U.S. Army Corps of Engineers
Portland District

Survival estimates of migrant juvenile salmonids in the Columbia River through The Dalles Dam using radiotelemetry, 2004.

Final Report of Research
April, 2006

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Contract No. W66QKZ40369527

Submitted:
April 24, 2006

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Executive Summary

During 2004, the USGS, Columbia River Research Laboratory evaluated the survival of yearling and subyearling Chinook salmon at The Dalles Dam during 40% spill operations. The objectives of these evaluations were to estimate the survival probabilities of juvenile Chinook salmon through the spillway, the ice and trash sluiceway, and the turbines. The route-specific estimates of passage and survival probabilities were then combined to estimate dam survival. Radio-tagged fish released in the tailraces of John Day Dam and The Dalles Dam, as well as releases directly into and below the ice and trash sluiceway were interrogated using radiotelemetry systems at and below The Dalles Dam. The capture histories generated from the interrogated fish were processed and analyzed using the route-specific survival model (Skalski et al. 2002) to estimate survival for the spring and summer study periods and for eight-day increments. We also evaluated a new survival estimation procedure, the triple-release model (Peven et al. 2005) that was formulated to address the potential for bias in the route-specific survival model. The paired release-recapture model was used to estimate survival through the ice and trash sluiceway and for the post-hoc evaluation of spillbay specific survival. The Dalles Dam survival estimates for 2004 are summarized in the Executive Summary Table.

Route-specific survival model

Yearling Chinook salmon

During the spring of 2004, The Dalles Dam was operated so that approximately 40% of total river flow was sent through the spillway 24 h a day. Under this operation, the estimated survival of radio-tagged yearling Chinook salmon was highest through the ice and trash sluiceway (S = 0.981, SE = 0.016, profile likelihood 95% confidence interval = 0.943, 1.01), followed by the spillway (S = 0.909, SE = 0.008, profile likelihood 95% confidence interval = 0.892, 0.925), and lowest through the turbines (S = 0.797, SE = 0.036, profile likelihood 95% confidence interval = 0.722, 0.863). Yearling Chinook salmon dam survival was estimated to be 0.906 (SE = 0.008, 95% confidence interval = 0.890, 0.922), pool survival was estimated to be 0.956 (SE = 0.005, 95% confidence interval = 0.947, 0.965), and project survival (the product of dam and pool survival) was estimated to be 0.866 (SE = 0.012, 95% confidence interval = 0.843, 0.889).

Subyearling Chinook salmon

During the summer of 2004, The Dalles Dam was operated so that approximately 40% of total river flow was sent through the spillway 24 h a day. Under this operation, the estimated survival of radio-tagged subyearling Chinook salmon was highest through the spillway (S = 0.860, SE = 0.011, profile likelihood 95% confidence interval = 0.838, 0.881), followed by the turbines (S = 0.674, SE = 0.031, profile likelihood 95% confidence interval = 0.613, 0.733), and lowest through the ice and trash sluiceway (S =

0.668, *SE* = 0.045, profile likelihood 95% confidence interval = 0.577, 0.753). Subyearling Chinook salmon dam survival was estimated to be 0.817 (*SE* = 0.011, 95% confidence interval = 0.795, 0.839), pool survival was estimated to be 0.850 (*SE* = 0.008, 95% confidence interval = 0.834, 0.865), and project survival (the product of dam and pool survival) was estimated to be 0.694 (*SE* = 0.014, 95% confidence interval = 0.667, 0.720).

Triple-release model

Yearling Chinook salmon

The absolute survival of yearling Chinook salmon through The Dalles Dam spillway was estimated to be 0.947 (*SE* = 0.025; 95% confidence interval = [0.897, 0.997]) using the triple-release model. For yearling Chinook passing the ice and trash sluiceway the estimated survival was 0.989 (*SE* = 0.014, 95% confidence interval [0.963, 1.016]) and for yearling Chinook passing via the turbines the estimated survival was 0.800 (*SE* = 0.046, 95% confidence interval [0.709, 0.890]). Yearling Chinook salmon dam survival was estimated to be 0.942 (*SE* = 0.024, 95% confidence interval = [0.894, 0.990]) during 40% spill operations at The Dalles Dam during 2004.

Subyearling Chinook salmon

The absolute survival of subyearling Chinook salmon through The Dalles Dam spillway was estimated to be 1.276 (*SE* = 0.095; 95% confidence interval = [1.091, 1.462]) using the triple-release model. For subyearling Chinook passing the ice and trash sluiceway the estimated survival was 0.982 (*SE* = 0.023, 95% confidence interval [0.936, 1.027]) and for subyearling Chinook passing via the turbines the estimated survival was 0.968 (*SE* = 0.086, 95% confidence interval [0.801, 1.136]). Subyearling Chinook salmon dam survival was estimated to be 1.214 (*SE* = 0.078, 95% confidence interval = [1.062, 1.366]) during 40% spill operations at The Dalles Dam during 2004.

Paired release-recapture model - ice and trash sluiceway survival

Yearling Chinook salmon

We estimated that the survival of yearling Chinook salmon through the ice and trash sluiceway to the release location of the control fish immediately below the ice and trash sluiceway ranged from 0.731 to 1.119. The average survival was estimated to be 0.988 (*SE* = 0.015, 95% confidence interval [0.957, 1.019]).

We estimated that the survival of yearling Chinook salmon through the ice and trash sluiceway to the release location of the control fish approximately 550 m downstream of the dam, beneath the I-197 bridge ranged from 0.789 to 1.152. The average survival was estimated to be 0.957 (*SE* = 0.016, 95% confidence interval [0.924, 0.991]).

Subyearling Chinook salmon

We estimated that the survival of subyearling Chinook salmon through the ice and trash sluiceway to the release location of the control fish immediately below the ice and trash sluiceway ranged from 0.586 to 3.625. The average survival was estimated to be 1.060 (*SE* = 0.083, 95% confidence interval [0.893, 1.228]).

We estimated that the survival of subyearling Chinook salmon through the ice and trash sluiceway to the release location of the control fish approximately 550 m downstream of the dam, beneath the I-197 bridge ranged from 0.189 to 1.068. The average survival was estimated to be 0.804 (*SE* = 0.031, 95% confidence interval [0.741, 0.866]).

Paired release-recapture model - spillbay specific survival

Yearling Chinook salmon

We estimated that the survival of yearling Chinook salmon through spillbays 1-4 ranged from 0.730 to 1.042, and averaged 0.933 (*SE* = 0.014, 95% confidence interval = [0.906, 0.960]). The estimated survival through spillbays 5-6 ranged from 0.740 to 1.000, and averaged 0.894 (*SE* = 0.014, 95% confidence interval [0.866, 0.922]).

Subyearling Chinook salmon

We estimated that the survival of subyearling Chinook salmon through spillbays 1-4 ranged from 0.602 to 1.032, and averaged 0.907 (*SE* = 0.019, 95% confidence interval [0.869, 0.945]). The estimated survival through spillbays 5-6 ranged from 0.391 to 1.031, and averaged 0.800 (*SE* = 0.036, 95% confidence interval [0.730, 0.870]).

Executive Summary Table. The estimated survival probabilities (S) and 95% confidence intervals (95% CI) for radio-tagged yearling and subyearling Chinook salmon passing through The Dalles Dam during 2004.

		Yearling Chinook		Subyearling Chinook	
	Model	S	95% CI	S	95% CI
Project	Route-specific	0.866	0.843, 0.889	0.694	0.667, 0.720
Pool	Route-specific	0.956	0.947, 0.965	0.850	0.834, 0.865
Dam	Route-specific	0.906	0.891, 0.921	0.817	0.796, 0.838
	Triple-release	0.942	0.894, 0.990	1.214	1.062, 1.366
Turbines	Route-specific	0.797	0.722, 0.863 [A]	0.674	0.613, 0.733 [A]
	Triple-release	0.800	0.709, 0.890	0.968	0.801, 1.136
Sluiceway	Route-specific	0.981	0.943, 1.010 [A]	0.668	0.577, 0.753 [A]
	Triple-release	0.989	0.963, 1.016	0.982	0.936, 1.027
	Paired release[B]	0.987	0.956, 1.018	1.060	0.893, 1.228
	Paired release[C]	0.957	0.924, 0.991	0.804	0.741, 0.866
Spillway	Route-specific	0.909	0.892, 0.925[A]	0.860	0.838, 0.881[A]
	Triple-release	0.947	0.897, 0.997	1.276	1.091, 1.462
Spillbays 1-4	Paired release	0.933	0.906, 0.960	0.907	0.869, 0.945
Spillbays 5-6	Paired release	0.894	0.866, 0.922	0.800	0.730, 0.870

[A]- Profile likelihood 95% confidence interval
[B]- Survival to the release location of control fish immediately below the ice and trash sluiceway
[C]- Survival to the release location of control fish released approximately 550 m downstream of the dam, beneath the I-197 bridge

Introduction

As anadromous juvenile salmonids migrate from freshwater rearing habitats to the ocean, they are vulnerable to a host of factors that affect their survival. Direct effects associated with dam passage (e.g., instantaneous mortality, injury, and loss of equilibrium) and indirect effects (e.g., predation, disease, and physiological stress) contribute to the total mortality of seaward migrating salmonids. Many studies (Raymond 1979, Stier and Kynard 1986, Iwamato et al. 1994, Muir et al. 1995, Smith et al. 1998, Bickford and Skalski 2000) have been conducted to estimate dam, reach, and route-specific (i.e. through spillways, bypass areas, and turbines) survival of juvenile salmon to help identify the potential sources of mortality. Based on these studies examining migrant salmonid behavior at dams in the Columbia River Basin, management actions are currently being implemented to improve the survival of juvenile salmonid migrants.

An objective of the National Marine Fisheries Service (NMFS) Federal Columbia River Power System (FCRPS) Biological Opinion is to increase survival of juvenile salmonid out-migrants through the federal hydrosystem (NMFS 2000). The 2000 Biological Opinion proposed the implementation of a spill program that was expected to provide a safer route of project passage than turbine passage. While there is consensus that survival is greater for fish diverted from turbines, questions regarding the effectiveness of different spill patterns and other passage scenarios remain (Dawley et al. 1998). Normandeau Associates et al. (1996) expressed concerns that spillway survival at The Dalles Dam was lower than other dams. For example, in 2000 the survival through the spillway was estimated to be 92.7% (Counihan et al. 2002) whereas other dams average 98% (Ploskey et al. 2001). The lower than expected spill passage survival under high spill conditions at The Dalles Dam could be due to 1) a short stilling basin and shallow tailrace, resulting in severe turbulence and lateral currents that may cause physical injury to migrant salmon, and 2) a large proportion of spillway-passed water moves through shallows and islands downstream where predation on salmonids by gulls (*Larus* spp.), northern pikeminnow (*Ptychocheilus oregonensis*), and smallmouth bass (*Micropterus dolomieu*) may be substantially higher than at other dams. In recent years various spill levels and configurations have been implemented to increase survival.

Survival studies by the NMFS at The Dalles Dam during 1997-2000 and the USGS in 2000 indicated spillway survival at 30% spill and 24 h 40% spill was typically higher than spillway survival at 64% spill; survival through the sluiceway was similar to the 30% spillway survival (Ploskey et al. 2001). In addition to spill level, NMFS found that survival for subyearling Chinook salmon was consistently higher at night than during the day. Previous studies were not able to separate day versus night spill pattern changes; however, the increased night survival was believed to be a result of passing during the juvenile spill pattern, which was used only at night. In 2000, 40% spill and the juvenile spill pattern were used 24 h a day. Observed spill passage efficiency values under the 24 h 40% spill pattern were similar to those seen at 64% spill in previous years, and even though survival was found to be higher at the lower spill (30–40%) percentages, the

survival of juvenile salmonids passing this project was determined to be unacceptably low for a primary passage route.

Results from studies conducted in 2001 – 2003 suggest that juvenile salmon passing through the stilling basin at The Dalles Dam may be susceptible to injury and mortality caused by lateral flow that passes along the stilling basin's length from south to north. During 2001, the USGS continued evaluations of the survival of yearling and subyearling Chinook salmon at The Dalles Dam, however, the emphasis shifted from developing point estimates of survival under varying operating conditions, to identifying the causal mechanisms of mortality. During 2002, evaluations of survival at the spillway suggested that survival was significantly lower for yearling Chinook salmon that passed via spillbay 13 (south) vs. spillbay 4 (north). A similar trend was seen for subyearling Chinook salmon, although the difference was not statistically significant. A concurrent engineering study determined that lateral flow in the stilling basin could be blocked by a longitudinal training wall extending from the downstream spillway pier nose between bays 6 and 7 to the end sill. Balloon-tag studies were conducted in 2003 to determine the amount of spill per bay that can be discharged with minimal fish injury and mortality. Preliminary results suggest that for typical summer migrant river conditions, 40% of the total river discharge could safely be passed through bays 1-6 with no measurable increase in fish injury or mortality.

During 2004, the USGS, Columbia River Research Laboratory evaluated the survival of yearling and subyearling Chinook salmon at The Dalles Dam during 40% spill operations. The objectives of these evaluations were to estimate the survival probabilities of yearling and subyearling Chinook salmon through the ice and trash sluiceway, spillway, and turbines, as well as dam survival after the construction of the training wall. Yearling and subyearling Chinook salmon were radio tagged and then interrogated using radiotelemetry systems at and below The Dalles Dam. The capture histories generated were then processed and analyzed using the route-specific survival model (RSSM; Skalski et al. 2002). In addition, we evaluated a new survival estimation procedure, the triple-release design (Peven et al. 2005) that was formulated to address the potential for bias in the RSSM.

Methods

Study area and system antenna configuration

To estimate the route-specific and dam survival of juvenile salmonids at The Dalles Dam during the 2004 spring and summer out migrations, we monitored radio-tagged juvenile salmonids released in the tailraces of John Day Dam and The Dalles Dam, as well as site-specific releases directly into and immediately below the ice and trash sluiceway. The study area (e.g., zone of inference; Peven et al. 2005) extended from John Day Dam downriver to Bonneville Dam (Figure 1). Antenna arrays within the study area were located on The Dalles Dam (RK 308.1), at the Chamberlain Lake Rest Area (RK 286.1), near the town of Lyle, WA (RK 285.8), 18 Mile Island (RK 279.8), at Koberg State Park (RK 275.3), near the town of Underwood, WA on the bluff (RK 270), at Spring Creek Hatchery (RK 268.9, spring only), on the Bridge of the Gods (RK 238.6), and on Bonneville Dam (RK 235.1). All detection arrays spanned the breadth of the river channel. The array at The Dalles Dam was set up so that passage route could be determined (Hansel et al. 2005).

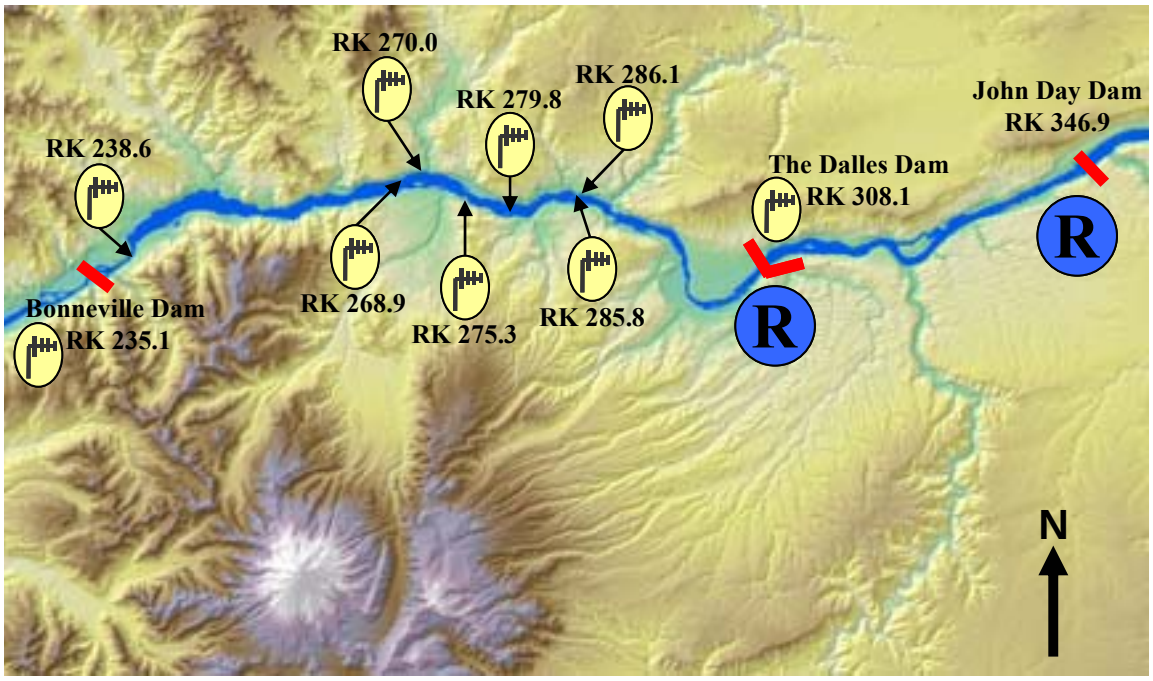

Figure 1. Release and detection locations for The Dalles Dam survival evaluation during 2004. Yellow ovals show locations of radio telemetry arrays, the red polygons represent the dams, and ® indicates release locations. River kilometers are given for each location.

The Dalles Dam consists of a single powerhouse of 22 horizontal-axis turbine units, each with three intakes, and a spillway with 23 spillbays each controlled by a tainter gate (Figure 2). The powerhouse is oriented approximately perpendicular to the natural river thalweg. Openings in the dam at the water's surface above each turbine intake allow water and debris to flow into an ice and trash sluiceway. Water and debris flow to an outfall and plunge into the tailrace near the powerhouse outflow. A non-overflow wall connects the powerhouse and spillway. A navigation lock is located at the northwest end of the dam. The dam has two adult fish ladders, one between the spillway and navigational lock, the other at the east end of the powerhouse.

Figure 2. Aerial view of The Dalles Dam looking upriver (northeast).

The radio telemetry antenna arrays at The Dalles Dam that were used to monitor movements and passage location of radio-tagged fish consisted of 4-element yagi aerial antennas and dipole underwater antennas placed on the forebay and tailrace sides of the dam and in the ice and trash sluiceway. On the forebay side of the dam, we placed 12 aerial antennas on the spillbays, 12 aerial antennas on the turbine bays, and 8 aerial antennas on the non-overflow wall. Each aerial antenna monitoring the spillway or powerhouse was directed 45° away from the dam and provided coverage for two adjacent bays. A total of 90 underwater antennas were attached to the spillway forebay pier noses, and 81 underwater antennas monitored the powerhouse forebay intakes. On the tailrace side, we placed 12 aerial antennas on the spillway and 12 aerial antennas on the powerhouse. The ice and trash sluiceway was monitored with 7 aerial antennas and 6 underwater antennas. The detection range for aerial antennas was approximately 100 m, but varied with the depth of the transmitter in the water column; the detection range for

underwater antennas was 10 m. Antennas were connected to either an SRX-400 data logging telemetry receiver (Lotek Wireless, Newmarket, Ontario, Canada), or a Multiprotocol Integrated Telemetry Acquisition System (MITAS; Grant Systems Engineering, King City, Ontario, Canada). Data logging devices stored detection records for individual channel codes; data were downloaded to a laptop computer every day.

Radio transmitters

We used pulse-coded transmitters (tags) manufactured by Lotek Engineering, Inc. (Newmarket, Ontario, Canada). Two sizes of transmitters were used to tag the juvenile yearling and subyearling Chinook migrants. Transmitters implanted in yearling Chinook salmon were 7.3 mm in diameter x 18.0 mm in length and weighed 1.4 g in air (Lotek Wireless model MCFT-3KM), and those implanted in subyearling Chinook salmon were 6.3 mm x 4.5 mm x 14.5 mm long and weighed 0.85 g in air (Lotek Wireless model NTC-3-1). Both types of tags had antennas 29.5 cm in length. Transmitters operated at frequencies between 150.280 and 150.760 MHz and used a pulse-coding scheme with 212 unique codes per frequency that allow each individual fish to be recognized. Transmitters emitted radio signals every 2 seconds; at this pulse rate the expected battery life was 8 days for both types of transmitters.

Fish tagging

Yearling and subyearling Chinook salmon that were radio tagged and released at John Day and The Dalles dams were collected from the juvenile collection and bypass facility at John Day Dam. Fish released at John Day Dam were held at the collection facility for approximately 12 to 36 h prior to tagging. Fish released at The Dalles Dam were collected at John Day Dam, transported to The Dalles Dam, and held approximately 12 to 36 h prior to tagging. Fish were considered suitable for tagging if they were free of recent injuries, severe descaling, external signs of gas bubble trauma, and other diseases and abnormalities, and met the minimum weight criterion. To minimize the impact of the tag, fish size criteria were established so that the radio tag weight in air would not exceed 6.5% of a fish's weight in air. The minimum weight for yearling Chinook salmon implanted with a Lotek Wireless model MCFT-3KM tag (weight = 1.4 g in air) was 21.5 g (with a corresponding estimated length of 130 mm), and for subyearling Chinook salmon implanted with a Lotek model NTC-3-1 "nanotag" (weight = 0.85 g in air) the minimum weight was 13 g (with a corresponding estimated length of 110 mm). Transmitters were gastrically implanted using the methods of Martinelli et al. (1998). After tagging, fish were held for approximately 18 to 28 h in perforated 19 L buckets (2 fish per bucket), in large, insulated, metal tanks supplied with flow-through river water. After the holding period, any dead fish or regurgitated transmitters were removed. Water quality parameters (temperature, dissolved oxygen, and total dissolved gas) were monitored to assure proper conditions for holding and transporting fish.

Release strategy

Radio-tagged yearling and subyearling Chinook salmon were released from boats into the John Day Dam tailrace approximately 2.5 km downstream of the dam (Appendix 1, Tables A1.1 and A1.5), and into The Dalles Dam tailrace approximately 550 m downstream of the dam, beneath the I-197 bridge (Appendix 1, Tables A1.2 and A1.6). Releases into the tailrace at The Dalles Dam were timed to coincide with the arrival of fish released in the tailrace at John Day Dam. The timing of the releases was formulated using a regression equation developed from the relationship between radio-tagged juvenile Chinook travel time data collected in past studies and dam discharge.

To accommodate the design considerations for the triple-release model, paired releases of fish were made into and immediately below the ice and trash sluiceway at The Dalles Dam (Appendix 1, Tables A1.3, A1.4, A1.7 and A1.8). Radio-tagged yearling and subyearling Chinook salmon were released into the ice and trash sluiceway near The Dalles Dam powerhouse main unit one. Flexible hose (0.1 m diameter), connected to the lower end of a 0.8 m diameter circular tank, extended over the parapet wall, dropped approximately 8 m to the water's surface, and was secured to a scintillation frame (Figure 3). Prior to releasing fish, a hose supplying well water was turned on to fill the release tank and eliminate any air pockets within the release hose. The temperature of the well water was measured before each release and was found to always be within two degrees Celsius of river temperature. Two radio-tagged fish at a time were put into the release tank. Fish generally exited the release tank within 5 s. Water was continuously routed through the tank and release hose to ensure that fish exited at the bottom. Releases at the sluiceway were made once a day at approximately 0100, 0700, 1300, or 1900 hours. Releases were randomized and equally allocated among the four release times. Release times were the midpoints of 6-hour blocks of divergent discharge conditions seen at The Dalles Dam in diel discharge patterns.

Figure 3. Ice and trash sluiceway release locations of yearling and subyearling Chinook salmon at The Dalles Dam, 2004. A. Two fish are transferred from the holding bucket into the release tank. B. Release hose that extends from the release tank on the deck of the dam to the ice and trash sluiceway. C. Sluiceway tailrace release location indicated by ®.

Converting radio signals into detection histories

After data collection, radio signals have to be interpreted and converted into detection histories. Aerial and underwater antennas attached to data logging equipment will often record spurious radio signals or "noise" and designate them as such, or misinterpret other radio signals (e.g., from cars or trucks) and label them with fish channel and code designations. We performed automated data processing using Statistical Analysis System (SAS) software to separate spurious radio signals from true radio signals and assign passage and location designators. The following criteria were used to classify data records as noise:

1. Records composed of invalid channel and code combinations, typically a result of erroneous radio transmissions (noise) that overlap with the radio frequencies that we are monitoring.
2. Records logged before a fish's release.
3. Records below an empirically determined signal strength threshold for each aerial and underwater array.
4. Fewer than two records recorded within a 20-min period for an individual fish.
5. Fewer than 5 records in a 60-min interval on the MITAS underwater antenna array for an individual fish.
6. Fewer than 5 records in a 60-min interval on a single aerial receiver unsupported by at least one record on the corresponding forebay aerial or underwater array during the same hour.
7. Fewer than 5 records in a 60-min interval unsupported by a minimum of two other records recorded on one receiver at the entrance, tailrace, or exit stations during the hour interval before or after the detections.

Once all times and locations of interest (events) were electronically assigned, individual fish histories were verified using criteria derived from manually-proofed radiotelemetry data obtained in past years for the same species. A fish's event history was considered potentially suspect if 1) the travel time between release and first forebay, tailrace, or exit detection, or travel time between sequential events was less than the 5th or greater than the 95th percentiles of past data from a similar flow year, 2) forebay, tailrace, and exit residence times exceeded the 95th percentile of similar past year's metrics, or 3) a fish's events were chronologically or geographically out of order. Fish whose event histories were suspect because of one or more of the above criteria were flagged to be manually proofed and reconciled with the electronic proof prior to further analyses. In addition to the flagged files, a random 10% of the fish from non-flagged files were manually examined by separate proofing staff and then reconciled by another staff member if any disagreement in either the time of passage or passage location were noted between the electronically assigned events and the manually assigned events.

Statistical methods

Route-specific survival model

Model assumptions

There are assumptions associated with using the route-specific survival model to estimate survival, some are biological and some pertain to the statistical models (Skalski et. al. 2002). The validity of some of the assumptions listed below can be evaluated using statistical tests and others can be met through careful consideration of fish collection, holding, tagging, and detection techniques. The assumptions associated with the route-specific survival model (RSSM) are described in detail in Skalski et al. (2002).

Assumptions of the RSSM are:

A1. Individuals marked for the study are a representative sample from the population of interest.

A2. Survival and capture probabilities are not affected by tagging or sampling (i.e., tagged animals have the same probabilities as untagged animals).

A3. All sampling events are "instantaneous" (i.e., sampling occurs over a short time relative to the length of the intervals between sampling events).

A4. The fate of each tagged individual is independent of the fate of all others.

A5. All tagged individuals alive at a sampling location have the same probability of surviving until the end of that event.

A6. All tagged individuals alive at a sampling location have the same probability of being detected.

A7. All tags are correctly identified and the status of fish (i.e., alive or dead) is correctly identified.

A8. Survival in the upriver segment (S) is conditionally independent of survival in the lower river segment.

A9. Both the upstream and downstream release groups within a paired release experience the same survival probability in the segment of the river that they travel together.

A10. Routes taken by the radio-tagged fish are known without error.

A11. Detections in the primary and secondary antenna arrays within a passage route are independent.

Assumption A1 of release-recapture models used to estimate survival of juvenile salmonids is that individuals marked for the study are a representative sample from the population of interest. In accordance with this assumption, we tag a range of sizes of fish and choose radiotelemetry tagging dates to coincide with the run timing for run-of-river fish. However, there are technological (e.g., tag size) and logistical (e.g., availability of fish of appropriate size) limitations dictating the size of fish tagged and the timing of the study. To minimize the impact of the tag, fish size criteria were established so that the radio tag weight in air would not exceed 6.5% of a fish's weight in air, and the tag volume would not rupture the fish's stomach. The minimum weight for yearling Chinook salmon implanted with Lotek Wireless model NTC-3-1-KMF tags (weight in air = 0.98 g, volume = 0.60 ml) was 21.5 g, with a corresponding estimated fork length of 130 mm, and for subyearling Chinook salmon implanted with Lotek model NTC-M-2 tags (weight in air = 0.43 g, volume = 0.22 ml) the minimum weight was 10 g, with a corresponding estimated fork length of 100 mm. Due to these limitations the resultant data need to be viewed critically in the context of these assumptions.

Assumption A2 again concerns making inferences to the target population (i.e., untagged fish). If tagging has a detrimental effect on fish survival, then survival estimates from the route-specific survival model will tend to be negatively biased. To limit tagging effects we have used the criteria established in Adams et al. (1998). Also, tagging should affect upstream and downstream release groups similarly, thus minimizing or eliminating any bias when survival is calculated.

The third assumption, A3, stipulates that mortality is negligible immediately near the sampling stations, so that the estimated mortality is associated with the river reaches and not the sampling event. For migrant salmonids, the time spent near detection equipment is typically brief relative to the time spent in the river reaches.

The assumption of independence, A4, suggests that the survival or death of one smolt has no effect on the fates of others. In the Columbia River where many thousands of migrants can be found, this is likely true. Violations of assumption A4 may bias the variance estimate (true variability would be greater than estimated).

Assumption A5 specifies that the prior detection history of the tagged fish does not affect subsequent survival. The lack of handling following initial release of radio-tagged fish minimizes the risk that detections affect survival. Similarly, assumption A6 could be violated if downstream detections were influenced by upstream passage routes taken by tagged fish. Violation of this assumption is minimized by placing radiotelemetry arrays across the breadth of the river or below the mixing zones for fish using different passage routes.

Assumption A6 states that all live tagged individuals should have the same probability of being detected at downstream detection arrays. However, radio-tags have a

limited and varied battery life. Radio-tag battery life may be affected by water temperature and may vary among years or production batches. Survival estimates may be biased if radio-tags expire prior to fish exiting all the detection arrays. To address the probability of tag failure at detection arrays a tag-life study was performed. Information obtained from a tag-life study can be used to adjust survival estimates if necessary (Townsend et al. 2004, Cowen and Schwartz 2005).

Assumption A7 implies that fish do not lose their tags and are subsequently misidentified as non-detected, or dead fish are not falsely recorded as alive at detection locations. Tag loss and tag failure would result in a negative bias (i.e., underestimation) of fish survival rates. Typically, the retention rate of active transmitters is high suggesting that the effects of tag loss on survival estimates would be minimal. The possibility of radio-tag failure will depend on travel time relative to battery life. To address the probability of tag failure at detection arrays, we performed a tag life study to determine potential bias in survival estimates. Dead fish drifting downstream could result in false-positive detections and upwardly bias survival estimates. Tailrace antenna arrays are therefore not used in estimating survival because they are too close to locations of potential mortality. In addition dead radio-tagged fish are released throughout the season with live radio-tagged fish.

Assumption A8 implies that smolts that survive the first river segment are no more or less susceptible to mortality in the second river segment than smolts released in the second river segment. And similarly, A9 specifies that upriver and downriver release groups in a paired release experience the same survival probability in the segment of river they travel together. A9 can be satisfied by downstream mixing of the two groups or if the survival process is stable over the course of smolt passage. Under similar flow and spill conditions, a stable survival process should be expected.

Skalski et al. (2002) suggest that assumption A10 can be qualitatively assessed by examining radio telemetry detection histories to determine whether inconsistencies in individual fish detection histories exist. Skalski et al. (2002) use an example of a situation where a radio-tagged fish is detected in the upstream array of a route and then in the downstream array of another route, resulting in uncertainty in the route taken. That is they used aerial antennas that monitored the tailrace area to help determine passage. Similar to the radiotelemetry system used in Skalski et al (2002), the double array we employed at The Dalles Dam consisted of aerial and underwater telemetry systems that interrogated fish in the immediate forebay area of each particular route, with the exception of the ice and trash sluiceway where underwater antennas were placed at two locations within the structure. However, while we did have a radiotelemetry system monitoring the tailrace area of each route, we did not consider detections in the tailrace when determining passage routes.

Skalski et al. (2002) determined that while assumption A11 is necessary for valid estimation of in-route detection probabilities, the assumption cannot be empirically assessed with the data collected with this type of study. Rather, they suggest that the detection fields of the primary and secondary arrays should be located in a way that fish

detected in one array does not have a higher or lower probability of being detected in the secondary array than the primary array. Further, they suggest that this is best accomplished by having independent receivers for each antenna array and by having the detection field of at least one array encompass the entire passage route. The arrays we deployed at the ice and trash sluiceway, spillway and turbines conform to these requirements.

Parameter estimation

The double radiotelemetry array systems that we deployed at The Dalles Dam allowed us to estimate route-specific detection probabilities. In turn, these route-specific detection probabilities can be incorporated into a statistical analysis that will extract route-specific passage and survival (Skalski et. al. 2002). The following parameters were defined for the construction of the RSSM used at The Dalles Dam: S_{POOL}, survival probability of treatment group from the release site at John Day Dam to the point of detection within passage routes at The Dalles Dam; E, the probability that fish will pass over the spillway; G, conditional probability of guidance into the ice and trash sluiceway, given that fish were going to the powerhouse (1-E); P_{TURB}, turbine primary array detection probability; ($q_{TURB} = 1 - P_{TURB}$); P'_{TURB}, turbine secondary array detection probability; ($q_{TURB} = 1-P'_{TURB}$); P_{SPILL}, spillway primary array detection probability; ($q_{SPILL} = 1 - P_{SPILL}$); P'_{SPILL}, spillway secondary array detection probability; ($q_{SPILL} = 1 - P'_{SPILL}$); P_{SLU}, sluiceway primary array detection probability; ($q_{SLU} = 1 - P_{SLU}$); P'_{SLU}, sluiceway secondary array detection probability; ($q_{SLU} = 1 - P'_{SLU}$); S_{TURB} , turbine survival probability; S_{SPILL}, spillway survival probability, S_{SLU}, ice and trash sluiceway survival probability, λ, joint probability of surviving and being detected at the arrays below The Dalles Dam. The releases made in the John Day Dam tailrace (R_1) and the releases in The Dalles Dam tailrace (R_2) were interrogated at eight arrays below The Dalles Dam, the furthest downriver being an array deployed on Bonneville Dam (Figure 1). A branching process was used to model the migration and survival of releases R_1 and R_2 (Figure 4). Additional details regarding the methodology used in the formulation of the RSSM and the estimation of the associated parameters can be found in Skalski et al. (2002). For the RSSM survival probabilities both standard errors and profile likelihood 95% confidence intervals are reported (Sklaski et al. 2002).

The route-specific survival and passage probabilities can be combined using maximum likelihood estimation to estimate survival through the dam. The survival through The Dalles Dam was estimated from the expression

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

The variance for the dam survival estimate was estimated using the delta method (Seber 1982, pp 7-9). All of the route-specific survival and passage probabilities were estimated using USER (User Specified Estimation Routine) developed at the University of Washington (Lady et al. 2003; see: www.cqs.washington.edu/paramEst/USER/).

Project survival was estimated from the expression

$$S_{PROJECT} = S_{POOL} \cdot S_{DAM}$$

Project survival estimates the survival of the fish released at John Day Dam to the release location of the fish released in the tailrace of The Dalles Dam approximately 550 m below the dam beneath the I-197 Bridge. The variance for the project survival estimate was also estimated using the delta method (Seber 1982, pp 7-9).

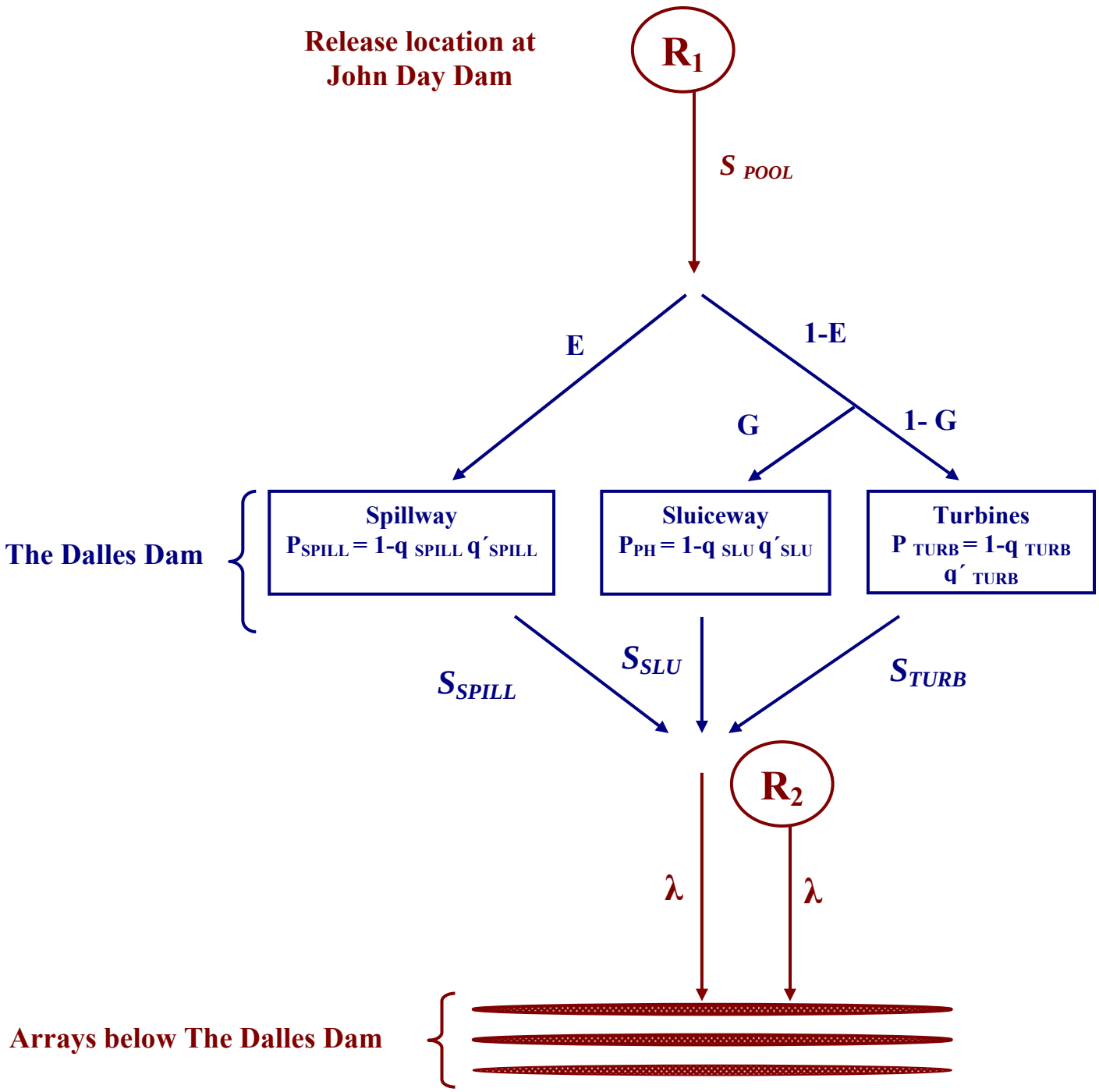

Figure 4. Schematic of route-specific passage and survival probabilities through The Dalles Dam for releases made at John Day Dam (RKM 347) and in the tailrace of The Dalles Dam (RKM 308).

Triple-release model

As discussed in Appendix 5, the route-specific survivals (Figure 5) were estimated in four steps. Rich Townsend and John Skalski, University of Washington provided the following discussion of methodology.

1. Estimate single-release survivals through each route using fish from the top-most release group (R_1) known to have passed through each route.
2. Estimate the relative survivals for the spillway (R_{sp}) and turbine (R_{turb}) routes to the sluiceway survival.
3. Estimate absolute survival through the sluiceway (S_L) using the paired releases (R_2 and R_3).
4. Using the absolute sluiceway survival and relative survivals, estimate absolute survival through the spillway and turbines.

Single-release survival estimation

Fish traveling through each Dalles Dam passage route are treated as a single release. As such, survival cannot be parsed between survival through a passage route and survival from the Dalles Dam tailrace to the first detection site ($\hat{S}_1$). Each survival is estimated using the number of unique downstream detections of the fish known to have passed through each route, i.e.,

$$\widehat{S_{route} * S_1} = \frac{x_{route}}{n_{route}},$$

where $\widehat{S_{route} * S_1}$ = estimated survival from the top of a particular Dalles Dam *route* to the first detection site downriver, (*route* = *TURB* (turbines), *SP* (spillway), or *SL* (sluiceway)).

x_{route} = total number of unique detections of fish known to have passed through a particular *route* detected downstream, and

n_{route} = total number of fish known to have passed through the *route*.

Assuming a binomial distribution, the variance on ($\widehat{S_{route} * S_1}$) is then

$$\mathrm{var}(\widehat{S_{route} * S_1}) = \frac{\left(\frac{x_{route}}{n_{route}}\right)\left(1 - \frac{x_{route}}{n_{route}}\right)}{n_{route}}.$$

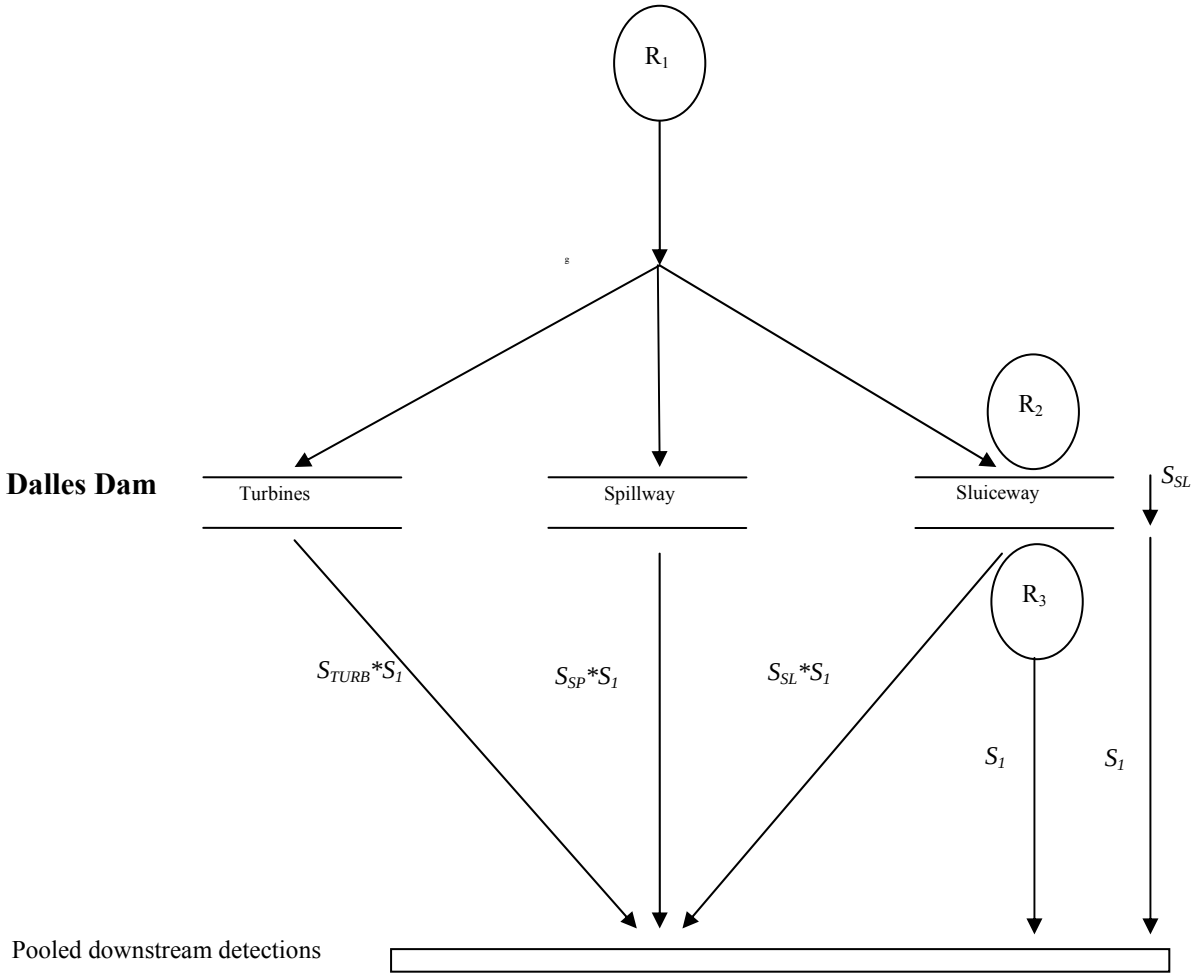

Figure 5. Schematic of Dalles Dam triple-release survival study design with releases R_1, R_2, and R_3.

