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Survival Estimates of Migrant Juvenile Salmonids through Bonneville Dam Using Radio Telemetry, 2005

Final Report of Research

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During 2005, we evaluated the survival of radio-tagged yearling and subyearling Chinook salmon and steelhead trout through the Bonneville Dam spillway, powerhouses 1 and 2, the corner collector and juvenile bypass system (JBS) at powerhouse 2, and through all routes collectively using the route-specific survival model. Radio-tagged fish were released at The Dalles Dam and in the tailrace of Bonneville Dam and were interrogated at Bonneville Dam and three radio-telemetry arrays below Bonneville Dam. We also evaluated the survival of radio-tagged yearling and subyearling Chinook salmon and steelhead trout using paired releases through the ice and trash sluiceway at Bonneville Dam's powerhouse 1. Site-specific releases were made directly into the ice and trash sluiceway and in the tailrace of Bonneville Dam below the outfall of powerhouse 2 juvenile bypass system.

Yearling Chinook salmon

Route-specific Survival Model

The survival of yearling Chinook salmon through Bonneville Dam spillway was estimated to be 0.930 (*SE* = 0.009, profile likelihood 95% confidence interval [0.912, 0.947]). For yearling Chinook salmon passing via powerhouse 1, the estimated survival was 0.950 (*SE* = 0.017, profile likelihood 95% confidence interval [0.912, 0.980]) and for yearling Chinook salmon passing via the powerhouse 2 turbines, the estimated survival was 0.965 (*SE* = 0.009, profile likelihood 95% confidence interval [0.947, 0.982]). For yearling Chinook salmon passing via the JBS the estimated survival was 1.008 (*SE* = 0.008, profile likelihood 95% confidence interval [0.992, 1.022]) and passing via the corner collector at powerhouse 2 the estimated survival was 1.020 (*SE* = 0.006, profile likelihood 95% confidence interval [1.008, 1.032]). Yearling Chinook salmon dam survival through Bonneville Dam was estimated to be 0.966 (*SE* = 0.007, 95% confidence interval [0.952, 0.980]).

75 kcfs spill operations

The survival of yearling Chinook salmon through Bonneville Dam spillway during 75 kcfs spill operations was estimated to be 0.897 (*SE* = 0.013, profile likelihood 95% confidence interval [0.872, 0.921]). For yearling Chinook salmon passing via powerhouse 1, the estimated survival was 0.943 (*SE* = 0.020, profile likelihood 95% confidence interval [0.900, 0.977]) and for yearling Chinook salmon passing via the powerhouse 2 turbines, the estimated survival was 0.952 (*SE* = 0.012, profile likelihood 95% confidence interval [0.926, 0.975]). For yearling Chinook salmon passing via the JBS the estimated survival was 0.999 (*SE* = 0.009, profile likelihood 95% confidence interval [0.980, 1.017]) and passing via the corner collector at powerhouse 2 the estimated survival was 1.012 (*SE* = 0.007, profile likelihood 95% confidence interval [0.999, 1.026]). Yearling Chinook salmon dam survival through Bonneville Dam during 75 kcfs spill operations was estimated to be 0.955 (*SE* = 0.008, 95% confidence interval [0.939, 0.971]).

Total dissolved gas cap spill operations

The survival of yearling Chinook salmon through Bonneville Dam spillway during total dissolved gas cap (TDG) spill operations was estimated to be 0.966 (*SE* = 0.012, profile likelihood 95% confidence interval [0.942, 0.990]). For yearling Chinook salmon passing via powerhouse 1, the estimated survival was 0.953 (*SE* = 0.035, profile likelihood 95% confidence interval [0.870, 1.007]) and for yearling Chinook salmon passing via the powerhouse 2 turbines, the estimated survival was 0.978 (*SE* = 0.013, profile likelihood 95% confidence interval [0.951, 1.004]). For yearling Chinook salmon passing via the JBS the estimated survival was 1.015 (*SE* = 0.013, profile likelihood 95% confidence interval [0.985, 1.039]) and passing via the corner collector at powerhouse 2 the estimated survival was 1.024 (*SE* = 0.017, profile likelihood 95% confidence interval [0.972, 1.049]). Yearling Chinook salmon dam survival through Bonneville Dam during TDG spill operations was estimated to be 0.978 (*SE* = 0.009, 95% confidence interval [0.961, 0.996]).

