonneville Dam).

A primary 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 resulted in a spill program of up to 120% total dissolved gas (TDG), which was expected to provide a safer route of project passage than turbine passage. While there is a 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 92.7% (Counihan et al. 2002) whereas other dams average 98% (Ploskey et al. 2001). The lower than expected spill passage survival 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) a large proportion of spillway-passed water moves through shallows and islands downstream where predation on salmonids by gulls (*Larus* spp.), northern pikeminnow (*Ptychocheilus oregonensis*), and smallmouth bass (*Micropterus dolomieu*) may be substantially higher than at other dams. In recent years, various spill levels and configurations (i.e. juvenile spill pattern) have been implemented to increase survival.

The Columbia River Research Laboratory has studied the behavior of migrant salmonids in the lower Columbia River since 1995. During 2005, we will use releases of radio-tagged juvenile salmonids in the tailrace of John Day Dam, in the tailrace of The Dalles Dam, and directly into and below the Ice and Trash sluiceway at The Dalles Dam to estimate the dam, project, and route specific survival of juvenile salmonids at The Dalles Dam.

CURRENT STATUS

Survival studies by NMFS at The Dalles Dam during 1997-2000 and the USGS in 2000, indicated spillway survival at 30% spill and 40% 24 h spill was typically higher than spillway survival at 64% spill and survival through the sluiceway was similar to the 30% spillway survival (Ploskey et al. 2001). In addition to spill level, NMFS found that survival for sub-yearling Chinook salmon was consistently higher at night than in 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 passing during the juvenile spill pattern, which was used only at night. In 2000, the 40% spill level and juvenile spill pattern were used for 24 h to evaluate the hypothesis that survival improves during the juvenile fish pattern. Observed spill passage efficiency values under the 24 h 40% spill pattern were similar to those seen at 64% spill in previous years and even though survival was found to be higher at the lower spill (30–40%) percentages, the survival was determined to be unacceptably low for a primary passage route.

During 2001, the USGS continued evaluations of the survival of yearling and sub-yearling Chinook salmon at The Dalles Dam; however the emphasis shifted from developing point survival estimates under various operating conditions, to identifying the causal mechanisms of mortality. Results from studies conducted in 2001 – 2003 suggest there is a direct effect on juvenile salmon survival and injury for fish passing through the stilling basin and that direct survival and injury appeared to be influenced by lateral flow that passes along the stilling basin's length from south to north.

During 2002, evaluations of survival at the spillway suggested that survival was significantly lower for yearling Chinook salmon that passed via spillbay 13 (north) v. spillbay 4 (south). Similar trends were seen for sub-yearling Chinook salmon although the difference was not statistically significant. A concurrent engineering study developed a solution to eliminate lateral flow in the stilling basin and determined that lateral flow could be blocked by a longitudinal training wall that extends 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. Preliminary results suggest 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. Primary issues to address for the post-construction evaluation include the wall's effect on survival and injury rates for spillway passed fish, spillway and fish passage efficiency.

OBJECTIVES AND METHODOLOGY

The methods described below pertain to tasks specifically associated with extracting survival estimates from research proposed by the Columbia River Research Laboratory, USGS with respect to the study code SPE-P-00-8. Descriptions of the methodologies associated with fish collection, tagging, tagging locations, telemetry receiver and antenna equipment and placement can be referenced in the proposals dealing with the planned evaluations of fish and spill passage efficiencies. There are certain common analyses that will be conducted for all of the potential survival estimation scenarios presented in the objectives below. In this section, we will present the proposed objectives and associated tasks and then follow with a discussion of the methodologies proposed for the survival analyses.

Objective 1: Estimate the project, dam, and route specific survival of juvenile yearling and sub-yearling Chinook salmon passing through The Dalles Dam (SPE-P-00-8).

Rationale

The current operation of The Dalles Dam has been formulated by fish and water managers based on past research that examined the effects of spilling water at The Dalles Dam on the survival of juvenile salmonids. 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 Oregon shallow water area increasing 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. Based on these results a spill percentage of 40% was implemented, however concerns regarding the effects of passing through the stilling basin at this project remain.

