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Survival estimates of migrant juvenile salmonids through The Dalles Dam using radiotelemetry, 2005.

Final Report of Research

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Executive Summary

During 2005, the USGS, Columbia River Research Laboratory evaluated the survival of yearling and subyearling Chinook salmon at The Dalles Dam. Our objectives 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 and The Dalles dams, and also directly into and immediately 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 evaluated using the route-specific survival model (Skalski et al. 2002). Estimates were also generated using the triple-release model (Peven et al. 2005). The Dalles Dam survival estimates for 2005 are summarized in the executive summary table.

Route-specific survival model

Yearling Chinook salmon

At The Dalles Dam during 2005, the estimated survival of radio-tagged yearling Chinook salmon was highest through the ice and trash sluiceway (S = 1.006, SE = 0.007, profile likelihood 95% confidence interval = 0.984, 1.015), followed by the spillway (S = 0.938, SE = 0.008, profile likelihood 95% confidence interval = 0.921, 0.954), and lowest through the turbines (S = 0.838, SE = 0.032, profile likelihood 95% confidence interval = 0.769, 0.895). Yearling Chinook salmon dam survival was estimated to be 0.933 (SE = 0.008, 95% confidence interval = [0.918, 0.949), pool survival was estimated to be 0.956 (SE = 0.006, 95% confidence interval = 0.944, 0.968), and project survival (the product of dam and pool survival) was estimated to be 0.892 (SE = 0.014, 95% confidence interval = 0.864, 0.920).

Subyearling Chinook salmon

At The Dalles Dam during 2005, the estimated survival of radio-tagged subyearling Chinook salmon was highest through the ice and trash sluiceway (S = 0.931, SE = 0.037, profile likelihood 95% confidence interval = 0.845, 0.988), followed by the spillway (S = 0.925, SE = 0.009, profile likelihood 95% confidence interval = 0.907, 0.942), and lowest through the turbines (S = 0.796, SE = 0.027, profile likelihood 95% confidence interval = 0.742, 0.845). Subyearling Chinook salmon dam survival was estimated to be 0.900 (SE = 0.009, 95% confidence interval = 0.881, 0.918), pool survival was estimated to be 0.947 (SE = 0.006, 95% confidence interval = 0.935, 0.959), and project survival (the product of dam and pool survival) was estimated to be 0.852 (SE = 0.014, 95% confidence interval = 0.824, 0.880).

Triple-release model

Yearling Chinook salmon

The absolute survival of yearling Chinook salmon through The Dalles Dam spillway was estimated to be 0.936 (*SE* = 0.012, 95% confidence interval [0.912, 0.960]) using the triple-release model. For yearling Chinook salmon passing the ice and trash sluiceway the estimated absolute survival was 1.004 (*SE* = 0.007, 95% confidence interval [0.990, 1.018]) and for yearling Chinook salmon passing via the turbines at the powerhouse the estimated absolute survival was 0.809 (*SE* = 0.038, 95% confidence interval [0.735, 0.882]). Yearling Chinook salmon dam survival was estimated to be 0.933 (*SE* = 0.018, 95% confidence interval [0.897, 0.968]) at The Dalles Dam during 2005.

Subyearling Chinook salmon

The absolute survival of subyearling Chinook salmon through The Dalles Dam spillway was estimated to be 0.955 (*SE* = 0.041, 95% confidence interval [0.876, 1.035]) using the triple-release model. For subyearling Chinook salmon passing the ice and trash sluiceway the estimated absolute survival was 0.962 (*SE* = 0.013, 95% confidence interval [0.937, 0.987]) and for subyearling Chinook salmon passing via the turbines at the powerhouse the estimated survival was 0.804 (*SE* = 0.044, 95% confidence interval [0.717, 0.891]). Subyearling Chinook salmon dam survival was estimated to be 0.933 (*SE* = 0.036, 95% confidence interval [0.863, 1.003]) at The Dalles Dam during 2005.

Executive Summary Table. The estimated survival probabilities (S) and 95% confidence intervals for radio-tagged yearling and subyearling Chinook salmon passing through The Dalles Dam during 2005.

		Yearling Chinook		Subyearling Chinook	
	Model	S	95% CI	S	95% CI
Dam	Route-specific	0.933	[0.918, 0.949]	0.900	[0.881, 0.918]
	Triple-release	0.933	[0.897, 0.968]	0.933	[0.863, 1.003]
Turbines	Route-specific	0.838	[0.769, 0.895][A]	0.796	[0.742, 0.845][A]
	Triple-release	0.809	[0.735, 0.882]	0.804	[0.717, 0.891]
Sluiceway	Route-specific	1.006	[0.984, 1.015][A]	0.931	[0.845, 0.988][A]
	Triple-release	1.004	[0.990, 1.018]	0.962	[0.937, 0.987]
Spillway	Route-specific	0.938	[0.921, 0.954][A]	0.925	[0.907, 0.942][A]
	Triple-release	0.936	[0.912, 0.960]	0.955	[0.876, 1.035]

[A]- Profile likelihood 95% confidence interval

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 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 0.927 (Counihan et al. 2002) whereas other dams average 0.98 (Ploskey et al. 2001). The lower than expected spill passage survival probabilities 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) predation; spillway-passed water moves through areas where predation on salmonids by gulls (*Larus* spp.), northern pikeminnow (*Ptychocheilus oregonensis*), and smallmouth bass (*Micropterus dolomieu*) likely occurs. 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 operations was typically higher than spillway survival at 64% spill operations; survival through the sluiceway was similar to the 30% spillway survival (Ploskey et al. 2001). In addition to spill level, the NMFS found that the survival of 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 passage during the juvenile spill pattern used only at night. In 2000, 40% spill operations 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 operations 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.

The estimated survival of yearling and subyearling Chinook salmon passing via The Dalles Dam during 2004 did not suggest that there was a large survival benefit associated with the new 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) 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.

In 2004 a new survival estimation model, the triple-release model (Peven et al. 2005), formulated to address the potential for a positive bias in the route-specific survival model, was evaluated. 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, suggesting that the route-specific survival model estimates were not positively biased.

During 2005, the USGS, Columbia River Research Laboratory continued to evaluate the effect of the training wall on the survival of yearling and subyearling Chinook salmon at The Dalles Dam. Survival probabilities of yearling and subyearling Chinook salmon were estimated using the route-specific survival model (Skalski et al. 2002) and the triple-release model (Peven et al. 2005) for the ice and trash sluiceway, spillway, turbines, and dam survival.

Methods

Study area and system antenna configuration

To estimate the route-specific and dam survival of juvenile salmonids at The Dalles Dam during the 2005 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), 18 Mile Island (RK 279.8), near the town of Underwood, WA on the bluff (RK 270), 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).

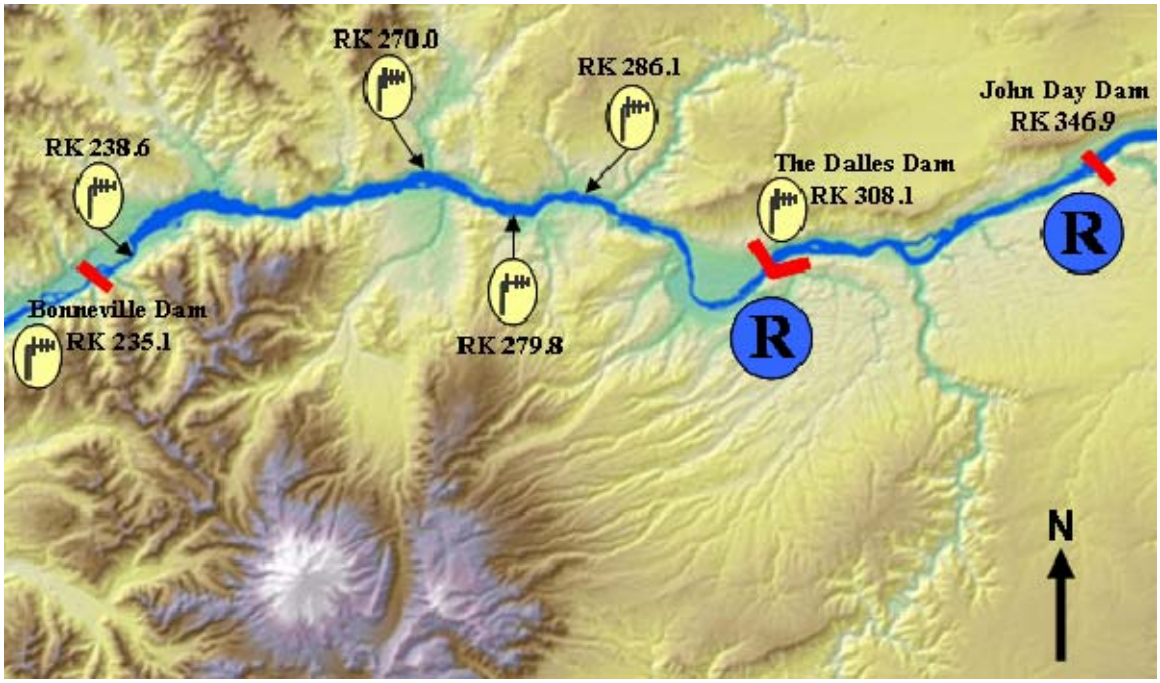

Figure 1. Release and detection locations for The Dalles Dam survival evaluation during 2005. Yellow ovals show locations of radiotelemetry arrays, the red polygons represent the dams, and ® indicates release locations. River kilometers are given for each location.

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 radiotelemetry antenna arrays at The Dalles Dam used to monitor movements and passage location of radio-tagged fish consisted of 4-element Yagi aerial antennas and dipole underwater antennas 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 spillway, 12 aerial antennas on the powerhouse, 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 12 underwater antennas. The detection range for aerial antennas can be as much as approximately 100 m from the dam, but varies with the depth of the transmitter in the water column. In 2005, the orientation

of the antennas was such that the coverage was focused on two spillbays. 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 daily.

Radio transmitters

We used pulse-coded transmitters (tags) manufactured by Lotek Engineering, Inc. (Newmarket, Ontario, Canada). Transmitters implanted in yearling Chinook salmon weighed approximately 0.98 g in air, had a volume of 0.60 ml, and a 22 cm long antenna, (Lotek Wireless model NTC-3-1-KMF), and those implanted in subyearling Chinook salmon weighed approximately 0.43 g in air, had a volume of 0.22 ml, and a 18 cm long antenna (Lotek Wireless model NTC-M-2). 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. NTC-3-1-KMF transmitters emitted radio signals every 2 seconds and NTC-M-2 transmitters emitted radio signals every 2.5 seconds; at this pulse rate the expected battery life was 8 d and 8.8 d respectively.

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 5% of a fish's weight in air, and the tag volume would not rupture the fish's stomach. The minimum weight for a yearling Chinook salmon implanted with a Lotek Wireless model NTC-3-1-KMF tag was 21.5 g (with a corresponding estimated fork length of 130 mm), and for a subyearling Chinook salmon implanted with a Lotek model NTC-M-2 tag the minimum weight was 10 g (with a corresponding estimated fork length of 100 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 A1.2), and into The Dalles Dam tailrace approximately 550 m downstream of the dam, beneath the I-197 bridge (Appendix 1, Tables A1.3 and A1.4). 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 to estimate travel times. Specifically, travel time for The Dalles reservoir was estimated such that:

$$\text{Travel rate (km/d)} = 17.342 + 0.1712 * \text{Discharge (kcfs)}.$$

The regression equation was formulated using past years radiotelemetry travel time data and discharge data. For the 2005 migration season, we used predicted discharge data obtained from Kyle Dittmer of Columbia River Inter-Tribal Fish Commission (Kyle Dittmer, personal communication). We then consider the output of this exercise in combination with crew logistics and dam operations to determine our release times.

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 A1.5 and A1.6). Radio-tagged yearling and subyearling Chinook salmon were released into the ice and trash sluiceway near The Dalles Dam powerhouse main unit one. A flexible release 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, water was pumped from the forebay to fill the release tank and eliminate any air pockets within the release hose. Two radio-tagged fish were put into the release tank at the same time. 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, 2005. 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 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 downstream survival.

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 lower river segments (S) is conditionally independent of survival in the upriver segments.

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 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 and 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 (Appendix 2). 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 (Appendix 2) 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 at the tailrace release location throughout the season with live radio-tagged fish (Appendix 1, Table A1.9).

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 radiotelemetry 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 a fish detected in one array does not have a higher or lower probability of being detected in the secondary array than a fish not detected in 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 powerhouse 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 from the release location at John Day Dam; G, conditional probability of guidance into the ice and trash sluiceway, given that fish were going to the powerhouse; P_{TURB}, powerhouse primary array detection probability ($q_{TURB} = 1 - P_{TURB}$); P'_{TURB}, powerhouse 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}, powerhouse survival probability; S_{SPILL}, spillway survival probability; S_{SLU}, juvenile bypass 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 five 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 (Skalski 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

$$\hat{S}_{DAM\cdots} = (1-\hat{E})(1-\hat{G})\ \hat{S}_{TURB} + (1-\hat{E})\hat{G}\hat{S}_{SLU} + \hat{E}\hat{S}_{SPILL}$$

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/).

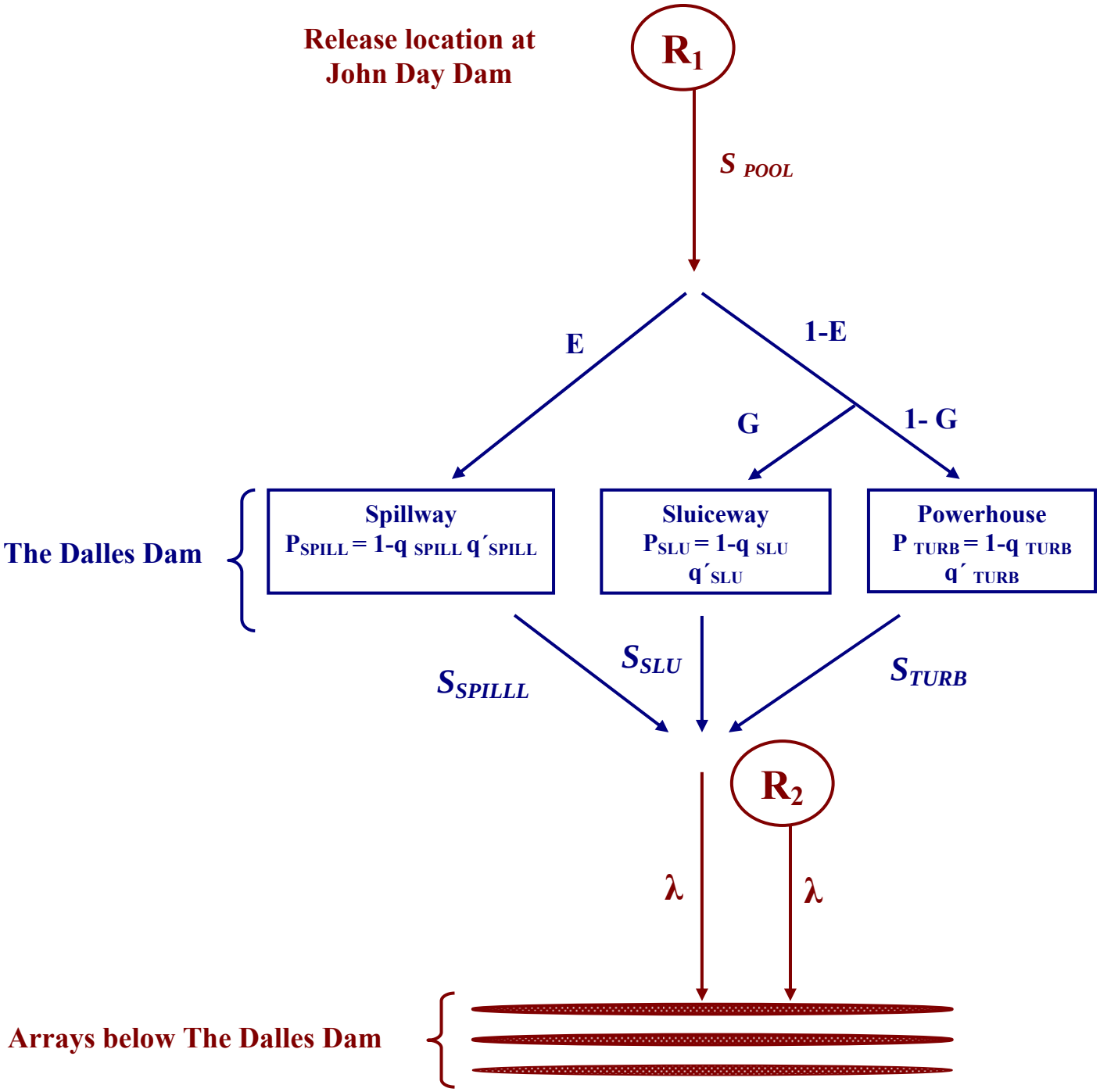

Figure 4. Schematic of route-specific passage and survival probabilities through The Dalles Dam for releases made at John Day Dam (RKM 347) and in the tailrace of The Dalles Dam (RKM 308).

Triple-release model

Rich Townsend and John Skalski, University of Washington provided the following discussion of methodology. 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 powerhouse turbine (R_{TURB}) routes to the sluiceway survival.
3. Estimate absolute survival through the sluiceway (S_{SL}) 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 powerhouse turbines.