Paired Release-recapture Model

Powerhouse 1 Ice and Trash Sluiceway

The estimated survival of yearling Chinook salmon released into the ice and trash sluiceway at Bonneville Dam's powerhouse 1, ranged from 0.778 to 1.000 during 2005. The average survival was estimated to be 0.919 (*SE* = 0.016, 95% confidence interval [0.885, 0.954]).

Steelhead Trout

Route-specific Survival Model

The survival of steelhead trout through the Bonneville Dam spillway was estimated to be 0.955 (*SE* = 0.008, profile likelihood 95% confidence interval [0.939, 0.971]). For steelhead trout passing via powerhouse 1 the estimated survival was 0.933 (*SE* = 0.017, profile likelihood 95% confidence interval [0.897, 0.963]) and for steelhead trout passing via the powerhouse 2 turbines, the estimated survival was 0.868 (*SE* = 0.019, profile likelihood 95% confidence interval [0.830, 0.903]). For steelhead trout passing via the powerhouse 2 JBS the estimated survival was 0.956 (*SE* = 0.017, profile likelihood 95% confidence interval [0.919, 0.985]). The estimated survival of steelhead trout passing via the powerhouse 2 corner collector was 1.009 (*SE* = 0.006, profile likelihood 95% confidence interval [0.997, 1.021]). Hatchery steelhead trout dam survival through Bonneville Dam was estimated to be 0.963 (*SE* = 0.007, 95% confidence interval [0.950, 0.976]).

75 kcfs spill operations

The survival of steelhead trout through the Bonneville Dam spillway during 75 kcfs spill operations was estimated to be 0.884 (*SE* = 0.018, profile likelihood 95% confidence interval [0.848, 0.917]). For steelhead trout passing via powerhouse 1 the estimated survival was 0.927 (*SE* = 0.023, profile likelihood 95% confidence interval [0.876, 0.968]) and for steelhead trout passing via the powerhouse 2 turbines, the estimated survival was 0.797 (*SE* = 0.034, profile likelihood 95% confidence interval [0.727, 0.858]). For steelhead trout passing via the powerhouse 2 JBS the estimated survival was 0.940 (*SE* = 0.027, profile likelihood 95% confidence interval [0.880, 0.985]). The estimated survival of steelhead trout passing via the powerhouse 2 corner collector was 1.008 (*SE* = 0.007, profile likelihood 95% confidence interval [0.995, 1.025]). Hatchery steelhead trout dam survival through Bonneville Dam during 75 kcfs spill operations was estimated to be 0.957 (*SE* = 0.008, 95% confidence interval [0.941, 0.972]).

Total dissolved gas cap spill operations

The survival of steelhead trout through the Bonneville Dam spillway during TDG spill operations was estimated to be 0.986 (*SE* = 0.009, profile likelihood 95% confidence interval [0.968, 1.005]). For steelhead trout passing via powerhouse 1 the estimated survival was 0.941 (*SE* = 0.024, profile likelihood 95% confidence interval [0.887, 0.982]) and for steelhead trout passing via the powerhouse 2 turbines, the estimated survival was 0.915 (*SE* = 0.021, profile likelihood 95% confidence interval [0.870, 0.953]). For steelhead trout passing via the powerhouse 2 JBS the estimated survival was 0.969 (*SE* = 0.021, profile likelihood 95% confidence interval [0.919, 1.005]). The estimated survival of steelhead trout passing via the powerhouse 2 corner collector was 0.998 (*SE* = 0.019, profile likelihood 95% confidence interval [0.950, 1.027]). Hatchery steelhead trout dam survival through Bonneville Dam during TDG spill operations was estimated to be 0.970 (*SE* = 0.009, 95% confidence interval [0.953, 0.987]).

Paired Release-recapture Model

Powerhouse 1 Ice and Trash Sluiceway

The estimated survival of hatchery steelhead trout released into the ice and trash sluiceway at Bonneville Dam's powerhouse 1, ranged from 0.750 to 1.074 during 2005. The average survival was estimated to be 0.910 (*SE* = 0.021, 95% confidence interval [0.864, 0.956]).

