PRELIMINARY PROPOSAL FOR FY 2007 FUNDING

Title: Migration behavior and survival of juvenile salmonids at Little Goose Dam, 2007

Study Code: SPE-W-04-2

Project Leader(s): John W. Beeman and Noah S. Adams

U.S. Geological Survey
Columbia River Research Laboratory
5501A Cook-Underwood Road
Cook, WA 98605
(509) 538-2299; FAX (509) 538-2843

Submitted to: U.S. Army Corp of Engineers
Walla Walla District
201 North 3rd Avenue
Walla Walla, WA 99362
(509) 527-7278

Administrative Contact: Michele F. Beeman
U.S. Geological Survey
Columbia River Research Laboratory
5501A Cook-Underwood Road
Cook, WA 98605
(509) 538-2299; FAX (509) 538-2843
DUNS # 025293577
ALC# 14-08-0001

Performance Period: January 1, 2007 through September 30, 2007.
Date of Submission: August 15, 2006

PROJECT SUMMARY

Research Goals

The goal of our study is to quantify the spatial and temporal movements of juvenile salmonids and estimate their survival as they approach, pass through, and continue migration after passage through Little Goose Dam to provide baseline data prior to installation of a removable spillway weir and to aid in choosing a weir location.

Objectives

Objective 1: Determine the approach path, route of passage, and tailrace egress for yearling Chinook salmon and juvenile steelhead at Little Goose Dam relative to dam operations.

Objective 2: Estimate route-specific survival of yearling Chinook salmon and juvenile steelhead passing through Little Goose Dam relative to dam operations.

Objective 3: Determine the approach path, route of passage, and tailrace egress for subyearling Chinook salmon at Little Goose Dam relative to dam operations.

Objective 4: Estimate route-specific survival of subyearling Chinook salmon passing through Little Goose Dam relative to dam operations.

Methodology

We propose to use radio telemetry techniques to obtain both survival and behavioral information for juvenile salmonids migrating past Little Goose Dam. PIT tags will be used to divert study fish back to the river for route-specific survival estimates. We will use the route-specific survival model (RSSM) developed by Skalski et al. (2002) to estimate passage and survival probabilities of juvenile salmonids for the turbines, spillway, juvenile bypass system, the overall survival probability of dam passage, and survival from release to the dam.

To provide passage information at Little Goose Dam, we propose to use fish collected at Little Goose Dam and released 25 km upriver at Central Ferry. During summer, fish from a planned summer study at Lower Granite Dam could also be used for this purpose. In addition, two spill treatments may be implemented during both spring and summer migration seasons. To obtain high power to detect small differences in survival between treatments, sample sizes may need to be increased over those currently proposed.

Relevance to the Biological Opinion

The relevance of this research to the operation of the Federal Columbia River Power System is discussed in Hydrosystem Substrategy 1.4, p 19 and ESU Specific Actions on pages 33, 39, and 43 of the “Updated Proposed Action for the FCRPS Biological Opinion Remand”, dated November 24, 2004.

PROJECT DESCRIPTION

Background and Justification

Reservoir drawdown, flow augmentation, and spill have been identified as potential means of improving the survival of juvenile salmonids, thereby assisting the recovery of threatened and endangered salmon stocks. The U.S. Army Corps of Engineers (COE) has worked with regional, state, and federal resource agencies to design and implement tests to determine whether various combinations of reservoir drawdown, flow augmentation, spill, and surface bypass would provide significant biological benefits to out-migrating smolts. A removable spillway weir is one management action being considered for implementation at Little Goose Dam.

Based on the surface bypass concept, the COE evaluated a removable spillway weir (RSW) at Lower Granite Dam during 2002 and 2003 (Plumb et al. 2003, 2004). This passage structure passed comparable percentages of fish as the current management strategy of spilling water to the 'gas cap' (i.e., BiOP spill) with just 7-8% of the total discharge. Furthermore, survival estimates of yearling Chinook salmon passing the RSW did not significantly differ from those passing through BiOP spill. Because the RSW may be selected as a basin-wide management strategy and installed at Little Goose Dam in the near future (proposed for 2008), baseline passage and survival data prior to RSW installation will provide useful information to aid in the design and location of a RSW at Little Goose Dam. This study would be the second year of a two-year study of baseline (i.e., pre-RSW) passage and survival.

Using radio telemetry and PIT tag techniques, we propose to estimate passage and survival rates of juvenile salmonids at Little Goose Dam. The USGS, Columbia River Research Laboratory uses radio- and acoustic telemetry techniques to monitor the migration behavior and survival of juvenile salmonids in the Snake and Columbia (Plumb et al. 2004; Counihan et al. 2002a, 2002b; Perry et al. 2003, In preparation).

Many methods are available to conduct mark-recapture experiments to estimate survival rates of juvenile salmonids. Methods include passive integrated transponder (PIT) tags (Skalski et al. 1998), balloon tags (Mathur et al. 1996), and radio telemetry (Skalski et al. 2001). Each method offers distinct advantages and limitations. A benefit of PIT tags is their small size relative to the size of the fish, but a limitation is the large sample size required to obtain high precision of survival estimates. Balloon tags allow for recovery of fish, and thus identifying the mechanisms of direct mortality. However, balloon tag studies are restricted to relatively large fish due to the tag size, and survival rates only apply to direct (1 h to 48 h) mortality. An advantage of radio-telemetry techniques is high detection probabilities, which reduces the sample size needed to obtain precise survival estimates. However, for some fish species, the size of the radio transmitter limits the size of fish that may be studied.

Project Overview

We will use radio telemetry to estimate passage and survival probabilities over a range of spatial scales and passage routes. At the finest spatial scale, we will use the route-specific survival model (RSSM) developed by Skalski et al. (2002) to estimate passage and survival probabilities for the turbines, spillway, and juvenile bypass system. The RSSM model uses double antenna arrays to calculate detection and passage probabilities for a given route of passage. Given passage and detection probabilities of passage routes, the RSSM then uses the paired release-recapture models (PRRM) described by Burnham et al. (1987) and expanded on by Skalski et al. (2002) to calculate route-specific survival relative to survival rates of control groups released into the tailrace. The foundation of both of these models is based on the classical release-recapture models of Cormack (1964), Jolly (1965), and Seber (1965; CJS model). In addition to route-specific survival probabilities, these models will allow us to estimate overall survival rates through the dam, and survival from release to the dam.

For quantifying migration behavior, we will monitor travel times, approach paths to Little Goose Dam, forebay movements, and routes of passage. Once fish pass the dam, we will examine their movements in the tailrace and monitor travel times downstream of the dam. To monitor fish behavior at Little Goose Dam we will use multiple aerial and underwater radio telemetry arrays. At the dam, aerial antenna arrays will be installed on barges in the forebay, and at the navigation wall, spillway, powerhouse, earthen dam, adult fish ladder, fish collection channel, juvenile fish bypass system, tailrace, and three detection sites below Little Goose Dam within Lower Monumental Reservoir. To obtain movement information at finer spatial scales, we will install underwater antennas on the extended-length submersible bar screens, spillway, and juvenile fish bypass system.

