PRELIMINARY PROPOSAL FOR FY 2005 FUNDING

Title:	Survival and migration behavior of juvenile salmonids at McNary Dam
Study Code:	SPE-W-04-03
Principal Investigators:	Russell W. Perry and Noah S. Adams
Project Leader:	Dennis W. Rondorf 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 Corps 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 Center 5501A Cook-Underwood Road Cook, WA. 98605 (509) 538-2299: FAX (509) 538-2843
Performance Period:	January 1, 2005 – September 31, 2005
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PROJECT SUMMARY

Introduction

This proposal outlines three objectives that will address research needs at McNary Dam for 2005. All objectives will address the estimation of survival and passage parameters for yearling Chinook salmon (Objective 1), juvenile steelhead (Objective 2), and subyearling Chinook salmon (Objective 3). Survival and passage parameters will be estimated under two treatments: project operations within the 1% range of peak turbine operating efficiency and project operations at maximum turbine discharge (i.e., >1% range of peak turbine efficiency). However, it is unclear whether these treatments will be implemented. Consequently, we have structured the proposal to provide managers the information needed to determine sample sizes whether or not treatments are implemented. To provide this information, we answered the following questions: 1) What is the precision of route-specific survival estimates that managers desire for each treatment? And 2) What is the minimum detectable difference in survival probabilities between two treatments?

Research Goals

The goal of this project is to estimate passage and survival probabilities of juvenile salmonids at McNary Dam. Furthermore, we will compare survival and passage probabilities between two treatments of project operations within and outside of the 1% range of peak turbine operating efficiency. We propose to use radio telemetry as the primary tool to address these goals.

Objectives

Objective 1. Quantify migration behavior and estimate survival rates of yearling (spring) Chinook salmon under two treatments of project operations.

Objective 2. Quantify migration behavior and estimate survival rates of juvenile steelhead under two treatments of project operations.

Objective 3. Quantify migration behavior and estimate survival rates of subyearling (fall) Chinook salmon under two treatments of project operations.

Note: These study objectives meet the research needs identified in SPE-W-04-03 Objective 1.a.iv.

Methodology

For all objectives, we propose to use radio telemetry techniques to obtain survival, passage, and behavioral information. Because radio-tagged fish are usually detected at high rates (>80% detection probability), radio telemetry techniques are well suited to estimating survival rates with small sample sizes and high precision of survival estimates. 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. In addition, using the RSSM, we will estimate the overall survival probability of dam passage and survival from release to the dam.

To estimate survival and passage probabilities, for each treatment of dam operation we propose to release between 1,500 and 2,000 (3,000 – 4,000 for two treatments) radio-tagged yearling Chinook salmon (*Oncorhynchus tshawytscha*), juvenile steelhead (*Oncorhynchus mykiss*), and subyearling Chinook salmon (*Oncorhynchus tshawytscha*). For most passage routes, analysis suggests that this sample size will yield survival probabilities with precision of ±0.03-0.04 (±95% confidence interval). However, the fewest fish are expected to pass through the turbines, which will yield lower precision for turbine survival estimates (±95% confidence interval > 0.05).

Relevance to the Biological Opinion

This study addresses the 1995 Biological Opinion, VIII, A, page 122 (NMFS 1995), Reasonable and Prudent Alternative to the Proposed Action number 15, 58, and 59 and sections 9.6.1.4.2, 9.6.1.4.3, 9.6.1.4.4, and 9.6.1.4.6 of the 2000 Biological Opinion.

PROJECT DESCRIPTION

Background and Justification

Many sources of mortality affect populations of juvenile salmonids in the Columbia River as they migrate from their natal streams to the ocean. As a result of passing through hydroelectric projects, juvenile salmonids can experience both direct, instantaneous mortality and indirect, delayed mortality. Direct mortality results from injury due to dam passage and indirect mortality occurs when passage through a dam increases a fish's probability of succumbing to predation, disease, or physiological stress. Many studies of the effects of dam operations on the mortality of juvenile salmonids have led to specific guidelines and management actions for operation of the Federal Columbia River Power System (NMFS 2001). As modernization continues at McNary Dam, one option is to operate turbines at discharges greater the 1% range of peak operating efficiency. Estimates of passage and survival probabilities are needed to ensure changes in project operations do not adversely impact threatened salmonid populations.

In the coming years, McNary Dam will undergo a modernization project intended to upgrade the aging turbines at McNary Dam. The typical turbine life is 25 to 30 years, but turbines at McNary Dam are almost 50 years old. Thus, the modernization project will replace all turbines at McNary Dam with new turbines. These new turbines are expected to increase the hydraulic capacity of the powerhouse and could increase electrical output by 90 megawatts. It is unknown how these new turbines will affect the survival rates of juvenile salmonids. In addition, because hydraulic capacity of each turbine will increase from 12.5 kcfs at peak operating efficiency to 16-17 kcfs at normal operating discharge, the amount of water passed through spillways may decrease. These changes in project operations could affect the proportion of the downstream migrant population passing through the available passage routes. Because survival is route-dependent, changes in fish passage could also affect the overall survival rate of the population. It is these changes to the infrastructure of McNary Dam and to project operations that necessitate estimates of passage and survival probabilities.

Using radio-telemetry, we propose to estimate survival rates that are needed to address objectives of the McNary modernization project and changes to project operations. The USGS, Columbia River Research Laboratory uses radio-telemetry techniques to monitor the migration behavior of juvenile salmonids in the Snake and Columbia rivers. More recently, the Columbia River Research Laboratory has successfully used radio-telemetry techniques to estimate survival rates of juvenile salmonids in the lower Columbia River (Counihan et al. 2002a, 2002b) and also at McNary Dam (Perry et al. 2003, Perry et al. 2004 in preparation).

Many methods are available to conduct mark-recapture experiments to estimate survival rates of juvenile salmonids. For example, survival rates through turbines at McNary Dam have historically been estimated using batch-marking techniques (Schoeneman et al. 1961). Other 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 of PIT tags 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.

