PRELIMINARY PROPOSAL FOR FY 2007 FUNDING

Title:	Passage, survival and approach patterns of juvenile salmonids at McNary Dam
Study Code:	SBE-W-05-02
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Performance Period:	January 1, 2007 – September 31, 2007
Date of Submission:	August 16, 2006

PROJECT SUMMARY

Research Goals

The goal of this project is to determine detailed approach paths and estimate passage and survival probabilities of juvenile salmonids at McNary Dam. We propose five objectives that will address information needs described in research summary SPE-W-05-02. This summary identifies the need to estimate survival and passage parameters for yearling Chinook salmon (Objective 1), juvenile steelhead (Objective 2), subyearling Chinook salmon (Objective 3), detailed approach path data for all three groups (Objective 4) and assess prior passage history as a determinant of survival through McNary Dam (Objective 5). Two treatments may be implemented at McNary Dam during spring of 2007, however, 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? We propose to use acoustic telemetry as the primary tool to address these goals and objectives.

Objectives

Objective 1. Estimate passage and survival rates of yearling (spring) Chinook salmon under two treatments of project operations.

Objective 2. Estimate passage and survival rates of juvenile steelhead under two treatments of project operations.

Objective 3. Estimate passage and survival rates of subyearling (fall) Chinook salmon under two treatments of project operations.

Objective 4. Characterize juvenile salmon behavior in the forebay of McNary Dam using three-dimensional telemetry techniques.

Objective 5. Assess prior passage history as a determinant of survival at McNary Dam.

Methodology

We propose to use acoustic telemetry techniques to obtain approach, survival, and passage information. Acoustic telemetry will allow us to obtain detailed 3-dimensional approach paths of juvenile salmonids to aid in the design and location of future surface bypass structures at McNary Dam. Furthermore, because acoustic-tagged fish are usually detected at high rates (>90% detection probability), acoustic telemetry techniques yield estimates of survival rates with relatively high precision using fairly small sample sizes.

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 1,500 (3,000 for two treatments) acoustic-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 ±0.04 (±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).

During 2005, the region determined that route-specific survival of juvenile steelhead was a lower priority than other species, and recommend releasing a smaller sample size of 1,000 acoustic-tagged steelhead to obtain passage and single-release survival estimates. In this proposal, we provide sample sizes based on the route-specific survival model, but we understand that the region may again choose a smaller sample size of steelhead for estimating single release survival estimates.

Because prior passage history at dams on the Snake River may affect survival through McNary Dam we propose to release 2,000 acoustic-tagged yearling Chinook salmon above Lower Granite Dam. By monitoring passage routes at dams on the Snake River we can, for example, determine if fish passing Snake River dams through non-turbine routes survive at higher rates than fish that have passed through at least one turbine during their outmigration to McNary Dam. The single release survival model will be used to determine if prior passage history affects survival through McNary Dam.

Relevance to the Biological Opinion

Hydrosystem Substrategy 1: Mainstem Juvenile Passage Improvements

PROJECT DESCRIPTION

Background and Justification

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). In the coming years, McNary Dam will undergo a modernization project intended to upgrade the aging turbines at McNary Dam. In addition, surface bypass structures are tentatively scheduled to be installed at McNary Dam by 2008. 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. However, installation of surface bypass structures could offset reduced spill discharge. The design of a Top-Spill Weir (TSW) has been initiated and is scheduled for installation and evaluation in 2007. Information on TSW performance will help guide further development of surface bypass structures for McNary Dam. 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. Furthermore, because the forebay of McNary Dam is nearly a mile wide, detailed approach path data of juvenile salmonids is critical to ensure that surface bypass structures are installed in areas where they will pass the most fish.

Using acoustic-telemetry, we propose to quantify 3-dimensional approach paths and estimate survival and passage rates that are needed to address objectives of the McNary modernization project and changes to project operations. The USGS, Columbia River Research Laboratory has used acoustic-telemetry techniques extensively to monitor the migration and dam passage behavior of juvenile salmonids in the Snake and Columbia rivers. More recently, the USGS 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. 2005).

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.

Release sizes for PIT tag survival estimates must be relatively large because of the potential low detection efficiencies at lower river projects resulting from spill and operation of surface bypass structures. Since detected fish and nondetected fish are physically segregated during PIT tag studies, tagged fish could die after detection but before mixing with nonbypassed fish resulting in a negatively biased survival estimate. Acoustic-tag studies do not have this problem since detected and nondetected fish are never physically segregated while crossing a detection array (Peven et al. 2005). An advantage of acoustic-telemetry techniques is high detection probabilities, which reduces the sample size needed to obtain precise survival estimates.

Juvenile salmonids must successfully pass eight hydropower projects while migrating from the Snake River to the Columbia River estuary. The survival rate of juvenile salmonids passing through turbines of Snake and Columbia River dams is generally lower than those passing the spillway or bypass systems (Muir et al. 2001; Counihan et al. 2003; Axel et al. 2004; Absolon et al. 2005; Hockersmith et al. 2005; Counihan et al. 2006, 2006a, 2006b). Increasing spill, collection and transport, and surface passage routes are methods being used to decrease turbine passage and thereby increase survival through the Columbia Basin hydropower system. Studies have shown that conditions experienced in the turbine environment can impose stress on juvenile salmonids. Juvenile salmonids commonly experience an array of stressful events during their seaward migration. Most of these events occur serially and can have cumulative effects, as when juvenile salmon are unloaded for fish transportation barges or when they pass through dams and enter predator-inhabited tailrace areas (Mesa 1994). If turbine passage imposes sub-lethal stress on surviving individuals, it may lead to a decreased ability to survive additional stressors (Mesa 1994; Budy et al. 2002). Data from PIT tags provide direct evidence that delayed mortality of both in-river-migrating and transported smolts was related to the hydropower system. The patterns of SAR could not be explained on the basis of estimates of direct survival within the hydropower system but instead must result from delayed mortality related to specific hydropower system experience (Budy et al. 2002). Because of high detection probabilites (>90%) associated with acoustic telemetry studies this technology uses relatively small sample sizes and can be used to determine if prior passage history at Snake River dams influences survival through McNary Dam.