Current Status

At Little Goose Dam and Reservoir, past research has estimated the behavior and survival of juvenile salmonids using PIT technology (Muir et al. 2001; Smith et al. 2002, 2003). Although very useful, PIT technology is limited to providing information over a dam-to-dam spatial scale. Consequently, there was little information on fish movement patterns and survival at Little Goose Dams at finer spatial scales prior to our work in 2005 (Perry et al., In preparation) and 2006 (analyses underway at the time of this proposal). The collection of fish passage and survival information at smaller spatial scales can help clarify location-specific factors that may affect fish passage and survival at Little Goose Dam. One of the primary goals of this research is to identify approach and egress patterns as well as survival of juvenile salmonids under a bulk spill pattern similar to what may be used after an RSW is installed in 2008. Research in 2006 and 2007 is planned as baseline, or “pre-RSW” data collection.

Data was collected during 2005 and 2006 to obtain passage information and route-specific survival estimates through Little Goose Dam, but there is little other information on fish behavior and passage through Little Goose Dam. From 1995 to 1997, Venditti et al. (2000) monitored the behavior of subyearling Chinook salmon as they migrated through Little Goose

Reservoir. The authors found that travel rates of subyearling Chinook salmon decreased as fish approached the dam and that a substantial portion (10-20%) of the tagged population remained in the forebay of Little Goose Dam for 7 d or more. In addition, Venditti et al. (2000) found that the frequency of upriver movement was 3-fold greater near the dam than in the upper reservoir. During their study at Lower Granite Dam, Plumb et al. (2004) also quantified fish behavior and Fish Collection Efficiency (FCE; i.e., percent guided turbine passage) at Little Goose Dam for yearling Chinook salmon and juvenile hatchery and wild steelhead. The authors found that residence time in the forebay and frequency of fish traveling 14 km upriver of the dam was greatest for hatchery steelhead, and that FCE was 51-58% depending on species and rearing types. Although the research by Venditti et al. (2000) and Plumb et al. (2004) provided insight into the behavior of fish within the forebay of Little Goose Dam, their research was not designed to estimate survival and route-specific passage through Little Goose Dam.

Methodology

To reduce repetition of methods common to each of the objectives, we have structured this section as follows: First, we describe tagging techniques we propose to use for implantation of transmitters into juvenile fish since these techniques are common to all objectives. Second, we combine the telemetry methods for all objectives since all will utilize the same system of antennas and receivers, and all survival estimates will be calculated using the route-specific survival model. Last, many statistical analyses and evaluation of assumptions are not presented here, but are detailed in Skalski et al. (2001 and 2002) and in Peven et al. (2004).

We propose to surgically implant radio transmitters and PIT tags into juvenile salmonids following procedures described by Adams et al. (1998a, 1998b). The method of tag implantation (surgical or gastric) should not influence the survival estimates. Hockersmith et al. (2003) showed no differences in survival of PIT-tagged, gastrically-tagged, or surgically-tagged yearling Chinook salmon over long distances (about 100 km) relative to distances proposed in this study (about 50 km). Furthermore, the route-specific survival model uses a paired release design that controls for factors such as potential tagging and handling effects.

The planned operation of the juvenile bypass facility in 2007 will necessitate using PIT tags to divert radio-tagged fish into the river to estimate survival through the bypass system. During the spring and summer, all fish collected by the bypass system will be transported by barges. If radio-tagged fish are barged, we will be unable to obtain valid downstream detections and therefore, unable to estimate survival through the bypass system.

We will use coded radio transmitters weighing no more than 0.65 g in air for yearling Chinook salmon and juvenile steelhead. For subyearling Chinook salmon, we will use tags weighing 0.43 g. This transmitter will allow us to tag subyearling Chinook salmon as small as 9 g, thereby increasing the proportion of the population represented by passage and survival estimates. PIT tags weigh 0.07 g. We will restrict the size of fish used so that the combined weight of the tags represents no more than 5% of the fish's weight.

To estimate passage and survival probabilities with the RSSM, we will conduct daily treatment releases of radio-tagged juvenile salmonids upstream of Little Goose Dam (R_t) and daily control releases in the tailrace (R_c; Figure 1). Fish will be released 25 km upstream of Little Goose Dam, at Central Ferry Bridge. Using the RSSM, we will estimate survival rates from the release point to a detection array in the forebay (S_{pool}) and from the forebay detection array to passage through the dam ($S_{forebay}$; Figure 1). Route-specific passage (Sp, By, and Tu) and detection probabilities (p_{Sp}, p_{By}, and p_{Tu}; Figure 1) will be estimated by using double detection arrays for each passage route. Double detection arrays will consist of two independent antenna systems, one underwater and one aerial system, allowing for the estimation of route specific parameters. Given these route-specific parameters, survival of fish passing through each route (S_{Sp}, S_{By}, S_{Tu}; Figure 1) will be estimated relative to the survival of control groups of fish released in the tailrace of Little Goose Dam. Given route-specific passage and survival probabilities, we will calculate the overall survival probability of dam passage.

For estimating survival, three distinct radio telemetry arrays will be installed downstream of Little Goose Dam (river kilometer, rkm 112) at the Tucannon River (rkm 100), Ayers, and Lower Monumental Dam (rkm 77; Figure 3). Each array will typically consist of three telemetry fixed sites, with one located on each shore and the third located in the center of the channel. The sites in center channel will either be mounted on an anchored barge or on a U.S. Coast Guard navigation marker.

To address some of the assumptions of survival models, we will conduct a tag life study and release a small subsample of euthanized, radio-tagged fish. A tag life study will be conducted to test the assumption that all tags are functional while fish are in the study area. The tag life study will estimate the probability of a tag being functional at a given point in time. In the case of premature tag failure or long travel times due to low flows, data from the tag life study can be used to adjust survival estimates if tags fail prior to fish exiting the study area. A small subsample of euthanized radio-tagged fish will be released to test the assumption that radio-tag detections represent detections of only live fish (i.e., test for false positive detections). Survival estimates may be positively biased if dead fish are detected.