Current Status

During the summer of 2003, the USGS estimated the turbine survival probability of subyearling Chinook salmon at McNary Dam (Perry et al. 2003). Bonneville Power Administration (BPA) had proposed to discontinue the mandate of operating turbines within ±1% of peak operating efficiency. As part of their proposal, BPA requested research at McNary Dam to compare survival of yearling and subyearling Chinook salmon during turbine operations within the ±1% range of peak operating efficiency and discharges outside this range. Because little data was available for subyearling Chinook salmon to estimate sample sizes that would be needed for this study, we conducted a pilot study with the objectives of 1) estimating turbine survival and detection probabilities of subyearling Chinook salmon, 2) using these survival and detection probabilities in a power analysis to estimate sample sizes needed to detect differences in survival between two turbine operation treatments, and 3) characterizing migration behavior for a small subset of fish released upstream of McNary Dam.

We obtained relatively high detection probabilities (>0.85) of subyearling Chinook salmon, but found that turbine survival was low, which affected the sample size needed to detect differences in survival between treatments. The unweighted average of S_{turb} was 0.774 (±0.032 standard error, SE; ± 0.068, ±95% confidence interval). Managers were interested in detecting a 0.01, 0.02, or 0.03 difference in survival with α=0.05 and β=0.20 (i.e., power=0.80). We found that subyearling Chinook would require larger sample sizes than yearling Chinook to detect these differences. For example, to determine if survival was lower when turbines are operated at discharges higher than the 1% range of peak efficiency (i.e., a 1-tailed test), we estimated that about 8,700 radio-tagged yearling Chinook salmon would be required to detect a 0.03 difference in survival. In contrast, over twice this sample size would be needed to detect this same difference for subyearling Chinook salmon because they are expected to have lower survival and detection probabilities than yearling Chinook salmon (Perry et al. 2003).

During 2004, the USGS conducted a study at McNary dam to estimate route-specific survival and passage probabilities of yearling Chinook salmon, steelhead, and subyearling Chinook salmon. Data analysis and results for this study are not yet completed, but our research during 2003 and 2004 provided valuable information for designing 2005 research activities. For instance, our studies have allowed us to identify and test the adequacy of downstream telemetry arrays for detecting fish, as well as telemetry arrays at McNary Dam. In addition, these studies provided data on migration behavior for fish released from two upstream release sites, which helped us to determine which site would be best for releasing fish in 2005. Lastly, our studies have helped us identify any potential problems or technical considerations for conducting a survival study with radio telemetry at McNary Dam.

Project Overview

We will use radio telemetry to estimate 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 (usually underwater and aerial antennas) 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.

To obtain an estimate of bypass survival, radio-tagged fish must be diverted into the river after being guided and passing through the juvenile bypass system. If radio-tagged fish are loaded onto barges, then we will be unable to obtain valid detections at downstream antenna arrays, and thus, unable to estimate bypass survival. Therefore, in addition to radio tags, we propose to implant PIT tags into all sample fish. Using PIT tags and "sort-by-code" technology will allow radio-tagged fish to be diverted into the tailrace after passing through the bypass system.

For quantifying migration behavior, we will monitor travel times, approach paths to McNary Dam, forebay movements, and passage routes of juvenile salmonids. 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 McNary Dam we will use multiple aerial and underwater radio telemetry arrays. Aerial antenna arrays will be installed at the navigation wall, spillway, powerhouse, earthen dam, adult fish ladder, fish collection channel, juvenile fish bypass system, tailrace, and the Interstate-82 Bridge. To obtain movement information at finer spatial scales, we will install underwater antennas on the extended-length submersible bar screens, spillbay piernoses, and in the juvenile fish bypass system.

Methodology

To reduce repetition of methods common to each of the three 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 will be common to all objectives. These methods will be presented in the section "Methods for Generating Survival Estimates".

We propose to gastrically implant radio transmitters and PIT tags into juvenile salmonids following procedures described by Adams et al. (1998a). 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. We will release all fish at Hat Rock State Park, about 10 km upstream of the dam. On average, fish should arrive at the dam about 1 day after release (Perry et al. 2003), which should provide sufficient time for fish to initiate their normal migration behavior and spread out over space and time.

The planned operation of the juvenile bypass facility in 2005 will necessitate using PIT tags to divert radio-tagged fish into the river to estimate survival through the bypass system. During the spring, operation of the juvenile collection system will consist of barging collected fish on one day, while diverting fish to the river on every other day (i.e., "full-flow bypass"). During the 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 plan to integrate the PIT tag into the radio tag to eliminate double tagging of fish. PIT tags integrated with radio tags are used often to divert fish from bypasses into the river and to obtain detections of fish after their radio tags have expired (Hockersmith et al. 2003).

We will use coded radio transmitters weighing no more than 1.4 g for yearling Chinook salmon, 1.8 g for juvenile steelhead, and 0.85 g for subyearling Chinook salmon (Lotek Inc., Newmarket, Ontario). 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 6.5% of the fish's weight. The additional weight of a PIT tag should have a negligible effect on spring migrants.

To estimate passage and survival probabilities with the RSSM, we will conduct daily treatment releases of radio-tagged juvenile salmon upstream of McNary Dam (R_t) and daily control releases in the tailrace (R_c; Figure 1). Fish will be released 10 km upstream at Hat Rock State Park. Releasing fish upstream will allow them to recover from handling stress and to reinitiate normal migration behavior. Using the RSSM, we will estimate survival rates from the release point to the dam (S_{pool}; 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};

