

**ESTIMATE OF DIRECT EFFECTS OF STEELHEAD KELT
PASSAGE THROUGH THE FIRST POWERHOUSE ICE-
TRASH-SLUICE AND SECOND POWERHOUSE CORNER
COLLECTOR AT BONNEVILLE DAM**

**Contract No. W912EF-08-D-0005
Task Order DT02**



SEPTEMBER 2011

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Prepared for

US ARMY CORPS OF ENGINEERS

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SEPTEMBER 2011

EXECUTIVE SUMMARY

The U.S. Army Corps of Engineers (Corps), Portland, Oregon, sponsored an investigation in March 2011 at Bonneville Dam (BON) to assess the direct effects (survival and condition) on adult steelhead kelts, *Oncorhynchus mykiss*, in passage through Bonneville Dam First Powerhouse Ice-Trash-Sluice (BON 1 ITS) and Bonneville Dam Second Powerhouse Corner Collector (BON 2 CC). The primary objective was to evaluate the performance of BON 1 ITS to BON 2 CC with respect to passage survival and condition of adult steelhead kelts.

The statistical criterion of the study was to release a sufficient number of fish to obtain a precision (ϵ) on survival and injury estimates $\pm 10.0\%$, 90% of the time.

Adult steelhead kelts for this investigation were transported from the Round Butte Fish Hatchery, OR to Bonneville Dam. A total of 200 treatment fish (100 at BON 1 ITS, 100 at BON 2 CC) were released. Thirty seven control fish were released downstream of the powerhouses. The total length of the treatment fish ranged from 475 to 800 mm with an average length of 633 mm. Control fish ranged from 540 to 760 mm with an average length of 644 mm.

The recapture rate (physical retrieval of alive and dead fish) was similar between BON 1 ITS and BON 2 CC and were 98 and 96 % respectively. Retrieval times at BON 1 ITS and BON 2 CC were 4 to 47 min and 4 to 57 min, respectively with an average recapture time of 11 min. The recapture times for the control group ranged from 2 to 81 min, with an average time of 10 min.

The 48 h survival estimates were calculated two ways including and excluding fish likely preyed on by seals. The 48 h survival estimates for the two release sites including predation were 98.0 and 97.9% for BON 1 ITS and BON 2 CC, respectively. Excluding 3 fish that were likely predation the 48 h estimates for BON 1 ITS and BON 2 CC were 100.0 and 99.0%, respectively. Precision (ϵ) on survival estimates for BON 1 ITS and BON 2 CC was $\pm 2.3\%$, 90% of the time and met the prespecified criterion. Difference between the two survival estimates was not significant ($P > 0.10$).

One fish (1%) with a passage related visible injury was identified at each of the two release sites. The respective malady-free (free of visible injuries, scale loss $> 20\%$ per side, and loss of equilibrium) estimates were 99.0% for both BON 1 ITS and BON 2 CC passage routes. The desired precision on the malady-free estimates was achieved ($CI \pm 1.6\%$, 90% of the time) and the estimates were not significantly different ($P > 0.10$).

The 2 injuries consisted of a bruise on top of head above the left eye for the BON 1 ITS fish and a torn right operculum for the BON 2 CC fish. The probable source of the injury for BON 1 ITS was mechanical and for BON 2 CC was shear. The severity of these 2 maladies was classified as major. Two fish from BON 1 ITS and 1 from BON 2 CC were likely preyed on by seals.

Passage through both BON 1 ITS and BON 2 CC appears to be quite benign and one route does not appear to be better than the other for passing adult steelhead kelt at the Bonneville Project.

Survival Study Summary Framework

Year: 2011
Study site(s): Bonneville Dam First Powerhouse Ice-Trash-Sluice and Second Powerhouse Corner Collector
Objective(s): Evaluate the performance of Bonneville First Powerhouse Ice-Trash-Sluice and Second Powerhouse Corner Collector by estimating and comparing relative survival/injury of adult steelhead kelts. Release sufficient number of fish to obtain survival/injury estimates within a precision (ϵ) of $\pm 10.0\%$, 90.0% of the time.
<p>Fish</p> <ul style="list-style-type: none"> • Species (race): steelhead salmon • Life stage: adult kelts • Source: Round Butte Fish Hatchery, OR
<p>Size (range and mean)</p> <ul style="list-style-type: none"> • Weight: Not taken • Length: 475 to 800 mm total length, mean = 633 mm
<p>Tag</p> <ul style="list-style-type: none"> • Type/model: HI-Z (balloon) Tags and Advanced Telemetry radio tags • Weight (gm): HI-Z = 3.0 gm, radio tags = 1.0 gm
<p>Implant procedure</p> <ul style="list-style-type: none"> • Externally attached (4 to 6 HI-Z tags) and then detached upon fish recapture
<p>Relative Survival estimate at 48 h</p> <ul style="list-style-type: none"> • Type (project, <i>etc.</i>): • Value (CI): BON 1 ITS 98.0% (95.7 to 100.0), BON 2 CC 97.9% (95.6 to 100.0%) • Excluding likely seal predation: BON 1 ITS 100.0%, BON 2 CC 99.0% (96.3 to 99.9%) • Sample size/replicate: 100- BON 1 ITS, 100- BON 2 CC, 37 controls
<p>Characteristics of estimate</p> <ul style="list-style-type: none"> • Effects reflected (direct, total, <i>etc.</i>): Direct
<p>Environmental/operating conditions</p> <ul style="list-style-type: none"> • Relevant discharge indices: BON 1 ITS 1.2 to 1.5 kcfs , BON 2 CC approx. 5 kcfs • Temperature: 3.5°C • Treatment(s): 1 treatment condition at each location
Unique study characteristics: some predation by seals affected results

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1.0 INTRODUCTION AND BACKGROUND

This study is part of a larger research study proposal (ADS-11-3) to determine relative dam, reach, and system survival estimates by passage route of adult steelhead kelts, *Oncorhynchus mykiss*, that is a mixed population comprised of kelts moving downriver and overwintering pre-spawners moving upriver. This study provides direct injury and relative survival estimates of adult steelhead and kelts passing a sluiceway and corner collector at Bonneville Dam. This study is applicable to 2008 BIOLOGICAL OPINION ACTION: Hydropower Strategy 2, RPA 28; Hydropower Strategy 5, RPA 33; RM&E Strategy 2, RPA 54, Adult Performance Standards, RPA 55.

The primary goal of this study at Bonneville Dam was to evaluate the performance of Bonneville Dam First Powerhouse Ice-Trash-Sluice (BON 1 ITS) and Bonneville Dam Second Powerhouse Corner Collector (BON 2 CC) by estimating and comparing the direct effects of passage and survival (1 and 48 h) and injury rates of adult steelhead kelts. The U.S. Army Corps (Corps) requested the HI-Z Turb’N Tag (HI-Z Tag) recapture technique be used to ascertain the direct effects of passage (Heisey *et al.* 1992) which facilitates quick retrieval of fish after passage through various passage routes and allows for immediate assessment of fish condition and injury type.

1.1 Study Objectives

The primary objectives of this study were to address research objectives 2 and 3 of research summary (ADS-11-3) which are: 1) estimate direct injury and relative survival of adult steelhead fallback and kelt (or surrogates) through BON 1 ITS and 2) estimate direct injury and relative survival of adult steelhead fallback and kelt (or surrogates) through BON 2 CC.

1.2 Site Description

Bonneville Dam is the first dam upriver (river mile 145 or 232 river km) on the main stem of the Columbia River (Figure 1-1) and is located east of Portland, Oregon. It consists of two powerhouses, a spillway, and a navigation lock. The first powerhouse (BON 1) was completed in 1938 and is located between the Oregon and Bradford Island. The second powerhouse (BON 2) was built in 1982 and is located between Washington and Cascade Island. The spillway, consisting of 18 gates, each 50 ft wide, and is located between Bradford and Cascade Island, spanning the North Channel. The spill gates are raised to allow excess river flow to pass under them at a depth of about 50 ft below the upstream water surface. Spill gates are typically raised 1 to 7 ft to facilitate downstream migration of juvenile salmon. The total hydraulic capacity of both BON 1 and BON 2 is 288,000 cfs. Powerhouse 1 has a rated generating capacity of 612 MW at full forebay. Hydraulic capacity of the spillways is 1,600,000 cfs. An outfall sluice originally designed to pass ice and trash is located on the south side of BON 1 (Figure 1-1). A bypass sluice on the south side of BON 2 was modified with a corner collector and a 2100 ft long discharge chute to bypass fish (Figure 1-1), operational head of 55 ft and exit velocity of 36 ft/s. The present study was conducted at both BON 1 ITS and BON 2 CC in March 2011.

2.0 STUDY DESIGN

The study was designed to obtain and also compare fish survival (1 and 48 h) and injury rates at BON 1 ITS and BON 2 CC.

Sufficient numbers of fish were released to be able to obtain these estimates $\pm 10.0\%$, 90% of the time (Table 2-1). A malady-free estimate, defined as a fish being free of visible injuries, scale loss ($\geq 20\%$ per side), and/or loss of equilibrium, was calculated.

Spill volume through BON 1 ITS was maintained between 1.2 and 1.5 kcfs and BON 2 was maintained near 5.0 kcfs. Table 2-2 provides average flow and tailwater conditions during the investigation. Appendix A provides the daily station parameters recorded during passage.