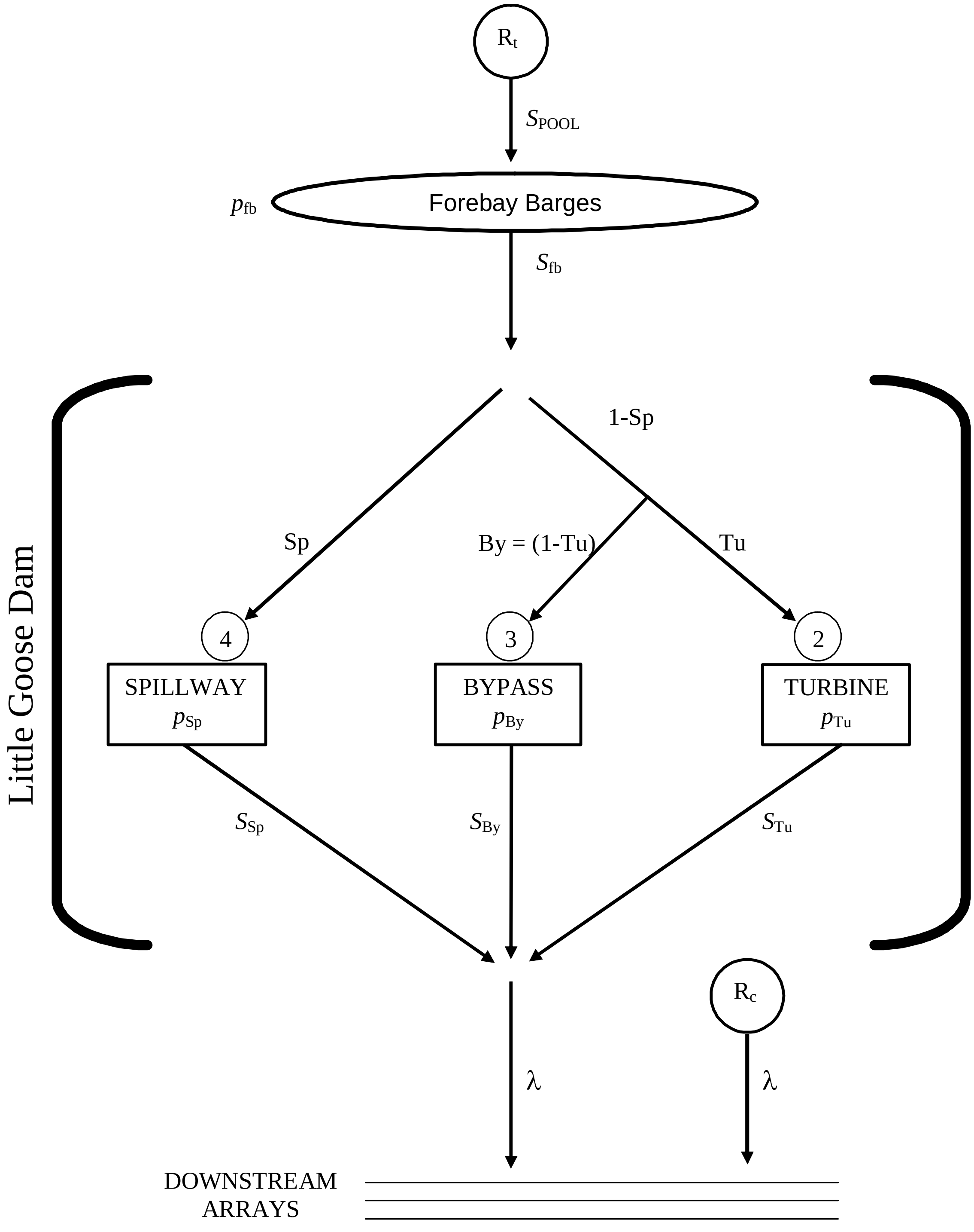

Figure 1. Schematic of route-specific survival model showing release sites, passage routes, and estimable parameters of detection, passage, and survival probabilities at Little Goose Dam. Shown are the treatment releases (R_t) upstream of Little Goose Dam and control releases in the tailrace (R_c). Estimable parameters include passage (Sp, By, and Tu), detection (p_{fb}, p_{Sp}, p_{By}, and p_{Tu}), and survival (S_{pool}, S_{fb}, S_{Sp}, S_{By}, and S_{Tu}) probabilities. Lamba (λ_t, λ_c) is the joint probability of surviving and being detected by the downstream antenna arrays.

Objectives and Tasks

For survival estimates below, we calculated expected standard errors and confidence intervals of survival probabilities over a range of sample sizes. In addition to sample size, standard errors of survival probabilities are affected by detection probabilities, the magnitude of the survival probability, and the proportion of fish passing through each route. To estimate expected standard errors, we assumed some of these parameter values and used others from Appendix D of the NMFS 2000 Biological Opinion. We emphasize that the standard errors and confidence intervals presented here are specific to the set of input parameters we used. These confidence intervals will change given the set of parameters we estimate from data collected during the field study. In addition, because standard errors include only the expected sampling variation, observed standard errors could be larger if survival probabilities are affected by external factors such as discharge or water temperature. Nonetheless, our objective here is to examine the sensitivity of confidence intervals to different sample sizes for each passage route. This approach should help identify a general range of sample sizes and differences among passage routes in the expected precision of survival estimates.

We also conducted a power analysis to estimate the detectable difference in dam survival (S_{dam}) between two treatments (using the methods of Perry et al. (2003)). We use S_{dam} for this analysis, rather than survival through a specific passage route, because too few fish will pass through each route to detect small survival differences with sufficient statistical power. In addition, differences in project operations could affect the proportion of fish passing through the available routes. Therefore, it is important to consider how changes in dam operations affect the overall survival rate of the population passing the dam, rather than just the survival rate of fish passing through a specific route.

Objective 1: Determine the approach path, route of passage, and tailrace egress for spring migrants (yearling Chinook salmon and juvenile steelhead) at Little Goose Dam relative spill and powerhouse operations.

We propose to monitor radio-tagged spring migrants to estimate forebay residence times, route of passage, and egress through the tailrace of Little Goose Dam during various spill and powerhouse operations. The proposed evaluation would be conducted during the April-June out-migration. In 2006, the treatments were 24-h 30% spill using either a flat or a modified bulk spill pattern. The design consisted of two-day treatments randomized within 4-day blocks. These 4-day blocks serve as replicates over the length of the study period. Currently, as this proposal is being written, spill treatments for 2007 have not been chosen. Until further discussion occurs, we have developed this proposal under the assumption that a similar study design will be used to evaluate any treatments that might occur at Little Goose Dam in 2007.

Schedule of Tasks

Task 1.1: Install fixed monitoring sites on and around Little Goose Dam.

Activity 1.1.1

Install, calibrate, and test the underwater and aerial antenna arrays at Little Goose Dam.

Schedule: March through May 2007.

Activity 1.1.2

Install, calibrate, and test fixed monitoring sites above Little Goose Dam, in the tailrace of Little Goose Dam, and at the Juvenile Fish Bypass Facility

Schedule: February through March 2007.

Task 1.2: Monitor releases of yearling Chinook salmon and juvenile steelhead in Little Goose Reservoir during the spring of 2007.