Relative survival estimation

To remove survival experienced from the Dalles Dam tailrace to the first detection site ($\hat{S}_1$), the single-release survival estimates for the spillway and turbines are divided by the sluiceway survival estimate to obtain a relative survival, i.e.

$$\hat{R}_{TURB/SL} = \frac{\widehat{S_{TURB} * S_1}}{\widehat{S_{SL} * S_1}} = \frac{\hat{S}_{TURB}}{\hat{S}_{SL}}, \text{ and} \qquad (1)$$

$$\hat{R}_{SP/SL} = \frac{\widehat{S_{SP} * S_1}}{\widehat{S_{SL} * S_1}} = \frac{\hat{S}_{SP}}{\hat{S}_{SL}}$$

Variance estimates for each relative survival are

$$\widehat{Var}(\hat{R}_{TURB/SL}) = \left(\frac{\widehat{S_{TURB} * S_1}}{\widehat{S_{SL} * S_1}} \right)^2 * \left(\frac{\widehat{Var}\left(\widehat{S_{TURB} * S_1}\right)}{\left(\widehat{S_{TURB} * S_1}\right)^2} + \frac{\widehat{Var}\left(\widehat{S_{SL} * S_1}\right)}{\left(\widehat{S_{SL} * S_1}\right)^2} \right), \text{ and}$$

$$\widehat{Var}(\hat{R}_{SP/SL}) = \left(\frac{\widehat{S_{SP} * S_1}}{\widehat{S_{SL} * S_1}} \right)^2 * \left(\frac{\widehat{Var}\left(\widehat{S_{SP} * S_1}\right)}{\left(\widehat{S_{SP} * S_1}\right)^2} + \frac{\widehat{Var}\left(\widehat{S_{SL} * S_1}\right)}{\left(\widehat{S_{SL} * S_1}\right)^2} \right).$$

Sluiceway passage survival

Assuming all releases experience the same probability of detection and survival for common stretches of the river traveled after release, survival through the sluiceway can be estimated with Ricker relative recovery estimates (1958) using the paired releases (R_2 and R_3).

$$\hat{S}_{SL} = \frac{\frac{x_{R_2}}{n_{R_2}}}{\frac{x_{R_3}}{n_{R_3}}}$$

where $\hat{S}_{SL}$ = estimated survival from the top of the Dalles Dam sluiceway to the first detection site downriver.

x_i = total number of unique detections from fish in Release i, (i = 1, 2) detected downstream, and

n_i = total number of fish in Release i, (i = 1, 2).

The variance for $\hat{S}_{SL}$ is estimated by

$$\widehat{Var}(\hat{S}_{SL}) = \left(\frac{x_{R_2} * n_{R_3}}{n_{R_2} * x_{R_3}} \right)^2 * \left(\frac{1}{x_{R_2}} - \frac{1}{n_{R_2}} + \frac{1}{x_{R_3}} - \frac{1}{n_{R_3}} \right).$$

Absolute passage survival for the turbines and spillway

Now that a good estimate for survival through the sluiceway has been calculated, the absolute survivals through the spillway and turbines can now be estimated. Rearranging the equation (1), and using the absolute survival through the sluiceway from the paired-release, absolute survivals are

$$\hat{S}_{PH} = \hat{R}_{PH/SL} * \hat{S}_{SL}, \text{ and}$$

$$\hat{S}_{SP} = \hat{R}_{SP/SL} * \hat{S}_{SL}.$$

Assuming independence between the relative survivals and sluiceway survival estimate, variances for each absolute survival are

$$\widehat{Var}(\hat{S}_{PH}) = \left(\hat{R}_{PH/SL}\right)^2 * \widehat{Var}(\hat{S}_{SL}) + \left(\hat{S}_{SL}\right)^2 * \widehat{Var}(\hat{R}_{PH/SL}), \text{ and}$$

$$\widehat{Var}(\hat{S}_{SP}) = \left(\hat{R}_{SP/SL}\right)^2 * \widehat{Var}(\hat{S}_{SL}) + \left(\hat{S}_{SL}\right)^2 * \widehat{Var}(\hat{R}_{SP/SL})$$

Paired release-recapture model

We used the paired release-recapture models of Burnham et al. (1987) to estimate the survival of yearling and subyearling Chinook salmon through the ice and trash sluiceway, and for the post-hoc evaluation of survival through spillbays 1-4, 5-6, and 7-20 at The Dalles Dam.

Model assumptions

There are assumptions associated with using the single release and paired release-recapture (PR) model to estimate survival, some are biological and some pertain to the statistical models (Burnham et al. 1987, Skalski et al. 1998, Skalski 1999). The validity of some of the assumptions listed below can be evaluated using statistical tests and others can be met through careful consideration of fish collection, holding, tagging, and detection techniques. The assumptions are as follows:

A1. Individuals marked for the study are a representative sample from the population of interest.

A2. Survival and capture probabilities are not affected by tagging or sampling (i.e., tagged animals have the same probabilities as untagged animals).

A3. All sampling events are "instantaneous" (i.e., sampling occurs over a short time relative to the length of the intervals between sampling events).

A4. The fate of each tagged individual is independent of the fate of all others.

A5. All individuals alive at a sampling location have the same probability of surviving until the end of that event.

A6. All tagged individuals alive at a sampling location have the same probability of being detected on that event.

A7. All tags are correctly identified and the status of fish (i.e., alive or dead) is correctly identified.

We conducted statistical tests to evaluate assumptions A5 and A6 using tests developed by Burnham et al. (1987). Burnham et al. (1987) presents a series of tests of assumptions named Test 2 that examine whether upstream or downstream detections affect downstream survival and/or detection. To examine whether upstream capture histories affect downstream survival and/or capture, Burnham et al. (1987) present a series of tests called Test 3.

Relative survival was estimated from paired releases by the expression:

$$\hat{S} = \frac{\hat{S}_{11}}{\hat{S}_{21}} \tag{1}$$

with a variance estimate based on the Delta method (Seber 1982) of:

$$\begin{aligned} \hat{Var}\left(\hat{S}_W\right) &\cong \left(\frac{\hat{S}_{11}}{\hat{S}_{21}}\right)^2 \left[\frac{Var\left(\hat{S}_{11}\right)}{\hat{S}_{11}^2} + \frac{Var\left(\hat{S}_{21}\right)}{\hat{S}_{21}^2}\right] \\ &\cong \hat{S}_W^2 \left[\hat{C}V\left(\hat{S}_{11}\right)^2 + \hat{C}V\left(\hat{S}_{21}\right)^2\right] \end{aligned} \tag{2}$$

where $\hat{S}_{11} =$ survival estimates for fish released above the project of interest and $\hat{S}_{22} =$ fish released below the project.

and where

$$\hat{C}V\left(\hat{\theta}\right) = \frac{\sqrt{Var\left(\hat{\theta}\right)}}{\theta}$$

In order to estimate S, the survival S_{11} is assumed to be of the form:

$$S_{11} = S \cong S_{21}$$

leading to the relationship

$$\frac{S_{11}}{S_{21}} = \frac{S \cdot S_{21}}{S_{21}} = S \tag{3}$$

The equality (3) suggests two additional assumptions for valid survival estimation using the paired release-recapture protocol.

A8. Survival in the upriver segment (S) is conditionally independent of survival in the lower river segment.

A9. Releases (R_1) and (R_2) have the same survival probability in the lower river segment (S_{21}).

The assumption of downstream mixing was tested at each downstream array. An R x C contingency table test of homogenous recoveries over time was performed using a table of the form:

		Release	
		R_1	R_2
Day of detections	1		
	2		
	3		
	⋮		
	D		

For each paired-release (R_1 and R_2), a chi-square test of homogeneity was performed at each downstream array. Tests were performed at $\alpha = 0.05$. Because there were multiple releases and tests across paired releases, the Type I error rates were adjusted for an overall experimental-wise error rate pertaining specifically to each paired release-recapture evaluation conducted at The Dalles Dam (Dunn-Sidak method, Sokal and Rohlf 1995).

Inferences regarding mixing will be largely based on the sequential use of likelihood ratio tests. In any given survival estimation scenario, a number of potential models will be generated and subsequently evaluated (Burnham et al. 1987, Leberton et al. 1992). Forward-sequential and reverse-sequential procedures will be used to find the most parsimonious statistical model that adequately describes the downstream survival and capture processes of the paired release. The most efficient estimate of survival will be based on the statistical model for the paired releases that properly share all common parameters between release groups. When the sequential procedures suggested that the treatment and control groups did not share all parameters in common we used Akaike's Information Criterion (AIC, Akaike 1973) to select the most parsimonious model. The treatment and control groups were then assumed to not be mixed or mixed and that some other process had differentially affected the survival and/or capture probabilities for the groups given that they were traveling downriver at approximately the same time.

Results

Model assumptions

Tagged fish size and study period relative to run-at-large

We obtained fork length data for run-of-river fish sampled at the John Day Dam smolt monitoring facility and compared them to fork length data for radio-tagged fish. To examine the timing of the study relative to the run timing of run-of-river fish, we obtained passage index data from the Fish Passage Center (see: www.fpc.org). The passage index is the number of fish sampled divided by the sample rate divided by the proportion of water passing through the sampling system.

Yearling Chinook salmon

Radio-tagged yearling Chinook salmon were of very similar sizes to the run-of-river fish; from 27 April to 29 May the mean fork length of run-of-river fish was 155 mm compared to 157 mm for radio-tagged fish (Appendix 2, Figure A2.1). We observed that 91% of the sampled run was larger than the 130 mm minimum size criterion throughout the season. The range and mean fork lengths and weights for tagged fish by release are reported in Appendix 1. The study period coincided well with the run timing of the run-of-river fish. The study started at approximately 10% of the run and ended at 89% (Appendix 2, Figure A2.2).

Subyearling Chinook salmon

The run-of-river subyearling Chinook salmon were unusually small during the summer of 2004. The mean fork length of run-of-river fish from 20 June to 29 July was 98 mm, while the mean radio-tagged fish length was 116 mm (Appendix 2, Figure A2.3). Further, less than 10% of the run-of-river fish sampled at the facilities were larger than 110 mm. The range and mean fork lengths and weights for tagged fish by release are reported in Appendix 1. The study period started at approximately 16% of the run and ended at 95% (Appendix 2, Figure A2.4).

Tag-life performance for determining potential bias of survival estimates

The objectives of the tag-life study were to: 1) estimate the probability a radio-tag was operational over time, 2) model the probability a radio-tag was operational, and 3) estimate the probability radio-tags were operational at detection arrays. We determined that the probability of a tag being operational at downstream arrays was high, with all probabilities greater than 0.999 (Table 1). The cumulative arrival distributions indicate that tagged juvenile salmonids passed through downstream detection arrays several days before tag-failure was substantial for fish released from the John Day Dam tailrace and The Dalles Dam tailrace (Appendix 3, Figure A3.3). Townsend et al. (2004) found that the probability of a tag being operational at downstream detection arrays was >98%,

therefore, the adjusted survival estimate (0.9387) changed very little from the unadjusted estimate (0.9339), having a difference of 0.0048. Since the estimated probabilities during our study were greater than those observed by Townsend et al. (2004), the survival estimates would be less affected. Thus, since the probability of a tag being operational at the downstream detection arrays was one or very near one (Table 1), we did not adjust our survival estimates.

Table 1. Estimated average probabilities (*SE*) a radio-tag was operational at The Dalles Dam and other downstream detection arrays during 2004 for the radio transmitters used to tag A) Yearling Chinook and B) Subyearling Chinook.

A) Yearling Chinook salmon implanted with Lotek MCFT-3KM transmitters

	Detection Array Locations	
Release Site	The Dalles Dam	Survival Gates
The John Day Dam Tailrace	0.9999 (1.176×10^{-6})	0.9996 (1.095×10^{-4})
The Dalles Dam Tail Race	NA	0.9999 (1.310×10^{-6})

B) Subyearling Chinook salmon implanted with Lotek NTC-3-1 transmitters

	Detection Array Locations	
Release Site	The Dalles Dam	Survival Gates
The John Day Dam Tailrace	1.000 (5.847×10^{-7})	1.000 (1.913×10^{-5})
The Dalles Dam Tail Race	NA	1.000 (3.990×10^{-6})

Recovery period tag loss and mortality

After tagging, fish were held for approximately 18 to 36 h for recovery. After the holding period, any dead fish or regurgitated transmitters were removed. For radio-tagged yearling Chinook salmon, for all releases combined, mortality was 1.0% and tag loss was 1.7%. For radio-tagged subyearling Chinook salmon, for all releases combined, mortality was 1.7% and tag loss was 1.1%. Recovery period mortality and tag loss by individual release can be found in Appendix 1.

Burnham tests

The results of the Burnham Tests 2 and 3 testing assumptions A5 and A6 for yearling and subyearling Chinook salmon survival evaluations through the ice and trash sluiceway and the spillway were inconclusive due to the number of tests that were incalculable because of the presence of all zeroes in either rows or columns of the contingency table. Of the tests that were calculated, a lack of fit for Burnham Test 2 was indicated for 1 of 65 tests for subyearlings in the sluiceway evaluation ($P < 0.0006$, Dunn-Šidák experimentwise error rate), 3 of 158 tests for yearlings in the spillbay evaluation ($P < 0.0003$, Dunn- Šidák experimentwise error rate), and 3 of 129 tests for subyearlings in the spillbay evaluation ($P < 0.0003$, Dunn- Šidák experimentwise error rate). The results of these tests can be found in Appendix 4.

Tests of the assumption of mixing of the treatment and control groups

The chi-square tests of homogeneity, testing for similarity in arrival times, indicated that there were no significant differences in arrival times between yearling Chinook salmon passing the ice and trash sluiceway paired with the sluiceway tailrace control, the ice and trash sluiceway paired with the spillway tailrace control, or spillbays 1-4, 5-6 and 7-20 paired with the spillway tailrace control. For subyearling Chinook salmon there were no significant differences in arrival times between fish passing the ice and trash sluiceway paired with the sluiceway tailrace control.

However, because of the post-hoc nature of the paired release evaluations through the sluiceway and through the spillway, 6 tests of the homogeneity of arrival times for paired release groups of subyearling Chinook that were released into the ice and trash sluiceway and approximately 550 m below the dam beneath the I-197 bridge and 24 tests for subyearling Chinook passing various spillbays paired with release groups in the tailrace suggested that the distribution of arrival times of the treatment and control groups were significantly different . Since the timing of the releases of treatment and control groups were not planned to "maximize" mixing, the high number of pairings with significantly different arrival times was most likely due to "paired" release groups being formed post-hoc from fish intended for other evaluations. The results of these tests can be found in Appendix 5.

Releases of dead radio-tagged fish

Assumption A7 of release-recapture models used to estimate survival of juvenile salmonids is that the status of the smolt (i.e., alive or dead) is correctly assessed. Dead radio-tagged fish drifting downstream could result in false-positive detections, positively biasing survival estimates. Thus, releases of dead radio-tagged fish were made to validate this assumption. No dead radio-tagged yearling or subyearling Chinook salmon were detected at any of the radiotelemetry arrays downstream of The Dalles Dam.

Survival estimates

Route-specific survival model

Yearling Chinook salmon

Using capture histories generated from the detections of radio-tagged yearling Chinook salmon (Table 2), maximum likelihood estimates of the route-specific passage and survival probabilities with associated standard errors and profile likelihood 95% confidence intervals were calculated for fish passing The Dalles Dam. The estimated survival of radio-tagged yearling Chinook salmon was highest through the ice and trash sluiceway (S = 0.981, SE = 0.016, profile likelihood 95% confidence interval = 0.943, 1.01), followed by the spillway (S = 0.909, SE = 0.008, profile likelihood 95% confidence interval = 0.892, 0.925), and lowest through the turbines (S = 0.797, SE = 0.036, profile likelihood 95% confidence interval = 0.722, 0.863) (Figure 6). Yearling Chinook salmon dam survival was estimated to be 0.906 (SE = 0.008, 95% confidence interval = 0.890, 0.922), pool survival was estimated to be 0.956 (SE = 0.005, 95% confidence interval = 0.947, 0.965), and project survival (the product of dam and pool survival) was estimated to be 0.866 (SE = 0.012, 95% confidence interval = 0.843, 0.889).

Subyearling Chinook salmon

Using capture histories generated from the detections of radio-tagged subyearling Chinook salmon (Table 3), maximum likelihood estimates of the route-specific passage and survival probabilities with associated standard errors and profile likelihood 95% confidence intervals were calculated for fish passing The Dalles Dam. The estimated survival of radio-tagged subyearling Chinook salmon was highest through the spillway (S = 0.860, SE = 0.011, profile likelihood 95% confidence interval = 0.838, 0.881), followed by the turbines (S = 0.674, SE = 0.031, profile likelihood 95% confidence interval = 0.613, 0.733), and lowest through the ice and trash sluiceway (S = 0.668, SE = 0.045, profile likelihood 95% confidence interval = 0.577, 0.753) (Figure 7). Subyearling Chinook salmon dam survival was estimated to be 0.817 (SE = 0.011, 95% confidence interval = 0.795, 0.839), pool survival was estimated to be 0.850 (SE = 0.008, 95% confidence interval = 0.834, 0.865), and project survival (the product of dam and pool survival) was estimated to be 0.694 (SE = 0.014, 95% confidence interval = 0.667, 0.720).

The 2004 summer study period was approximately one week longer than previous years. To make 2004 estimates comparable with past years, survival estimates were generated for releases made from June 20 to July 21. The maximum likelihood estimates of the route-specific passage and survival probabilities with associated standard errors for the shorted study period are presented in Figure 8. The estimated survival of radio-tagged subyearling Chinook salmon was highest through the spillway (S = 0.916, SE = 0.010, profile likelihood 95% confidence interval = 0.895, 0.936), followed by the ice and trash sluiceway (S = 0.735, SE = 0.055, profile likelihood 95% confidence interval =

0.622, 0.834), and lowest through the turbines (*S* = 0.729, *SE* = 0.037, profile likelihood 95% confidence interval = 0.655, 0.798). Subyearling Chinook salmon dam survival was estimated to be 0.878 (*SE* = 0.011, 95% confidence interval = 0.857, 0.899), pool survival was estimated to be 0.911 (*SE* = 0.008, 95% confidence interval = 0.895, 0.927), and project survival (the product of dam and pool survival) was estimated to be 0.799 (*SE* = 0.015, 95% confidence interval = 0.769, 0.830).

Table 2. Counts of radio-tagged yearling Chinook salmon based on the releases from John Day Dam (R1) and in the tailrace approximately 550 m downstream of The Dalles Dam, beneath the I-197 bridge (R2) used in the route-specific survival model. Detection history recorded as: 1, detected; 0, not detected. For R1, the first position indicates the release event, the second position indicates detection or not at The Dalles Dam, the third position indicates detection or not at at least one of the arrays below The Dalles Dam. For R2, the second position indicates the release event and the third position indicates detection or not at at least one of the arrays below The Dalles Dam. For within-route detection histories, the first position indicates detection or not on the first antenna array and the second position indicates detection or not on the second antenna array.

				Within-route histories at The Dalles Dam		
Release	Detection History	Route	Counts	11	01	10
R_1 = 2230	100	Unknown	107			
	101		52			
	110	Spillway	201	1563	90	110
	111		1562			
	110	Turbines [A]	31	56	8	62
	111		95			
	110	Ice and trash sluiceway	8	162	14	6
	111		174			
R_2 = 2995	010		75			
	011		2920			

[A] - Unguided passage

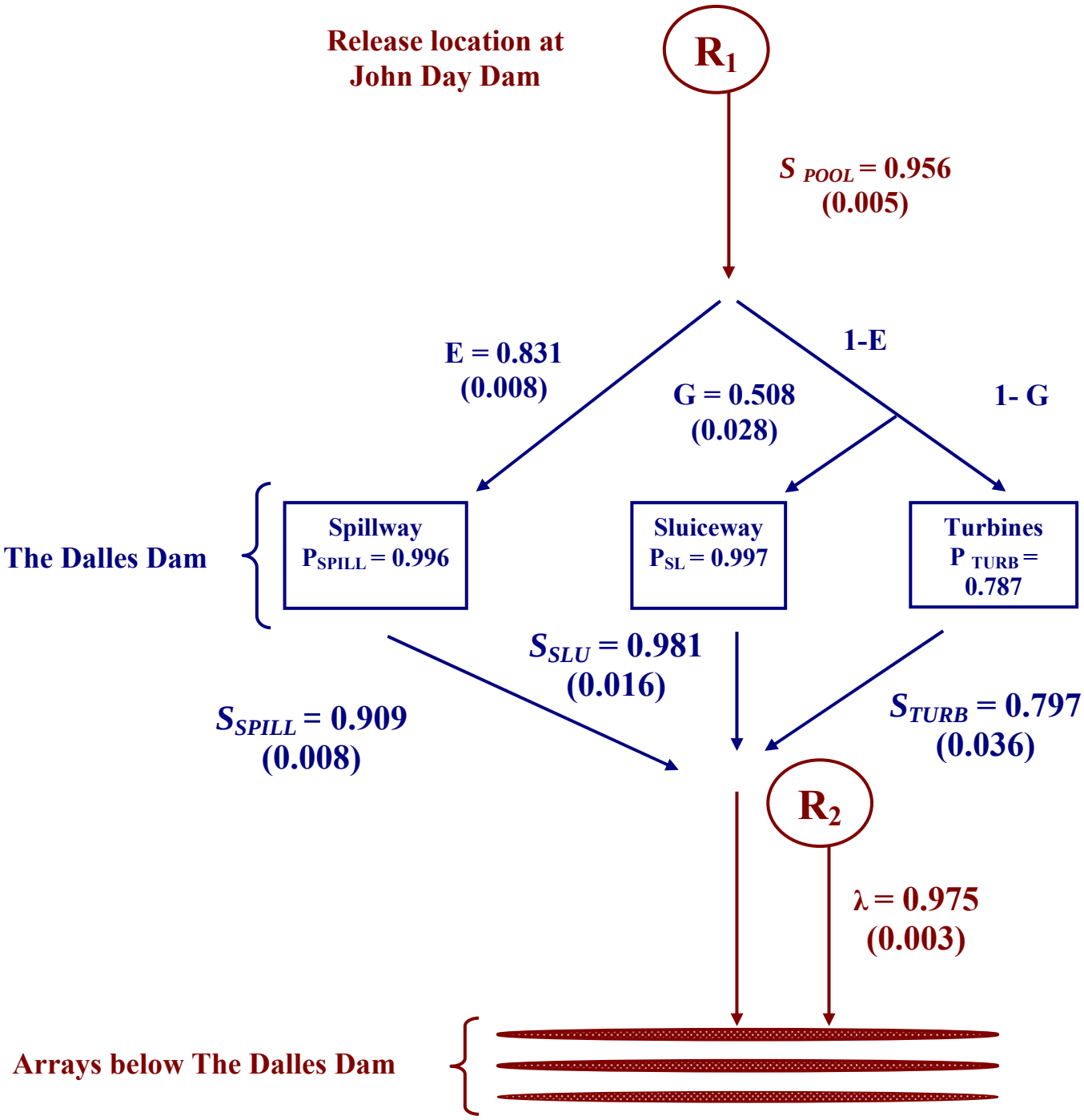

Figure 6. Schematic of estimated route-specific passage, detection, and survival probabilities for yearling Chinook salmon through The Dalles Dam during 2004. Estimated standard errors are in parentheses. See text (page 12) for definitions of parameters.

Table 3. Counts of radio-tagged subyearling Chinook salmon based on the releases from John Day Dam (R1) and in the tailrace approximately 550 m downstream of The Dalles Dam, beneath the I-197 bridge (R2) used in the route-specific survival model. Detection history recorded as: 1, detected; 0, not detected. For R1, the first position indicates the release event, the second position indicates detection or not at The Dalles Dam, the third position indicates detection or not at at least one of the arrays below The Dalles Dam. For R2, the second position indicates the release event and the third position indicates detection or not at at least one of the arrays below The Dalles Dam. For within-route detection histories, the first position indicates detection or not on the first antenna array and the second position indicates detection or not on the second antenna array.

				Within-route histories at The Dalles Dam		
Release	Detection History	Route	Counts	11	01	10
R_1 = 2210	100	Unknown	353			
	101		56			
	110	Spillway	258	1213	57	162
	111		1174			
	110	Turbines [A]	92	115	40	90
	111		153			
	110	Ice and trash sluiceway	45	121	0	3
	111		79			
R_2 = 6917	010		320			
	011		6597			

[A] - Unguided passage

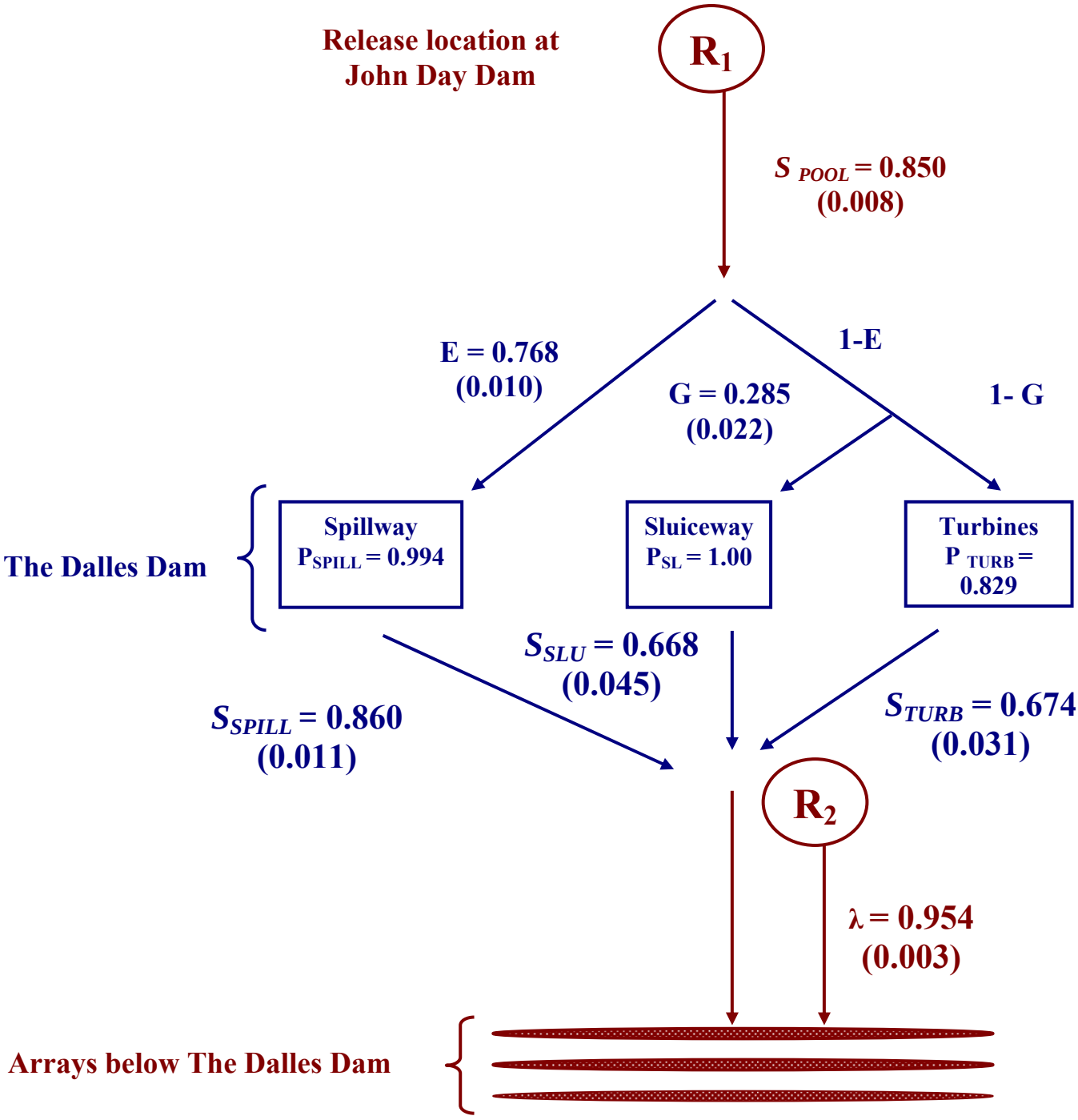

Figure 7. Schematic of estimated route-specific passage, detection, and survival probabilities for subyearling Chinook salmon through The Dalles Dam from June 20, 2004 to July 29, 2004. Estimated standard errors are in parentheses. See text (page 12) for definitions of parameters.

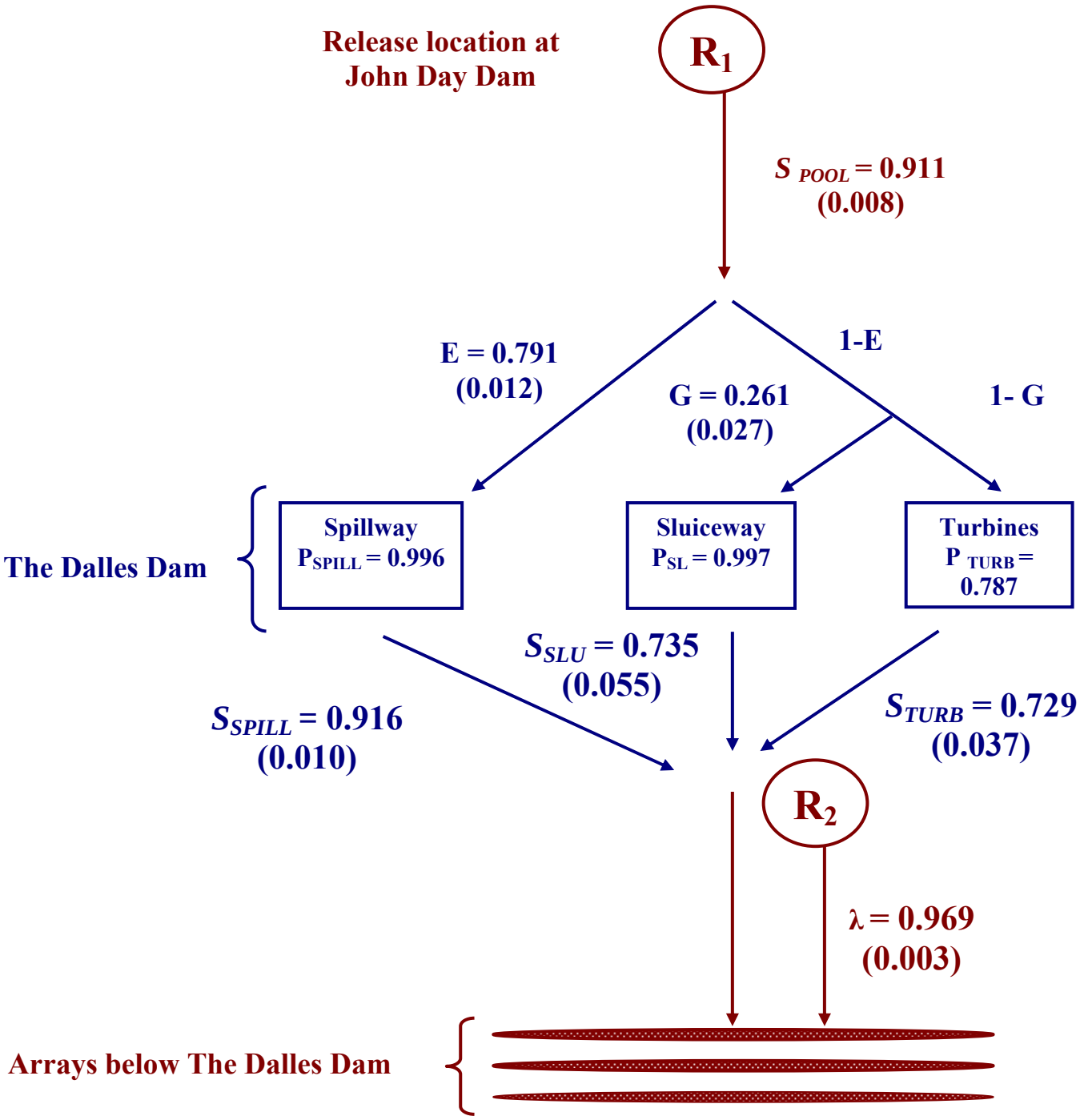

Figure 8. Schematic of estimated route-specific passage, detection, and survival probabilities for subyearling Chinook salmon through The Dalles Dam from June 20, 2004 to July 21, 2004. Estimated standard errors are in parentheses. See text (page 12) for definitions of parameters.

Survival throughout the spring and summer release season

We estimated the dam survival of yearling and subyearling Chinook salmon that passed through The Dalles Dam in 8-d increments throughout the spring and summer study periods using the route-specific survival model. The estimates were generated from the detections of radio-tagged yearling and subyearling Chinook salmon released into the John Day Dam tailrace and The Dalles Dam tailrace. Based on these detection histories we grouped releases of fish that were known to have passed during each of four 8-d increments for yearling Chinook and each of five 8-d increments for subyearling Chinook.

Yearling Chinook salmon

Survival of yearling Chinook salmon from April 27 to May 4 was relatively low; survival increased and was relatively constant for the remainder of the spring study period (Figure 9). Dam discharge, water temperature, and tailwater elevation were all low from April 27 to May 4 compared to the rest of the study period (Figure 10).

Subyearling Chinook salmon

Survival of subyearling Chinook salmon declined over time as water temperatures increased and dam discharge decreased (Figures 11 & 12).

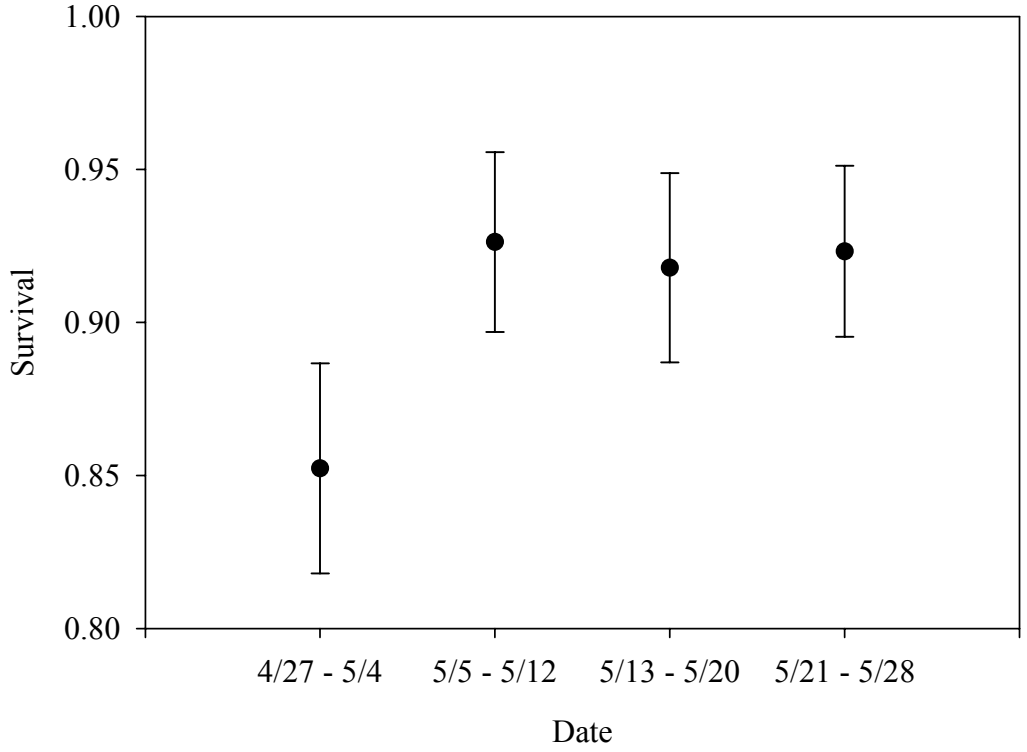

Figure 9. Yearling Chinook salmon dam survival estimates for The Dalles Dam during spring 2004. Survival probabilities and associated 95% confidence intervals were calculated using the route-specific survival model for 8-d increments from 4/27- 5/28.

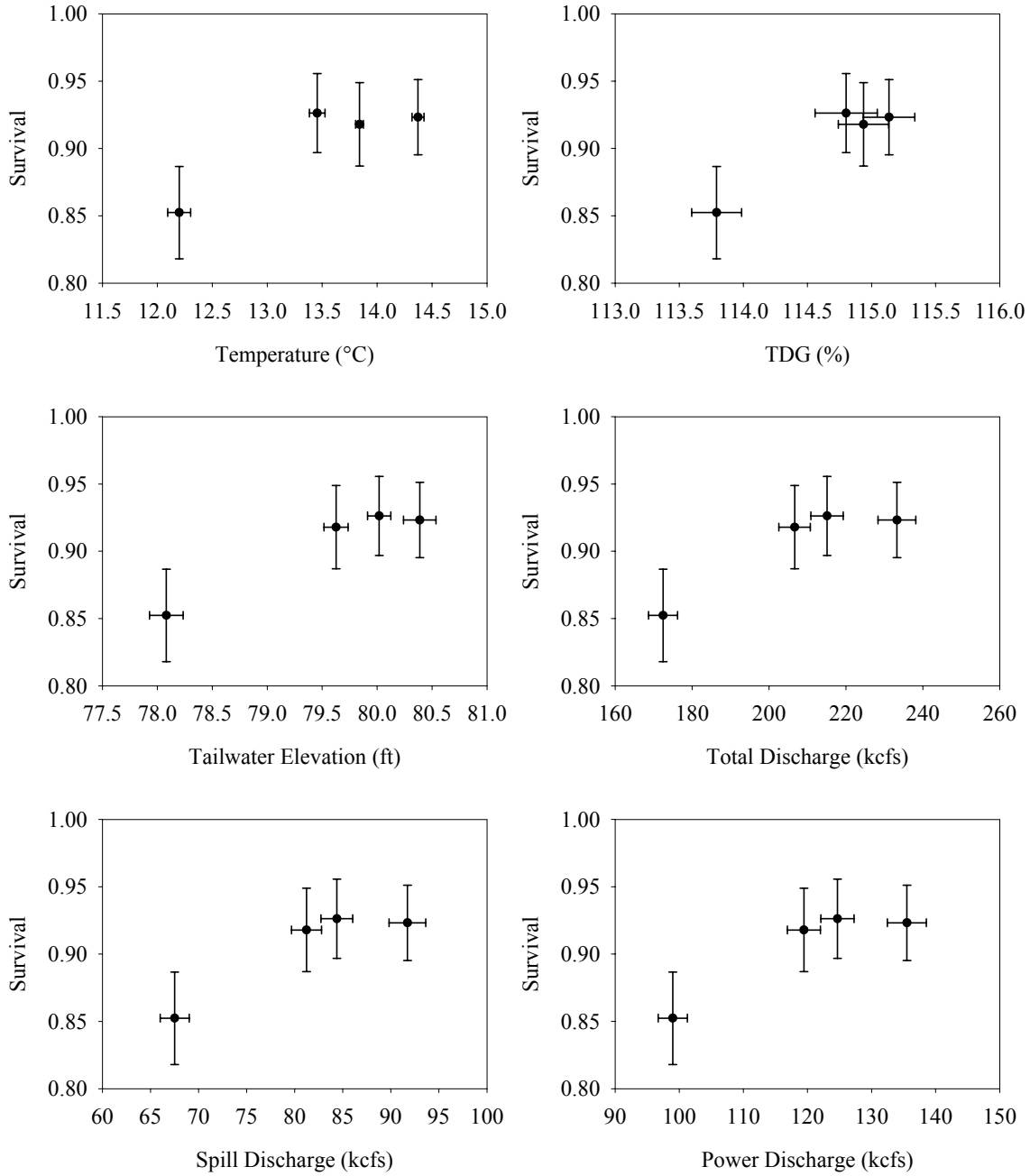

Figure 10. The relation of yearling Chinook salmon dam survival during eight-day increments from 4/27 – 5/28 to river water temperature, total dissolved gas (TDG), tailwater elevation, and total, spill, and powerhouse discharge through The Dalles Dam. Survival probabilities and associated 95% confidence intervals were estimated using the route-specific survival model. Environmental variables are 8-d averages (with 95% confidence intervals) of hourly data measured at The Dalles Dam (see: www.nwd-wc.usace.army.mil/tmt/).