During 2002, the USGS released radio-tagged yearling Chinook salmon into spillbays 4, 9, and 13 and radio-tagged sub-yearling Chinook salmon into spillbays 4 and 13 to evaluate potential differences in survival for fish passing via each spillbay during a 40% spill operation at The Dalles Dam. The results of these evaluations of survival at the spillway suggested that survival was significantly lower for yearling Chinook salmon that passed via spillbay 13 (north) v. spillbay 4 (south). Similar trends were seen for sub-yearling Chinook salmon although the difference was not statistically significant. A concurrent engineering study developed a solution to eliminate lateral flow in the stilling basin and determined that lateral flow could be blocked by a longitudinal training wall that extends from the downstream spillway pier nose between bays 6 and 7 to the end sill.

The Army Corps of Engineers will continue to modify the spillway stilling basin and spill pattern at The Dalles Dam during the winter of 2004-05, in response to Action 68 in the 2000 Biological Opinion on operation of the FCRPS (Mike Langeslay, ACOE, Portland District, Personal communication). The modifications of the spillway stilling basin and spill pattern at The Dalles Dam are intended to increase the survival of juvenile salmonids that pass through the spillway. To assess the post-construction performance of the modifications, the USGS evaluated the survival of yearling and sub-yearling Chinook salmon through The Dalles Dam during 2004, the first of a planned two-year evaluation. Objectives for both years are similar, and include estimating project, dam, and route-specific survival, and evaluating fish passage distribution and tailrace egress. In 2004, yearling and sub-yearling Chinook salmon were evaluated. In 2005, steelhead trout will be evaluated in addition to yearling and sub-yearling Chinook salmon.

During 2005, 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 1998b), we will estimate survival through The Dalles Dam. Using the release and detection schemes in

Figure 1, the parameters in Figure 1 will be estimable. In addition, we will make releases directly into and below the ice and trash sluiceway and then use the new triple release model being developed by the University of Washington (see Objective 2) that will account for potential bias in the RSSM estimates to estimate survival through the routes mentioned above.

Task 1.1 Prepare data for input into USER 1.0 software.

Activity 1.1.1 Proof database of contacted radio-tagged fish for accuracy by applying established protocols for determining the validity of records.

Schedule: June through September 2005

Activity 1.1.2 Generate capture-history matrices from the proofed database using the Statistical Analysis System (SAS).

Schedule: September 2005

Task 1.2 Generate dam and route-specific survival estimates using the RSSM and the USER 1.0 software.

Schedule: September through November 2005

Objective 2. Evaluate a new survival estimation procedure, the triple release design, to address potential bias in survival estimates generated using the RSSM.

During 2004, the ACOE and the SRWG requested that the USGS employ a survival estimation model that would account for the potential bias in survival estimates generated using the RSSM. As of the submission date of this proposal, the USGS has made the necessary releases to employ this model and are proceeding with the necessary data processing steps to allow this model to be evaluated. During 2005, we plan to continue the evaluation of this model at The Dalles Dam.

Objective 3. Evaluate tailrace egress at The Dalles Dam using drogues, mobile tracking, and fixed-site monitoring of radio-tagged fish.