Activity 1.2.1

Continue to develop analytical procedures for examining radio-telemetry data. We will consult with statisticians as the Region reaches consensus on a design for the 2007 test.

Schedule: Work will continue through the 2007 field season.

Activity 1.2.2

Complete the necessary Endangered Species Act documentation and obtain the necessary permits and approval to work in the Snake River.

Schedule: January 2007.

Activity 1.2.3

Coordinate with appropriate agencies to sequester, implant tags, and release spring migrating smolts during the months of April, May, and June 2007 (the spring out-migration period).

Schedule: February through June 2007.

Activity 1.2.4

Monitor the movements of radio-tagged fish in the forebay and tailrace areas of Little Goose Dam.

Schedule: April through June 2007.

Task 1.4: Continue to develop and refine data reduction, storage, analysis, and transfer procedures.

Activity 1.4.1

The regional researchers and managers continue to request the results of these studies almost immediately after the field tests are completed. The data is vital to make informed management decisions regarding the operation of the Columbia River hydropower system. In response to these needs, we will continue to improve and refine our ability to report this data quickly.

Schedule: Complete by September 2007

Task 1.5: Explore means to improve and expand information collected during subsequent field seasons.

Activity 1.5.1

Acquire and test telemetry systems manufactured by Advanced Telemetry Systems, Lotek Engineering, and other vendors if appropriate as a means to increase the resolution and accuracy of data collected on fish movements.

Schedule: Ongoing.

Objective 2: Estimate route-specific survival of spring migrants (yearling Chinook salmon and juvenile steelhead) passing through Little Goose Dam.

We propose to estimate route-specific survival of spring migrants passing Little Goose Dam. To estimate standard errors and confidence intervals of survival probabilities, we assumed parameter values for the route-specific survival model (see Figure 1). We used the best available parameter estimates for both yearling Chinook salmon and juvenile steelhead. In addition, we used the same passage and survival estimates for both species. First, we assumed 95% of fish survived from release to Little Goose Dam (i.e., S_{pool} x S_{fb} = 0.95). Next, we set detection probabilities (p) to 0.90. We set probabilities of turbine survival (S_{Tu}) to 0.923, spillway survival (S_{Sp}) to 0.95, and bypass survival to 0.964. For all reaches downstream of the dam, survival probabilities were set to 0.95 for both treatments and controls. We set the probability of passing through the spillway (Sp) to 0.27. We based this estimate on a spill efficiency of 1:1 and a 10-year average of 27% of river discharge through the spillway for the period April 1 – May 31 (excluding 2001 data because of low discharge). Last, we determined the probability of passing the dam through the juvenile bypass system (By) based on an FGE estimate of 0.90 for Little Goose Dam.

The 95% confidence intervals show the affect of sample size on precision and the difference in precision among survival probabilities (Figure 2). Turbine survival probabilities will likely have the lowest precision because the fewest fish are expected to pass through this route and turbine survival probabilities are expected to be the lowest of all available passage routes. Overall survival for all passage routes (S_{dam}) is expected to have the highest precision because this estimate incorporates the increased sample size of all passage routes. If precision of survival estimates is the primary goal, then a sample size between 1,000 and 1,500 (per treatment and species/rearing type) should yield precision of ±0.03-0.04 (±95% confidence interval) with lower precision for turbine survival (Table 1).

For statistically comparing S_{dam} among the two treatments, we calculated the minimum detectable difference in survival over a range of sample sizes and based on four combinations of alpha, beta (power=1-beta), and a 1- or 2-tailed test. To calculate standard errors for the power analysis we assumed the same survival and passage parameters described above. We assumed S_{dam} to be the average survival of fish passing through all routes weighted by the proportion of fish passing through each route. Figure 3 allows managers to examine how a range of sample sizes affects the minimum detectable difference between treatments to determine the most appropriate sample size under a given test scenario.

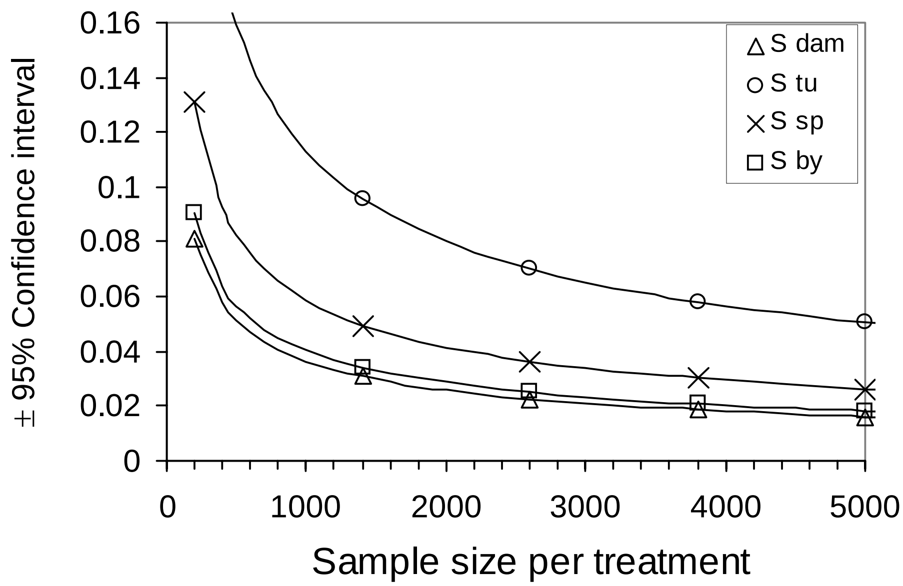

Figure 2. The effect of sample size on precision of dam survival (S_{Dam}), turbine survival (S_{Tu}), spill survival (S_{Sp}), and bypass survival (S_{By}) probabilities for spring migrants at Little Goose Dam. Sample sizes are for one treatment of dam operations and for one species/rearing type. Note: about 100 additional tags will be needed for releasing euthanized tagged fish and for conducting a tag life study.

Table 1. Sample size, expected standard error, and 95% confidence interval for route-specific survival probabilities of spring migrants. Sample sizes are for one species/rearing type and total sample size assumes two treatments of dam operations. Note: about 100 additional tags will be needed for releasing euthanized tagged fish and for conducting a tag life study.