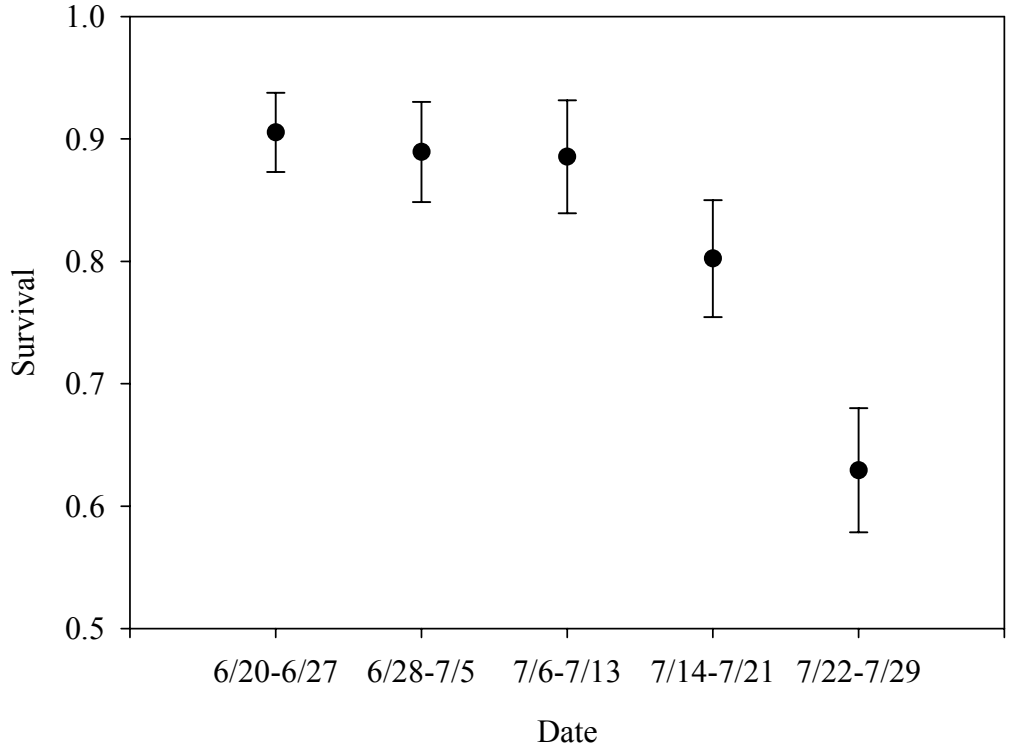

Figure 11. Subyearling Chinook salmon dam survival estimates for The Dalles Dam during summer 2004. Survival probabilities and associated 95% confidence intervals were calculated using the route-specific survival model for 8-d increments from 6/20 – 7/29.

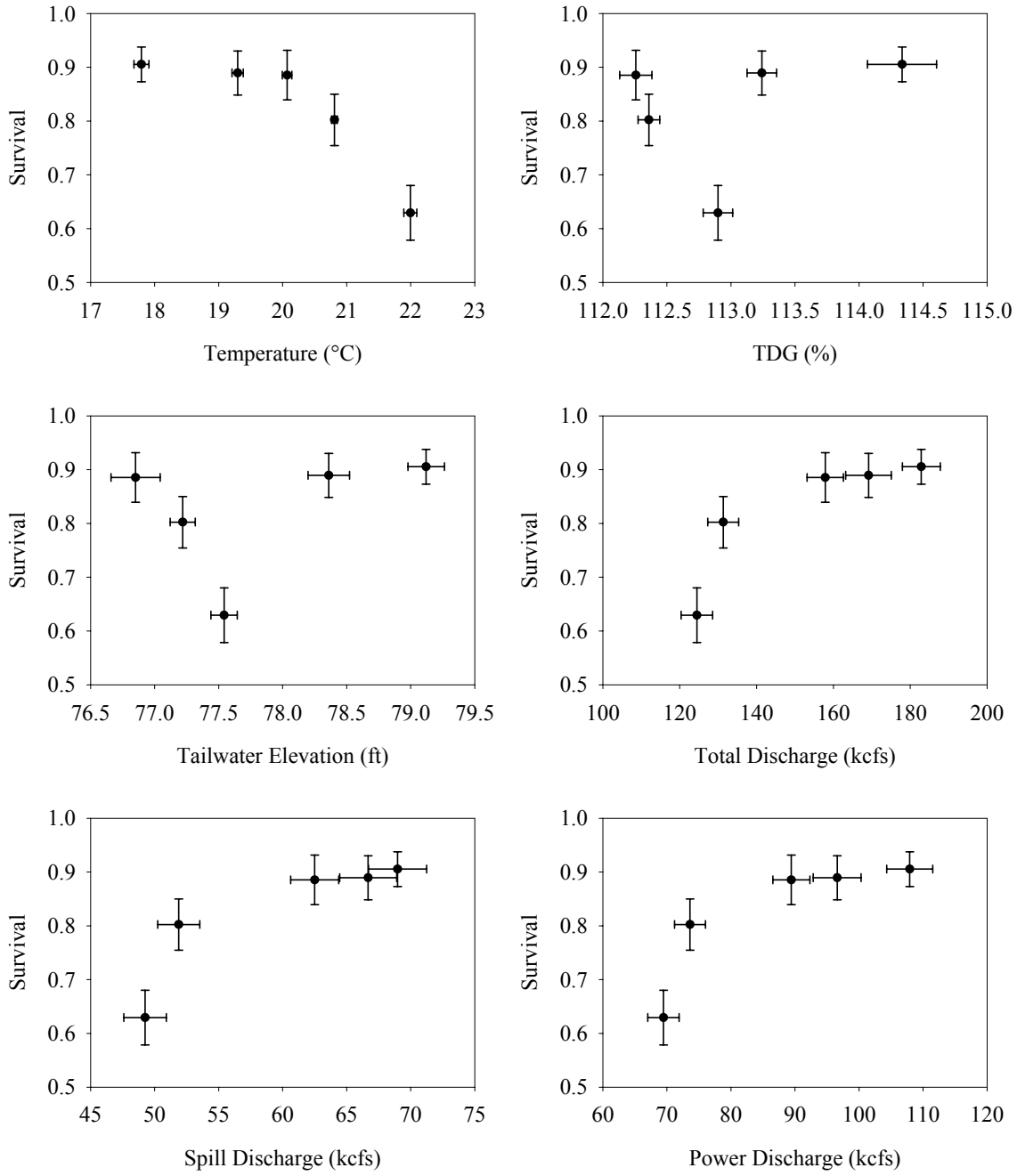

Figure 12. The relation of subyearling Chinook salmon dam survival during eight-day increments from 6/20 – 7/29 to river temperature, total dissolved gas (TDG), tailwater elevation, and total, spill, and powerhouse discharge. Survival probabilities and associated 95% confidence intervals were estimated using the route-specific survival model. Environmental variables are 8-d averages (with 95% confidence intervals) of hourly data measured at The Dalles Dam (see: www.nwd-wc.usace.army.mil/tmt/).

Triple-release model

Yearling Chinook salmon

Using releases of yearling Chinook salmon at John Day Dam and fish released above and below the ice and trash sluiceway, we employed the triple-release model to generate the following absolute and relative route-specific and dam survival probabilities.

Using the paired releases at the sluiceway the absolute survival through the sluiceway was estimated to be:

$$\hat{S}_{SL} = 0.9894(\widehat{SE} = 0.0135)$$

and using the fish from the first release that traveled through the 3 passage routes:

$$\widehat{S_{SL} * S_1} = 0.9231\ (\widehat{SE} = 0.0198)$$
$$\widehat{S_{SP} * S_1} = 0.8837\ (\widehat{SE} = 0.0076)$$
$$\widehat{S_{TURB} * S_1} = 0.7460\ (\widehat{SE} = 0.0388)$$

The following relative survivals were estimated as follows:

Spillway to sluiceway:

$$R_{SP/SL} = \frac{0.8837}{0.9231} = 0.9573(\widehat{SE} = 0.0221)$$

Turbines to sluiceway:

$$R_{TURB/SL} = \frac{0.7460}{0.9231} = 0.8081(\widehat{SE} = 0.0455)$$

and the absolute survivals through other routes are

$$\text{Spillway: } \hat{R}_{SP/SL} \bullet \hat{S}_{SL} = (0.9573)(0.9894) = 0.9472(\widehat{SE} = 0.0254)$$
$$\text{Turbines: } \hat{R}_{TURB/SL} \bullet \hat{S}_{SL} = (0.8081)(0.9894) = 0.7995(\widehat{SE} = 0.0463)$$

and the overall dam survival, assuming 100% detection at The Dalles Dam, and where P = portion of fish through each route from uppermost release group, was estimated to be 0.942.

	Sluiceway		Spillway		Turbines	
	$P_{SL} = 0.0879$		$P_{SP} = 0.8513$		$P_{TURB} = 0.0608$	
	x		X		x	
	$S_{SL} = 0.9894$		$S_{SP} = 0.9472$		$S_{TURB} = 0.7995$	
$\boldsymbol{S_{DAM}} =$	**0.0870**	+	**0.8064**	+	**0.0486**	**= 0.9420**

Subyearling Chinook salmon

Using releases of subyearling Chinook salmon at John Day Dam and fish released above and below the ice and trash sluiceway, we employed the triple-release model to generate the following absolute and relative route-specific and dam survival probabilities.

Using the paired releases at the sluiceway the absolute survival through the sluiceway was estimated to be:

$$\hat{S}_{SL} = 0.9818 \ (\widehat{SE} = 0.0232)$$

and using the fish from the first release that traveled through the 3 passage routes:

$$\widehat{S_{SL} * S_1} = 0.6290 \ (\widehat{SE} = 0.0434)$$
$$\widehat{S_{SP} * S_1} = 0.8177 \ (\widehat{SE} = 0.0102)$$
$$\widehat{S_{TURB} * S_1} = 0.6204 \ (\widehat{SE} = 0.0310)$$

The following relative survivals were estimated as follows:

Spillway to sluiceway:

$$\hat{R}_{SP/SL} = 1.3000 \ (\widehat{SE} = 0.0912)$$

Turbines to sluiceway:

$$\hat{R}_{TURB/SL} = 0.9863 \ (\widehat{SE} = 0.0840)$$

and the absolute survivals through other routes are

$$\text{Spillway: } \hat{R}_{SP/SL} * \hat{S}_{SL} = (1.3000)(0.9818) = 1.2763 \ (\widehat{SE} = 0.0945)$$
$$\text{Turbines: } \hat{R}_{TURB/SL} * \hat{S}_{SL} = (0.9863)(0.9818) = 0.9683 \ (\widehat{SE} = 0.0856)$$

and the overall dam survival, assuming 100% detection at The Dalles Dam, and where P = portion of fish through each route from uppermost release group, was estimated to be 1.2141.

	Sluiceway		Spillway		Turbines	
	$P_{SL} = 0.0689$		$P_{SP} = 0.7951$		$P_{TURB} = 0.1360$	
	x		X		x	
	$S_{SL} = 0.9818$		$S_{SP} = 1.2763$		$S_{TURB} = 0.9683$	
$\boldsymbol{S_{DAM}} =$	**0.0676**	+	**1.0148**	+	**0.1317**	**= 1.2141**

Ice and trash sluiceway survival

As part of the evaluation of the triple release model, we made releases directly into and directly below the ice and trash sluiceway at The Dalles Dam. Thus, while the releases were not specifically intended to do so, we were able to estimate the survival of yearling an subyearling Chinook salmon through the ice and trash sluiceway to the release location of the control fish immediately below the ice and trash sluiceway and to the release location of the control fish approximately 550 m downstream of the dam, beneath the I-197 bridge during 2004 using the paired release-recapture model. For each release of fish into the ice and trash sluiceway two survival estimates were calculated, one pairing treatment fish with a control release immediately below the ice and trash sluiceway (sluiceway tailrace control) and a second pairing treatment fish with a control release made 550 m downstream of the spillway under the I-197 bridge (spillway tailrace control).

Yearling Chinook salmon

We estimated that the survival of yearling Chinook salmon through the ice and trash sluiceway to the release location of the control fish immediately below the ice and trash sluiceway ranged from 0.731 to 1.119 (Appendix 7, Table A7.1). The average survival was estimated to be 0.988 (*SE* = 0.015, 95% confidence interval [0.957, 1.019]).

We estimated that the survival of yearling Chinook salmon through the ice and trash sluiceway to the release location of the control fish approximately 550 m downstream of the dam, beneath the I-197 bridge ranged from 0.789 to 1.152 (Appendix 7, Table A7.1). The average survival was estimated to be 0.957 (*SE* = 0.016, 95% confidence interval [0.924, 0.991]).

Subyearling Chinook salmon

We estimated that the survival of subyearling Chinook salmon through the ice and trash sluiceway to the release location of the control fish immediately below the ice and trash sluiceway ranged from 0.586 to 3.625 (Appendix 7, Table A7.2). Survival estimates much grater than one (Appendix 7, Table A7.2) were due to poor survival of control fish relative to treatment fish. The average survival was estimated to be 1.060 (*SE* = 0.083, 95% confidence interval [0.893, 1.228]).

We estimated that the survival of subyearling Chinook salmon through the ice and trash sluiceway to the release location of the control fish approximately 550 m downstream of the dam, beneath the I-197 bridge ranged from 0.189 to 1.068 (Appendix 7, Table A7.2). The average survival was estimated to be 0.804 (*SE* = 0.031, 95% confidence interval [0.741, 0.866]).

Spillbay specific survival

At the request of the ACOE Portland District, a post-hoc evaluation of survival through The Dalles Dam spillway was conducted. The impetus for the post-hoc evaluation was to further explore reports of poor survival through spillbay 6, which is immediately adjacent to the new training wall. Fish released into the tailrace of John Day Dam (Appendix 1, Tables A1.1 and A1.5) that were detected passing The Dalles Dam spillway were used for the analyses. Because the number of fish passing through an individual spillbay from an individual release was often low, spillbays and releases were combined to improve the precision of estimates. Fish were assigned passage through spillbays 1-4, 5-6 and 7-20 based on interrogations on underwater antennas at the spillway. After assigning fish to spillbay groupings, fish were further combined based on their passage time. Time frames delineating the new release groups were established so that there was a minimum of 8 fish in the bays 1-4 and bays 5-6 groupings. The new release groups were then paired with groupings of control releases that were made within the corresponding time frame (Appendix 8, Tables A8.1 - A8.6). Because very few fish passed through spillbays 7-20, fish passing via spillbays 7-20 were grouped based on the groupings of fish passing through bays 1-4 and 5-6. Survival was not estimated for bays 7-20 releases when these groupings contained less than 8 fish. Data for bays 7-20 are presented in Figures 13 & 14 and in Appendix 8, Tables A8.3 & A8.6, but will not be discussed further.

Yearling Chinook salmon

Average survival of yearling Chinook salmon passing through spillbays 5-6 was lower than through spillbays 1-4 (Table 4). The ranges of survival estimates were similar for bays 1-4 and 5-6 as were the overall trends during the study period (Figure 13, Appendix 8, Tables A8.1 & A8.2)

Subyearling Chinook salmon

Average survival of subyearling Chinook salmon passing through spillbays 5-6 was lower than through spillbays 1-4 (Table 4). Seasonal trends were comparable for bays 1-4 and 5-6 with survival estimates through bays 5-6 being more variable throughout the study period and declining more pronouncedly at the end (Figure 14, Appendix 8, Tables A8.4 & A8.5).

Table 4. The estimated survival probabilities (S), standard errors (*SE*), 95% confidence intervals, and sample size (N; number of releases) associated with paired releases of radio-tagged juvenile yearling and subyearling Chinook salmon passing via spillbays 1-4 and spillbays 5-6 of The Dalles Dam spillway. The paired release groups were formed post-hoc from fish released into the John Day Dam tailrace (treatment) and in The Dalles Dam tailrace (control) during 2004.

Species	Spill bays	S	*SE*	95% CI	N
Yearling Chinook	1-4	0.933	0.014	[0.906, 0.960]	28
	5-6	0.894	0.014	[0.866, 0.922]	28
Subyearling Chinook	1-4	0.907	0.019	[0.869, 0.945]	27
	5-6	0.800	0.036	[0.730, 0.870]	27

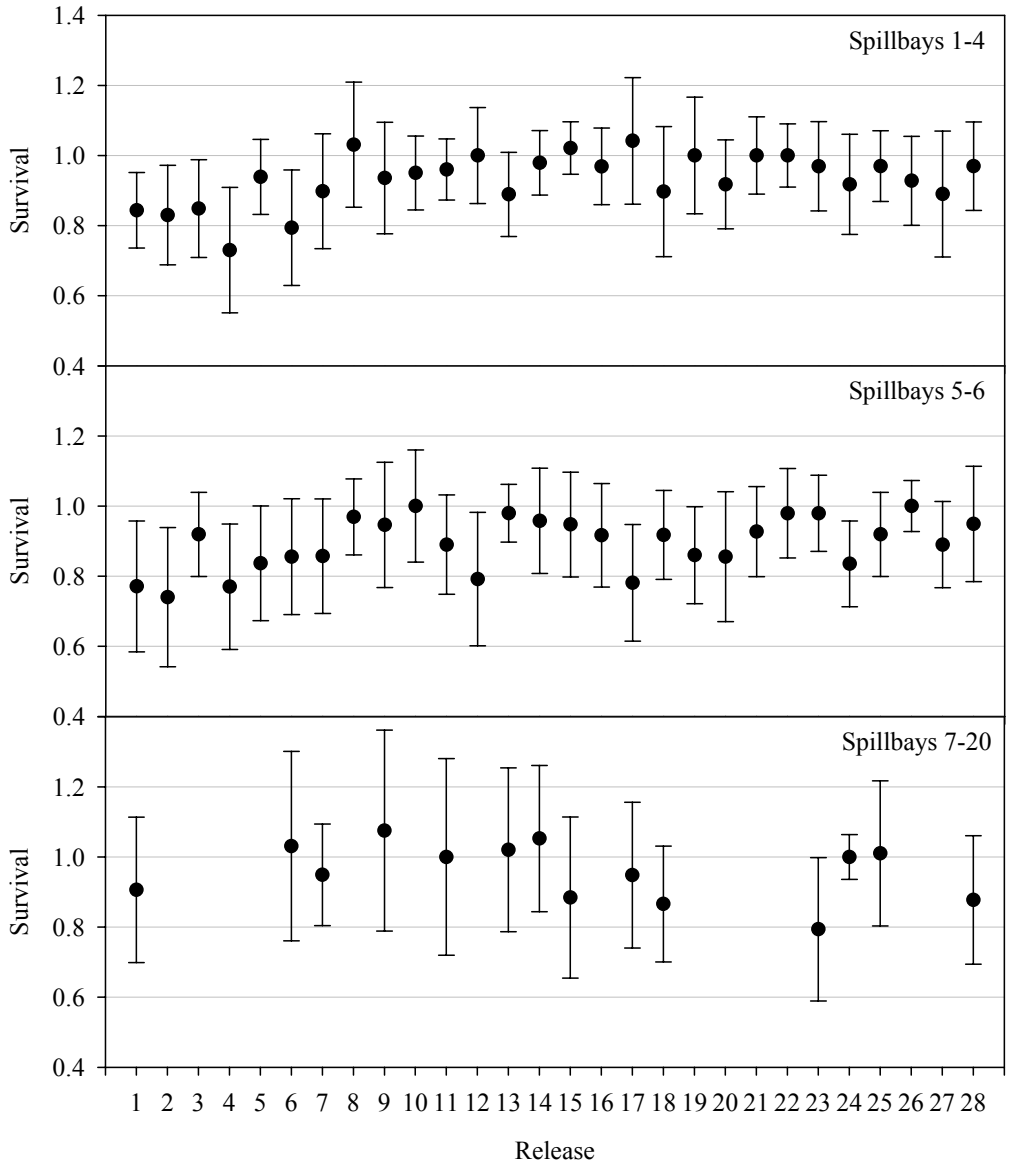

Figure 13. The estimated survival probabilities (95% CI error bars) calculated from paired releases of yearling Chinook salmon through spillbays 1-4, 5-6, and 7-20 at The Dalles Dam by release (see Appendix 8, Tables A8.1 - A8.3). The paired release groupings were formed post-hoc.

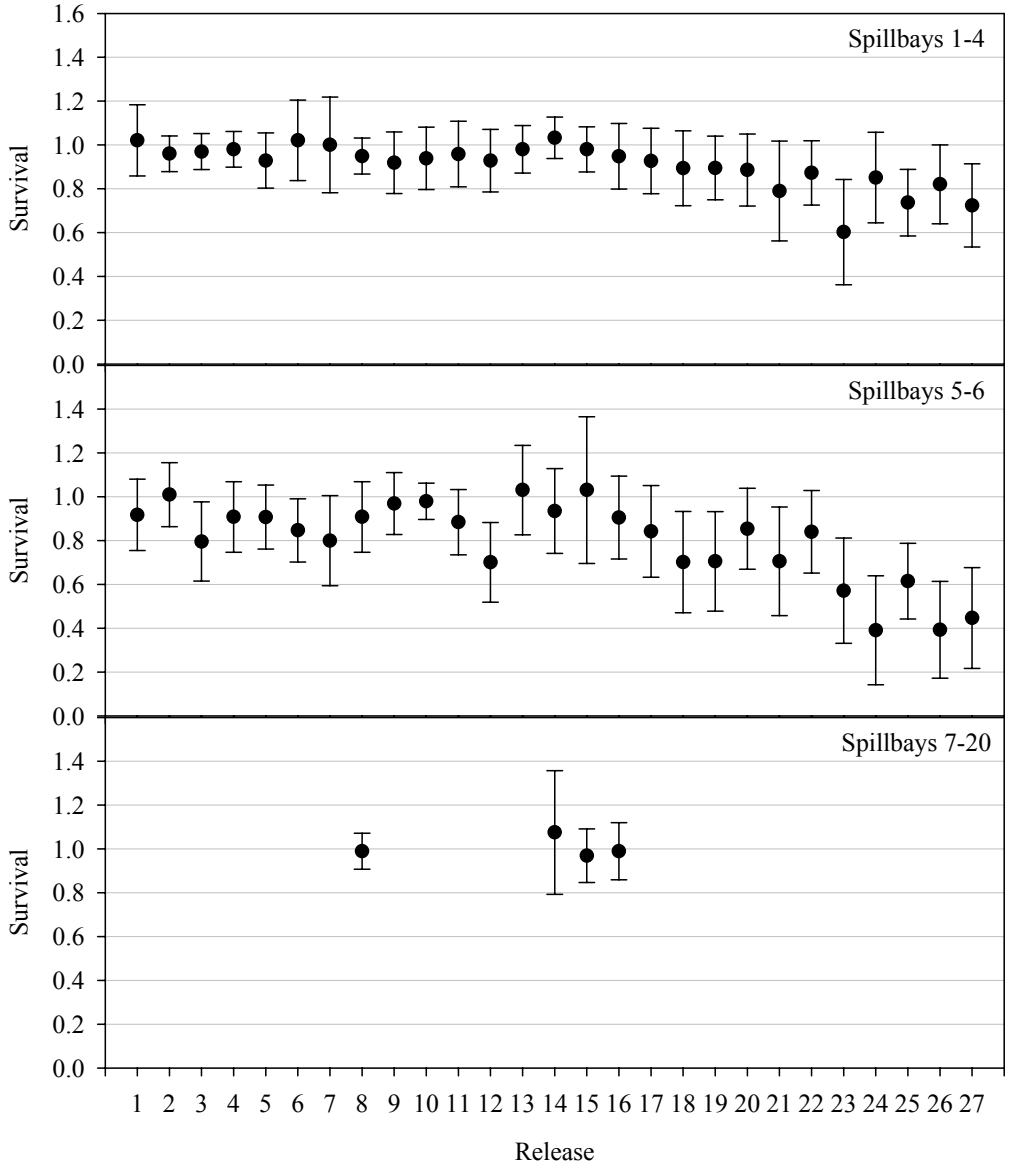

Figure 14. The estimated survival probabilities (95% CI error bars) calculated from paired releases of subyearling Chinook salmon through spillbays 1-4, 5-6, and 7-20 at The Dalles Dam by release (see Appendix 8, Tables A8.4 - A8.6). The paired release groupings were formed post-hoc.

Discussion

The estimated survival of yearling and subyearling Chinook salmon passing The Dalles Dam during 2004 did not suggest that there was a large survival benefit associated with the installation of the training wall in the spillway. The point estimates of survival for yearling and subyearling Chinook salmon passing through the spillway were slightly higher during 2004 (post-construction) than 2002 (pre-construction) (Figures 15 & 16) but there was considerable overlap of the 95% confidence intervals. Given that the comparisons are from data collected during one year pre-construction and one year post-construction, the interpretation of the results is confounded by differences in the environmental conditions experienced by fish passing The Dalles Dam during the two years and the absence of multiple years of data estimating survival during pre- and post-construction periods. We will continue this evaluation during 2005.

Similar trends in survival between the passage routes during 2002 and 2004 were observed for yearling Chinook salmon; survival was highest for fish passing via the ice and trash sluiceway, lower for the spillway, and lowest for the turbines (Figure 15). However, survival estimates for subyearling Chinook salmon passing via the ice and trash sluiceway and the turbines were much lower during 2004 than 2002 (Figure 16). Despite lower estimated survival of subyearling Chinook through the ice and trash sluiceway and turbines during 2004 compared to 2002, the dam survival estimates for the two years were very similar. This suggests that the lower survival through these routes was not sufficient to alter the dam survival significantly given the relatively low probability of fish passing via these routes.

The estimated survival through the ice and trash sluiceway was 0.256 lower for subyearling Chinook with control fish released 500m downstream of the spillway tailrace compared to immediately below the sluiceway. The installation of the training wall at the spillway may have created tailrace hydraulic conditions that resulted in increased predation of fish passing via the sluiceway or turbines. Fish passing through the turbines or the sluiceway had slower egress times than fish passing through the spillway. Median egress times of yearling and subyearling Chinook salmon were significantly different between the three routes of passage (Appendix 9, Tables A9.1 & A9.3). Fish passing The Dalles Dam via the sluiceway and turbines travel along shallows and islands during tailrace egress where predation on salmonids by gulls (*Larus* spp.), northern pikeminnow (*Ptychocheilus oregonensis*), and smallmouth bass (*Micropterus dolomieu*) may be substantially higher than at other dams.

The triple-release model was formulated to address the potential for positive bias in the route-specific survival model. The triple-release model and the route-specific survival model produced similar trends in survival estimates, however all triple-release survival estimates were higher than the route-specific estimates (Figure 17). This result does not suggest that the route-specific survival model estimates were positively biased. We will continue this evaluation during 2005.

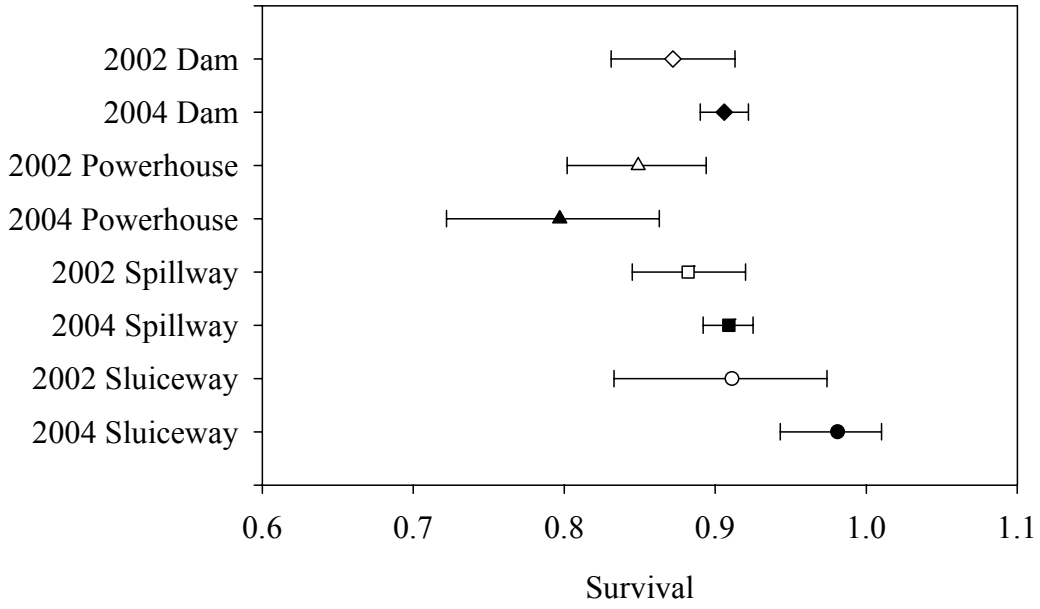

Figure 15. Survival estimates at The Dalles Dam for April 30 - May 31, 2002 (open symbols) and April 28 - May 29, 2004 (closed symbols) for yearling Chinook salmon. Dam survival probabilities and associated 95% confidence intervals and route-specific survival probabilities and associated profile likelihood 95% confidence intervals were calculated using the route-specific survival model.

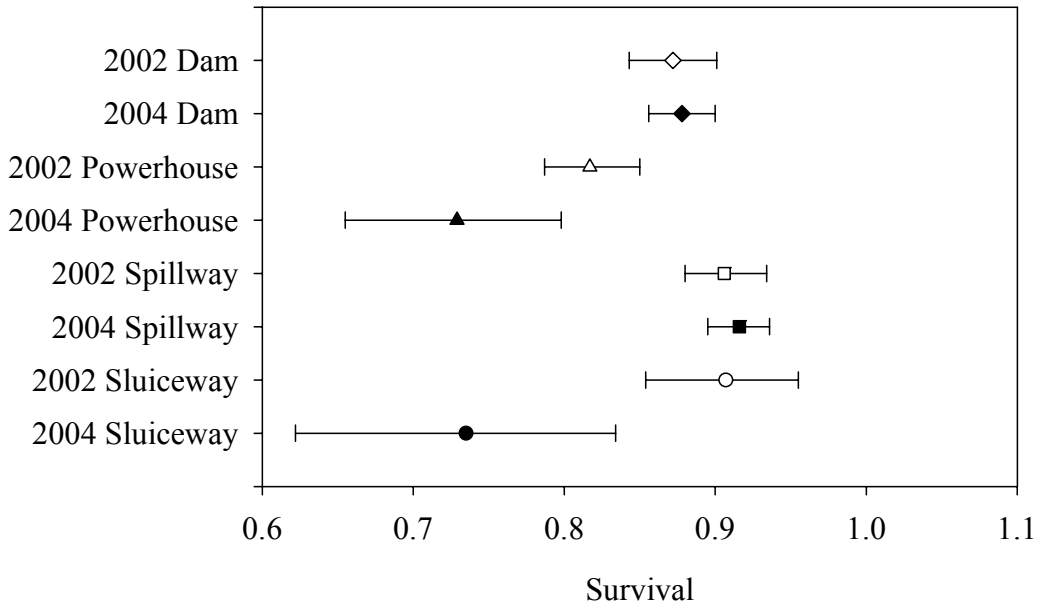

Figure 16. Survival estimates at The Dalles Dam for June 21 - July 22, 2002 (open symbols) and June 20 - July 21, 2004 (closed symbols) for subyearling Chinook salmon. Dam survival probabilities and associated 95% confidence intervals and route-specific survival probabilities and associated profile likelihood 95% confidence intervals were calculated using the route-specific survival model.

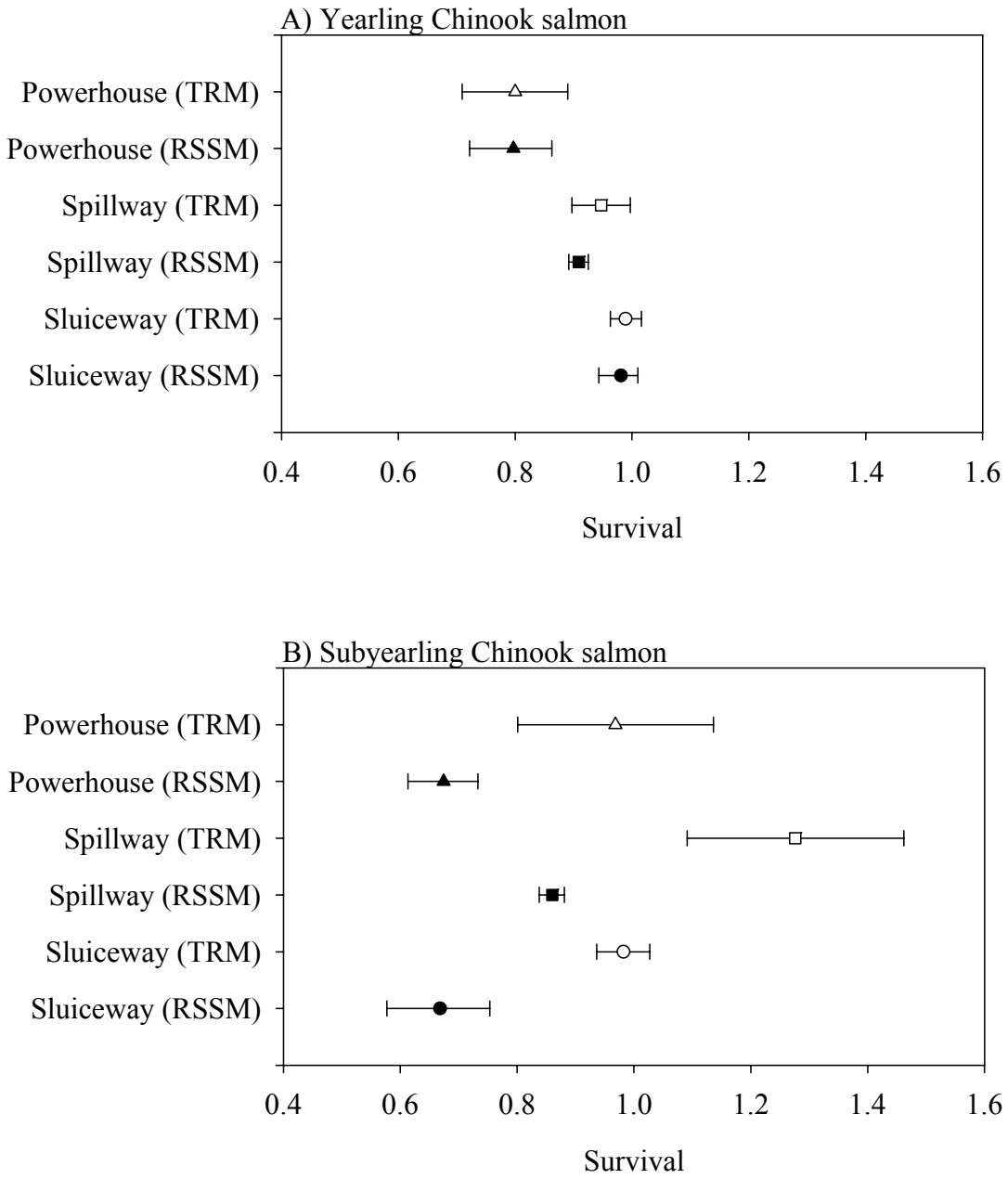

Figure 17. Comparison of survival estimates calculated using the triple-release model (TRM, open symbols) and the route-specific survival model (RSSM, closed symbols) at The Dalles Dam from April 28 - May 31, 2004 for yearling Chinook salmon (A) and from June 20 - July 29, 2004 for subyearling Chinook salmon (B). Error bars on triple-release estimates represent the 95% confidence intervals and on route-specific estimates the profile likelihood 95% confidence intervals.

Acknowledgements

We thank Mike Langeslay, Dan Feil, and Rock Peters and other personnel at the Army Corps of Engineers for their assistance in administering our contract and assisting with the logistics involved with coordinating this research at John Day, The Dalles, and Bonneville dams. We thank Brad Eppard for reviewing earlier versions of this report. We also thank the countless staff at the Columbia River Research Laboratory who participated in the planning, collection, and processing of the data associated with these studies. John Sklaski and Rich Townsend at the University of Washington contributed much to the analyses presented in this report and their advice and assistance was invaluable. In particular, the formulation of the model, methods and results for the triple-release design; it is their work that we present. We also acknowledge the assistance of the administrative staff at the Columbia River Research Laboratory for their support in managing the contracts for this research.

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Appendix 1: Release Dates, Times, Fork lengths, and Weights

Table A1.1. Summary of yearling Chinook salmon releases at the John Day Dam tailrace during spring 2004. Dates, times, numbers of tagged fish released (N), 24 h post-tagging tag loss and mortality, and means, standard deviations (SD) and ranges for fork lengths and weights are presented. Release times are the start of releases and include fish released up to 1 hour later.

						Fork length (mm)			Weight (g)		
Release	Date	Time	N	Tag loss	Mortality	Mean	SD	Range	Mean	SD	Range
1	27-Apr	07:17	30	6	0	149	9.6	132 - 180	31.7	6.2	24.2 - 57.4
2	27-Apr	19:45	34	1	1	151	10.1	135 - 175	35.0	7.9	24.9 - 56.5
3	28-Apr	07:12	34	1	1	150	9.6	134 - 172	34.0	7.1	22.8 - 52.4
4	28-Apr	19:07	34	2	0	150	8.4	135 - 172	34.0	6.0	23.8 - 48.1
5	29-Apr	07:56	35	1	0	153	9.3	137 - 188	34.7	7.2	25.1 - 66.6
6	29-Apr	19:25	38	0	0	158	11.0	140 - 188	38.8	8.7	25.9 - 66.8
7	30-Apr	08:00	34	1	1	145	9.8	127 - 179	37.6	8.1	23.6 - 70.3
8	30-Apr	19:25	36	0	0	151	10.0	133 - 176	35.7	7.9	22.3 - 54.5
9	1-May	07:21	36	0	0	142	9.7	124 - 178	34.6	6.7	25.2 - 60.7
10	1-May	19:00	36	0	0	152	8.8	138 - 179	35.8	6.8	25.5 - 59.9
11	2-May	06:58	35	1	0	152	11.5	135 - 194	35.6	8.5	25.7 - 69.5
12	2-May	19:37	38	0	0	154	9.4	135 - 180	35.2	6.6	24.9 - 51.9
13	3-May	07:15	36	0	0	154	10.6	140 - 183	36.4	8.0	26.3 - 60.7
14	3-May	19:06	34	0	2	153	10.7	140 - 182	36.1	7.5	26.6 - 56.6
15	4-May	07:03	35	1	0	150	12.8	131 - 180	33.8	8.3	23.9 - 55.9
16	4-May	19:14	35	1	0	152	11.9	131 - 188	35.8	8.7	25.0 - 66.8
17	5-May	07:22	35	0	1	147	8.6	134 - 169	31.9	6.2	22.4 - 47.9
18	5-May	19:12	34	1	1	148	9.6	134 - 175	32.7	7.0	22.3 - 54.3
19	6-May	07:15	35	1	0	145	8.9	132 - 172	29.2	6.5	21.5 - 50.2
20	6-May	19:12	34	1	2	152	14.8	130 - 185	35.8	11.4	21.5 - 62.7
21	7-May	07:24	31	3	2	155	11.6	136 - 185	36.6	8.3	25.8 - 57.4
22	7-May	18:58	35	1	0	155	11.7	139 - 189	37.3	8.7	28.8 - 62.0
23	8-May	07:05	35	1	0	153	12.5	134 - 186	34.9	8.8	24.3 - 54.7
24	8-May	18:56	35	1	0	151	13.9	132 - 186	39.5	11.5	25.9 - 69.6

Table A1.1. Continued.

						Fork length (mm)			Weight (g)		
Release	Date	Time	N	Tag loss	Mortality	Mean	SD	Range	Mean	SD	Range
25	9-May	06:52	35	1	0	155	14.2	135 - 191	37.1	10.4	23.5 - 62.1
26	9-May	19:10	35	0	0	148	13.6	130 - 186	36.6	9.2	25.2 - 64.0
27	10-May	07:10	35	0	1	154	16.4	134 - 205	36.4	12.9	21.5 - 82.9
28	10-May	19:10	36	0	0	157	12.8	135 - 189	39.7	9.7	25.1 - 68.3
29	11-May	07:04	34	1	0	152	15.1	132 - 194	35.0	11.4	22.3 - 68.9
30	11-May	19:11	36	0	1	162	18.1	134 - 202	42.9	14.6	24.4 - 80.6
31	12-May	07:00	37	0	0	155	16.4	138 - 190	35.8	11.1	25.3 - 68.8
32	12-May	19:11	36	0	0	158	16.4	134 - 204	38.6	12.8	24.2 - 86.9
33	13-May	07:15	35	2	0	163	16.0	135 - 193	41.7	12.5	22.4 - 66.7
34	13-May	19:00	36	0	0	165	18.2	137 - 204	45.7	15.2	23.5 - 81.0
35	14-May	07:10	35	1	0	162	18.6	139 - 200	43.2	14.8	24.4 - 77.9
36	14-May	19:15	36	0	0	158	15.1	135 - 185	38.6	11.2	21.7 - 59.7
37	15-May	07:05	33	2	1	167	18.8	136 - 230	45.1	18.7	22.3 - 124.6
38	15-May	19:15	37	0	0	162	16.5	135 - 196	41.9	13.0	22.4 - 74.2
39	16-May	07:11	36	0	0	166	18.9	137 - 200	44.8	15.2	23.4 - 78.7
40	16-May	19:11	34	0	1	164	20.5	135 - 210	44.0	16.4	22.5 - 87.9
41	17-May	07:04	35	0	0	159	15.1	138 - 194	39.7	12.0	23.6 - 70.4
42	17-May	19:24	35	0	1	162	15.3	138 - 196	41.5	12.6	24.3 - 77.0
43	18-May	07:18	35	1	0	168	17.2	137 - 206	47.2	14.9	22.9 - 87.9
44	18-May	18:50	36	0	0	162	13.6	137 - 185	40.6	9.6	25.5 - 60.6
45	19-May	07:17	35	0	0	162	17.7	133 - 197	42.0	13.9	24.6 - 76.1
46	19-May	19:10	33	0	2	163	14.7	133 - 189	42.7	12.0	24.2 - 72.6
47	20-May	07:06	34	1	0	166	16.6	137 - 192	43.5	12.0	22.8 - 64.1
48	20-May	18:56	35	0	0	156	14.6	133 - 193	36.1	10.8	21.9 - 66.2
49	21-May	07:00	35	0	0	157	16.6	134 - 191	37.5	12.2	21.8 - 65.0
50	21-May	19:07	35	0	0	162	17.4	136 - 216	41.3	15.4	21.9 - 93.4
51	22-May	07:04	35	0	0	155	17.3	134 - 194	35.3	12.6	21.6 - 67.9

Table A1.1. Continued.

						Fork length (mm)			Weight (g)		
Release	Date	Time	N	Tag loss	Mortality	Mean	SD	Range	Mean	SD	Range
52	22-May	18:55	33	2	0	168	14.6	139 - 200	44.5	12.5	23.6 - 80.4
53	23-May	07:40	35	0	0	162	18.5	133 - 220	42.9	15.5	22.5 - 98.5
54	23-May	19:00	33	0	0	158	12.6	132 - 186	35.9	9.1	22.7 - 59.9
55	24-May	07:00	34	0	0	162	16.5	134 - 205	40.8	13.8	21.9 - 82.8
56	24-May	19:08	34	0	0	162	16.0	136 - 193	41.0	13.0	23.8 - 66.1
57	25-May	07:12	34	0	0	170	18.7	137 - 222	47.5	17.8	24.7 - 112.7
58	25-May	19:10	34	0	0	160	18.0	134 - 200	39.9	14.2	22.6 - 76.7
59	26-May	06:49	34	0	0	158	16.3	132 - 208	38.9	12.9	22.9 - 86.9
60	26-May	19:08	35	0	0	167	17.9	139 - 201	47.0	15.3	23.9 - 86.4
61	27-May	07:55	35	1	0	172	21.6	135 - 212	51.0	19.9	23.6 - 91.3
62	27-May	19:05	35	0	0	170	19.3	133 - 210	48.7	17.8	22.8 - 94.2
63	28-May	07:06	36	0	0	167	18.1	134 - 204	47.0	16.0	23.4 - 86.2
64	28-May	19:15	35	0	0	167	18.0	145 - 205	46.1	16.4	28.2 - 82.1
Overall			2230	36	18	158	16.2	124 - 230	39.2	12.7	21.5 - 124.6

Table A1.2. Summary of yearling Chinook salmon releases at The Dalles Dam tailrace during spring 2004. Dates, times, numbers of tagged fish released (N), 24 h post-tagging tag loss and mortality, and means, standard deviations (SD) and ranges for fork lengths and weights are presented. Release times are the start of releases and include fish released up to 1 hour later.