Overall, the study followed the guidelines and recommended protocols for conducting, analyzing, and reporting survival studies in the Columbia River Basin (Peven *et. al.* 2005).

2.1 Sample Size

A sufficient number of HI-Z tagged adult steelhead kelts were released so that the resulting estimates were within a level of precision (ϵ) of $\pm 10.0\%$, 90% of the time

Based on previous results of recapture rates, control fish survival and projected survival rates for adult fish, 100 treatment fish per treatment condition and 37 pooled control fish were released (Table 2-3).

2.2 Source and Maintenance of Test Specimens

Adult steelhead kelt were transported from the Round Butte Fish Hatchery, located on the Deschutes River, near Madras, OR via a tank-truck to the project site and held in 1600 gal capacity circular tanks. The transport tank was equipped with a recirculation system and supplemental oxygen supply. Approximately 150 fish were transported in two separate trips. The approximate fish transportation time was three hours. Upon arrival at the site, fish were acclimated by gradually tempering the transport tank water temperature to the ambient river temperature. This was accomplished by mixing the warmer water from the transport tank with ambient river water in the selected holding tank. The fish were then transferred to the holding tank and allowed to slowly acclimate to the falling temperature in the tank. Fish were held a minimum of 24 h prior to tagging to alleviate handling and transport stress, and to allow them to acclimate to ambient river conditions at BON. Ambient river temperatures ranged from 3.5 to 4.0°C (38.3 to 39.2°F) during the study (Table 2-3).

The treatment fish for a given day were randomly drawn from the holding pool (Figure 2-1) thereby assuring that all treatment fish were of a similar size and condition. Figure 2-2 shows the total length frequency distribution of treatment and control fish. The combined treatment fish lengths ranged from 475 to 800 mm. Average lengths were 624 and 641 mm for BON 1 ITS and BON 2 CC, respectively. Control fish size was similar ranging from 540 to 760 mm with an average length of 644 mm.

2.3 Tagging and Release

Tagging and release procedures for handling, tagging, release and recapture of adult steelhead kelt were similar for treatment and control groups. In order to bring larger fish to the surface for rapid recapture, four to six HI-Z tags were attached with a small cable tie through the musculature at two to three locations along the steelheads back and at the anal fin area via a curved cannula needle (Figure 2-3). Radio tags were attached in combination with one of the HI-Z tags to aid in tracking released fish. Specially designed fish restraint devices developed and built by Normandeau aided in tagging the larger fish (Figure 2-4).

Adult steelhead kelts were individually marked and identified with small numbered floy tags. The tubular floy tags were inserted into musculature near the anterior region of the dorsal fin. Just prior to release, the HI-Z tags were activated by injecting a small amount of water into the HI-Z tag (Figure 2-3), which causes the tag to inflate in approximately 2 to 4 minutes.

The treatment fish were released through an induction apparatus constructed by Normandeau (Figures 2-5

and 2-6). The induction apparatus was connected to a 8 inch diameter flex-hose which allowed the fish to pass freely to the desired treatment release points (Figures 2-5 and 2-6). The end of the fish release hose was attached to two ropes to position it to the middle of both sluiceway entrances just above the water surface. The length of release hose at both BON 1 ITS and BON 2 CC was approximately 25 ft. Control fish were released through the same induction system into the tailrace discharge downstream at the Hamilton boat ramp Figure 2-7. Procedures for handling, tagging, release and recapture of fish were similar for treatment and control groups.

2.4 Fish Recapture

Treatment and control fish were retrieved from the tailwater by two boat crews (Figures 2-8, 2-9, and 2-10). Boat crews were notified of the radio tag frequency of each fish upon its release. Only crew members trained in fish handling retrieved tagged fish.

Radio signals (48 and 49 Mhz) were received on a loop antenna coupled to a receiver (Advanced Telemetry). The radio signal transmission enabled the boat crew(s) to follow the movement of each fish after sluiceway passage, and position the boat for quick retrieval when the HI-Z tags buoyed the fish to the surface Figures 2-8. The boats maintained a safe distance downstream of the turbulent water from the turbines and sluiceways. Any fish with active radio tags that failed to surface were tracked for about 30 minutes, and then periodically to ascertain if fish were displaying movement patterns typical of that of a predator (seals). Recaptured fish were placed into an on-board holding facility, and the tag(s) removed. Each fish was examined for scale loss and injuries and assigned codes relative to descriptions presented in Tables 2-4 and 2-5.

Seals were present in the BON 1 and BON 2 tailwaters during the conduct of most of the study and in 3 instances the radio signals were lost and nothing was recaptured. Since nothing was ever detected later during the days testing as would be typical for other studies, it was assumed that seals had preyed upon the steelhead. Additionally, one tagged fish that had floated to the surface at the downstream face of BON 1 was observed being preyed upon by a seal.

Recaptured fish were transferred in large (25 gal) ice chests to an on-shore holding pool, (750 gal) for assessment of long-term effects (48 h). Pools were continuously supplied with ambient river water and shielded to prevent fish escapement.

2.5 Classification of Recaptured Fish

The immediate status of an individual fish was designated as alive, dead, predation, dislodged inflated tag(s) recovered, or unknown (Mathur *et.al* 1996, 2000, Normandeau Associates and Skalski: 1998 and 2006, North/South Consultants and Normandeau Associates 2007, 2009). The following criteria have been established to clearly define these designations: 1) alive--recaptured alive and remained so for 1 h; 2) alive--fish does not surface but radio signals indicate movement patterns typical of emigrating kelts juveniles; 3) dead--recaptured dead or dead within 1 h of release; 4) dead--only inflated tag(s) are recovered without the fish and telemetric tracking or the manner in which tags surfaced is not indicative of predation; 5) unknown--neither tags nor fish are recovered and radio signals are not received or only briefly and a more detailed status cannot be ascertained; and 6) predation--fish are either observed being preyed upon, the predator is buoyed to the surface, distinctive bite marks are present, or subsequent radio telemetric tracking and/or dislodged tag recovery indicate predation (*i.e.*, rapid movements of tagged fish in and out of turbulent waters or sudden appearance of fully inflated dislodged tags). In estimation of passage survival, these fish are typically treated as dead.

Mortalities occurring > 1 h post-passage were considered 48 h mortalities. However, fish were evaluated at intervals of approximately 12 h. Dead fish were identified by the numbered floy tag, examined for

descaling and injury, and necropsy to determine the potential cause of death.

Injuries were evaluated immediately following recapture, and later during a detailed examination after completion of the 48 h holding period. Injury and descaling were categorized by type, extent, and area of body. Photographs of injured fish were taken. Fish without any visible injuries that were not actively swimming were classified as “loss of equilibrium”. This condition has been noted in past studies and often disappears within 10 to 15 minutes after recapture if the fish is not injured.

The re-examination of immobilized fish minimized the need for extensive handling and associated stress upon immediate recapture. The initial examination allowed detection of some injuries, such as bleeding and minor bruising that may not be evident after 48 h due to natural healing processes.

A malady category was established to include fish with visible injuries, scale loss ($\geq 20\%$ on either side), or loss of equilibrium. Fish without maladies are designated “malady-free”. This malady-free metric was established to provide a standard way to present a rate depicting how a specific route affects the condition of passed fish. Malady-free, the absence of maladies was chosen so that this metric may be more comparable to survival; however, the malady-free metric is based solely on fish physically recaptured and examined. Additionally, the malady-free estimate in concert with site-specific hydraulic and physical data can provide insight into what passage conditions may provide safer fish passage.

Visible injuries, scale loss, and loss of equilibrium (LOE) were categorized as minor or major, based on laboratory studies by PNNL *et al.* (2001) and Normandeau’s field observations. The disposition of individual fish is presented in Appendix B.

2.7 Sluiceway Hydraulic Conditions

The volume of water spilled through BON 1 ITS was 1.2 to 1.5 kcfs and BON 2 CC was approximately 5 kcfs, flows depended primarily on the forebay elevation; (Table 2-2). Forebay elevation was maintained between 72 and 74 ft for the tests. The hydraulic conditions are shown in Appendix A.

Laboratory studies suggest that water velocities exceeding 58 ft/s are capable of inflicting injury/mortality on fish when discharged into water surface without hard objects (Neitzel *et al.* 2000). Fish may begin to suffer injuries if discharged onto hard objects at velocity ≥ 20 ft/s (Bell *et al.* 1972). The estimated maximum water velocities in BON 1 ITS and BON 2 CC were 1.8 kcfs and 5.0 kcfs, respectively.

2.8 Statistical Analysis

Passage survival probabilities for the two test sites were estimated relative to the control fish survival to calculate immediate (1 h) and latent (48 h) survival. A Chi-square (Appendix C) test was used to test homogeneity ($\alpha = 0.10$) with respect to recapture probabilities of alive, dead, and non-recovered fish and determine whether the data from each of the daily trials could be pooled.

A likelihood ratio test was used to determine whether recapture probabilities are similar for alive (PA) and dead (PD) fish (RMC and Skalski 1994a, b). This statistic tests the null hypothesis of the simplified model ($H_0: PA = PD$) versus the alternative of the generalized model ($H_a: PA \neq PD$). Based on the outcome of this analysis, the parameters and their associated standard errors were calculated using the appropriate model Appendix C. Survival estimates were calculated including and excluding fish likely preyed on by seals. The difference in survival or malady rate between two sluiceways was tested by Z statistic (one-tailed test).