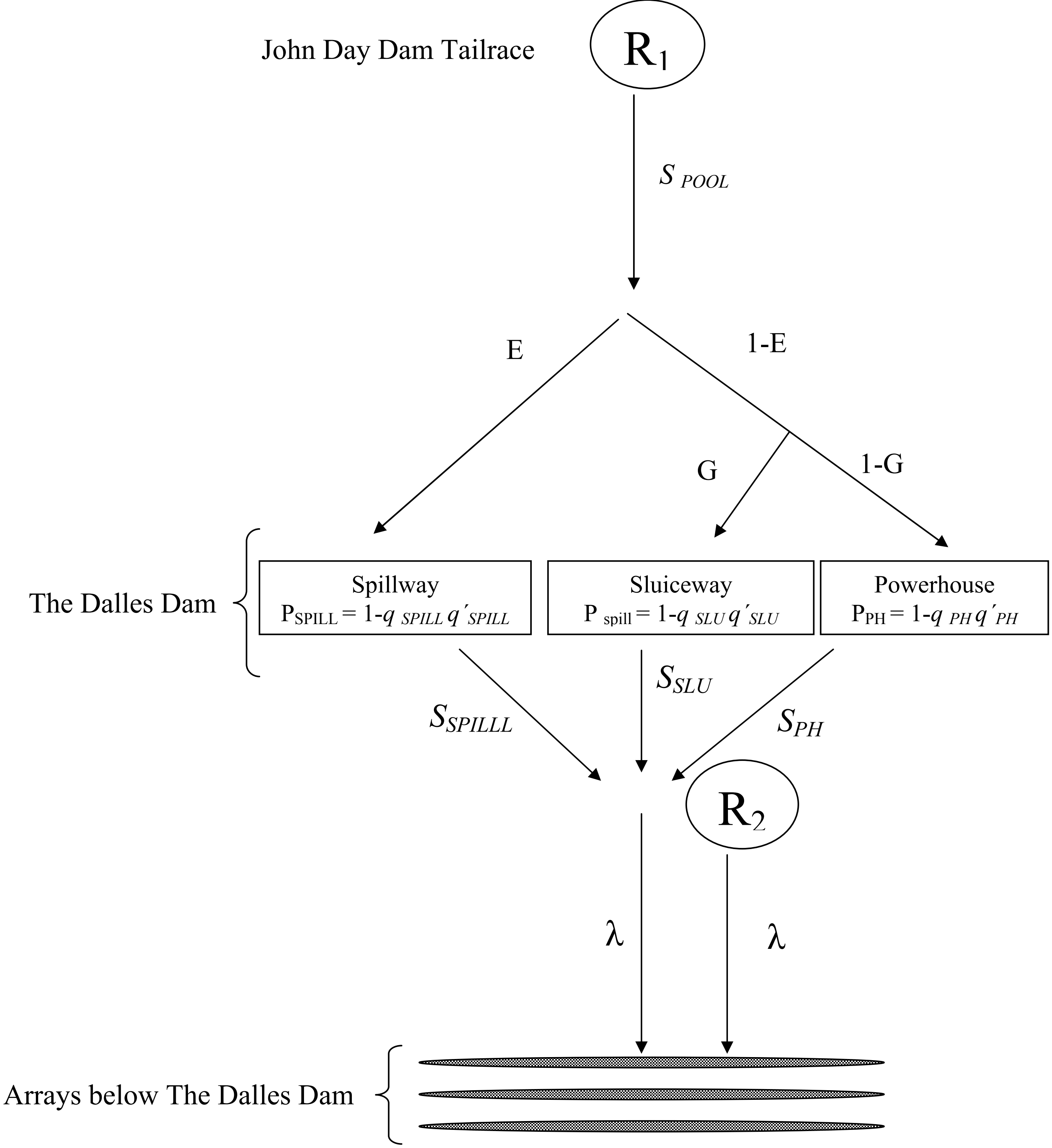


Figure 1. Description of estimable parameters using the route specific survival model (RSSM) given release and detection schemes in place during 2004. Included in the detection scheme is a double radio-telemetry array at The Dalles Dam that is necessary to use the RSSM.

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 a hydraulic modeling exercise performed in a 1:80 physical model, the new spillway configuration is expected to influence tailrace egress (Mike Langeslay, ACOE Portland District, personal communication). 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 use drogues released through the spillway to evaluate tailrace egress within the boat-restricted zone (BRZ). Drogues can be used to describe movement paths relative to the new wall and quantify any lateral transport effects that may remain. Drogue egress times will be compared with egress times of radio-tagged fish that pass through the spillway under similar dam operational conditions.

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 each route of passage at The Dalles Dam, and they will be compared at each detection location.

Task 3.1 Use drogue releases at the spillway to evaluate the tailrace egress times and travel routes in the stilling basin.