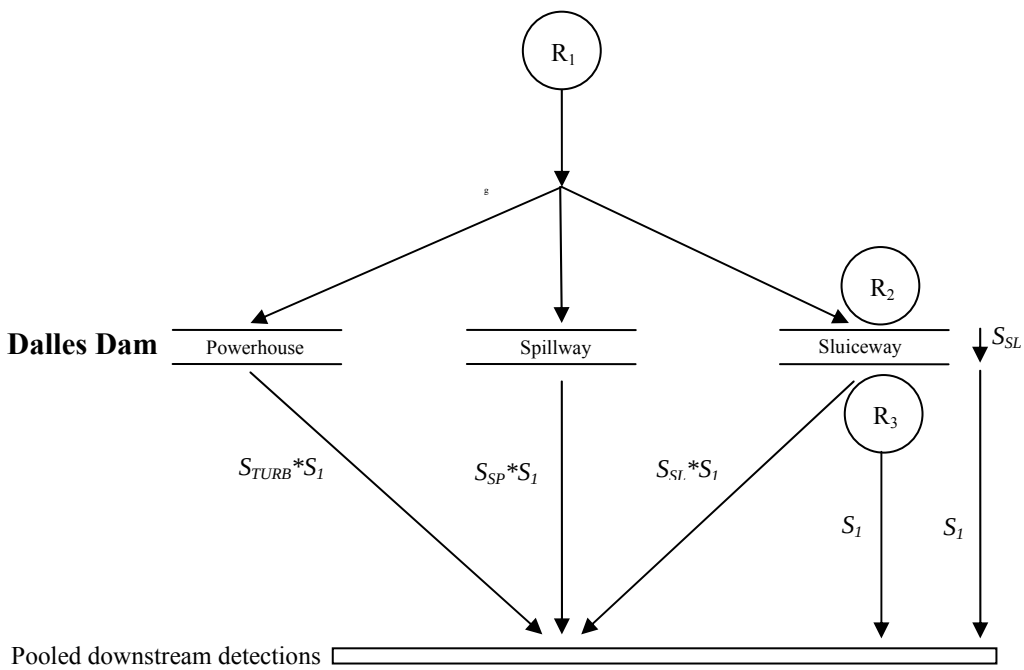

Figure 5. Schematic of Dalles Dam triple-release survival study design with releases R_1, R_2, and R_3.

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* (powerhouse 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 powerhouse 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 powerhouse turbines and spillway

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

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

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

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

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

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

Results

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

The mean length of yearling Chinook salmon at the sampling facility from 30 April to 31 May was 148 mm, while the mean radio-tagged fish length was 154 mm (Figure 6). We observed that 83% 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 started at approximately 20% of the run and ended at 96% (Figure 7).

Subyearling Chinook salmon

The mean length of subyearling Chinook salmon at the sampling facility from 16 June to 17 July was 99 mm, while the mean radio-tagged fish length was 108 mm (Figure 8). Further, only 45% of the run-of-river fish sampled at the facility were larger than 100 mm. The range and mean fork lengths and weights for tagged fish by release are reported in Appendix 1. The study started at approximately 8% of the run and ended at 81% (Figure 9).

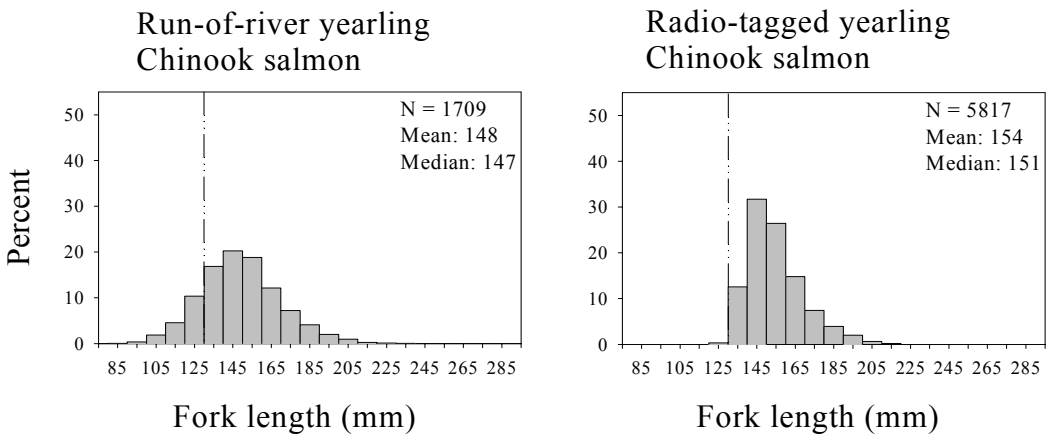

Figure 6. Seasonal (4/30 - 5/31) comparison of yearling Chinook salmon fork length frequency distributions at John Day Dam, 2005. The graph on the left depicts run-of-river fish that were sampled at the John Day Dam smolt monitoring facility. The graph on the right depicts fish that were collected at the John Day Dam smolt monitoring facility, tagged with NTC-3-1-KMF radio transmitters (Lotek Engineering, Newmarket, Ontario), and released at John Day and The Dalles dams during 2005. 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.

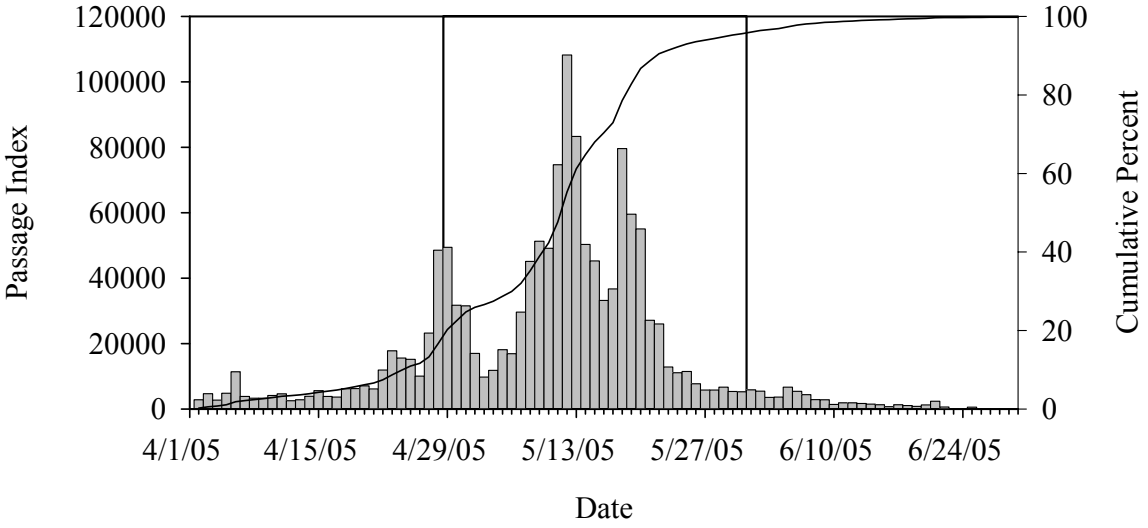

Figure 7. Yearling Chinook salmon passage index at John Day Dam, 2005. The vertical bars represent the passage index (see: www.fpc.org) for a given day. Vertical lines represent the start and end dates for radiotelemetry tagging.

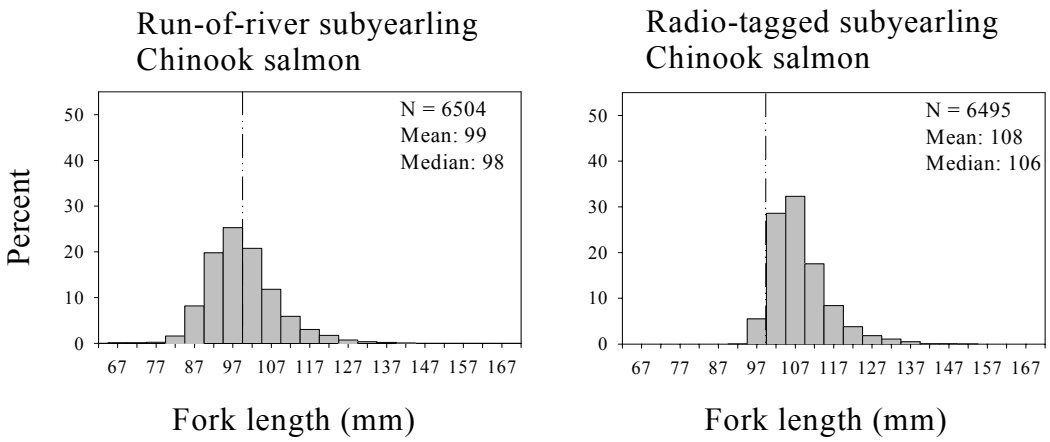

Figure 8. Seasonal (6/16 - 7/17) comparison of subyearling Chinook salmon fork length frequency distributions at John Day Dam, 2005. The graph on the left depicts run-of-river fish that were sampled at the John Day Dam smolt monitoring facility. The graph on the right depicts fish that were collected at the John Day Dam smolt monitoring facility, tagged with NTC-M-2 radio transmitters (Lotek Engineering, Newmarket, Ontario), and released at John Day and The Dalles dams during 2005. 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.

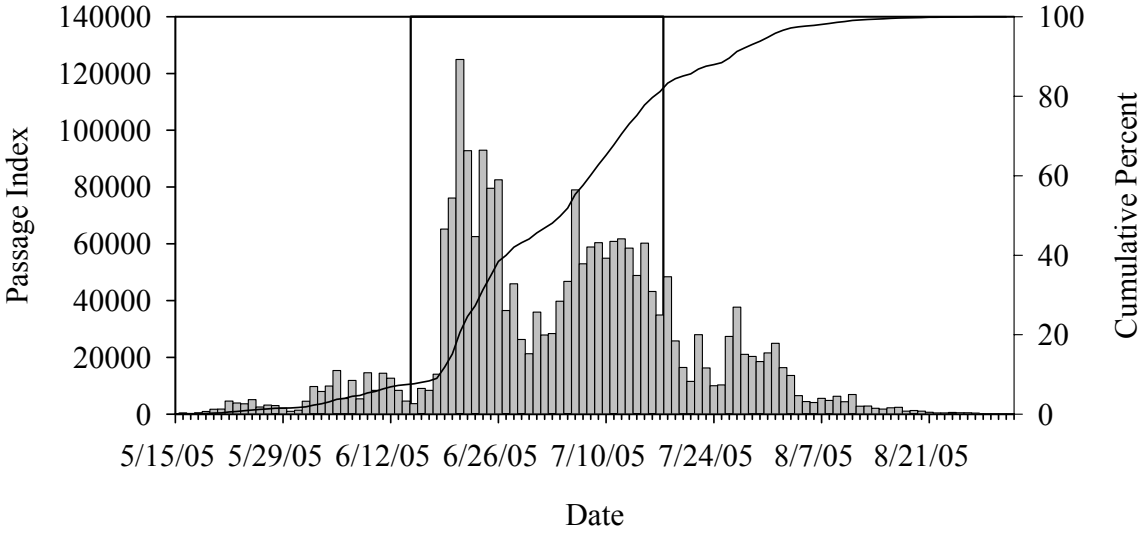

Figure 9. Subyearling Chinook salmon passage index at John Day Dam, 2005. The vertical bars represent the passage index (see: www.fpc.org) for a given day. Vertical lines represent the start and end dates for radiotelemetry tagging.

Tag-life performance

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 2, Figure A2.2). Townsend et al. (2004) found that the probability of a tag being operational at their 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 2005 for the radio transmitters used to tag A) Yearling Chinook and B) Subyearling Chinook salmon.

A) Yearling Chinook salmon implanted with Lotek NTC-3-1-KMF transmitters

	Detection Array Locations	
Release Site	The Dalles Dam	Survival Gates
John Day Dam Tailrace	1.000 (1.902×10^{-7})	1.000 (1.267×10^{-5})
The Dalles Dam Tailrace	NA	1.000 (1.935×10^{-5})

B) Subyearling Chinook salmon implanted with Lotek NTC-M-2 transmitters

	Detection Array Locations	
Release Site	The Dalles Dam	Survival Gates
John Day Dam Tailrace	1.000 (4.859×10^{-7})	0.9999 (2.364×10^{-5})
The Dalles Dam Tailrace	NA	1.000 (4.303×10^{-7})

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 = 1.006, SE = 0.007, profile likelihood 95% confidence interval = 0.984, 1.015), followed by the spillway (S = 0.938, SE = 0.008, profile likelihood 95% confidence interval = 0.921, 0.954), and lowest through the turbines (S = 0.838, SE = 0.032, profile likelihood 95% confidence interval = 0.769, 0.895) (Figure 10). Yearling Chinook salmon dam survival was estimated to be 0.933 (SE = 0.008, 95% confidence interval = [0.918, 0.949), pool survival was estimated to be 0.956 (SE = 0.006, 95% confidence interval = 0.944, 0.968), and project survival (the product of dam and pool survival) was estimated to be 0.892 (SE = 0.014, 95% confidence interval = 0.864, 0.920).

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 ice and trash sluiceway (S = 0.931, SE = 0.037, profile likelihood 95% confidence interval = 0.845, 0.988), followed by the spillway (S = 0.925, SE = 0.009, profile likelihood 95% confidence interval = 0.907, 0.942), and lowest through the turbines (S = 0.796, SE = 0.027, profile likelihood 95% confidence interval = 0.742, 0.845) (Figure 11). Subyearling Chinook salmon dam survival was estimated to be 0.900 (SE = 0.009, 95% confidence interval = 0.881, 0.918), pool survival was estimated to be 0.947 (SE = 0.006, 95% confidence interval = 0.935, 0.959), and project survival (the product of dam and pool survival) was estimated to be 0.852 (SE = 0.014, 95% confidence interval = 0.824, 0.880).

Table 2. Counts of radio-tagged yearling Chinook salmon based on the releases from John Day Dam (R_1) and in the tailrace approximately 550 m downstream of The Dalles Dam, beneath the I-197 bridge (R_2) used in the route-specific survival model.

				Within-route histories at The Dalles Dam [A]		
Release	Detection History [A]	Route	Counts	11	01	10
R_1 = 1469	100		72			
	101		63			
	110	Spillway	78	865	157	37
	111		981			
	110	Turbines	24	69	17	34
	111		96			
	110	Ice and trash	1	152	0	3
	111	sluiceway	154			
R_2 = 2871	010		36			
	011		2835			

[A] - 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.

Table 3. Counts of radio-tagged subyearling Chinook salmon based on the releases from John Day Dam (R_1) and in the tailrace approximately 550 m downstream of The Dalles Dam, beneath the I-197 bridge (R_2) used in the route-specific survival model.

				Within-route histories at The Dalles Dam [A]		
Release	Detection History [A]	Route	Counts	11	01	10
R_1 = 1959	100		131			
	101		140			
	110	Spillway	144	961	299	110
	111		1226			
	110	Turbines	61	99	51	97
	111		186			
	110	Ice and trash	7	68	0	3
	111	sluiceway	64			
R_2 = 2579	010		82			
	011		2497			

[A] - 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.

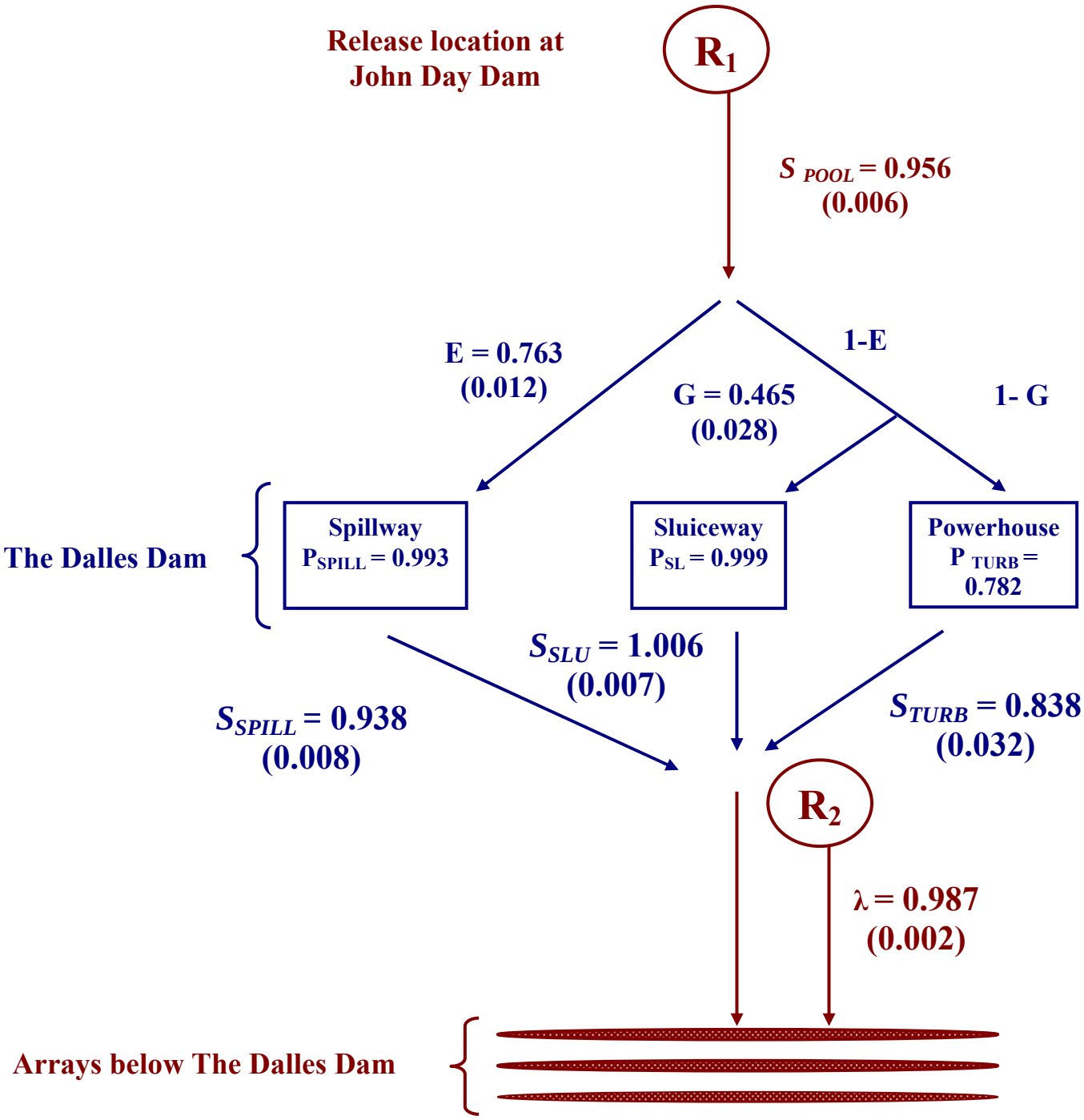

Figure 10. Schematic of estimated route-specific passage and survival probabilities for yearling Chinook salmon through The Dalles Dam during 2005. Estimated standard errors are in parentheses.