3.0 RESULTS

3.1 Recapture Rates

Recapture rates (physical retrieval of alive and dead fish) for both treatment groups BON 1 ITS and BON 2 CC were 98.0 and 96.0%, respectively (Table 3-1). Additionally, two fish from BON 1 ITS and 1 fish from BON 2 CC were likely seals predation based on radio telemetry information and disappearance of the fish and signal during the presence of seals in the area. Three additional fish from BON 2 CC were classified as unknown status, no information on tags were obtained on these individuals following their release.

3.2 Retrieval Times

Recapture times at BON 1 ITS and BON 2 CC ranged from 4 to 47 min and 4 to 57 min, respectively. The average recapture time was 11 min. The recapture times for the control group ranged from 2 to 81 min, with an average time of 10 min (Figure 3-1).

3.3 Passage Survival

The 1 and 48 h alive/dead status for the two treatments are displayed in Table 3-1. The estimated 1 h survival for the BON 1 ITS and BON 2 CC including likely predation were 98.0 and 99.0%, respectively. The respective values excluding seal predation 100% for both treatment sites. The 48 h survival estimates for the two release sites including predation were 98.0 and 97.9% for BON 1 ITS and BON 2 CC, respectively. Excluding the 3 fish that were likely predation the 48 h estimates for BON 2 CC and BON 1 ITS were 100.0 and 99.0%, respectively. Precision (ϵ) on survival estimates for BON 1 ITS and BON 2 CC were $\pm 2.3\%$, 90% of the time and met the prespecified criterion. Difference between the BON 1 and BON 2 survival estimates was not significant ($P > 0.10$). No treatment or control fish were recovered dead.

3.4 Injuries

Most (97.0%) of the fish were examined for injuries after sluiceway passage Table 3-2 and Appendix D. Two (1%) of 200 treatment fish examined displayed visible injuries that were attributed to sluiceway passage (Table 3-3). None of the fish displayed only loss of equilibrium. The results for malady-free rates were 99.0% for both BON 1 ITS and BON 2 CC tests, (Table 3-2). The precision was $\pm 1.6\%$, 90% of the time on these estimates. The malady-free rates were not significantly different between the two passage routes ($P > 0.10$).

The one injured fish for BON 1 ITS suffered a bruise above the left eye and the fish from BON 2 CC had a torn left operculum (Figure 3-2). Both of these maladies were considered major and the fish from BON 2 CC injury was a fatality at 48 h. The probable source of the bruise appeared to be due to mechanical and the torn operculum was attributed to shear forces (Table 3-3). None of the 37 control fish had any maladies.

4.0 CONCLUSIONS AND DISCUSSION

The 48 h survival of fish released at BON 1 ITS including likely seal predation was 98.0 and 97.9% at BON 2 CC. Excluding likely seal predation the 48 h estimates were 100 and 99% for BON 1 ITS and BON 2 CC, respectively. Both BON 1 ITS and BON 2 CC passed fish had the same number of fish with visible injuries (1 fish each, 1%). The malady-free rate was 99.0% for both passage sites. The precision

(ε) on all estimates of survival and malady probabilities was within $\pm 2.3\%$, 90% of the time. Differences in survival and malady rates between the two sluiceway sites were not significant.

The results of the present study were similar to those obtained on adult steelhead passed over a flow control structure at the Willamette Falls. Willamette Falls is a naturally occurring, horseshoe shaped 40 ft high basalt rock formation with a low concrete gravity dam along the entire crest. A total of 47 (38 treatment and 9 control) adult steelhead were released. The recapture rate was 89.5%; 43 fish recovered alive and 4 treatment fish unrecovered but assigned alive based on radio telemetry information. The recapture times for both treatment and control fish ranged from 2 to 77 min with an average time of 6 minutes. Fish length for the treatment and control fish ranged from 508 to 914 with a median length of 716 mm total length. The survival rate was 100.0 % and one of the 43 adult steelhead examined experienced injuries.

The overall impact of both sluiceways on adult steelhead kelts survival and injury condition appears to be minimal and there doesn't seem to be any difference between the two locations; however, there does seem to be some issue with seals predation.

5.0 LITERATURE CITED

- Bell, M. C., A. C. DeLacy, and H. D. Copp. 1972. A compendium on the survival of fish passing through spillways and conduits. Report prepared for U.S. Army Corps of Engineers, Portland, OR.
- Heisey, P. G., D. Mathur, and T. Rineer. 1992. A reliable tag-recapture technique for estimating turbine passage survival: application to young-of-the-year American shad (*Alosa sapidissima*). Can. Jour. Fish. Aquat. Sci. 49:1826-1834.
- Mathur, D., P. G. Heisey, E. T. Euston, J. R. Skalski, and S. Hays. 1996. Turbine passage survival estimation for Chinook salmon smolts (*Oncorhynchus tshawytscha*) at a large dam on the Columbia River. Can. Jour. Fish. Aquat. Sci. 53:542-549.
- Mathur, D., P. G. Heisey, J. R. Skalski, and D. R. Kenney. 2000. Salmonid smolt survival relative to turbine efficiency and entrainment depth in hydroelectric power generation. Jour. Amer. Water Resour. Assoc. 36:737-747.
- Neitzel, D. A., and nine co-authors. 2000. Laboratory studies of the effects of shear on fish, final report FY 1999. Prepared for Advanced Hydropower Turbine System Team, U. S. Department of Energy, Idaho Falls, ID.
- Normandeau Associates, Inc., and J. R. Skalski. 2006. Comparative direct survival and injury rates of juvenile salmon passing the new removable spillway weir (RSW) and a spillbay at Ice Harbor Dam, Snake River. Report prepared for U. S. Army Corps of Engineers, Walla Walla District, Walla Walla, WA.
- Normandeau Associates, Inc., and J. R. Skalski. 1998. Chinook salmon smolt passage survival through modified and unmodified spillbays at Rock Island Dam, Columbia River, Washington. Report prepared for Public Utility District No. 1 of Chelan County, Wenatchee, WA.
- North/South Consultants, Inc., and Normandeau Associates, Inc. 2007. Fish movements and turbine passage at selected Manitoba hydro generating stations. 2005-2006 interim report prepared for Manitoba Hydro, Winnipeg, Manitoba.
- North/South Consultants, Inc., and Normandeau Associates, Inc. 2009. Survival and movement of fish experimentally passed through a re-runnered turbine at the Kelsey Generating Station, 2008. Report prepared for Manitoba Hydro, Winnipeg, Manitoba.
- Pacific Northwest National Laboratory (PNNL), BioAnalysts, ENSR International Inc., and Normandeau Associates, Inc. 2001. Design guidelines for high flow smolt bypass outfalls: Field, laboratory, and modeling studies. Report prepared for US Army Corps of Engineers, Portland District, Portland, OR.
- Peven, C., and eight co-authors. 2005. Guidelines and recommended protocols for conducting, analyzing, and reporting juvenile salmonid survival studies in the Columbia River Basin (multi-agency sponsored report).
- RMC, and J. R. Skalski. 1994. Survival of juvenile fall chinook salmon (*Oncorhynchus tshawytscha*) in passage through a fixed blade Kaplan turbine at the Rocky Reach Dam, Washington. Report prepared for Public Utility District No. 1 of Chelan County, Wenatchee, WA.

RMC, Mid Columbia Consulting, Inc., and J. R. Skalski. 1994. Turbine passage survival of spring migrant chinook salmon (*Oncorhynchus tshawytscha*) at Lower Granite Dam, Snake River, Washington. Report prepared for Dept. of Army, Corps of Engineers, Walla Walla District, Walla Walla, WA

TABLES

Table 2-1

Required sample sizes for treatment and control fish releases for various combinations of control survival (S), recapture probability (P_A), and passage route related mortality ($1-\hat{\tau}$) to obtain a precision (ϵ) of $\leq \pm 0.10$ at $1-\alpha = 0.90$.

Control Survival (S)	Recapture Rate (P_A)	Passage Mortality		
		($1-\hat{\tau}$)	Number of Fish	
1.00	0.99	0.05	18	
		0.10	29	
		0.15	39	
	0.95	0.95	0.05	39
			0.10	49
			0.15	57
		0.90	0.05	69
			0.10	76
			0.15	82
0.95	0.99	0.05	45	
		0.10	54	
		0.15	61	
	0.95	0.95	0.05	67
			0.10	74
			0.15	80
		0.90	0.05	98
			0.10	103
			0.15	107

¹ Also applicable for passage injury

Table 2-2

Average station parameters measured for adult steelhead kelts, passed through Bonneville Dam, March 2011. Controls released into the tailrace discharge downstream at the boat launch.

Date	Spill (kcf)	Total Flow (kcf)	FB Elev. (ft)	TW Elev. (ft)	Head (m) estimation
<u>BON 1 ITS</u>					
March 2011	2.5	240.5	73.3	20.1	53.3
<u>BON 2 CC</u>					
March 2011	2.3	235.7	72.9	19.9	53.0

Table 2-3

Daily schedule for releases of adult steelhead kelts, passed through Bonneville Dam, March 2011. Controls released into the tailrace discharge downstream at the boat launch.