Current Status

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 (Perry et al. 2005). We found that route-specific survival rates combined with the proportion of fish passing through each route interacted to influence the overall survival of dam passage. Furthermore, dam operations ("biop" spill) differed between day and night, thereby affecting the proportion of fish passing through available routes, which ultimately affected dam survival of spring migrants. Dam survival during the day was about 15 percentage points lower than during the night for spring migrants. During the day, when little water was spilled, few fish passed through the spillway and most fish passed through the turbines and juvenile bypass system. In contrast, at night during spill, about 80% of fish passed through spillway.

Among routes, passage through the spillway led to the highest survival rates, followed by the juvenile bypass system, and the turbines. Our analysis showed that survival through each route was similar between night and day. These findings suggest that dam survival during the night was higher than during the day not because of differences in route-specific survival, but because at night most spring migrants passed through the spillway where survival rates were highest. These findings led to experiments during 2005 to determine whether 24-h spill operations could increase dam survival rates compared to the standard “Biop spill” operation.

During 2005, 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 (Perry et al. 2006). We found that different dam operations affected the passage and survival of all juvenile salmonids passing McNary Dam. However, we found that the response was species-specific. In the spring, 24-h spill increased the proportion of yearling Chinook salmon passing through the spillway and decreased the proportion passing through the turbines, relative to the 12-h spill treatment. We found no significant difference in survival probabilities of yearling Chinook salmon between the 12-h and 24-h spill treatment. In contrast, during 24-h spill, a lower proportion of juvenile steelhead passed through the spillway than during 12-h spill, and forebay survival was significantly lower during the 12-h spill treatment. For subyearling Chinook salmon, passage through the spillway was significantly higher during court-ordered spill when much of the discharge was routed through the spillway. Survival through the spillway was near 1.0 and was higher than the alternative passage routes. We found dam survival (S_{Dam}) during court-ordered spill was significantly higher than during involuntary spill because a higher proportion of fish passed through the spillway. Under most operational scenarios and for all species, the spillway provided the route with the highest probability of survival. Future management actions that aim to further increase spill passage and reduce forebay residence should maximize both dam and forebay survival.

In 2006, we conducted survival and behavior studies at McNary Dam using acoustic telemetry techniques. We released 3,000 yearling Chinook salmon and 1,000 steelhead during the spring and 3,000 subyearling Chinook salmon during the summer. We also monitored the passage at McNary Dam for 7,000 acoustic tagged fish from Mid-Columbia River survival and behavior studies as well as 300 yearling Chinook salmon released at Lower Granite Dam. Our intent in monitoring these two groups was to compare approach behavior in the forebay of McNary Dam of Snake River and Mid-Columbia river migrants. To meet study objectives in 2006 we successfully developed methodology for deploying autonomous hydrophone nodes (HTI Inc., Seattle, WA). The autonomous nodes were combined with wireless networking and satellite hardware. This allowed us to access, troubleshoot, and download data from the nodes in real-time from the Columbia River Research Laboratory. Real-time data availability is essential for providing in season updates. We are currently completing the analysis of the data collected during the 2006 study.

Project Overview

We will use acoustic 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 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, acoustic-tagged fish must be diverted into the river after being guided and passing through the juvenile bypass system. If acoustic-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 acoustic tags, we propose to implant PIT tags into all sample fish. Using PIT tags and "sort-by-code" technology will allow acoustic-tagged fish to be diverted into the tailrace after passing through the bypass system.

For quantifying juvenile salmonid migration behavior, we will monitor travel times, 3-dimensional approach paths to the dam, forebay movements, passage routes at McNary Dam, and prior passage history of juvenile salmonids at one or more Snake River dams. We will develop prior passage histories for fish approaching McNary Dam by monitoring one or more Snake River dams using at least 6 surface-mounted acoustic hydrophones to determine route of passage. To monitor fish behavior at McNary Dam we will use multiple underwater acoustic telemetry arrays. The acoustic arrays will be installed on barges in the forebay and at the spillway, powerhouse, fish collection channel, and the Interstate-82 Bridge. We will concentrate hydrophones upstream of the TSW(s) to improve data resolution and determine the zone of influence of the passage structure relative to fish behavior. Once fish pass the dam, we will examine their movements in the tailrace and monitor travel times downstream of the dam.

Methodology

To reduce repetition of methods common to each of the four 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 hydrophones and receivers, and all survival estimates will be calculated using the route-specific or single-release survival model. Last, many statistical analyses and evaluations of assumptions are not presented here, but can be found in Skalski et al. (2001 and 2002).

We propose to surgically implant acoustic transmitters and PIT tags into juvenile salmonids following procedures described by Adams et al. (1998a). PIT tags are needed to divert acoustic-tagged fish into the river to estimate survival through the bypass system.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 12 h after release (Perry et al. 2005), which should provide sufficient time for fish to initiate their normal migration behavior and spread out over space and time.