Subyearling Chinook salmon

Route-specific Survival Model

Survival estimates

The survival of subyearling Chinook salmon through the Bonneville Dam spillway was estimated to be 0.911 (*SE* = 0.009, profile likelihood 95% confidence interval [0.893, 0.928]). For subyearling Chinook salmon passing via powerhouse 1 the estimated survival was 0.976 (*SE* = 0.030, profile likelihood 95% confidence interval [0.904, 1.023]) and for subyearling Chinook salmon passing via the powerhouse 2 turbines, the estimated survival was 0.895 (*SE* = 0.015, profile likelihood 95% confidence interval [0.866, 0.923]). For subyearling Chinook salmon passing via the powerhouse 2

JBS the estimated survival was 0.984 (*SE* = 0.016, profile likelihood 95% confidence interval [0.949, 1.012]). The estimated survival of subyearling Chinook salmon passing via the powerhouse 2 corner collector was 1.013 (*SE* = 0.008, profile likelihood 95% confidence interval [0.997, 1.028]). Subyearling Chinook salmon dam survival through Bonneville Dam was estimated to be 0.938 (*SE* = 0.007, 95% confidence interval [0.924, 0.952]).

75 kcfs spill operations

The survival of subyearling Chinook salmon through the Bonneville Dam spillway during 75 kcfs spill operations was estimated to be 0.870 (*SE* = 0.012, profile likelihood 95% confidence interval [0.847, 0.892]). For subyearling Chinook salmon passing via powerhouse 1 the estimated survival was 0.959 (*SE* = 0.033, profile likelihood 95% confidence interval [0.881, 1.009]) and for subyearling Chinook salmon passing via the powerhouse 2 turbines, the estimated survival was 0.880 (*SE* = 0.016, profile likelihood 95% confidence interval [0.847, 0.911]). For subyearling Chinook salmon passing via the powerhouse 2 JBS the estimated survival was 0.968 (*SE* = 0.020, profile likelihood 95% confidence interval [0.923, 1.003]). The estimated survival of subyearling Chinook salmon passing via the powerhouse 2 corner collector was 0.999 (*SE* = 0.009, profile likelihood 95% confidence interval [0.981, 1.016]). Subyearling Chinook salmon dam survival through Bonneville Dam during 75 kcfs spill operations was estimated to be 0.916 (*SE* = 0.008, 95% confidence interval [0.901, 0.931]).

Total dissolved gas spill operations

The survival of subyearling Chinook salmon through the Bonneville Dam spillway during TDG spill operations was estimated to be 0.986 (*SE* = 0.013, profile likelihood 95% confidence interval [0.960, 1.011]). For subyearling Chinook salmon passing via powerhouse 1 the estimated survival was 0.886 (*SE* = 0.162, profile likelihood 95% confidence interval [0.474, 1.055]) and for subyearling Chinook salmon passing via the powerhouse 2 turbines, the estimated survival was 0.926 (*SE* = 0.032, profile likelihood 95% confidence interval [0.856, 0.981]). For subyearling Chinook salmon passing via the powerhouse 2 JBS the estimated survival was 1.006 (*SE* = 0.026, profile likelihood 95% confidence interval [0.943, 1.046]). The estimated survival of subyearling Chinook salmon passing via the powerhouse 2 corner collector was 1.052 (*SE* = 0.014, profile likelihood 95% confidence interval [1.010, 1.073]). Subyearling Chinook salmon dam survival through Bonneville Dam during TDG spill operations was estimated to be 0.985 (*SE* = 0.011, 95% confidence interval [0.964, 1.005]).

Paired Release-recapture Model

Powerhouse 1 Ice and Trash Sluiceway

We evaluated the survival of subyearling Chinook salmon released into the ice and trash sluiceway at Bonneville Dam's powerhouse 1. The estimated survival of subyearling Chinook salmon released into the ice and trash sluiceway ranged from 0.836 to 1.263 during 2005. The average survival was estimated to be 0.976 (*SE* =0.018, 95% confidence interval [0.938, 1.013]).

Executive Summary Table 1. Summary of the estimated route-specific, dam, and pool survival probabilities (S) and 95% confidence intervals (95% CI) for juvenile salmonids passing through Bonneville Dam, 2005. Parameters are as follows: S_{PH1}, the first powerhouse survival probability; S_{B2Turb}, survival through turbine units at the second powerhouse; S_{B2CC}, the corner collector survival probability; S_{B2JBS}, the second powerhouse juvenile bypass system survival probability; S_{SPILL}, spillway survival probability; S_{DAM}, the dam survival; S_{POOL}, survival from the release location at The Dalles Dam. Dam operations were 75 kcfs day (0500 to 2200 hrs spring and 0600 to 2300 hrs summer) and spill up to total dissolved gas cap (TDG) in the tailrace during night.