Date	Daily River Temperature (°C)	Treatment		Control Boat Launch	Total	Actual* Release
		<u>BON 1</u> <u>Ice-and-Trash</u> (ITS)	<u>BON 2</u> <u>Corner</u> (CC)			
28-Feb	4.0		Pretest		0	2
1-Mar	4.0	51			51	55
2-Mar	4.0	49			49	51
3-Mar	3.5		75		75	75
4-Mar	3.5		25	37	62	62
5-Mar		delayed assessment				
6-Mar		delayed assessment				
Total		100	100	37	237	245

*Six fish removed from analysis because they were in unrecoverable conditions/areas i.e. trash, hazardous discharge site

Table 2-4

Condition codes assigned to fish and dislodged HI-Z tags for fish passage survival studies.

Status Codes	Description		
*	Turbine/passage-related malady		
4	Damaged gill(s): hemorrhaged, torn or inverted		
5	Major scale loss, >20%		
6	Severed body or nearly severed		
7	Decapitated or nearly decapitated		
8	Damaged eye: hemorrhaged, bulged, ruptured or missing, blown pupil		
9	Damaged operculum: torn, bent, inverted, bruised, abraded		
A	No visible marks on fish		
B	Flesh tear at tag site(s)		
C	Minor scale loss, <20%		
E	Laceration(s): tear(s) on body or head (not severed)		
F	Torn isthmus		
G	Hemorrhaged, bruised head or body		
H	LOE		
J	Major		
K	Failed to enter system		
L	Fish likely preyed on (telemetry, circumstances relative to recapture)		
M	Minor		
P	Predator marks		
Q	Other information		
S	Eel study only - Functionally dead		
R	Removed from sample		
T	Trapped in the rocks/recovered from shore		
V	Fins displaced, or hemorrhaged (ripped, torn, or pulled) from origin		
W	Abrasion / Scrape		
Survival Codes			
1	Recovered alive		
2	Recovered dead		
3	Unrecovered – tag & pin only		
4	Unrecovered – no information or brief radio telemetry signal		
5	Unrecovered – trackable radio telemetry signal or other information		
Dissection Codes			
1	Shear	M	Minor
2	Mechanical	N	Heart damage, rupture, hemorrhaged
3	Pressure	O	Liver damage, rupture, hemorrhaged
4	Undetermined	R	Necropsied, no obvious injuries
5	Mechanical/Shear	S	Necropsied, internal injuries
6	Mechanical/Pressure	T	Tagging/Release
7	Shear/Pressure	W	Head removed; i.e., otolith
B	Swim bladder ruptured or expanded		
D	Kidneys damaged (hemorrhaged)		
E	Broken bones obvious		
F	Hemorrhaged internally		
J	Major		
L	Organ displacement		

Table 2-5

Guidelines for major and minor injury classifications for fish passage survival studies using the HI-Z Tags.

A fish with only LOE is classified as major if the fish dies within 1 hour. If it survives or dies beyond 1 hour it is classified as minor.

A fish with no visible external or internal maladies is classified as a passage related major injury if the fish dies within 1 hour. If it dies beyond 1 hour it is classified as a non passage related minor injury.

Any minor injury that leads to death within 1 hour is classified as a major injury. If it lives or dies after 1 hour it remains a minor injury.

Hemorrhaged eye: minor if less than 50%. Major if 50% or more

Deformed pupil(s) are a: major injury.

Bulged eye: major unless one eye is only slightly bulged. Minor if slight.

Bruises are size-dependent. Major if 10% or more of fish body per side. Otherwise minor.

Operculum tear at dorsal insertion is: major if it is 5 % of the fish or greater. Otherwise minor.

Operculum folded under or torn off is a major injury

Scale loss: major if 20% or more of fish per side. Otherwise minor

Scraping (damage to epidermis): major if 10% or more per side of fish. Otherwise minor.

Cuts and lacerations are generally classified as major injuries. Small flaps of skin or skinned up snouts are: minor.

Internal hemorrhage or rupture of kidney, heart or other internal organs that results in death at 1 to 48 hours is a major injury.

Multiple injuries: use the worst injury

Table 3-1

Summary tag-recapture data and survival estimates with and without likely seal predation of adult steelhead kelts, passed through Bonneville Dam, March 2011. Controls released into the tailrace discharge downstream at the boat launch. Proportions are given in parentheses.

	<u>Treatment</u>		<u>Controls</u>
	BON 1 ITS	BON 2 CC	
Number released	100	100	37
Number recaptured alive	98 (0.980)	96 (0.960)	37 (1.000)
Number recaptured dead	0 (0.000)	0 (0.000)	0 (0.000)
Number assigned dead	2 (0.020)	1 (0.010)	0 (0.000)
Stationary radio signals*	2 (0.020)	1 (0.010)	0 (0.000)
Number undetermined	0 (0.000)	3 (0.030)	0 (0.000)
Number held	98	96	37
Including Predation			
1 hour survival rate	0.980	0.990	
SE	0.014	0.010	
90% CI (+/-)	0.023	0.016	
Number alive 48 hour	98 (0.980)	95 (0.950)	37
Number died in holding	0	1	0
48 hour survival rate	0.980	0.979	
SE	0.014	0.014	
90% CI (+/-)	0.023	0.023	
Excluding Predation			
1 hour survival rate**	0.100	0.100	37
SE	N/A	N/A	0
90% CI (+/-)	N/A	N/A	
48 hour survival rate**	0.100	0.990	
SE	N/A	0.010	
90% CI (+/-)	N/A	0.016	

*Based on radio telemetry and the presence of sea lions near outfall at time of release, 3 fish were likely predation.

** Likely seal predation fish not included in analysis.

Table 3-2

Summary malady data and malady-free estimates for recaptured adult steelhead kelts, passed through Bonneville Dam, March 2011. Controls released into the tailrace discharge downstream at the boat launch. Proportions are given in parentheses.

	<u>Treatment</u>		<u>Controls</u>
	BON 1 ITS	BON 2 CC	
Number released	100	100	37
Number examined for maladies	98 (0.980)	96 (0.960)	37 (1.000)
Number with passage related maladies	1 (0.010)	1 (0.010)	0 (0.000)
Visible injuries	1 (0.010)	1 (0.010)	0 (0.000)
Loss of equilibrium only	0 (0.000)	0 (0.000)	0 (0.000)
Number without passage related maladies	97 (0.990)	95 (0.990)	37 (1.000)
Without passage related maladies that died	0 (0.000)	0 (0.000)	0 (0.000)
Malady-free rate	0.990	0.990	
SE	0.010	0.010	
90% CI (+/-)	0.016	0.016	

Table 3-3

Incidence of maladies, including visible injury, and loss of equilibrium (LOE) observed on adult steelhead kelts passed through Bonneville Dam, March 2011. Controls released into tailrace discharge downstream at the boat launch.

Date	Lot	Tag	Test Fish Live/Dead	Maladies	Passage Malady	Photo	Probable Cause	Status
BON 1 ITS								
3/1/11	1	517	alive 48h	bruised on head above left eye	Yes	Yes	Mechanical	Major
BON 2 CC								
3/3/11	4	648	dead 48h	torn right operculum	Yes	Yes	Shear	Major