Sample size for each treatment	Total sample size	Route	Expected sample size for each route and each treatment	Expected standard error	± 95% Confidence Interval
1000	2000	Turbine	42	0.056	0.113
		Spill	154	0.029	0.059
		Bypass	374	0.020	0.040
		Dam	570	0.018	0.036
1500	3000	Turbine	62	0.046	0.090
		Spill	231	0.023	0.046
		Bypass	562	0.016	0.032
		Dam	855	0.014	0.028

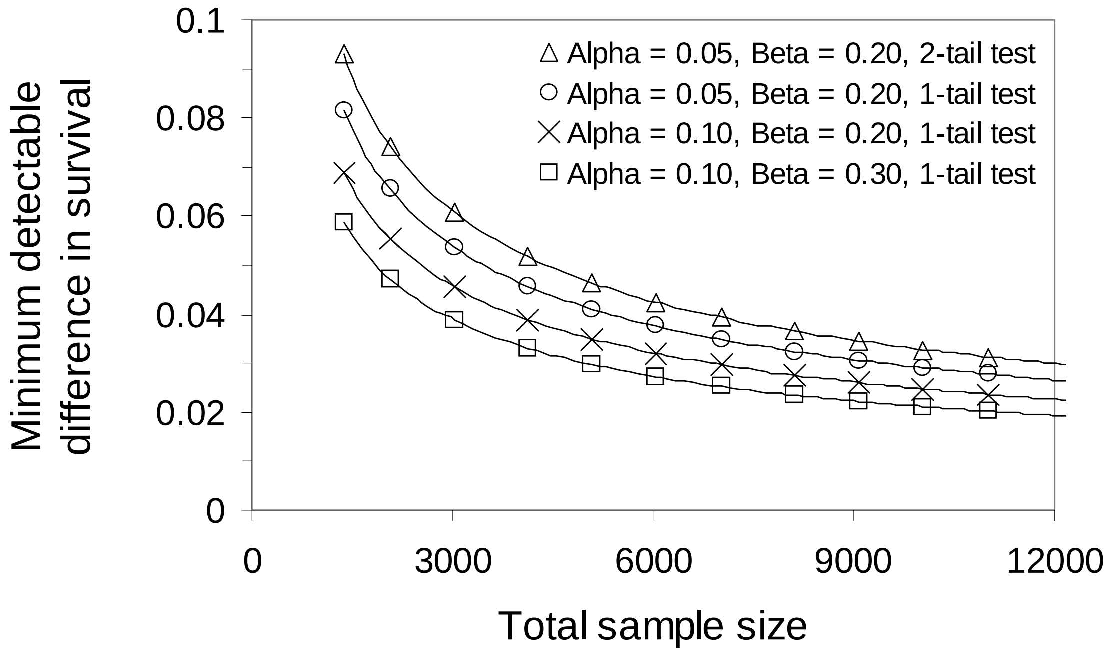

Figure 3. The minimum detectable difference in survival probabilities (S_{dam}) between two treatments for a range of sample sizes and test scenarios for spring migrants at Little Goose Dam.

Schedule of Tasks

Note: Many of the tasks for Objective 2 will be completed under Objective 1. To minimize repetition, we include only additional tasks that will be needed to achieve Objective 2.

Task 2.1: Conduct treatment and control releases of radio-tagged spring migrants in the tailrace of Little Goose Dam during the spring of 2007.

Activity 2.1.1

Develop analytical procedures for determining route-specific survival estimates for yearling Chinook salmon and juvenile steelhead. Since our laboratory has extensive experience conducting survival studies using radio telemetry data, much of the groundwork has been completed to accomplish this task. We will consult with statisticians prior to finalizing survival estimates tasks and objectives.

Schedule: January 2007.

Activity 2.1.2

Install and test additional monitoring sites downstream of Little Goose Dam. These additional sites will be needed below the dam to collect the necessary capture history data inherent to generating survival estimates.

Schedule: February through March 2007.

Activity 2.1.3

Release fish in either 1) the tailrace of Lower Granite Dam to supplement tagged fish if a Lower Granite study is conducted or 2) At Central Ferry Bridge if studies are completely independent. Release control fish in the tailrace of Little Goose Dam.

Schedule: April-May 2007.

Activity 2.1.4

Monitor the movements of radio-tagged fish released above and below Little Goose Dam to estimate route specific survival of spring migrants.

Schedule: April-May 2007.

Task 2.2: Estimate false-positive detection rates for radio-tagged spring migrants released in the tailrace of Little Goose Dam.

Activity 2.2.1

Release radio-tagged spring migrants that have been euthanized to estimate the probability of false-positive detections.

Schedule: Apr. – May, 2007

Task 2.3: Compile and proof fish release data, telemetry data, and environmental data using standard database and statistical analysis software.

Activity 2.3.1:

Compile fish release data, telemetry data, and environmental data into standard database and statistical analysis software.

Schedule: Sept. 2007

Activity 2.3.2

Proof telemetry data and conduct standardized data quality control/assurance procedures necessary for survival analysis.

Schedule: Sept. 2007

Activity 2.5.3

Generate detection-history matrices from the proofed telemetry data in preparation for analysis.

Schedule: Sept, 2007

Objective 3: Determine the approach path, route of passage, and tailrace egress for subyearling Chinook salmon at Little Goose Dam relative to spill and powerhouse operations.

We propose to release radio-tagged subyearling Chinook salmon and monitor forebay residence times, route of passage, and egress through the tailrace of Little Goose Dam during various spill and powerhouse operations. The proposed evaluation would be conducted during the June-July out-migration in 2007. At this time, no specific study design for implementing treatments has been proposed for this evaluation. If only passage information is required, we propose to monitor subyearling Chinook salmon released for the Lower Granite study (if conducted) to obtain passage information at Little Goose Dam. We expect a useable sample size of about 800 – 1,200 radio-tagged subyearling Chinook would arrive with functional transmitters at Little Goose Dam. Therefore, no additional transmitters would need to be purchased for this objective.

Schedule of Task

Note: Many of the tasks for Objective 3 will be completed under previous objectives. To minimize repetition, we include only additional tasks that will be needed to achieve Objective 3.

Task 3.1: Monitor releases of subyearling Chinook salmon in Little Goose Reservoir during the summer of 2007.

Activity 3.3.3

Complete the necessary Endangered Species Act documentation and obtain the necessary permits and approval to work in the Snake River.

Schedule: January 2007.

Activity 3.3.5

Monitor the movements of radio-tagged fish in the forebay and tailrace of Little Goose Dam relative to treatment tests.

Schedule: June through July 2007.

Objective 4: Estimate route-specific survival of subyearling Chinook salmon passing through Little Goose Dam.