We will use coded acoustic transmitters weighing no more than 1.5 g for yearling Chinook salmon and for juvenile steelhead. For subyearling Chinook salmon, we will use newly-developed tags weighing 0.65 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. 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 acoustic-tagged juvenile salmon upstream of McNary Dam (R_t) and daily control releases in the tailrace (R_c; Figure 1). 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 hydrophone systems that are specific to each route. 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 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 acoustic telemetry arrays will be installed downstream of McNary Dam, Big Blalock Island (rkm 446), and Crow Butte (rkm 424; Figure 3). Each array will typically consist of three acoustic 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, acoustic-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 operational 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 acoustic-tagged fish will be released to test the assumption that acoustic-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.

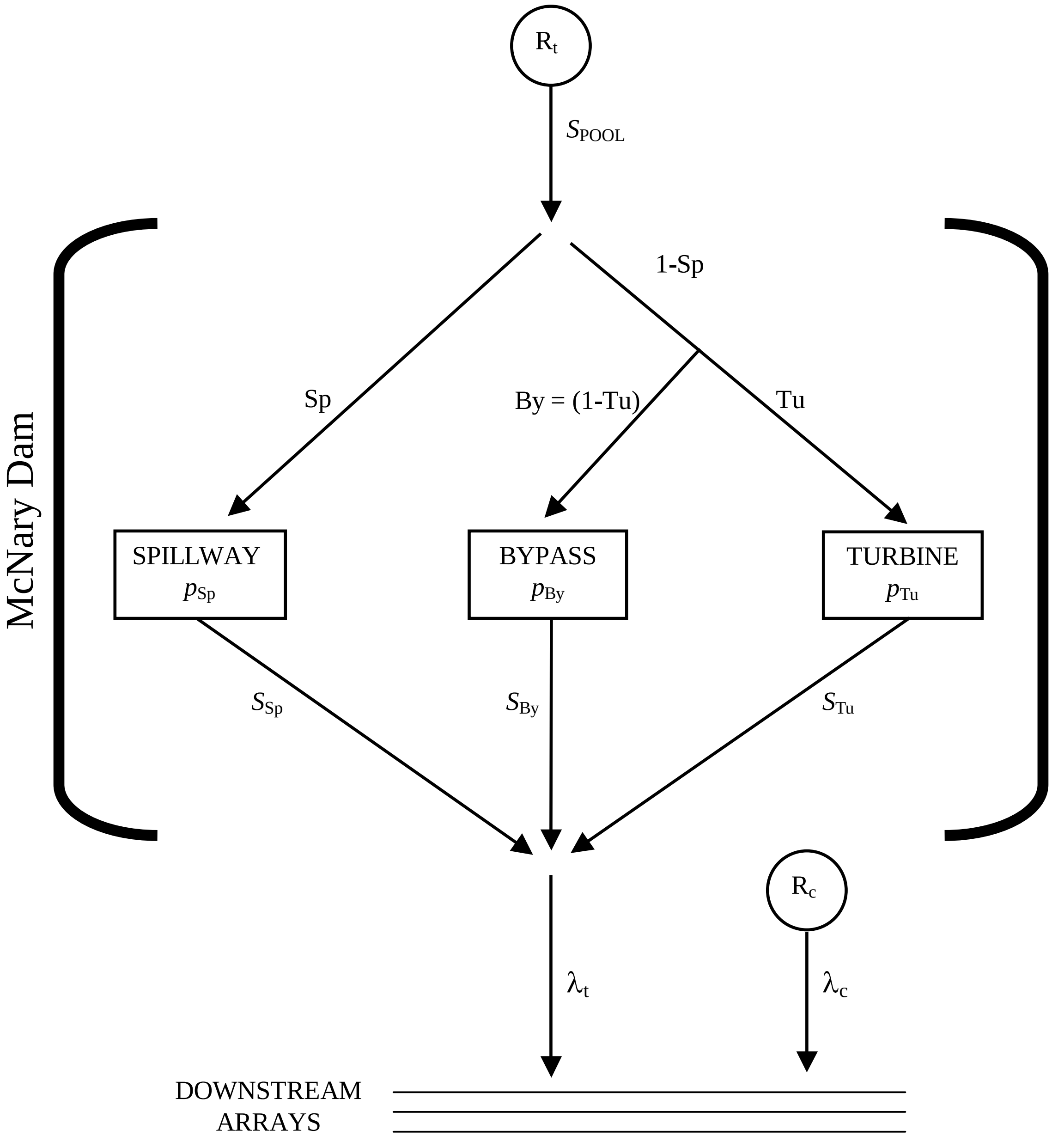

Figure 1. Schematic of route-specific survival model showing release sites, passage routes, and parameters to estimate route-specific detection, passage, and survival probabilities at McNary Dam. Shown are the treatment releases (R_t) upstream of McNary Dam, control releases in the tailrace (R_c), and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

We will estimate the effect of prior passage history on survival through McNary Dam by monitoring passage location (spillway, turbine, etc.) at one or more Snake River dams. We will deploy at least 6 acoustic hydrophones per project to assess passage location of acoustic-tagged fish. We will categorize prior passage history and use a single release survival model to determine if different passage histories have different survival probabilities through McNary Dam and compare results to fish released 10 km upstream of McNary Dam.

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, because precision of S_{dam} will be higher than survival through individual routes, providing the highest 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.

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. 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. Estimate passage and survival rates of yearling (spring) Chinook salmon under two treatments of project operations.