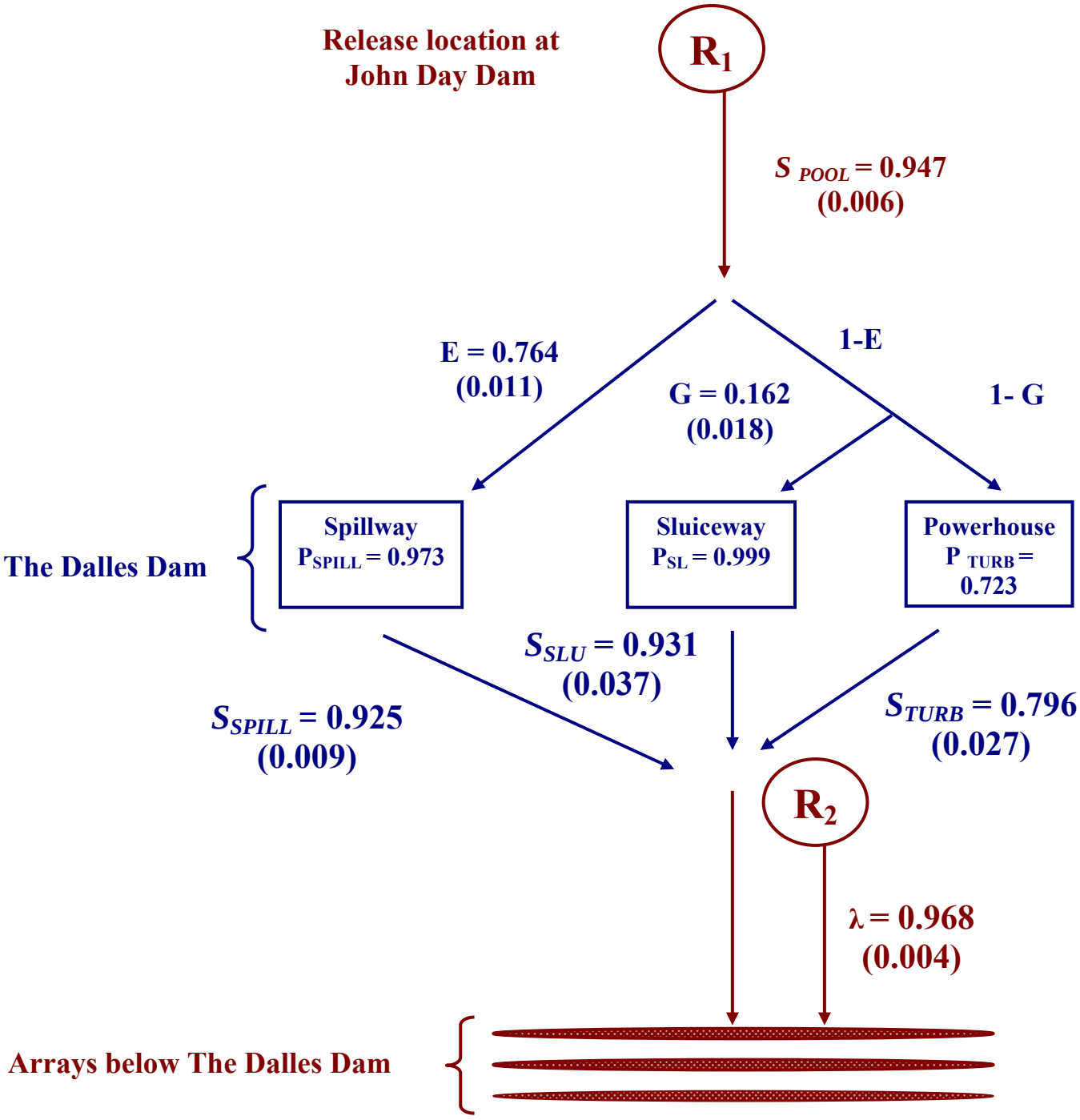

Figure 11. Schematic of estimated route-specific passage and survival probabilities for subyearling Chinook salmon through The Dalles Dam during 2005. Estimated standard errors are in parentheses.

Triple-release model

Yearling Chinook salmon

Rich Townsend and John Skalski, University of Washington provided the following discussion of the results of the triple release model. 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.
Detection histories for yearling Chinook salmon are displayed in Table 4.

Table 4. Yearling Chinook salmon detection histories for the 2005 Dalles Dam triple-release study. Detections are pooled from all downstream detection sites.

Release group	Release size	Number detected downriver
R1-sluiceway	155	154
R1-spillway	1059	981
R1-turbines	120	96
R2	740	728
R3	740	725

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

$$\hat{S}_{SL} = 1.0041(\widehat{SE} = 0.0071)$$

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

$$\widehat{S_{SL} * S_1} = 0.9935 \ (\widehat{SE} = 0.0064)$$
$$\widehat{S_{SP} * S_1} = 0.9263 \ (\widehat{SE} = 0.0080)$$
$$\widehat{S_{TURB} * S_1} = 0.8000 \ (\widehat{SE} = 0.0365)$$

The following relative survivals were estimated as follows:

Spillway to sluiceway:

$$R_{SP/SL} = \frac{0.9263}{0.9935} = 0.9324(\widehat{SE} = 0.0101)$$

Powerhouse turbines to sluiceway:

$$R_{TURB/SL} = \frac{0.8000}{0.9935} = 0.8052(\widehat{SE} = 0.0371)$$

and the absolute survivals through other routes are

$$\text{Spillway: } \hat{R}_{SP/SL} \bullet \hat{S}_{SL} = (0.9324)(1.0041) = 0.9362(\widehat{SE} = 0.0121)$$

$$\text{Powerhouse turbines: } \hat{R}_{TURB/SL} \bullet \hat{S}_{SL} = (0.8052)(1.0041) = 0.8085(\widehat{SE} = 0.0377)$$

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 powerhouse turbines to the first detection site.

By making an additional assumption of 100% detection at The Dalles Dam, overall dam survival was estimated to be 0.9326.

	Sluiceway	Spillway	Turbines	
	$\boldsymbol{P_{SL}}$ **= 0.1162**	$\boldsymbol{P_{SP}}$ **= 0.7939**	$\boldsymbol{P_{TURB}}$ **= 0.0899**	
	($\widehat{SE} = 0.0088$)	($\widehat{SE} = 0.0111$)	($\widehat{SE} = 0.0078$)	
	x	x	x	
	$\boldsymbol{S_{SL}}$ **= 1.0041**	$\boldsymbol{S_{SP}}$ **= 0.9362**	$\boldsymbol{S_{TURB}}$ **= 0.8085**	
	($\widehat{SE} = 0.0071$)	($\widehat{SE} = 0.0121$)	($\widehat{SE} = 0.0377$)	
$\boldsymbol{S_{DAM}}$ =	**0.1167**	+ **0.7432**	+ **0.0727**	= **0.9326**
	($\widehat{SE} = 0.0088$)	($\widehat{SE} = 0.0141$)	($\widehat{SE} = 0.0072$)	($\widehat{SE} = 0.0182$)

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

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. Detection histories for subyearling Chinook salmon are displayed in Table 5.

Table 5. Subyearling Chinook salmon detection histories for the 2005 Dalles Dam triple-release study. Detections are pooled from all downstream detection sites.

Release group	Release size	Number detected downriver
R1-sluiceway	71	64
R1-spillway	1370	1226
R1-turbines	247	186
R2	979	885
R3	978	919

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

$$\hat{S}_{SL} = 0.9620 \ (\widehat{SE} = 0.0127)$$

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

$$\widehat{S_{SL} * S_1} = 0.9014 \ (\widehat{SE} = 0.0354)$$
$$\widehat{S_{SP} * S_1} = 0.8949 \ (\widehat{SE} = 0.0083)$$
$$\widehat{S_{TURB} * S_1} = 0.7530 \ (\widehat{SE} = 0.0274)$$

The following relative survivals were estimated as follows:

Spillway to sluiceway:

$$\hat{R}_{SP/SL} = 0.9928 \ (\widehat{SE} = 0.0400)$$

Powerhouse turbines to sluiceway:

$$\hat{R}_{TURB/SL} = 0.8354 \ (\widehat{SE} = 0.0447)$$

and the absolute survivals through other routes are

Spillway: $\hat{R}_{SP/SL} * \hat{S}_{SL} = (0.9928)(0.9620) = 0.9551 \ (\widehat{SE} = 0.0405)$

Powerhouse turbines: $\hat{R}_{TURB/SL} * \hat{S}_{SL} = (0.8354)(0.9620) = 0.8037 \ (\widehat{SE} = 0.0443)$

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 powerhouse turbines to the first detection site.

By making an additional assumption of 100% detection at The Dalles Dam, overall dam survival was estimated to be 0.9333.

	Sluiceway		Spillway		Turbines	
	$\boldsymbol{P_{SL}}$ **= 0.0421**		$\boldsymbol{P_{SP}}$ **= 0.8116**		$\boldsymbol{P_{TURB}}$ **= 0.1463**	
	$(\widehat{SE} = 0.0049)$		$(\widehat{SE} = 0.0095)$		$(\widehat{SE} = 0.0086)$	
	x		x		x	
	$\boldsymbol{S_{SL}}$ **= 0.9620**		$\boldsymbol{S_{SP}}$ **= 0.9551**		$\boldsymbol{S_{TURB}}$ **= 0.8037**	
	$(\widehat{SE} = 0.0127)$		$(\widehat{SE} = 0.0405)$		$(\widehat{SE} = 0.0443)$	
$\boldsymbol{S_{DAM}}$ =	**0.0405**	+	**0.7751**	+	**0.1176**	= **0.9332**
	$(\widehat{SE} = 0.0047)$		$(\widehat{SE} = 0.0341)$		$(\widehat{SE} = 0.0095)$	$(\widehat{SE} = 0.0357)$

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

River conditions and project operations

River conditions and project operations data were obtained from the Army Corps of Engineers' Technical Management Team website: www.nwd-wc.usace.army.mil/tmt/. During the spring study period average daily river temperature gradually increased from 11.2 to 15.2°C (Figure 12). Average hourly total discharge ranged from 112 kcfs to 308 kcfs (Figure 13), averaging 223 kcfs. Average hourly spill discharge ranged from 50 kcfs to 85 kcfs (Figure 13), averaging 74 kcfs. This resulted in 21-61% (average: 34%) of the discharge going through the spillway (Figure 13). Spillway operations in spring and summer of 2005 differed from previous years due to a problem with structural components of the tainter gates. Prior to the 2005 spill season (10 April – 31 August), an inspection of the spill-gate wire ropes used to raise and lower the gates revealed that some were unsafe for operation (Brad Eppard, ACOE Portland District, personal communication). Spillbays 3-9 and 11-13 were deemed inoperable. The U. S. Army Corps of Engineers designed and installed pendant cables in bays 3-6 to facilitate a spill level of 40% through bays 1-6. Three lengths of pendant cables were used to suspend the spill gates and provide gate openings to maintain approximately 40% spill at forecasted river flows (Table 6). While spillbays 3-6 were at 1 of 3 gate openings, spillbays 1 and 2 were used to allow for some adjustment in spill levels.

Table 6. Length of pendant cables and range of flows and spill volume used at The Dalles Dam, 2005 (provided by Brad Eppard, ACOE, Portland District).

Dates	Gate Opening (feet)	Range of River Discharge	Range of Spill
April 10 – May 2	6	90 Kcfs – 240 Kcfs	36.8 Kcfs – 72 Kcfs
May 2 – Aug 8	8	110 Kcfs – 320 Kcfs	54 Kcfs – 84 Kcfs
Aug 8 – Aug 31	6	90 Kcfs – 220 Kcfs	36.8 Kcfs – 72 Kcfs

During the summer study period average daily river temperature gradually increased from 16.3 to 20.4°C (Figure 12). Average hourly total discharge ranged from 103 kcfs to 320 kcfs (Figure 14), averaging 181 kcfs. Average hourly spill discharge ranged from 0 kcfs to 82 kcfs (Figure 14), averaging 67 kcfs. This resulted in 0-50% (average: 38%) of the discharge going through the spillway (Figure 14).

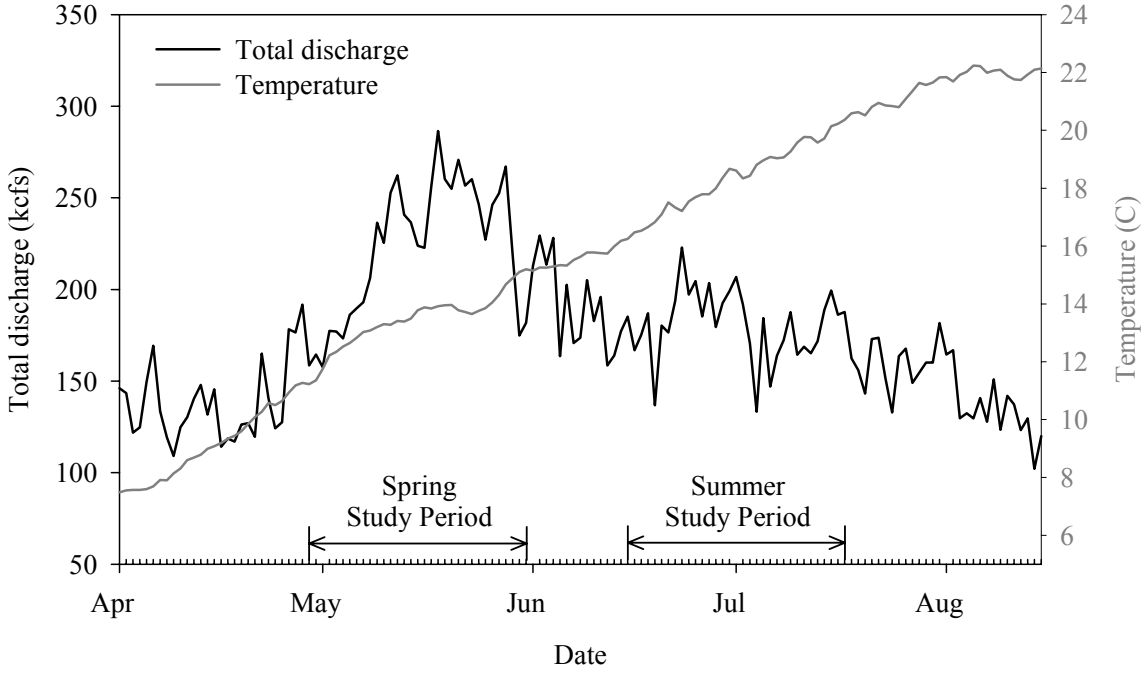

Figure 12. Average daily total discharge (kcfs) and river temperature (°C) at The Dalles Dam during 2005.

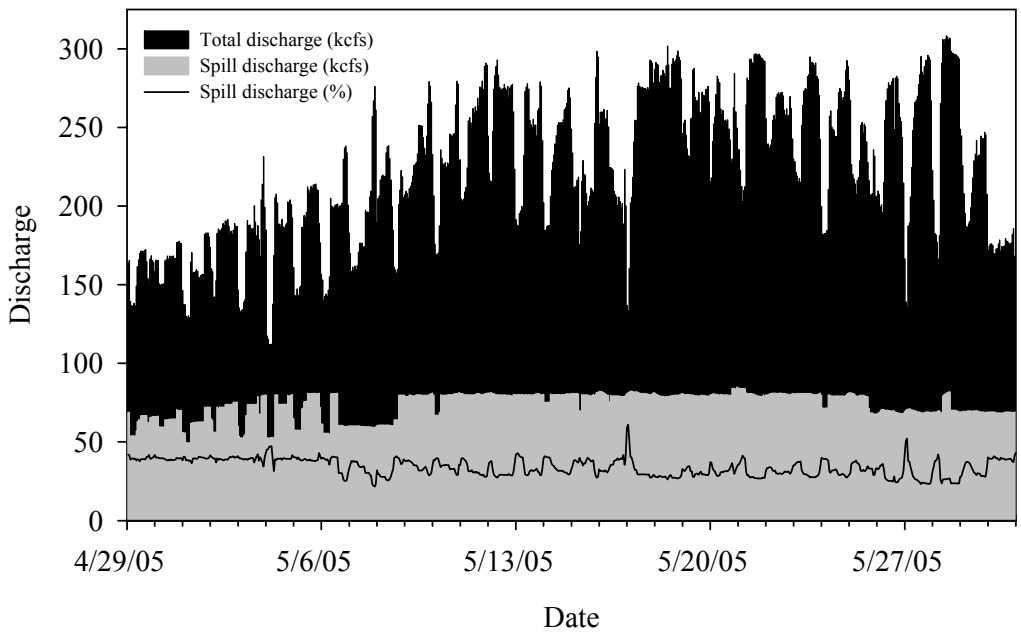

Figure 13. Hourly averages of total discharge (kcfs), spill discharge (kcfs), and percent spill discharge at The Dalles Dam during the spring study period, 2005.

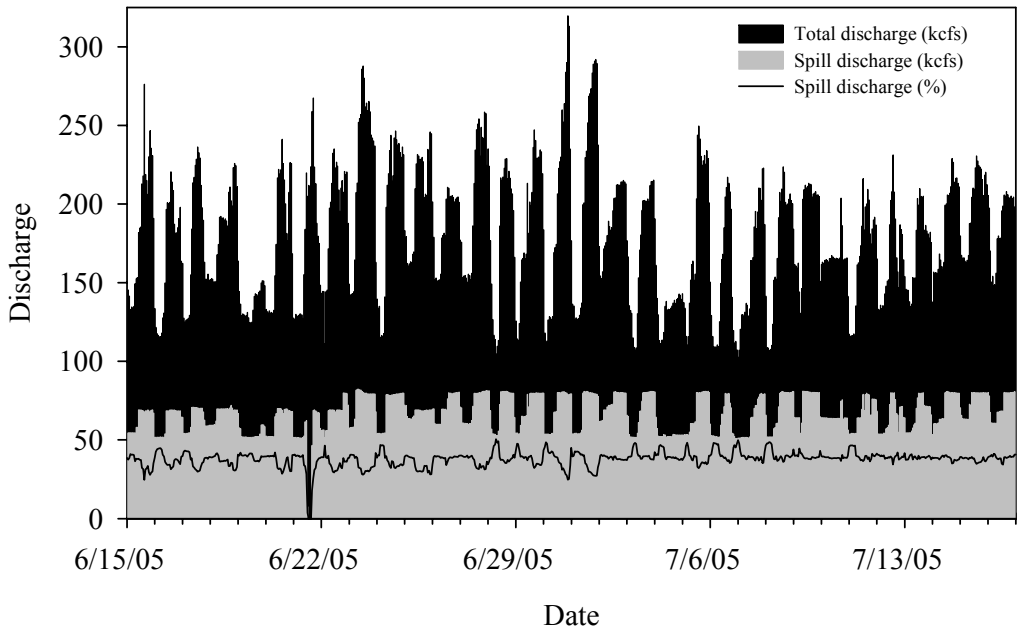

Figure 14. Hourly averages of total discharge (kcfs), spill discharge (kcfs), and percent spill discharge at The Dalles Dam during the summer study period, 2005.