To estimate route specific survival of subyearling Chinook salmon, treatment releases must be conducted close to Little Goose Dam (at Central Ferry Bridge) because the battery life of transmitters is too short to use fish release from Lower Granite Dam. The short battery life (~ 20 days) is due to the goals of route-specific and bay-specific passage, which dictates that tags pulse frequently. Much longer tag lives are possible if less-specific information is needed during dam passage. To estimate standard errors and confidence intervals of survival probabilities, we assumed parameter values for the route-specific survival model (see Figure 1). We used the best available parameter estimates for subyearling Chinook salmon. First, we assumed 90% of fish survived from release to Little Goose Dam (i.e., S_{pool} x S_{fb} = 0.90). Next, we set detection probabilities (p) to 0.80, about 0.10 lower than detection probabilities we typically obtain for spring migrants (Plumb et al. 2004). We set probabilities of turbine survival (S_{Tu}) to 0.90, spillway survival (S_{Sp}) to 0.98, and bypass survival to 0.98. For all reaches downstream of the dam, survival probabilities were set to 0.90 for both treatments and controls. Next, we assumed 84% of fish would pass through the spillway, which is based on preliminary estimates from our 2005 research. Last, we estimated the probability of passing the dam through the juvenile bypass system (By) based on an FGE estimate of 0.83 for Little Goose Dam also from our 2005 research.

The 95% confidence intervals show the affect of sample size on precision and the difference in precision among survival probabilities (Figure 4). Turbine survival probabilities will likely have the lowest precision because the fewest fish are expected to pass through this route and turbine survival probabilities are expected to be the lowest of all available passage routes. Overall survival for all passage routes (S_{dam}) is expected to have the highest precision because this estimate incorporates the increased sample size of all passage routes. A sample size of 1,000 fish per treatment should yield precision of ±0.054 for S_{dam} (±95% confidence interval, Table 2). Larger sample size would improve precision of S_{dam} (Table 2).

For statistically comparing S_{dam} among the two treatments, we calculated the minimum detectable difference in survival over a range of sample sizes and based on four combinations of alpha, beta (power=1-beta), and a 1- or 2-tailed test. To calculate standard errors for the power analysis we assumed the same survival and passage parameters described above. We assumed S_{dam} to be the average survival of fish passing through all routes weighted by the proportion of fish passing through each route. Figure 5 allows managers to examine how a range of sample sizes affects the minimum detectable difference between treatments to determine the most appropriate sample size under a given test scenario.

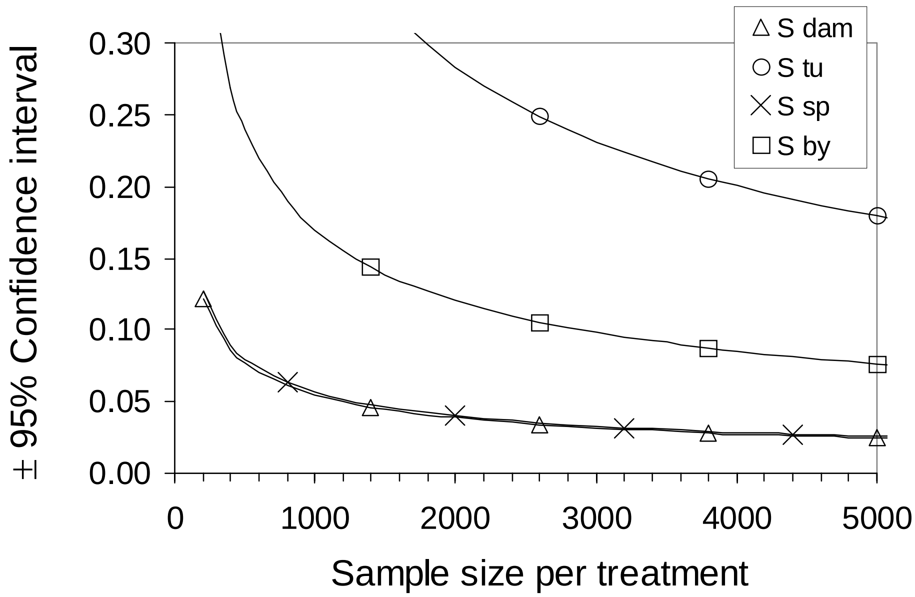

Figure 4. The effect of sample size on precision of dam survival (S_{Dam}), turbine survival (S_{Tu}), spill survival (S_{Sp}), and bypass survival (S_{By}) probabilities for subyearling Chinook salmon at Little Goose Dam. Sample sizes are for one treatment of dam operations. Note: about 100 additional tags will be needed for releasing euthanized tagged fish and for conducting a tag life study.

Table 2. Sample size, expected standard error, and 95% confidence interval for route-specific survival probabilities of subyearling Chinook salmon. Total sample size assumes two treatments of dam operations. Note: about 100 additional tags will be needed for releasing euthanized tagged fish and for conducting a tag life study.

Sample size for each treatment	Total sample size	Route	Expected sample size for each route and each treatment	Expected standard error	± 95% Confidence Interval
1000	2000	Turbine	15	0.198	0.400
		Spill	454	0.028	0.057
		Bypass	71	0.084	0.170
		Dam	540	0.027	0.054
1500	3000	Turbine	22	0.105	0.205
		Spill	680	0.024	0.046
		Bypass	108	0.044	0.087
		Dam	1080	0.022	0.043
2000	4000	Turbine	29	0.140	0.283
		Spill	907	0.020	0.040
		Bypass	144	0.059	0.120
		Dam	1080	0.019	0.039

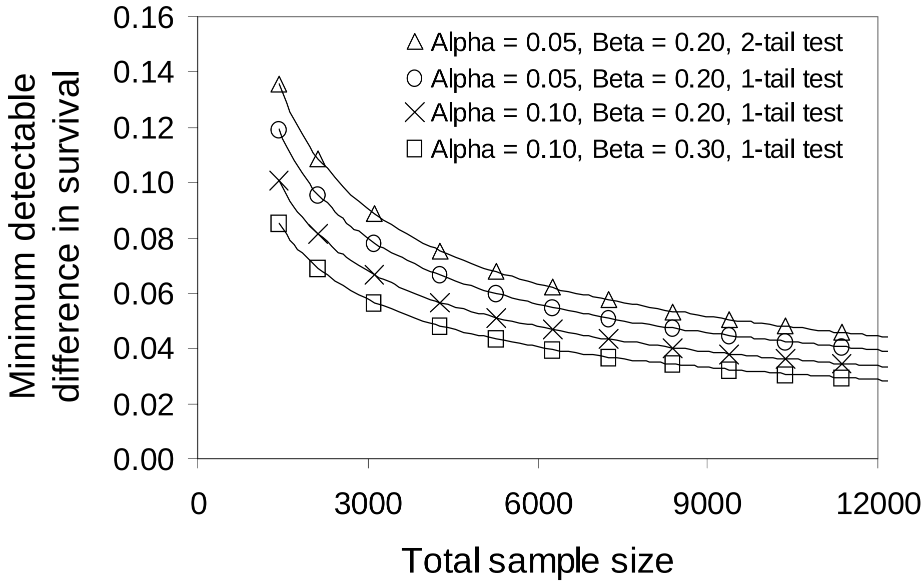

Figure 5. The minimum detectable difference in survival probabilities (S_{dam}) between two treatments for a range of sample sizes and test scenarios for subyearling Chinook salmon at Little Goose Dam.