Rationale

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 McNary Dam from Appendix D of the NMFS 2000 Biological Opinion.

The 95% confidence intervals show the effect 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 of 1,500 (per treatment) should yield precision of ±0.04 (±95% confidence interval) with lower precision for the turbine survival (Table 1).

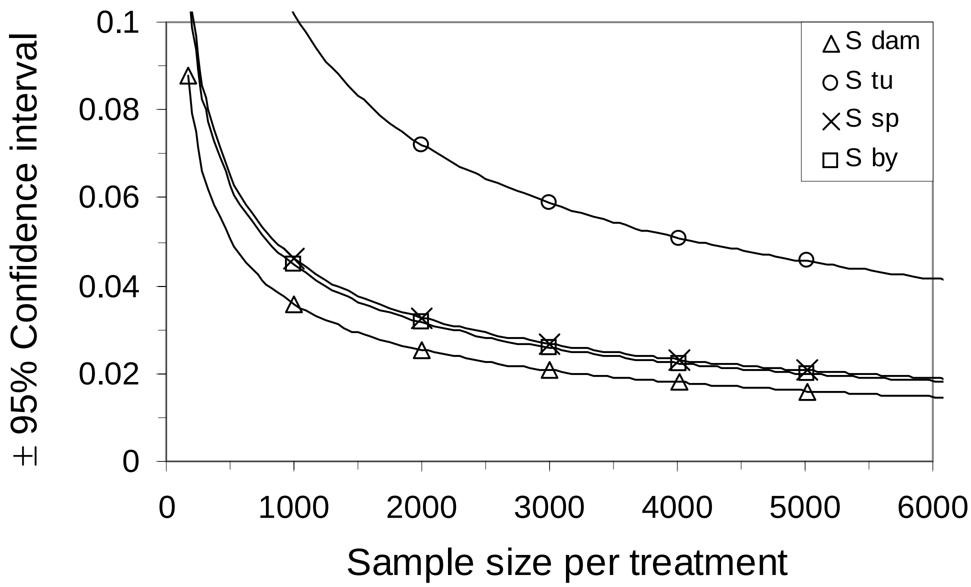

Figure 2. The effect of sample size on precision of dam survival (S_{dam}), turbine survival (S_{Tu}), spill survival (S_{Sp}), and bypass survival (S_{By}) probabilities for yearling Chinook salmon at McNary Dam. Sample sizes are for one treatment of dam operations. Note: about 100 additional tags will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

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.

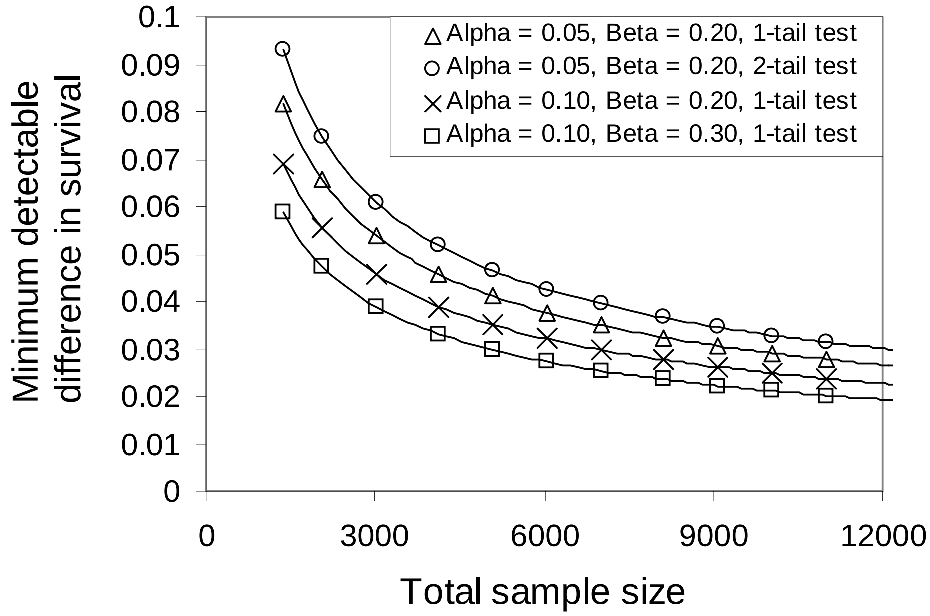

Figure 3. The minimum detectable difference in survival probabilities (S_{dam}) between two treatments for a range of sample sizes and test scenarios for yearling Chinook salmon at McNary Dam.

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., 2007

Activity 1.1.2: Obtain appropriate permits and permissions to install fixed monitoring sites on federally owned land and navigation markers.

Schedule: Jan. – Feb., 2007

Activity 1.1.3: Install fixed monitoring sites downstream of McNary Dam.

Schedule: Jan. – Feb., 2007

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

Activity 1.2.1: Install hydrophones along the face of the dam and in the forebay.

Schedule: Feb. – Apr., 2007

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., 2007

Activity 1.3.2: Coordinate with personnel at the fish bypass collection facility to collect, hold, and tag juvenile yearling Chinook salmon.

Schedule: Mar. – Jul., 2007

Activity 1.3.3: Conduct daily releases of acoustic-tagged yearling Chinook salmon upstream of McNary Dam and in the tailrace of McNary Dam.

Schedule: Apr. – May, 2007

<u>Task 1.4</u>: Estimate false-positive detection rates for acoustic-tagged yearling Chinook salmon released in the tailrace of McNary Dam.