						Fork length (mm)			Weight (g)		
Release	Date	Time	N	Tag loss	Mortality	Mean	SD	Range	Mean	SD	Range
1	28-Apr	01:25	41	6	0	148	10.5	130 - 188	34.8	9.2	23.8 - 76.4
2	28-Apr	12:23	45	0	0	152	7.4	139 - 169	33.2	5.2	25.9 - 44.7
3	29-Apr	01:49	40	6	1	155	12.1	131 - 185	36.7	9.0	24.5 - 58.2
4	29-Apr	12:30	44	0	0	156	13.0	132 - 200	38.2	9.3	23.4 - 62.2
5	30-Apr	01:33	38	6	2	152	9.9	135 - 180	35.1	8.0	23.0 - 62.6
6	30-Apr	13:06	47	1	0	153	8.4	133 - 178	35.1	5.6	22.5 - 51.6
7	1-May	00:10	48	0	0	150	7.0	136 - 167	32.9	4.7	24.2 - 50.5
8	1-May	13:15	45	1	0	153	9.8	137 - 180	35.5	7.4	24.2 - 55.6
9	2-May	00:30	47	0	0	149	7.8	136 - 170	33.0	5.6	24.3 - 48.1
10	2-May	13:38	47	0	0	148	12.4	130 - 178	35.0	7.8	25.4 - 57.5
11	3-May	00:48	46	2	0	153	10.5	135 - 186	34.9	7.7	25.1 - 60.0
12	3-May	12:30	45	1	0	150	14.2	127 - 192	36.2	10.8	21.5 - 69.5
13	4-May	00:37	44	2	0	149	9.3	137 - 190	33.0	6.4	22.5 - 56.0
14	4-May	12:46	47	1	0	150	9.8	136 - 176	32.5	6.5	23.9 - 54.9
15	5-May	00:33	46	0	1	147	10.2	130 - 176	30.7	8.0	21.8 - 63.3
16	5-May	12:28	47	1	0	149	10.8	131 - 191	31.6	7.1	21.7 - 60.8
17	6-May	00:33	47	0	0	154	13.9	133 - 184	35.4	10.3	21.5 - 59.5
18	6-May	12:35	46	1	0	152	12.2	131 - 183	34.0	8.5	21.7 - 58.7
19	7-May	00:19	41	6	0	149	11.7	132 - 177	35.5	8.0	21.8 - 54.1
20	7-May	12:04	45	1	1	152	14.2	130 - 180	34.6	10.2	22.5 - 55.8
21	8-May	00:03	46	2	0	154	10.1	139 - 174	38.9	6.7	27.4 - 54.5
22	8-May	12:33	43	2	0	156	10.9	140 - 184	36.0	7.2	25.7 - 55.1
23	9-May	00:06	47	0	0	147	12.5	132 - 181	31.8	10.5	21.5 - 77.5
24	9-May	13:01	47	0	0	147	12.5	132 - 205	30.1	9.8	22.0 - 75.1

Table A1.2. Continued.

						Fork length (mm)			Weight (g)		
Release	Date	Time	N	Tag loss	Mortality	Mean	SD	Range	Mean	SD	Range
25	10-May	01:30	48	0	0	157	13.3	133 - 192	37.5	9.8	23.6 - 70.2
26	10-May	12:47	47	0	0	154	12.1	134 - 191	35.9	9.3	23.5 - 66.7
27	11-May	00:43	48	0	0	149	12.4	133 - 181	32.2	8.5	23.3 - 58.9
28	11-May	12:05	48	0	1	147	11.9	131 - 188	30.3	8.6	21.6 - 62.0
29	12-May	00:26	46	1	0	159	18.1	134 - 200	39.4	13.5	22.8 - 74.7
30	12-May	12:06	45	2	1	159	14.7	136 - 189	39.2	10.7	23.9 - 64.5
31	13-May	00:31	48	0	0	154	16.9	133 - 190	36.2	12.4	22.6 - 65.4
32	13-May	12:10	48	0	0	163	17.3	131 - 197	42.3	13.8	22.3 - 71.2
33	14-May	00:55	48	0	1	155	15.2	135 - 199	36.1	12.2	21.7 - 76.6
34	14-May	13:06	48	0	1	159	17.6	136 - 198	38.4	12.4	23.5 - 69.3
35	15-May	01:04	47	0	2	160	18.8	136 - 218	40.7	15.9	22.5 - 94.1
36	15-May	12:29	47	1	0	161	18.0	135 - 208	40.8	14.8	21.5 - 83.0
37	16-May	00:21	47	1	2	160	19.3	136 - 205	39.7	14.7	21.8 - 72.2
38	16-May	12:40	47	0	0	159	18.6	137 - 200	38.7	14.6	21.8 - 76.9
39	17-May	00:39	45	1	5	161	18.2	130 - 200	41.0	13.7	21.6 - 72.9
40	17-May	12:28	48	0	0	161	16.0	134 - 189	40.0	13.1	21.9 - 68.8
41	18-May	00:20	46	1	3	160	17.9	138 - 195	40.0	14.3	24.1 - 76.0
42	18-May	12:47	43	4	0	165	17.8	135 - 198	42.7	13.9	22.2 - 73.5
43	19-May	00:10	48	0	4	155	15.6	135 - 194	36.0	11.4	22.2 - 69.6
44	19-May	12:19	47	1	0	156	14.6	131 - 191	35.6	9.5	22.0 - 60.3
45	20-May	00:04	53	0	0	160	15.9	130 - 197	39.9	11.7	21.6 - 75.9
46	20-May	12:40	51	1	0	163	15.3	131 - 205	41.5	11.4	25.2 - 70.3
47	21-May	00:59	52	0	1	160	15.5	133 - 200	39.7	11.1	24.3 - 69.9
48	21-May	12:03	53	0	2	158	15.3	130 - 185	37.1	10.5	21.6 - 58.6
49	22-May	00:55	53	0	0	160	15.2	131 - 200	39.3	11.7	22.9 - 81.1
50	22-May	12:26	52	0	0	159	13.4	134 - 190	37.4	9.8	22.3 - 67.6
51	23-May	00:04	51	2	1	162	14.7	139 - 216	40.2	11.8	24.6 - 91.0

Table A1.2. Continued.

						Fork length (mm)			Weight (g)		
Release	Date	Time	N	Tag loss	Mortality	Mean	SD	Range	Mean	SD	Range
52	23-May	12:20	53	0	0	161	13.6	133 - 191	40.0	9.9	22.3 - 65.8
53	24-May	00:36	52	0	0	162	13.8	141 - 205	40.0	11.6	26.4 - 83.6
54	24-May	12:40	48	0	0	160	15.6	135 - 191	39.0	11.5	21.7 - 62.5
55	25-May	00:43	51	2	1	159	16.6	136 - 199	37.7	12.6	23.9 - 70.8
56	25-May	15:47	51	1	0	162	18.5	135 - 209	42.5	16.0	24.3 - 94.1
57	26-May	00:18	51	1	2	162	18.3	136 - 215	41.0	16.7	22.0 - 100.6
58	26-May	12:40	52	0	1	161	16.8	137 - 205	41.1	14.9	24.7 - 91.7
59	27-May	00:57	53	0	1	163	17.8	135 - 214	41.8	15.7	21.9 - 96.7
60	27-May	12:04	53	0	1	161	16.4	135 - 202	40.9	14.2	22.1 - 87.9
61	28-May	00:47	44	0	2	168	20.5	134 - 210	48.8	19.5	26.4 - 99.8
62	28-May	12:08	47	0	0	169	21.8	133 - 224	48.5	20.9	21.8 - 112.6
63	29-May	01:10	28	0	4	166	21.1	141 - 202	46.5	18.9	26.0 - 84.7
64	29-May	12:10	29	2	2	169	19.3	145 - 212	47.1	19.1	26.5 - 88.0
Overall			2995	60	43	157	15.8	127 - 224	37.8	12.4	21.5 - 112.6

Table A1.3. Summary of yearling Chinook salmon releases at The Dalles Dam ice and trash sluiceway during spring 2004. Dates, times, numbers of tagged fish released (N), 24 h post-tagging tag loss and mortality, and means, standard deviations (SD) and ranges for fork lengths and weights are presented. Release times are the start of releases and include fish released up to 1 hour later.

						Fork length (mm)			Weight (g)		
Release	Date	Time	N	Tag loss	Mortality	Mean	SD	Range	Mean	SD	Range
1	28-Apr	12:29	13	0	0	153	6.3	142 - 162	33.4	4.8	26.0 - 42.2
2	29-Apr	19:09	22	2	0	154	8.1	142 - 175	35.9	5.3	28.7 - 49.2
3	1-May	01:59	24	0	0	156	11.5	136 - 178	37.5	8.2	24.2 - 54.5
4	1-May	07:05	20	3	1	150	10.2	132 - 173	33.9	6.8	23.5 - 49.7
5	2-May	13:00	21	2	0	144	7.2	131 - 157	32.5	4.0	27.1 - 43.5
6	3-May	07:00	24	0	0	147	10.8	132 - 180	34.6	8.3	23.1 - 58.0
7	5-May	01:00	24	0	0	149	10.7	135 - 179	32.7	8.1	23.5 - 55.5
8	5-May	19:09	23	0	0	148	10.4	136 - 174	31.2	8.1	23.2 - 52.5
9	6-May	07:00	24	0	0	154	14.8	131 - 192	35.6	10.7	22.2 - 63.1
10	8-May	01:00	24	0	0	160	12.4	136 - 189	45.3	11.7	30.2 - 65.2
11	8-May	19:00	21	0	2	147	12.0	122 - 178	31.7	8.7	22.4 - 58.7
12	9-May	13:00	24	0	0	149	11.2	135 - 178	32.1	8.8	23.8 - 58.7
13	10-May	19:00	23	1	0	151	14.0	134 - 189	34.2	11.6	21.9 - 66.2
14	11-May	13:00	22	1	0	152	19.9	130 - 210	34.2	15.5	22.2 - 79.8
15	12-May	07:08	24	0	0	160	17.9	139 - 210	40.8	16.0	23.4 - 95.6
16	14-May	01:00	22	0	1	158	19.7	134 - 203	38.9	15.7	23.4 - 77.4

Table A1.3. Continued.

						Fork length (mm)			Weight (g)		
Release	Date	Time	N	Tag loss	Mortality	Mean	SD	Range	Mean	SD	Range
17	15-May	01:12	23	0	0	167	19.5	137 - 203	46.5	16.2	24.2 - 74.0
18	15-May	07:00	23	0	1	161	19.5	132 - 206	41.5	16.4	21.6 - 85.4
19	16-May	19:00	24	0	0	157	18.6	130 - 190	37.1	14.4	22.2 - 69.1
20	17-May	13:00	23	0	0	167	16.2	136 - 191	44.5	13.1	22.8 - 66.7
21	19-May	01:00	23	1	0	156	13.3	132 - 176	35.8	9.1	22.5 - 50.7
22	19-May	13:01	23	1	0	159	16.8	134 - 195	38.5	12.8	22.1 - 64.5
23	20-May	07:03	27	0	0	169	13.7	142 - 200	44.8	11.0	26.9 - 73.9
24	21-May	19:00	27	0	0	157	18.7	130 - 200	37.4	13.2	22.4 - 71.0
25	22-May	13:00	27	0	0	162	16.3	133 - 189	39.6	12.5	22.9 - 68.2
26	23-May	19:00	27	0	0	157	13.7	132 - 185	36.6	10.0	22.9 - 59.5
27	25-May	01:01	25	1	0	165	18.0	141 - 214	43.0	16.7	24.6 - 92.0
28	25-May	07:01	27	0	0	166	16.4	137 - 200	43.9	13.0	23.4 - 77.2
29	27-May	01:02	27	0	0	168	21.1	140 - 211	46.7	20.1	24.2 - 99.0
30	27-May	13:03	27	0	0	165	16.0	134 - 198	45.3	14.0	24.1 - 74.7
31	28-May	07:00	23	0	0	158	18.5	138 - 195	38.7	16.7	24.6 - 76.0
32	29-May	19:00	11	0	0	163	15.2	141 - 189	42.8	12.7	26.3 - 64.1
Overall			742	12	5	157	16.5	122 - 214	38.5	13.1	21.6 - 99.0

Table A1.4. Summary of yearling Chinook salmon releases at The Dalles Dam ice and trash sluiceway tailrace during spring 2004. Dates, times, numbers of tagged fish released (N), 24 h post-tagging tag loss and mortality, and means, standard deviations (SD) and ranges for fork lengths and weights are presented. Release times are the start of releases and include fish released up to 1 hour later.

						Fork length (mm)			Weight (g)		
Release	Date	Time	N	Tag loss	Mortality	Mean	SD	Range	Mean	SD	Range
1	28-Apr	14:05	19	0	0	159	9.6	147 - 180	38.2	7.2	27.5 - 52.1
2	29-Apr	20:00	22	2	0	154	9.4	143 - 173	36.2	7.7	27.9 - 53.8
3	1-May	02:52	19	0	0	151	9.3	141 - 179	33.5	6.9	26.4 - 56.2
4	1-May	08:02	22	0	0	151	10.1	130 - 168	33.7	6.5	25.5 - 46.5
5	2-May	13:00	22	1	1	150	15.1	132 - 186	32.8	8.3	22.9 - 55.9
6	3-May	08:00	23	1	0	147	10.5	125 - 171	32.7	7.6	21.7 - 55.4
7	5-May	01:53	24	0	0	150	11.9	134 - 176	33.6	9.3	22.4 - 50.7
8	5-May	19:58	23	1	0	146	8.9	136 - 173	29.9	5.7	21.6 - 43.4
9	6-May	07:45	23	0	0	149	12.0	133 - 182	31.3	8.7	21.7 - 57.2
10	8-May	01:47	22	1	0	156	14.9	138 - 185	40.6	12.2	28.4 - 69.5
11	8-May	19:45	22	0	3	158	15.7	132 - 185	39.4	11.9	22.0 - 60.1
12	9-May	13:42	24	0	0	149	8.5	136 - 165	31.4	5.4	23.7 - 44.0
13	10-May	19:47	24	0	0	154	15.8	133 - 205	35.8	15.5	23.2 - 98.6
14	11-May	13:41	25	0	0	149	17.1	134 - 200	32.1	13.0	22.6 - 73.9
15	12-May	08:04	24	0	0	152	14.4	129 - 188	34.4	10.2	21.8 - 63.8
16	14-May	01:44	22	0	0	163	15.8	135 - 189	41.1	11.4	23.7 - 67.3

Table A1.4. Continued.

						Fork length (mm)			Weight (g)		
Release	Date	Time	N	Tag loss	Mortality	Mean	SD	Range	Mean	SD	Range
17	15-May	01:53	25	0	0	164	20.3	132 - 207	43.8	16.9	21.9 - 79.0
18	15-May	07:48	24	0	0	161	22.7	137 - 220	42.1	19.9	22.4 - 97.3
19	16-May	19:41	22	1	0	164	16.5	137 - 186	41.9	12.3	22.0 - 62.7
20	17-May	13:39	25	0	0	160	17.3	137 - 205	40.3	16.0	22.9 - 91.1
21	19-May	01:46	24	0	0	164	17.0	138 - 194	41.0	12.2	23.7 - 67.3
22	19-May	13:48	24	0	0	157	12.8	137 - 188	36.5	9.9	24.0 - 63.3
23	20-May	07:56	27	0	0	162	14.9	137 - 193	39.4	10.9	23.3 - 67.0
24	21-May	19:37	27	1	0	154	13.3	136 - 192	36.0	9.2	24.8 - 64.5
25	22-May	13:40	28	0	0	160	14.9	135 - 202	39.0	11.8	23.1 - 78.4
26	23-May	19:43	26	0	0	163	12.8	142 - 184	39.5	8.7	22.5 - 53.8
27	25-May	01:50	27	0	0	167	17.2	135 - 200	42.9	14.8	21.5 - 72.5
28	25-May	08:01	28	0	0	163	14.4	134 - 195	41.5	12.2	23.8 - 81.2
29	27-May	01:46	25	0	2	162	18.5	132 - 215	41.3	16.4	22.3 - 96.6
30	27-May	13:52	26	1	0	168	22.1	136 - 214	48.2	21.4	23.7 - 96.8
31	28-May	07:39	22	1	0	164	17.9	139 - 210	42.1	16.3	25.4 - 87.6
32	29-May	19:33	9	0	0	169	26.2	137 - 202	50.6	23.3	25.6 - 85.6
Overall			749	10	6	157	16.3	125 - 220	38.1	13.1	21.5 - 98.6

Table A1.5. Summary of subyearling Chinook salmon releases at the John Day Dam tailrace during summer 2004. Dates, times, numbers of tagged fish released (N), 24 h post-tagging tag loss and mortality, and means, standard deviations (SD) and ranges for fork lengths and weights are presented. Release times are the start of releases and include fish released up to 1 hour later.

						Fork length (mm)			Weight (g)		
Release	Date	Time	N	Tag loss	Mortality	Mean	SD	Range	Mean	SD	Range
1	19-Jun	06:07	31	0	0	115	4.6	109 - 126	16.2	2.0	13.0 - 21.8
2	19-Jun	18:07	29	1	0	116	5.8	110 - 130	16.2	2.4	13.1 - 21.6
3	20-Jun	06:02	30	1	0	119	6.5	110 - 136	17.4	2.9	13.7 - 24.9
4	20-Jun	18:04	29	1	0	118	6.8	110 - 135	17.8	3.3	14.6 - 26.6
5	21-Jun	06:05	31	1	0	120	7.7	111 - 138	18.2	3.4	14.6 - 28.0
6	21-Jun	18:07	32	0	0	114	3.5	110 - 125	15.7	1.7	13.3 - 20.9
7	22-Jun	06:07	30	0	0	124	8.4	111 - 143	20.9	4.4	15.4 - 32.2
8	22-Jun	18:24	30	1	1	115	4.4	110 - 128	15.7	1.8	13.4 - 20.4
9	23-Jun	05:58	31	0	0	118	6.8	109 - 133	18.0	3.2	14.2 - 25.0
10	23-Jun	18:04	31	1	1	114	3.7	110 - 127	15.0	1.7	13.1 - 20.9
11	24-Jun	06:03	31	0	0	115	4.3	108 - 125	15.7	1.9	13.0 - 21.6
12	24-Jun	18:15	29	0	0	112	2.0	108 - 117	14.6	1.0	13.3 - 17.0
13	25-Jun	06:15	30	0	0	116	7.3	110 - 150	15.8	3.6	13.3 - 32.8
14	25-Jun	18:07	31	1	0	112	2.2	107 - 116	14.5	1.0	13.0 - 16.7
15	26-Jun	06:30	22	0	1	115	10.5	108 - 160	15.6	5.9	13.0 - 41.2
16	26-Jun	18:00	23	2	0	119	11.2	109 - 157	17.4	6.5	13.0 - 41.6
17	27-Jun	06:37	25	1	1	118	10.2	109 - 152	16.9	5.4	13.0 - 36.3
18	27-Jun	17:47	17	1	0	114	1.8	111 - 119	15.4	1.2	13.6 - 17.3
19	28-Jun	06:08	16	1	0	113	1.4	110 - 115	15.2	1.5	13.0 - 18.3
20	28-Jun	17:59	29	0	1	115	3.8	110 - 123	15.8	1.9	13.2 - 20.0
21	29-Jun	06:08	29	0	0	117	9.3	107 - 141	17.3	4.4	13.4 - 28.7
22	29-Jun	18:12	20	0	1	115	6.3	110 - 138	15.9	2.6	13.1 - 25.0
23	30-Jun	05:50	20	0	1	113	2.5	109 - 118	14.7	1.5	13.1 - 18.4
24	30-Jun	18:00	28	0	3	116	8.9	108 - 142	17.5	4.1	13.0 - 30.4
25	1-Jul	06:16	27	1	0	115	7.0	107 - 136	15.8	3.5	13.2 - 25.9
26	1-Jul	18:40	20	0	0	116	7.0	109 - 135	16.3	3.0	13.0 - 23.5
27	2-Jul	06:05	20	0	0	112	2.8	106 - 117	14.7	1.1	13.2 - 17.0

Table A1.5. Continued.

						Fork length (mm)			Weight (g)		
Release	Date	Time	N	Tag loss	Mortality	Mean	SD	Range	Mean	SD	Range
28	2-Jul	18:10	21	1	0	116	8.3	108 - 142	17.3	4.6	13.1 - 31.0
29	3-Jul	06:03	22	0	0	116	7.7	108 - 138	17.2	4.0	13.8 - 29.4
30	3-Jul	17:58	20	0	0	114	6.2	108 - 132	16.6	3.9	13.1 - 28.3
31	4-Jul	05:52	19	0	0	116	11.0	105 - 148	16.7	5.5	13.0 - 35.0
32	4-Jul	17:56	17	0	2	123	14.7	109 - 148	20.2	7.2	13.4 - 33.4
33	5-Jul	05:53	17	0	1	120	10.5	110 - 141	18.9	5.6	13.2 - 29.2
34	5-Jul	18:09	18	0	0	113	2.5	109 - 117	15.3	1.3	13.4 - 18.1
35	6-Jul	06:08	18	0	0	115	7.5	109 - 141	16.3	3.9	13.2 - 30.1
36	6-Jul	17:59	19	1	0	111	4.2	106 - 125	15.7	2.4	13.3 - 23.6
37	7-Jul	06:20	19	0	0	118	11.4	110 - 148	17.9	6.6	13.0 - 35.9
38	7-Jul	18:14	22	1	0	114	8.2	107 - 145	16.1	4.7	13.3 - 35.5
39	8-Jul	06:06	20	0	1	120	12.9	106 - 149	18.3	6.6	13.1 - 36.8
40	8-Jul	17:45	19	0	0	111	4.7	105 - 125	15.1	2.3	13.2 - 22.7
41	9-Jul	06:02	13	0	0	116	8.8	106 - 133	16.9	3.9	13.2 - 26.1
42	9-Jul	18:20	19	0	1	118	14.4	107 - 150	18.6	7.6	13.3 - 37.8
43	10-Jul	05:51	14	0	1	114	10.1	106 - 146	15.7	5.5	13.1 - 34.4
44	10-Jul	18:10	23	0	0	121	13.9	105 - 154	19.6	7.4	13.2 - 39.4
45	11-Jul	06:00	23	0	1	125	12.8	114 - 175	20.6	8.5	13.5 - 56.3
46	11-Jul	18:00	20	0	2	115	8.8	107 - 144	16.0	3.6	13.1 - 27.5
47	12-Jul	06:13	20	0	0	117	10.0	110 - 146	16.7	4.6	13.0 - 29.8
48	12-Jul	18:07	16	0	0	116	10.3	108 - 149	17.2	5.1	13.2 - 34.5
49	13-Jul	05:53	14	0	0	126	9.6	110 - 140	20.3	4.2	14.0 - 28.5
50	13-Jul	17:55	20	0	0	124	12.5	105 - 145	19.7	5.8	13.3 - 30.3
51	14-Jul	06:01	18	0	2	131	18.4	108 - 163	26.1	11.8	13.1 - 53.0
52	14-Jul	17:56	28	0	1	115	9.7	105 - 141	17.4	4.0	13.6 - 30.3
53	15-Jul	05:55	24	0	3	116	9.8	105 - 142	17.2	4.4	13.6 - 31.5
54	15-Jul	17:54	22	1	2	115	10.1	107 - 147	16.1	5.1	13.0 - 32.6
55	16-Jul	06:05	24	0	0	118	9.6	105 - 154	18.7	5.7	13.8 - 42.2
56	16-Jul	18:13	29	0	2	117	8.9	107 - 137	17.4	3.8	13.1 - 26.5

Table A1.5. Continued.

						Fork length (mm)			Weight (g)		
Release	Date	Time	N	Tag loss	Mortality	Mean	SD	Range	Mean	SD	Range
57	17-Jul	06:20	31	1	0	129	14.9	107 - 167	22.5	8.1	13.0 - 52.3
58	17-Jul	17:47	33	0	3	116	7.2	106 - 138	17.1	3.2	13.4 - 28.6
59	18-Jul	06:40	20	0	0	117	10.6	106 - 153	17.0	4.2	13.1 - 31.4
60	18-Jul	17:46	29	0	4	115	8.2	105 - 137	17.3	3.0	13.8 - 25.0
61	19-Jul	06:00	33	2	1	117	8.0	106 - 137	17.7	3.5	13.3 - 25.6
62	19-Jul	18:06	33	0	2	115	9.8	105 - 147	16.7	4.4	13.0 - 33.5
63	20-Jul	06:00	31	0	1	115	8.4	107 - 145	16.1	3.4	13.2 - 28.9
64	20-Jul	18:30	32	0	4	116	12.7	103 - 165	19.3	8.7	13.0 - 56.3
65	21-Jul	06:16	35	0	1	118	9.7	107 - 157	18.3	5.2	13.3 - 42.2
66	21-Jul	18:20	35	0	2	111	5.7	105 - 125	15.2	2.3	13.0 - 22.5
67	22-Jul	06:05	34	1	1	116	11.4	106 - 156	17.7	5.9	13.3 - 41.5
68	22-Jul	18:07	33	0	1	113	11.2	102 - 150	16.7	4.8	13.0 - 33.4
69	23-Jul	06:16	36	0	0	114	8.9	104 - 134	16.8	4.1	13.3 - 28.4
70	23-Jul	18:45	21	0	0	111	5.7	103 - 120	15.4	1.9	13.0 - 19.3
71	24-Jul	06:06	31	1	1	115	7.5	105 - 129	17.9	3.4	13.6 - 27.6
72	24-Jul	18:14	52	0	3	110	5.3	103 - 126	15.8	2.1	13.2 - 22.6
73	25-Jul	06:07	50	0	4	112	7.5	102 - 135	17.0	3.2	13.5 - 29.5
74	25-Jul	17:49	50	1	9	113	7.2	103 - 140	16.2	2.7	13.3 - 25.8
75	26-Jul	06:20	63	0	1	113	6.7	104 - 142	16.5	2.9	13.1 - 29.2
76	26-Jul	17:50	57	0	3	111	6.6	100 - 130	17.6	3.0	13.0 - 28.5
77	27-Jul	06:12	60	0	2	112	8.5	102 - 147	16.7	3.7	13.1 - 33.1
78	27-Jul	17:55	35	0	1	110	5.5	103 - 130	15.5	2.4	13.2 - 25.7
79	28-Jul	07:31	32	0	2	112	8.6	102 - 136	16.4	3.7	13.0 - 27.8
80	28-Jul	18:16	45	0	1	109	6.1	101 - 130	16.5	2.7	13.0 - 26.8
Overall			2210	23	76	115	9.2	100 - 175	17.0	4.5	13.0 - 56.3

Table A1.6. Summary of subyearling Chinook salmon releases at The Dalles Dam tailrace during summer 2004. Dates, times, numbers of tagged fish released (N), 24 h post-tagging tag loss and mortality, and means, standard deviations (SD) and ranges for fork lengths and weights are presented. Release times are the start of releases and include fish released up to 1 hour later.

						Fork length (mm)			Weight (g)		
Release	Date	Time	N	Tag loss	Mortality	Mean	SD	Range	Mean	SD	Range
1	20-Jun	00:41	117	2	0	119	8.8	106 - 149	18.6	4.1	14.0 - 34.6
2	20-Jun	12:35	106	1	0	117	6.9	108 - 138	16.6	3.1	13.0 - 26.2
3	21-Jun	00:31	117	2	0	118	6.9	109 - 137	18.1	3.5	13.2 - 28.2
4	21-Jun	12:35	115	4	0	121	8.0	108 - 146	18.4	4.0	13.0 - 33.2
5	22-Jun	00:23	114	3	0	120	7.6	104 - 141	18.0	3.5	14.1 - 31.0
6	22-Jun	13:05	65	1	0	119	7.0	111 - 145	17.4	3.1	13.6 - 28.4
7	23-Jun	01:05	116	2	0	119	7.4	109 - 140	18.5	3.2	13.4 - 27.6
8	23-Jun	12:38	118	1	1	118	7.6	109 - 142	17.1	3.4	13.1 - 28.3
9	24-Jun	00:43	117	2	0	115	4.9	108 - 132	16.5	2.4	13.2 - 24.9
10	24-Jun	13:38	118	1	0	116	7.0	109 - 153	16.4	3.4	13.3 - 38.1
11	25-Jun	00:35	88	2	0	115	6.3	109 - 142	15.3	3.0	13.0 - 30.9
12	25-Jun	13:13	47	1	0	114	5.5	107 - 137	15.5	3.0	13.0 - 30.1
13	26-Jun	00:56	89	4	0	115	6.7	108 - 140	15.6	3.2	13.1 - 29.3
14	26-Jun	13:05	46	3	3	117	9.1	110 - 150	16.5	4.9	13.1 - 35.1
15	27-Jun	01:07	19	1	0	117	6.3	110 - 132	17.2	2.9	13.4 - 24.1
16	27-Jun	13:04	35	1	0	121	11.4	109 - 153	19.2	6.5	13.4 - 36.1
17	28-Jun	01:16	32	0	1	118	9.1	109 - 147	17.5	4.3	13.3 - 32.1
18	28-Jun	13:12	14	0	0	116	6.1	111 - 135	16.2	3.3	13.0 - 26.3
19	29-Jun	00:45	58	0	0	114	4.4	107 - 134	16.3	2.3	13.2 - 24.9
20	29-Jun	12:53	81	0	0	115	7.0	107 - 146	16.1	3.7	13.0 - 32.3
21	30-Jun	01:02	28	0	0	117	10.8	106 - 149	17.7	5.4	13.1 - 36.3
22	30-Jun	12:49	165	2	2	115	7.9	107 - 146	16.2	3.9	13.0 - 34.2
23	1-Jul	00:18	101	2	3	115	7.5	104 - 146	15.5	3.6	13.0 - 31.8
24	1-Jul	12:36	125	1	2	115	7.4	107 - 148	16.5	3.8	13.0 - 35.2
25	2-Jul	01:12	27	0	2	115	8.3	105 - 138	16.1	4.2	13.1 - 27.1
26	2-Jul	12:48	53	2	0	115	7.1	107 - 136	16.0	3.5	13.1 - 26.6
27	3-Jul	01:36	73	0	2	115	10.5	102 - 154	16.7	5.6	13.0 - 40.5

Table A1.6. Continued.

						Fork length (mm)			Weight (g)		
Release	Date	Time	N	Tag loss	Mortality	Mean	SD	Range	Mean	SD	Range
28	3-Jul	13:08	50	0	0	115	7.5	107 - 142	16.1	3.9	13.0 - 31.0
29	4-Jul	00:38	40	0	0	114	6.8	107 - 139	15.9	3.3	13.1 - 27.1
30	4-Jul	13:30	18	0	0	117	8.5	109 - 142	17.3	4.1	13.0 - 28.1
31	5-Jul	00:46	64	1	0	117	11.1	103 - 150	18.6	5.9	13.2 - 40.0
32	5-Jul	13:01	27	0	0	116	8.8	107 - 150	16.8	5.1	13.0 - 37.8
33	6-Jul	00:55	33	0	0	118	11.8	107 - 151	18.7	6.1	13.5 - 38.5
34	6-Jul	12:31	100	1	0	116	11.4	104 - 168	17.6	6.1	13.0 - 48.2
35	7-Jul	00:46	43	0	0	114	6.9	107 - 137	16.2	3.1	13.0 - 27.4
36	7-Jul	12:49	108	1	2	115	8.8	105 - 147	16.9	4.3	13.1 - 34.0
37	8-Jul	00:37	82	0	4	114	9.1	103 - 146	16.2	4.4	13.0 - 32.6
38	8-Jul	13:01	79	1	0	113	8.2	101 - 144	15.7	3.6	13.0 - 32.2
39	9-Jul	01:00	11	0	1	122	13.0	108 - 145	19.6	6.7	13.5 - 30.1
40	9-Jul	13:03	39	0	0	111	6.4	105 - 142	15.3	2.8	13.0 - 29.4
41	10-Jul	00:49	78	0	0	115	10.7	103 - 149	17.6	5.1	13.1 - 36.1
42	10-Jul	12:47	42	0	3	119	14.8	103 - 156	18.6	7.7	13.0 - 41.0
43	11-Jul	00:34	58	1	1	124	13.9	106 - 159	21.3	7.5	13.1 - 49.8
44	11-Jul	13:10	60	0	2	127	17.4	105 - 169	22.9	10.5	13.0 - 50.2
45	12-Jul	00:38	50	0	1	120	12.9	105 - 158	19.6	6.9	13.0 - 42.8
46	12-Jul	12:46	59	0	2	119	12.2	105 - 163	18.7	6.4	13.0 - 47.0
47	13-Jul	00:28	63	1	1	125	15.8	105 - 162	21.6	9.2	13.0 - 48.8
48	13-Jul	13:12	49	0	0	125	16.8	106 - 168	21.4	8.5	13.1 - 50.5
49	14-Jul	01:10	25	0	1	129	14.5	109 - 162	23.1	8.6	13.7 - 47.4
50	14-Jul	13:10	21	0	0	120	11.8	104 - 142	18.1	4.9	13.1 - 27.9
51	15-Jul	01:08	92	0	1	117	10.1	104 - 156	17.3	4.7	13.0 - 38.6
52	15-Jul	12:46	62	0	0	119	11.3	107 - 145	17.6	4.6	13.0 - 30.1
53	16-Jul	00:40	68	0	2	118	10.3	105 - 149	17.5	4.7	13.0 - 35.5
54	16-Jul	12:54	59	0	2	118	12.2	104 - 150	18.1	5.5	13.2 - 36.9
55	17-Jul	00:18	101	2	1	121	14.1	104 - 165	19.6	7.6	13.1 - 49.9
56	17-Jul	12:40	106	1	1	121	12.2	105 - 153	19.1	5.9	13.0 - 41.9

Table A1.6. Continued.

						Fork length (mm)			Weight (g)		
Release	Date	Time	N	Tag loss	Mortality	Mean	SD	Range	Mean	SD	Range
57	18-Jul	00:44	79	0	2	114	8.4	104 - 147	16.9	4.7	13.1 - 43.8
58	18-Jul	13:08	108	4	1	118	10.5	105 - 161	17.8	5.6	13.1 - 47.2
59	19-Jul	00:29	162	2	0	115	8.5	103 - 157	16.5	3.7	13.1 - 43.1
60	19-Jul	13:11	158	0	2	116	9.5	103 - 160	17.2	5.0	13.1 - 46.0
61	20-Jul	00:34	106	0	1	113	7.5	103 - 138	16.1	2.9	13.0 - 28.8
62	20-Jul	12:33	193	0	6	114	8.1	101 - 142	16.3	3.3	13.0 - 30.8
63	21-Jul	00:31	153	1	1	114	8.1	103 - 158	16.2	3.9	13.0 - 47.8
64	21-Jul	12:50	134	2	2	115	10.0	103 - 162	17.3	6.0	13.0 - 58.8
65	22-Jul	00:10	151	2	1	112	5.7	103 - 128	15.6	2.2	13.1 - 22.3
66	22-Jul	12:57	143	1	2	113	7.0	103 - 147	16.4	3.1	13.0 - 33.8
67	23-Jul	00:18	139	2	1	112	9.8	102 - 168	16.4	4.9	13.0 - 54.8
68	23-Jul	12:41	152	1	2	114	9.4	102 - 153	17.2	4.1	13.0 - 37.4
69	24-Jul	01:04	100	0	4	112	8.2	103 - 145	16.6	3.8	13.0 - 34.4
70	24-Jul	12:52	109	1	2	113	6.0	105 - 135	16.0	2.6	13.0 - 24.7
71	25-Jul	00:03	113	0	3	113	6.4	104 - 135	17.0	2.8	13.1 - 26.5
72	25-Jul	12:49	123	2	4	114	8.4	102 - 149	16.7	3.8	13.2 - 35.8
73	26-Jul	00:00	89	2	7	111	6.4	101 - 135	16.6	3.1	13.3 - 31.3
74	26-Jul	12:27	92	3	2	112	6.1	104 - 133	15.9	2.3	13.0 - 23.5
75	27-Jul	00:30	121	2	1	111	5.5	102 - 135	16.0	2.3	13.2 - 26.4
76	27-Jul	12:33	118	2	4	114	8.3	100 - 142	17.3	3.9	13.1 - 32.0
77	28-Jul	00:20	113	1	1	111	7.4	102 - 150	16.4	3.4	13.0 - 41.5
78	28-Jul	12:41	135	2	3	113	8.1	102 - 145	17.1	3.7	13.0 - 32.7
79	29-Jul	00:30	120	3	2	112	5.7	103 - 130	16.3	2.4	13.1 - 23.4
80	29-Jul	12:40	135	1	2	115	7.2	102 - 137	17.6	3.2	13.1 - 31.4
Overall			6917	81	97	116	9.4	100 - 169	17.1	4.6	13.0 - 58.8

Table A1.7. Summary of subyearling Chinook salmon releases at The Dalles Dam ice and trash sluiceway during summer 2004. Dates, times, numbers of tagged fish released (N), 24 h post-tagging tag loss and mortality, and means, standard deviations (SD) and ranges for fork lengths and weights are presented. Release times are the start of releases and include fish released up to 1 hour later.

						Fork length (mm)			Weight (g)		
Release	Date	Time	N	Tag loss	Mortality	Mean	SD	Range	Mean	SD	Range
1	20-Jun	07:00	31	0	0	122	8.3	110 - 141	18.9	3.9	14.2 - 27.9
2	21-Jun	13:21	29	1	0	121	6.8	113 - 135	17.9	3.2	13.5 - 25.1
3	22-Jun	09:12	31	0	0	119	6.3	110 - 130	17.5	2.6	14.1 - 23.3
4	23-Jun	19:00	31	0	0	114	3.6	109 - 126	16.1	2.0	13.5 - 21.7
5	24-Jun	19:00	30	1	0	113	2.3	110 - 119	14.2	0.7	13.2 - 15.6
6	25-Jun	13:00	29	0	0	116	5.4	109 - 130	16.4	2.5	13.4 - 23.5
7	26-Jun	07:00	30	0	0	115	8.7	110 - 154	16.5	5.5	13.1 - 42.4
8	27-Jun	01:02	14	0	0	122	12.0	109 - 145	19.7	6.0	14.1 - 32.8
9	28-Jun	07:06	13	1	0	118	7.7	110 - 136	17.3	3.9	13.3 - 25.7
10	29-Jun	19:04	13	0	1	115	6.5	109 - 133	16.1	3.1	13.9 - 25.0
11	30-Jun	01:00	18	0	0	115	6.2	108 - 129	16.2	3.1	13.0 - 24.3
12	1-Jul	13:16	31	0	0	114	8.0	107 - 148	15.8	4.0	13.1 - 33.0
13	2-Jul	01:05	16	0	0	114	4.5	109 - 125	15.0	2.2	13.0 - 20.3
14	3-Jul	19:01	19	1	0	113	5.1	109 - 132	14.9	1.1	13.1 - 17.7
15	4-Jul	13:05	14	2	0	121	12.3	109 - 142	18.8	6.3	13.4 - 30.1
16	5-Jul	07:00	16	0	0	115	7.3	106 - 130	16.7	2.9	13.3 - 23.5
17	6-Jul	01:00	17	1	0	118	11.9	105 - 144	18.7	6.4	13.2 - 33.4
18	7-Jul	13:14	37	2	0	117	9.3	106 - 146	17.5	4.2	13.0 - 31.7
19	8-Jul	19:00	13	0	0	116	10.5	106 - 141	17.2	4.7	13.1 - 27.9
20	9-Jul	01:00	12	0	0	117	10.5	105 - 140	17.8	4.9	13.0 - 28.1

Table A1.7. Continued.

						Fork length (mm)			Weight (g)		
Release	Date	Time	N	Tag loss	Mortality	Mean	SD	Range	Mean	SD	Range
21	10-Jul	13:22	24	0	2	118	12.7	107 - 151	17.9	6.8	13.0 - 36.7
22	11-Jul	07:00	28	0	0	124	11.6	106 - 143	20.2	5.7	13.0 - 32.1
23	12-Jul	01:02	26	1	0	124	14.5	104 - 156	21.5	8.0	13.0 - 45.0
24	13-Jul	19:00	21	0	0	138	18.4	107 - 167	28.4	11.2	14.3 - 52.2
25	14-Jul	07:07	23	1	0	130	15.3	107 - 157	23.6	8.9	13.0 - 45.5
26	15-Jul	01:02	41	0	0	119	11.6	106 - 152	18.4	5.8	13.4 - 39.8
27	16-Jul	13:11	24	2	1	119	11.4	105 - 150	18.1	5.5	13.0 - 35.6
28	17-Jul	19:00	28	1	0	115	7.2	105 - 129	16.5	2.6	13.1 - 21.2
29	18-Jul	13:10	31	0	0	118	8.9	103 - 136	17.6	3.8	13.1 - 26.3
30	19-Jul	07:00	33	0	1	114	5.9	105 - 135	16.1	2.0	13.3 - 23.0
31	20-Jul	01:06	31	0	0	114	8.6	103 - 144	16.5	3.7	13.1 - 30.9
32	21-Jul	19:03	35	0	0	117	14.0	102 - 161	18.4	7.3	13.2 - 49.0
33	22-Jul	13:05	32	1	0	112	6.7	105 - 135	16.0	2.8	13.3 - 27.9
34	23-Jul	07:05	29	0	1	114	8.9	103 - 140	17.0	3.5	13.1 - 27.6
35	24-Jul	19:00	32	0	0	112	4.8	105 - 124	16.4	2.1	14.2 - 21.7
36	25-Jul	01:24	25	0	0	111	4.2	105 - 120	16.5	2.4	13.8 - 23.1
37	26-Jul	13:01	16	0	0	113	7.3	105 - 132	16.9	4.6	13.2 - 29.7
38	27-Jul	01:03	20	0	0	112	7.8	102 - 130	16.7	3.9	13.3 - 26.9
39	28-Jul	07:02	23	0	0	110	5.7	103 - 126	15.6	2.2	13.0 - 22.0
40	29-Jul	19:00	24	0	0	113	7.5	102 - 133	16.9	3.3	13.3 - 25.7
Overall			990	15	6	117	10.3	102 - 167	17.6	5.1	13.0 - 52.2

Table A1.8. Summary of subyearling Chinook salmon releases at The Dalles Dam ice and trash sluiceway tailrace during summer 2004. Dates, times, numbers of tagged fish released (N), 24 h post-tagging tag loss and mortality, and means, standard deviations (SD) and ranges for fork lengths and weights are presented. Release times are the start of releases and include fish released up to 1 hour later.