Activity 3.1.1. Drogues (equipped with GPS units) will be released through the spillway to evaluate egress times and routes within the BRZ. Drogues will be released through the same spillbays as the radio-tagged fish that will be used to generate a spillway survival estimate. We propose to release 20 drogues through each study spillbay during the spring out-migration, and 20 drogues through each study spillbay during the summer out-migration.
Schedule: April-July, 2005.

Activity 3.1.2. Equip some drogues with a basic accelerometer package to describe the forces the drogue encounters as it passes through the stilling basin. Video monitoring of the drogue, combined with GPS positioning will be able to show where the drogue was located when it encountered high acceleration events.
Schedule: April-July, 2005.

Activity 3.1.3. Calculate drogue egress times to the basin islands and compare them to egress times of radio-tagged fish that passed through the study spillbays during similar dam operating conditions.
Schedule: August-November, 2005.

Task 3.2 Use mobile tracking and fixed-site receiving equipment to monitor the tailrace egress of radio-tagged fish passing The Dalles Dam.

Activity 3.2.1. Establish fixed-site receiving stations on the basin islands, on the north shore directly across from the basin islands, and at a point 6 km downriver of the dam (exit station).
Schedule: March-May, 2005

Activity 3.2.2. Monitor all radio-tagged fish released by USGS. The sites will be configured to detect all fish on compatible channel and code schemes.
Schedule: May-July, 2005.

Activity 3.2.3. Determine tailrace egress times in zones (basin island and exit station), and compare times for groups of fish that passed the dam through different routes and under different dam operational conditions.
Schedule: August-December, 2005.

Objective 4: Estimate false-positive detection rates for radio-tagged dead fish released in the tailrace area of The Dalles Dam.

Rationale

A basic assumption when using release-recapture models to estimate survival is that all fish detected at a particular detection array are alive. However, radio tags on dead fish may result in false-positive detections (Skalski et al. 1998a); which would result in positively biased estimates of survival. Since false-positive detections may occur from dead radio-tagged fish that are transported downstream by the river current or predators, flow conditions may affect the numbers of fish detected at downstream locations. No dead fish have been detected from releases during past studies at The Dalles Dam. However, two dead steelhead trout were detected at arrays below Bonneville Dam during 2000 and one yearling Chinook and one sub-yearling Chinook were detected below Bonneville Dam during 2001. Thus, we propose to release radio-tagged dead fish in the tailrace areas of John Day and Bonneville dams and near the new Bonneville Dam juvenile bypass system and outfall to empirically evaluate false detection rates.

Task 4.1 Implant radio transmitters, euthanize, and release dead fish in areas below The Dalles Dam.

Activity 4.1.1 Juvenile salmonids will be implanted with radio transmitters, subjected to a lethal dose of MS-222, and released at normal release locations below The Dalles Dam.

Schedule: May through July 2005

Task 4.2 Calculate the percent false-positive detections for radio-tagged fish.

Activity 4.2.1 Verify the validity of contacts of dead radio-tagged fish detected at arrays downstream of release sites.

Schedule: June through September 2005

Activity 4.2.2 Estimate the rate of false-positive detections for all areas of interest.

Schedule: September 2005

METHODS FOR GENERATING SURVIVAL ESTIMATES

Route Specific Survival Model

Model Assumptions

The assumptions associated with the RSSM are described in detail in Skalski et. al. (2002) and are similar to those for the paired–release recapture model of Burnham et. al. (1987).

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_{PH}, the powerhouse primary array detection probability; ($q_{PH} = 1 - P_{PH}$); P'_{PH}, the powerhouse secondary array detection probability; ($q'_{PH} = 1 - P'_{PH}$); 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_{PH}, the powerhouse survival probability, λ, 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 (Figure 2). A branching process will be used to model the migration and survival of releases R_1 and R_2 (Figure 1). 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

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

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) software developed at the University of Washington (Lady et al. 2004; see: http://www.cqs.washington.edu/paramEst/USER/).

Sample Size for the RSSM analyses

As results from the 2004 studies become available, we will update the information in Table 1, which presents the expected precision for yearling and sub-yearling Chinook salmon based on information available prior to 2004. Using the information collected during 2004, including information collected for steelhead trout, we will refine the expected precision estimates for 2005.