Discussion

Trends in route-specific survival estimates for yearling and subyearling Chinook salmon during 2005 were similar to previous years (Figures 15 & 16); survival was highest for fish passing via the ice and trash sluiceway, lower for the spillway, and lowest for fish passing via the turbines at the powerhouse. 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 spillway survival for 2005 were higher than 2002 (pre-construction) and 2004 (post-construction) (Figures 15 & 16); however, the differences were small and there was significant overlap in the 95% confidence intervals of the estimates.

Recent research suggests that survival at The Dalles Dam spillway is lower for juvenile Chinook salmon passing more southern spillbays compared to those passing more northern spillbays (Counihan et al. 2003, Normandeau Associates Inc. 2003, Counihan et al. 2006, also see: Appendix 3). Fish passage at The Dalles Dam spillway is influenced by spill patterns. Spill patterns were different from 2002 to 2005, so that each year spillway discharge was sent through fewer and more northern bays (Hausmann 2004, Hansel et al. 2005, Hansel et al. *in prep.*). Concurrently, juvenile Chinook salmon passage was different each year so that fish were passing more northern bays (Hausmann 2004, Hansel et al. 2005, Hansel et al. *in prep.*) where survival probabilities were higher (Counihan et al. 2003, Normandeau Associates Inc. 2003, Counihan et al. 2006, also see Appendix 3). The small increases in survival from 2002 to 2005 may be a result of the differences in fish passage. However, interpretation of the survival results at The Dalles Dam spillway is confounded by differences in environmental conditions during the one year of pre-construction and the subsequent two years of post-construction survival evaluations. Similar trends towards increasing survival is evident for fish passing the ice and trash sluiceway for yearling Chinook salmon (Figure 15) and, after a marked decrease in survival during 2004, the point estimate of the survival of subyearling Chinook salmon passing the ice and trash sluiceway during 2005 was higher than that observed during 2002 and 2004 (Figure 16). This suggests that other factors (e.g. environmental conditions) may have affected survival.

Overall dam survival increased slightly from 2002 to 2005 (Figures 15 & 16). However, because of the variability in dam operations and environmental conditions across years, comparisons of survival across years are confounded. For example, in addition to differences in spillway operations, powerhouse turbines and sluiceway operations in 2002 differed from 2004 and 2005. In 2002, turbine passage with and without a series of steel plates designed to occlude the upper portion of the turbine intakes (sluiceway guidance improvement devices (SGID)) were tested at several turbines. Operating turbines at The Dalles Dam are typically alternated along the powerhouse, but in 2002 main units 1 through 5 were block loaded to provide consistent conditions for the SGID tests (Hausmann 2004). Research results suggest that these operations resulted in greater turbine entrainment of juvenile salmonids (Hausmann 2004, Johnson et al. 2003).

The triple-release model was formulated to address the potential for positive bias in the route-specific survival model. That is, there was a concern that estimates from the RSSM would be positively biased because treatment fish released above the project that have expressed post-release handling mortality in the pool above the dam are paired with a fresh tailrace release whose post-release handling mortality would be expressed in the first reach the two groups travel together. The triple-release model and the route-specific survival model produced similar trends in survival for both yearling and subyearling Chinook salmon (Figure 17). Point estimates of survival generated by the two models for yearling Chinook salmon were very similar for spillway and sluiceway passage, but the route-specific estimate for powerhouse turbine passage was higher than the triple-release estimate. For subyearling Chinook salmon, triple-release survival estimates were higher than the route-specific estimates for all routes (Figure 17). These results do not suggest that the route-specific survival model estimates were positively biased for the evaluations of survival at The Dalles Dam.

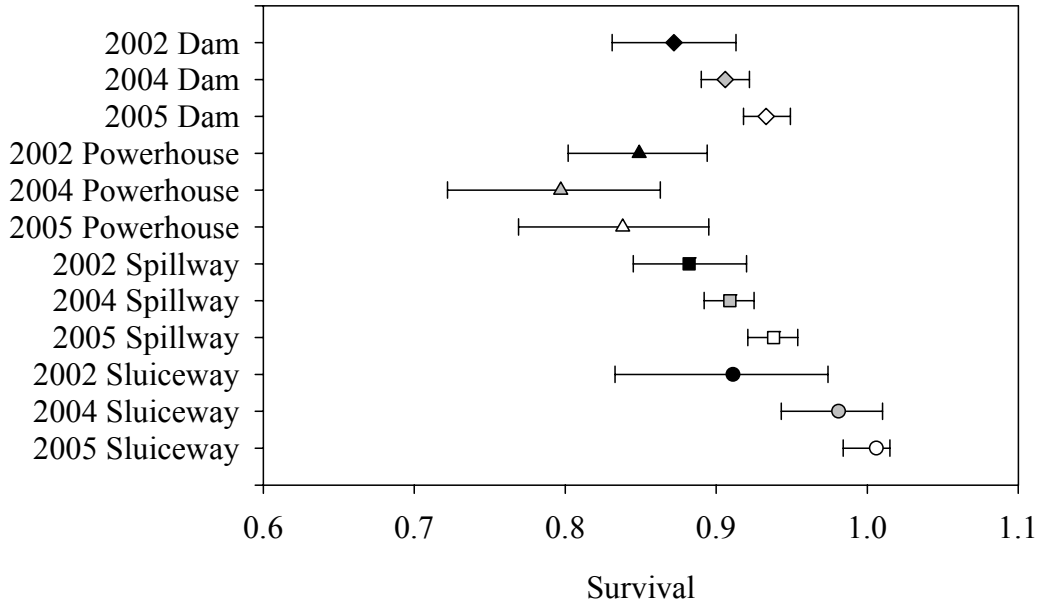

Figure 15. Survival estimates at The Dalles Dam for April 30 - May 31, 2002 (black symbols), April 28 - May 29, 2004 (gray symbols), and April 29 - May 31, 2005 (white symbols) for yearling Chinook salmon. Dam survival probabilities and associated 95% confidence intervals and route-specific survival probabilities and associated profile likelihood 95% confidence intervals were calculated using the route-specific survival model.

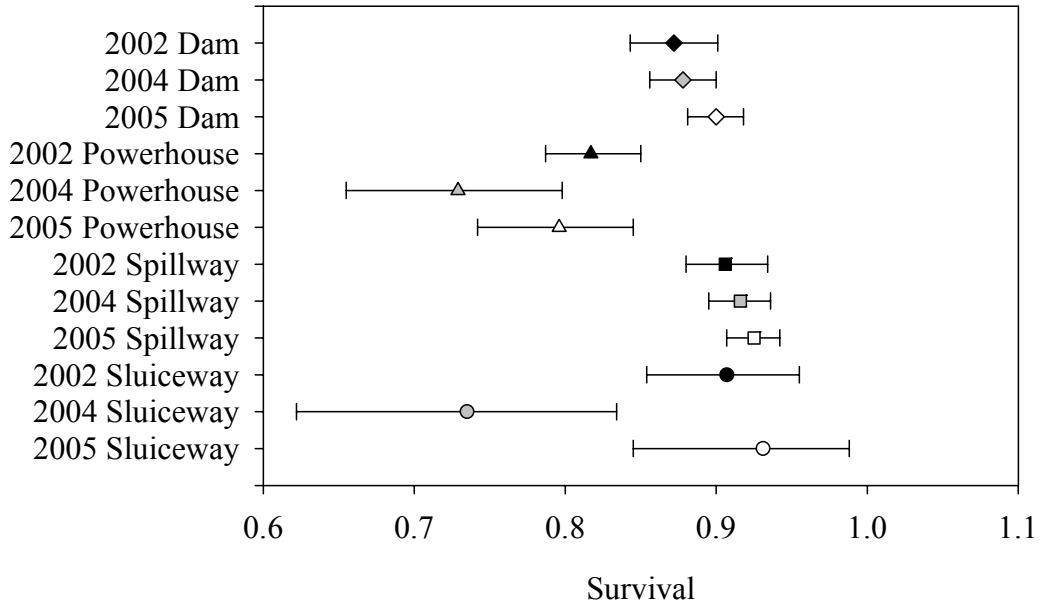

Figure 16. Survival estimates at The Dalles Dam for June 21 - July 22, 2002 (black symbols), June 20 - July 21, 2004 (gray symbols), and June 15 - July 17, 2005 (white symbols) for subyearling Chinook salmon. Dam survival probabilities and associated 95% confidence intervals and route-specific survival probabilities and associated profile likelihood 95% confidence intervals were calculated using the route-specific survival model.

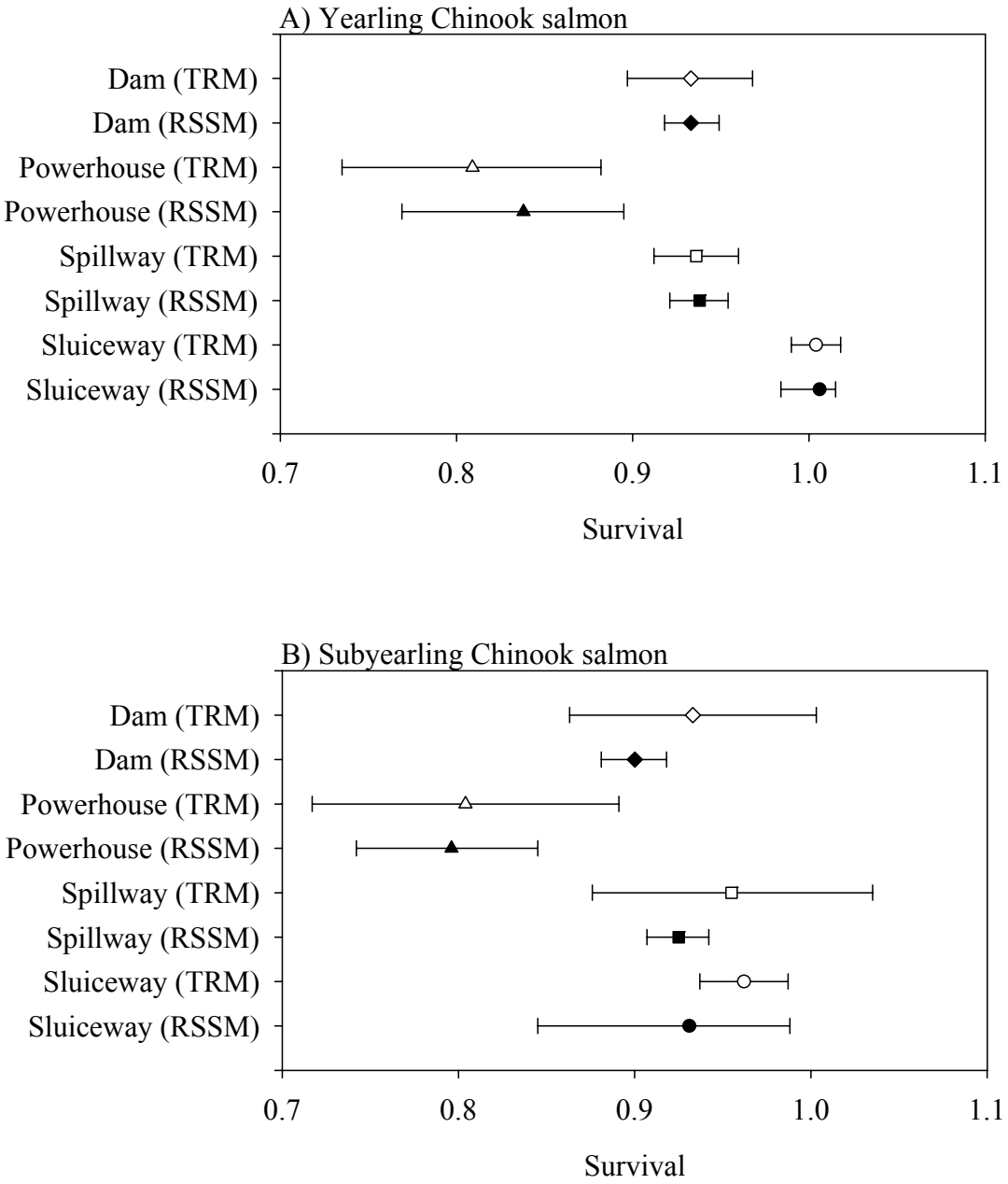

Figure 17. Comparison of survival estimates calculated using the triple-release model (TRM, open symbols) and the route-specific survival model (RSSM, closed symbols) at The Dalles Dam from April 29 - May 31, 2005 for yearling Chinook salmon (A) and from June 15 - July 17, 2005 for subyearling Chinook salmon (B). Error bars on triple-release estimates represent the 95% confidence intervals and on route-specific estimates the profile likelihood 95% confidence intervals.

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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 2005. 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	29-Apr	08:43	24	0	0	158	6.8	143 - 172	36.5	4.7	26.0 - 44.9
2	29-Apr	22:17	24	0	0	154	5.1	144 - 163	33.1	3.5	27.2 - 40.6
3	30-Apr	08:28	21	2	0	156	11.0	137 - 186	36.7	8.2	25.2 - 59.8
4	30-Apr	21:57	24	0	0	157	7.8	145 - 174	35.3	5.7	27.8 - 50.2
5	1-May	08:23	24	0	0	153	11.0	132 - 180	33.1	7.1	21.6 - 50.1
6	1-May	21:59	23	1	0	151	6.9	136 - 162	32.0	5.3	23.7 - 44.1
7	2-May	08:17	26	0	0	155	11.8	138 - 188	36.0	8.3	25.5 - 59.8
8	2-May	21:58	24	0	0	151	11.2	131 - 170	32.2	7.7	21.6 - 46.6
9	3-May	08:29	22	2	0	150	9.7	135 - 166	32.6	6.6	22.3 - 45.2
10	3-May	22:02	20	3	0	153	10.3	141 - 187	33.5	7.6	24.5 - 60.2
11	4-May	08:11	24	0	0	155	11.2	140 - 184	35.3	8.0	26.2 - 57.5
12	4-May	21:58	24	0	0	151	9.9	140 - 167	34.3	7.2	24.7 - 47.9
13	5-May	08:09	21	2	0	152	11.2	132 - 171	33.8	7.1	23.0 - 50.8
14	5-May	21:58	23	0	0	151	7.6	138 - 165	32.9	5.9	23.5 - 45.0
15	6-May	08:07	22	3	0	154	10.2	137 - 179	35.0	7.2	23.6 - 52.5
16	6-May	22:31	26	0	0	151	10.4	132 - 170	34.0	7.0	23.4 - 48.2
17	7-May	08:11	25	0	0	153	9.1	136 - 170	34.6	7.0	23.8 - 52.3
18	7-May	22:02	22	1	0	154	11.7	140 - 194	35.3	8.9	26.6 - 68.7
19	8-May	08:03	22	0	0	150	11.7	135 - 192	32.2	9.5	22.6 - 69.7
20	8-May	21:48	22	1	0	149	8.3	135 - 168	31.7	5.7	24.8 - 47.1
21	9-May	08:17	20	3	0	150	9.5	135 - 170	32.9	7.3	23.8 - 49.3
22	9-May	21:52	21	2	0	155	13.7	133 - 184	38.0	11.4	22.5 - 65.7
23	10-May	07:57	24	2	0	154	15.7	133 - 186	36.4	11.4	22.6 - 64.9
24	10-May	22:02	24	1	0	152	14.6	133 - 192	34.5	10.8	21.7 - 68.7

Table A1.1. Continued.

						Fork Length (mm)			Weight (g)		
Release	Date	Time	N	Tag loss	Mortality	Mean	SD	Range	Mean	SD	Range
25	11-May	08:06	18	3	0	148	10.5	131 - 167	31.3	6.9	22.3 - 45.2
26	11-May	21:58	23	1	0	160	17.4	136 - 198	40.9	15.0	23.3 - 82.5
27	12-May	08:13	26	0	0	150	11.6	135 - 172	32.7	6.9	24.1 - 47.8
28	12-May	22:12	24	1	0	160	15.5	138 - 185	41.3	11.5	25.5 - 63.8
29	13-May	08:19	26	0	0	163	16.8	136 - 195	42.8	12.2	24.0 - 63.8
30	13-May	21:58	22	0	1	157	11.9	141 - 177	40.6	7.3	29.8 - 54.6
31	14-May	08:13	25	0	0	155	15.0	133 - 186	37.0	11.3	23.1 - 67.8
32	14-May	22:02	23	2	0	158	14.8	130 - 182	38.8	11.0	22.4 - 57.8
33	15-May	08:16	22	0	0	146	12.1	135 - 188	30.3	8.6	22.3 - 61.8
34	15-May	22:09	23	1	0	151	13.1	137 - 190	33.3	9.6	23.6 - 64.0
35	16-May	08:11	22	0	0	156	12.3	141 - 195	37.3	7.8	25.8 - 59.3
36	16-May	22:00	25	0	0	156	16.7	137 - 196	38.9	11.7	24.5 - 70.5
37	17-May	08:02	23	0	0	161	21.1	138 - 210	41.7	18.2	24.9 - 92.1
38	17-May	21:49	24	0	0	158	18.1	132 - 207	41.5	14.7	24.4 - 88.1
39	18-May	08:11	23	0	0	160	17.6	135 - 195	39.0	12.2	22.8 - 63.1
40	18-May	21:57	23	0	0	149	15.5	131 - 192	31.5	11.8	22.6 - 69.2
41	19-May	08:16	23	0	0	151	11.7	135 - 190	34.1	8.6	24.2 - 66.3
42	19-May	22:00	23	0	0	155	14.9	133 - 184	35.4	11.0	21.6 - 57.0
43	20-May	08:00	22	0	0	150	9.0	135 - 169	32.1	6.0	22.6 - 44.9
44	20-May	22:25	23	0	0	157	15.8	138 - 188	36.7	12.9	24.2 - 63.3
45	21-May	08:12	23	0	0	154	17.9	132 - 194	34.2	12.1	21.7 - 61.0
46	21-May	22:19	25	0	0	159	23.0	133 - 205	39.6	17.7	21.7 - 82.3
47	22-May	08:12	24	0	0	149	15.6	133 - 205	31.4	12.6	22.2 - 81.8
48	22-May	22:14	23	0	0	156	13.6	135 - 180	36.4	10.6	22.7 - 63.3
49	23-May	08:15	25	0	0	152	13.6	137 - 175	33.3	10.2	21.7 - 52.9
50	23-May	22:12	24	0	0	154	19.6	129 - 210	36.9	16.3	21.5 - 86.4
51	24-May	07:58	24	0	0	155	13.8	132 - 183	37.3	9.4	22.9 - 55.6

Table A1.1. Continued.