Schedule of Tasks
Note: Many of the tasks for Objective 4 will be completed under Objective 3. To minimize repetition, we include only additional tasks that will be needed to achieve Objective 4.

Task 4.1: Conduct releases of subyearling Chinook salmon in the forebay and tailrace of Little Goose Dam during the summer of 2007.

Activity 4.1.1
Develop analytical procedures for determining route-specific survival estimates for subyearling Chinook salmon. Since our laboratory has extensive experience conducting survival studies using radio telemetry data, much of the groundwork has been completed to accomplish this task. We will consult with statisticians prior to finalizing survival estimates tasks and objectives.
Schedule: January 2007.

Activity 4.1.2
Install and test additional monitoring sites downstream of Little Goose Dam. These additional sites will be needed below the dam to collect the necessary capture history data inherent to generating survival estimates.
Schedule: February through March 2007.

Activity 4.1.3
Monitor the movements of radio-tagged fish released above and below Little Goose Dam to estimate route specific survival of subyearling Chinook salmon.

Schedule: July-August 2007.

Task 4.2: Estimate false-positive detection rates for radio-tagged subyearling Chinook salmon released in the tailrace of Little Goose Dam.

Activity 4.2.1

Release radio-tagged subyearling Chinook salmon that have been euthanized to estimate the probability of false-positive detections.

Schedule: July-August 2007.

Task 4.3: Compile and proof fish release data, telemetry data, and environmental data using standard database and statistical analysis software.

Activity 4.3.1:

Compile fish release data, telemetry data, and environmental data into standard database and statistical analysis software.

Schedule: Sept. 2007

Activity 4.3.2

Proof telemetry data and conduct standardized data quality control/assurance procedures necessary for survival analysis.

Schedule: Sept. 2007

Activity 4.5.3

Generate detection-history matrices from the proofed telemetry data in preparation for analysis.

Schedule: Sept. 2007

FACILITIES AND EQUIPMENT

Although some of the special or expensive equipment or services for the proposed study have been purchased during previous years of this study, there is a need for additional equipment. The purchase of the radio transmitters will perhaps be the most significant purchase for the proposed study. The coded radio transmitters manufactured by Lotek Engineering cost about $200.00 each.

The USGS operates the Columbia River Research Laboratory that includes research boats, vehicles, office space, and laboratory facilities to conduct this study. Boats will be operated at cost with no additional lease cost to the project. Only department of Interior certified boat operators trained in CPR and First Aid will operate boats. In order to meet U.S. Coast Guard standards boats will be inspected by a third party. Furthermore, USGS will provide a quality control system consistent with the Good Laboratory Practices Act.

Other resources include:

-A selection of 30 boats up to 30 feet in length for work on the river.

-Two 2700 square foot storage facilities with a shop.

-4000 square foot wet lab facility.

-A local computer network integrating state-of-the-art GIS capabilities.

-A technical staff of 60-100 fishery biologists, ecologists, and GIS specialists.

-An office and analytical laboratory in a 15,000 square foot facility.

IMPACTS

Impacts to other researchers

Because we will be using radio-telemetry technology to study the movements of the test fish, there is a great potential for interference with other studies that use the same technology. Other studies using radio tags with the same frequencies may cause interference and could cause the loss of data that would otherwise be collected. During 1994, 1995, and 1996 our ability to collect data was compromised due to radio interference caused by other researchers. An extensive coordination effort throughout the basin allowed us to minimize this problem during 1997-1998. In conjunction with coded tag manufacturers we were able to incorporate radio tags that operated on a unique frequency used only by USGS scientists. During the 2000-2001 study periods we used these modified radio tag frequencies to reduce multiple signal collisions and eliminate unwanted detections (of fish released by other researchers), and therefore increased overall data integrity. This unique tag frequency will be used during the 2007 evaluation.

Coordination with researchers conducting the evaluation of JSATS vs. PIT tags (NOAA Fisheries and Battelle PNNL) will be required due to competing needs for study fish. In 2006 both research needs were met at Little Goose Dam after brief coordination. The contact person for the tag evaluation study is Brad Ryan and NOAA Fisheries.

Impacts to the Little Goose Project

Pre-season installation of equipment will start in February 2007 and continue through May 2007. The equipment will be in use through the end July 2007. We are capable of installing most of the necessary equipment for the aerial arrays, and the impact to the Little Goose project should be minimal. However, we are not equipped to repair and install all of the underwater antennas at the turbine intakes and Extended Length Barrier Screens. At this stage in the development of the 2007 study design, the impacts to the Little Goose Project, and the assistance we might require from COE personnel is as follows:

Underwater antennas on spillway -- We may require divers to repair underwater antennas on the spillway. Turbine outages and spill gate closures must be in effect during diving activities. As a result, this work must be coordinated with the Little Goose project and should be completed prior to increased flows in the Snake River. Perhaps the most effective way to meet all the diving needs is to have all the work covered in one contract that is awarded by the COE.

Underwater antennas on Extended Length Bar Screens-- We will need the assistance of Little Goose Project personnel to raise and lower each screen during the repair and reinstallation of underwater antennas on the ELBS. Re-installation of the ELBS telemetry arrays is dependent on the work of numerous other contractors, and therefore a more specific schedule is difficult to estimate.

COLLABORATIVE ARRANGEMENTS AND SUB-CONTRACTS

Some of the labor needed to complete the activities outlined in this proposal may be furnished through a sub-contract with a labor service provider.

LIST OF KEY PERSONNEL AND PROJECT DUTIES

Personnel	Organization	Project Duties
Dennis Rondorf	BRD	Section Leader
John Beeman	BRD	Project Leader
Noah Adams	BRD	Co-Project Leader

TECHNOLOGY TRANSFER

The data we propose to collect during the 2007 season will provide detailed information on the movements and passage routes of juvenile salmonids at Little Goose Dam relative to spill and powerhouse operations. We plan to transfer information obtained from our analysis in the manners listed below. Once this information is transferred, it will be used to make decisions relative to operation of the Federal Columbia River Power System and Juvenile Transportation Program as discussed in the draft Biological Opinion, July 27, 2000, 9.6.1.4.2, page 9-69. In addition, the information will be used by other federal and state agencies, Indian Tribes, and the public to make management decisions to aid in the recovery of threatened and endangered populations of salmon in the Columbia Basin.

1. Expected draft report for 2007 by December, 2007 and final report by March 31, 2008.

2. Presentation to the Anadromous Fish Evaluation Program (AFEP) in November 2007.

3. Presentations to the Army Corps of Engineers staff and study review groups.

4. Presentations at professional meetings (e.g., American Fisheries Society) and publication of information in peer-reviewed journals.