FIGURES

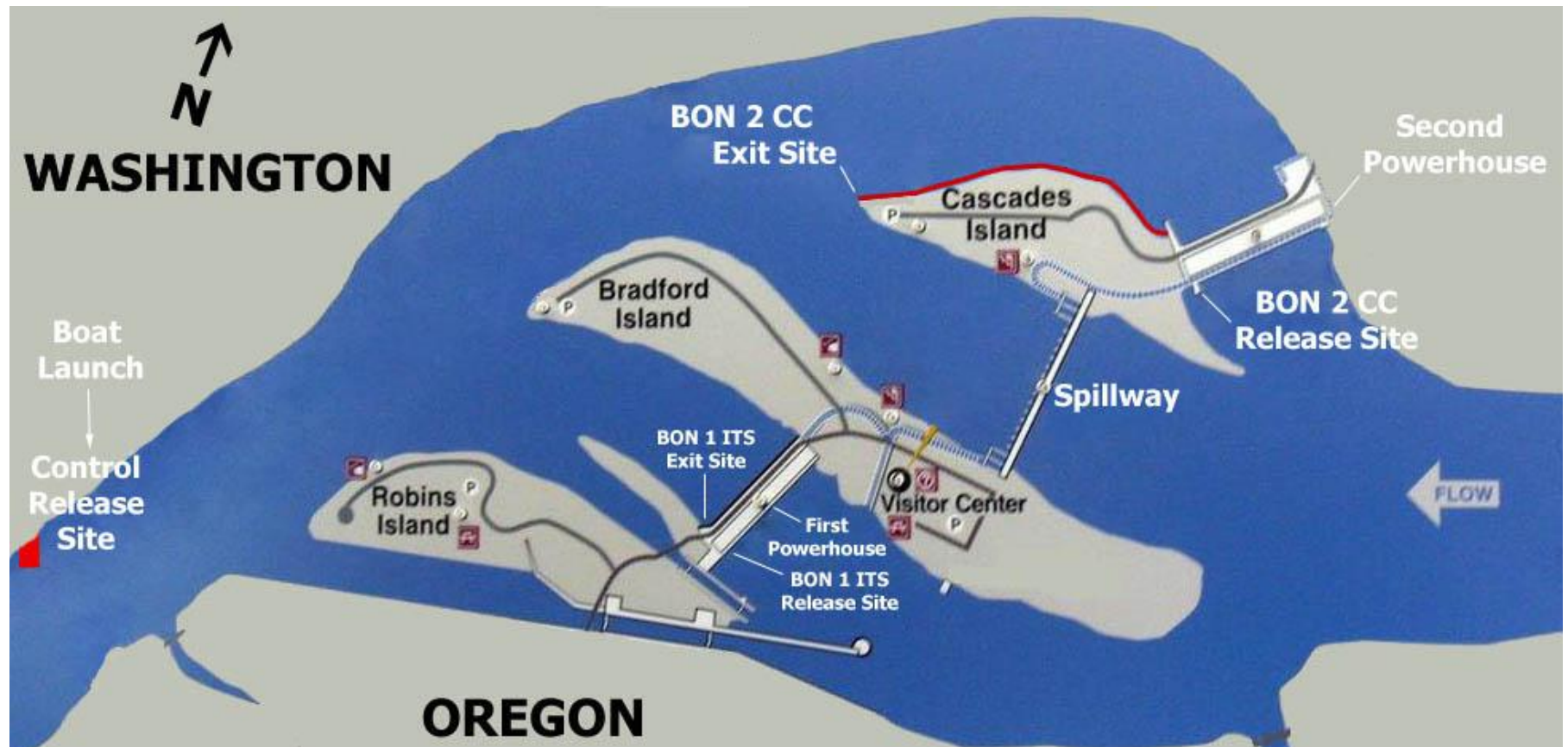


Figure 1-1 Overview of Bonneville Dam Hydroelectric Project including control release site.



Figure 2-1 Fish holding pools for fish prior to release.

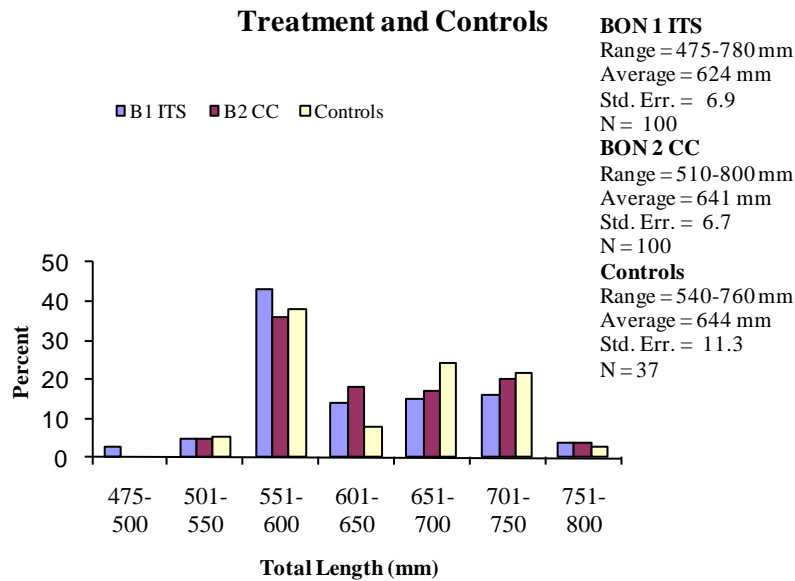


Figure 2-2 Total length (mm) frequency distribution of treatment and control adult steelhead kelt, passed through Bonneville Dam, March 2011. Controls released into tailrace discharge downstream of boat launch.



Figure 2-3 Attachment procedure for HI-Z tags (cannula, cable tie, injection).



Figure 2-4 Fish restraint device for attachment of HI-Z tags.



Figure 2-5 BON 1 ITS release site.



Figure 2-6 BON 2 CC release site.



Figure 2-7 Control release site.



Figure 2-8 Tracking fish by boat crew.



Figure 2-9 HI-Z tags buoy fish to surface.



Figure 2-10 Recaptured fish in the boat.

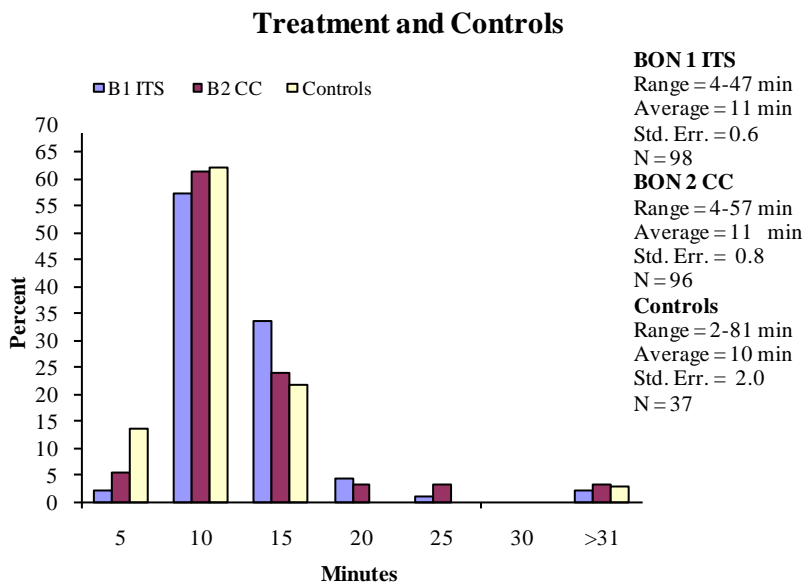


Figure 3-1 Frequency distribution of retrieval times (minutes) of treatment and control adult steelhead kelt, passed through Bonneville Dam, March 2011. Controls released into tailrace discharge downstream at boat launch.



Treatment fish with a torn right operculum from BON 2 CC



Treatment fish from BON 1 ITS with a bruise on top of head (dead at 48 h)

Figure 3-2 Injuries of BON 1 ITS and BON 2 CC.

APPENDIX A
STATION PARAMETERS

Appendix A

Physical parameters (mean values for each scenario) measured during the release of adult steelhead kelts, passed through Bonneville Dam, March 2011. Controls released into the tailrace discharge downstream at the boat launch.

DATE	HR	SPILL (KCFS)	TOTAL FLOW (KCFS)	FB ELEV (FT)	TW ELEV (FT)
BON 1 ITS					
3/1/2011	8	2.5	234.6	73.7	19.8
3/1/2011	9	2.5	276.2	72.4	21.8
3/1/2011	10	2.5	284.6	72.4	21.9
3/1/2011	11	2.5	283.4	72.5	21.9
3/1/2011	12	2.5	240.5	74.0	19.8
3/1/2011	13	2.5	234.7	73.8	19.8
3/1/2011	14	2.5	234.0	73.7	19.8
3/1/2011	15	2.5	234.9	73.5	19.7
3/1/2011	16	2.5	236.7	73.4	19.8
BON 1 ITS					
3/2/2011	8	2.4	235.5	73.2	19.8
3/2/2011	9	2.4	235.7	73.1	19.8
3/2/2011	10	2.4	237.0	73.2	20.0
3/2/2011	11	2.4	235.5	73.3	19.9
3/2/2011	12	2.4	237.0	73.4	20.0
3/2/2011	13	2.4	236.7	73.6	19.7
3/2/2011	14	2.4	214.2	73.5	19.1
3/2/2011	15	2.4	213.2	73.5	19.0
3/2/2011	16	2.5	213.9	73.6	19.0
BON 2 CC					
3/3/2011	8	2.4	241.5	72.1	20.3
3/3/2011	9	2.4	241.4	72.4	20.4
3/3/2011	10	2.4	241.1	72.5	20.3
3/3/2011	11	2.4	242.1	72.4	20.5
3/3/2011	12	2.4	237.2	72.6	20.2
3/3/2011	13	2.4	226.5	72.9	19.7
3/3/2011	14	2.4	223.3	73.1	19.6
3/3/2011	15	2.4	223.7	73.1	19.4
3/3/2011	16	2.4	222.5	73.2	19.4
BON 2 CC					
3/4/2011	8	2.2	237.3	72.5	19.7
3/4/2011	9	2.2	238.6	72.7	19.6
3/4/2011	10	2.2	239.0	72.8	19.9
3/4/2011	11	2.2	239.8	73.0	19.8
3/4/2011	12	2.2	237.9	73.2	19.7
3/4/2011	13	2.2	236.5	73.2	19.7
3/4/2011	14	2.2	237.3	73.1	19.9
3/4/2011	15	2.2	239.2	73.3	19.9
3/4/2011	16	2.2	238.3	73.2	19.8

APPENDIX B
FISH DISPOSITION DATA

Appendix B

Short term passage survival data for recaptured adult steelhead kelt, passed through Bonneville Dam, March 2011. Controls released into tailrace discharge downstream of boat launch.

Description of codes and details on injured fish are presented in Table 2-4.