						Fork Length (mm)			Weight (g)		
Release	Date	Time	N	Tag loss	Mortality	Mean	SD	Range	Mean	SD	Range
52	24-May	21:59	24	0	0	166	20.3	135 - 201	44.6	15.9	22.6 - 75.2
53	25-May	08:14	23	0	0	160	17.6	130 - 197	40.7	13.6	21.6 - 73.2
54	25-May	21:46	21	0	0	157	15.9	132 - 192	41.7	12.8	24.1 - 70.9
55	26-May	08:01	23	0	0	153	13.0	135 - 185	35.0	8.8	23.7 - 56.0
56	26-May	21:52	21	1	0	156	17.2	129 - 200	37.7	14.4	22.2 - 77.5
57	27-May	07:53	22	1	0	159	15.3	133 - 195	39.5	11.4	23.2 - 64.8
58	27-May	22:00	23	0	0	163	14.5	141 - 200	41.9	10.8	26.2 - 68.2
59	28-May	08:09	21	1	0	159	15.5	137 - 192	38.4	11.8	23.5 - 63.2
60	28-May	22:18	23	0	0	156	10.2	137 - 168	35.7	7.3	24.4 - 49.2
61	29-May	21:48	27	0	0	162	15.0	135 - 205	41.3	11.4	22.9 - 75.2
62	30-May	08:29	27	0	0	160	14.5	141 - 201	41.6	11.2	29.9 - 76.7
63	30-May	21:51	31	0	0	154	11.2	135 - 175	35.4	7.8	22.4 - 51.3
Overall			1469	34	1	155	14.1	129 - 210	36.3	10.7	21.5 - 92.1

Table A1.2. Summary of yearling Chinook salmon releases at The Dalles Dam tailrace during spring 2005. 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	30-Apr	00:35	42	5	0	154	7.6	138 - 177	35.5	6.2	24.7 - 58.4
2	30-Apr	14:18	47	0	0	152	6.9	138 - 168	33.1	5.1	23.0 - 43.8
3	1-May	00:12	47	0	0	151	8.3	135 - 175	33.0	6.3	23.5 - 54.2
4	1-May	13:56	46	1	0	154	9.0	140 - 176	34.6	5.7	24.6 - 49.6
5	2-May	00:04	38	8	0	152	8.9	136 - 173	33.7	7.4	23.4 - 61.4
6	2-May	14:21	43	4	0	149	8.3	135 - 175	31.4	5.6	23.0 - 54.6
7	3-May	00:04	45	2	0	150	11.8	131 - 187	33.9	8.8	21.8 - 70.5
8	3-May	14:00	45	1	0	147	11.3	126 - 188	32.5	9.2	22.2 - 69.2
9	4-May	00:08	43	3	1	152	13.4	135 - 197	37.1	11.1	25.4 - 83.4
10	4-May	13:59	45	2	0	152	9.0	135 - 175	34.3	6.5	24.4 - 52.5
11	5-May	00:08	42	5	0	148	7.1	127 - 160	32.6	4.3	23.0 - 41.6
12	5-May	13:53	43	3	0	149	10.7	134 - 178	32.7	7.2	23.1 - 54.6
13	6-May	00:04	45	2	0	150	9.9	131 - 179	33.9	7.1	24.4 - 55.4
14	6-May	14:45	45	2	0	150	13.6	129 - 205	35.4	10.8	21.9 - 82.8
15	7-May	00:01	37	10	0	154	11.3	130 - 181	38.4	9.0	22.4 - 60.3
16	7-May	14:27	37	10	0	150	9.8	135 - 180	34.9	6.7	24.3 - 57.0
17	7-May	23:45	43	4	0	152	14.2	131 - 198	36.4	11.4	23.8 - 80.0
18	8-May	14:22	44	3	0	151	10.4	131 - 183	33.1	7.9	22.3 - 58.6
19	9-May	00:06	44	2	0	152	12.9	131 - 193	34.8	9.2	23.1 - 68.0
20	9-May	14:02	43	3	0	154	11.0	137 - 186	36.0	8.7	25.0 - 65.2
21	10-May	00:14	46	1	0	146	7.4	135 - 173	30.8	4.9	23.8 - 51.7
22	10-May	14:08	41	5	0	149	13.3	130 - 183	33.8	9.6	21.9 - 66.7
23	11-May	00:13	43	2	0	149	14.4	130 - 191	33.6	11.3	21.8 - 70.1
24	11-May	14:06	43	4	0	153	17.9	127 - 210	37.0	14.2	22.3 - 81.8

Table A1.2. Continued.

						Fork Length (mm)			Weight (g)		
Release	Date	Time	N	Tag loss	Mortality	Mean	SD	Range	Mean	SD	Range
25	12-May	00:12	44	0	0	154	14.8	131 - 208	37.2	12.3	23.0 - 92.2
26	12-May	14:08	44	2	0	152	13.1	131 - 187	35.5	10.6	23.2 - 67.2
27	12-May	23:51	45	2	0	156	16.6	130 - 200	38.2	13.2	22.7 - 81.3
28	13-May	14:07	44	0	0	149	11.6	130 - 179	33.2	8.7	23.0 - 57.4
29	14-May	00:03	43	4	0	152	13.8	130 - 188	35.0	10.2	21.8 - 65.0
30	14-May	14:23	47	0	0	152	10.9	133 - 173	34.5	7.7	23.7 - 53.2
31	14-May	23:53	46	0	0	152	14.8	129 - 195	36.6	10.1	22.9 - 62.3
32	15-May	14:09	46	1	0	151	17.0	132 - 206	34.9	13.5	21.5 - 81.3
33	16-May	00:12	47	0	0	156	12.7	132 - 185	36.9	9.0	25.5 - 63.1
34	16-May	13:52	46	0	0	152	12.6	133 - 190	35.0	9.0	22.6 - 61.4
35	17-May	00:10	46	1	0	152	15.5	130 - 214	35.1	12.5	21.8 - 97.7
36	17-May	13:57	46	0	0	155	16.2	130 - 197	37.7	12.3	21.5 - 75.9
37	18-May	00:09	45	0	2	155	17.6	131 - 210	37.6	13.8	21.6 - 86.4
38	18-May	13:51	47	0	0	154	15.7	132 - 199	37.0	11.9	22.5 - 76.7
39	19-May	00:03	47	0	0	152	14.3	134 - 195	34.7	10.4	23.2 - 66.6
40	19-May	13:59	46	0	0	153	14.1	129 - 185	35.9	9.9	21.9 - 57.8
41	20-May	00:05	45	1	0	157	19.2	130 - 205	39.2	15.0	21.8 - 83.2
42	20-May	13:58	46	1	0	155	15.7	133 - 189	36.0	11.0	21.9 - 66.0
43	21-May	00:14	46	0	0	150	14.9	131 - 186	33.4	10.7	21.7 - 60.8
44	21-May	13:56	46	0	1	150	16.2	130 - 203	32.7	12.0	21.6 - 77.0
45	22-May	00:03	46	0	0	154	21.1	130 - 215	36.7	17.1	21.6 - 96.3
46	22-May	14:02	46	1	0	153	18.4	131 - 200	35.9	13.1	22.8 - 71.9
47	23-May	00:02	47	0	0	154	18.1	129 - 210	36.6	14.8	21.6 - 96.7
48	23-May	14:16	46	0	0	154	18.9	132 - 205	37.3	15.4	21.5 - 78.5
49	24-May	00:01	47	0	0	160	18.6	126 - 200	40.6	14.5	21.6 - 82.9
50	24-May	14:20	45	1	0	153	18.0	131 - 212	35.0	14.6	21.6 - 82.0
51	25-May	00:04	47	0	0	160	17.4	135 - 197	42.0	14.5	22.8 - 72.1

Table A1.2. Continued.

						Fork Length (mm)			Weight (g)		
Release	Date	Time	N	Tag loss	Mortality	Mean	SD	Range	Mean	SD	Range
52	25-May	14:00	46	1	0	160	18.8	131 - 196	40.7	14.4	21.7 - 74.4
53	25-May	23:52	42	0	0	160	18.9	133 - 203	41.7	15.4	21.9 - 81.3
54	26-May	13:53	46	1	0	160	15.1	137 - 196	40.1	11.8	21.9 - 70.5
55	27-May	00:01	44	3	0	156	15.5	132 - 201	38.6	12.4	22.0 - 75.0
56	27-May	14:03	47	0	0	157	16.4	133 - 197	38.4	11.6	22.2 - 71.3
57	28-May	00:07	46	1	0	157	15.1	131 - 190	38.5	10.6	23.3 - 63.1
58	28-May	13:59	45	2	0	165	16.1	139 - 209	45.6	14.3	27.3 - 96.6
59	28-May	23:45	47	0	0	158	17.0	127 - 220	39.9	13.4	22.1 - 97.9
60	29-May	14:51	47	0	0	160	19.8	130 - 205	42.2	16.2	22.4 - 83.2
61	29-May	23:54	47	0	0	155	16.0	130 - 199	37.7	11.6	21.9 - 76.6
62	30-May	14:07	47	0	0	157	16.3	133 - 200	38.4	13.2	23.7 - 77.7
63	31-May	00:02	47	0	0	158	16.2	132 - 211	40.8	13.4	22.1 - 92.1
64	31-May	14:15	47	0	0	157	15.1	134 - 198	39.4	10.9	23.7 - 70.3
Overall			2871	104	4	154	14.9	126 - 220	36.4	11.5	21.5 - 97.9

Table A1.3. Summary of yearling Chinook salmon releases at The Dalles Dam ice and trash sluiceway during spring 2005. 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	30-Apr	19:03	24	0	0	155	8.6	139 - 173	35.5	6.0	24.4 - 46.6
2	1-May	06:53	24	0	0	157	12.6	137 - 182	37.8	9.9	23.7 - 60.8
3	2-May	13:08	23	1	0	154	9.9	140 - 181	34.9	7.5	25.3 - 56.3
4	3-May	01:00	23	1	0	152	13.2	129 - 189	34.4	9.8	21.5 - 64.8
5	4-May	18:57	19	5	0	151	11.0	130 - 184	34.1	8.2	22.4 - 60.8
6	5-May	00:59	24	0	0	150	10.8	134 - 185	34.5	9.8	22.1 - 70.3
7	6-May	13:00	24	0	0	151	7.9	135 - 169	35.1	5.4	24.6 - 48.8
8	7-May	07:10	24	0	0	154	12.6	137 - 179	37.4	10.3	24.2 - 58.6
9	8-May	13:00	23	1	0	155	12.0	139 - 181	36.5	9.0	26.2 - 63.4
10	9-May	01:16	19	4	0	152	12.3	138 - 180	35.6	9.0	25.4 - 58.6
11	10-May	18:53	24	0	0	155	16.9	132 - 189	37.8	12.3	24.6 - 63.8
12	11-May	07:02	21	2	0	150	9.3	136 - 175	33.4	6.8	26.0 - 53.9
13	12-May	19:00	23	1	0	151	12.5	136 - 187	34.4	9.4	23.3 - 61.6
14	13-May	01:00	24	0	0	159	15.9	135 - 191	41.4	12.8	23.7 - 64.0
15	14-May	13:04	21	2	1	148	10.4	133 - 169	31.2	6.5	22.1 - 43.5
16	15-May	06:58	23	0	0	149	11.3	134 - 177	32.1	7.1	23.1 - 52.9

Table A1.3. Continued.

						Fork Length (mm)			Weight (g)		
Release	Date	Time	N	Tag loss	Mortality	Mean	SD	Range	Mean	SD	Range
17	16-May	06:59	24	0	0	151	12.3	130 - 179	35.1	7.1	25.3 - 54.3
18	17-May	01:10	23	0	0	157	15.1	133 - 193	37.8	11.3	22.7 - 67.7
19	18-May	18:58	24	0	0	150	13.5	128 - 177	33.8	10.4	22.4 - 60.6
20	19-May	13:00	24	0	0	149	11.5	131 - 178	33.7	7.9	22.2 - 55.2
21	20-May	00:58	24	0	0	153	15.8	134 - 190	36.2	12.3	21.9 - 68.2
22	21-May	18:58	24	0	0	151	22.2	130 - 204	34.6	17.1	22.6 - 79.2
23	22-May	06:59	24	0	0	147	14.4	130 - 195	30.2	10.1	22.2 - 66.6
24	23-May	12:59	24	0	0	156	20.8	130 - 195	38.8	15.7	22.8 - 69.1
25	24-May	12:56	24	0	0	156	19.9	130 - 204	38.8	17.7	22.1 - 89.5
26	25-May	07:02	24	0	0	159	14.4	134 - 181	38.9	10.3	25.2 - 55.2
27	26-May	01:00	21	0	1	154	14.9	133 - 194	36.7	10.5	22.3 - 69.3
28	27-May	19:00	23	0	0	163	17.6	136 - 194	41.4	13.6	23.9 - 71.4
29	28-May	19:00	24	0	0	158	12.4	138 - 188	40.0	10.3	24.6 - 67.0
30	29-May	01:00	24	0	0	160	11.8	129 - 178	39.9	8.6	22.5 - 54.7
31	30-May	06:59	23	0	0	160	15.3	135 - 206	40.0	11.4	24.9 - 77.3
32	31-May	12:58	23	1	0	152	12.0	132 - 182	35.8	8.6	24.8 - 56.1
Overall			740	18	2	154	14.2	128 - 206	36.2	10.7	21.5 - 89.5

Table A1.4. Summary of yearling Chinook salmon releases at The Dalles Dam ice and trash sluiceway tailrace during spring 2005. 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	30-Apr	19:48	22	1	0	152	10.9	140 - 178	34.1	7.6	25.2 - 56.2
2	1-May	07:42	23	1	0	152	9.2	140 - 173	34.0	6.5	24.7 - 50.2
3	2-May	13:35	24	0	0	154	9.2	140 - 182	34.8	7.1	24.9 - 56.8
4	3-May	01:35	23	1	0	152	13.9	135 - 204	35.6	12.2	24.5 - 84.9
5	4-May	19:34	22	2	0	150	14.3	130 - 184	34.5	11.2	22.6 - 64.3
6	5-May	01:40	22	2	0	152	12.8	135 - 176	36.0	9.7	25.2 - 56.8
7	6-May	13:21	21	2	0	147	8.7	135 - 174	33.1	6.9	24.5 - 56.0
8	7-May	07:31	22	2	0	151	7.7	140 - 166	35.0	6.0	26.3 - 48.8
9	8-May	13:24	23	0	1	152	7.9	138 - 166	34.2	5.9	26.5 - 46.1
10	9-May	01:54	24	1	0	151	9.3	135 - 173	34.1	6.6	24.5 - 56.5
11	10-May	19:17	23	1	0	148	15.9	126 - 204	33.0	12.2	21.6 - 81.5
12	11-May	07:24	23	1	0	151	14.8	135 - 180	35.1	10.2	22.4 - 60.2
13	12-May	19:20	23	1	0	159	16.0	136 - 189	39.1	11.5	23.8 - 63.3
14	13-May	01:15	21	2	0	159	17.1	133 - 186	39.7	12.2	23.0 - 62.3
15	14-May	13:24	24	0	0	151	14.6	134 - 209	33.6	11.4	23.8 - 82.5
16	15-May	07:18	24	0	0	150	12.5	128 - 191	32.3	9.1	21.8 - 66.9

Table A1.4. Continued.

						Fork Length (mm)			Weight (g)		
Release	Date	Time	N	Tag loss	Mortality	Mean	SD	Range	Mean	SD	Range
17	16-May	07:28	24	0	0	150	9.3	135 - 171	34.2	7.1	22.5 - 50.2
18	17-May	01:27	24	0	0	156	12.8	130 - 193	37.1	9.9	22.2 - 68.2
19	18-May	19:20	23	0	0	155	15.3	134 - 186	38.7	11.7	24.6 - 62.3
20	19-May	13:17	24	0	0	151	10.0	136 - 177	34.8	7.2	25.3 - 54.2
21	20-May	01:31	24	0	0	151	20.0	130 - 211	36.7	16.8	21.8 - 97.0
22	21-May	19:13	24	0	0	150	12.9	133 - 190	32.9	9.8	22.1 - 64.7
23	22-May	07:18	22	0	1	148	13.8	130 - 178	31.7	10.5	21.7 - 58.1
24	23-May	13:22	24	0	0	152	18.6	133 - 200	35.9	15.5	22.2 - 77.0
25	24-May	13:16	24	0	0	155	20.0	134 - 195	36.2	16.4	22.4 - 73.1
26	25-May	07:25	24	0	0	161	16.7	134 - 187	41.4	13.6	21.8 - 65.8
27	26-May	01:18	21	0	0	156	16.1	139 - 195	38.9	12.5	26.5 - 69.6
28	27-May	19:17	24	0	0	163	15.9	133 - 197	43.1	13.3	22.5 - 77.7
29	28-May	19:15	23	0	0	155	11.1	139 - 185	37.2	9.2	24.3 - 66.0
30	29-May	01:18	23	0	0	155	15.9	138 - 197	37.8	11.9	25.7 - 70.0
31	30-May	07:12	24	0	0	152	12.3	131 - 174	35.2	8.2	22.9 - 51.2
32	31-May	13:22	24	0	0	154	15.1	128 - 190	37.5	11.4	21.6 - 64.6
Overall			740	17	2	153	14.1	126 - 211	35.9	10.9	21.6 - 97.0

Table A1.5. Summary of subyearling Chinook salmon releases at the John Day Dam tailrace during summer 2005. 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	15-Jun	08:00	31	0	0	110	7.7	103 - 140	14.0	3.4	10.9 - 29.2
2	15-Jun	20:03	30	0	0	110	5.0	102 - 119	13.5	2.0	10.3 - 17.7
3	16-Jun	08:15	31	0	0	112	5.3	104 - 125	16.1	3.2	11.8 - 24.1
4	16-Jun	20:09	31	0	0	115	7.3	105 - 133	16.3	3.9	11.8 - 27.5
5	17-Jun	08:22	27	0	0	114	6.0	105 - 126	17.2	3.0	13.7 - 24.9
6	17-Jun	20:01	30	0	0	108	5.3	100 - 123	13.2	2.2	10.4 - 20.0
7	18-Jun	08:11	32	1	0	108	7.0	95 - 131	13.8	2.9	10.3 - 25.4
8	18-Jun	20:02	29	1	0	111	7.3	101 - 132	14.6	3.3	10.9 - 25.6
9	19-Jun	08:12	29	2	0	108	7.7	96 - 130	14.2	3.2	10.2 - 24.8
10	19-Jun	20:19	32	0	0	111	4.8	102 - 124	13.8	1.9	11.5 - 18.4
11	20-Jun	07:57	30	1	0	111	3.7	105 - 121	14.2	1.5	12.1 - 19.8
12	20-Jun	20:15	31	0	0	112	5.1	105 - 134	14.2	2.6	11.3 - 25.9
13	21-Jun	08:00	33	0	0	110	5.9	102 - 130	13.4	2.4	10.7 - 22.5
14	21-Jun	20:00	29	1	0	107	3.4	99 - 115	12.3	1.5	10.4 - 17.4
15	22-Jun	08:03	31	0	0	108	4.5	100 - 122	12.7	1.6	10.6 - 16.8
16	22-Jun	20:19	28	2	0	109	5.0	103 - 125	13.2	1.8	11.4 - 18.3
17	23-Jun	08:00	30	1	0	110	4.5	102 - 124	13.5	2.1	10.6 - 20.5
18	23-Jun	20:11	31	2	0	107	7.9	100 - 138	13.0	3.3	10.6 - 27.4
19	24-Jun	08:13	33	1	0	106	4.4	100 - 123	11.8	1.8	10.0 - 19.4
20	24-Jun	20:00	31	1	0	107	4.6	102 - 129	12.5	2.4	10.9 - 24.8
21	25-Jun	08:12	32	0	0	107	4.1	100 - 116	12.1	1.7	10.3 - 16.7
22	25-Jun	20:00	33	0	0	105	2.3	102 - 113	11.5	0.8	10.4 - 14.3
23	26-Jun	07:56	30	2	0	107	3.2	104 - 118	12.4	1.3	10.7 - 17.1
24	26-Jun	20:17	30	1	0	107	2.8	103 - 115	12.9	1.2	11.1 - 16.0

Table A1.5. Continued.