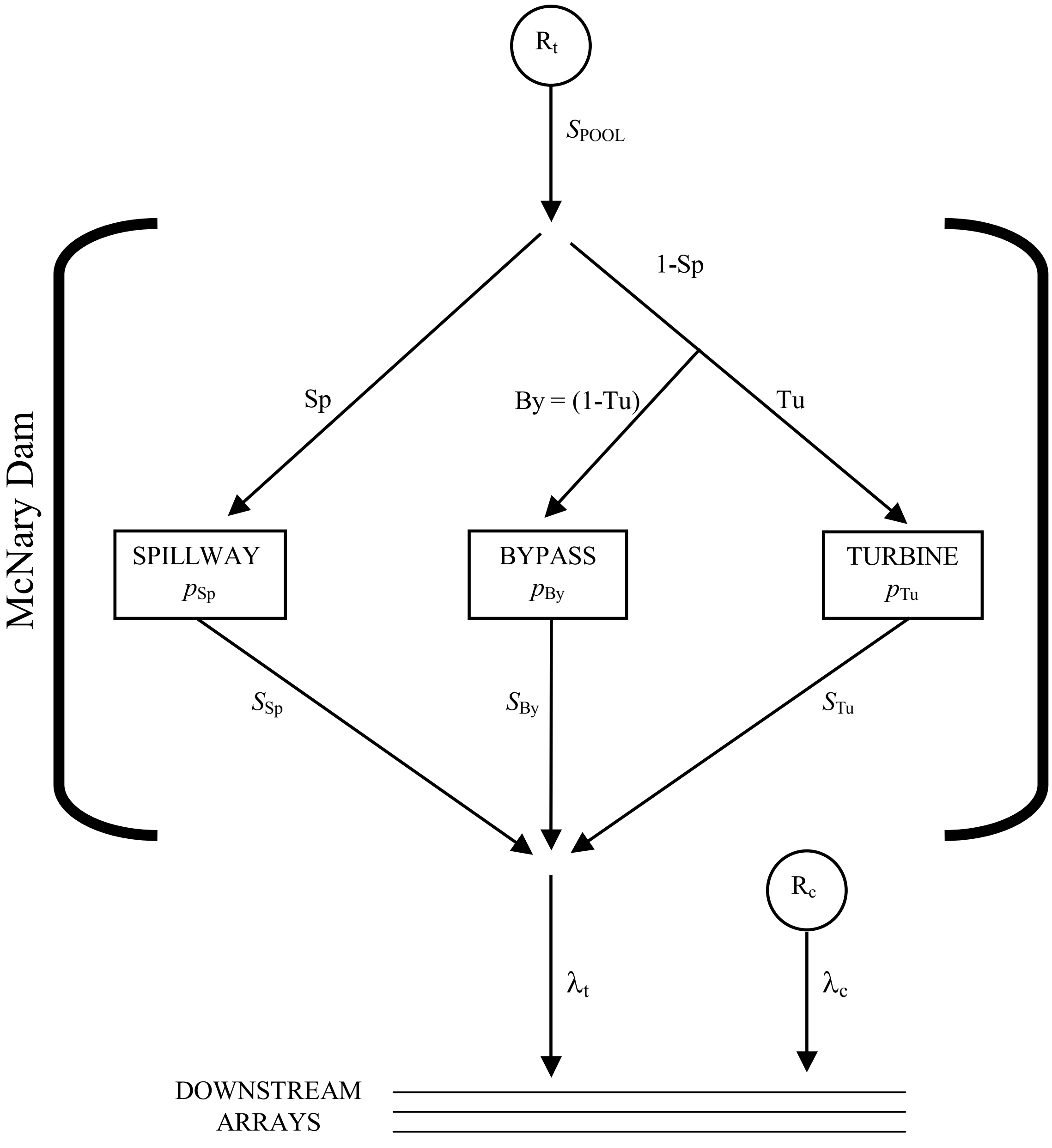

Figure 1. Schematic of route-specific survival model showing release sites, passage routes, and parameters to estimate route-specific detection, passage, and survival probabilities at McNary Dam. Shown are the treatment releases (R_t) upstream of McNary Dam, control releases in the tailrace (R_c), and estimable parameters. Estimable parameters include passage (Sp, By, and Tu), detection (p_{Sp}, p_{By}, and p_{Tu}), and survival (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.

Figure 1) will be estimated relative to the survival of control groups of fish released in the tailrace of McNary Dam. From the 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 McNary Dam at Irrigon (river kilometer, rkm 459), Big Blalock Island (rkm 446), and Crow Butte (rkm 424; 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 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 biased high if dead fish are detected.

Tasks and Objectives

Two important statistical questions arise regarding the goals of survival estimates under two treatments of differing dam operations. First, what is the precision that managers desire for route-specific survival estimates obtained under each treatment. Second, when statistically comparing survival estimates between the two treatments, what is the detectable difference between survival estimates that managers desire? To address these questions, first we calculated standard errors and confidence intervals of each route-specific survival estimate for a range of sample sizes. This allows managers to compare the expected precision among passage routes as well as between sample sizes. Second, we conducted a power analysis to estimate the detectable difference in dam survival (S_{dam}) between the two treatments (using the methods of Perry et al. (2003)). We use S_{dam} for this analysis, rather than turbine survival, because too few fish are expected to pass through the turbines to detect small survival differences with sufficient statistical power. In addition, changes in turbine discharge could affect the proportion of fish passing through the available routes by reducing spill discharge. 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.

We used the paired-release recapture model to calculate expected standard errors and confidence intervals of survival probabilities. For this preliminary proposal, expected standard errors based on multinomial variation were estimated by assuming some parameter values noted in Figure 1 and using others from Appendix D of the NMFS 2000 Biological Opinion. However, if better parameter estimates become available from our 2004 research, we will update this analysis prior to submittal of the final proposal. 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. We used the paired-release recapture model to estimate standard errors because currently, software is not available to estimate standard errors with the route-specific survival model. 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 should help identify a general range of sample sizes and differences among passage routes in the expected precision of survival estimates.

Objective 1. Quantify migration behavior and estimate survival rates of yearling (spring) Chinook salmon under two treatments of project operations.

To estimate standard errors and confidence intervals of survival probabilities, we assumed parameter values for the route-specific survival model (see Figure 1). First, we assumed 95% of fish survived from release to McNary Dam (i.e., $S_{pool} = 0.95$). Next, we set detection probabilities (p) to 0.90, about 0.05 lower than capture probabilities we typically obtain for yearling Chinook salmon. Based on Appendix D of the NMFS 2000 Biological Opinion, we set probabilities of turbine survival (S_{Tu}) to 0.90, spillway survival (S_{Sp}) to 98. We assumed bypass survival was 0.95. 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 0.37. We based this estimate on a spill efficiency of 1:1 and a 5-year average of 37% of river discharge through the spillway for the period April 1 – May 31 (excluding 2001 data because of low discharge). 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 from Appendix D of the NMFS 2000 Biological Opinion.

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 1,500 and 2,000 (per treatment) should yield precision of ±0.03-0.04 (±95% confidence interval) with lower precision for the turbine survival (Table 1).