Fish ID	Total Length (mm)	Time			No. HI-Z tags recovered	Survival Code	Status Codes				
		Re-leased	Re-covered	Minutes at large			1	2	3	4	
1-Mar-11		Testlot 2			Water temp = 4.0°C						
BON 1 ITS											
504	700	9:00	9:12	12	6	1	A				
505	730	9:16	9:31	15	6	1	A				
506	660	9:33	9:48	15	6	1	A				
507	690	9:50	10:03	13	6	1	A				
508	735	10:09	10:22	13	6	1	A				
509	675	10:28	10:38	10	6	1	A				
510	705	10:18	10:38	20	6	1	A				
511	660	10:44	10:53	9	4	1	A				
512	700	10:50	10:59	9	6	1	A				
513	675	10:56	11:03	7	6	1	A				
514	720	11:03	11:40	37	6	1	A				
515	715	11:08	11:20	12	6	1	A				
516	720	11:18	11:30	12	6	1	A				
517	755	11:31	11:54	23	6	1	*	G			
519	720	11:47	11:51	4	6	1	A				
520	580	11:52			0	5	T	R			
521	570	11:57	12:09	12	6	1	A				
522	590	12:05	12:18	13	6	1	A				
523	590	12:22			0	5	R				
524	585	12:28	12:40	12	6	1	A				
525	690	12:32	12:46	14	6	1	A				
526	565	12:41	12:51	10	6	1	A				
527	670	12:46	12:54	8	6	1	A				
528	585	12:58	13:45	47	6	1	A				
529	615	13:04	13:14	10	6	1	A				
530	595	13:09	13:18	9	6	1	A				
531	565	13:14	13:24	10	6	1	A				
532	570	13:20	13:28	8	6	1	A				
533	580	13:26	13:39	13	6	1	A				
534	545	13:33	13:47	14	6	1	A				
535	610	13:50	13:57	7	6	1	A				
536	590	13:55	14:10	15	6	1	A				
537	530	14:01	14:09	8	6	1	A				
538	560	14:07	14:22	15	6	1	A				
539	645	14:12	14:19	7	6	1	A				
540	575	14:18	14:26	8	6	1	A				
541	605	14:23	14:29	6	6	1	A				
543	560	14:35	14:42	7	6	1	A				
544	560	14:39	14:46	7	6	1	A				
545	575	14:43	14:52	9	6	1	A				
546	630	14:48	14:55	7	6	1	A				
547	780	14:52	15:03	11	6	1	A				

Appendix B

Continued.

Fish ID	Total Length (mm)	Time			No. HI-Z tags recovered	Survival Code	Status Codes				
		Re-leased	Re-covered	Minutes at large			1	2	3	4	
548	615	15:20	15:27	7	6	1	A				
549	605	15:24	15:32	8	6	1	A				
550	680	15:29	15:39	10	6	1	A				
551	570	15:32	15:42	10	6	1	A				
552	570	15:37	15:47	10	6	1	A				
553	570	15:42	15:50	8	6	1	A				
554	575	15:47	15:57	10	6	1	A				
555	580	15:51	16:00	9	6	1	A				
556	770	15:55	16:14	19	6	1	A				
557	645	16:00	16:05	5	6	1	A				
558	640	16:04	16:12	8	6	1	A				
503	680	8:39			0	4	R				
542	675	14:30			0	4	R				
2-Mar-11		Testlot 3			Water temp = 4.0°C						
BON 1 ITS											
559	665	8:03	8:16	13	6	1	A				
560	475	8:07	8:14	7	6	1	A				
561	585	8:11	8:20	9	6	1	A				
562	540	8:17	8:25	8	6	1	A				
563	570	8:21	8:29	8	6	1	A				
564	605	8:28	8:34	6	6	1	A				
565	585	8:31	8:37	6	6	1	A				
566	575	8:36	8:43	7	6	1	A				
567	720	8:40	8:51	11	6	1	A				
568	600	8:44	8:54	10	6	1	A				
569	580	8:48	8:56	8	6	1	A				
570	695	8:56	9:11	15	6	1	A				
571	705	9:16	9:24	8	6	1	A				
572	635	9:19	9:35	16	6	1	A				
573	740	9:25	9:35	10	6	1	A				
574	580	9:29	9:39	10	6	1	A				
575	500	9:32	9:42	10	6	1	A				
576	695	9:42	9:53	11	6	1	A				
577	580	9:46	10:00	14	6	1	A				
578	713	9:50	10:07	17	6	1	A				
579	560	9:57	10:08	11	6	1	A				
580	580	10:04	10:16	12	6	1	A				
581	725	10:16	10:29	13	6	1	A				
582	730	10:20	10:34	14	6	1	A				
583	790	10:24			0	5	T	R			
584	580	10:32	10:40	8	6	1	A				
585	605	10:37	10:44	7	6	1	A				
586	695	10:44	10:51	7	6	1	A				
587	670	10:52	11:05	13	5	1	A				
588	550	10:55			0	5	L				
589	580	11:14	11:25	11	6	1	A				
590	560	11:18	11:26	8	6	1	A				
591	570	11:33	11:40	7	6	1	A				

Appendix B

Continued.

Fish ID	Total Length (mm)	Time			No. HI-Z tags recovered	Survival Code	Status Codes				
		Re-leased	Re-covered	Minutes at large			1	2	3	4	
592	610	11:38	11:47	9	6	1	A				
593	715	11:43	11:52	9	6	1	A				
594	585	11:47	11:55	8	6	1	A				
595	590	11:51	12:02	11	6	1	A				
596	590	11:54	12:03	9	6	1	A				
597	720	11:58	12:09	11	6	1	A				
598	575	12:01	12:14	13	6	1	A				
599	760	12:13	12:24	11	8	1	A				
600	600	12:18	12:26	8	6	1	A				
601	770	12:23				5	R	T			
602	500	12:21	12:35	14	6	1	A				
603	560	12:30	12:39	9	6	1	A				
604	550	12:43	12:52	9	6	1	A				
605	560	12:47	12:57	10	6	1	A				
606	570	12:50	12:59	9	6	1	A				
607	705	12:55			0	5	L				
608	610	12:58	13:08	10	6	1	A				
609	560	13:05	13:16	11	6	1	A				
3-Mar-11		Testlot 4			Water temp = 3.5°C						
				BON 2 CC							
610	570	9:07	9:19	12	6	1	A				
611	715	9:13			0	4					
612	720	9:17	9:31	14	6	1	A				
613	595	9:25	9:32	7	6	1	A				
614	650	9:29	9:46	17	6	1	A				
615	625	9:55	10:02	7	6	1	A				
616	710	9:59	10:08	9	6	1	A				
617	745	10:03	10:13	10	6	1	A				
618	615	10:06	10:14	8	6	1	A				
619	580	10:09	10:14	5	6	1	A				
620	605	10:17	10:32	15	6	1	A				
621	745	10:20	10:43	23	6	1	A				
622	590	10:25	10:50	25	6	1	A				
623	680	10:29	10:40	11	6	1	A				
624	720	10:36	10:58	22	6	1	A				
625	530	10:55	11:02	7	6	1	A				
626	640	10:59	11:16	17	6	1	A				
627	590	11:02	11:13	11	6	1	A				
628	565	11:07	11:14	7	6	1	A				
629	590	11:17	11:24	7	6	1	A				
630	685	11:22	11:33	11	6	1	A				
631	645	11:25	11:31	6	6	1	A				
632	600	11:29	11:37	8	6	1	A				
633	715	11:33	11:43	10	6	1	A				
634	800	11:38	11:46	8	6	1	A				
635	600	11:42	11:47	5	6	1	A				
636	590	11:45	11:55	10	6	1	A				
637	670	11:47	11:57	10	6	1	A				

Appendix B

Continued.

Fish ID	Total Length (mm)	Time			No. HI-Z tags recovered	Survival Code	Status Codes				
		Re-leased	Re-covered	Minutes at large			1	2	3	4	
638	590	11:51	11:58	7	6	1	A				
639	550	11:54	12:05	11	6	1	A				
640	710	12:23	12:30	7	6	1	A				
641	720	12:30	12:39	9	6	1	A				
642	580	12:34	12:45	11	6	1	A				
643	710	12:39	12:47	8	6	1	A				
644	665	12:43	12:52	9	6	1	A				
645	635	12:46	12:54	8	6	1	A				
646	570	12:49	12:56	7	6	1	A				
647	575	12:53	13:01	8	6	1	A				
648	725	12:58	13:09	11	6	1	A	*			
649	690	13:03	14:00	57	6	1	A				
650	595	13:06	13:14	8	6	1	A				
651	580	13:11	13:20	9	6	1	A				
652	745	13:14	13:24	10	7	1	A				
653	745	13:20			0	4					
654	620	13:23	14:00	37	6	1	A				
655	590	14:08	14:15	7	6	1	A				
656	510	14:12	14:19	7	6	1	A				
657	600	14:16	14:28	12	6	1	A				
658	570	14:19	14:24	5	6	1	A				
659	590	14:22			0	5	L				
660	745	14:28	14:37	9	8	1	A				
661	600	14:30	14:38	8	6	1	A				
662	535	14:35	14:44	9	4	1	A				
663	640	14:40	14:44	4	6	1	A				
664	580	14:49	14:55	6	6	1	A				
665	600	14:52	14:58	6	6	1	A				
666	700	15:06	15:15	9	6	1	A				
667	740	15:10	15:21	11	6	1	A				
668	700	15:14			0	4					
669	610	15:18	15:24	6	6	1	A				
670	595	15:22	15:28	6	6	1	A				
671	600	15:27	15:40	13	6	1	A				
672	780	15:33	15:44	11	8	1	A				
673	550	15:53	16:01	8	6	1	A				
674	660	15:57	16:07	10	6	1	A				
675	600	16:01	16:09	8	6	1	A				
676	710	16:06	16:11	5	8	1	A				
677	700	16:11	16:22	11	8	1	A				
678	620	16:15	16:24	9	6	1	A				
679	570	16:18	16:28	10	6	1	A				
680	560	16:23	16:34	11	6	1	A				
681	560	16:26	16:32	6	6	1	A				
682	700	16:30	16:41	11	6	1	A				
683	560	16:33	16:40	7	6	1	A				
684	610	16:36	16:45	9	6	1	A				
4-Mar-11		Testlot 5			Water temp = 3.5°C						

Appendix B

Continued.