References

Adams, N.S., D.W. Rondorf, S.D. Evans, J.E. Kelly, and R.W. Perry. 1998a. Effects of surgically and gastrically implanted radio transmitters on swimming performance and predator avoidance of juvenile Chinook salmon (*Oncorhynchus tshawytscha*). Canadian Journal of Fisheries and Aquatic Sciences. 55: 781-787.

Adams, N. S., D. W. Rondorf, S. D. Evans, and J. E. Kelly. 1998b. Effects of surgically and gastrically implanted radio transmitters on growth and feeding behavior of juvenile Chinook salmon. Transactions of the American Fisheries Society 127: 128-136.

Burnham, K.P., D.R. Anderson, G.C. White, C. Brownie, and K.H. Pollock. 1987. Design and analysis methods for fish survival estimates based on release-recapture. American Fisheries Society Monograph No. 5. Baltimore, Maryland.

Cormack, R. M. 1964. Estimates of survival from the sighting of marked animals. Biometrika 51:429-438.

Counihan, T.D., G.S. Holmberg, J.H. Petersen. 2002. Survival estimates of migrant juvenile salmonids in the Columbia River through John Day Dam using radio-telemetry, 2002. Draft final annual report of research by U.S. Geological Survey to the US Army Corps of Engineers. Contract No. W66QKZ20384546. Portland, Oregon.

Hockersmith, E.E., W.D. Muir, S.G. Smith, B.P. Sanford, R.W. Perry, N.S. Adams, and D.W. Rondorf. 2003. Comparison of migration rate and survival between radio-tagged and PIT-tagged migrant yearling Chinook salmon in the Snake and Columbia rivers. North American Journal of Fisheries Management. 23: 404-413.

Jolly, G. M. 1965. Explicit estimates from capture-recapture data with both death and immigration-stochastic model. Biometrika 52:225-247.

Leberton, J.D., K.P. Burnham, J. Clobert, and D. R. Anderson. 1992. Modeling survival and testing biological hypotheses: using marked animals: A unified approach. Ecological Monographs 62:67-118.

Mathur, D., P.G. Heisey, E.T. Euston, and J.R. Skalski. 1996. Turbine passage survival estimation for Chinook salmon smolts (*Oncorhynchus tshawytscha*) at a large dam on the Columbia River. Canadian Journal of Fisheries and Aquatic Sciences. 53: 542-549.

Muir, W. D., S. G. Smith, J. G. Williams, and E. E. Hockersmith. 2001. Survival estimates for migrant yearling Chinook salmon and steelhead tagged with passive integrated transponders in the lower Snake and lower Columbia rivers, 1993-1998. North American Journal of Fisheries Management 21:269-282.

National Marine Fisheries Service (NMFS). 2001. Biological Opinion. Reinitiation of consultation on operation of the Federal Columbia River Power System, including the Juvenile Fish Transportation Program, and 19 Bureau of Reclamation Projects in the Columbia Basin. Northwest Region.

Perry, R.W., S.D. Fielding, A.C. Cochran, J.L. Schei, J.M. Sprando, G.T. George, N.S. Adams, and D.W. Rondorf. 2003. Turbine survival and migration behavior of subyearling Chinook salmon at McNary Dam, 2003. Draft Annual Report by the U. S. Geological Survey to the U.S. Department of Energy, Bonneville Power Administration, Contract 00014243, Portland, Oregon.

Perry, R. W., and several coauthors. In preparation. Migration behavior and survival of radio-tagged juvenile salmonids during two spill treatments at Little Goose Dam in 2005. In preparation.

Peven, C., A. Giorgi, J. Skalski, M. Langesley, A. Grassel, S. G. Smith, T. Counihan., R. Perry, and S. Bickford. 2005. Guidelines and Recommended Protocols For Conducting, Analyzing, and Reporting Juvenile Salmonid Survival Studies in the Columbia River Basin. Report to the U.S. Army Corps of Engineers, Portland District, Portland, Oregon.

Plumb, J. M., A. C. Braatz, J. N. Lucchesi, S. D. Fielding, J. M. Sprando, G. T. George, R.W. Perry, N. S. Adams and D. W. Rondorf. 2003. Behavior of radio-tagged juvenile Chinook salmon and steelhead and performance of a removable spillway weir at Lower Granite Dam, Washington, 2002. Annual Report by the U. S. Geological Survey to the U. S. Army Corps of Engineers, contract W68SBV00104592, Walla Walla, Washington.

Plumb, J. M., A. C. Braatz, J. N. Lucchesi, S. D. Fielding, A. D. Cochran, T. K. Nation, J. M. Sprando, J. L. Schei, R. W. Perry, and N. S. Adams. 2004. Behavior of radio-tagged juvenile Chinook salmon and steelhead and performance of a removable spillway weir at Lower Granite Dam, Washington, 2003. Annual Report by the U. S. Geological Survey to the U. S. Army Corps of Engineers, contract W68SBV00104592, Walla Walla, Washington.

Seber, G. A. F. 1965. A note on the multiple recapture census. Biometrika 52:249-259.

Skalski, J.R., S.G. Smith, R.N. Iwamoto, J.G. Williams, and A. Hoffman. 1998. Use of passive integrated transponder tags to estimate survival of migrant juvenile salmonids in the Snake and Columbia rivers. Canadian Journal of Fisheries and Aquatic Sciences. 55: 1484-1493.

Skalski, J.R., J. Lady, R. Townsend, A.E. Giorgi, J.R. Stevenson, C.M. Peven, and R.D. McDonald. 2001. Estimating in-river survival of migrating salmonid smolts using radiotelemetry. Canadian Journal of Fisheries and Aquatic Sciences. 58: 1987-1997.

Skalski, J.R., R. Townsend, J. Lady, A.E. Giorgi, J.R. Stevenson, and R.D. McDonald. 2002.

Estimating route-specific passage and survival probabilities at a hydroelectric project from smolt radiotelemetry studies. Canadian Journal of Fisheries and Aquatic Sciences. 59: 1385-1393.

Smith, S. G., W. D. Muir, J. G. Williams, and J. R. Skalski. 2002. Factors associated with travel time and survival of migrant yearling Chinook salmon and steelhead in the lower Snake River. North American Journal of Fisheries Management 22:385-405.

Smith, S. G., W. D. Muir, E. E. Hockersmith, R. J. Graves, C. V. Ross, W. P. Connor, B. D. Arnsberg. 2003. Influence of river conditions on survival and travel time of Snake River subyearling fall Chinook salmon. North American Journal of Fisheries Management 23:939-961.

Sokal, R. R. and F. J. Rohlf. 1981. Biometry, Second Edition, W. H. Freeman and Company, San Francisco.

Venditti, D. A., D. W. Rondorf, and J. M. Kraut. 2000. Migratory behavior and forebay delay of radio-tagged juvenile fall Chinook salmon in a lower Snake River impoundment. North American Journal of Fisheries Management 20:41-52.