						Fork length (mm)			Weight (g)		
Release	Date	Time	N	Tag loss	Mortality	Mean	SD	Range	Mean	SD	Range
1	20-Jun	07:44	30	1	0	117	5.4	110 - 132	16.7	2.9	13.6 - 27.5
2	21-Jun	14:07	28	2	0	119	6.3	110 - 135	17.6	3.4	13.3 - 25.8
3	22-Jun	10:02	30	1	0	115	5.2	108 - 134	15.5	2.4	13.1 - 25.4
4	23-Jun	19:43	30	1	0	117	6.8	110 - 135	17.7	3.1	14.6 - 26.6
5	24-Jun	19:43	29	2	0	116	6.2	110 - 142	15.5	2.7	13.0- 26.7
6	25-Jun	13:39	29	0	0	117	9.3	108 - 144	16.6	4.4	13.5 - 29.7
7	26-Jun	07:52	28	0	0	115	7.3	109 - 140	16.1	3.8	13.0 - 28.5
8	27-Jun	01:41	14	0	0	115	4.4	108 - 121	16.0	1.8	13.7 - 19.9
9	28-Jun	07:47	14	0	0	115	4.4	110 - 125	15.7	2.3	13.0 - 21.2
10	29-Jun	19:40	12	0	0	114	4.8	109 - 125	15.3	2.1	13.0 - 19.8
11	30-Jun	01:39	19	0	0	114	5.3	108 - 130	15.5	2.0	13.2 - 21.4
12	1-Jul	13:56	29	1	0	113	5.7	108 - 138	15.3	2.8	13.1 - 27.5
13	2-Jul	01:50	18	0	0	118	8.3	109 - 138	16.6	3.6	13.6 - 27.6
14	3-Jul	19:39	20	0	0	117	7.1	108 - 133	17.1	3.6	13.3 - 27.4
15	4-Jul	13:39	16	0	0	115	8.4	107 - 138	16.4	3.9	13.2 - 27.4
16	5-Jul	07:37	16	0	0	118	15.1	104 - 160	18.2	8.7	13.1 - 40.7
17	6-Jul	01:44	17	0	1	121	11.7	109 - 145	20.0	6.5	13.2 - 34.2
18	7-Jul	13:55	39	0	0	116	7.6	105 - 140	17.2	3.8	13.2 - 30.5
19	8-Jul	19:30	13	0	0	116	11.1	104 - 148	17.1	5.8	13.4 - 35.7
20	9-Jul	01:44	13	0	0	118	16.2	105 - 146	18.8	7.6	13.0 - 32.5

Table A1.8. Continued.

						Fork length (mm)			Weight (g)		
Release	Date	Time	N	Tag loss	Mortality	Mean	SD	Range	Mean	SD	Range
21	10-Jul	13:39	26	0	0	116	8.2	107 - 136	16.9	4.2	13.0 - 26.1
22	11-Jul	07:36	27	0	0	124	13.8	107 - 151	20.5	7.2	13.0 - 37.3
23	12-Jul	01:44	25	0	1	117	12.3	106 - 150	18.4	6.4	13.3 - 39.1
24	13-Jul	19:39	21	0	1	128	13.1	107 - 150	22.8	7.5	13.3 - 37.9
25	14-Jul	07:53	24	0	0	126	15.1	105 - 164	21.4	8.4	13.0 - 50.2
26	15-Jul	01:42	29	0	1	119	12.4	105 - 154	18.4	5.9	13.3 - 42.1
27	16-Jul	13:49	27	0	2	117	8.8	106 - 142	17.2	4.0	13.3 - 29.1
28	17-Jul	19:33	28	0	0	115	6.3	105 - 126	16.4	2.5	13.0 - 20.7
29	18-Jul	13:47	28	0	0	116	9.5	106 - 149	17.2	4.9	13.1 - 35.6
30	19-Jul	07:40	34	0	0	113	5.2	105 - 123	15.9	2.0	13.0 - 20.7
31	20-Jul	01:49	29	0	2	112	5.3	104 - 125	15.4	2.0	13.2 - 21.9
32	21-Jul	19:36	31	1	0	119	13.4	105 - 163	19.1	7.9	13.0 - 51.8
33	22-Jul	13:41	31	0	1	116	10.1	103 - 143	17.8	4.5	13.3 - 31.9
34	23-Jul	07:47	35	0	0	114	11.0	105 - 157	17.3	5.3	13.3 - 40.0
35	24-Jul	19:39	28	0	1	115	8.5	102 - 135	17.9	4.1	13.1 - 30.5
36	25-Jul	02:05	32	0	0	114	8.1	106 - 135	16.9	3.3	13.8 - 27.2
37	26-Jul	13:41	14	0	1	111	4.1	106 - 123	15.5	1.7	13.2 - 20.4
38	27-Jul	01:40	18	0	0	113	8.5	104 - 133	16.9	3.6	13.3 - 26.4
39	28-Jul	07:36	21	0	0	109	5.0	103 - 122	15.0	1.9	13.0 - 19.5
40	29-Jul	19:34	25	0	0	115	6.8	106 - 133	17.4	2.8	13.4 - 24.6
Overall			977	9	11	116	9.5	102 - 164	17.2	4.8	13.0 - 51.8

Appendix 2: Tagged fish size and study period relative to run-at-large

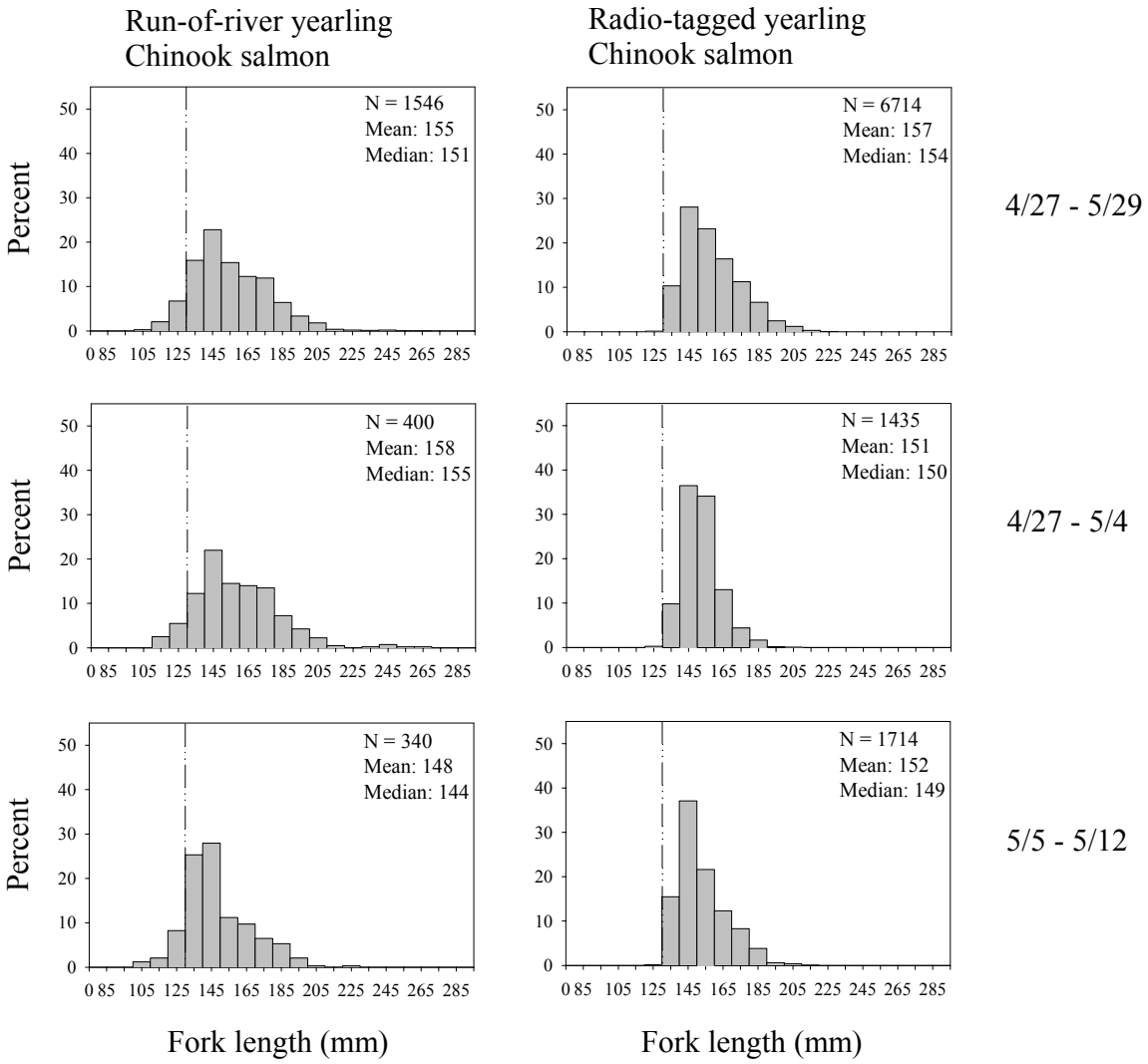


Figure A2.1. Seasonal (4/27 - 5/29) and 8-day (4/27 - 5/4, 5/5 - 5/12, 5/13 - 5/20, 5/21 - 5/29) comparisons of yearling Chinook salmon fork length frequency distributions at John Day Dam, 2004. Graphs on the left depict run-of-river fish that were sampled at the John Day Dam smolt monitoring facility. Graphs on the right depict fish tagged with MCFT-3KM radio transmitters (Loteck Engineering, Newmarket, Ontario) that were collected at the John Day Dam smolt monitoring facility and released at John Day and The Dalles dams during 2004. Based on length to weight regression equations and the tag weight to fish weight criterion, fish to the left of the dashed lines were too small to be tagged with the transmitters.

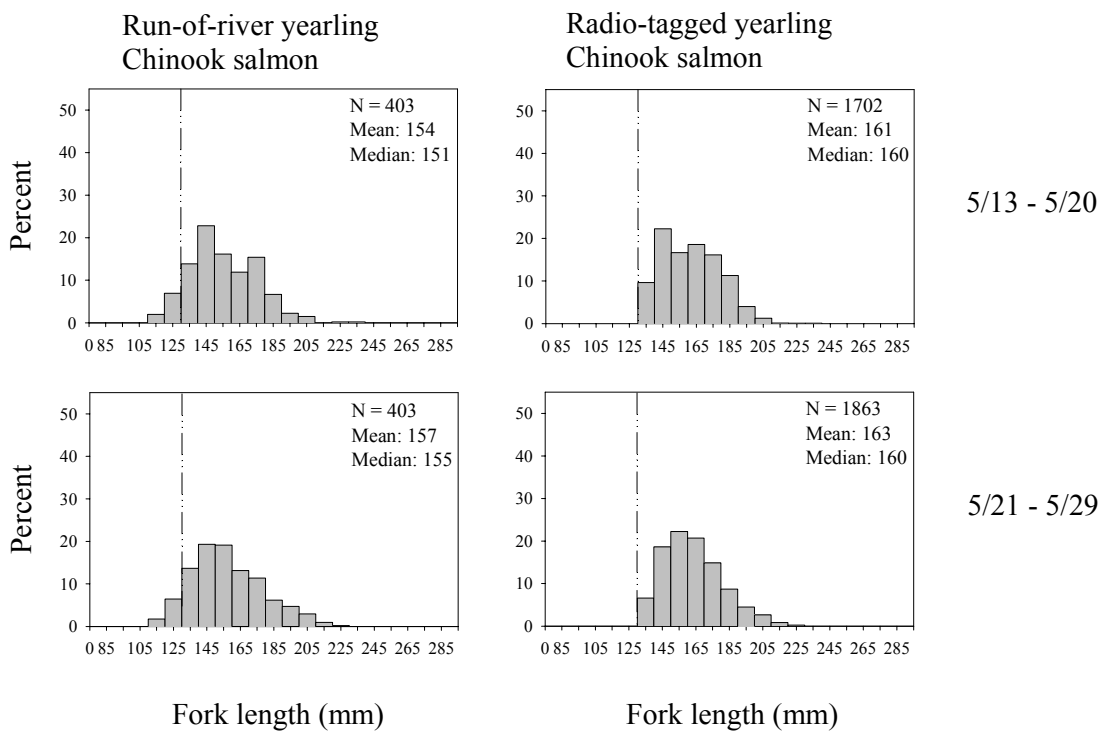


Figure A2.1. (Continued) Seasonal (4/27 - 5/29) and 8-day (4/27 - 5/4, 5/5 - 5/12, 5/13 - 5/20, 5/21 - 5/29) comparisons of yearling Chinook salmon fork length frequency distributions at John Day Dam, 2004. Graphs on the left depict run-of-river fish that were sampled at the John Day Dam smolt monitoring facility. Graphs on the right depict fish tagged with MCFT-3KM radio transmitters (Loteck Engineering, Newmarket, Ontario) that were collected at the John Day Dam smolt monitoring facility and released at John Day and The Dalles dams during 2004. Based on length to weight regression equations and the tag weight to fish weight criterion, fish to the left of the dashed lines were too small to be tagged with the transmitters.

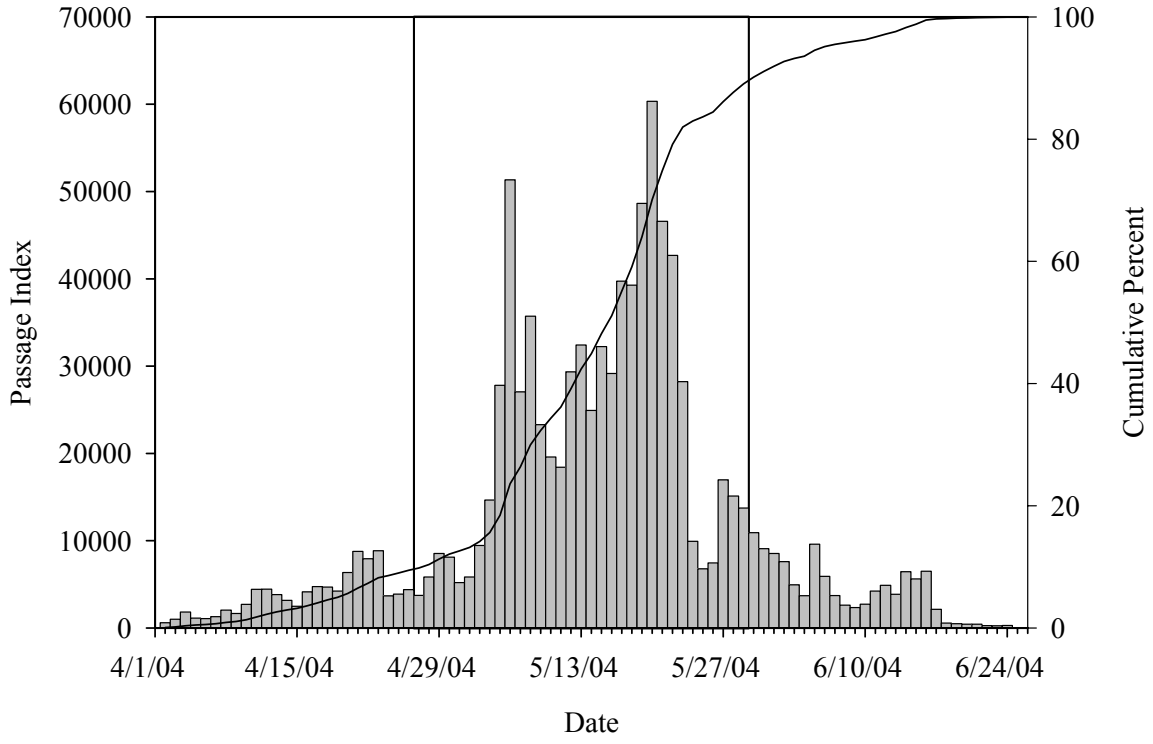


Figure A2.2. Yearling Chinook salmon passage index at John Day Dam, 2004. The vertical bars represent the passage index (see: www.fpc.org) for a given day. Vertical lines represent the start and end dates for radio telemetry tagging.

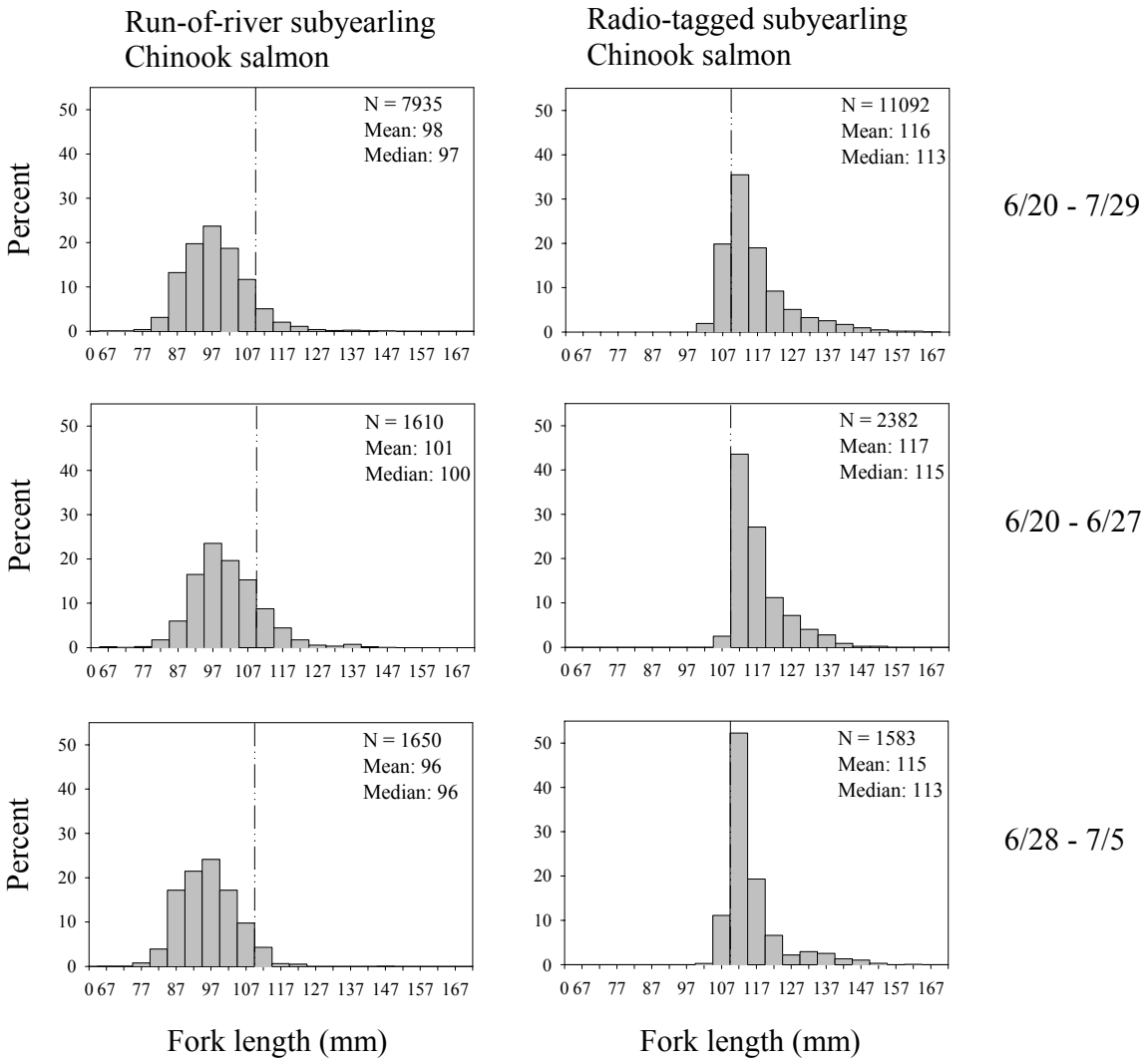


Figure A2.3. Seasonal (6/20 - 7/29) and 8-day (6/20 - 6/27, 6/28 - 7/5, 7/6 - 7/13, 7/14 - 7/21, 7/22 - 7/29) comparisons of subyearling Chinook salmon fork length frequency distributions at John Day Dam, 2004. Graphs on the left depict run-of-river fish that were sampled at the John Day Dam smolt monitoring facility. Graphs on the right depict fish tagged with NTC-3-1 radio transmitters (Loteck Engineering, Newmarket, Ontario) that were collected at the John Day Dam smolt monitoring facility and released at John Day and The Dalles dams during 2004. Based on length to weight regression equations and the tag weight to fish weight criterion, fish to the left of the dashed lines were too small to be tagged with the transmitters.

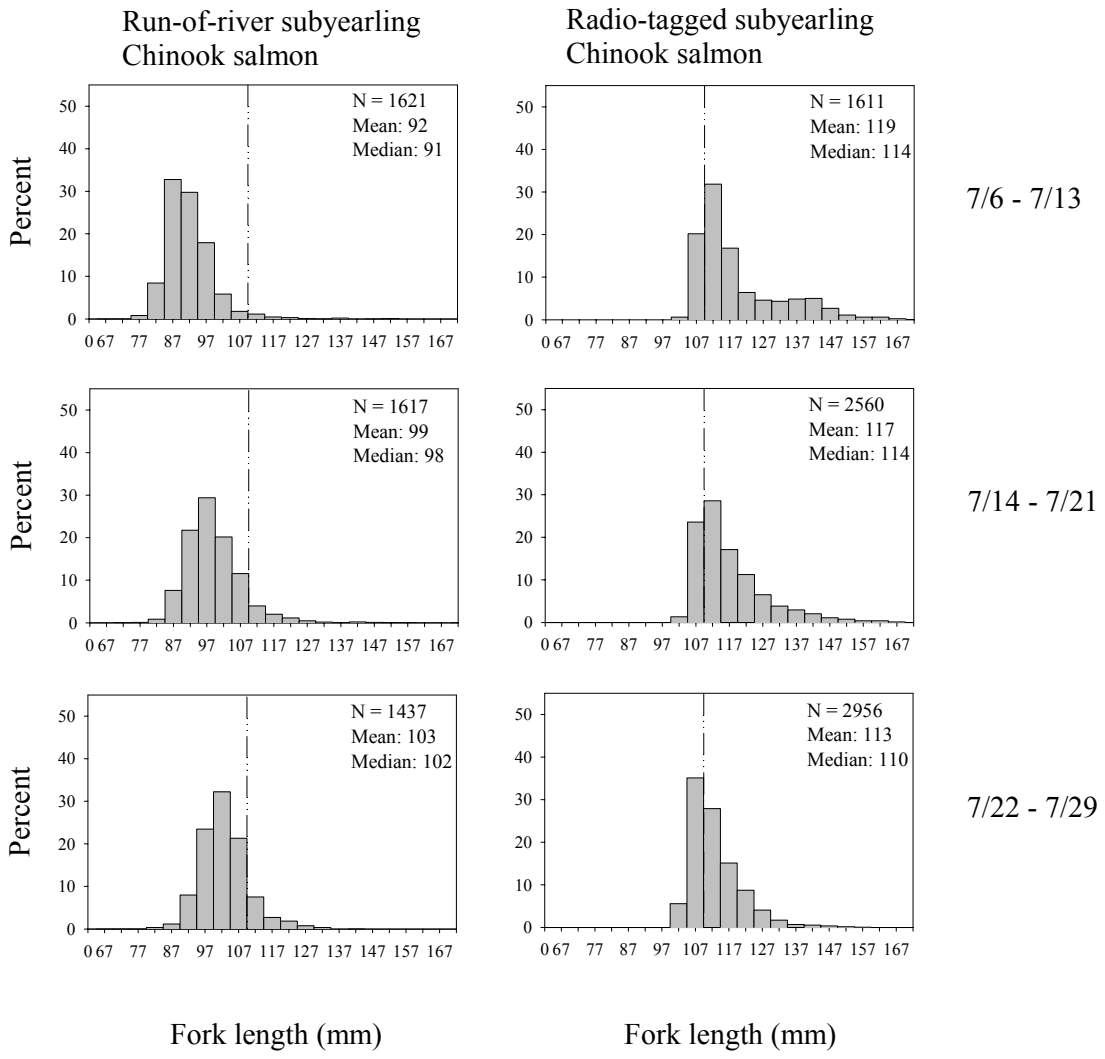


Figure A2.3. (Continued) Seasonal (6/20 - 7/29) and 8-day (6/20 - 6/27, 6/28 - 7/5, 7/6 - 7/13, 7/14 - 7/21, 7/22 - 7/29) comparisons of subyearling Chinook salmon fork length frequency distributions at John Day Dam, 2004. Graphs on the left depict run-of-river fish that were sampled at the John Day Dam smolt monitoring facility. Graphs on the right depict fish tagged with NTC-3-1 radio transmitters (Loteck Engineering, Newmarket, Ontario) that were collected at the John Day Dam smolt monitoring facility and released at John Day and The Dalles dams during 2004. Based on length to weight regression equations and the tag weight to fish weight criterion, fish to the left of the dashed lines were too small to be tagged with the transmitters.

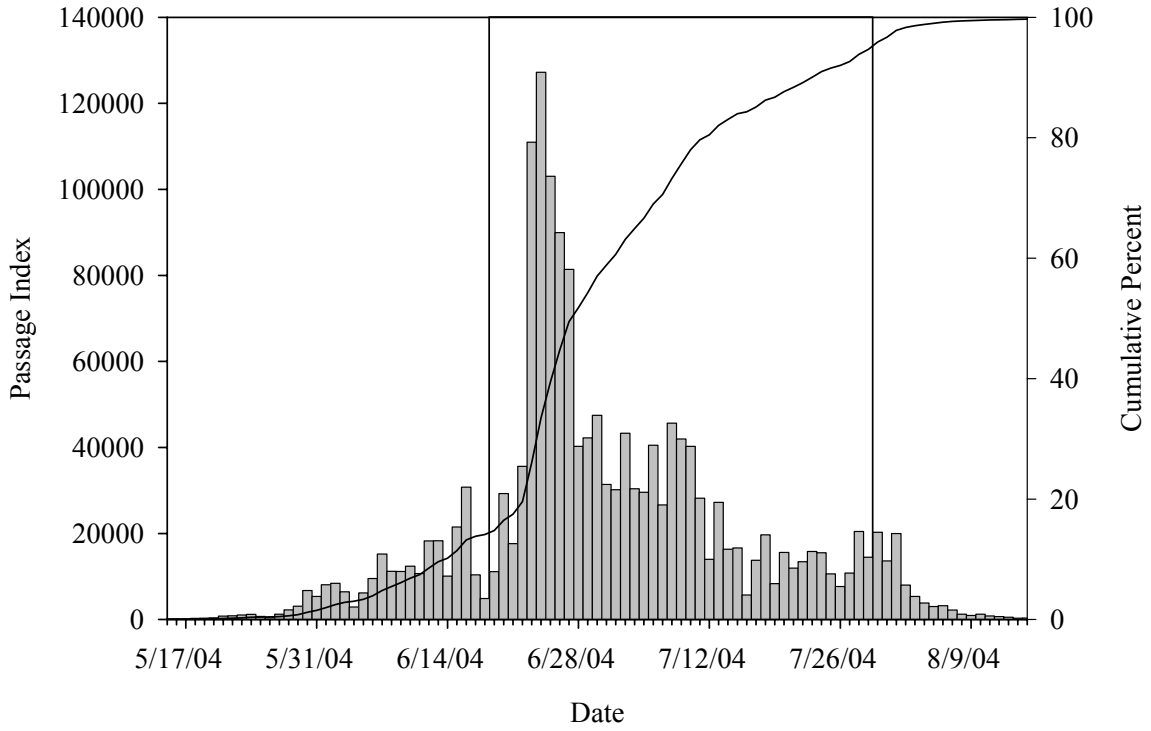


Figure A2.4. Subyearling Chinook salmon passage index at John Day Dam, 2004. The vertical bars represent the passage index (see: www.fpc.org) for a given day. Vertical lines represent the start and end dates for radio telemetry tagging.

Appendix 3: Tag-life performance for determining potential bias of survival estimates

Author: Christopher E. Walker

Introduction

An assumption of release-recapture models used to estimate survival of juvenile salmonids is that all live, tagged individuals have the same probability of being detected at downstream arrays. However, radio-tags have a limited and varied battery-life. Survival estimates may be biased if the radio-tag expires prior to a fish exiting all the detection arrays. Radio-tags may expire before fish exit the study area due to malfunction, extended travel times of fish during periods of low discharge, or if tags were on for an extended duration prior to release. Survival estimates can be adjusted if the probability that tags will expire prior to fish exiting the study area is known (Townsend et al. 2004, Cowan and Schwartz in press). To address the probability of tag failure at detection arrays, a tag-life study was performed. Our objectives were to: 1) estimate the probability a radio-tag was operational over time, 2) model the probability a radio-tag was operational, and 3) estimate the probability radio-tags were operational at detection arrays.

Methods

Several factors can affect the operational life of a radio-tag. For example, some tags lose a constant percentage (per unit time) of their battery life after the battery has been attached. Also, tag-life may be affected by water temperature and may vary among years or production batches. Therefore, it is necessary to conduct the tag-life study concurrent with the survival study and under ambient conditions to emulate, as close as possible, the source of the tags and the conditions they experience after they are released in fish.

The tag-life study entailed activating tags during spring and summer of 2004 at John Day Dam, and monitoring tag failure over time. A stratified random sub-sample of approximately the same number of tags from each frequency (channel) during early, middle, and late season for both spring (n=65) and summer (n=89) survival studies were taken. During the study, transmitters were set to emit a radio signal every 2 seconds and were held underwater at ambient water temperatures and monitored with a Lotek SRX-400 telemetry receiver. The receiver was programmed to scan all channels present for 15 s each hour with the gain set at zero. The receiver was checked daily to ensure that it was working properly and the data was downloaded from the receiver at least once per week. The expiration of each tag was noted at the time at which transmission ceased. Also, water temperature was recorded continuously at the study site with a recording thermograph. The Lotek Wireless model 3KM (7.3 mm in diameter x 18.0 mm in length and 1.4 g weight in air) transmitters were used during the spring tag-life study and the Lotek model NTC-3-1 (6.3 mm wide x 14.5 mm length x 4.5 mm high and 0.85 g weight

in air) transmitters were used during the summer tag-life study corresponding to what was used for survival studies.

Our analytical approach was modeled after Townsend et al. (2004). Tag-life data was used to model tag survivorship and for calculating the probability of a tag being operational at detection arrays. The tag-life data was fit to a Gompertz distribution (Elandt-Johnson and Johnson 1980) for each season. A non-parametric form of the tag survival function was used because arrival times for radio-tagged salmonids had non-normal distributions (Figure A3.1). This involved ranking tag-life data for calculating model parameters. Estimates for model parameters α and β were generated for the tag survival function below and were used to calculate probabilities, where S is the probability the radio-tag is operational and t is time in days.

$$S(t) = e^{(\beta/\alpha)(1-e^{\alpha t})} \quad (1)$$

Travel times to different detection arrays were then substituted into this function for estimating the probability a tag was operating when a fish arrived at a particular detection array. During our tagging procedures, tags were turned on prior to release ($\approx$ 24 hours), so the elapsed time a tag was operating before release was added to travel times.

Results and Discussion

For spring, tag-failure was observed around 7-8 days and continued until day 12, at which time all tags (model 3KM) were no longer operational. The average tag-life was estimated to be 9.87 days (Figure A3.2). For the summer tag-life study, the majority of radio-tags (model NTC 3-1) began to fail at day 7 and continued to day 12, averaging 8.96 days. Most tags were not operational by day 10. There were two radio-tags where transmission ceased around day 1 of the study at 25.44 and 27.36 hours. When these defective tags are excluded the average tag-life was 9.14 days. For our tagging and release procedures, it is protocol to hold tagged fish at least 24 hours before release to reduce the possibility of releasing fish with defective tags. In 2004, tags were operating for about 30 hours prior to release for both spring and summer. These tags would be recorded as not heard at time of release.

The tag-life studies for spring and summer were analyzed for generating model parameters of the Gompertz distribution and calculating probabilities that radio-tags were operational at detection arrays. Our tag-life data fit well with the Gompertz distribution for both the spring and summer tag-life studies allowing us to use this model for calculating probabilities (Figure A3.2, Table A3.1).

In our study, the probability a tag was operational at downstream arrays was high, with all probabilities being greater than 99.9% (Table A3.2). Probabilities were higher for the summer study than for the spring study. The cumulative arrival distributions plotted with the Gompertz model over time shows that tagged juvenile salmonids passed through downstream detection arrays several days before tag-failure was substantial for both treatment and control fish (Figure A3.3).

Townsend et al. (2004) found that the probability of a tag being operational at downstream detection arrays was >98%, therefore, the adjusted survival estimate (0.9387) changed very little from the unadjusted estimate (0.9339) having a difference of just 0.0048. Our probabilities being greater than this indicates our survival estimates would change even less after correction. Since the probability of a tag being operational at the downstream detection arrays for our survival studies were very close to one (Table A3.2), we did not adjust our survival estimates.

References

Elandt-Johnson, R.C. and Johnson, N.L. 1980. Survival models and data analysis. Wiley, New York.

Townsend, R.L., Skalski, J.R., Dillingham, P. & Steig, T.W. 2004. Correcting Bias in Survival Estimation Resulting from Tag Failure in Acoustic and Radiotelemetry Studies. Report prepared for the Bonneville Power Administration, Contract No. 00012494.

Table A3.1. Parameter estimates for tag-life using the Gompertz model during spring and summer during 2004, model estimate and (*SE*).

Tag-life Study	N	α	β	R^2
Spring	65	1.0374 (0.0259)	2.600×10^{-5} (5.995×10^{-6})	0.9961
Summer	89	1.6386 (0.0256)	3.405×10^{-7} (7.59×10^{-8})	0.9982

Table A3.2. Estimated probabilities (mean, *SE* in parentheses) a radio-tag was operational at The Dalles Dam and other downstream detection arrays during 2004, A) yearling Chinook salmon, spring, B) subyearling Chinook salmon, summer.

A) Yearling Chinook salmon	Detection Array Locations	
Release Site	The Dalles Dam	Survival Gates
The John Day Dam Tailrace (Treatment)	0.9999 (1.176×10^{-6})	0.9996 (1.095×10^{-4})
The Dalles Dam Tailrace (Control)	NA	0.9999 (1.310×10^{-6})

B) Subyearling Chinook salmon	Detection Array Locations	
Release Site	The Dalles Dam	Survival Gates
The John Day Dam Tailrace (Treatment)	1.000 (5.847×10^{-7})	1.000 (1.913×10^{-5})
The Dalles Dam Tailrace (Control)	NA	1.000 (3.990×10^{-6})

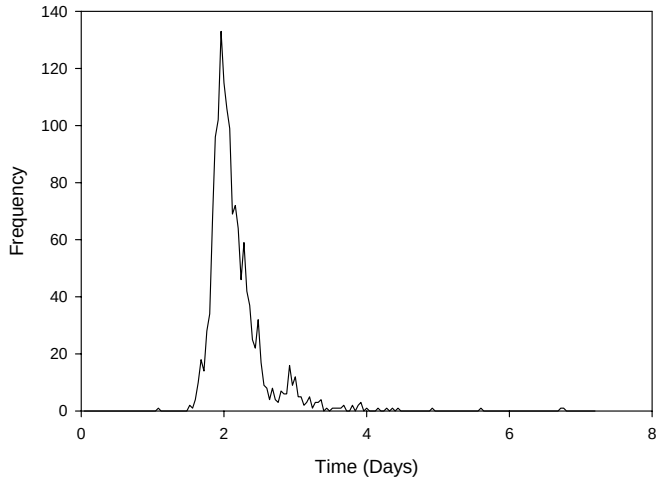


Figure A3.1. Arrival distribution of subyearling Chinook salmon treatment fish for The Dalles Dam survival assessment during summer of 2004.

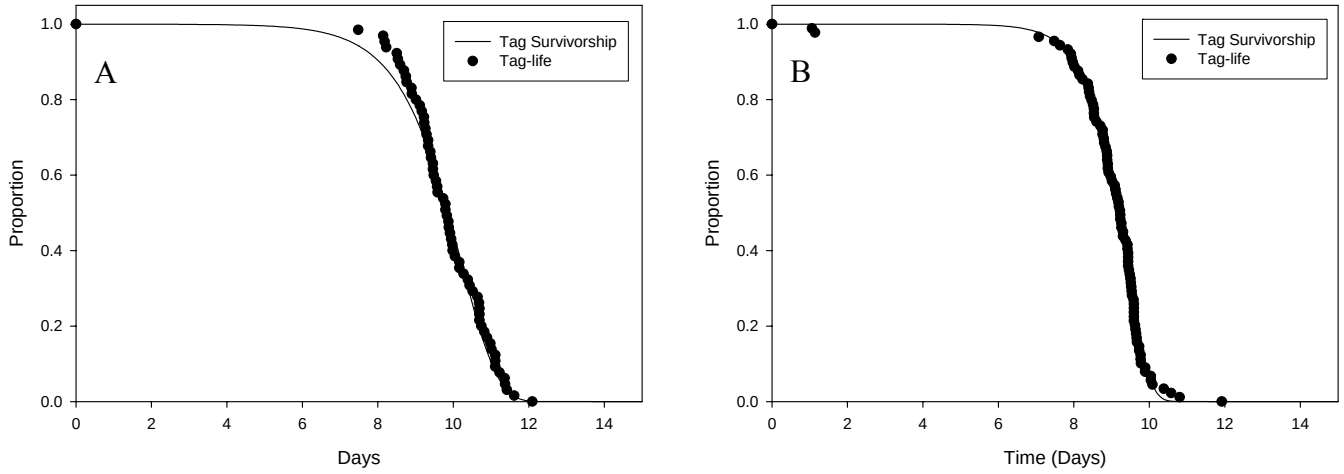
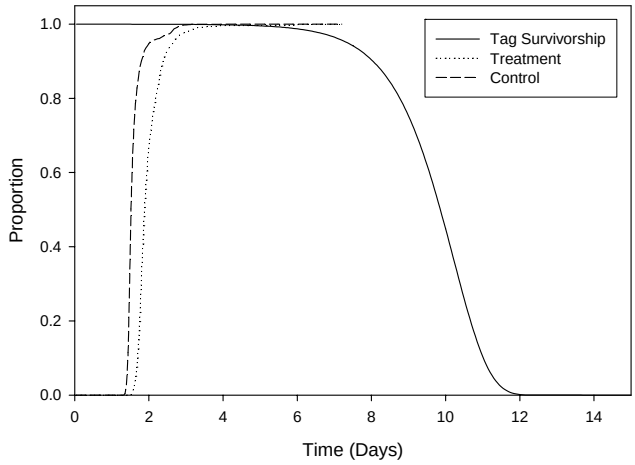


Figure A3.2. Fitted Gompertz model with tag-life data for a) spring and b) summer studies.

A) Yearling Chinook salmon, Spring



B) Subyearling Chinook salmon, Summer

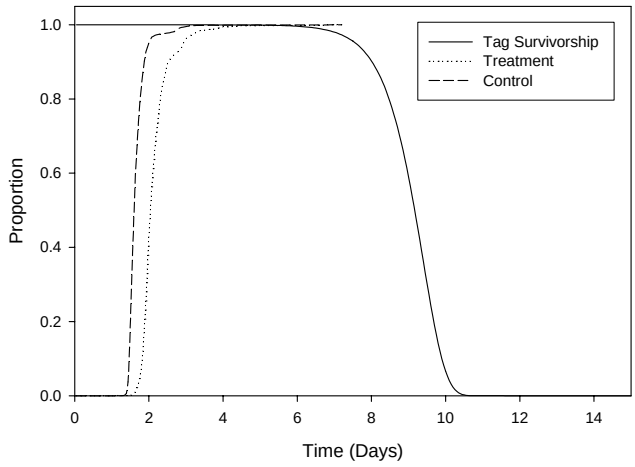


Figure A3.3. Probability distributions for radio-tags being operational over time with cumulative arrival distributions at downstream survival gates for The Dalles Dam survival assessment during 2004.

Appendix 4: Burnham tests 2 and 3

Table A4.1. Summary statistics for goodness-of-fit tests (tests 2 and 3, Burnham et al. 1987) for paired releases of radio-tagged yearling Chinook salmon at The Dalles Dam during 2004. Treatment fish were released into the ice and trash sluiceway and control fish were released immediately below the ice and trash sluiceway.

		Test 2			Test 3		
Release	Population	df	χ^2	P	df	χ^2	P
1	Treatment	[a]	[a]	[a]	[a]	[a]	[a]
	Control	[a]	[a]	[a]	[a]	[a]	[a]
2	Treatment	1	0.00	1.00	1	0.22	0.64
	Control	1	0.85	0.36	1	0.12	0.73
3	Treatment	1	0.22	0.64	1	1.10	0.29
	Control	1	0.12	0.73	1	0.62	0.43
4	Treatment	1	0.04	0.85	1	0.43	0.51
	Control	1	0.02	0.88	1	0.33	0.57
5	Treatment	1	0.41	0.52	1	1.00	0.32
	Control	1	0.37	0.55	[a]	[a]	[a]
6	Treatment	1	0.73	0.39	1	0.25	0.62
	Control	1	0.23	0.63	1	0.36	0.55
7	Treatment	1	2.38	0.12	1	0.08	0.78
	Control	1	0.03	0.86	1	0.04	0.84
8	Treatment	[a]	[a]	[a]	[a]	[a]	[a]
	Control	[a]	[a]	[a]	1	0.24	0.63
9	Treatment	1	0.09	0.77	1	5.11	0.02
	Control	1	0.02	0.88	1	0.08	0.77
10	Treatment	1	0.20	0.65	1	0.42	0.52
	Control	1	0.03	0.87	1	0.17	0.68
11	Treatment	1	0.44	0.51	1	0.15	0.70
	Control	[a]	[a]	[a]	1	0.26	0.61
12	Treatment	[a]	[a]	[a]	1	0.04	0.84
	Control	1	0.00	0.95	1	0.10	0.76
13	Treatment	1	0.01	0.91	1	0.29	0.59
	Control	1	1.07	0.30	1	0.42	0.52
14	Treatment	1	1.45	0.23	1	0.87	0.35
	Control	1	0.29	0.59	1	0.14	0.71
15	Treatment	1	0.17	0.68	1	1.45	0.23
	Control	1	0.00	1.00	1	0.20	0.66
16	Treatment	1	0.07	0.79	1	0.11	0.74
	Control	1	0.05	0.82	1	0.41	0.52

[a] - Chi-square statistic was not calculable for these tests due to the presence of only zeroes in rows or columns in the contingency tables.