Activity 1.4.1. Release acoustic-tagged yearling Chinook salmon that have been euthanized to estimate the probability of false-positive detections.

Schedule: Apr. – May, 2007

<u>Task 1.5</u>: 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., 2007

Activity 1.5.2: Proof telemetry data and conduct standardized data quality control/assurance procedures necessary for survival analysis.

Schedule: Sept, 2007

Activity 1.5.3: Generate detection-history matrices from the proofed telemetry data in preparation for analysis.

Schedule: Sept, 2007

<u>Objective 2.</u> Estimate passage and survival rates of juvenile steelhead under two treatments of project operations.

Rationale

For this objective, we propose to estimate route-specific survival rates of juvenile steelhead. However, in 2005, discussion with regional managers identified a number of factors that reduced the need for route-specific survival estimates. First, due to the run-timing and operation of the bypass facility (fish collection every other day), it is feasible, but could be labor-intensive to collect enough steelhead to compare route-specific survival between two treatments. Furthermore, we found that route-specific and dam-passage survival rates were high for juvenile steelhead. Therefore, at this time, the region may not require precise estimates of route-specific survival of juvenile steelhead. If this is the case, we recommend releasing a reduced sample size of 1,000 acoustic-tagged juvenile steelhead to understand their passage behavior in response to dam operations. We found substantial differences in passage behavior of juvenile steelhead and yearling Chinook salmon. Therefore, we believe it is important to understand how operational treatments affect passage of both yearling Chinook salmon and steelhead. In addition to passage, we will be able to generate survival estimates of juvenile steelhead using the single release model. Although less robust than the paired release model, the single release model will allow us to estimate pool and forebay survival, which is of particular interest to managers. Below, we also present sample sizes needed for route specific survival estimates in the event that managers determine these estimates are high priority.

For juvenile steelhead, we used the same parameter values as for yearling Chinook salmon to estimate sample sizes and precision of route-specific survival estimates. 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. Therefore, the sample sizes, confidence intervals, and minimum detectable difference for juvenile steelhead are the same as for yearling Chinook salmon (Table 1, Figures 2 and 3).

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.

<u>Task 2.1</u>: Tag and conduct daily releases of juvenile steelhead.

Activity 2.1.1: Conduct daily releases of acoustic-tagged juvenile steelhead upstream of McNary Dam and in the tailrace of McNary Dam.
Schedule: Apr. – May, 2007

<u>Task 2.2</u>: Estimate false-positive detection rates for acoustic-tagged steelhead released in the tailrace of McNary Dam.

Activity 2.2.1. Release acoustic-tagged steelhead that have been euthanized to estimate the probability of false-positive detections.
Schedule: Apr. – May, 2007

<u>Task 2.3</u>: 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. 2007

<u>Objective 3.</u> Estimate passage and 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., $S_{\text{pool}} = 0.90$). 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 with 600 of these fish 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 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 between 1,500 (per treatment) should yield precision of ±0.04 (±95% confidence interval) with lower precision for the turbine survival (Table 3).

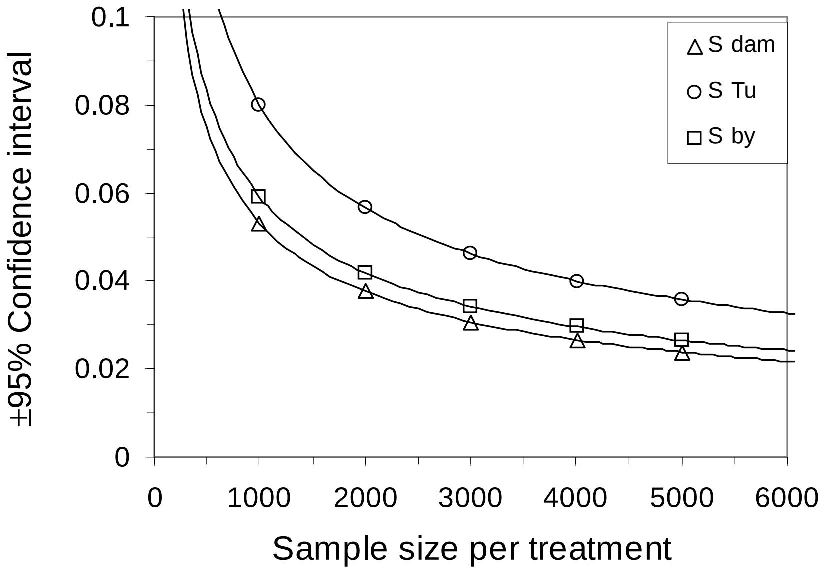

Figure 4. The effect of sample size on precision of dam survival (S_{Dam}), turbine survival (S_{Tu}), spill survival (S_{Sp}), and bypass survival (S_{By}) probabilities for subyearling Chinook salmon at McNary Dam. Sample sizes are for one treatment of dam operations. Note: about 100 additional tags 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	1,500	3,000	Turbine	308	0.030	0.058
			Spill	0	na	na
			Bypass	502	0.021	0.043
			Dam	810	0.019	0.039

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.