						Fork Length (mm)			Weight (g)		
Release	Date	Time	N	Tag loss	Mortality	Mean	SD	Range	Mean	SD	Range
25	27-Jun	08:05	31	0	0	110	5.8	102 - 127	13.4	2.3	10.5 - 19.5
26	27-Jun	20:00	29	1	0	108	8.5	100 - 135	13.5	3.2	10.9 - 23.3
27	28-Jun	08:00	27	2	0	105	3.7	100 - 113	11.5	1.4	10.0 - 16.2
28	28-Jun	20:20	33	0	0	107	6.7	100 - 130	12.9	2.9	10.4 - 24.1
29	29-Jun	08:00	31	0	0	110	9.2	99 - 132	14.2	4.3	10.0 - 28.3
30	29-Jun	20:06	29	2	0	108	5.6	100 - 119	12.6	2.0	10.2 - 18.4
31	30-Jun	08:08	30	0	0	108	5.0	101 - 124	12.8	2.5	10.6 - 21.3
32	30-Jun	20:11	32	0	0	110	7.8	101 - 131	14.5	3.7	11.2 - 26.1
33	1-Jul	07:54	31	1	0	110	5.4	103 - 126	13.8	2.3	10.8 - 19.9
34	1-Jul	20:08	31	0	0	108	6.1	98 - 128	13.0	2.6	10.0 - 22.7
35	2-Jul	07:55	32	0	0	109	7.2	99 - 133	13.8	3.2	10.3 - 25.9
36	2-Jul	19:56	33	0	0	113	6.5	103 - 128	15.4	3.3	11.7 - 24.6
37	3-Jul	08:09	30	0	0	109	5.9	100 - 129	13.7	2.5	10.6 - 22.3
38	3-Jul	20:20	31	0	0	110	8.4	102 - 140	15.3	3.9	11.4 - 31.0
39	4-Jul	08:26	31	0	0	110	8.4	99 - 140	14.0	4.4	10.6 - 32.6
40	4-Jul	19:53	31	0	0	114	11.5	100 - 145	15.9	5.7	10.5 - 33.4
41	5-Jul	08:21	30	0	0	113	8.3	101 - 133	15.5	3.9	10.9 - 26.4
42	5-Jul	20:15	31	0	0	110	6.3	100 - 125	14.2	2.5	11.1 - 20.5
43	6-Jul	08:20	32	0	0	108	6.5	97 - 131	13.6	2.5	10.5 - 23.2
44	6-Jul	20:22	31	0	0	110	6.8	99 - 126	14.4	2.6	10.7 - 21.7
45	7-Jul	08:10	28	0	0	108	4.8	100 - 124	13.4	2.1	10.6 - 20.7
46	7-Jul	20:08	31	0	0	107	5.7	99 - 120	13.1	2.2	10.6 - 19.0
47	8-Jul	07:58	31	0	0	107	7.9	98 - 135	13.2	3.9	10.2 - 30.4
48	8-Jul	19:56	31	0	0	108	5.5	99 - 125	13.0	2.5	10.3 - 21.2
49	9-Jul	08:07	30	0	0	105	5.9	95 - 121	13.2	2.3	11.1 - 21.8
50	9-Jul	19:50	31	0	0	105	5.7	98 - 122	12.3	2.3	10.3 - 19.7
51	10-Jul	08:10	32	0	0	108	7.0	100 - 128	15.4	3.0	11.6 - 23.7

Table A1.5. Continued.

						Fork Length (mm)			Weight (g)		
Release	Date	Time	N	Tag loss	Mortality	Mean	SD	Range	Mean	SD	Range
52	10-Jul	20:19	31	0	0	105	6.9	97 - 135	12.6	2.7	10.8 - 25.6
53	11-Jul	08:09	31	0	0	108	11.4	98 - 148	14.2	5.5	10.0 - 34.3
54	11-Jul	20:14	30	1	0	108	8.9	98 - 130	14.2	3.4	10.3 - 22.8
55	12-Jul	08:12	31	0	0	106	7.9	97 - 130	13.2	3.3	10.2 - 23.4
56	12-Jul	20:03	31	0	0	108	7.3	99 - 127	13.3	2.8	10.3 - 21.3
57	13-Jul	07:50	30	0	0	107	8.3	99 - 126	13.1	3.2	10.0 - 20.2
58	13-Jul	20:01	31	0	0	109	11.1	99 - 148	14.8	5.4	10.7 - 38.0
59	14-Jul	08:26	31	0	0	109	8.8	97 - 138	14.1	3.9	10.2 - 27.2
60	14-Jul	20:23	31	0	0	109	7.0	100 - 126	15.8	2.7	11.9 - 21.2
61	15-Jul	08:00	30	0	0	109	9.0	99 - 139	14.6	3.7	10.8 - 26.2
62	15-Jul	19:48	31	0	0	112	7.5	98 - 125	14.9	2.9	10.2 - 20.4
63	16-Jul	08:17	28	2	0	109	11.3	96 - 145	14.1	4.7	10.0 - 30.0
64	16-Jul	20:24	29	0	0	109	7.8	99 - 122	15.6	2.7	11.8 - 20.5
Overall			1959	25	0	109	7.1	95 - 148	13.8	3.2	10.0 - 38.0

Table A1.6. Summary of subyearling Chinook salmon releases at The Dalles Dam tailrace during summer 2005. 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	16-Jun	00:04	39	1	1	108	6.3	99 - 125	14.2	2.7	10.4 - 23.3
2	16-Jun	14:02	40	0	0	108	5.5	98 - 123	14.1	2.4	10.4 - 20.6
3	17-Jun	00:02	40	1	0	112	5.6	100 - 123	15.1	2.4	11.3 - 20.3
4	17-Jun	13:56	41	0	0	112	7.0	101 - 132	15.2	2.9	11.1 - 24.5
5	18-Jun	00:06	41	0	0	112	5.8	100 - 126	15.2	2.5	10.4 - 23.1
6	18-Jun	14:05	40	0	1	111	6.7	102 - 125	15.7	3.5	10.6 - 25.4
7	19-Jun	00:02	41	0	0	109	6.4	101 - 132	14.2	2.9	10.1 - 26.0
8	19-Jun	14:14	41	0	0	113	6.5	104 - 130	15.3	3.0	11.4 - 23.2
9	20-Jun	00:00	39	1	0	111	6.0	102 - 130	15.0	2.8	11.9 - 24.2
10	20-Jun	13:58	41	0	0	111	5.2	104 - 133	14.9	2.7	12.0 - 25.4
11	20-Jun	23:53	41	0	0	108	4.6	99 - 122	13.5	1.8	10.8 - 19.4
12	21-Jun	13:57	41	0	0	108	5.0	101 - 119	14.2	2.2	11.3 - 19.9
13	22-Jun	00:01	38	0	0	106	4.7	98 - 119	12.6	1.8	10.0 - 19.7
14	22-Jun	14:10	40	0	0	107	3.7	101 - 117	12.2	1.3	10.3 - 16.6
15	23-Jun	00:01	40	1	0	109	6.1	100 - 131	14.0	3.0	10.0 - 25.2
16	23-Jun	14:17	41	0	0	108	5.8	100 - 128	13.0	2.4	10.1 - 22.5
17	24-Jun	00:05	40	1	0	108	5.2	100 - 125	13.2	1.9	10.5 - 19.2
18	24-Jun	14:13	40	1	0	107	6.6	101 - 135	12.8	2.6	10.1 - 23.6
19	25-Jun	00:01	38	2	1	107	7.1	100 - 134	14.2	3.3	10.6 - 26.7
20	25-Jun	14:05	41	0	0	110	7.1	99 - 125	14.8	3.5	10.4 - 24.3
21	26-Jun	00:07	40	1	0	107	6.5	100 - 134	13.3	2.9	10.8 - 29.1
22	26-Jun	14:12	39	1	0	107	4.7	99 - 121	14.2	2.7	10.8 - 21.4
23	27-Jun	00:04	41	0	0	109	9.3	100 - 150	13.9	4.7	10.4 - 38.0
24	27-Jun	13:59	41	0	0	108	4.6	99 - 118	14.2	2.2	10.5 - 19.7

Table A1.6. Continued.

						Fork Length (mm)			Weight (g)		
Release	Date	Time	N	Tag loss	Mortality	Mean	SD	Range	Mean	SD	Range
25	28-Jun	00:02	29	2	0	105	5.2	96 - 123	12.4	2.8	10.0 - 23.1
26	28-Jun	14:00	41	0	0	103	5.0	97 - 122	12.0	1.9	10.0 - 19.2
27	29-Jun	00:00	40	1	0	108	6.9	100 - 134	13.4	3.2	10.8 - 27.5
28	29-Jun	13:58	40	0	0	106	5.0	99 - 119	13.0	2.0	10.4 - 19.4
29	30-Jun	00:00	41	0	0	104	3.7	99 - 112	12.1	1.5	10.0 - 16.3
30	30-Jun	14:04	40	0	1	107	5.0	100 - 123	12.4	2.2	10.0 - 20.8
31	30-Jun	23:51	40	0	1	109	6.1	102 - 127	15.1	3.4	11.0 - 25.6
32	1-Jul	14:00	40	1	0	106	7.1	95 - 136	13.4	3.4	10.5 - 29.4
33	2-Jul	00:06	40	1	0	106	6.8	95 - 125	13.8	3.3	10.1 - 23.7
34	2-Jul	13:59	41	0	0	110	8.9	100 - 138	14.2	4.2	10.3 - 30.4
35	3-Jul	00:01	40	1	0	108	7.3	100 - 132	15.2	3.3	11.9 - 26.5
36	3-Jul	14:08	41	0	0	109	6.9	100 - 128	15.2	2.8	11.8 - 23.9
37	4-Jul	00:01	40	1	0	106	5.5	97 - 120	13.1	2.1	10.5 - 19.5
38	4-Jul	13:55	40	1	0	106	8.0	98 - 138	13.9	4.0	11.0 - 30.2
39	5-Jul	00:01	40	1	0	110	8.8	99 - 135	15.0	4.0	10.7 - 26.6
40	5-Jul	14:06	40	0	1	112	8.8	100 - 135	15.8	4.1	11.1 - 27.5
41	6-Jul	00:02	40	1	0	108	8.0	97 - 133	14.7	3.6	10.6 - 27.5
42	6-Jul	14:07	41	0	0	110	6.2	99 - 126	14.7	2.2	11.0 - 19.4
43	6-Jul	23:56	41	0	0	107	6.5	100 - 131	15.0	3.0	11.9 - 26.4
44	7-Jul	14:01	40	1	0	110	8.5	97 - 136	14.9	4.0	10.7 - 29.7
45	8-Jul	00:00	41	0	0	108	7.6	97 - 123	15.2	3.1	10.8 - 22.8
46	8-Jul	14:02	41	0	0	105	8.6	96 - 142	13.2	3.9	10.4 - 32.4
47	9-Jul	00:04	39	2	0	104	6.5	97 - 129	13.0	2.7	10.3 - 24.8
48	9-Jul	13:56	40	0	1	107	9.2	97 - 138	14.7	4.0	10.2 - 28.9
49	10-Jul	00:00	40	1	0	106	6.8	97 - 131	13.1	2.8	10.3 - 25.2
50	10-Jul	14:09	41	0	0	106	8.9	96 - 132	13.7	3.6	10.0 - 24.7
51	11-Jul	00:00	39	0	2	105	5.9	96 - 123	13.5	2.1	10.8 - 20.4

Table A1.6. Continued.

						Fork Length (mm)			Weight (g)		
Release	Date	Time	N	Tag loss	Mortality	Mean	SD	Range	Mean	SD	Range
52	11-Jul	13:58	41	0	0	108	8.4	97 - 136	15.2	3.8	10.4 - 26.6
53	12-Jul	00:00	40	0	0	108	9.9	98 - 135	14.4	4.0	10.7 - 26.4
54	12-Jul	14:20	39	2	0	105	6.4	98 - 124	13.2	2.6	10.3 - 21.6
55	13-Jul	00:04	39	1	1	106	10.8	96 - 138	13.9	4.6	10.0 - 28.1
56	13-Jul	14:01	41	0	0	106	10.8	96 - 148	14.3	5.5	10.2 - 40.2
57	13-Jul	23:56	40	1	0	108	10.6	95 - 147	14.9	5.0	10.3 - 37.9
58	14-Jul	13:57	41	0	0	107	8.5	97 - 134	13.7	3.6	10.3 - 25.6
59	15-Jul	00:10	40	0	1	106	7.0	94 - 125	13.9	2.3	10.7 - 18.7
60	15-Jul	13:53	42	0	0	109	8.2	98 - 131	14.3	3.2	10.5 - 25.4
61	16-Jul	00:02	40	1	1	109	6.9	96 - 121	15.2	3.5	10.0 - 22.2
62	16-Jul	13:58	42	0	0	110	9.6	95 - 134	14.8	3.7	10.1 - 26.9
63	17-Jul	00:10	45	0	0	107	8.8	98 - 126	14.1	3.5	10.2 - 22.4
64	17-Jul	14:13	49	0	0	104	6.7	95 - 127	12.8	3.0	10.1 - 22.2
Overall			2579	29	12	108	7.3	94 - 150	14.1	3.3	10.0 - 40.2

Table A1.7. Summary of subyearling Chinook salmon releases at The Dalles Dam ice and trash sluiceway during summer 2005. 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	16-Jun	01:00	30	1	0	109	6.6	98 - 125	13.8	2.5	10.2 - 23.2
2	17-Jun	06:56	31	0	0	113	8.2	102 - 137	16.0	3.9	11.2 - 30.7
3	18-Jun	19:00	31	0	0	109	5.5	100 - 121	14.0	2.0	10.3 - 18.1
4	19-Jun	13:00	30	1	0	112	8.9	100 - 145	15.3	5.1	10.8 - 36.3
5	20-Jun	06:59	31	0	0	109	3.7	103 - 121	14.4	1.5	11.6 - 19.2
6	21-Jun	18:59	28	0	0	104	2.9	99 - 113	12.1	1.2	10.0 - 15.3
7	22-Jun	00:59	30	0	0	107	7.0	100 - 129	13.5	2.9	10.1 - 22.4
8	23-Jun	13:00	31	0	0	107	4.6	98 - 119	12.6	1.6	10.2 - 16.6
9	24-Jun	07:00	31	0	0	106	3.4	101 - 116	12.2	1.5	10.3 - 17.2
10	25-Jun	19:05	31	0	0	108	7.6	98 - 131	13.4	3.7	10.3 - 27.8
11	26-Jun	13:00	31	0	0	108	3.7	102 - 115	14.0	1.9	10.3 - 17.8
12	27-Jun	00:00	31	0	0	107	6.3	96 - 125	12.9	2.9	10.0 - 24.0
13	28-Jun	07:00	30	1	0	103	3.7	95 - 112	11.7	1.2	10.1 - 15.3
14	29-Jun	18:58	31	0	0	107	8.3	99 - 131	13.8	3.9	10.2 - 26.7
15	30-Jun	12:56	31	0	0	109	9.2	100 - 138	13.7	4.5	10.3 - 29.7
16	1-Jul	00:57	30	0	0	111	7.6	102 - 132	16.7	4.6	10.5 - 28.3

Table A1.7. Continued.