Table A4.1. Continued.

Release	Population	Test 2 df	Test 2 χ^2	Test 2 P	Test 3 df	Test 3 χ^2	Test 3 P
17	Treatment	1	0.31	0.58	1	0.00	1.00
	Control	1	0.10	0.75	1	0.24	0.62
18	Treatment	1	0.11	0.74	1	0.43	0.51
	Control	1	0.15	0.70	[a]	[a]	[a]
19	Treatment	[a]	[a]	[a]	[a]	[a]	[a]
	Control	1	4.24	0.04	1	0.01	0.91
20	Treatment	[a]	[a]	[a]	[a]	[a]	[a]
	Control	1	0.01	0.91	1	0.85	0.36
21	Treatment	1	0.12	0.73	1	0.10	0.75
	Control	1	0.11	0.74	1	0.01	0.90
22	Treatment	1	0.66	0.42	[a]	[a]	[a]
	Control	1	0.01	0.91	1	0.36	0.55
23	Treatment	1	0.03	0.87	1	1.12	0.29
	Control	1	0.07	0.80	1	0.26	0.61
24	Treatment	[a]	[a]	[a]	[a]	[a]	[a]
	Control	1	1.42	0.23	1	0.38	0.54
25	Treatment	1	0.69	0.41	1	0.37	0.55
	Control	1	0.08	0.78	1	0.04	0.84
26	Treatment	1	4.99	0.03	1	0.00	0.96
	Control	1	0.85	0.36	1	0.09	0.76
27	Treatment	1	0.31	0.58	1	2.00	0.16
	Control	[a]	[a]	[a]	[a]	[a]	[a]
28	Treatment	1	0.01	0.91	[a]	[a]	[a]
	Control	1	0.11	0.74	1	1.95	0.16
29	Treatment	1	5.74	0.02	1	1.34	0.25
	Control	1	2.37	0.12	1	0.71	0.40
30	Treatment	1	0.06	0.81	[a]	[a]	[a]
	Control	[a]	[a]	[a]	[a]	[a]	[a]
31	Treatment	1	0.00	0.96	1	0.06	0.81
	Control	1	0.08	0.77	1	0.06	0.81
32	Treatment	1	0.63	0.43	1	0.38	0.54
	Control	[a]	[a]	[a]	[a]	[a]	[a]

[a] - Chi-square statistic was not calculable for these tests due to the presence of only zeroes in rows or columns in the contingency tables.

Table A4.2. Summary statistics for goodness-of-fit tests (tests 2 and 3, Burnham et al. 1987) for paired releases of radio-tagged subyearling Chinook salmon at The Dalles Dam during 2004. Treatment fish were released into the ice and trash sluiceway and control fish were released immediately below the ice and trash sluiceway.

		Test 2			Test 3		
Release	Population	df	χ^2	P	df	χ^2	P
1	Treatment	1	3.97	0.05	1	0.10	0.76
	Control	[a]	[a]	[a]	1	0.04	0.83
2	Treatment	[a]	[a]	[a]	[a]	[a]	[a]
	Control	1	0.83	0.36	1	0.16	0.69
3	Treatment	1	0.00	0.97	1	0.14	0.71
	Control	1	0.20	0.65	1	0.13	0.71
4	Treatment	1	0.00	0.97	1	1.37	0.24
	Control	1	0.19	0.66	1	0.16	0.69
5	Treatment	1	5.82	0.02	1	0.07	0.79
	Control	1	0.11	0.74	1	0.01	0.92
6	Treatment	1	0.09	0.77	1	0.44	0.51
	Control	1	0.40	0.53	1	0.11	0.74
7	Treatment	1	0.14	0.71	1	0.07	0.79
	Control	1	4.13	0.04	1	0.07	0.79
8	Treatment	1	0.15	0.70	1	0.50	0.48
	Control	1	5.88	0.02	[a]	[a]	[a]
9	Treatment	1	0.01	0.91	[a]	[a]	[a]
	Control	[a]	[a]	[a]	[a]	[a]	[a]
10	Treatment	[a]	[a]	[a]	1	0.29	0.59
	Control	[a]	[a]	[a]	[a]	[a]	[a]
11	Treatment	1	0.04	0.84	1	0.01	0.94
	Control	1	0.00	1.00	1	0.38	0.54
12	Treatment	1	0.31	0.58	1	0.22	0.64
	Control	1	0.00	1.00	1	0.00	1.00
13	Treatment	1	0.18	0.67	1	0.08	0.78
	Control	1	0.02	0.90	1	0.04	0.85
14	Treatment	1	0.03	0.87	1	0.87	0.35
	Control	1	0.01	0.92	1	0.06	0.81
15	Treatment	[a]	[a]	[a]	1	0.15	0.70
	Control	[a]	[a]	[a]	1	0.13	0.71
16	Treatment	[a]	[a]	[a]	[a]	[a]	[a]
	Control	1	0.08	0.78	1	1.72	0.19

[a] - Chi-square statistic was not calculable for these tests due to the presence of only zeroes in rows or columns in the contingency tables.

Table A4.2. Continued

Release	Population	Test 2 df	Test 2 χ^2	Test 2 P	Test 3 df	Test 3 χ^2	Test 3 P
17	Treatment	1	0.34	0.56	[a]	[a]	[a]
	Control	1	1.37	0.24	1	0.52	0.47
18	Treatment	1	0.36	0.55	1	0.09	0.77
	Control	1	0.13	0.72	1	0.73	0.39
19	Treatment	[a]	[a]	[a]	[a]	[a]	[a]
	Control	[a]	[a]	[a]	[a]	[a]	[a]
20	Treatment	1	0.04	0.84	1	1.47	0.23
	Control	[a]	[a]	[a]	1	0.39	0.53
21	Treatment	[a]	[a]	[a]	1	0.31	0.58
	Control	[a]	[a]	[a]	1	1.18	0.28
22	Treatment	1	5.49	0.02	1	0.31	0.58
	Control	1	4.49	0.03	1	0.03	0.87
23	Treatment	[a]	[a]	[a]	1	1.18	0.28
	Control	[a]	[a]	[a]	1	0.26	0.61
24	Treatment	[a]	[a]	[a]	1	0.03	0.87
	Control	[a]	[a]	[a]	[a]	[a]	[a]
25	Treatment	1	0.02	0.90	1	0.22	0.64
	Control	1	0.35	0.55	1	0.53	0.47
26	Treatment	1	0.33	0.57	1	0.03	0.85
	Control	1	0.01	0.94	1	0.10	0.75
27	Treatment	1	3.74	0.05	1	0.07	0.79
	Control	[a]	[a]	[a]	[a]	[a]	[a]
28	Treatment	1	4.24	0.04	[a]	[a]	[a]
	Control	[a]	[a]	[a]	[a]	[a]	[a]
29	Treatment	[a]	[a]	[a]	[a]	[a]	[a]
	Control	[a]	[a]	[a]	[a]	[a]	[a]
30	Treatment	1	1.37	0.24	1	1.25	0.26
	Control	1	0.96	0.33	1	0.05	0.82
31	Treatment	1	0.07	0.78	1	0.09	0.77
	Control	1	0.83	0.36	1	4.49	0.03
32	Treatment	1	1.42	0.23	1	0.04	0.85
	Control	1	0.73	0.39	1	0.11	0.74

[a] - Chi-square statistic was not calculable for these tests due to the presence of only zeroes in rows or columns in the contingency tables.

Table A4.2. Continued.

Release	Population	Test 2 df	Test 2 χ^2	Test 2 P	Test 3 df	Test 3 χ^2	Test 3 P
33	Treatment	[a]	[a]	[a]	[a]	[a]	[a]
	Control	1	2.37	0.12	1	0.00	0.97
34	Treatment	[a]	[a]	[a]	[a]	[a]	[a]
	Control	[a]	[a]	[a]	[a]	[a]	[a]
35	Treatment	[a]	[a]	[a]	[a]	[a]	[a]
	Control	[a]	[a]	[a]	[a]	[a]	[a]
36	Treatment	1	2.98	0.08	1	0.01	0.94
	Control	1	0.01	0.92	1	0.08	0.77
37	Treatment	1	0.01	0.94	1	0.06	0.81
	Control	[a]	[a]	[a]	[a]	[a]	[a]
38	Treatment	[a]	[a]	[a]	[a]	[a]	[a]
	Control	1	0.09	0.76	1	0.23	0.63
39	Treatment	[a]	[a]	[a]	[a]	[a]	[a]
	Control	[a]	[a]	[a]	[a]	[a]	[a]
40	Treatment	1	3.74	0.05	1	0.68	0.41
	Control	1	0.44	0.51	1	0.07	0.79

[a] - Chi-square statistic was not calculable for these tests due to the presence of only zeroes in rows or columns in the contingency tables.

Table A4.3. Summary statistics for goodness-of-fit tests (tests 2 and 3, Burnham et al. 1987) for paired releases of radio-tagged yearling Chinook salmon at The Dalles Dam during 2004. Treatment fish were released into the ice and trash sluiceway and control fish were released into The Dalles Dam tailrace.

		Test 2			Test 3		
Release	Population	df	χ^2	P	df	χ^2	P
1	Treatment	[a]	[a]	[a]	[a]	[a]	[a]
	Control	1	0.27	0.61	1	0.04	0.85
2	Treatment	1	0.00	1.00	1	0.22	0.64
	Control	1	0.09	0.76	1	0.26	0.61
3	Treatment	1	0.22	0.64	1	0.10	0.29
	Control	1	0.01	0.94	1	0.33	0.57
4	Treatment	1	0.04	0.85	1	0.43	0.51
	Control	1	0.01	0.94	1	0.33	0.57
5	Treatment	1	0.41	0.52	1	1.00	0.32
	Control	1	0.87	0.35	1	1.14	0.29
6	Treatment	1	0.73	0.39	1	0.25	0.62
	Control	1	0.21	0.65	1	0.00	0.98
7	Treatment	1	2.38	0.12	1	0.08	0.78
	Control	1	0.22	0.64	1	0.01	0.91
8	Treatment	[a]	[a]	[a]	[a]	[a]	[a]
	Control	1	0.21	0.65	1	0.10	0.75
9	Treatment	1	0.09	0.77	1	5.11	0.02
	Control	1	4.87	0.03	1	0.37	0.55
10	Treatment	1	0.20	0.65	1	0.42	0.52
	Control	1	0.11	0.74	1	0.01	0.91
11	Treatment	1	0.44	0.51	1	0.15	0.70
	Control	1	0.01	0.94	1	1.66	0.20
12	Treatment	[a]	[a]	[a]	1	0.04	0.84
	Control	1	1.23	0.27	1	4.19	0.04
13	Treatment	1	0.01	0.91	1	0.29	0.59
	Control	1	0.05	0.83	1	0.07	0.79
14	Treatment	1	1.45	0.23	1	0.87	0.35
	Control	1	0.01	0.92	1	0.29	0.59
15	Treatment	1	0.17	0.68	1	1.45	0.23
	Control	1	0.49	0.49	1	0.23	0.63
16	Treatment	1	0.07	0.79	1	0.11	0.74
	Control	1	0.00	0.98	1	0.02	0.88

[a] - Chi-square statistic was not calculable for these tests due to the presence of only zeroes in rows or columns in the contingency tables.

Table A4.3. Continued.

		Test 2			Test 3		
Release	Population	df	χ^2	P	df	χ^2	P
17	Treatment	1	0.31	0.58	1	0.00	1.00
	Control	1	5.02	0.03	1	0.01	0.94
18	Treatment	1	0.11	0.74	1	0.43	0.51
	Control	1	5.02	0.03	1	0.01	0.94
19	Treatment	[a]	[a]	[a]	[a]	[a]	[a]
	Control	1	0.58	0.44	1	1.70	0.19
20	Treatment	[a]	[a]	[a]	[a]	[a]	[a]
	Control	1	0.08	0.78	1	3.25	0.07
21	Treatment	1	0.12	0.73	1	0.10	0.75
	Control	1	0.16	0.69	1	0.00	0.97
22	Treatment	1	0.66	0.42	[a]	[a]	[a]
	Control	1	2.03	0.15	1	0.00	0.98
23	Treatment	1	0.03	0.87	1	1.12	0.29
	Control	1	0.31	0.58	1	0.28	0.60
24	Treatment	[a]	[a]	[a]	[a]	[a]	[a]
	Control	1	0.05	0.82	1	0.37	0.55
25	Treatment	1	0.69	0.41	1	0.37	0.55
	Control	1	0.09	0.76	1	5.21	0.02
26	Treatment	1	4.99	0.03	1	0.00	0.96
	Control	1	0.36	0.55	[a]	[a]	[a]
27	Treatment	1	0.31	0.58	1	2.00	0.16
	Control	1	0.36	0.55	[a]	[a]	[a]
28	Treatment	1	0.01	0.91	[a]	[a]	[a]
	Control	1	0.36	0.55	[a]	[a]	[a]
29	Treatment	1	5.74	0.02	1	1.34	0.25
	Control	1	0.82	0.37	1	0.01	0.92
30	Treatment	1	0.06	0.81	[a]	[a]	[a]
	Control	1	1.22	0.27	1	1.32	0.25
31	Treatment	1	0.00	0.96	1	0.06	0.81
	Control	1	0.02	0.90	1	0.03	0.87
32	Treatment	1	0.63	0.43	1	0.38	0.54
	Control	1	0.05	0.83	1	0.67	0.41

[a] - Chi-square statistic was not calculable for these tests due to the presence of only zeroes in rows or columns in the contingency tables.

Table A4.4. Summary statistics for goodness-of-fit tests (tests 2 and 3, Burnham et al. 1987) for paired releases of radio-tagged subyearling Chinook salmon at The Dalles Dam during 2004. Treatment fish were released into the ice and trash sluiceway and control fish were released into The Dalles Dam tailrace.

		Test 2			Test 3		
Release	Population	df	χ^2	P	df	χ^2	P
1	Treatment	1	3.97	0.05	1	0.10	0.76
	Control	1	2.68	0.10	1	0.02	0.90
2	Treatment	[a]	[a]	[a]	[a]	[a]	[a]
	Control	1	0.09	0.77	1	6.20	0.01
3	Treatment	1	0.00	0.97	1	0.14	0.71
	Control	1	0.02	0.89	1	1.14	0.29
4	Treatment	1	0.00	0.97	1	1.37	0.24
	Control	1	8.25	0.00	1	0.66	0.42
5	Treatment	1	5.82	0.02	1	0.07	0.79
	Control	1	2.14	0.14	1	0.02	0.90
6	Treatment	1	0.09	0.77	1	0.44	0.51
	Control	1	0.08	0.78	1	0.31	0.58
7	Treatment	1	0.14	0.71	1	0.07	0.79
	Control	1	0.06	0.81	1	0.38	0.54
8	Treatment	1	0.15	0.70	1	0.50	0.48
	Control	1	0.11	0.74	1	3.05	0.08
9	Treatment	1	0.01	0.91	[a]	[a]	[a]
	Control	1	0.12	0.73	1	0.20	0.65
10	Treatment	[a]	[a]	[a]	1	0.29	0.59
	Control	1	3.61	0.06	1	0.04	0.84
11	Treatment	1	0.04	0.84	1	0.01	0.94
	Control	1	0.00	0.95	1	0.59	0.44
12	Treatment	1	0.31	0.58	1	0.22	0.64
	Control	1	0.01	0.90	1	0.81	0.37
13	Treatment	1	0.18	0.67	1	0.08	0.78
	Control	1	0.21	0.64	1	0.07	0.79
14	Treatment	1	0.03	0.87	1	0.87	0.35
	Control	1	0.15	0.70	1	0.00	0.96
15	Treatment	[a]	[a]	[a]	1	0.15	0.70
	Control	1	0.57	0.45	1	0.04	0.85
16	Treatment	[a]	[a]	[a]	[a]	[a]	[a]
	Control	1	0.03	0.86	1	0.01	0.94

[a] - Chi-square statistic was not calculable for these tests due to the presence of only zeroes in rows or columns in the contingency tables.

Table A4.4. Continued.

		Test 2			Test 3		
Release	Population	df	χ^2	P	df	χ^2	P
17	Treatment	1	0.34	0.56	[a]	[a]	[a]
	Control	1	6.53	0.01	1	0.28	0.60
18	Treatment	1	0.36	0.55	1	0.09	0.77
	Control	1	1.33	0.25	1	0.00	0.95
19	Treatment	[a]	[a]	[a]	[a]	[a]	[a]
	Control	1	0.50	0.48	1	0.17	0.68
20	Treatment	1	0.04	0.84	1	1.47	0.23
	Control	[a]	[a]	[a]	[a]	[a]	[a]
21	Treatment	[a]	[a]	[a]	1	0.31	0.58
	Control	1	0.06	0.81	1	2.90	0.09
22	Treatment	1	5.49	0.02	1	0.31	0.58
	Control	1	0.27	0.61	1	0.17	0.68
23	Treatment	[a]	[a]	[a]	1	1.18	0.28
	Control	1	0.03	0.86	1	0.42	0.52
24	Treatment	[a]	[a]	[a]	1	0.03	0.87
	Control	1	0.02	0.89	1	0.05	0.83
25	Treatment	1	0.02	0.90	1	0.22	0.64
	Control	1	0.00	1.00	1	1.25	0.26
26	Treatment	1	0.33	0.57	1	0.03	0.85
	Control	1	0.00	0.94	1	3.33	0.07
27	Treatment	1	3.74	0.05	1	0.07	0.79
	Control	1	0.42	0.51	1	0.01	0.93
28	Treatment	1	4.24	0.04	[a]	[a]	[a]
	Control	1	0.69	0.41	1	0.31	0.58
29	Treatment	[a]	[a]	[a]	[a]	[a]	[a]
	Control	1	5.32	0.02	1	0.10	0.75
30	Treatment	1	1.37	0.24	1	1.25	0.26
	Control	1	0.05	0.82	1	0.03	0.86
31	Treatment	1	0.07	0.78	1	0.09	0.77
	Control	1	1.07	0.30	1	0.05	0.82
32	Treatment	1	1.42	0.23	1	0.04	0.85
	Control	1	1.54	0.21	1	0.02	0.89

[a] - Chi-square statistic was not calculable for these tests due to the presence of only zeroes in rows or columns in the contingency tables.

Table A4.4. Continued.

Release	Population	Test 2 df	Test 2 χ^2	Test 2 P	Test 3 df	Test 3 χ^2	Test 3 P
33	Treatment	[a]	[a]	[a]	[a]	[a]	[a]
	Control	1	0.02	0.88	1	0.07	0.79
34	Treatment	[a]	[a]	[a]	[a]	[a]	[a]
	Control	1	0.07	0.78	1	0.40	0.53
35	Treatment	[a]	[a]	[a]	[a]	[a]	[a]
	Control	1	5.45	0.02	1	2.26	0.13
36	Treatment	1	2.98	0.08	1	0.01	0.94
	Control	1	0.18	0.67	1	0.10	0.75
37	Treatment	1	0.01	0.94	1	0.06	0.81
	Control	1	0.08	0.77	1	0.06	0.80
38	Treatment	[a]	[a]	[a]	[a]	[a]	[a]
	Control	1	0.00	0.95	1	0.22	0.64
39	Treatment	[a]	[a]	[a]	[a]	[a]	[a]
	Control	1	0.02	0.88	1	0.00	1.00
40	Treatment	1	3.74	0.05	1	0.68	0.41
	Control	1	0.49	0.49	1	0.00	0.95

[a] - Chi-square statistic was not calculable for these tests due to the presence of only zeroes in rows or columns in the contingency tables.

Table A4.5. Summary statistics for goodness-of-fit tests (tests 2 and 3, Burnham et al. 1987) for releases used to estimate survival of yearling Chinook salmon through spillbays 1-4, 5-6, and 7-20 during spring 2004. Treatment fish were released at the John Day Dam tailrace and control fish were released into The Dalles Dam tailrace.

			Test 2			Test 3		
Release	Spillbay	Population	df	χ^2	P	df	χ^2	P
1	1-4	Treatment	[1]	1.14	0.28	[a]	[a]	[a]
		Control	1	0.13	0.72	1	0.07	0.80
	5-6	Treatment	1	0.38	0.54	1	3.23	0.07
		Control	1	0.13	0.72	1	0.07	0.80
	7-20	Treatment	1	0.75	0.39	1	1.98	0.16
		Control	1	0.13	0.72	1	0.07	0.80
2	1-4	Treatment	1	1.34	0.25	[a]	[a]	[a]
		Control	1	0.04	0.84	1	0.01	0.92
	5-6	Treatment	1	0.24	0.62	[a]	[a]	[a]
		Control	1	0.04	0.84	1	0.01	0.92
	7-20	Treatment	1	0.75	0.39	1	1.98	0.16
		Control	1	0.13	0.72	1	0.07	0.80
3	1-4	Treatment	1	0.03	0.87	[a]	[a]	[a]
		Control	1	2.52	0.11	1	0.13	0.72
	5-6	Treatment	1	0.13	0.71	[a]	[a]	[a]
		Control	1	2.52	0.11	[a]	[a]	[a]
	7-20	Treatment	[a]	[a]	[a]	[a]	[a]	[a]
		Control	1	2.52	0.11	1	0.13	0.72
4	1-4	Treatment	1	1.23	0.27	[a]	[a]	[a]
		Control	1	0.18	0.67	1	0.03	0.87
	5-6	Treatment	1	0.07	0.79	[a]	[a]	[a]
		Control	1	0.18	0.67	1	0.03	0.87
	7-20	Treatment	[a]	[a]	[a]	[a]	[a]	[a]
		Control	1	0.18	0.67	1	0.03	0.87
5	1-4	Treatment	1	0.39	0.53	1	1.50	0.22
		Control	1	0.28	0.60	1	0.04	0.85
	5-6	Treatment	1	0.01	0.93	1	0.75	0.39
		Control	1	0.28	0.60	1	0.04	0.85
	7-20	Treatment	1	0.18	0.67	[a]	[a]	[a]
		Control	1	0.28	0.60	1	0.04	0.85
6	1-4	Treatment	1	0.07	0.80	[a]	[a]	[a]
		Control	1	0.00	0.99	1	0.27	0.60

[a] - Chi-square statistic was not calculable for these tests due to the presence of only zeroes in rows or columns in the contingency tables.

Table A4.5. Continued.

Release	Spillbay	Population	Test 2 df	Test 2 χ^2	Test 2 P	Test 3 df	Test 3 χ^2	Test 3 P
	5-6	Treatment	1	0.11	0.74	[a]	[a]	[a]
		Control	1	0.00	0.99	1	0.27	0.60
	7-20	Treatment	1	0.23	0.63	1	0.15	0.70
		Control	1	0.00	0.99	1	0.27	0.60
7	1-4	Treatment	1	0.00	0.95	[a]	[a]	[a]
		Control	1	0.00	0.95	1	0.00	0.99
	5-6	Treatment	1	0.06	0.81	[a]	[a]	[a]
		Control	1	0.00	0.95	1	0.00	0.99
	7-20	Treatment	1	0.00	0.95	[a]	[a]	[a]
		Control	1	0.00	0.95	1	0.00	0.99
8	1-4	Treatment	1	0.14	0.71	1	1.37	0.24
		Control	1	0.10	0.76	[a]	[a]	[a]
	5-6	Treatment	[a]	[a]	[a]	[a]	[a]	[a]
		Control	1	0.10	0.76	[a]	[a]	[a]
	7-20	Treatment	[a]	[a]	[a]	[a]	[a]	[a]
		Control	1	0.10	0.76	[a]	[a]	[a]
9	1-4	Treatment	1	0.04	0.83	1	1.00	0.32
		Control	1	0.86	0.35	1	1.03	0.31
	5-6	Treatment	1	0.01	0.90	[a]	[a]	[a]
		Control	1	0.86	0.35	[a]	[a]	[a]
	7-20	Treatment	1	0.03	0.85	[a]	[a]	[a]
		Control	1	0.86	0.35	1	1.03	0.31
10	1-4	Treatment	1	0.36	0.55	[a]	[a]	[a]
		Control	1	1.49	0.22	[a]	[a]	[a]
	5-6	Treatment	1	0.07	0.80	1	0.01	0.94
		Control	1	1.49	0.22	[a]	[a]	[a]
	7-20	Treatment	[a]	[a]	[a]	[a]	[a]	[a]
		Control	1	1.49	0.22	[a]	[a]	[a]
11	1-4	Treatment	1	1.40	0.24	[a]	[a]	[a]
		Control	1	2.92	0.09	1	0.55	0.46
	5-6	Treatment	1	0.33	0.57	[a]	[a]	[a]
		Control	1	2.92	0.09	1	0.55	0.46
	7-20	Treatment	1	0.63	0.43	[a]	[a]	[a]
		Control	1	2.92	0.09	[1]	0.55	0.46

[a] - Chi-square statistic was not calculable for these tests due to the presence of only zeroes in rows or columns in the contingency tables.

Table A4.5. Continued.

Release	Spillbay	Population	Test 2 df	Test 2 χ^2	Test 2 P	Test 3 df	Test 3 χ^2	Test 3 P
12	1-4	Treatment	1	1.81	0.18	[a]	[a]	[a]
		Control	1	0.21	0.65	1	0.07	0.80
	5-6	Treatment	1	0.21	0.65	1	0.29	0.59
		Control	1	0.21	0.65	1	0.21	0.65
	7-20	Treatment	1	0.21	0.65	1	0.02	0.89
		Control	1	0.21	0.65	1	0.07	0.80
13	1-4	Treatment	1	0.34	0.56	1	0.31	0.58
		Control	1	0.16	0.69	1	0.28	0.60
	5-6	Treatment	1	0.00	0.95	[a]	[a]	[a]
		Control	1	0.16	0.69	1	0.28	0.60
	7-20	Treatment	1	0.16	0.69	[a]	[a]	[a]
		Control	1	0.16	0.69	1	0.28	0.60
14	1-4	Treatment	1	0.29	0.59	[a]	[a]	[a]
		Control	1	2.96	0.09	1	0.00	0.99
	5-6	Treatment	1	0.60	0.44	[a]	[a]	[a]
		Control	1	2.96	0.09	1	0.00	0.99
	7-20	Treatment	1	0.17	0.68	[a]	[a]	[a]
		Control	1	2.96	0.09	1	0.00	0.99
15	1-4	Treatment	1	0.48	0.49	1	2.50	0.11
		Control	1	0.32	0.57	1	0.28	0.60
	5-6	Treatment	1	0.29	0.59	[a]	[a]	[a]
		Control	1	0.32	0.57	1	0.28	0.60
	7-20	Treatment	1	0.01	0.91	[a]	[a]	[a]
		Control	1	0.32	0.57	1	0.28	0.60
16	1-4	Treatment	1	0.12	0.73	[a]	[a]	[a]
		Control	1	1.62	0.20	1	0.00	0.95
	5-6	Treatment	1	0.05	0.83	[a]	[a]	[a]
		Control	1	1.62	0.20	1	0.00	0.95
	7-20	Treatment	[a]	[a]	[a]	[a]	[a]	[a]
		Control	1	1.62	0.20	1	0.00	0.95
17	1-4	Treatment	1	1.75	0.19	[a]	[a]	[a]
		Control	1	2.02	0.16	1	0.43	0.51
	5-6	Treatment	1	0.05	0.82	[a]	[a]	[a]
		Control	1	2.02	0.16	1	0.43	0.51
	7-20	Treatment	1	0.08	0.78	[a]	[a]	[a]
		Control	1	2.02	0.16	1	0.43	0.51

[a] - Chi-square statistic was not calculable for these tests due to the presence of only zeroes in rows or columns in the contingency tables.

Table A4.5. Continued.

Release	Spillbay	Population	Test 2 df	Test 2 χ^2	Test 2 P	Test 3 df	Test 3 χ^2	Test 3 P
18	1-4	Treatment	1	1.00	0.32	[a]	[a]	[a]
		Control	1	0.24	0.63	[a]	[a]	[a]
	5-6	Treatment	1	0.24	0.62	[a]	[a]	[a]
		Control	1	0.24	0.63	[a]	[a]	[a]
	7-20	Treatment	[a]	[a]	[a]	[a]	[a]	[a]
		Control	1	0.24	0.63	[a]	[a]	[a]
19	1-4	Treatment	1	0.03	0.87	1	0.22	0.64
		Control	1	0.06	0.81	1	0.23	0.63
	5-6	Treatment	1	0.17	0.68	1	1.12	0.29
		Control	1	0.06	0.81	1	0.23	0.63
	7-20	Treatment	1	0.08	0.78	[a]	[a]	[a]
		Control	1	0.06	0.81	1	0.23	0.63
20	1-4	Treatment	1	0.02	0.89	[a]	[a]	[a]
		Control	1	1.55	0.21	1	0.05	0.82
	5-6	Treatment	1	0.11	0.74	[a]	[a]	[a]
		Control	1	1.55	0.21	1	0.05	0.82
	7-20	Treatment	1	0.26	0.61	[a]	[a]	[a]
		Control	1	1.55	0.21	1	0.05	0.82
21	1-4	Treatment	1	0.16	0.68	[a]	[a]	[a]
		Control	1	4.76	0.03	1	0.04	0.83
	5-6	Treatment	1	0.38	0.54	[a]	[a]	[a]
		Control	1	4.76	0.03	1	0.04	0.83
	7-20	Treatment	1	0.19	0.67	[a]	[a]	[a]
		Control	1	4.76	0.03	1	0.04	0.83
22	1-4	Treatment	1	0.30	0.58	1	0.03	0.87
		Control	1	8.78	0.00	1	0.40	0.53
	5-6	Treatment	1	0.30	0.58	1	0.40	0.53
		Control	1	8.78	0.00	1	0.40	0.53
	7-20	Treatment	[a]	[a]	[a]	[a]	[a]	[a]
		Control	1	8.78	0.00	1	0.40	0.53
23	1-4	Treatment	1	0.17	0.68	[a]	[a]	[a]
		Control	1	0.17	0.68	1	0.05	0.83
	5-6	Treatment	1	0.00	1.00	[a]	[a]	[a]
		Control	1	0.17	0.68	1	0.05	0.83
	7-20	Treatment	1	0.17	0.68	[a]	[a]	[a]
		Control	1	0.17	0.68	1	0.05	0.83

[a] - Chi-square statistic was not calculable for these tests due to the presence of only zeroes in rows or columns in the contingency tables.

Table A4.5. Continued.

Release	Spillbay	Population	Test 2 df	Test 2 χ^2	Test 2 P	Test 3 df	Test 3 χ^2	Test 3 P
24	1-4	Treatment	1	3.48	0.06	[a]	[a]	[a]
		Control	1	0.06	0.81	[a]	[a]	[a]
	5-6	Treatment	1	0.02	0.89	[a]	[a]	[a]
		Control	1	0.06	0.81	[a]	[a]	[a]
	7-20	Treatment	[a]	[a]	[a]	[a]	[a]	[a]
		Control	1	0.06	0.81	[a]	[a]	[a]
25	1-4	Treatment	1	0.04	0.84	[a]	[a]	[a]
		Control	1	0.22	0.64	1	0.00	0.96
	5-6	Treatment	1	0.18	0.67	[a]	[a]	[a]
		Control	1	0.22	0.64	1	0.00	0.96
	7-20	Treatment	1	0.00	0.95	[a]	[a]	[a]
		Control	1	0.22	0.64	1	0.00	0.96
26	1-4	Treatment	[a]	[a]	[a]	[a]	[a]	[a]
		Control	1	0.15	0.70	1	0.18	0.67
	5-6	Treatment	1	0.00	0.97	[a]	[a]	[a]
		Control	1	0.15	0.70	1	0.18	0.67
	7-20	Treatment	1	0.44	0.50	[a]	[a]	[a]
		Control	1	0.15	0.70	1	0.18	0.67
27	1-4	Treatment	1	1.56	0.21	[a]	[a]	[a]
		Control	1	1.56	0.21	1	0.13	0.72
	5-6	Treatment	1	0.00	0.96	[a]	[a]	[a]
		Control	1	1.56	0.21	1	0.13	0.72
	7-20	Treatment	1	0.36	0.55	[a]	[a]	[a]
		Control	1	1.56	0.21	1	0.13	0.72
28	1-4	Treatment	1	0.75	0.39	[a]	[a]	[a]
		Control	1	0.75	0.39	[a]	[a]	[a]
	5-6	Treatment	1	0.16	0.69	[a]	[a]	[a]
		Control	1	0.75	0.39	1	3.17	0.08
	7-20	Treatment	1	0.36	0.55	[a]	[a]	[a]
		Control	1	0.75	0.39	1	3.17	0.08

[a] - Chi-square statistic was not calculable for these tests due to the presence of only zeroes in rows or columns in the contingency tables.

Table A4.6. Summary statistics for goodness-of-fit tests (tests 2 and 3, Burnham et al. 1987) for releases used to estimate survival of subyearling Chinook salmon through spillbays 1-4, 5-6, and 7-20 during summer 2004. Treatment fish were released at the John Day Dam tailrace and control fish were released into The Dalles Dam tailrace.

			Test 2			Test 3		
Release	Spillbay	Population	df	χ^2	P	df	χ^2	P
1	1-4	Treatment	1	2.05	0.15	[a]	[a]	[a]
		Control	1	0.91	0.34	1	0.86	0.35
	5-6	Treatment	1	0.07	0.79	[a]	[a]	[a]
		Control	1	0.91	0.34	1	0.86	0.35
	7-20	Treatment	[a]	[a]	[a]	[a]	[a]	[a]
		Control	1	0.91	0.34	1	0.86	0.35
2	1-4	Treatment	1	0.01	0.93	[a]	[a]	[a]
		Control	1	1.54	0.21	1	0.55	0.46
	5-6	Treatment	1	0.47	0.49	[a]	[a]	[a]
		Control	1	1.54	0.21	1	0.55	0.46
	7-20	Treatment	1	0.02	0.88	[a]	[a]	[a]
		Control	1	1.54	0.21	1	0.55	0.46
3	1-4	Treatment	1	0.14	0.71	1	0.54	0.46
		Control	1	1.45	0.23	1	0.26	0.61
	5-6	Treatment	1	0.00	1.00	[a]	[a]	[a]
		Control	1	1.45	0.23	1	0.26	0.61
	7-20	Treatment	1	0.11	0.74	[a]	[a]	[a]
		Control	1	1.45	0.23	1	0.26	0.61
4	1-4	Treatment	1	0.35	0.55	1	0.44	0.51
		Control	1	1.98	0.16	1	0.73	0.39
	5-6	Treatment	1	0.16	0.69	[a]	[a]	[a]
		Control	1	1.98	0.16	1	0.73	0.39
	7-20	Treatment	[a]	[a]	[a]	[a]	[a]	[a]
		Control	1	1.98	0.16	1	0.73	0.39
5	1-4	Treatment	1	0.03	0.87	1	0.21	0.65
		Control	1	10.47	0.00	1	0.73	0.39
	5-6	Treatment	1	1.37	0.24	[a]	[a]	[a]
		Control	1	10.47	0.00	1	0.18	0.67
	7-20	Treatment	[a]	[a]	[a]	[a]	[a]	[a]
		Control	1	10.47	0.00	1	0.18	0.67
6	1-4	Treatment	1	0.00	1.00	1	0.47	0.49
		Control	1	0.64	0.43	1	0.02	0.89

[a] - Chi-square statistic was not calculable for these tests due to the presence of only zeroes in rows or columns in the contingency tables.

Table A4.6. Continued.

Release	Spillbay	Population	Test 2 df	Test 2 χ^2	Test 2 P	Test 3 df	Test 3 χ^2	Test 3 P
	5-6	Treatment	1	0.05	0.82	1	0.47	0.49
		Control	1	0.64	0.43	1	0.02	0.89
	7-20	Treatment	1	2.13	0.14	[a]	[a]	[a]
		Control	1	0.64	0.43	1	0.02	0.89
7	1-4	Treatment	1	0.04	0.85	[a]	[a]	[a]
		Control	1	0.02	0.89	[a]	[a]	[a]
	5-6	Treatment	1	0.00	1.00	[a]	[a]	[a]
		Control	1	0.02	0.89	[a]	[a]	[a]
	7-20	Treatment	1	0.70	0.40	[a]	[a]	[a]
		Control	1	0.02	0.89	[a]	[a]	[a]
8	1-4	Treatment	1	1.31	0.25	[a]	[a]	[a]
		Control	1	2.05	0.15	1	1.02	0.31
	5-6	Treatment	1	0.02	0.90	[a]	[a]	[a]
		Control	1	2.05	0.15	1	1.02	0.31
	7-20	Treatment	1	0.13	0.71	1	1.00	0.32
		Control	1	2.05	0.15	1	1.02	0.31
9	1-4	Treatment	1	0.02	0.90	1	0.19	0.66
		Control	1	0.51	0.48	1	0.02	0.88
	5-6	Treatment	1	0.12	0.73	1	0.14	0.71
		Control	1	0.51	0.48	1	0.02	0.88
	7-20	Treatment	[a]	[a]	[a]	[a]	[a]	[a]
		Control	1	0.51	0.48	1	0.02	0.88
10	1-4	Treatment	1	0.01	0.93	[a]	[a]	[a]
		Control	1	6.31	0.01	1	0.03	0.87
	5-6	Treatment	1	3.00	0.08	1	0.31	0.58
		Control	1	6.31	0.01	1	0.03	0.87
	7-20	Treatment	1	0.44	0.50	1	0.19	0.67
		Control	1	6.31	0.01	1	0.03	0.87
11	1-4	Treatment	1	0.09	0.77	1	0.63	0.43
		Control	1	0.80	0.37	1	0.00	0.96
	5-6	Treatment	1	0.72	0.40	1	1.50	0.22
		Control	1	0.80	0.37	1	0.00	0.96

[a] - Chi-square statistic was not calculable for these tests due to the presence of only zeroes in rows or columns in the contingency tables.

Table A4.6 Continued

Release	Spillbay	Population	Test 2 df	Test 2 χ^2	Test 2 P	Test 3 df	Test 3 χ^2	Test 3 P
	7-20	Treatment	[a]	[a]	[a]	[a]	[a]	[a]
		Control	1	0.80	0.37	1	0.00	0.96
12	1-4	Treatment	1	1.16	0.28	1	0.14	0.71
		Control	1	0.00	0.99	1	4.09	0.04
	5-6	Treatment	1	0.50	0.48	1	0.13	0.71
		Control	1	0.00	0.99	1	4.09	0.04
	7-20	Treatment	[a]	[a]	[a]	[a]	[a]	[a]
		Control	1	0.00	0.99	1	4.09	0.04
13	1-4	Treatment	1	1.50	0.22	1	3.48	0.06
		Control	1	0.04	0.84	1	0.06	0.80
	5-6	Treatment	1	0.16	0.69	[a]	[a]	[a]
		Control	1	0.04	0.84	1	0.06	0.80
	7-20	Treatment	1	0.04	0.84	1	0.70	0.40
		Control	1	0.04	0.84	1	0.70	0.40
14	1-4	Treatment	1	1.18	0.28	[a]	[a]	[a]
		Control	1	0.03	0.87	1	4.74	0.03
	5-6	Treatment	[a]	[a]	[a]	[a]	[a]	[a]
		Control	1	0.03	0.87	1	4.74	0.03
	7-20	Treatment	1	0.38	0.54	1	0.00	0.95
		Control	1	0.12	0.73	1	0.00	0.95
15	1-4	Treatment	1	0.38	0.54	1	0.00	0.95
		Control	1	0.12	0.73	1	0.00	0.95
	5-6	Treatment	1	0.38	0.54	[a]	[a]	[a]
		Control	1	0.12	0.73	1	0.00	0.95
	7-20	Treatment	1	2.73	0.10	1	0.87	0.35
		Control	1	0.12	0.73	1	0.00	0.95
16	1-4	Treatment	1	0.08	0.77	[a]	[a]	[a]
		Control	1	0.05	0.82	1	0.05	0.82
	5-6	Treatment	1	3.20	0.07	[a]	[a]	[a]
		Control	1	0.05	0.82	1	0.05	0.82
	7-20	Treatment	[a]	[a]	[a]	[a]	[a]	[a]
		Control	1	0.05	0.82	1	0.05	0.82

[a] - Chi-square statistic was not calculable for these tests due to the presence of only zeroes in rows or columns in the contingency tables.

Table A4.6 Continued.

Release	Spillbay	Population	Test 2 df	Test 2 χ^2	Test 2 P	Test 3 df	Test 3 χ^2	Test 3 P
17	1-4	Treatment	1	2.00	0.16	1	0.93	0.34
		Control	1	0.03	0.87	1	1.07	0.30
	5-6	Treatment	[a]	[a]	[a]	[a]	[a]	[a]
		Control	1	0.03	0.87	1	1.07	0.30
	7-20	Treatment	[a]	[a]	[a]	[a]	[a]	[a]
		Control	1	0.03	0.87	1	1.07	0.30
18	1-4	Treatment	[a]	[a]	[a]	[a]	[a]	[a]
		Control	1	0.55	0.46	1	0.05	0.83
	5-6	Treatment	1	0.00	1.00	1	0.50	0.48
		Control	1	0.55	0.46	1	0.05	0.83
	7-20	Treatment	[a]	[a]	[a]	[a]	[a]	[a]
		Control	1	0.55	0.46	1	0.05	0.83
19	1-4	Treatment	[a]	[a]	[a]	[a]	[a]	[a]
		Control	1	6.41	0.01	1	0.02	0.87
	5-6	Treatment	1	0.12	0.73	1	0.21	0.65
		Control	1	6.41	0.01	1	0.02	0.87
	7-20	Treatment	[a]	[a]	[a]	[a]	[a]	[a]
		Control	1	6.41	0.01	1	0.02	0.87
20	1-4	Treatment	[a]	[a]	[a]	1	0.68	0.41
		Control	1	0.02	0.90	1	0.14	0.71
	5-6	Treatment	1	0.33	0.57	1	1.12	0.29
		Control	1	0.02	0.90	1	0.14	0.71
	7-20	Treatment	[b]	[b]	[b]	[b]	[b]	[b]
		Control	[b]	[b]	[b]	[b]	[b]	[b]
21	1-4	Treatment	1	2.23	0.14	[a]	[a]	[a]
		Control	1	0.21	0.65	[a]	[a]	[a]
	5-6	Treatment	[a]	[a]	[a]	1	1.98	0.16
		Control	1	0.21	0.65	1	0.04	0.84
	7-20	Treatment	[b]	[b]	[b]	[b]	[b]	[b]
		Control	[b]	[b]	[b]	[b]	[b]	[b]
22	1-4	Treatment	1	0.05	0.82	1	0.02	0.90
		Control	1	0.81	0.37	1	0.36	0.55

[a] - Chi-square statistic was not calculable for these tests due to the presence of only zeroes in rows or columns in the contingency tables.
[b] - Chi-square statistic was not calculable. Treatment fish did not pass through these bays during the specified releases (time period).

Table A4.6 Continued.