Fish ID	Total Length (mm)	Time			No. HI-Z tags recovered	Survival Code	Status Codes			
		Re-leased	Re-covered	Minutes at large			1	2	3	4
BON 2 CC										
685	600	8:12	8:19	7	6	1	A			
686	570	8:16	8:25	9	6	1	A			
687	665	8:20	8:33	13	6	1	A			
688	640	8:25	8:38	13	6	1	A			
689	560	8:30	8:38	8	6	1	A			
690	770	8:34	8:43	9	8	1	A			
691	665	8:38	8:48	10	6	1	A			
692	610	8:42	8:50	8	6	1	A			
693	700	8:46	9:02	16	8	1	A			
694	710	8:53	9:07	14	8	1	A			
695	595	8:57	9:48	51	6	1	A			
696	730	9:02	9:13	11	8	1	A			
697	750	9:08	9:17	9	8	1	A			
698	605	9:12	9:20	8	6	1	A			
699	660	9:48	9:59	11	6	1	A			
700	690	9:51	10:04	13	6	1	A			
701	560	9:56	10:02	6	6	1	A			
702	710	10:03	10:12	9	8	1	A			
703	610	10:07	10:17	10	6	1	A			
704	590	10:12	10:22	10	6	1	A			
705	760	10:17	10:28	11	8	1	A			
706	640	10:20	10:29	9	6	1	A			
707	660	10:24	10:33	9	6	1	A			
708	610	10:29	10:36	7	8	1	A			
709	655	10:33	10:42	9	6	1	A			
4-Mar-11		Testlot 6			Water temp = 3.5°C					
Controls										
710	570	13:08	13:19	11	6	1	A			
711	720	13:14	13:27	13	8	1	A			
712	640	13:20	13:29	9	6	1	A			
713	680	13:24	13:32	8	6	1	A			
714	750	13:31	13:44	13	8	1	A			
715	560	13:35	13:44	9	6	1	A			
716	560	13:39	13:44	5	6	1	A			
717	590	13:44	13:50	6	6	1	A			
718	600	13:48	15:09	81	6	1	A			
719	695	13:54	14:03	9	6	1	A			
720	690	14:01	14:09	8	6	1	A			
721	670	14:10	14:21	11	6	1	A			
722	600	14:19	14:28	9	6	1	A			
724	555	14:28	14:36	8	6	1	A			
725	680	14:33	14:48	15	6	1	A			
726	655	14:38	14:44	6	6	1	A			
727	595	14:42	14:52	10	6	1	A			
728	575	14:59	15:07	8	6	1	A			
729	760	15:08	15:15	7	8	1	A			
730	700	15:15	15:21	6	6	1	A			

Appendix B

Continued.

Fish ID	Total Length (mm)	Time			No. HI-Z tags recovered	Survival Code	Status Codes				
		Re-leased	Re-covered	Minutes at large			1	2	3	4	
731	695	15:21	15:31	10	6	1	A				
732	710	15:26	15:35	9	8	1	A				
733	720	15:31	15:44	13	8	1	A				
734	615	15:39	15:43	4	6	1	A				
735	705	15:45	15:53	8	8	1	A				
736	600	15:52	16:00	8	6	1	A				
737	740	15:59	16:05	6	8	1	A				
738	640	16:04	16:15	11	6	1	A				
739	590	16:11	16:20	9	6	1	A				
740	580	16:15	16:23	8	6	1	A				
742	560	16:25	16:27	2	6	1	A				
743	540	16:20	16:35	15	6	1	A				
744	730	16:39	16:46	7	8	1	A				
745	690	16:48	16:52	4	6	1	A				
746	740	16:57	17:03	6	8	1	A				
741	560	16:20	16:30	10	6	1	A				
723	550	14:24	14:28	4	6	1	A				

APPENDIX C
STATISTICAL ANALYSIS

Appendix C

One hour survival estimates for adult steelhead kelts, passed through Bonneville Dam, March 2011. Controls released into the tailrace discharge downstream at the boat launch.

Control fish released 37, 37 alive and 0 dead; BON B1 ITS: 100 released, 98 alive and 2 assigned dead; BON B2 CC: 100 released, 96 alive and 1 assigned dead.

RESULTS FOR REDUCED MODEL (EQUAL LIVE/DEAD RECOVERY)

estim. std.err.

S1 = 1.0 N/A Control group survival*
Pa = Pd 0.9873 (0.0073) Recovery probability
S2 = 0.9800 (0.0140) BON B1 ITS survival
S3 = 0.9897 (0.0103) BON B2 CC survival

* -- Because of constraints in the data set, this probability is assumed equal to 1.0; not estimated.
log-likelihood : -31.4627

Tau = 0.9800 (0.0140) BON B1 ITS/Control ratio

Tau = 0.9897 (0.0103) BON B2 CC/Control ratio

Z statistic for the equality of equal spillway survivals: 0.5584

Compare with quantiles of the normal distribution:

	1-tailed	2-tailed
For significance level 0.10:	1.2816	1.6449
For significance level 0.05:	1.6449	1.9600
For significance level 0.01:	2.3263	2.5758

Variance-Covariance matrix for estimated probabilities:

0.00000000	0.00000000	0.00000000	0.00000000
0.00000000	0.00005273	0.00000000	0.00000000
0.00000000	0.00000000	0.00019600	0.00000000
0.00000000	0.00000000	0.00000000	0.00010519

Confidence intervals:

	BON B1 ITS Tau	BON B2 CC Tau
90 percent:	(0.9570, 1.0030)	(0.9728, 1.0066)
95 percent:	(0.9526, 1.0074)	(0.9696, 1.0098)
99 percent:	(0.9440, 1.0160)	(0.9633, 1.0161)

Likelihood ratio statistic for equality of recovery probabilities: 1.4110

Compare with quantiles of the chi-squared distribution with 1 d.f.:

For significance level 0.10: 2.706
For significance level 0.05: 3.841
For significance level 0.01: 6.635

Appendix C

Forty-eight hour survival estimates for adult steelhead kelts excluding seal predation fish, passed through Bonneville Dam, March 2011. Controls released into the tailrace discharge downstream at the boat launch.

Control fish released 37, 37 alive and 0 dead; BON B2 CC: 99 released, 95 alive and 1 assigned dead.

RESULTS FOR REDUCED MODEL (EQUAL LIVE/DEAD RECOVERY)

estim. std.err.
S = 1.0 N/A Control group survival*
Pa = Pd 0.9779 (0.0126) Recovery probability
Tau = 0.9896 (0.0104) BON B2 CC survival
1-Tau = 0.0104 (0.0104) BON B2 CC mortality

* -- Because of constraints in the data set, this probability is assumed equal to 1.0; not estimated.
log-likelihood : -19.967915

Variance-Covariance matrix for estimated probabilities:
0.00016 0.00000
0.00000 0.00011

Profile likelihood intervals:
BON B2 CC survival BON B2 CC mortality
90 percent: (0.9625, 0.9989) (0.0011, 0.0375)
95 percent: (0.9549, 0.9994) (0.0006, 0.0451)
99 percent: (0.9378, 0.9999) (0.0001, 0.0622)

=====
Likelihood ratio statistic for equality of recovery probabilities: 1.930383
Compare with quantiles of the chi-squared distribution with 1 d.f.:
For significance level 0.10: 2.706
For significance level 0.05: 3.841
For significance level 0.01: 6.635

Appendix C

Forty-eight hour survival estimates for adult steelhead kelts, passed through Bonneville Dam, March 2011. Controls released into the tailrace discharge downstream at the boat launch.

Control fish released 37, 37 alive and 0 dead; BON B1 ITS: 100 released, 98 alive and 2 assigned dead; BON B2 CC: 100 released, 95 alive and 2 assigned dead.

RESULTS FOR REDUCED MODEL (EQUAL LIVE/DEAD RECOVERY)

estim. std.err.