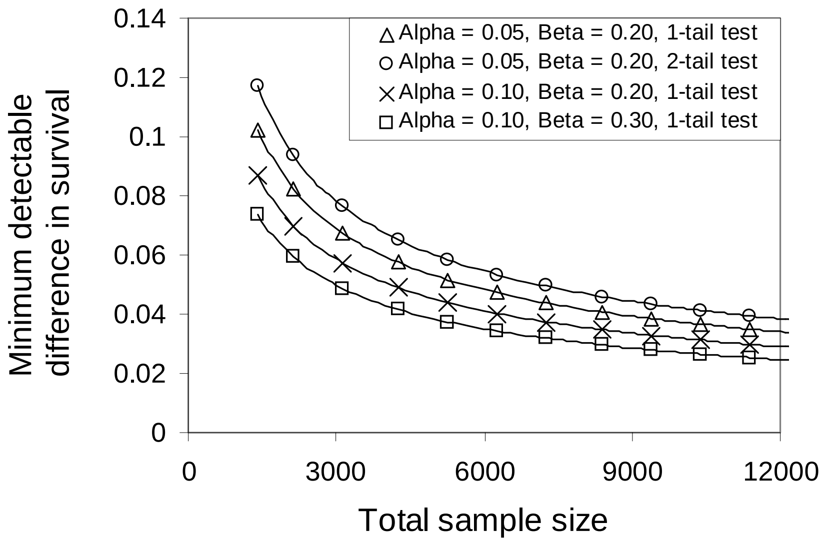

Figure 5. The minimum detectable difference in survival probabilities (S_{dam}) between two treatments for a range of sample sizes and test scenarios for subyearling Chinook salmon at McNary Dam.

Schedule of Tasks

<u>Task 3.1</u>: 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., 2007

> Activity 3.1.2: Coordinate with personnel at the fish bypass collection facility to collect, hold, and tag subyearling Chinook salmon.
> *Schedule*: Mar. – Jul., 2007

> Activity 3.1.3: Conduct daily releases of acoustic-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., 2007

<u>Task 3.2</u>: Estimate false-positive detection rates for acoustic-tagged fish released in the tailrace of McNary Dam.

> Activity 3.2.1. Release acoustic-tagged fish that have been euthanized to estimate the probability of false-positive detections.
> *Schedule*: Jul. – Aug., 2007

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., 2007

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. 2007

Activity 3.4.2: Proof telemetry data and conduct standardized data quality control/assurance procedures necessary for survival analysis.
Schedule: Sept. 2007

Activity 3.4.3: Generate detection-history matrices from the proofed telemetry data in preparation for analysis.
Schedule: Sept. 2007

Objective 4: Characterize juvenile salmonid behavior in the forebay of the McNary Dam using three-dimensional telemetry techniques.

Note: This study objective meets the research needs identified in SBE-P-00-17 objectives 2 and 3.

Rationale

In the coming years, McNary Dam will undergo a modernization project intended to upgrade the aging turbines at McNary Dam. In addition, surface bypass and behavioral guidance structures are tentatively scheduled to be installed at McNary Dam by 2008. Radio-telemetry studies have provided estimates of survival and passage distributions at McNary Dam, however, the detailed movements of juvenile salmon in relation to dam operations within the region 400 m upstream of the dam is lacking. This information is critical for the implementation of any plan that would use a behavioral guidance structure to divert juvenile salmon from the turbine units, and into the spillway or surface passage systems. The design of a Top-Spill Weir (TSW) has been initiated and is scheduled for installation and evaluation in 2007. Information on TSW performance will help guide further development of surface bypass structures for McNary Dam.

We propose to use a three-dimensional (3-D) fish tracking system to examine the movements of acoustically-tagged fish as they approach and pass McNary Dam and quantify the zone of influence of the TSW(s). Detailed data about the behavior of juvenile salmonids as they approach the dam is critical to the development of future juvenile passage improvements. These data can be used to determine the location and size of guidance structures. Integration of hydraulic data and fish behavior data may provide information that could lead to improvements in fish passage not only at McNary Dam, but at many other sites in the Columbia River Basin.

The USGS worked out many of the logistic difficulties conducting 3-D telemetry at The Dalles Dam by deploying and operating 5 sixteen channel 3-D receivers concurrently during 2004. Implementing a 3-D system in 2007 will allow us to gather continuous data in three-dimensions on fish as they move through McNary Dam forebay. The 3-D fish information could be combined with CFD data to develop and validate predictive models for fish behavior relative to changes in flow characteristics near passage routes at McNary Dam.

<u>Task 4.1:</u> Finalize technical issues related to implementation of a 3-D positioning system to monitor the movements of juvenile salmonids upstream of McNary Dam.

> *Note: Because we have conducted feasibility tests in 1999 and fully implemented a 3-D system in the forebay of Lower Granite Dam in 2000, 2001, 2002, 2003 and operated 5 3-D systems at The Dalles Dam in 2004,and operated 5 3-D systems and 15 autonomous hydrophone nodes concurrently at McNary Dam in 2006 most of the logistical difficulties inherent in implementing a similar system in the forebay of McNary Dam in 2007 have been overcome.*
>
> Activity 4.1.1: Cooperate with McNary Dam project personnel to analyze the noise spectrum and identify sources of acoustic noise at the project and upstream of the TSW. In 2005, we found a source of noise associated with the prototype vertical barrier screen (VBS) drive motor. Hydrophones in the immediate vicinity of the VBS were negatively affected. In fall of 2006, we will work with project and Walla Walla District personnel to identify and isolate the source of the background noise at McNary Dam and consider actions to minimize impacts to 3-D data collection. This information will be used to identify and minimize sources of noise and adjust system configurations to ensure data quality.
> *Schedule:* January, 2007.

<u>Task 4.2:</u> Gather fish movement information at McNary Dam.