						Fork Length (mm)			Weight (g)		
Release	Date	Time	N	Tag loss	Mortality	Mean	SD	Range	Mean	SD	Range
17	2-Jul	07:00	31	0	0	107	3.9	100 - 117	13.0	1.4	10.5 - 16.4
18	3-Jul	12:54	29	2	0	111	8.5	101 - 138	15.8	4.1	12.2 - 29.0
19	4-Jul	19:02	30	0	1	107	5.2	99 - 121	13.5	2.0	10.6 - 19.5
20	5-Jul	01:03	30	1	0	109	9.8	96 - 137	14.9	4.3	10.3 - 28.7
21	6-Jul	12:55	31	0	0	112	9.0	98 - 133	16.0	4.1	10.8 - 25.1
22	7-Jul	07:00	31	0	0	109	8.7	98 - 134	14.6	3.8	10.6 - 27.1
23	8-Jul	00:59	31	0	0	107	9.3	95 - 130	15.1	3.9	10.6 - 25.7
24	9-Jul	18:56	31	0	0	105	5.8	95 - 118	12.7	2.1	10.2 - 17.8
25	10-Jul	00:57	30	0	1	103	4.4	95 - 113	12.0	1.3	10.5 - 15.4
26	11-Jul	07:00	28	2	1	105	5.8	97 - 117	13.9	3.3	10.2 - 23.2
27	12-Jul	12:57	31	0	0	102	3.9	98 - 114	12.4	1.5	10.3 - 16.3
28	13-Jul	18:52	30	0	0	108	8.0	96 - 129	14.4	3.4	10.1 - 22.6
29	14-Jul	06:58	31	0	0	107	10.1	95 - 139	13.9	4.2	10.0 - 28.9
30	15-Jul	19:00	32	0	0	110	11.6	97 - 153	15.9	5.8	10.6 - 38.9
31	16-Jul	01:02	32	0	0	110	10.1	96 - 144	15.4	4.1	10.1 - 29.0
32	17-Jul	12:57	33	0	1	107	8.5	96 - 133	13.6	3.1	10.1 - 24.5
Overall			979	8	4	108	7.6	95 - 153	14.0	3.5	10.0 - 38.9

Table A1.8. Summary of subyearling Chinook salmon releases at The Dalles Dam ice and trash sluiceway tailrace during summer 2005. 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	16-Jun	01:16	30	1	0	109	8.2	98 - 138	14.3	4.1	10.1 - 32.4
2	17-Jun	07:26	30	0	1	110	7.6	101 - 135	14.7	3.2	11.2 - 23.2
3	18-Jun	19:15	31	0	0	107	5.8	100 - 125	13.3	2.0	10.8 - 18.7
4	19-Jun	13:27	31	0	0	110	5.3	100 - 122	14.4	2.7	10.8 - 20.7
5	20-Jun	07:11	30	0	0	110	5.9	104 - 133	14.5	3.0	12.0 - 27.8
6	21-Jun	19:18	30	0	0	104	3.9	96 - 114	12.1	1.3	10.0 - 15.6
7	22-Jun	01:24	30	0	0	106	5.0	100 - 124	13.0	2.1	10.4 - 20.0
8	23-Jun	13:19	31	0	0	107	4.3	100 - 117	12.5	1.5	10.1 - 16.7
9	24-Jun	07:16	31	0	0	107	6.5	100 - 133	13.1	3.1	10.8 - 25.6
10	25-Jun	19:29	29	2	0	105	4.2	95 - 114	12.4	1.4	10.5 - 15.4
11	26-Jun	13:17	31	0	0	107	4.0	99 - 119	14.0	2.4	11.2 - 22.2
12	27-Jun	01:22	31	0	0	107	4.3	101 - 119	13.1	2.0	10.3 - 18.9
13	28-Jun	07:14	31	0	0	104	5.2	96 - 121	12.5	2.2	10.0 - 21.0
14	29-Jun	19:23	31	0	0	105	3.4	100 - 114	12.3	1.5	10.4 - 16.3
15	30-Jun	13:17	30	0	0	106	5.3	98 - 126	12.0	1.8	10.0 - 20.2
16	1-Jul	01:26	31	0	0	109	6.1	99 - 129	15.7	3.5	11.0 - 25.8

Table A1.8. Continued.

						Fork Length (mm)			Weight (g)		
Release	Date	Time	N	Tag loss	Mortality	Mean	SD	Range	Mean	SD	Range
17	2-Jul	07:19	31	0	0	111	8.4	101 - 141	14.3	4.3	10.6 - 32.2
18	3-Jul	13:13	31	0	0	111	7.1	104 - 133	15.4	4.0	11.8 - 29.6
19	4-Jul	19:17	31	0	0	111	10.0	98 - 136	15.2	4.9	10.9 - 29.8
20	5-Jul	01:18	31	0	0	107	8.1	96 - 129	14.0	3.4	10.5 - 25.0
21	6-Jul	13:19	31	0	0	107	6.5	99 - 127	13.9	2.7	10.8 - 22.4
22	7-Jul	07:18	30	0	0	108	9.3	99 - 144	14.1	4.7	10.5 - 34.7
23	8-Jul	01:19	31	0	0	105	5.5	97 - 120	13.9	2.0	11.1 - 19.3
24	9-Jul	19:09	31	0	0	107	7.9	97 - 125	13.7	3.0	10.0 - 20.2
25	10-Jul	01:20	30	0	1	104	4.7	100 - 118	12.4	1.8	10.5 - 18.9
26	11-Jul	07:19	31	0	0	108	10.0	97 - 139	15.5	4.8	10.1 - 31.5
27	12-Jul	13:17	29	2	0	103	5.0	97 - 120	12.6	2.4	10.3 - 21.6
28	13-Jul	19:17	31	0	0	109	12.2	96 - 151	15.0	5.8	10.4 - 40.5
29	14-Jul	07:16	30	0	0	103	5.3	96 - 115	12.4	2.0	10.2 - 17.4
30	15-Jul	19:18	31	0	1	111	8.3	92 - 131	15.8	3.7	10.0 - 24.4
31	16-Jul	01:16	31	0	0	107	6.8	97 - 121	14.3	3.0	10.7 - 20.5
32	17-Jul	13:19	30	3	0	104	8.1	94 - 132	12.8	3.1	10.4 - 25.3
Overall			978	8	3	107	7.1	92 - 151	13.7	3.3	10.0 - 40.5

Table A1.9. Summary of yearling (CH1) and subyearling (CH0) Chinook salmon dead fish releases at The Dalles Dam tailrace during 2005. Species, dates, times, numbers of dead tagged fish released (N), 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	Species	Date	Time	N	Mean	SD	Range	Mean	SD	Range
1	CH1	2-May	23:56	4	152	3.7	146 - 154	35.7	4.2	30.4 - 40.3
2	CH1	3-May	13:58	3	154	22.8	140 - 180	36.9	15.9	27.6 - 55.3
3	CH1	10-May	00:13	4	152	13.6	138 - 166	35.8	9.9	27.6 - 48.2
4	CH1	10-May	14:08	4	154	21.4	140 - 185	39.9	21.2	25.8 - 71.3
5	CH1	22-May	00:02	3	146	11.0	135 - 157	29.2	4.6	25.2 - 34.2
6	CH1	22-May	13:59	4	143	10.2	135 - 158	29.1	7.5	24.4 - 40.2
7	CH1	26-May	23:57	4	156	12.5	140 - 170	35.8	6.8	28.2 - 44.8
8	CH1	27-May	14:22	4	150	7.9	140 - 156	32.5	4.3	27.1 - 37.4
Overall	CH1			30	151	12.8	135 - 185	34.4	10.1	24.4 - 71.3
1	CH0	18-Jun	00:09	3	114	7.8	109 - 123	16.1	1.6	14.7 - 17.8
2	CH0	18-Jun	14:06	3	112	6.2	107 - 119	14.7	1.6	13.5 - 16.5
3	CH0	27-Jun	00:04	4	106	4.0	104 - 112	12.8	1.6	11.2 - 15.0
4	CH0	27-Jun	13:58	4	110	4.3	106 - 116	15.5	2.3	13.4 - 18.6
5	CH0	4-Jul	23:57	4	110	3.7	105 - 114	14.3	1.6	12.6 - 16.3
6	CH0	5-Jul	14:04	4	110	5.5	103 - 115	15.4	3.0	12.0 - 18.4
7	CH0	15-Jul	00:09	4	114	12.8	99 - 127	17.6	6.2	10.2 - 25.2
8	CH0	15-Jul	13:54	4	105	3.4	102 - 109	13.3	1.5	11.3 - 14.8
Overall	CH0			30	110	6.6	99 - 127	14.9	3.0	10.2 - 25.2

Appendix 2: 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, Cowen and Schwartz 2005). 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 2005 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) at the beginning, middle, and end of the study period for both spring (n=75) and summer (n=75) survival studies were taken. Lotek Wireless Model NTC-3-1 KMF transmitters were used during the spring tag-life study and Lotek model NTC-M-2 transmitters were used during the summer tag-life study, corresponding to what was used for the survival studies. Transmitters were secured 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 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.

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. 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 (≈ 24 hours), so the elapsed time a tag was operating before release was added to travel times.

Results and Discussion

For spring (Model NTC-3-1 KMF), tag-failure began around day 8 and continued until day 13 (Figure A2.1). The average tag-life was 9.62 days. For the summer tag-life study, the majority of radio-tags (model NTC-M-2) began to fail at days 7-8 and continued to day 14, averaging 9.81 days (Figure A2.1). There was one radio-tag for the summer study where transmission ceased around day 3, and a few that were no longer operational between days 6-8 of the study.

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 A2.1, Table A2.1).

In our study, the probability a tag was operational at downstream arrays was high, with all probabilities being greater than 0.999 (Table A2.2). 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 A2.2).

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 A2.2), we did not adjust our survival estimates.

References

Cowen, L. and C. J. Schwarz. 2005. Capture-recapture studies using radio telemetry with premature radio-tag failure. Biometrics. 61:657.

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.

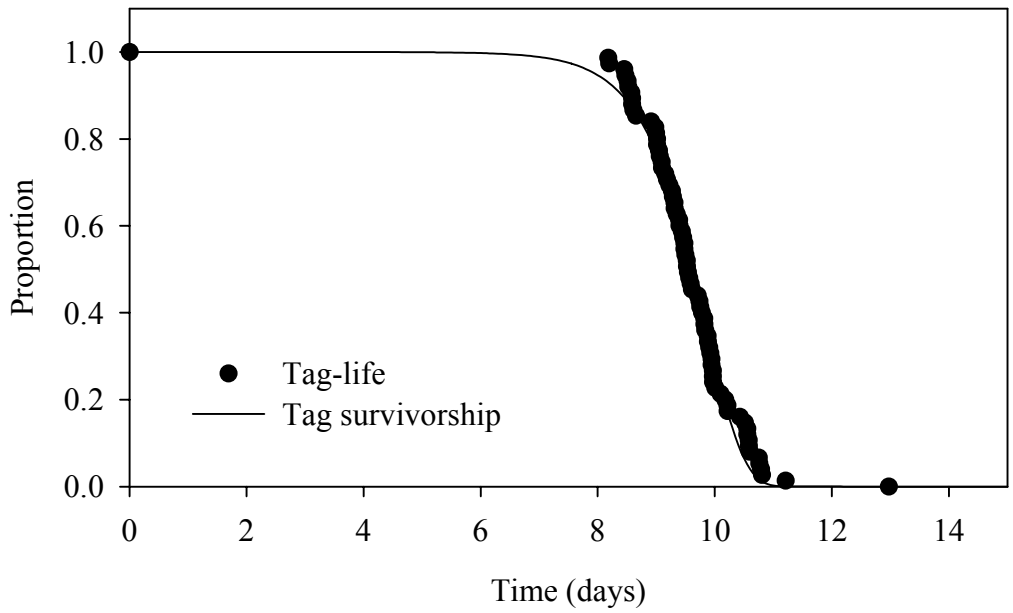
Table A2.1. Parameter estimates for tag-life using the Gompertz model during spring and summer during 2005, model estimate and (SE).

Tag-life Study	N	α	β	R^2
Spring	75	1.5648 (0.1346)	3.136×10^{-7} (3.813×10^{-7})	0.9556
Summer	75	1.1618 (0.0962)	7.747×10^{-6} (6.856×10^{-6})	0.9554

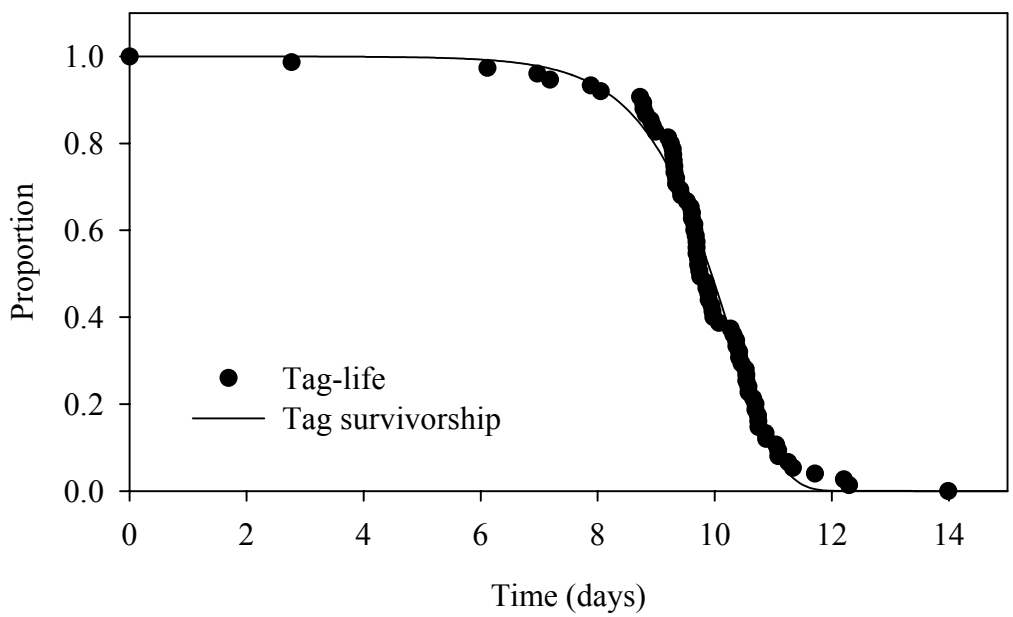
Table A2.2. Estimated probabilities (mean, SE in parentheses) a radio-tag was operational at The Dalles Dam and other downstream detection arrays during 2005, A) yearling Chinook salmon, spring, B) subyearling Chinook salmon, summer.

A) Yearling Chinook salmon	Detection Array Locations	
Release Site	The Dalles Dam	Survival Gates
John Day Dam Tailrace (Treatment)	1.000 (1.902×10^{-7})	1.000 (1.267×10^{-5})
The Dalles Dam Tailrace (Control)	NA	1.000 (1.935×10^{-5})

B) Subyearling Chinook salmon	Detection Array Locations	
Release Site	The Dalles Dam	Survival Gates
John Day Dam Tailrace (Treatment)	1.000 (4.859×10^{-7})	0.9999 (2.364×10^{-5})
The Dalles Dam Tailrace (Control)	NA	1.000 (4.303×10^{-7})

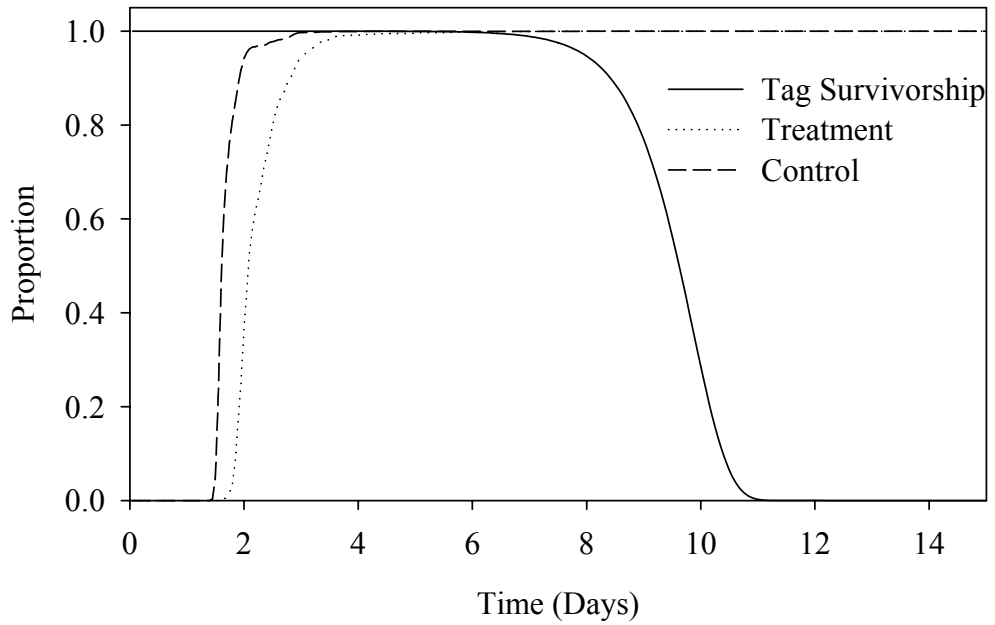


A) Spring

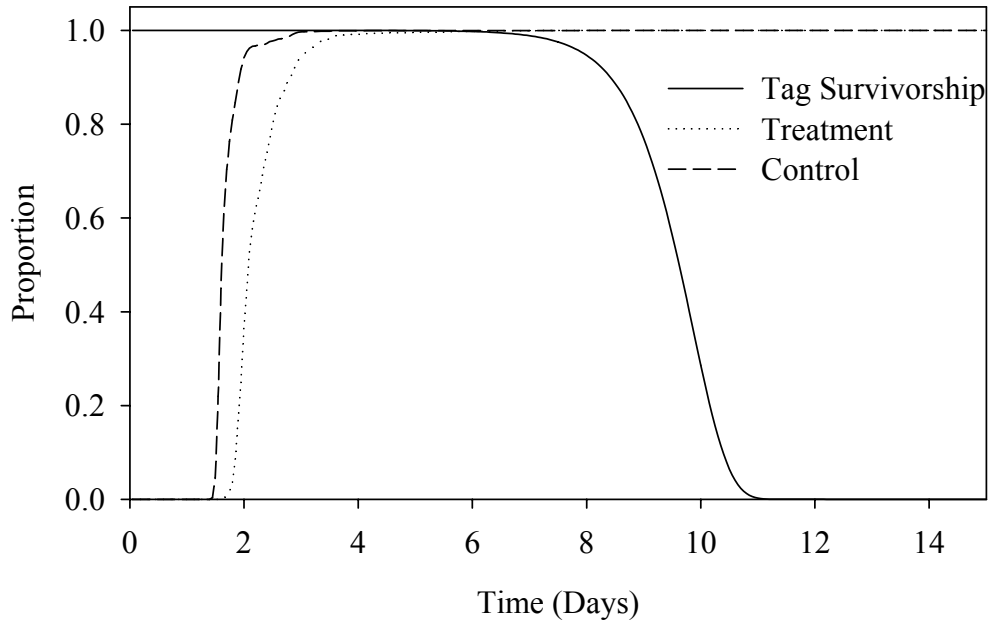


B) Summer

Figure A2.1. 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 A2.2. Probability distributions for radio-tags being operational over time with cumulative arrival distributions at downstream survival gates for The Dalles Dam survival assessment during 2005.