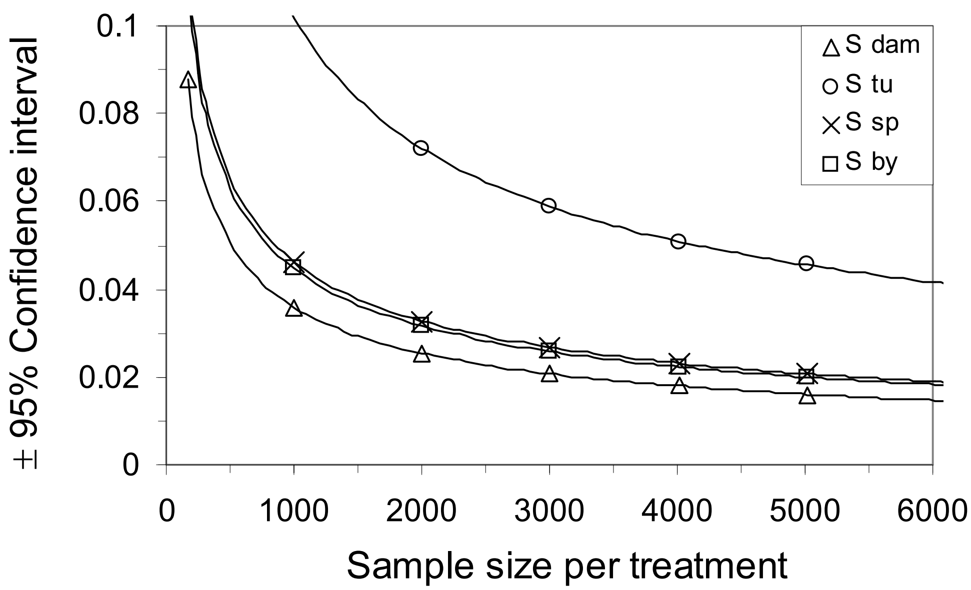

Figure 2. The effect of sample size on precision of dam survival (S_{Dam}), turbine survival (S_{Tu}), spill survival (S_{Sp}), and bypass survival (S_{By}) probabilities for yearling Chinook salmon at McNary Dam. Sample sizes are for one treatment of dam operations. Note: about 100 additional tags will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

Table 1. Total sample size, expected standard error, and 95% confidence interval for route-specific survival probabilities of yearling Chinook salmon. Note: about 100 additional tags will be needed for releasing euthanized tagged fish and for conducting a tag life study.

Species	Sample size for each treatment	Total sample size	Route	Expected sample size for each route and each treatment	Expected standard error	± 95% Confidence Interval
Yearling Chinook Salmon	1500	3000	Turbine	92	0.041	0.082
			Spill	316	0.019	0.038
			Bypass	447	0.018	0.037
			Dam	855	0.014	0.029
Yearling Chinook Salmon	2000	4000	Turbine	122	0.035	0.071
			Spill	422	0.016	0.033
			Bypass	596	0.016	0.032
			Dam	1140	0.013	0.025

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.

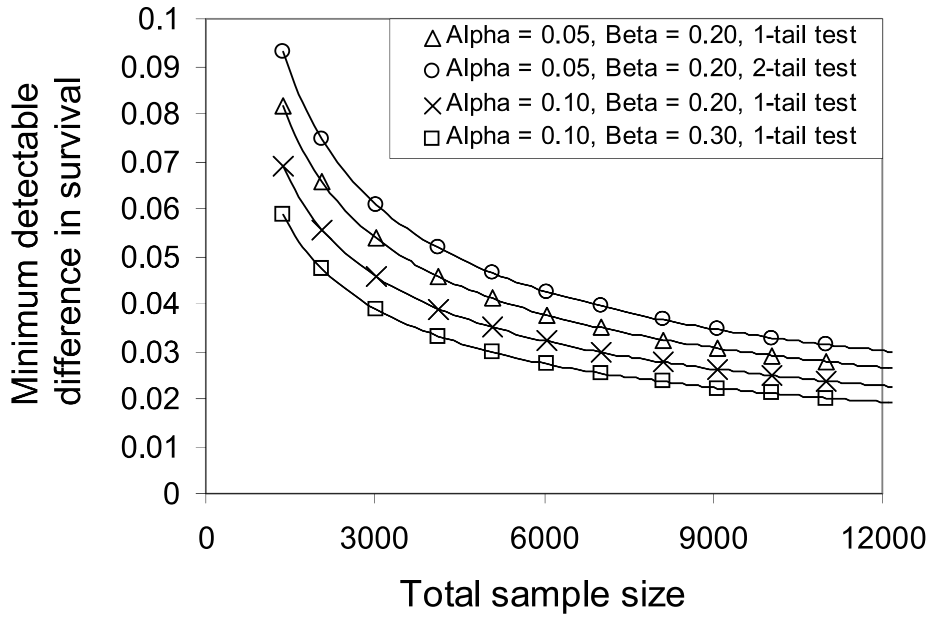

Figure 3. The minimum detectable difference in survival probabilities (S_{dam}) between two treatments for a range of sample sizes and test scenarios for yearling Chinook salmon at McNary Dam.

Schedule of Tasks

Task 1.1: Install fixed monitoring sites (i.e., "survival gates") below McNary Dam.

Activity 1.1.1: Identify 3 to 4 locations separated by 7 to 15 river miles that will be suitable to obtain high detection probabilities of tagged fish.
Schedule: Jan., 2005

Activity 1.1.2: Obtain appropriate permits and permissions to install fixed monitoring sites on federally owned land and navigation markers.
Schedule: Jan. – Feb., 2005

Activity 1.1.3: Install fixed monitoring sites downstream of McNary Dam.
Schedule: Jan. – Feb., 2005

Task 1.2: Install fixed monitoring sites on the face of McNary Dam.

Activity 1.2.1: Install aerial antennas along the face of the dam.
Schedule: Feb. – Apr., 2005

Activity 1.2.2: Install underwater antennas on the spillway, turbines, and juvenile bypass system.
Schedule: Feb. – Apr., 2005

Task 1.3: Tag and conduct daily releases of yearling Chinook salmon.

Activity 1.3.1: Obtain appropriate federal ESA permit and State of Oregon collection and transport permits.
Schedule: Jan. – Feb., 2005

Activity 1.3.2: Coordinate with personnel at the fish bypass collection facility to collect, hold, and radio-tag juvenile yearling Chinook salmon.
Schedule: Mar. – Jul., 2005

Activity 1.3.3: Conduct daily releases of radio-tagged yearling Chinook salmon upstream of McNary Dam and in the tailrace of McNary Dam.
Schedule: Apr. – May, 2005

Task 1.4: Estimate false-positive detection rates for radio-tagged yearling Chinook salmon released in the tailrace of McNary Dam.