Table 1. Potential release scenarios that could be used during 2005 and the estimated 95% confidence intervals for yearling and sub-yearling Chinook salmon RSSM estimates through the spillway, powerhouse and ice and trash sluiceway at The Dalles Dam. The 95% confidence intervals are presented for *S ph* (survival of yearling and sub-yearling Chinook salmon through powerhouse, unguided), *S sp* (survival through The Dalles spillway), *S I and T sluice* (survival through the ice and trash sluiceway at The Dalles Dam), *S dam* (total dam passage survival through The Dalles Dam). R1 refers to releases made above The Dalles Dam and R2 refers to releases in the tailrace area of The Dalles Dam. The R2 releases incorporate radio-tagged yearling and sub-yearling Chinook salmon released as part of the survival evaluations at Bonneville Dam during 2005.

			95% confidence interval			
Release	Sample size per release group	Total release per treatment	*S ph*	*S sp*	*S I and T sluice*	*S dam*
			Yearling Chinook Salmon			
R1	2250	6150	0.033	0.025	0.052	0.029
R2	3900					
			Sub-yearling Chinook Salmon			
R1	2000	8400	0.038	0.025	0.066	0.033
R2	6400					

Triple-Release Model

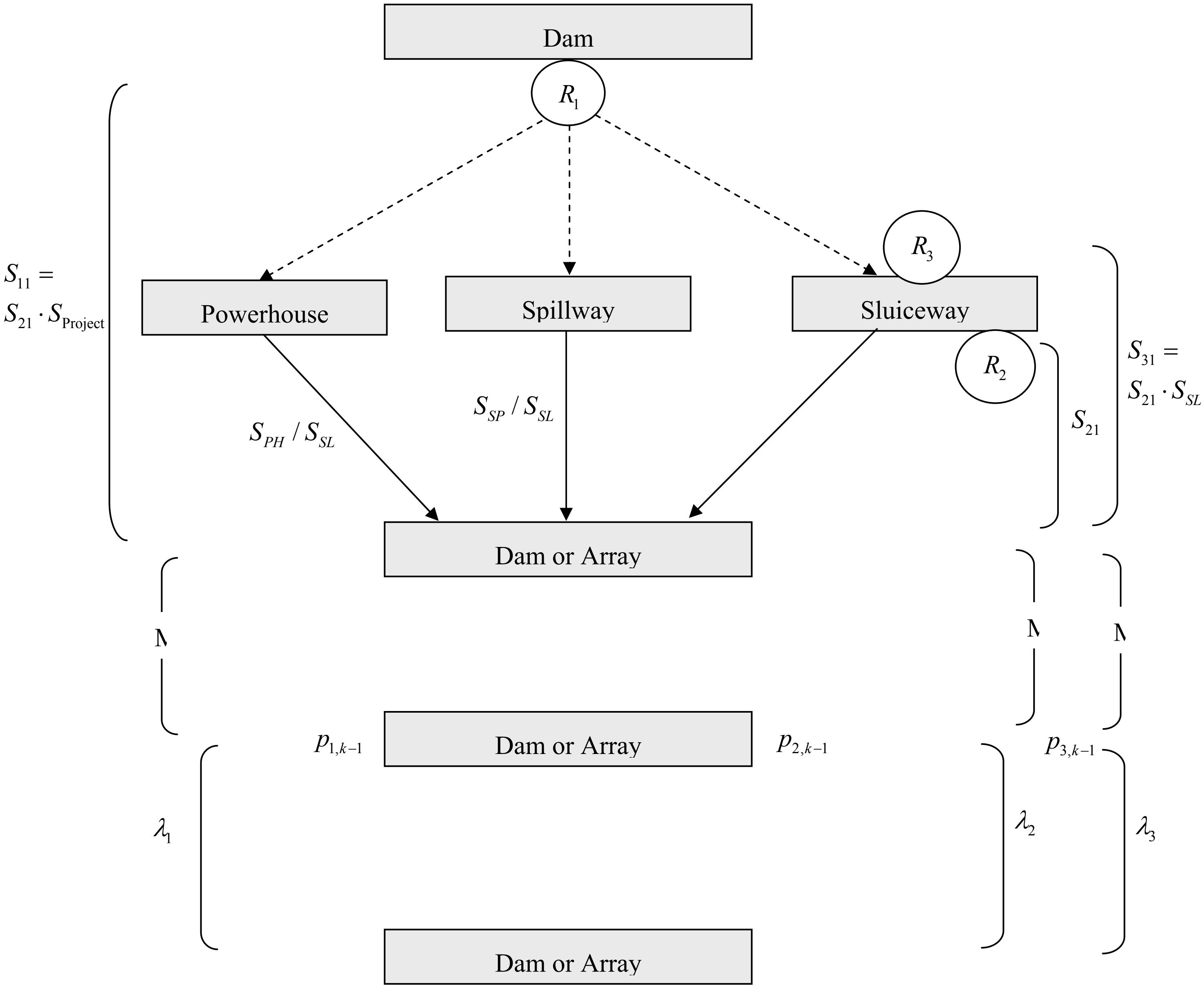
The sampling scheme shown in Figure 2 describes the release and detection scheme for the triple release design (Skalski 2004). The triple release design uses the same detection fields as the route-specific model, but introduces a third release to directly estimate route-specific survival through one designated route. The methods described here are paraphrased from Skalski (2004).