Appendix 3: Post-hoc spillbay survival analysis

At the request of the ACOE Portland District, a post-hoc evaluation of survival through The Dalles Dam spillway in 2005 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 training wall. Data used in the post-hoc analysis were from fish tagged and released as part of the 2005 USGS survival study at The Dalles Dam; details regarding the radio-telemetry system configuration, and fish tagging and release procedures can be found in this report.

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 this 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 or 5-6 based on interrogations on underwater antennas at the spillway. After assigning fish to spillbay groupings, fish were temporally combined into 2 day blocks based on their passage time. A block started at 18:00 hours and ended 48 hours later at 17:59. The new release groups were then paired with groupings of control releases that were made within the corresponding time frame (Tables A3.1 - A3.4).

We used the paired release-recapture models of Burnham et al. (1987) to estimate the survival of yearling and subyearling Chinook salmon for the post-hoc evaluation of survival through spillbays 1-4 and 5-6 at The Dalles Dam. The assumptions associated with using the paired release-recapture model to estimate survival are the same as the first nine assumptions of the route-specific model and are discussed in this report starting on page 9.

Spillbay specific survival estimates

Yearling Chinook salmon

We estimated that the survival of yearling Chinook salmon through spillbays 1-4 ranged from 0.786 to 1.028 (Table A3.1 and Figure A3.1), and averaged 0.967 (*SE* = 0.017, 95% confidence interval = [0.931, 1.003]) (Table A3.5). The estimated survival through spillbays 5-6 ranged from 0.857 to 1.016 (Table A3.2 and Figure A3.1), and averaged 0.933 (*SE* = 0.016, 95% confidence interval [0.899, 0.966]) (Table A3.5).

Subyearling Chinook salmon

We estimated that the survival of subyearling Chinook salmon through spillbays 1-4 ranged from 0.889 to 1.037 (Table A3.3 and Figure A3.1), and averaged 0.972 (*SE* = 0.011, 95% confidence interval [0.950, 0.995]) (Table A3.5). The estimated survival through spillbays 5-6 ranged from 0.694 to 1.029 (Table A3.4 and Figure A3.1), and averaged 0.887 (*SE* = 0.021, 95% confidence interval [0.843, 0.930]) (Table A3.5).

Table A3.1. The estimated survival probabilities (S), standard errors (SE), 95% confidence intervals, sample sizes (N; number of fish), and dates and times associated with 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 from fish released into the John Day Dam tailrace (treatment) and in The Dalles Dam tailrace (control) during 2005.

Release	S	SE	95% CI	Treatment N	Control N	Start date	time	End date	time
1	0.786	0.120	0.552, 1.020	13	182	29 Apr	18:00	01 May	17:59
2	1.018	0.010	0.998, 1.039	16	171	01 May	18:00	03 May	17:59
3	1.028	0.014	1.001, 1.055	28	173	03 May	18:00	05 May	17:59
4	1.000	0.074	0.855, 1.145	23	164	05 May	18:00	07 May	17:59
5	1.000	0.087	0.830, 1.170	19	174	07 May	18:00	09 May	17:59
6	1.000	0.095	0.814, 1.186	17	173	09 May	18:00	11 May	17:59
7	1.005	0.006	0.993, 1.017	23	177	11 May	18:00	13 May	17:59
8	0.961	0.042	0.879, 1.042	24	182	13 May	18:00	15 May	17:59
9	0.959	0.056	0.850, 1.068	18	185	15 May	18:00	17 May	17:59
10	1.020	0.011	0.998, 1.043	17	185	17 May	18:00	19 May	17:59
11	0.916	0.061	0.795, 1.036	22	183	19 May	18:00	21 May	17:59
12	0.916	0.056	0.805, 1.026	30	185	21 May	18:00	23 May	17:59
13	0.989	0.056	0.879, 1.098	19	185	23 May	18:00	25 May	17:59
14	1.010	0.008	0.994, 1.026	17	179	25 May	18:00	27 May	17:59
15	0.902	0.080	0.744, 1.059	17	232	27 May	18:00	30 May	17:59

Table A3.2. The estimated survival probabilities (S), standard errors (SE), 95% confidence intervals, sample sizes (N; number of fish), and dates and times associated with 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 from fish released into the John Day Dam tailrace (treatment) and in The Dalles Dam tailrace (control) during 2005.

Release	S	SE	95% CI	Treatment N	Control N	Start date	time	End date	time
1	0.985	0.038	0.910, 1.060	27	182	29 Apr	18:00	01 May	17:59
2	0.982	0.037	0.909, 1.054	28	171	01 May	18:00	03 May	17:59
3	0.857	0.079	0.702, 1.012	24	173	03 May	18:00	05 May	17:59
4	0.944	0.068	0.811, 1.077	40	164	05 May	18:00	07 May	17:59
5	0.869	0.052	0.767, 0.971	44	174	07 May	18:00	09 May	17:59
6	1.000	0.046	0.910, 1.090	40	173	09 May	18:00	11 May	17:59
7	0.880	0.060	0.764, 0.997	32	177	11 May	18:00	13 May	17:59
8	0.859	0.055	0.750, 0.967	41	182	13 May	18:00	15 May	17:59
9	1.016	0.009	0.998, 1.034	42	185	15 May	18:00	17 May	17:59
10	0.884	0.060	0.766, 1.001	36	185	17 May	18:00	19 May	17:59
11	1.005	0.005	0.995, 1.015	38	183	19 May	18:00	21 May	17:59
12	0.912	0.058	0.797, 1.026	29	185	21 May	18:00	23 May	17:59
13	0.957	0.049	0.862, 1.053	37	185	23 May	18:00	25 May	17:59
14	0.983	0.029	0.925, 1.040	35	179	25 May	18:00	27 May	17:59
15	0.861	0.061	0.741, 0.981	38	232	27 May	18:00	30 May	17:59

Table A3.3. The estimated survival probabilities (S), standard errors (SE), 95% confidence intervals, sample sizes (N; number of fish), and dates and times associated with 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 from fish released into the John Day Dam tailrace (treatment) and in The Dalles Dam tailrace (control) during 2005.

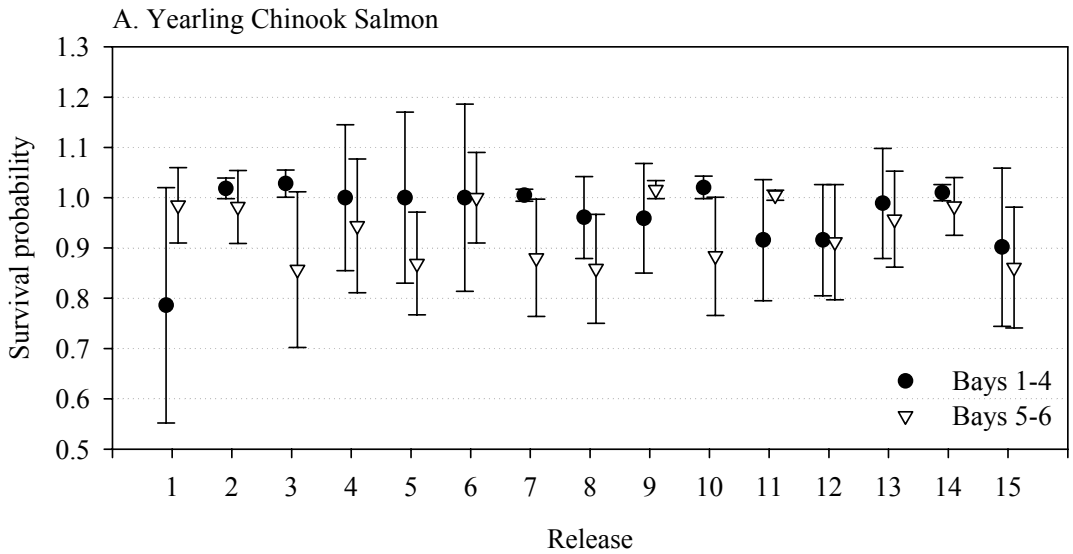
Release	S	SE	95% CI		Treatment N	Control N	Start date	time	End date	time
1	0.989	0.039	0.912,	1.065	28	160	15 Jun	18:00	17 Jun	17:59
2	0.977	0.054	0.871,	1.084	19	163	17 Jun	18:00	19 Jun	17:59
3	1.000	0.117	0.771,	1.229	13	162	19 Jun	18:00	21 Jun	17:59
4	0.969	0.044	0.882,	1.055	23	159	21 Jun	18:00	23 Jun	17:59
5	0.932	0.064	0.807,	1.057	22	159	23 Jun	18:00	25 Jun	17:59
6	1.037	0.054	0.931,	1.143	33	161	25 Jun	18:00	27 Jun	17:59
7	0.995	0.057	0.884,	1.106	28	150	27 Jun	18:00	29 Jun	17:59
8	0.908	0.069	0.772,	1.044	33	161	29 Jun	18:00	01 Jul	17:59
9	0.981	0.053	0.877,	1.085	20	162	01 Jul	18:00	03 Jul	17:59
10	1.012	0.046	0.923,	1.102	26	160	03 Jul	18:00	05 Jul	17:59
11	0.972	0.072	0.831,	1.114	21	162	05 Jul	18:00	07 Jul	17:59
12	1.035	0.016	1.004,	1.067	18	161	07 Jul	18:00	09 Jul	17:59
13	0.923	0.069	0.787,	1.059	20	161	09 Jul	18:00	11 Jul	17:59
14	0.963	0.036	0.892,	1.033	20	159	11 Jul	18:00	13 Jul	17:59
15	0.972	0.048	0.877,	1.066	21	163	13 Jul	18:00	15 Jul	17:59
16	0.889	0.077	0.738,	1.039	22	176	15 Jul	18:00	17 Jul	17:59

Table A3.4. The estimated survival probabilities (S), standard errors (SE), 95% confidence intervals, sample sizes (N; number of fish), and dates and times associated with 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 from fish released into the John Day Dam tailrace (treatment) and in The Dalles Dam tailrace (control) during 2005.

Release	S	SE	95% CI		Treatment N	Control N	Start date	time	End date	time
1	0.823	0.074	0.678,	0.968	31	160	15 Jun	18:00	17 Jun	17:59
2	0.956	0.044	0.869,	1.043	41	163	17 Jun	18:00	19 Jun	17:59
3	0.898	0.047	0.806,	0.989	41	162	19 Jun	18:00	21 Jun	17:59
4	0.694	0.080	0.538,	0.851	35	159	21 Jun	18:00	23 Jun	17:59
5	0.952	0.039	0.876,	1.029	46	159	23 Jun	18:00	25 Jun	17:59
6	0.972	0.054	0.867,	1.077	41	161	25 Jun	18:00	27 Jun	17:59
7	1.029	0.048	0.934,	1.123	25	150	27 Jun	18:00	29 Jun	17:59
8	0.894	0.075	0.746,	1.042	30	161	29 Jun	18:00	01 Jul	17:59
9	0.940	0.058	0.827,	1.053	31	162	01 Jul	18:00	03 Jul	17:59
10	0.872	0.072	0.731,	1.013	34	160	03 Jul	18:00	05 Jul	17:59
11	0.951	0.051	0.852,	1.051	53	162	05 Jul	18:00	07 Jul	17:59
12	0.886	0.053	0.783,	0.989	54	161	07 Jul	18:00	09 Jul	17:59
13	0.844	0.059	0.728,	0.960	45	161	09 Jul	18:00	11 Jul	17:59
14	0.818	0.059	0.703,	0.934	47	159	11 Jul	18:00	13 Jul	17:59
15	0.868	0.048	0.774,	0.962	56	163	13 Jul	18:00	15 Jul	17:59
16	0.790	0.063	0.666,	0.914	48	176	15 Jul	18:00	17 Jul	17:59

Table A3.5. 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 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 2005.

Species	Spillbays	S	SE	95% CI	N
Yearling Chinook	1-4	0.967	0.017	[0.931, 1.003]	15
	5-6	0.933	0.016	[0.899, 0.966]	15
Subyearling Chinook	1-4	0.972	0.011	[0.950, 0.995]	16
	5-6	0.887	0.021	[0.843, 0.930]	16



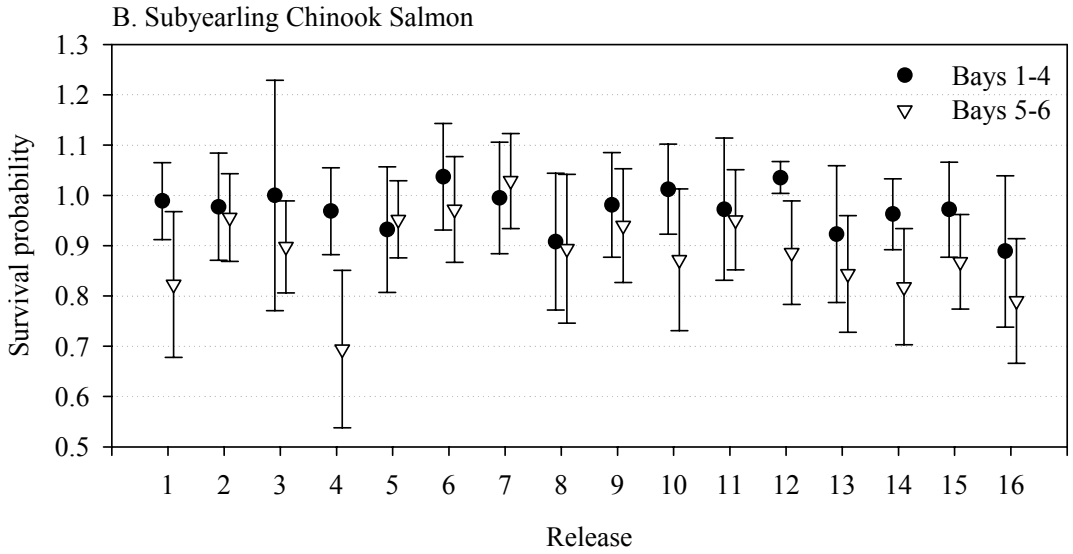


Figure A3.1. The estimated survival probabilities (95% CI error bars) of (A) yearling and (B) subyearling Chinook salmon passing through spillbays 1-4 (closed circles) and 5-6 (open triangles) at The Dalles Dam spillway by release. Release groupings were formed post-hoc.

Appendix 4: Study Summary

Year	2005					
Study Site	The Dalles Dam					
Objectives	Estimate the survival probabilities of yearling and subyearling Chinook salmon at The Dalles Dam during 40% spill operations using the route specific survival model and the triple release model. Estimates were generated for the spillway, ice and trash sluiceway, turbines and the dam overall.					
Fish species and source	Hatchery yearling and subyearling Chinook Salmon collected from John Day smolt monitoring facility					
Fish size	Yearling Chinook salmon			Subyearling Chinook Salmon		
		Length (mm)	Weight (g)		Length (mm)	Weight (g)
	Min	126	21.5	Min	92	10.0
	Max	261	97.9	Max	158	40.5
	Mean	154	36.3	Mean	108	13.9
	Median	151	33.4	Median	106	13.0
Tags		Yearling Chinook		Subyearling Chinook		
	Type	Lotek Engineering, Radio tag		Lotek Engineering, Radio tag		
	Model	NTC-3-1-KMF		NTC-M-2		
	Weight (g, in air)	0.98		0.43		
Tag procedure	Gastrically implanted					
Route-specific survival model estimates for yearling Chinook salmon	Species: CH1 Model: RSSM	Survival	SE	Total # of fish released	# of releases	
	Pool	0.956	0.006	R_1=1469 R_2=2871	R_1=63 R_2=64	
	Turbines	0.838	0.032			
	Sluiceway	1.006	0.007			
	Spillway	0.938	0.008			
	Dam	0.933	0.008			
Route-specific survival model estimates for subyearling Chinook salmon	Species: CH0 Model: RSSM	Survival	SE	Total # of fish released	# of releases	
	Pool	0.947	0.006	R_1=1959 R_2=2579	R_1=64 R_2=64	
	Turbines	0.796	0.027			
	Sluiceway	0.931	0.037			
	Spillway	0.925	0.009			
	Dam	0.900	0.009			
Triple-release model estimates for yearling Chinook salmon	Species: CH1 Model: 3R	Survival	SE	Total # of fish released	# of releases	
	Turbines	0.809	0.038	As above + 740 above & 740 below sluiceway	As above + 32 paired sluiceway releases	
	Sluiceway	1.004	0.007			
	Spillway	0.936	0.012			
	Dam	0.933	0.018			

Triple-release model estimates for subyearling Chinook salmon	Species: CH0 Model: 3R	Survival	SE	Total # of fish released	# of releases
	Turbines	0.804	0.044	As above + 979 above & 978 below sluiceway	As above + 32 paired sluiceway releases
	Sluiceway	0.962	0.013		
	Spillway	0.955	0.041		
	Dam	0.933	0.036		
Environmental/ Operating conditions		Yearling Chinook		Subyearling Chinook	
		mean	range	mean	range
	Avg. daily temperature (°C)	13.4	11.2 - 15.2	18.4	16.3 - 20.4
	Avg. hourly total discharge (kcfs)	223	112 - 308	181	103 - 320
	Avg. hourly spill discharge (kcfs)	74	50 - 85	67	0 - 82
	Avg. hourly spill discharge (%)	34	21 - 61	38	0 - 50
Unique study characteristics	Spillway operations in spring and summer of 2005 differed from previous years due to a problem with structural components of the tainter gates. Prior to the 2005 spill season (10 April – 31 August), an inspection of the spill-gate wire ropes used to raise and lower the gates revealed that some were unsafe for operation (Brad Eppard, ACOE Portland District, personal communication). Spillbays 3-9 and 11-13 were deemed inoperable. The U. S. Army Corps of Engineers designed and installed pendant cables in bays 3-6 to facilitate a spill level of 40% through bays 1-6. Three lengths of pendant cables were used to suspend the spill gates and provide gate openings to maintain approximately 40% spill at forecasted river flows. While spillbays 3-6 were at 1 of 3 gate openings, spillbays 1 and 2 were used to allow for some adjustment in spill levels.				