Activity 1.4.1. Release radio-tagged yearling Chinook salmon that have been euthanized to estimate the probability of false-positive detections.
Schedule: Apr. – May, 2005

Task 1.5: Compile and proof fish release data, telemetry data, and environmental data using standard database and statistical analysis software.

Activity 1.5.1: Compile fish release data, telemetry data, and environmental data into standard database and statistical analysis software.
Schedule: Sept. – Oct., 2005

Activity 1.5.2: Proof telemetry data and conduct standardized data quality control/assurance procedures necessary for survival analysis.
Schedule: Sept. – Oct., 2005

Activity 1.5.3: Generate detection-history matrices from the proofed telemetry data in preparation for analysis.
Schedule: Sept.– Oct., 2005

Task 1.6: Calculate passage, detection, and survival probabilities using the route-specific survival model. Examine how survival estimates vary with environmental covariates.

Activity 1.6.1: Test validity of model assumptions.
Schedule: Oct. – Nov., 2005

Activity 1.6.2: Model the survival and capture probabilities.
Schedule: Oct. – Nov., 2005

Activity 1.6.3: Examine variation of survival estimates with environmental data.
Schedule: Oct. – Nov., 2005

Objective 2. Quantify migration behavior and estimate survival rates of juvenile steelhead under two treatments of project operations.

Rationale

For juvenile steelhead, we used the same parameter values as for yearling Chinook salmon. All parameter values for juvenile steelhead as identified in the Appendix D of the NMFS 2000 Biological Opinion were the same for yearling Chinook salmon. Since there is little past data for juvenile steelhead at McNary Dam, we also set all other parameters for juvenile steelhead equal to those for yearling Chinook salmon. After setting the fixed parameters, we estimated standard errors and confidence intervals for two scenarios of sample size based on the proportion of fish passing through each route. We used a total sample size of 1,500 and 2,000 fish with 600 and 800 of these fish, respectively, released as controls in the tailrace.

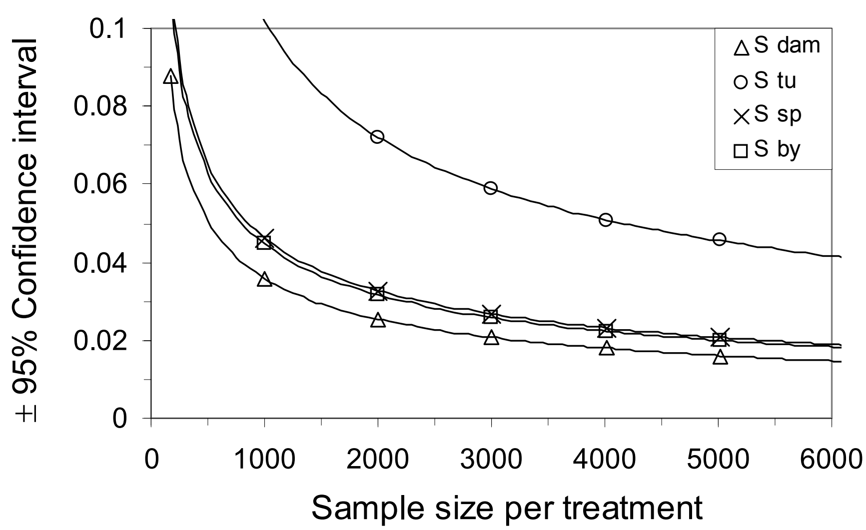

Figure 4. The effect of sample size on precision of dam survival (S_{Dam}), turbine survival (S_{Tu}), spill survival (S_{Sp}), and bypass survival (S_{By}) probabilities for juvenile steelhead at McNary Dam. Sample sizes are for one treatment of dam operations. Note: about 100 additional tags will be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

Table 2. Total sample size, expected standard error, and 95% confidence interval for route-specific survival probabilities of juvenile steelhead. Note: about 100 additional tags will be needed for releasing euthanized tagged fish and for conducting a tag life study.

Species	Sample size for each treatment	Total sample size	Route	Expected sample size for each route and each treatment	Expected standard error	± 95% Confidence Interval
Juvenile Steelhead	1500	3000	Turbine	92	0.041	0.082
			Spill	316	0.019	0.038
			Bypass	447	0.018	0.037
			Dam	855	0.014	0.029
Juvenile Steelhead	2000	4000	Turbine	122	0.035	0.071
			Spill	422	0.016	0.033
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			Dam	1140	0.013	0.025

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.

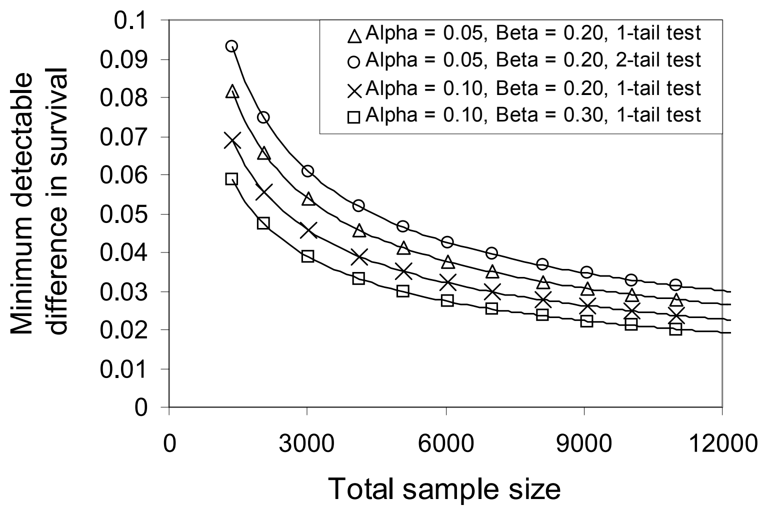

Figure 5. The minimum detectable difference in survival probabilities (S_{dam}) between two treatments for a range of sample sizes and test scenarios for juvenile steelhead at McNary Dam.

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: Tag and conduct daily releases of yearling Chinook salmon and juvenile steelhead.

Activity 2.1.1: Conduct daily releases of radio-tagged juvenile steelhead upstream of McNary Dam and in the tailrace of McNary Dam.
Schedule: Apr. – May, 2005

Task 2.2: Estimate false-positive detection rates for radio-tagged steelhead released in the tailrace of McNary Dam.