The primary difference between the triple-release and route-specific model is how the route-specific survival estimates are obtained. In the route-specific model, fish previously released and that have survived to the dam are paired with newly released fish in the tailrace. The difference in experience at the point of pairing is a source for potential bias in the route-specific model. In the triple-release method, fresh releases of tagged fish are used to estimate survival through one designated route. Because both groups are recently released, both groups should experience the same post-release handling mortality and tag loss, thereby providing a reliable estimate of passage-route survival.

In using the triple-release approach, a well-confined passage route such as a sluiceway or juvenile bypass is recommended. With such routes, there is limited discretion about where to release the downstream and in-route release groups. This is not true of the powerhouse or spillways with multiple intakes.

Model Assumptions

The assumptions of the triple-release design are essentially the same as the assumptions (A1-A11) of the route-specific model and thus, will not be repeated in this section (Skalski 2004).



Project survival: $\hat{S}_{\text{Project}} = \dfrac{\hat{S}_{11}}{\hat{S}_{21}}$; Sluiceway survival: $\hat{S}_{SL} = \dfrac{\hat{S}_{31}}{\hat{S}_{21}}$

Figure 2. Schematic of triple-release design showing releases R_1, R_2, and R_3 and route-specific detection capabilities at the dam of interest.

Parameter Estimation

The study design is devised to provide the following information directly from the tagging data:

1. Project survival using the paired releases R_1 and R_2.
2. Passage proportions through the various routes using release R_1 and the dual-detection arrays at the various dam routes.
3. Relative survival quotients using the relative recovery information from the tagged fish known to have passed through the various dam routes.
4. Route-specific survival using the paired releases R_2 and R_3 for a single selected route at the dam.

With release R_1 sufficiently upriver, the arrival distribution at the dam should be adequately characterized using a properly implemented dual-array system at each passage route. The fish detected at the various passage routes can then be tracked downriver to estimate relative survival. For instance, let

R_{PH} = the number of tagged fish known to have passed through the powerhouse,

x_{PH} = the number of fish from R_{PH} subsequently detected downriver,

R_{SL} = the number of tagged fish known to have passed through the sluiceway,

x_{SL} = the number of fish from R_{SL} subsequently detected downriver.

Then the quotient $\left(R_{SP/SL}\right) = x_{PH}R_{SL} / x_{SL}R_{SP}$ has the approximate expected value

$$E\left[\frac{\left(\frac{x_{PH}}{R_{PH}}\right)}{\left(\frac{x_{SL}}{R_{SL}}\right)}\right] \cong \frac{S_{PH}\cdot p}{S_{SL}\cdot p} = \frac{S_{PH}}{S_{SL}},$$

the ratio of powerhouse passage survival to sluiceway passage survival.