> Activity 4.2.1: Install, calibrate, and test the 3-D underwater hydrophones at McNary Dam (Figure 6).
> *Schedule:* February through March, 2007.
>
> Activity 4.2.2: Install, calibrate, and test autonomous hydrophones downstream of McNary Dam.
> *Schedule:* February through March, 2007.
>
> Activity 4.2.3: Determine release site, number of fish per release, and time interval between releases.
> *Schedule:* January, 2007.
>
> Activity 4.2.4: Conduct releases of acoustically-tagged subyearling chinook salmon, yearling chinook salmon, steelhead, and collect 3-D data in The Dalles Dam forebay during the spring and summer of 2007.

Schedule: April through July, 2007.

Activity 4.2.5: Collect high resolution 3-D data (>1.5 m accuracy) within 30 m of the TSW.
Schedule: April through July, 2007.

Activity 4.2.6: Coordinate with appropriate agencies to sequester, implant tags, and release steelhead smolts during the months of April, May, and July, 2007.
Schedule: February through March, 2007.

Activity 4.2.7: Complete the necessary Endangered Species Act documentation and obtain the necessary permits and approval to work in the Columbia River.
Schedule: December, 2005.

<u>Task 4.3:</u> Analyze juvenile fish behavior upstream of McNary Dam.

Activity 4.3.1: Integrate fish behavior information with modeled flow information. This integration will allow us to better define the flow characteristics influencing fish behavior upstream of McNary Dam and predict fish response to proposed structural modifications in the forebay.
Schedule: May through August, 2007.

Activity 4.3.2: Determine approach distributions and behavior of fish along McNary Dam powerhouse and spillway and compare behavior between proposed treatments.
Schedule: June through September, 2007.

Activity 4.3.3: Determine approach distributions and behavior of fish upstream of the TSW and define zone of influence of TSW relative to fish behavior.
Schedule: June through September, 2007.

Activity 4.3.4: Compare approach distributions and behavior of Mid-Columbia river migrants to Snake River migrants.
Schedule: June through September, 2007.

<u>Objective 5.</u> Characterize prior passage history as a determinant of survival at McNary Dam.

<u>Rationale</u>

Juvenile salmonids migrating past Snake River dams experience many different passage histories on their way to McNary Dam. Current dam survival studies assume that mortality at each project is independent of prior passage history. The stress associated with passing multiple dams for some specific passage route histories may disproportionately contribute to decreased survival for subsequent dam passage. Detailed data about prior passage history relative to project survival is critical to the understanding of mechanisms influencing survival of juvenile salmonids as they pass McNary Dam.

For estimating both route specific mortality at dams and reach survival, PIT tags have worked well (Muir et al. 2001). However, PIT tag studies generally require large numbers of smolts and fish passing spillways are not monitored for PIT tags. Therefore, developing detailed passage route histories using this technology is not currently possible. Because of the high detection probabilities (>90%) associated with acoustic telemetry studies and the relatively small sample size needed to achieve the desired precision for survival estimates, this technology will work well for developing detailed fish passage route histories.

We propose to use an acoustic telelmetry systems to examine the passage routes of acoustically-tagged fish as they pass the lower Snake River dams. The scope of this work can be adjusted to meet regional priorities. At the largest scale, all four lower Snake River dams would be monitored to determine passage histories of fish released above Lower Granite Dam. At a reduced scale, one or two of the lower Snake River dams would be monitored to determine passage histories. The USGS currently has the technology and experience to meet study objectives at McNary Dam including determining prior passage history at the lower Snake River dams for fish released above Lower Grainte Dam. At McNary Dam in 2006, we successfully monitored the passage of 300 yearling Chinook salmon released at Lower Granite Dam

Task 5.1: Finalize technical issues related to implementation of a 2-D detection system to monitor the passage routes of juvenile salmonids upstream of McNary Dam.

Activity 5.1.1: Cooperate with Snake River dam project personnel to analyze the noise spectrum and identify sources of acoustic noise at the projects to determine ideal hydrophone placement locations

Schedule: January, 2007.

Task 5.2: Gather fish movement information at McNary Dam.

Activity 5.2.1: Install, calibrate, and test underwater hydrophones at Snake River dam(s).

Schedule: February through March, 2007.

Activity 5.2.2: Determine release site, number of fish per release, and time interval between releases.

Schedule: January, 2007.

Activity 5.2.3: Conduct releases of acoustically-tagged yearling chinook salmon, and steelhead, and collect passage route history information during the spring of 2007.

Schedule: April through July, 2007.

Activity 5.2.4: Coordinate with appropriate agencies to sequester, implant tags, and release steelhead smolts during the months of April, May, and July, 2007.

Schedule: February through March, 2007.

Activity 5.2.5: Complete the necessary Endangered Species Act documentation and obtain the necessary permits and approval to work in the Columbia River.
Schedule: December, 2006.

Task 5.3: Analyze survival through McNary Dam based on prior passage history of Snake River migrants.

Activity 5.3.1: Group fish by passage history and calculate survival through Mcnary Dam.
Schedule: May through August, 2007.

Activity 5.3.2: Determine approach distributions and behavior of fish along McNary Dam powerhouse and spillway and compare behavior to Mid-Columbia River migrants and between proposed treatments.
Schedule: June through September, 2007.