Release	Spillbay	Population	Test 2 df	Test 2 χ^2	Test 2 P	Test 3 df	Test 3 χ^2	Test 3 P
	5-6	Treatment	1	0.11	0.74	1	0.33	0.57
		Control	1	0.81	0.37	1	0.36	0.55
	7-20	Treatment	b	b	b	b	b	b
		Control	b	b	b	b	b	b
23	1-4	Treatment	a	a	a	a	a	a
		Control	1	0.61	0.43	1	0.38	0.54
	5-6	Treatment	1	1.72	0.19	a	a	a
		Control	1	0.61	0.43	1	0.38	0.54
	7-20	Treatment	a	a	a	a	a	a
		Control	1	0.61	0.43	1	0.38	0.54
24	1-4	Treatment	a	a	a	a	a	a
		Control	1	2.80	0.09	1	1.54	0.21
	5-6	Treatment	a	a	a	1	2.80	0.09
		Control	1	2.80	0.09	1	1.54	0.21
	7-20	Treatment	a	a	a	a	a	a
		Control	1	2.80	0.09	a	a	a
25	1-4	Treatment	1	1.67	0.20	1	0.25	0.62
		Control	1	0.39	0.53	1	0.04	0.83
	5-6	Treatment	a	a	a	1	0.26	0.61
		Control	1	0.39	0.53	1	0.04	0.83
	7-20	Treatment	a	a	a	a	a	a
		Control	1	0.39	0.53	1	0.04	0.83
26	1-4	Treatment	a	a	a	1	0.01	0.93
		Control	1	0.16	0.69	1	0.14	0.71
	5-6	Treatment	1	0.38	0.54	1	0.96	0.33
		Control	1	0.16	0.69	1	0.14	0.71
	7-20	Treatment	a	a	a	a	a	a
		Control	1	0.16	0.69	1	0.14	0.71
27	1-4	Treatment	1	1.37	0.24	1	0.07	0.79
		Control	1	0.00	1.00	1	0.68	0.41
	5-6	Treatment	a	a	a	a	a	a
		Control	1	0.00	1.00	1	0.68	0.41
	7-20	Treatment	a	a	a	a	a	a
		Control	1	0.00	1.00	1	0.68	0.41

[a] - Chi-square statistic was not calculable for these tests due to the presence of only zeroes in rows or columns in the contingency tables.
b- Chi-square statistic was not calculable. Treatment fish did not pass through these bays during the specified releases (time period).

Appendix 5: Chi-square tests

Table A5.1. Summary of chi-square tests for homogeneity of arrival times at Sauter, Eighteen-Mile Island and the Bridge of the Gods arrays for paired releases of radio-tagged yearling Chinook salmon released into the ice and trash sluiceway (treatment) and the tailrace immediately below the sluiceway (control) at The Dalles Dam during 2004.

	Sauter			Eighteen-Mile			Bridge of the Gods		
Rel	DF	Chi-square	P	DF	Chi-square	P	DF	Chi-square	P
1	0	0	[a]	0	0	[a]	1	1.41	0.236
2	1	0.97	0.324	1	1.17	0.279	1	0.77	0.381
3	0	0	[a]	0	0	[a]	0	0	[a]
4	0	0	[a]	0	0	[a]	0	0	[a]
5	0	0	[a]	0	0	[a]	1	1.10	0.294
6	0	0	[a]	0	0	[a]	0	0	[a]
7	0	0	[a]	0	0	[a]	1	0.93	0.335
8	0	0	[a]	0	0	[a]	0	0	[a]
9	0	0	[a]	0	0	[a]	0	0	[a]
10	0	0	[a]	0	0	[a]	0	0	[a]
11	0	0	[a]	0	0	[a]	0	0	[a]
12	0	0	[a]	0	0	[a]	0	0	[a]
13	0	0	[a]	0	0	[a]	0	0	[a]
14	0	0	[a]	0	0	[a]	0	0	[a]
15	0	0	[a]	0	0	[a]	0	0	[a]
16	0	0	[a]	0	0	[a]	0	0	[a]
17	0	0	[a]	0	0	[a]	0	0	[a]
18	1	0.94	0.331	1	2.80	0.94	1	0.56	0.452
19	1	0.85	0.358	0	0	[a]	1	0.82	0.366
20	0	0	[a]	0	0	[a]	0	0	[a]
21	0	0	[a]	0	0	[a]	0	0	[a]
22	0	0	[a]	0	0	[a]	0	0	[a]
23	0	0	[a]	0	0	[a]	0	0	[a]
24	0	0	[a]	1	1.02	0.312	1	0.85	0.356
25	0	0	[a]	0	0	[a]	0	0	[a]
26	0	0	[a]	0	0	[a]	[0]	0	[a]
27	0	0	[a]	0	0	[a]	0	0	[a]
28	0	0	[a]	0	0	[a]	1	0.98	0.322
29	0	0	[a]	0	0	[a]	0	0	[a]
30	0	0	[a]	0	0	[a]	0	0	[a]
31	0	0	[a]	0	0	[a]	0	0	[a]
32	0	0	[a]	0	0	[a]	0	0	[a]

[a] - All fish arrived on the same day at this detection array.

Table A5.2. Summary of chi-square tests for homogeneity of arrival times at Sauter, Eighteen-Mile Island and the Bridge of the Gods arrays for paired releases of radio-tagged yearling Chinook salmon released into the ice and trash sluiceway (treatment) and the spillway tailrace (control) at The Dalles Dam during 2004.

	Sauter			Eighteen-Mile			Bridge of the Gods		
Rel	DF	Chi-square	P	DF	Chi-square	P	DF	Chi-square	P
1	0	0	[a]	0	0.00	[a]	1	0.76	0.383
2	1	2.09	0.148	1	1.98	0.160	2	6.96	0.031
3	0	0	[a]	0	0.00	[a]	0	0.00	[a]
4	0	0	[a]	1	3.29	0.070	1	7.44	0.006
5	0	0	[a]	0	0.00	[a]	1	2.65	0.104
6	0	0	[a]	1	4.93	0.026	1	3.52	0.060
7	0	0	[a]	0	0	[a]	1	1.84	0.175
8	0	0	[a]	0	0	[a]	1	2.67	0.102
9	0	0	[a]	0	0	[a]	0	0	[a]
10	0	0	[a]	0	0	[a]	0	0	[a]
11	0	0	[a]	0	0	[a]	0	0	[a]
12	0	0	[a]	0	0	[a]	0	0	[a]
13	0	0	[a]	0	0	[a]	0	0	[a]
14	0	0	[a]	0	0	[a]	0	0	[a]
15	1	2.72	0.099	0	0	[a]	1	1.87	0.171
16	0	0	[a]	0	0	[a]	0	0.00	[a]
17	0	0	[a]	0	0	[a]	0	0.00	[a]
18	1	4.09	0.043	1	6.08	0.014	1	6.38	0.012
19	1	1.90	0.168	0	0	[a]	1	5.65	0.017
20	0	0	[a]	0	0	[a]	1	0.76	0.382
21	0	0	[a]	0	0	[a]	0	0	[a]
22	0	0	[a]	0	0	[a]	0	0	[a]
23	0	0	[a]	0	0	[a]	0	0	[a]
24	0	0	[a]	1	1.69	0.193	2	8.70	0.013
25	0	0	[a]	0	0	[a]	0	0	[a]
26	0	0	[a]	0	0	[a]	1	4.07	0.044
27	0	0	[a]	0	0	[a]	0	0	[a]
28	0	0	[a]	0	0	[a]	0	0	[a]
29	0	0	[a]	0	0	[a]	0	0	[a]
30	0	0	[a]	0	0	[a]	0	0	[a]
31	0	0	[a]	0	0	[a]	0	0	[a]
32	0	0	[a]	0	0	[a]	0	0	[a]

[a] - All fish arrived on the same day at this detection array.

Table A5.3. Summary of chi-square tests for homogeneity of arrival times at Sauter, Eighteen-Mile Island and the Bridge of the Gods arrays for paired releases of radio-tagged subyearling Chinook salmon released into the ice and trash sluiceway (treatment) and the tailrace immediately below the sluiceway (control) at The Dalles Dam during 2004.

	Sauter			Eighteen-Mile			Bridge of the Gods		
Rel	DF	Chi-square	P	DF	Chi-square	P	DF	Chi-square	P
1	1	1.40	0.237	1	1.54	0.215	2	2.07	0.354
2	0	0	[a]	0	0	[a]	0	0	[a]
3	0	0	[a]	0	0	[a]	1	0.00	1.000
4	0	0	[a]	0	0	[a]	1	0.89	0.345
5	1	0.93	0.335	1	0.83	0.362	0	0	[a]
6	0	0	[a]	0	0	[a]	1	0.44	0.509
7	0	0	[a]	0	0	[a]	2	1.91	0.385
8	0	0	[a]	0	0	[a]	1	0.95	0.329
9	0	0	[a]	0	0	[a]	0	0	[a]
10	0	0	[a]	0	0	[a]	0	0	[a]
11	0	0	[a]	0	0	[a]	0	0	[a]
12	0	0	[a]	0	0	[a]	1	1.08	0.298
13	0	0	[a]	0	0	[a]	2	2.45	0.294
14	0	0	[a]	0	0	[a]	1	0.91	0.341
15	0	0	[a]	0	0	[a]	0	0	[a]
16	0	0	[a]	0	0	[a]	0	0	[a]
17	0	0	[a]	0	0	[a]	1	0	0.957
18	2	2.73	0.256	0	0	[a]	2	2.03	0.363
19	0	0	[a]	0	0	[a]	0	0	[a]
20	0	0	[a]	0	0	[a]	1	0.83	0.362
21	0	0	[a]	0	0	[a]	1	1.57	0.210
22	1	1.35	0.246	1	1.24	0.265	1	2.08	0.150
23	0	0	[a]	0	0	[a]	0	0	[a]
24	0	0	[a]	0	0	[a]	0	0	[a]
25	0	0	[a]	0	0	[a]	1	0.57	0.452
26	0	0	[a]	0	0	[a]	1	0.07	0.791
27	0	0	[a]	0	0	[a]	0	0	[a]
28	0	0	[a]	0	0	[a]	1	0.30	0.583
29	0	0	[a]	0	0	[a]	0	0	[a]
30	0	0	[a]	0	0	[a]	1	0.30	0.582
31	0	0	[a]	0	0	[a]	2	6.59	0.037
32	0	0	[a]	0	0	[a]	1	1.47	0.226
33	0	0	[a]	0	0	[a]	1	2.84	0.092
34	0	0	[a]	0	0	[a]	1	0.35	0.554
35	0	0	[a]	0	0	[a]	1	0.88	0.347
36	0	0	[a]	0	0	[a]	0	0	[a]
37	0	0	[a]	0	0	[a]	1	0.63	0.428
38	0	0	[a]	0	0	[a]	1	0.04	0.849
39	0	0	[a]	0	0	[a]	0	0	[a]
40	0	0	[a]	0	0	[a]	0	0	[a]

[a] - All fish arrived on the same day at this detection array.

Table A5.4. Summary of chi-square tests for homogeneity of arrival times at Sauter, Eighteen-Mile Island and the Bridge of the Gods arrays for paired releases of radio-tagged subyearling Chinook salmon released into the ice and trash sluiceway (treatment) and the spillway tailrace (control) at The Dalles Dam during 2004.

	Sauter			Eighteen-Mile			Bridge of the Gods		
Rel	DF	Chi-square	P	DF	Chi-square	P	DF	Chi-square	P
1	1	6.56	0.010	1	6.12	0.013	1	4.34	0.037
2	0	0	[a]	0	0	[a]	2	0.79	0.675
3	1	0.24	0.626	0	0	[a]	1	0.17	0.678
4	0	0	[a]	0	0	[a]	1	9.07	0.003
5	1	1.34	0.246	1	3.56	0.059	1	1.27	0.260
6	0	0	[a]	0	0	[a]	1	4.30	0.038
7	0	0	[a]	0	0	[a]	1	3.64	0.056
8	0	0	[a]	0	0	[a]	1	1.33	0.250
9	0	0	[a]	0	0	[a]	1	0.36	0.551
10	0	0	[a]	0	0	[a]	1	7.36	0.007
11	0	0	[a]	0	0	[a]	0	0	[a]
12	0	0	[a]	0	0	[a]	2	5.72	0.057
13	0	0	[a]	0	0	[a]	2	2.89	0.236
14	0	0	[a]	0	0	[a]	1	8.21	0.004
15	0	0	[a]	0	0	[a]	0	0	[a]
16	0	0	[a]	0	0	[a]	1	0.10	0.747
17	1	0.39	0.534	0	0	[a]	1	1.90	0.168
18	2	5.23	0.073	0	0	[a]	1	1.56	0.211
19	0	0	[a]	0	0	[a]	1	10.50	0.001
20	0	0	[a]	0	0	[a]	1	1.06	0.303
21	0	0	[a]	0	0	[a]	1	0.41	0.523
22	0	0	[a]	0	0	[a]	0	0	[a]
23	0	0	[a]	0	0	[a]	0	0	[a]
24	0	0	[a]	0	0	[a]	1	3.25	0.071
25	0	0	[a]	0	0	[a]	1	2.89	0.089
26	0	0	[a]	0	0	[a]	1	0.16	0.691
27	0	0	[a]	0	0	[a]	1	1.11	0.291
28	0	0	[a]	1	4.88	0.027	2	12.60	0.002
29	0	0	[a]	0	0	[a]	1	0.06	0.801
30	1	0.11	0.743	0	0	[a]	1	3.63	0.057
31	0	0	[a]	0	0	[a]	2	7.17	0.028
32	1	4.71	0.030	2	0.36	0.837	1	0.62	0.431
33	0	0	[a]	1	0.13	0.721	1	13.88	0.000
34	0	0	[a]	0	0	[a]	1	16.26	0.000
35	0	0	[a]	0	0	[a]	2	5.89	0.053
36	0	0	[a]	0	0	[a]	1	1.19	0.274
37	1	0.12	0.724	0	0	[a]	1	1.10	0.294
38	0	0	[a]	0	0	[a]	1	0.07	0.796
39	2	25.02	0.000	2	20.52	0.000	1	14.96	0.000
40	0	0	[a]	0	0	[a]	1	21.56	0.000

[a] - All fish arrived on the same day at this detection array.

Table A5.5. Summary of chi-square tests for homogeneity of arrival times at Sauter, Underwood and Bonneville Dam arrays for radio-tagged yearling Chinook salmon passing via spillbays 1-4, 5-6, and 7-20 of The Dalles Dam spillway. The paired release groups were formed post-hoc based on passage times at The Dalles Dam of fish released into the John Day Dam tailrace (treatment) and in The Dalles Dam tailrace (control) during 2004.

		Sauter			Underwood			Bonneville		
Rel	Spillbay	DF	Chi-square	P	DF	Chi-square	P	DF	Chi-square	P
1	Bays 1-4	1	0.00	0.953	2	3.03	0.220	3	1.03	0.793
	Bays 5-6	2	7.46	0.024	2	1.79	0.408	3	0.31	0.959
	Bays 7-20	1	4.40	0.036	2	1.66	0.437	3	5.51	0.138
2	Bays 1-4	1	2.96	0.086	1	0.58	0.445	1	0.01	0.936
	Bays 5-6	1	9.12	0.003	1	0.13	0.722	1	0.01	0.918
	Bays 7-20	1	10.74	0.001	1	1.43	0.232	1	0.11	0.737
3	Bays 1-4	1	0.11	0.736	1	0.68	0.410	1	1.91	0.167
	Bays 5-6	1	9.02	0.003	1	4.77	0.029	1	0.95	0.331
	Bays 7-20	0	0	[a]	1	0.05	0.816	1	1.19	0.276
4	Bays 1-4	0	0	[a]	0	0	[a]	1	2.06	0.152
	Bays 5-6	0	0	[a]	0	0	[a]	1	1.17	0.280
	Bays 7-20	0	0	[a]	0	0	[a]	1	0.17	0.682
5	Bays 1-4	1	0.41	0.522	0	0	[a]	1	1.25	0.264
	Bays 5-6	1	10.37	0.001	1	6.86	0.009	1	4.95	0.026
	Bays 7-20	1	4.19	0.041	0	0	[a]	1	0.31	0.580
6	Bays 1-4	1	0.29	0.591	0	0	[a]	1	0.88	0.348
	Bays 5-6	0	0	[a]	0	0	[a]	1	0.05	0.826
	Bays 7-20	1	0.12	0.727	0	0	[a]	1	0.37	0.541
7	Bays 1-4	0	0	[a]	0	0	[a]	1	0.35	0.554
	Bays 5-6	0	0	[a]	0	0	[a]	1	0.42	0.519
	Bays 7-20	0	0	[a]	0	0	[a]	1	0.28	0.593
8	Bays 1-4	0	0	[a]	1	0.21	0.650	2	0.94	0.624
	Bays 5-6	0	0	[a]	0	0	[a]	2	0.60	0.742
	Bays 7-20	0	0	[a]	0	0	[a]	2	0.15	0.926
9	Bays 1-4	0	0	[a]	0	0	[a]	1	2.61	0.106
	Bays 5-6	0	0	[a]	1	11.00	0.001	1	0.32	0.572
	Bays 7-20	0	0	[a]	0	0	[a]	1	0.96	0.326
10	Bays 1-4	0	0	[a]	0	0	[a]	1	0.15	0.694
	Bays 5-6	0	0	[a]	0	0	[a]	1	1.76	0.184
	Bays 7-20	0	0	[a]	0	0	[a]	1	0.60	0.441
11	Bays 1-4	0	0	[a]	1	0.27	0.605	2	0.78	0.677
	Bays 5-6	0	0	[a]	1	0.19	0.660	2	1.21	0.545
	Bays 7-20	1	9.49	0.002	1	0.11	0.743	2	1.58	0.453
12	Bays 1-4	0	0	[a]	0	0	[a]	1	1.20	0.273
	Bays 5-6	0	0	[a]	0	0	[a]	1	2.34	0.126
	Bays 7-20	0	0	[a]	0	0	[a]	1	0.35	0.554
13	Bays 1-4	1	2.41	0.120	1	0.02	0.897	1	4.63	0.031
	Bays 5-6	1	1.91	0.167	1	0.18	0.668	1	0.23	0.631
	Bays 7-20	1	0.15	0.695	1	4.03	0.045	1	0.80	0.371

[a] - All fish arrived on the same day at this detection array.

Table A5.5. Continued.

		Sauter			Underwood			Bonneville		
Rel	Spillbay	DF	Chi-square	P	DF	Chi-square	P	DF	Chi-square	P
14	Bays 1-4	1	1.66	0.197	1	0.14	0.705	1	0.08	0.779
	Bays 5-6	1	0.08	0.775	1	0.00	0.986	1	0.00	0.983
	Bays 7-20	1	0.13	0.715	1	0.31	0.576	1	0.01	0.936
15	Bays 1-4	0	0	[a]	1	0.35	0.556	1	3.33	0.068
	Bays 5-6	0	0	[a]	0	0	[a]	1	1.02	0.313
	Bays 7-20	0	0	[a]	0	0	[a]	1	0.39	0.535
16	Bays 1-4	0	0	[a]	1	0.31	0.577	1	2.12	0.145
	Bays 5-6	1	7.65	0.006	1	7.65	0.006	2	7.68	0.022
	Bays 7-20	0	0	[a]	0	0	[a]	1	0.11	0.742
17	Bays 1-4	1	0.20	0.652	1	4.99	0.025	1	1.58	0.209
	Bays 5-6	1	2.96	0.085	1	2.96	0.085	1	0.10	0.749
	Bays 7-20	0	0	[a]	0	0	[a]	1	0.80	0.372
18	Bays 1-4	0	0	[a]	1	0.16	0.687	2	0.40	0.819
	Bays 5-6	0	0	[a]	1	0.88	0.348	2	0.61	0.737
	Bays 7-20	1	4.94	0.026	1	0.42	0.519	2	4.16	0.125
19	Bays 1-4	0	0	[a]	0	0	[a]	1	0.23	0.634
	Bays 5-6	0	0	[a]	0	0	[a]	1	0.31	0.580
	Bays 7-20	0	0	[a]	0	0	[a]	1	0.10	0.749
20	Bays 1-4	1	1.25	0.263	1	0.46	0.499	1	0.39	0.530
	Bays 5-6	1	4.21	0.040	1	3.23	0.072	2	10.30	0.006
	Bays 7-20	1	2.26	0.133	1	0.17	0.684	1	2.09	0.148
21	Bays 1-4	0	0	[a]	1	0.18	0.675	1	2.33	0.127
	Bays 5-6	0	0	[a]	0	0	[a]	1	2.23	0.135
	Bays 7-20	0	0	[a]	0	0	[a]	1	0.07	0.793
22	Bays 1-4	0	0	[a]	2	5.49	0.064	1	7.01	0.008
	Bays 5-6	0	0	[a]	2	0.66	0.718	1	0.23	0.634
	Bays 7-20	0	0	[a]	2	0.63	0.728	1	1.37	0.242
23	Bays 1-4	0	0	[a]	0	0	[a]	1	0.68	0.409
	Bays 5-6	0	0	[a]	0	0	[a]	1	0.03	0.852
	Bays 7-20	0	0	[a]	1	0.17	0.683	1	0.15	0.702
24	Bays 1-4	2	0.98	0.613	2	0.23	0.892	2	0.94	0.627
	Bays 5-6	2	1.44	0.487	2	3.09	0.213	2	3.30	0.192
	Bays 7-20	1	1.02	0.313	2	0.88	0.643	2	5.71	0.057
25	Bays 1-4	1	0.41	0.525	1	0.00	0.946	1	0.00	0.975
	Bays 5-6	1	3.00	0.083	1	1.25	0.264	1	0.62	0.432
	Bays 7-20	1	0.31	0.577	1	0.05	0.818	1	0.47	0.492
26	Bays 1-4	0	0	[a]	0	0	[a]	1	0.48	0.487
	Bays 5-6	0	0	[a]	0	0	[a]	1	0.09	0.760
	Bays 7-20	0	0	[a]	0	0	[a]	1	0.15	0.703
27	Bays 1-4	1	5.10	0.024	0	0	[a]	1	0.20	0.655
	Bays 5-6	0	0	[a]	0	0	[a]	1	3.34	0.067
	Bays 7-20	0	0	[a]	0	0	[a]	1	0.10	0.752
28	Bays 1-4	0	0	[a]	0	0	[a]	1	1.19	0.276
	Bays 5-6	0	0	[a]	0	0	[a]	1	0.21	0.644
	Bays 7-20	0	0	[a]	0	0	[a]	1	1.19	0.275

[a] - All fish arrived on the same day at this detection array.

Table A5.6. Summary of chi-square tests for homogeneity of arrival times at Sauter, Underwood and Bonneville Dam arrays for radio-tagged subyearling Chinook salmon passing via spillbays 1-4, 5-6, and 7-20 of The Dalles Dam spillway. The paired release groups were formed post-hoc based on passage times at The Dalles Dam of fish released into the John Day Dam tailrace (treatment) and in The Dalles Dam tailrace (control) during 2004.

		Sauter			Underwood			Bonneville		
Rel	Spillbay	DF	Chi-square	P	DF	Chi-square	P	DF	Chi-square	P
1	Bays 1-4	0	0	[a]	1	0.235	0.628	2	9.146	0.010
	Bays 5-6	0	0	[a]	1	0.154	0.695	2	0.355	0.838
	Bays 7-20	0	0	[a]	1	0.028	0.869	2	0.216	0.898
2	Bays 1-4	2	10.759	0.005	1	10.759	0.001	3	0.873	0.832
	Bays 5-6	2	7.341	0.025	1	7.341	0.007	3	0.540	0.910
	Bays 7-20	2	2.265	0.322	1	2.265	0.132	2	0.377	0.828
3	Bays 1-4	1	10.827	0.001	1	14.675	0.000	2	15.002	0.001
	Bays 5-6	1	5.212	0.022	1	7.105	0.008	2	19.480	0.000
	Bays 7-20	1	2.627	0.105	1	7.140	0.058	1	7.140	0.008
4	Bays 1-4	2	6.400	0.041	1	5.720	0.017	2	2.613	0.271
	Bays 5-6	2	4.556	0.102	1	4.070	0.044	2	0.358	0.836
	Bays 7-20	2	1.083	0.582	1	0.966	0.326	2	0.787	0.675
5	Bays 1-4	1	0.155	0.693	1	0.155	0.693	1	0.012	0.914
	Bays 5-6	1	0.178	0.674	1	0.178	0.674	1	0.138	0.710
	Bays 7-20	1	0.037	0.847	1	0.037	0.847	1	0.353	0.552
6	Bays 1-4	1	8.597	0.003	1	5.710	0.017	1	0.019	0.891
	Bays 5-6	1	12.963	0.000	1	8.699	0.003	2	3.868	0.145
	Bays 7-20	1	3.970	0.046	1	2.602	0.107	1	0.329	0.566
7	Bays 1-4	0	0	[a]	0	0	[a]	1	0.828	0.363
	Bays 5-6	0	0	[a]	0	0	[a]	1	0.674	0.412
	Bays 7-20	0	0	[a]	0	0	[a]	1	1.482	0.224
8	Bays 1-4	2	35.617	1.845	2	27.217	0.000	2	2.130	0.345
	Bays 5-6	2	16.601	0.000	2	12.562	0.002	3	0.956	0.812
	Bays 7-20	2	24.019	6.085	2	18.247	0.000	2	3.119	0.210
9	Bays 1-4	0	0	[a]	1	0.266	0.606	2	0.474	0.789
	Bays 5-6	0	0	[a]	1	0.200	0.655	2	0.585	0.747
	Bays 7-20	0	0	[a]	1	0.053	0.817	2	0.604	0.739
10	Bays 1-4	1	8.845	0.003	2	10.788	0.005	3	5.954	0.114
	Bays 5-6	1	13.880	0.000	2	16.858	0.000	3	0.190	0.979
	Bays 7-20	1	1.823	0.177	2	2.238	0.327	3	3.720	0.293
11	Bays 1-4	2	9.607	0.008	1	9.048	0.003	3	0.268	0.966
	Bays 5-6	2	14.066	0.001	1	13.2666	0.000	3	5.769	0.123
	Bays 7-20	2	2.014	0.365	1	1.892	0.169	3	0.756	0.860
12	Bays 1-4	2	9.999	0.007	2	16.930	0.000	3	3.580	0.311
	Bays 5-6	2	14.555	0.001	2	24.435	0.000	3	12.762	0.005
	Bays 7-20	2	4.279	0.118	2	7.328	0.026	3	5.067	0.167
13	Bays 1-4	1	4.002	0.0454	1	5.938	0.015	2	0.402	0.818
	Bays 5-6	1	3.567	0.059	1	5.299	0.021	2	0.456	0.796
	Bays 7-20	1	1.358	0.244	1	2.032	0.154	2	0.256	0.880
14	Bays 1-4	1	16.181	0.000	2	15.165	0.001	2	0.726	0.696
	Bays 5-6	1	10.771	0.001	2	10.082	0.007	2	1.239	0.538
	Bays 7-20	1	7.985	0.005	2	7.469	0.024	2	2.143	0.343

[a] - All fish arrived on the same day at this detection array.

[b] - Chi-square statistic was not calculable. Treatment fish did not pass through these bays during the specified releases (time period).

Table A5.6. Continued.

		Sauter			Underwood			Bonneville		
Rel	Spillbay	DF	Chi-square	P	DF	Chi-square	P	DF	Chi-square	P
15	Bays 1-4	1	7.492	0.006	1	4.490	0.034	2	4.201	0.122
	Bays 5-6	1	3.401	0.065	1	2.021	0.155	1	1.212	0.271
	Bays 7-20	1	6.282	0.012	1	3.755	0.053	2	0.894	0.640
16	Bays 1-4	2	35.299	0.000	2	32.847	0.000	4	6.305	0.178
	Bays 5-6	2	24.108	0.000	2	22.367	0.000	4	7.285	0.122
	Bays 7-20	2	24.107	0.000	2	22.367	0.000	4	18.204	0.001
17	Bays 1-4	1	13.064	0.000	2	14.539	0.001	3	2.032	0.566
	Bays 5-6	1	7.993	0.005	2	8.916	0.012	3	1.525	0.676
	Bays 7-20	1	0.550	0.458	2	0.615	0.735	3	1.871	0.560
18	Bays 1-4	1	0.313	0.576	2	1.905	0.168	2	1.159	0.560
	Bays 5-6	1	0.329	0.566	1	2.004	0.157	2	5.043	0.080
	Bays 7-20	1	0.033	0.856	1	0.202	0.653	2	0.516	0.773
19	Bays 1-4	2	11.795	0.003	1	10.829	0.001	2	2.284	0.319
	Bays 5-6	2	8.229	0.016	1	7.550	0.006	2	0.398	0.819
	Bays 7-20	2	0.465	0.793	1	0.426	0.514	2	0.746	0.689
20	Bays 1-4	0	0	[a]	1	0.455	0.500	2	5.066	0.079
	Bays 5-6	0	0	[a]	1	0.503	0.478	2	0.736	0.692
	Bays 7-20	0	0	[b]	0	0	[b]	0	0	[b]
21	Bays 1-4	1	0.056	0.813	1	0.818	0.366	2	8.970	0.011
	Bays 5-6	1	0.052	0.819	1	0.767	0.381	2	0.090	0.956
	Bays 7-20	0	0	[b]	0	0	[b]	0	0	[b]
22	Bays 1-4	1	11.719	0.001	1	15.869	0.000	3	6.932	0.074
	Bays 5-6	1	8.749	0.003	1	11.873	0.001	4	2.268	0.687
	Bays 7-20	0	0	[b]	0	0	[b]	0	0	[b]
23	Bays 1-4	1	0.996	0.318	1	2.193	0.139	3	1.945	0.584
	Bays 5-6	1	1.055	0.304	1	2.321	0.128	3	0.561	0.905
	Bays 7-20	1	0.118	0.732	1	0.260	0.610	3	0.722	0.868
24	Bays 1-4	1	0.996	0.318	1	2.193	0.139	3	1.945	0.584
	Bays 5-6	1	1.055	0.304	1	2.321	0.128	3	0.561	0.905
	Bays 7-20	1	0.118	0.732	1	0.260	0.610	3	0.722	0.868
25	Bays 1-4	2	39.973	0.000	2	32.918	0.000	4	2.680	0.613
	Bays 5-6	2	35.844	0.000	2	29.472	0.000	4	10.096	0.039
	Bays 7-20	2	6.696	0.035	2	5.440	0.066	4	0.418	0.981
26	Bays 1-4	1	0.117	0.732	1	0.355	0.551	1	0.206	0.650
	Bays 5-6	1	0.093	0.760	1	0.281	0.596	1	1.742	0.187
	Bays 7-20	1	0.008	0.928	1	0.245	0.876	1	2.073	0.150
27	Bays 1-4	0	0	[a]	2	0.297	0.862	1	0.263	0.608
	Bays 5-6	0	0	[a]	2	0.226	0.893	1	0.854	0.356
	Bays 7-20	0	0	[a]	2	0.012	0.994	1	20.413	0.000

[a] - All fish arrived on the same day at this detection array.

b - Chi-square statistic was not calculable. Treatment fish did not pass through these bays during the specified releases (time period).

Appendix 6: Analysis of The Dalles Dam triple-release study

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10 June 2005

This analysis uses an alternative methodology to analyze The Dalles Dam triple-release study. Should further analysis be desired than this simplified approach, the model can easily be expanded to include more downstream detection histories. The goal of the analysis is to pair fish with more similar handling histories to better estimate route-specific survivals.

Methods

Figure A6.1 shows the triple-release study set up, with possible passage routes through The Dalles Dam by study fish. Route-specific survivals were estimated in four steps.

1. Estimate single-release survivals through each route using fish from the top-most release group (R_1) known to have passed through each route.
2. Estimate the relative survivals for the spillway (R_{sp}) and turbine (R_{turb}) routes to the sluiceway survival.
3. Estimate absolute survival through the sluiceway (S_L) using the paired releases (R_2 and R_3).
4. Using the absolute sluiceway survival and relative survivals, estimate absolute survival through the spillway and turbines.

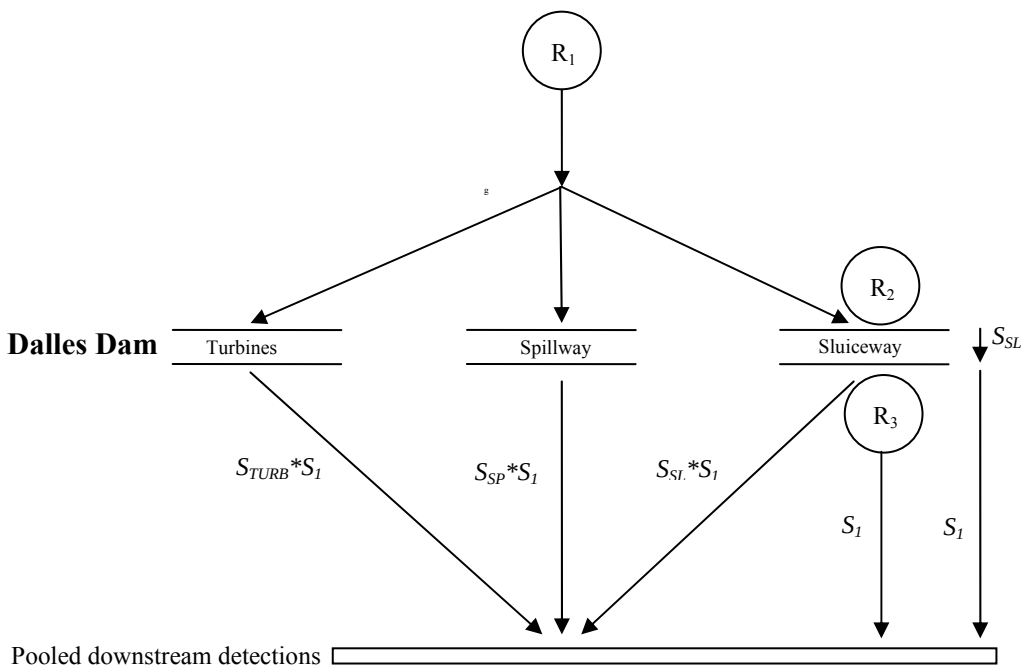

Figure A6.1. Schematic of Dalles Dam triple-release survival study design with releases R_1, R_2, and R_3.

Single-release survival estimation

Fish traveling through each Dalles Dam passage route are treated as a single release. As such, survival cannot be parsed between survival through a passage route and survival from the Dalles Dam tailrace to the first detection site ($\hat{S}_1$). Each survival is estimated using the number of unique downstream detections of the fish known to have passed through each route, i.e.,

$$\widehat{S_{route} * S_1} = \frac{x_{route}}{n_{route}},$$

where $\widehat{S_{route} * S_1}$ = estimated survival from the top of a particular Dalles Dam *route* to the first detection site downriver, (*route* = *TURB* (turbines), *SP* (spillway), or *SL* (sluiceway)).

x_{route} = total number of unique detections of fish known to have passed through a particular *route* detected downstream, and

n_{route} = total number of fish known to have passed through the *route*.

Assuming a binomial distribution, the variance on ($\widehat{S_{route} * S_1}$) is then

$$\text{var}(\widehat{S_{route} * S_1}) = \frac{\left(\frac{x_{route}}{n_{route}}\right)\left(1 - \frac{x_{route}}{n_{route}}\right)}{n_{route}}.$$

Relative survival estimation

To remove survival experienced from the Dalles Dam tailrace to the first detection site ($\hat{S}_1$), the single-release survival estimates for the spillway and turbines are divided by the sluiceway survival estimate to obtain a relative survival, i.e.

$$\hat{R}_{TURB/SL} = \frac{\widehat{S_{TURB} * S_1}}{\widehat{S_{SL} * S_1}} = \frac{\hat{S}_{TURB}}{\hat{S}_{SL}}, \text{ and} \qquad (1)$$

$$\hat{R}_{SP/SL} = \frac{\widehat{S_{SP} * S_1}}{\widehat{S_{SL} * S_1}} = \frac{\hat{S}_{SP}}{\hat{S}_{SL}}$$

Variance estimates for each relative survival are

$$\widehat{Var}(\hat{R}_{TURB/SL}) = \left(\frac{\widehat{S_{TURB} * S_1}}{\widehat{S_{SL} * S_1}} \right)^2 * \left(\frac{\widehat{Var}\left(\widehat{S_{TURB} * S_1}\right)}{\left(\widehat{S_{TURB} * S_1}\right)^2} + \frac{\widehat{Var}\left(\widehat{S_{SL} * S_1}\right)}{\left(\widehat{S_{SL} * S_1}\right)^2} \right), \text{ and}$$

$$\widehat{Var}(\hat{R}_{SP/SL}) = \left(\frac{\widehat{S_{SP} * S_1}}{\widehat{S_{SL} * S_1}} \right)^2 * \left(\frac{\widehat{Var}\left(\widehat{S_{SP} * S_1}\right)}{\left(\widehat{S_{SP} * S_1}\right)^2} + \frac{\widehat{Var}\left(\widehat{S_{SL} * S_1}\right)}{\left(\widehat{S_{SL} * S_1}\right)^2} \right).$$

Sluiceway passage survival

Assuming all releases experience the same probability of detection and survival for common stretches of the river traveled after release, survival through the sluiceway can be estimated with Ricker relative recovery estimates (1958) using the paired releases (R_2 and R_3).

$$\hat{S}_{SL} = \frac{\frac{x_{R_2}}{n_{R_2}}}{\frac{x_{R_3}}{n_{R_3}}}$$

where $\hat{S}_{SL}$ = estimated survival from the top of the Dalles Dam sluiceway to the first detection site downriver.

x_i = total number of unique detections from fish in Release i, (i = 1, 2) detected downstream, and

n_i = total number of fish in Release i, (i = 1, 2).

The variance for $\hat{S}_{SL}$ is estimated by

$$\widehat{Var}(\hat{S}_{SL}) = \left(\frac{x_{R_2} * n_{R_3}}{n_{R_2} * x_{R_3}} \right)^2 * \left(\frac{1}{x_{R_2}} - \frac{1}{n_{R_2}} + \frac{1}{x_{R_3}} - \frac{1}{n_{R_3}} \right).$$

Absolute passage survival for the turbines and spillway

Now that a good estimate for survival through the sluiceway has been calculated, the absolute survivals through the spillway and turbines can now be estimated. Rearranging the equation (1), and using the absolute survival through the sluiceway from the paired-release, absolute survivals are

$$\hat{S}_{PH} = \hat{R}_{PH/SL} * \hat{S}_{SL}, \text{ and}$$

$$\hat{S}_{SP} = \hat{R}_{SP/SL} * \hat{S}_{SL}.$$

Assuming independence between the relative survivals and sluiceway survival estimate, variances for each absolute survival are

$$\widehat{Var}(\hat{S}_{PH}) = \left(\hat{R}_{PH/SL}\right)^2 * \widehat{Var}(\hat{S}_{SL}) + \left(\hat{S}_{SL}\right)^2 * \widehat{Var}(\hat{R}_{PH/SL}), \text{ and}$$

$$\widehat{Var}(\hat{S}_{SP}) = \left(\hat{R}_{SP/SL}\right)^2 * \widehat{Var}(\hat{S}_{SL}) + \left(\hat{S}_{SL}\right)^2 * \widehat{Var}(\hat{R}_{SP/SL})$$

Results

The results for the 2004 Dalles Dam triple-release survival study for both the yearling and subyearling chinook salmon are presented below. An overall-dam survival for each species, assuming that there was 100% probability of detection at the Dalles Dam, is given in the last section.

Dalles Dam Route-specific Survival for the 2004 Yearling Chinook Salmon

Detection histories of the yearling chinook salmon in the 2004 Dalles Dam triple-release study are displayed in Table A6.1. Due to the large number of smolt passing through the spillway, single-release estimates of survival for the spillway are quite small.

Table A6.1. Yearling chinook detection histories for the 2004 Dalles Dam triple-release study. Detections are pooled from all downstream detection sites.

Release group	Release size	Number detected downriver
R1-sluiceway	182	168
R1-spillway	1763	1558
R1-turbines	126	94
R2	742	690
R3	749	704

Table A6.2. Estimates of survival from the 2004 Dalles Dam triple-release study for yearling chinook salmon.

Single-release survival	
Turbines	$\widehat{S_{PH} * S_1} = \frac{94}{126} = 0.7460\ (\widehat{SE} = 0.0388)$
Sluiceway	$\widehat{S_{SL} * S_1} = \frac{168}{182} = 0.9231\ (\widehat{SE} = 0.0198)$
Spillway	$\widehat{S_{SP} * S_1} = \frac{1558}{1763} = 0.8837\ (\widehat{SE} = 0.0076)$
Relative survival	
Turbines to sluiceway	$\hat{R}_{PH/SL} = \frac{0.7460}{0.9231} = 0.8081\ (\widehat{SE} = 0.0455)$
Spillway to sluiceway	$\hat{R}_{SP/SL} = \frac{0.8837}{0.9231} = 0.9573\ (\widehat{SE} = 0.0221)$
Absolute passage survival for the Turbines and Spillway	
Sluiceway (from paired releases)	$\hat{S}_{SL} = \frac{690/742}{704/749} = 0.9894\ (\widehat{SE} = 0.0135)$
Turbines	$\hat{R}_{PH/SL} * \hat{S}_{SL} = (0.8081)(0.9894) = 0.7995\ (\widehat{SE} = 0.0463)$
Spillway	$\hat{R}_{SP/SL} * \hat{S}_{SL} = (0.9573)(0.9894) = 0.9472\ (\widehat{SE} = 0.0254)$

where $\hat{S}_1$ = survival from the Dalles Dam tailrace to the first detection site,

$\hat{S}_{SL}$ = survival from through the sluiceway to the first detection site,

$\hat{S}_{SP}$ = survival from through the spillway to the first detection site, and

$\hat{S}_{TURB}$ = survival from through the turbines to the first detection site.

Dalles Dam Route-specific Survival for the 2004 Subyearling Chinook Salmon

Repeating this process for the 2004 subyearling chinook salmon study:

Table A6.3. Subyearling chinook detection histories for the 2004 Dalles Dam triple-release study. Detections are pooled from all downstream detection sites.

Release group	Release size	Number detected downriver
R1-sluiceway	124	78
R1-spillway	1432	1171
R1-turbines	245	152
R2	990	769
R3	977	773

Table A6.4. Estimates of survival from the 2004 Dalles Dam triple-release study for subyearling chinook salmon.