Activity 2.2.1. Release radio-tagged steelhead that have been euthanized to estimate the probability of false-positive detections.
Schedule: Apr. – May, 2005

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: Generate detection-history matrices for steelhead from the proofed telemetry data in preparation for analysis.
Schedule: Sep. – Oct., 2005

Task 2.4: Calculate passage, detection, and survival probabilities of steelhead using the route-specific survival model. Examine how survival estimates vary with environmental covariates.

Activity 2.4.1: Model the survival and capture probabilities of steelhead.
Schedule: Oct. – Nov., 2005

Activity 2.4.2: Examine variation of survival estimates of steelhead with environmental data.
Schedule: Oct. – Nov., 2005

Objective 3. Quantify migration behavior and estimate survival rates of subyearling (fall) Chinook salmon under two treatments of project operations.

Rationale
To estimate standard errors and confidence intervals for subyearling Chinook salmon, we assumed some survival and detection probabilities based on a survival study we conducted in 2003 (Perry et al. 2003). For most other parameters, we used values identified in Appendix D of the NMFS 2000 Biological Opinion. First, we assumed 90%

of yearling Chinook salmon survived from release to McNary Dam (i.e., S_{pool} = 0.90). Next, we set detection probabilities (p) to 0.85 based on Perry et al. (2003). We assumed S_{By} was 0.95 and S_{Tu} was 0.80. Below the dam, we set survival probabilities of controls in reach 1 to 0.93 and for both treatment and controls to 0.93 and 0.80 for reaches 2 and 3 respectively.

We used a total sample size of 1,500 and 2,000 fish, with 600 and 800 of these fish, respectively, released as controls in the tailrace. We assumed there would be no spill occurring during the subyearling Chinook salmon migration (Sp=0), as occurred during 2003. Lastly, we estimated the probability of passing the dam through the juvenile bypass system (By=0.62) based on FGE estimates for McNary Dam from Appendix D of the NMFS 2000 Biological Opinion.

The 95% confidence intervals show the affect of sample size on precision and the difference in precision among survival probabilities (Figure 6). 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 (Sdam) 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 1,500 and 2,000 (per treatment) should yield precision of ±0.03-0.04 (±95% confidence interval) with lower precision for the turbine survival (Table 3).

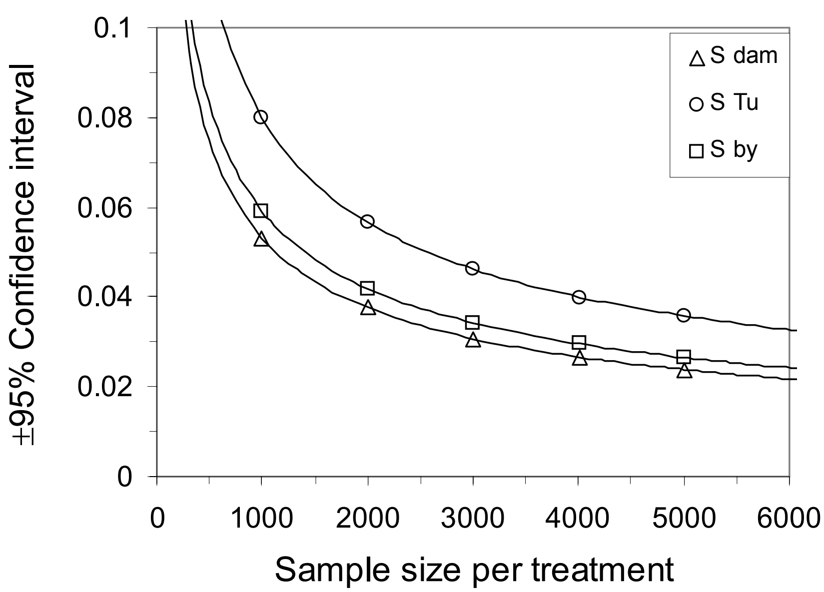

Figure 6. The effect of sample size on precision of dam survival (S_{Dam}), turbine survival (S_{Tu}), spill survival (S_{Sp}), and bypass survival (S_{By}) probabilities for subyearling Chinook salmon at McNary Dam. Sample sizes are for one treatment of dam operations. Note: about 100 additional tags will be needed for releasing euthanized tagged fish and for conducting a tag life study.

Table 3. Total sample size, expected standard error, and 95% confidence interval for route-specific survival probabilities of subyearling Chinook salmon. Note: about 100 additional tags will be needed for releasing euthanized tagged fish and for conducting a tag life study.

Species	Sample size for each treatment	Total sample size	Route	Expected sample size for each route and each treatment	Expected standard error	± 95% Confidence Interval
Subyearling Chinook Salmon	1500	3000	Turbine	308	0.030	0.058
			Spill	0	na	na
			Bypass	502	0.021	0.043
			Dam	810	0.019	0.039
Subyearling Chinook Salmon	2000	4000	Turbine	410	0.026	0.053
			Spill	0	na	na
			Bypass	670	0.018	0.037
			Dam	1080	0.016	0.034

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 7 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.

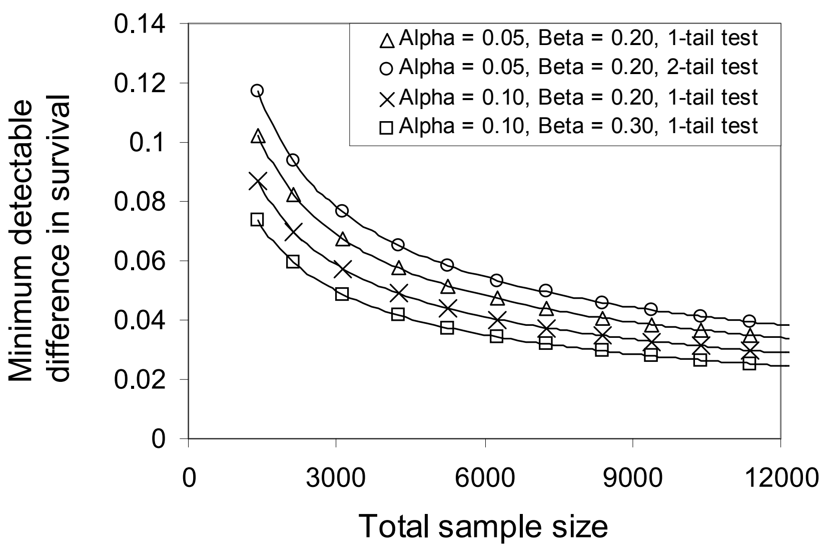

Figure 7. The minimum detectable difference in survival probabilities (S_{dam}) between two treatments for a range of sample sizes and test scenarios for subyearling Chinook salmon at McNary Dam.