	Yearling Chinook Salmon					
	75 kcfs day/TDG night		75 kcfs day		TDG night	
Parameters	S	95% CI	S	95% CI	S	95% CI
S_{PH1}	0.950	0.912, 0.980[A]	0.943	0.900, 0.977[A]	0.953	0.870, 1.007[A]
S_{B2Turb}	0.965	0.947, 0.982[A]	0.952	0.926, 0.975[A]	0.978	0.951, 1.004[A]
S_{B2CC}	1.020	1.008, 1.032[A]	1.012	0.999, 1.026[A]	1.024	0.972, 1.049[A]
S_{B2JBS}	1.008	0.992, 1.022[A]	0.999	0.980, 1.017[A]	1.015	0.985, 1.039[A]
S_{SPILL}	0.930	0.912, 0.947[A]	0.897	0.872, 0.921[A]	0.966	0.942, 0.990[A]
S_{DAM}	0.966	0.952, 0.980	0.955	0.939, 0.971	0.978	0.961, 0.996
S_{POOL}	0.962	0.956, 0.968[A]	0.964	0.957, 0.971[A]	0.959	0.949, 0.968[A]
	Hatchery Steelhead Trout					
S_{PH1}	0.933	0.897, 0.963[A]	0.927	0.876, 0.968[A]	0.941	0.887, 0.982[A]
S_{B2Turb}	0.868	0.830, 0.903[A]	0.797	0.727, 0.858[A]	0.915	0.870, 0.953[A]
S_{B2CC}	1.009	0.997, 1.021[A]	1.008	0.995, 1.025[A]	0.998	0.950, 1.027[A]
S_{B2JBS}	0.956	0.919, 0.985[A]	0.940	0.880, 0.985[A]	0.969	0.919, 1.005[A]
S_{SPILL}	0.955	0.939, 0.971[A]	0.884	0.848, 0.917[A]	0.986	0.968, 1.005[A]
S_{DAM}	0.963	0.950, 0.976	0.957	0.941, 0.972	0.970	0.953, 0.987
S_{POOL}	0.931	0.923, 0.938[A]	0.927	0.916, 0.937[A]	0.935	0.923, 0.946[A]
	Subyearling Chinook Salmon					
S_{PH1}	0.976	0.904, 1.023[A]	0.959	0.881, 1.009[A]	0.886	0.474, 1.055[A]
S_{B2Turb}	0.895	0.866, 0.923[A]	0.880	0.847, 0.911[A]	0.926	0.856, 0.981[A]
S_{B2CC}	1.013	0.997, 1.028[A]	0.999	0.981, 1.016[A]	1.052	1.010, 1.073[A]
S_{B2JBS}	0.984	0.949, 1.012[A]	0.968	0.923, 1.003[A]	1.006	0.943, 1.046[A]
S_{SPILL}	0.911	0.893, 0.928[A]	0.870	0.847, 0.892[A]	0.986	0.960, 1.011[A]
S_{DAM}	0.938	0.924, 0.952	0.916	0.901, 0.931	0.985	0.964, 1.005
S_{POOL}	0.900	0.891, 0.909[A]	0.901	0.890, 0.911[A]	0.898	0.879, 0.916[A]

[A] - Profile likelihood confidence intervals

Executive Summary Table 2. Summary of the estimated passage, detection, and lambda probabilities and 95% confidence intervals for juvenile salmonids at Bonneville Dam during 2005. The parameter E, is the probability that fish will pass via the spillway; PH2, conditional probability of passing via the second powerhouse, given fish did not pass via the spillway; B_2CC, conditional probability of passing via the corner collector and B_2JBS, conditional probability of passing via the juvenile bypass system, given that fish were going to powerhouse 2. Detection probabilities by route: $P_{B2CC,}$ the corner collector; $P_{B2JBS,}$ the juvenile bypass system; P_{B2Turb}, the second powerhouse; P_{PH1}, the first powerhouse; P_{SPILL}, spillway; λ, the joint probability of surviving and being detected at arrays below Bonneville Dam. Dam operations were 75 kcfs day (0500 to 2200 hrs spring and 0600 to 2300 hrs summer) and total dissolved gas cap (TDG) at night.