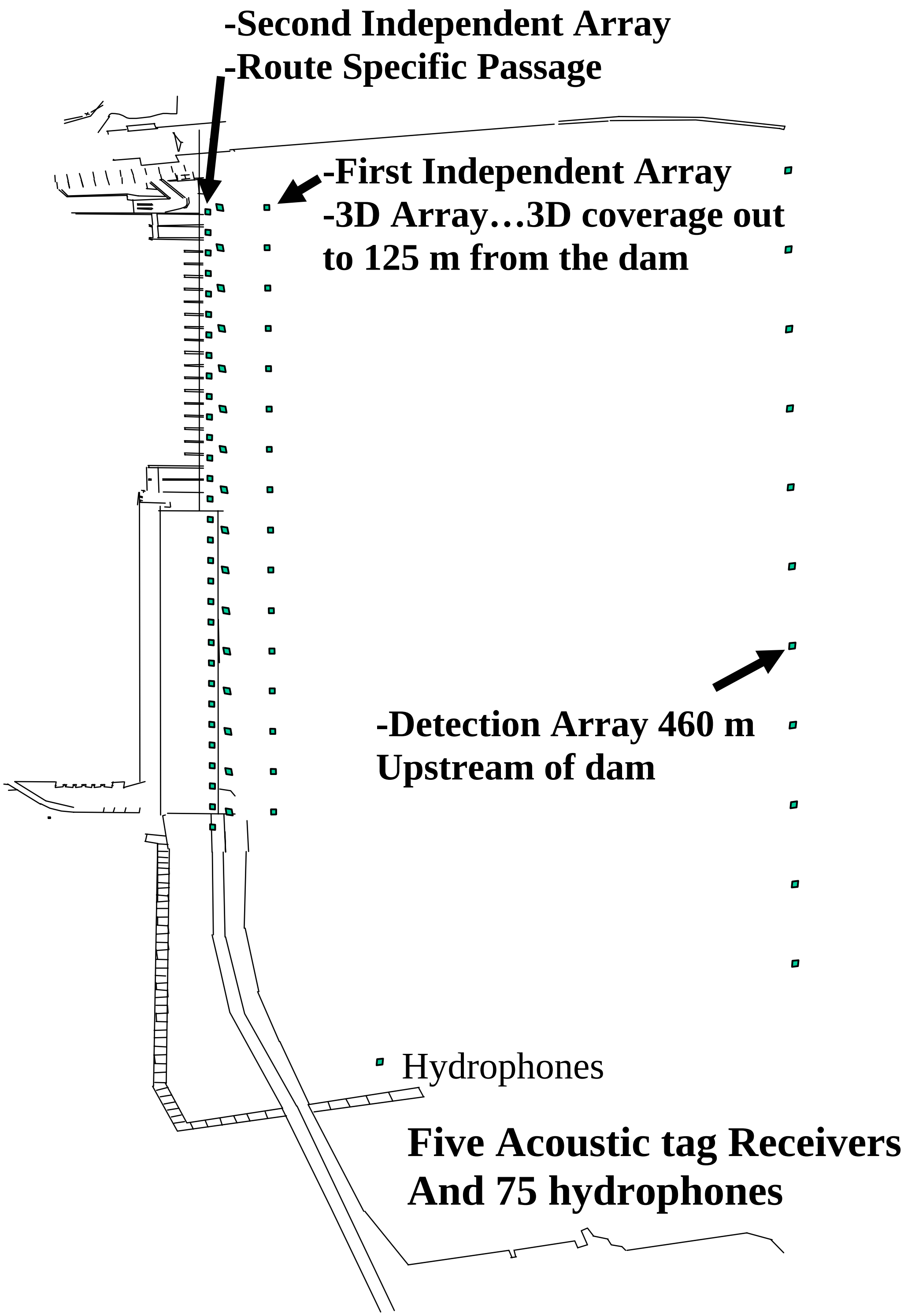

Figure 6. Proposed hydrophone deployment in the forebay of McNary Dam.

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 and The Dalles Dam. The COE has agreed to let USGS use this equipment at McNary dam. The purchase of the acoustic transmitters will perhaps be the most significant purchase for the proposed study. The acoustic transmitters manufactured by HTI Inc. cost about $195.00 each. Divers and a crane barge will be necessary to deploy bottom-mounted hydrophones. It will be necessary to contract surveying of bottom-mounted hydrophones using multi-beam acoustics. Without this information, the 3-D data cannot be analyzed.

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 acoustic-telemetry technology to study the movements of juvenile salmonids, there is potential for interference with or from other studies that use the same technology. We will coordinate with other researchers to insure that each study uses a unique tag coding scheme to avoid overlap of tagged fish.

Impacts to the McNary Project

Pre-season installation of equipment will start in February 2007 and continue through early April 2007. The equipment will be in use through Mid-August 2007. It will be necessary to place a data collection trailer on the spillway and due to the layout of the McNary Dam spillway constructing a platform on the forebay side of the spillway deck may be necessary. We are capable of installing most of the necessary equipment for the hydrophone arrays, and the impact to the McNary project should be minimal.

COLLABORATIVE ARRANGEMENTS and/or SUB-CONTRACTS

See tasks for collaborative arrangements to complete this study.

List of Key Personnel and Project Duties

Personnel	Organization	Project Duties
Noah Adams	USGS	Co-Principal Investigator/Project Leader
Kenneth Cash	USGS	Co-Principal Investigator/Project Leader
Timothy Counihan	USGS	Co-Principal Investigator/Project Leader
Dennis Rondorf	USGS	Section 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 2007 as invited. Present preliminary findings to fisheries agencies, tribes, and the public upon invitation to the Studies Review Work Group in fall, 2007.

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

3. Expected draft report by December, 2007 and final report by March 10, 2008. 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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