Schedule of Tasks

Task 3.1: Tag and conduct daily releases of subyearling Chinook salmon.

Activity 3.1.1: Obtain appropriate federal ESA permit and State of Oregon collection and transport permits.
Schedule: Jan. – Feb., 2005

Activity 3.1.2: Determine if PIT tag implantation is necessary to estimate route specific survival of subyearling Chinook salmon passing via the juvenile bypass system.

Activity 3.1.2: Coordinate with personnel at the fish bypass collection facility to collect, hold, and radio-tag subyearling Chinook salmon.
Schedule: Mar. – Jul., 2005

Activity 3.1.4: Conduct daily releases of radio-tagged subyearling Chinook salmon upstream of McNary Dam and in the tailrace of McNary Dam. Day and night releases will be conducted.
Schedule: Jul. – Aug., 2005

Task 3.2: Estimate false-positive detection rates for radio-tagged fish released in the tailrace of McNary Dam.

Activity 3.2.1. Release radio-tagged fish that have been euthanized to estimate the probability of false-positive detections.
Schedule: Jul. – Aug., 2005

Task 3.3: Demobilize telemetry fixed sites and other telemetry equipment.

Activity 3.3.1: Remove telemetry fixed sites at and downstream of McNary Dam.
Schedule: Aug., 2005

Task 3.4: Compile and proof fish release data, telemetry data, and environmental data using standard database and statistical analysis software.

Activity 3.4.1: Compile fish release data, telemetry data, and environmental data into standard database and statistical analysis software.
Schedule: Sept.– Oct., 2005

Activity 3.4.2: Proof telemetry data and conduct standardized data quality control/assurance procedures necessary for survival analysis.
Schedule: Sept.– Oct., 2005

Activity 3.4.3: Generate detection-history matrices from the proofed telemetry data in preparation for analysis.

Schedule: Sept.– Oct., 2005

<u>Task 3.5</u>: Calculate passage, detection, and survival probabilities using the route-specific survival model. Examine how survival estimates vary with environmental covariates.

Activity 3.5.1: Test validity of model assumptions.
Schedule: Nov. – Dec., 2005

Activity 3.5.2: Model the survival and capture probabilities using USER.
Schedule: Nov. – Dec., 2005

Activity 3.5.3: Examine variation of survival estimates with environmental data.
Schedule: Nov. – Dec., 2005

<u>Task 3.6</u>: Produce and disseminate draft and final reports.

Activity 3.6.1: Write draft report.
Schedule: Nov – Dec., 2005

Activity 3.6.2: Submit draft report.
Schedule: Dec. 2005

Activity 3.6.3: Allow 60 day comment period on draft report; compile comments, revise draft and produce final report within 45 days following comment period.
Schedule: Mar., 2006

Activity 3.6.4: Submit final report.
Schedule: March 10, 2006

Methods for generating survival estimates

We will use the route-specific survival model (Skalski et al. 2002) to estimate passage, detection, and survival probabilities from the replicated paired releases of radio-tagged juvenile salmonids. The foundation of this model is based on the classical single release-recapture models of Cormack (1964), Jolly (1965), and Seber (1965; CJS model) and the paired release-recapture model of Burnham et al. (1987). Here, we discuss the 11 assumptions of the route-specific survival model and briefly describe how detection histories are used to estimate passage, survival, and detection probabilities. Readers can refer to Skalski et al. (2002) for detailed methods on estimating parameters of the route specific-survival model.

Detection histories of each fish form the basis of CJS models and allow for the estimation of passage, survival, and detection probabilities. In general, survival and detection probabilities are estimated by:

1) Creating detection histories for each fish.

2) Estimating the probability of each possible detection history from the number of fish with that detection history (i.e., from the observed frequencies of each detection history).
3) Using maximum likelihood theory to find parameter estimates of passage (*Sp*, *By*, *Tu*), survival (S_i), and detection (p_i) probabilities that were most likely, given the observed data set of detection histories.

We will use the USER (User Specified Estimation Routine) software package to estimate parameters of the route-specific survival model (http://www.cqs.washington.edu/paramEst/ USER). To prepare the data for input into USER, records for each fish will be summarized into detection histories to indicate whether a fish was detected at each downstream telemetry array. Detection histories are composed of '1's, which indicated a fish was detected at an array, and '0's, indicating the fish was not detected. For example, the detection history '011' means that a fish was not detected at telemetry array 1 (0), but was subsequently detected at arrays 2 and 3 (11).

Each unique detection history has a probability of occurrence that can be completely specified by 1) the probability that a fish survived (*S*) through reach *i*, S_i, and 2) the probability of detection (*p*) at array *i*, p_i. For example, if a fish was detected at an array then it must have survived through the preceding reach. Thus, the probability of this event is the joint probability that it survived and was detected, $S_i p_i$. However, if a fish was not detected at an array then two possibilities arise, 1) the fish died ($1-S_i$, the probability of not surviving), or 2) the fish survived but was not detected $S_i(1-p_i)$, the joint probability of surviving and not being detected. For the detection history 011, we can rule out the possibility that the fish died in reach 1 because it was subsequently detected at arrays 2 and 3. Therefore, the probability of detection history 011 can be specified as $S_1(1-p_1)\ S_2p_2\ S_3p_3$. Explicitly stated, the probability of detection history 011 is the joint probability that this fish survived through reach 1 and was not detected at array 1, survived through reach 2 and was detected at array 2, and survived through reach 3 and was detected at array 3. The probability function of each unique detection history can be specified in this fashion.

The expected probability of each detection history is then estimated from the observed frequencies of fish with that detection history. Given the expected probability of each detection history and its probability function in terms of S_i and p_i, maximum likelihood methods will be used to find the combination of S_i and p_i that were most likely to occur, given the data set of detection histories. The maximum likelihood function to be maximized is simply the joint probability of all possible detection histories. Further details on the maximum likelihood methods for estimating survival and detection probabilities, including estimation of theoretical variances, can be found in Burnham et al. (1987), Lebreton et al. (1992), and Skalski et al. (2002).