S1 = 1.0 N/A Control group survival*
Pa = Pd 0.9873 (0.0073) Recovery probability
S2 = 0.9800 (0.0140) BON B1 ITS survival
S3 = 0.9794 (0.0144) BON B2 CC survival

* -- Because of constraints in the data set, this probability is assumed equal to 1.0; not estimated.
log-likelihood : -35.6356

Tau = 0.9800 (0.0140) BON B1 ITS/Control ratio
Tau = 0.9794 (0.0144) BON B2 CC/Control ratio

Z statistic for the equality of equal spillwaysurvivals: 0.0308

Compare with quantiles of the normal distribution:

	1-tailed	2-tailed
For significance level 0.10:	1.2816	1.6449
For significance level 0.05:	1.6449	1.9600
For significance level 0.01:	2.3263	2.5758

Variance-Covariance matrix for estimated probabilities:

0.00000000	0.00000000	0.00000000	0.00000000
0.00000000	0.00005273	0.00000000	0.00000000
0.00000000	0.00000000	0.00019600	0.00000000
0.00000000	0.00000000	0.00000000	0.00020818

Confidence intervals:

	BON B1 ITS Tau	BON B2 CC Tau
90 percent:	(0.9570, 1.0030)	(0.9556, 1.0031)
95 percent:	(0.9526, 1.0074)	(0.9511, 1.0077)
99 percent:	(0.9439, 1.0160)	(0.9422, 1.0165)

Likelihood ratio statistic for equality of recovery probabilities: 2.3995

Compare with quantiles of the chi-squared distribution with 1 d.f.:

For significance level 0.10: 2.706
For significance level 0.05: 3.841
For significance level 0.01: 6.635

Appendix C

Malady-free rates for adult steelhead kelts, passed through Bonneville Dam, March 2011. Controls released into the tailrace discharge downstream at the boat launch.

Control fish examined: 37, 37 alive no maladies and 0 with maladies; BOB B1 ITS: 98 examined, 97 alive no maladies and 1 with maladies; BON B2 CC: 96 examined, 95 alive no maladies and 1 with maladies.

RESULTS FOR REDUCED MODEL (EQUAL LIVE/DEAD RECOVERY)

estim. std.err.

S1 = 1.0 N/A Control group malady-free rate*

Pa = Pd 1.0 N/A Recovery probability*

S2 = 0.9898 (0.0102) BON B1 ITS malady-free rate

S3 = 0.9896 (0.0104) BON B2 CC malady-free rate

* -- Because of constraints in the data set, this probability is assumed equal to 1.0; not estimated.

log-likelihood : -11.1390

Tau = 0.9898 (0.0102) BON B1 ITS/Control ratio

Tau = 0.9896 (0.0104) BON B2 CC/Control ratio

Z statistic for the equality of equal spillway malady-free rates: 0.0147

Compare with quantiles of the normal distribution:

1-tailed 2-tailed

For significance level 0.10: 1.2816 1.6449

For significance level 0.05: 1.6449 1.9600

For significance level 0.01: 2.3263 2.5758

Variance-Covariance matrix for estimated probabilities:

0.00000002 0.00000000 0.00000000 0.00000000

0.00000000 0.00000000 0.00000000 0.00000000

0.00000000 0.00000000 0.00010306 0.00000000

0.00000000 0.00000000 0.00000000 0.00010738

Confidence intervals:

BON B1 ITS Tau BON B2 CC Tau

90 percent: (0.9731, 1.0065) (0.9725, 1.0066)

95 percent: (0.9699, 1.0097) (0.9693, 1.0099)

99 percent: (0.9637, 1.0159) (0.9629, 1.0163)

=====
Likelihood ratio statistic for equality of recovery probabilities: 0.0000

Compare with quantiles of the chi-squared distribution with 1 d.f.:

For significance level 0.10: 2.706

For significance level 0.05: 3.841

For significance level 0.01: 6.635

Appendix C

Chi square tests of the recovery of adult steelhead kelt
 11:23 Wednesday, April 20, 2011
 released through Bonneville Dam, March 2011.

----- Description=B1 -----

The FREQ Procedure

Table of release by cond

release	cond		Total
Frequency			
Expected			
Cell Chi-Square	alive	dead	Total
B1	1	0	51
	49.98	1.02	
	0.0208	1.02	
B1	2	2	49
	48.02	0.98	
	0.0217	1.0616	
Total	98	2	100

Statistics for Table of release by cond

Statistic	DF	Value	Prob
Chi-Square	1	2.1241	0.1450
Likelihood Ratio Chi-Square	1	2.8959	0.0888
Continuity Adj. Chi-Square	1	0.5521	0.4575
Mantel-Haenszel Chi-Square	1	2.1029	0.1470
Phi Coefficient		0.1457	
Contingency Coefficient		0.1442	
Cramer's V		0.1457	

WARNING: 50% of the cells have expected counts less than 5. Chi-Square may not be a valid test.

Fisher's Exact Test

Cell (1,1) Frequency (F)	51
Left-sided Pr <= F	1.0000
Right-sided Pr >= F	0.2376
Table Probability (P)	0.2376
Two-sided Pr <= P	0.2376

Sample Size = 100

Chi square tests of the recovery of adult steelhead kelt
 11:23 Wednesday, April 20, 2011
 released through Bonneville Dam, March 2011.

----- Description=B2 -----

The FREQ Procedure

Table of release by cond

release	cond	
Frequency		
Expected		

Cell Chi-Square	alive	dead	unkn	Total
B2	1	71	1	75
		72	0.75	2.25
		0.0139	0.0833	0.25
B2	2	25	0	25
		24	0.25	0.75
		0.0417	0.25	0.75
Total	96	1	3	100

Statistics for Table of release by cond

Statistic	DF	Value	Prob
Chi-Square	2	1.3889	0.4994
Likelihood Ratio Chi-Square	2	2.3565	0.3078
Mantel-Haenszel Chi-Square	1	1.2926	0.2556
Phi Coefficient		0.1179	
Contingency Coefficient		0.1170	
Cramer's V		0.1179	

WARNING: 67% of the cells have expected counts less than 5. Chi-Square may not be a valid test.

Sample Size = 100

APPENDIX D
SURVIVAL AND MALADY-FREE DATA

Appendix D-1

Daily tag-recapture data for adult steelhead kelts, passed through Bonneville Dam, March 2011. Controls released into the tailrace discharge downstream at the boat launch.

	3/1	3/2	3/3	3/4	Totals
<u>BON 1 ITS</u>					
Number released	51	49	--	--	100
Number alive	51	47	--	--	98
Number recovered dead	0	0	--	--	0
Assigned dead	0	2	--	--	2
Dislodged tags	--	--	--	--	0
Stationary radio signals*	--	2	--	--	2
Undetermined	0	0	--	--	0
Held and Alive 1 h	51	47	--	--	98
Alive 24 h	51	47	--	--	98
Alive 48 h	51	47	--	--	98
<u>BON 2 CC</u>					
Number released	--	--	75	25	100
Number alive	--	--	71	25	96
Number recovered dead	--	--	0	0	0
Assigned dead	--	--	1	0	1
Dislodged tags	--	--	--	--	0
Stationary radio signals*	--	--	1	--	1
Undetermined	--	--	3	0	3
Held and Alive 1 h	--	--	71	25	96
Alive 24 h	--	--	71	25	96
Alive 48 h	--	--	70	25	95
<u>Controls</u>					
Number released	--	--	--	37	37
Number alive	--	--	--	37	37
Number recovered dead	--	--	--	0	0
Assigned dead	--	--	--	0	0
Dislodged tags	--	--	--	--	0
Stationary radio signals	--	--	--	--	0
Undetermined	--	--	--	0	0
Held and Alive 1 h	--	--	--	37	37
Alive 24 h	--	--	--	37	37
Alive 48 h	--	--	--	37	37

* Likely seal predation

Appendix D-2

Daily 48 h survival/malady free data observed on recaptured adult steelhead kelts, passed through Bonneville Dam, March 2011. Controls released into the tailrace discharge downstream at the boat launch.

	3/1	3/2	3/3	3/4	Totals
		<u>BON 1 ITS</u>			
Number released	51	49	--	--	100
Number examined	51	47	--	--	98
Number alive and malady free	50	47	--	--	97
Maladies / died	1	0	--	--	1
Number assigned dead	0	2	--	--	2
Undetermined	0	0	--	--	0
		<u>BON 2 CC</u>			
Number released	--	--	75	25	100
Number examined	--	--	71	25	96
Number alive and malady free	--	--	70	25	95
Maladies / died	--	--	1	0	1
Number assigned dead	--	--	1	0	1
Undetermined	--	--	3	0	3
		<u>Controls</u>			
Number released	--	--	--	37	37
Number examined	--	--	--	37	37
Number alive and malady free	--	--	--	37	37
Maladies / died	--	--	--	0	0
Number assigned dead	--	--	--	0	0
Undetermined	--	--	--	0	0

Appendix D-3

Daily malady data for adult recaptured adult steelhead kelts, passed through Bonneville Dam, March 2011. Controls released into the tailrace discharge downstream at the boat launch.

	3/1	3/2	3/3	3/4	Totals
<u>BON 1 ITS</u>					
Number released	51	49	--	--	100
Number examined	51	47	--	--	98
Passage related maladies	1	0	--	--	1
Visible injuries	1	--	--	--	1
Loss of equilibrium only	--	--	--	--	0
Without maladies	50	47	--	--	97
Without maladies that died	0	0	--	--	0
<u>BON 2 CC</u>					
Number released	--	--	75	25	100
Number examined	--	--	71	25	96
Passage related maladies	--	--	1	0	1
Visible injuries	--	--	1	--	1
Loss of equilibrium only	--	--	--	--	0
Without maladies	--	--	70	25	95
Without maladies that died	--	--	0	0	0
<u>Adults Controls</u>					
Number released	--	--	--	37	37
Number examined	--	--	--	37	37
Passage related maladies	--	--	--	0	0
Visible injuries	--	--	--	--	0
Loss of equilibrium only	--	--	--	--	0
Without maladies	--	--	--	37	37
Without maladies that died	--	--	--	0	0