Single-release survival	
Turbines	$\widehat{S_{PH} * S_1} = 0.6204$ $(\widehat{SE} = 0.0310)$
Sluiceway	$\widehat{S_{SL} * S_1} = 0.6290$ $(\widehat{SE} = 0.0434)$
Spillway	$\widehat{S_{SP} * S_1} = 0.8177$ $(\widehat{SE} = 0.0102)$
Relative survival	
Turbines to sluiceway	$\hat{R}_{PH/SL} = 0.9863$ $(\widehat{SE} = 0.0840)$
Spillway to sluiceway	$\hat{R}_{SP/SL} = 1.3000$ $(\widehat{SE} = 0.0912)$
Absolute passage survival for the turbines and spillway	
Sluiceway (from paired releases)	$\hat{S}_{SL} = 0.9818$ $(\widehat{SE} = 0.0232)$
Turbines	$\hat{R}_{PH/SL} * \hat{S}_{SL} = (0.9863)(0.9818) = 0.9683$ $(\widehat{SE} = 0.0856)$
Spillway	$\hat{R}_{SP/SL} * \hat{S}_{SL} = (1.3000)(0.9818) = 1.2763$ $(\widehat{SE} = 0.0945)$

where $\hat{S}_1$ = survival from the Dalles Dam tailrace to the first detection site,
$\hat{S}_{SL}$ = survival from through the sluiceway to the first detection site,
$\hat{S}_{SP}$ = survival from through the spillway to the first detection site, and
$\hat{S}_{TURB}$ = survival from through the turbines to the first detection site.

Overall Dalles Dam Survival

By making an additional assumption of 100% detection at The Dalles Dam, overall dam survival in 2004 can be estimated for both yearling and subyearling chinook salmon.

Table A6.5. Estimates of overall dam survival from the 2004 Dalles Dam triple-release study for yearling chinook salmon. Columns show the survival attributable to each passage route to the overall dam survival.

	Sluiceway		Spillway		Turbines	
	$\boldsymbol{P_{SL}}$ **= 0.0879**		$\boldsymbol{P_{SP}}$ **= 0.8513**		$\boldsymbol{P_{TURB}}$ **= 0.0608**	
	$(\widehat{SE} = 0.0062)$		$(\widehat{SE} = 0.0078)$		$(\widehat{SE} = 0.0053)$	
	x		x		x	
	$\boldsymbol{S_{SL}}$ **= 0.9894**		$\boldsymbol{S_{SP}}$ **= 0.9472**		$\boldsymbol{S_{TURB}}$ **= 0.7995**	
	$(\widehat{SE} = 0.0135)$		$(\widehat{SE} = 0.0254)$		$(\widehat{SE} = 0.0463)$	
$\boldsymbol{S_{DAM}}$ **=**	**0.0870**	+	**0.8064**	+	**0.0486**	**= 0.9420**
	$(\widehat{SE} = 0.0062)$		$(\widehat{SE} = 0.0229)$		$(\widehat{SE} = 0.0051)$	$(\widehat{SE} = 0.0243)$

where P = portion of fish through each route from uppermost release group (R_1).

Table A6.6. Estimates of overall dam survival from the 2004 Dalles Dam triple-release study for subyearling chinook salmon. Columns show the survival attributable to each passage route to the overall dam survival.

	Sluiceway		Spillway		Turbines	
	$\boldsymbol{P_{SL}}$ **= 0.0689**		$\boldsymbol{P_{SP}}$ **= 0.7951**		$\boldsymbol{P_{TURB}}$ **= 0.1360**	
	$(\widehat{SE} = 0.0060)$		$(\widehat{SE} = 0.0095)$		$(\widehat{SE} = 0.0081)$	
	x		x		x	
	$\boldsymbol{S_{SL}}$ **= 0.9818**		$\boldsymbol{S_{SP}}$ **= 1.2763**		$\boldsymbol{S_{TURB}}$ **= 0.9683**	
	$(\widehat{SE} = 0.0232)$		$(\widehat{SE} = 0.0945)$		$(\widehat{SE} = 0.0856)$	
$\boldsymbol{S_{DAM}}$ **=**	**0.0676**	+	**1.0148**	+	**0.1317**	**= 1.2141**
	$(\widehat{SE} = 0.0061)$		$(\widehat{SE} = 0.0761)$		$(\widehat{SE} = 0.0140)$	$(\widehat{SE} = 0.0776)$

where P = portion of fish through each route from uppermost release group (R_1).

References Cited

Ricker, W.E. 1958. Handbook of Computations for Biological Statistics of Fish Populations. Fisheries Research Board of Canada, Bulletin no. 119, Ottawa. 300 pp.

Appendix 7: Ice and trash sluiceway survival estimates

Table A7.1. Survival (S), standard error (*SE*), and 95% confidence intervals for paired releases of yearling Chinook salmon at The Dalles Dam ice and trash sluiceway during 2004. Treatment fish were released directly into the sluiceway, and control fish were released into the tailrace immediately below the sluiceway as well as into the tailrace 550 m downstream of the spillway.

	Sluiceway tailrace control				Spillway tailrace control			
Release	S	*SE*	95% CI		S	*SE*	95% CI	
1	0.731	0.141	0.455,	1.007	0.799	0.157	0.492,	1.106
2	1.000	0.047	0.907,	1.093	1.024	0.064	0.898,	1.151
3	1.038	0.138	0.767,	1.309	0.952	0.090	0.776,	1.128
4	0.983	0.128	0.733,	1.234	0.886	0.089	0.713,	1.060
5	0.976	0.143	0.696,	1.256	0.845	0.093	0.662,	1.028
6	1.119	0.152	0.821,	1.416	0.936	0.081	0.778,	1.095
7	1.107	0.098	0.915,	1.300	1.017	0.055	0.908,	1.125
8	1.047	0.082	0.886,	1.208	0.957	0.043	0.873,	1.041
9	1.034	0.047	0.942,	1.126	1.068	0.041	0.988,	1.149
10	1.000	0.000	1.000,	1.000	1.000	0.000	1.000,	1.000
11	1.051	0.088	0.878,	1.225	0.960	0.049	0.864,	1.056
12	0.894	0.135	0.629,	1.159	0.789	0.088	0.618,	0.961
13	1.098	0.164	0.777,	1.419	1.148	0.080	0.991,	1.306
14	0.981	0.110	0.766,	1.196	0.942	0.096	0.753,	1.131
15	1.045	0.079	0.889,	1.200	0.995	0.049	0.899,	1.091
16	1.045	0.049	0.949,	1.141	1.086	0.047	0.993,	1.178
17	1.073	0.064	0.947,	1.199	1.011	0.022	0.967,	1.055
18	1.008	0.092	0.828,	1.189	0.859	0.085	0.692,	1.025
19	1.054	0.084	0.890,	1.218	1.002	0.053	0.898,	1.106
20	0.947	0.073	0.805,	1.090	0.934	0.064	0.809,	1.058
21	1.022	0.045	0.934,	1.111	1.152	0.070	1.014,	1.290
22	0.996	0.064	0.871,	1.121	0.997	0.048	0.902,	1.092
23	0.819	0.075	0.672,	0.966	0.830	0.078	0.677,	0.983
24	1.039	0.068	0.905,	1.172	0.937	0.044	0.851,	1.023
25	0.908	0.117	0.678,	1.137	0.808	0.086	0.639,	0.978
26	0.892	0.061	0.772,	1.012	0.927	0.069	0.793,	1.062
27	0.961	0.039	0.885,	1.037	0.999	0.049	0.902,	1.096
28	0.873	0.077	0.723,	1.023	0.887	0.075	0.740,	1.034
29	1.000	0.000	1.000,	1.000	1.015	0.020	0.977,	1.054
30	0.863	0.070	0.726,	1.000	0.903	0.079	0.749,	1.057
31	1.004	0.109	0.790,	1.219	0.940	0.065	0.813,	1.067
32	1.000	0.000	1.000,	1.000	1.032	0.036	0.961,	1.103
Mean	0.988	0.015	0.957,	1.019	0.957	0.016	0.924,	0.991

Table A7.2. Survival (S), standard error (*SE*), and 95% confidence intervals for paired releases of subyearling Chinook salmon at The Dalles Dam ice and trash sluiceway during 2004. Treatment fish were released directly into the sluiceway, and control fish were released into the tailrace immediately below the sluiceway, as well as into the tailrace 550 m downstream of the spillway.

	Sluiceway tailrace control				Spillway tailrace control			
Release	S	*SE*	95% CI		S	*SE*	95% CI	
1	0.965	0.100	0.769,	1.161	0.814	0.089	0.640,	0.988
2	1.000	0.091	0.822,	1.178	0.916	0.060	0.799,	1.034
3	1.007	0.116	0.779,	1.235	0.877	0.072	0.736,	1.019
4	1.012	0.049	0.916,	1.108	1.068	0.051	0.969,	1.167
5	0.894	0.054	0.787,	1.001	1.017	0.062	0.895,	1.140
6	0.803	0.076	0.655,	0.951	0.864	0.078	0.711,	1.018
7	0.784	0.107	0.575,	0.993	0.760	0.094	0.576,	0.944
8	1.000	0.110	0.785,	1.215	0.905	0.110	0.688,	1.121
9	0.877	0.203	0.479,	1.275	0.708	0.133	0.448,	0.969
10	0.926	0.074	0.781,	1.071	0.928	0.074	0.783,	1.073
11	0.939	0.094	0.755,	1.122	0.930	0.085	0.764,	1.095
12	1.010	0.103	0.808,	1.212	0.875	0.061	0.755,	0.995
13	0.947	0.061	0.827,	1.067	0.942	0.000	0.942,	0.942
14	0.800	0.095	0.614,	0.986	0.806	0.097	0.616,	0.996
15	0.938	0.070	0.801,	1.075	0.969	0.093	0.787,	1.151
16	0.586	0.187	0.220,	0.952	0.462	0.131	0.205,	0.719
17	0.824	0.092	0.644,	1.004	0.899	0.112	0.679,	1.118
18	1.101	0.087	0.930,	1.271	0.988	0.041	0.908,	1.068
19	0.923	0.074	0.778,	1.068	0.947	0.070	0.810,	1.084
20	1.420	0.266	0.898,	1.942	1.000	0.000	1.000,	1.000
21	0.895	0.096	0.708,	1.082	0.812	0.087	0.641,	0.983
22	1.253	0.158	0.944,	1.562	0.998	0.063	0.874,	1.122
23	1.008	0.083	0.846,	1.169	0.930	0.053	0.826,	1.034
24	0.948	0.082	0.788,	1.108	0.941	0.072	0.799,	1.082
25	0.835	0.125	0.590,	1.080	0.698	0.096	0.510,	0.886
26	0.891	0.123	0.649,	1.133	0.793	0.085	0.626,	0.960
27	1.007	0.182	0.650,	1.364	0.747	0.100	0.550,	0.943
28	1.112	0.206	0.709,	1.515	0.757	0.092	0.576,	0.938
29	0.804	0.330	0.156,	1.451	0.270	0.083	0.108,	0.433
30	2.746	1.136	0.520,	4.972	0.520	0.094	0.336,	0.704
31	1.043	0.082	0.882,	1.204	0.945	0.045	0.856,	1.033
32	0.821	0.095	0.635,	1.007	0.764	0.077	0.612,	0.915
33	0.736	0.126	0.490,	0.983	0.617	0.091	0.438,	0.795
34	0.872	0.229	0.423,	1.320	0.491	0.102	0.290,	0.691
35	0.875	0.147	0.586,	1.163	0.682	0.088	0.509,	0.854
36	1.087	0.211	0.673,	1.502	0.854	0.124	0.611,	1.098
37	1.084	0.283	0.529,	1.639	0.744	0.128	0.494,	0.994
38	0.980	0.142	0.701,	1.260	0.939	0.092	0.758,	1.120
39	3.625	3.844	-3.909,	11.159	0.189	0.086	0.021,	0.357
40	1.042	0.179	0.691,	1.392	0.779	0.093	0.598,	0.961
Mean	1.060	0.083	0.893,	1.228	0.804	0.031	0.741,	0.866

Appendix 8: Post-hoc spillbay survival estimates and release statistics

Table A8.1. The estimated survival probabilities (S), standard errors (*SE*), 95% confidence intervals, sample sizes (N; number of fish), and start and end dates and times of paired releases of radio-tagged yearling Chinook salmon passing via spillbays 1-4 of The Dalles Dam spillway. The paired release groups were formed post-hoc based on passage times at The Dalles Dam of fish released into the John Day Dam tailrace (treatment) and in The Dalles Dam tailrace (control) during 2004.

Release	S	*SE*	95% CI		Treatment N	Control N	Start Date	Time	End Date	Time
1	0.844	0.055	0.736,	0.951	53	170	27-Apr	18:00	29-Apr	18:00
2	0.830	0.072	0.688,	0.972	29	85	29-Apr	18:00	30-Apr	18:00
3	0.848	0.071	0.709,	0.988	31	93	30-Apr	18:00	1-May	18:00
4	0.730	0.091	0.551,	0.909	26	94	1-May	18:00	2-May	18:00
5	0.939	0.054	0.832,	1.046	37	91	2-May	18:00	3-May	18:00
6	0.794	0.084	0.629,	0.959	26	91	3-May	18:00	4-May	18:00
7	0.898	0.084	0.734,	1.062	16	93	4-May	18:00	5-May	18:00
8	1.031	0.091	0.853,	1.209	19	93	5-May	18:00	6-May	18:00
9	0.935	0.081	0.777,	1.094	22	86	6-May	18:00	7-May	18:00
10	0.950	0.054	0.844,	1.056	19	89	7-May	18:00	8-May	18:00
11	0.960	0.044	0.873,	1.047	25	94	8-May	18:00	9-May	18:00
12	1.000	0.070	0.863,	1.137	18	95	9-May	18:00	10-May	18:00
13	0.889	0.061	0.769,	1.009	38	142	10-May	18:00	12-May	6:00
14	0.979	0.047	0.887,	1.071	41	141	12-May	6:00	13-May	18:00
15	1.021	0.038	0.946,	1.096	33	96	13-May	18:00	14-May	18:00
16	0.969	0.056	0.859,	1.078	29	94	14-May	18:00	15-May	18:00
17	1.042	0.092	0.861,	1.222	19	94	15-May	18:00	16-May	18:00
18	0.897	0.095	0.711,	1.082	15	93	16-May	18:00	17-May	18:00
19	1.000	0.085	0.834,	1.166	20	89	17-May	18:00	18-May	18:00
20	0.918	0.065	0.791,	1.044	27	148	18-May	18:00	20-May	6:00
21	1.000	0.056	0.890,	1.110	18	103	20-May	6:00	21-May	6:00
22	1.000	0.046	0.910,	1.090	28	106	21-May	6:00	22-May	6:00
23	0.969	0.065	0.842,	1.096	17	103	22-May	6:00	23-May	6:00
24	0.918	0.073	0.775,	1.060	18	204	23-May	6:00	25-May	6:00
25	0.970	0.051	0.869,	1.071	20	154	25-May	6:00	26-May	18:00
26	0.928	0.065	0.801,	1.055	21	106	26-May	18:00	27-May	18:00
27	0.890	0.092	0.710,	1.070	18	91	27-May	18:00	28-May	18:00
28	0.969	0.064	0.843,	1.095	16	57	28-May	18:00	29-May	18:00

Table A8.2. The estimated survival probabilities (S), standard errors (*SE*), 95% confidence intervals, sample sizes (N; number of fish), and start and end dates and times of paired releases of radio-tagged yearling Chinook salmon passing via spillbays 5-6 of The Dalles Dam spillway. The paired release groups were formed post-hoc based on passage times at The Dalles Dam of fish released into the John Day Dam tailrace (treatment) and in The Dalles Dam tailrace (control) during 2004.

Release	S	*SE*	95% CI		Treatment N	Control N	Start Date	Time	End Date	Time
1	0.771	0.095	0.584,	0.957	23	170	27-Apr	18:00	29-Apr	18:00
2	0.740	0.101	0.541,	0.939	19	85	29-Apr	18:00	30-Apr	18:00
3	0.919	0.061	0.799,	1.039	21	93	30-Apr	18:00	1-May	18:00
4	0.770	0.091	0.591,	0.949	21	94	1-May	18:00	2-May	18:00
5	0.837	0.083	0.673,	1.000	27	91	2-May	18:00	3-May	18:00
6	0.856	0.084	0.690,	1.021	23	91	3-May	18:00	4-May	18:00
7	0.857	0.083	0.694,	1.021	19	93	4-May	18:00	5-May	18:00
8	0.969	0.055	0.861,	1.077	18	93	5-May	18:00	6-May	18:00
9	0.946	0.091	0.767,	1.125	16	86	6-May	18:00	7-May	18:00
10	1.000	0.082	0.840,	1.160	21	89	7-May	18:00	8-May	18:00
11	0.890	0.072	0.748,	1.032	18	94	8-May	18:00	9-May	18:00
12	0.792	0.097	0.602,	0.982	23	95	9-May	18:00	10-May	18:00
13	0.980	0.042	0.897,	1.062	22	142	10-May	18:00	12-May	6:00
14	0.958	0.076	0.808,	1.108	20	141	12-May	6:00	13-May	18:00
15	0.947	0.076	0.798,	1.097	19	96	13-May	18:00	14-May	18:00
16	0.917	0.075	0.769,	1.064	25	94	14-May	18:00	15-May	18:00
17	0.781	0.085	0.615,	0.948	32	94	15-May	18:00	16-May	18:00
18	0.918	0.065	0.791,	1.044	27	93	16-May	18:00	17-May	18:00
19	0.860	0.071	0.722,	0.998	27	89	17-May	18:00	18-May	18:00
20	0.856	0.094	0.671,	1.041	17	148	18-May	18:00	20-May	6:00
21	0.927	0.065	0.799,	1.055	27	103	20-May	6:00	21-May	6:00
22	0.979	0.065	0.852,	1.107	17	106	21-May	6:00	22-May	6:00
23	0.979	0.055	0.871,	1.088	21	103	22-May	6:00	23-May	6:00
24	0.835	0.062	0.713,	0.957	41	204	23-May	6:00	25-May	6:00
25	0.919	0.061	0.799,	1.039	27	154	25-May	6:00	26-May	18:00
26	1.000	0.037	0.927,	1.073	25	106	26-May	18:00	27-May	18:00
27	0.890	0.063	0.767,	1.013	27	91	27-May	18:00	28-May	18:00
28	0.949	0.084	0.785,	1.113	12	57	28-May	18:00	29-May	18:00

Table A8.3. The estimated survival probabilities (S), standard errors (*SE*), 95% confidence intervals, sample sizes (N; number of fish), and start and end dates and times of paired releases of radio-tagged yearling Chinook salmon passing via spillbays 7-20 of The Dalles Dam spillway. The paired release groups were formed post-hoc based on passage times at The Dalles Dam of fish released into the John Day Dam tailrace (treatment) and in The Dalles Dam tailrace (control) during 2004.

Release	S	*SE*	95% CI		Treatment N	Control N	Start Date	Time	End Date	Time
1	0.906	0.106	0.699,	1.114	14	170	27-Apr	18:00	29-Apr	18:00
6	1.031	0.138	0.761,	1.301	11	91	3-May	18:00	4-May	18:00
7	0.949	0.074	0.804,	1.094	13	93	4-May	18:00	5-May	18:00
9	1.075	0.146	0.789,	1.362	11	86	6-May	18:00	7-May	18:00
11	1.000	0.143	0.720,	1.280	10	94	8-May	18:00	9-May	18:00
13	1.020	0.119	0.787,	1.254	13	142	10-May	18:00	12-May	6:00
14	1.053	0.106	0.844,	1.261	16	141	12-May	6:00	13-May	18:00
15	0.884	0.117	0.654,	1.114	12	96	13-May	18:00	14-May	18:00
17	0.948	0.106	0.740,	1.156	10	94	15-May	18:00	16-May	18:00
18	0.866	0.084	0.701,	1.031	19	93	16-May	18:00	17-May	18:00
23	0.794	0.104	0.589,	0.998	17	103	22-May	6:00	23-May	6:00
24	1.000	0.033	0.936,	1.064	33	204	23-May	6:00	25-May	6:00
25	1.010	0.106	0.803,	1.217	15	154	25-May	6:00	26-May	18:00
28	0.878	0.094	0.694,	1.061	14	57	28-May	18:00	29-May	18:00

Table A8.4. The estimated survival probabilities (S), standard errors (*SE*), 95% confidence intervals, sample sizes (N; number of fish), and start and end dates and times of paired releases of radio-tagged subyearling Chinook salmon passing via spillbays 1-4 of The Dalles Dam spillway. The paired release groups were formed post-hoc based on passage times at The Dalles Dam of fish released into the John Day Dam tailrace (treatment) and in The Dalles Dam tailrace (control) during 2004.

Release	S	*SE*	95% CI		Treatment N	Control N	Start Date	Time	End Date	Time
1	1.021	0.083	0.858,	1.184	26	223	19-Jun	18:00	20-Jun	18:00
2	0.960	0.042	0.878,	1.041	34	346	20-Jun	18:00	22-Jun	6:00
3	0.969	0.042	0.887,	1.052	38	299	22-Jun	6:00	23-Jun	18:00
4	0.980	0.042	0.898,	1.061	24	323	23-Jun	18:00	25-Jun	6:00
5	0.929	0.064	0.803,	1.054	21	136	25-Jun	6:00	26-Jun	6:00
6	1.020	0.094	0.836,	1.204	18	100	26-Jun	6:00	27-Jun	18:00
7	1.000	0.111	0.782,	1.218	15	46	27-Jun	18:00	28-Jun	18:00
8	0.949	0.042	0.867,	1.031	38	433	28-Jun	18:00	1-Jul	6:00
9	0.918	0.072	0.777,	1.060	20	152	1-Jul	6:00	2-Jul	6:00
10	0.938	0.073	0.795,	1.081	20	216	2-Jul	6:00	4-Jul	6:00
11	0.958	0.076	0.808,	1.108	20	142	4-Jul	6:00	6-Jul	6:00
12	0.928	0.073	0.785,	1.071	19	333	6-Jul	6:00	8-Jul	6:00
13	0.979	0.055	0.871,	1.088	18	129	8-Jul	6:00	9-Jul	18:00
14	1.032	0.048	0.937,	1.127	23	238	9-Jul	18:00	11-Jul	18:00
15	0.979	0.053	0.876,	1.082	18	172	11-Jul	18:00	13-Jul	6:00
16	0.947	0.076	0.798,	1.097	20	187	13-Jul	6:00	15-Jul	18:00
17	0.926	0.076	0.777,	1.076	25	228	15-Jul	18:00	17-Jul	6:00
18	0.894	0.087	0.723,	1.065	19	185	17-Jul	6:00	18-Jul	6:00
19	0.895	0.074	0.749,	1.040	26	428	18-Jul	6:00	19-Jul	18:00
20	0.885	0.084	0.721,	1.050	16	287	19-Jul	18:00	20-Jul	18:00
21	0.789	0.116	0.562,	1.017	19	299	20-Jul	18:00	21-Jul	18:00
22	0.872	0.075	0.725,	1.019	31	433	21-Jul	18:00	23-Jul	6:00
23	0.602	0.123	0.362,	0.842	17	252	23-Jul	6:00	24-Jul	6:00
24	0.851	0.105	0.644,	1.057	23	345	24-Jul	6:00	25-Jul	18:00
25	0.736	0.077	0.585,	0.888	45	420	25-Jul	18:00	26-Jul	18:00
26	0.820	0.092	0.640,	1.000	29	248	27-Jul	18:00	28-Jul	18:00
27	0.723	0.097	0.533,	0.913	25	255	28-Jul	18:00	30-Jul	6:00

Table A8.5. The estimated survival probabilities (S), standard errors (*SE*), 95% confidence intervals, sample sizes (N; number of fish), and start and end dates and times of paired releases of radio-tagged subyearling Chinook salmon passing via spillbays 5-6 of The Dalles Dam spillway. The paired release groups were formed post-hoc based on passage times at The Dalles Dam of fish released into the John Day Dam tailrace (treatment) and in The Dalles Dam tailrace (control) during 2004.

Release	S	*SE*	95% CI		Treatment N	Control N	Start Date	Time	End Date	Time
1	0.918	0.083	0.755,	1.080	17	223	19-Jun	18:00	20-Jun	18:00
2	1.010	0.074	0.864,	1.156	23	346	20-Jun	18:00	22-Jun	6:00
3	0.796	0.092	0.615,	0.977	18	299	22-Jun	6:00	23-Jun	18:00
4	0.908	0.082	0.747,	1.069	17	323	23-Jun	18:00	25-Jun	6:00
5	0.907	0.075	0.761,	1.053	24	136	25-Jun	6:00	26-Jun	6:00
6	0.847	0.073	0.703,	0.991	28	100	26-Jun	6:00	27-Jun	18:00
7	0.800	0.105	0.595,	1.005	15	46	27-Jun	18:00	28-Jun	18:00
8	0.908	0.082	0.747,	1.069	17	433	28-Jun	18:00	1-Jul	6:00
9	0.969	0.072	0.828,	1.111	15	152	1-Jul	6:00	2-Jul	6:00
10	0.979	0.042	0.896,	1.063	32	216	2-Jul	6:00	4-Jul	6:00
11	0.884	0.076	0.735,	1.033	30	142	4-Jul	6:00	6-Jul	6:00
12	0.701	0.093	0.519,	0.883	28	333	6-Jul	6:00	8-Jul	6:00
13	1.031	0.104	0.827,	1.235	16	129	8-Jul	6:00	9-Jul	18:00
14	0.935	0.099	0.742,	1.129	15	238	9-Jul	18:00	11-Jul	18:00
15	1.031	0.171	0.696,	1.366	8	172	11-Jul	18:00	13-Jul	6:00
16	0.905	0.097	0.716,	1.095	14	187	13-Jul	6:00	15-Jul	18:00
17	0.842	0.107	0.633,	1.051	15	228	15-Jul	18:00	17-Jul	6:00
18	0.702	0.118	0.471,	0.933	20	185	17-Jul	6:00	18-Jul	6:00
19	0.705	0.116	0.478,	0.933	18	428	18-Jul	6:00	19-Jul	18:00
20	0.854	0.094	0.670,	1.039	21	299	19-Jul	18:00	20-Jul	18:00
21	0.705	0.127	0.457,	0.953	15	287	20-Jul	18:00	21-Jul	18:00
22	0.840	0.096	0.652,	1.029	23	433	21-Jul	18:00	23-Jul	6:00
23	0.571	0.123	0.331,	0.812	18	252	23-Jul	6:00	24-Jul	6:00
24	0.391	0.127	0.142,	0.639	18	345	24-Jul	6:00	25-Jul	18:00
25	0.615	0.088	0.443,	0.788	40	420	25-Jul	18:00	26-Jul	18:00
26	0.393	0.113	0.172,	0.614	23	248	27-Jul	18:00	28-Jul	18:00
27	0.447	0.117	0.217,	0.677	19	255	28-Jul	18:00	30-Jul	6:00

Table A8.6. The estimated survival probabilities (S), standard errors (*SE*), 95% confidence intervals, sample sizes (N; number of fish), and start and end dates and times of paired releases of radio-tagged subyearling Chinook salmon passing via spillbays 7-20 of The Dalles Dam spillway. The paired release groups were formed post-hoc based on passage times at The Dalles Dam fish released into the John Day Dam tailrace (treatment) and in The Dalles Dam tailrace (control) during 2004.

Release	S	*SE*	95% CI		Treatment N	Control N	Start Date	Time	End Date	Time
8	0.990	0.042	0.907	1.072	25	433	28-Jun	18:00	1-Jul	6:00
14	1.075	0.144	0.793	1.357	11	238	9-Jul	18:00	11-Jul	18:00
15	0.969	0.063	0.846	1.092	15	172	11-Jul	18:00	13-Jul	6:00
16	0.989	0.067	0.859	1.120	17	187	13-Jul	6:00	15-Jul	18:00

Appendix 9: Tailrace Egress of Yearling and Subyearling Chinook Salmon Following Passage at The Dalles Dam, 2004.

Report of Research for 2004

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Introduction

During the spring and summer of 2004, the U. S. Geological Survey used fixed-site radio telemetry to examine the behavior of yearling and subyearling Chinook salmon (*Oncorhynchus tshawytscha*) passing through The Dalles Dam (TDA). The fish used in our study were collected, tagged, and released from John Day Dam. We were specifically interested in tailrace egress following spillway passage, but we also report on the egress times of fish passing through the turbine units and the ice/trash sluiceway.

Methods

Radio Telemetry Detection Arrays

Radio telemetry detection arrays were established at TDA and at the exit site (rkm 329.6, Figure A9.1). The arrays at TDA collected time and route of passage for all detected radio-tagged fish. The potential routes of passage at TDA are the spillway, sluiceway, and powerhouse. The exit array consisted of stations on the Oregon and Washington shores, each configured to cover as much of the river as possible.

Data Analysis

The egress times of study fish were calculated from the time fish were last detected within the forebay of TDA to the time of their last detection at the exit site. Fish were assigned a passage hour based on time of passage indicated by telemetry records. Daily sunrise and sunset data from http://aa.usno.navy.mil/data/docs/RS_OneDay.html were used to assign day or night passage. We present egress time medians with ranges, means, and standard errors. All comparisons were made using nonparametric methods, and findings with $P \leq 0.05$ were considered statistically significant. Individual releases were pooled in order to depict the entire yearling or subyearling outmigration.

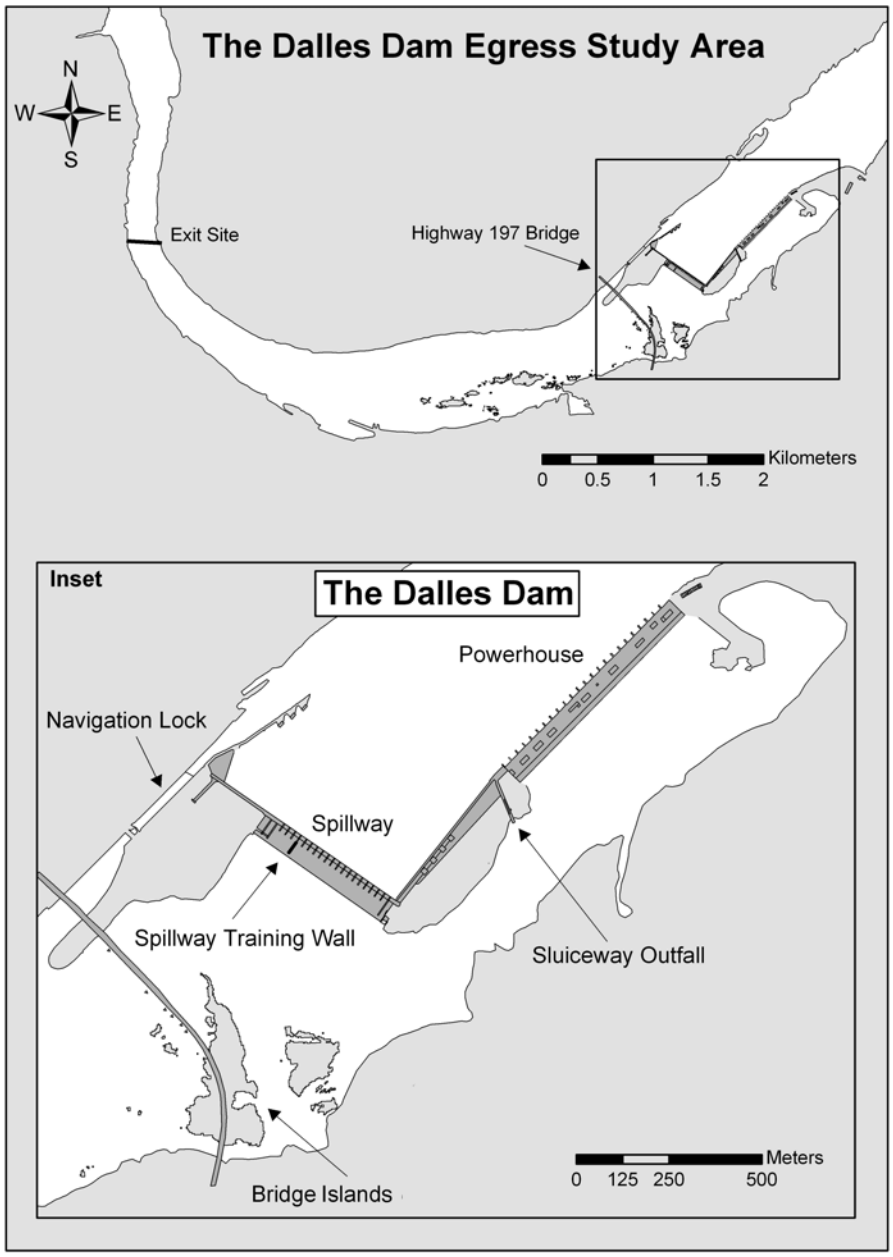

Figure A9.1. The Dalles Dam egress study area, 2004. The exit site is located 4.7 km downstream of The Dalles Dam. A close-up of The Dalles Dam is presented in the inset.

Results

Yearling Chinook Salmon

Median egress times of yearling Chinook salmon were significantly different between the three routes of passage (Table A9.1). Fish passing through the spillway had faster egress times than fish passing through the powerhouse or sluiceway. Yearling Chinook salmon that passed TDA through the powerhouse had the longest egress times.

Table A9.1. Egress times of yearling Chinook salmon passing through The Dalles Dam. Median egress times were significantly different between the three passage sites (Kruskal-Wallis Test, $P < 0.0001$).

Passage Site	N	Median (h)	Range (h)	Mean (h)	*SE*
Powerhouse	54	2.59	1.35 - 59.30	4.42	1.17
Sluiceway	126	2.45	1.48 - 15.17	3.33	0.21
Spillway	1067	1.72	0.22 - 33.60	2.37	0.07
Overall	1247	1.79	0.22 - 59.30	2.55	0.08

Egress times for day and night passage were compared within each passage route (Table A9.2). The only passage route with significantly different egress times by diel period was the spillway. Fish that passed during the day had significantly shorter egress times than those passing at night. Median egress times were shorter during the day for fish that passed via the powerhouse and sluiceway, but the differences were not significant (Table A9.2A). Spillway passage hour of yearling Chinook salmon with associated egress times and passage numbers are presented in Figure A9.2. Similar graphs for the powerhouse and sluiceway are not presented due to lower passage numbers.

Table A9.2. Diel egress times of yearling Chinook salmon passing through the powerhouse (A), sluiceway (B), and spillway (C) at The Dalles Dam. An asterisk indicates a significant difference between medians (Kruskal-Wallis Test).

A. Powerhouse (P = 0. 16)

Passage Time	N	Median (h)	Range (h)	Mean (h)	*SE*
Day	12	2.40	1.25 - 3.70	2.48	0.18
Night	42	2.65	1.68 - 59.30	4.98	1.49

B. Sluiceway (P = 0.84)

Passage Time	N	Median (h)	Range (h)	Mean (h)	*SE*
Day	51	2.35	1.48 - 11.59	3.85	0.41
Night	75	2.47	1.50 - 15.17	2.54	0.21

C. Spillway (P = 0.025)

Passage Time	N	Median (h)	Range (h)	Mean (h)	*SE*
Day	758	1.68*	0.22 - 33.60	2.38	0.09
Night	309	1.78*	1.01 - 16.59	2.34	0.11

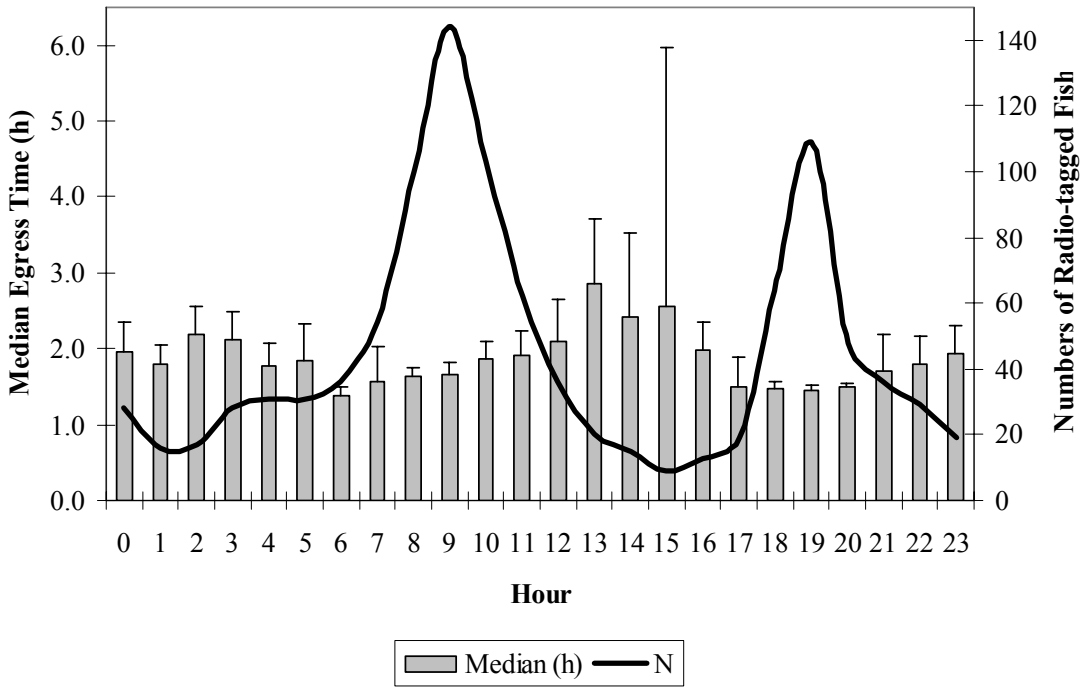

Figure A9.2. Hourly egress times (bars) and passage numbers (line) of radio-tagged yearling Chinook salmon passing The Dalles Dam via the spillway. Whisker bars indicate one standard error.

Subyearling Chinook Salmon

Median egress times of subyearling Chinook salmon were significantly different between the three routes of passage (Table A9.3). As was noted for yearling Chinook salmon, fish passing through the spillway had faster egress times than fish passing through the powerhouse or the sluiceway. Similarly, fish that passed TDA through the powerhouse had the longest egress times (Table A9.3).

Table A9.3. Egress times of subyearling Chinook salmon passing through The Dalles Dam. Median egress times were significantly different between the three passage sites (Kruskal-Wallis Test, $P < 0.0001$)

Passage Site	N	Median (h)	Range (h)	Mean (h)	*SE*
Powerhouse	125	3.72	1.63 - 117.03	6.45	1.19
Sluiceway	59	3.60	1.73 - 16.38	4.47	0.38
Spillway	868	2.00	0.20 - 22.47	2.60	0.06
Overall	1052	2.19	0.20 - 117.03	3.16	0.16

Egress times for day and night passage were compared within each passage route. Median egress times of subyearling Chinook salmon that passed TDA were fastest during the day for all three passage routes (Table A9.4). However, the differences between day and night egress were only significant for powerhouse and spillway-passed fish (Table A9.4 B). Spillway passage hour with associated egress times and passage numbers of subyearling Chinook salmon are presented in Figure A9.3. Similar graphs for the powerhouse and sluiceway are not presented due to lower passage numbers.

Table A9.4. Diel egress times of subyearling Chinook salmon passing through the powerhouse (A), sluiceway (B), and spillway (C) at The Dalles Dam. An asterisk indicates significant difference between medians (Kruskal-Wallis Test).

A. Powerhouse (P = 0.0003)

Passage Time	N	Median (h)	Range (h)	Mean (h)	*SE*
Day	38	2.75*	1.63 - 9.98	3.73	0.36
Night	87	3.99*	1.95 - 117.03	7.64	1.69

B. Sluiceway (P = 0.15)

Passage Time	N	Median (h)	Range (h)	Mean (h)	*SE*
Day	36	3.11	1.73 - 16.38	3.39	0.58
Night	23	3.76	2.38 - 8.57	3.60	0.36

C. Spillway (P < 0.0001)

Passage Time	N	Median (h)	Range (h)	Mean (h)	*SE*
Day	694	1.84*	0.20 - 15.52	2.44	0.07
Night	174	2.72*	1.20 - 22.47	3.23	0.17

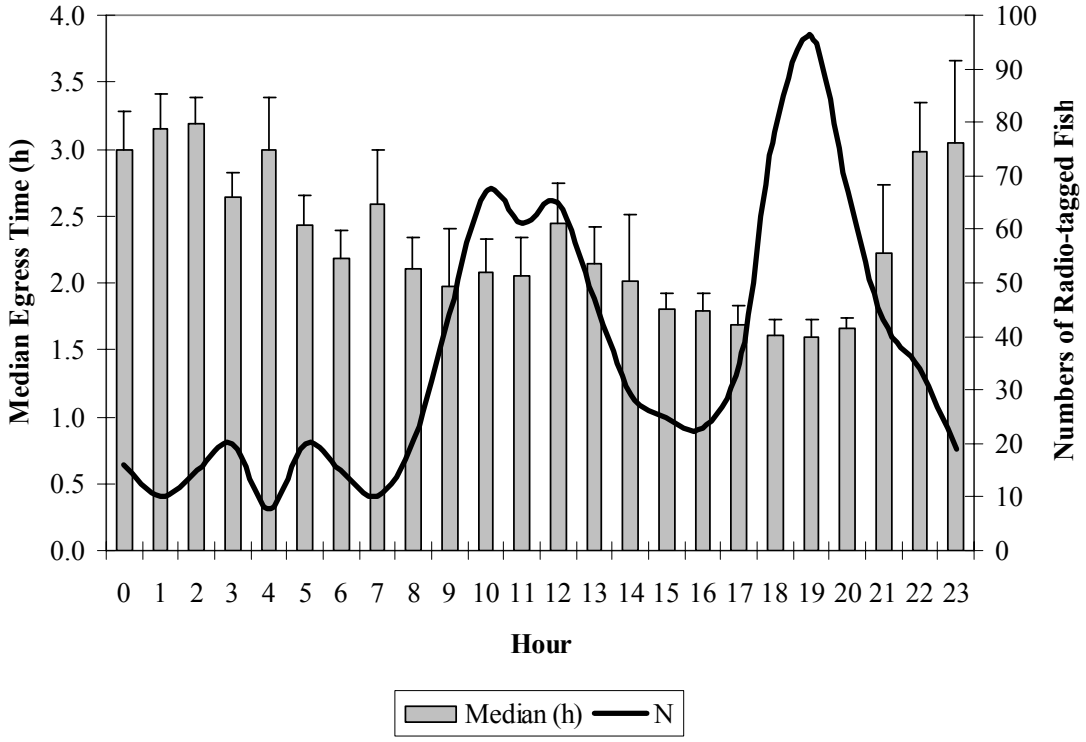

Figure A9.3. Hourly egress times (bars) and passage numbers (line) of radio-tagged subyearling Chinook salmon passing The Dalles Dam via the spillway. Whisker bars indicate one standard error.

Acknowledgements

We thank Mike Langeslay, Miroslaw Zyndol and other COE personnel for their efforts in managing our contract and assisting in planning and executing this research. Many thanks go to Rick Martinson and Greg Kovalchuk of the Pacific States Marine Fisheries Commission, and the entire John Day fish facility crew for collecting and sorting our research fish. This work would not have been possible without the efforts and technical assistance of Philip Haner, Hal Hansel, Steven Juhnke, and other U.S. Geological Survey colleagues.