Passage, survival, and detection probabilities from the route-specific survival model are subject to 11 assumptions. Seven of these assumptions apply to CJS models, two apply to the paired release model, and two apply specifically to the route-specific survival model. For CJS models, these assumptions relate to inferences to the population of interest, error in interpreting radio signals, and statistical fit of the data to the model's structure:

1) Tagged individuals are representative of the population of interest. For example, if the target population is subyearling Chinook salmon then the sample of tagged fish should be drawn from that population.
2) Survival and detection probabilities of tagged fish are the same as that of untagged fish. For example, the tagging procedures or sampling of fish at downstream telemetry arrays should not influence survival or detection probabilities. If the tag negatively affects survival, then single-reach estimates of survival rates will be biased accordingly.
3) All sampling events are instantaneous. That is, sampling should take place over a short distance relative to the distance between telemetry arrays so that the chance of mortality at a telemetry array is minimized. This assumption is necessary to correctly attribute mortality to a specific reach. This assumption is usually satisfied by the location of telemetry arrays and the downstream migration rates of juvenile salmonids.
4) The fate of each tagged fish is independent of the fate of other tagged fish. In other words, survival or mortality of one fish has no effect on that of others.
5) The prior detection history of a tagged fish has no effect on its subsequent survival. This assumption could be violated if there are portions of the river that are not monitored for tagged fish. For example, for PIT-tagged fish some fish may repeatedly pass through fish bypasses where PIT tag readers are located, whereas other fish may consistently pass through spillways, which are not monitored. If fish passing through these routes have different survival rates, then this assumption could be violated. For radio telemetry, this assumption is usually satisfied by the passive nature of detecting radio tags, by monitoring all routes of passage at a dam, and by monitoring the entire channel cross-section of the river.
6) All tagged fish alive at a sampling location have the same detection probability. This assumption could also be violated as described in assumption 5, but is usually satisfied with radio telemetry by monitoring the entire channel cross-section.
7) All tags are correctly identified and the status of tagged fish (i.e., alive or dead) is known without error. This assumes fish do not lose their tags and that the tag is functioning while the fish is in the study area. Additionally, this assumes that all detections are of live fish and that dead fish are not detected and interpreted as live (i.e., false positive detections). We will test this assumption by releasing a sample of euthanized tagged fish to estimate the probability of false positive detections.

We will formally test assumptions 5 and 6 using χ^2 Goodness of Fit tests known as Test 2 and Test 3 (Burnham et al. 1987). In addition, the pooled results of Test 2 and Test 3 represent an overall test of how well the CJS model fits the data. Both Test 2 and 3 are implemented as a series of contingency tables. Test 2 is informally known as the "recapture test" because it assesses whether detection at an upstream array affects detections at subsequent downstream arrays (assumption 6). Test 3 is known as the "survival test" because it assesses assumption 5 that fish alive at array i have the same probability of surviving to array i+1.

Two additional assumptions apply to the paired release-recapture model:

8) Survival for the treatment group (R_t) from its release point to the release point of control group is conditionally dependent on survival of the control group (R_c) from its release point to the first downstream telemetry array (S_{c1}).
9) Survival is equal for R_t and R_c between the release point of R_c and the first downstream telemetry array.

These assumptions imply that effects of the treatment on survival occur in the first reach only and that delayed mortality due to the treatment is not expressed below the release point of the control group. These assumptions can be satisfied if the two groups (R_t and R_c) are mixed during their downstream migration, suggesting that factors influencing survival are similar among the two release groups. However, these assumptions may also be satisfied if factors affecting survival are stable over the course of migration. To test whether paired release groups were mixed we used RxC contingency tables where the rows (R) represent treatment and control groups and the columns (C) are the day of arrival at the downstream array. Tests of mixing will be performed for each downstream array at the α=0.10 level and adjusted using the Dunn-Šidák method (Sokal and Rohlf 1981) to control the experiment-wise Type I error rate at 0.10.

Last, two additional assumptions apply to the route-specific survival model:

10) Passage routes of radio-tagged fish are known without error. This assumption can be satisfied by strategic placement of antenna arrays to avoid overlap that could result in assignment of fish to the wrong passage route. In cases where passage routes cannot be determined, the radio-tagged fish will be right-censored to it's last known location to avoid estimation bias.
11) Detection in the primary and secondary antenna arrays within a passage route are independent. This assumption will be fulfilled by having primary and secondary arrays on different receiver systems and by having the detection field for one array encompass the entire passage route.

FACILITIES AND EQUIPMENT

Most of the special or expensive equipment for the proposed study have been purchased during previous years of research by the Walla Walla District of the Army Corps of Engineers (COE). The majority of this equipment has been used to conduct studies at Lower Granite Dam. The COE has agreed to let USGS use this equipment at McNary dam. 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 $195.00 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 27 boats up to 30 feet in length for work on the river.

-Two 2700 square foot storage facilities with a shop.

-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 2004 evaluation at McNary Dam.

Impacts to the McNary Project

Pre-season installation of equipment will start in February 2005 and continue through early April 2005. The equipment will be in use through Mid-August 2005. We are capable of installing most of the necessary equipment for the aerial arrays, and the impact to the McNary project should be minimal.

COLLABORATIVE ARRANGEMENTS and/or SUB-CONTRACTS

USGS currently has a service contract through Johnson Controls Inc. Some of the personnel working on this project are Johnson Controls employees.

List of Key Personnel and Project Duties

Personnel	Organization	Project Duties
Russell Perry	USGS	Principal Investigator
Noah Adams	USGS	Co-Principal Investigator
Dennis Rondorf	USGS	Project Leader

TECHNOLOGY TRANSFER

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. 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. Presentation to the Anadromous Fish Evaluation Program (AFEP) in November 2005 as invited. Present preliminary findings to fisheries agencies, tribes, and the public upon invitation to the Studies Review Work Group in fall, 2005.

2. Quarterly Progress Reports to the U.S. Army Corps of Engineers, Walla Walla, District.

3. Expected draft report by December, 2005 and final report by March 10, 2006. This timeline provides up to 60 days for external peer review by parties determined by the U.S. Army Corps of Engineers and 45 days for USGS staff to revise and resubmit the manuscript in its final form.

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

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