Dam-passage survival can be reconstructed from the release-recapture data where

$$\begin{aligned}\hat{S}_{\text{Dam}} &= \hat{P}_{PH}\cdot\hat{S}_{PH} + \hat{P}_{SP}\cdot\hat{S}_{SP} + \left(1-\hat{P}_{PH}-\hat{P}_{SP}\right)\hat{S}_{SL} \\ &= \hat{P}_{PH}\cdot\hat{R}_{PH/SL}\cdot\hat{S}_{SL} + \hat{P}_{SP}\cdot\hat{R}_{SP/SL}\cdot\hat{S}_{SL} + \left(1-\hat{P}_{PH}-\hat{P}_{SP}\right)\hat{S}_{SL} \\ &= \hat{S}_{SL}\left[1+\hat{P}_{PH}\left(\hat{R}_{PH/SL}-1\right)+\hat{P}_{SP}\left(\hat{R}_{SP/SL}-1\right)\right].\end{aligned}$$

Discussion of Bias

This design has been implemented at The Dalles Dam but the results of this research are still being formulated. Consequently, the deficiencies of the design are still unknown. Nevertheless, certain concerns need to be satisfied. The first necessity is to obtain unbiased estimates of fish proportions through the various routes of a dam. Valid Lincoln/Petersen estimates and proper detection-array deployment are therefore essential.

Pivotal to this study design is the requirement that the product of the relative survival estimate of one route to another (i.e., $R_{SP/SL}$) and estimate of absolute passage survival (S_{SL}), e.g.,

$$\hat{R}_{SP/SL} \cdot \hat{S}_{SL} = \hat{S}_{SP} ,$$

provides a valid estimate of survival for the routes not directly measured (i.e., S_{SP}). Hence, survival through the selected route for absolute estimation must be representative of the conditions over which relative survival was estimated. If relative passage survival was estimated over days, weeks, or months, then so must the absolute passage survival. If the estimate of absolute passage survival is not comparable to the estimate of relative survival, bias of dam passage survival will occur, either high or low.

IMPACTS

The impacts of the objectives discussed in this proposal are listed in the corresponding Columbia River Research Laboratory proposals pertaining to study codes SPE-P-00-8 and SPE-P-02-1.

COLLABORATIVE ARRANGEMENTS and/or SUB-CONTRACTS

As stated previously, the activities contained within this research proposal will be coordinated with other work proposed by the Columbia River Research Laboratory for 2005. To assist with the analyses of the data and the design of these studies the U.S. Geological Survey will collaborate with John Skalski who has many years of experience with survival estimation methodologies and is one of the principal authorities on this subject.

List of Key Personnel and Project Duties

Jim Petersen	Project Leader	Project administration, research product review
Tim Counihan	Principal Investigator	Project management, data analysis, interpretation, reporting
Jill Hardiman	Principal Investigator	Data management, analysis, interpretation, and reporting

John R. Skalski Consulting Statistician   Consulting on statistical models and design

TECHNOLOGY TRANSFER

Results from this study will aid in the evaluation of the relation between dam operations and juvenile salmonid survival. We believe that the detailed survival information from this study will be used in the decision-making process for operation of the Federal Columbia River Power System and Juvenile Transportation Program as discussed in the 1995 Biological Opinion (NMFS 1995). Results will be disseminated in the form of preliminary reports, annual reports of research, oral presentations and briefings, and peer-reviewed journal publications. Preliminary reports for the spring and summer out-migration periods will be available November 1, 2005. The draft annual report of research will be completed by December 31, 2005, with the final version on March 31, 2005. As per an agreement with the ACOE, comments on the draft report will be received in our office on or before 45 days from the mailing of this draft. After the 45-day period, if we receive comments pertaining to the draft, we will produce a final report within 60 days. If we do not receive comments within the 45 days of mailing this draft report, we will consider the draft report suitable for printing as the final report.

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