	Yearling Chinook Salmon					
	75 kcfs day/TDG night		75 kcfs day		TDG night	
Parameters	Probability	95% CI	Probability	95% CI	Probability	95% CI
E	0.379	0.364, 0.394[A]	0.326	0.307, 0.344[A]	0.465	0.440, 0.492[A]
PH2	0.888	0.873, 0.901[A]	0.878	0.861, 0.893[A]	0.904	0.877, 0.930[A]
B_2CC	0.293	0.274, 0.311[A]	0.396	0.372, 0.421[A]	0.088	0.070, 0.110[A]
B_2JBS	0.377	0.354, 0.401[A]	0.430	0.398, 0.462[A]	0.310	0.277, 0.345[A]
P_{B2CC}	0.9999	0.9997, 1.000	0.9999	0.9997, 1.000	0.999	0.997, 1.001
P_{B2JBS}	0.9995	0.999, 1.000	0.999	0.997, 1.001	0.999	0.997, 1.001
P_{B2Turb}	0.991	0.987, 0.995	0.994	0.990, 0.997	0.991	0.986, 0.997
P_{PH1}	0.928	0.890, 0.966	0.934	0.901, 0.966	0.882	0.773, 0.991
P_{SPILL}	0.988	0.985, 0.991	0.993	0.990, 0.995	0.983	0.977, 0.989
λ	0.971	0.962, 0.980[A]	0.980	0.968, 0.989[A]	0.963	0.946, 0.975[A]
	Hatchery Steelhead Trout					
E	0.386	0.371, 0.402[A]	0.202	0.186, 0.219[A]	0.618	0.594, 0.641[A]
PH2	0.851	0.836, 0.866[A]	0.891	0.875, 0.905[A]	0.738	0.702, 0.774[A]
B_2CC	0.671	0.650, 0.691[A]	0.818	0.799, 0.837[A]	0.202	0.168, 0.239[A]
B_2JBS	0.377	0.341, 0.414[A]	0.419	0.363, 0.477[A]	0.350	0.304, 0.399[A]
P_{B2CC}	0.9999	0.9998, 1.000	0.9999	0.9998, 1.000	0.9998	0.999, 1.000
P_{B2JBS}	0.999	0.997, 1.001	0.998	0.993, 1.002	0.998	0.995, 1.002
P_{B2Turb}	0.985	0.978, 0.992	0.993	0.986, 0.999	0.986	0.978, 0.995
P_{PH1}	0.898	0.867, 0.928	0.913	0.882, 0.944	0.864	0.805, 0.924
P_{SPILL}	0.991	0.988, 0.993	0.996	0.993, 0.998	0.989	0.985, 0.992
λ	0.973	0.964, 0.981[A]	0.975	0.961, 0.985[A]	0.972	0.957, 0.983[A]
	Subyearling Chinook Salmon					
E	0.491	0.475, 0.531[A]	0.434	0.417, 0.452[A]	0.677	0.646, 0.706[A]
PH2	0.915	0.897, 0.985[A]	0.909	0.892, 0.925[A]	0.980	0.954, 0.992[A]
B_2CC	0.464	0.441, 0.487[A]	0.504	0.479, 0.529[A]	0.271	0.224, 0.321[A]
B_2JBS	0.273	0.245, 0.301[A]	0.238	0.209, 0.269[A]	0.392	0.329, 0.457[A]
P_{B2CC}	0.9999	0.9997, 1.000	0.9999	0.9997, 1.000	0.999	0.996, 1.001
P_{B2JBS}	0.9998	0.999, 1.000	0.9996	0.999, 1.000	0.9999	0.9996, 1.000
P_{B2Turb}	0.957	0.945, 0.969	0.967	0.955, 0.978	0.916	0.879, 0.953
P_{PH1}	0.469	0.393, 0.546	0.480	0.407, 0.553	0.901	0.702, 1.101
P_{SPILL}	0.984	0.980, 0.987	0.999	0.998, 0.9998	0.917	0.902, 0.932
λ	0.950	0.942, 0.958[A]	0.960	0.950, 0.970[A]	0.940	0.927, 0.951[A]

[A] - Profile likelihood confidence intervals

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, loss of equilibrium, etc.) and indirect effects (e.g., predation, disease, and physiological stress) contribute to the total mortality of seaward migrating salmonids. Many studies have been conducted to determine the effects of hydroelectric dams on the survival of salmonid migrants (Raymond 1979; Stier and Kynard 1986; Iwamato et al. 1994; Muir et al. 1995; Smith et al. 1998; Bickford and Skalski 2000). Thus, studies designed to estimate dam, project, and route-specific survival of juvenile salmon have been conducted to identify sources of mortality and potential mitigation opportunities. Based on this research management actions are being implemented to improve the survival of juvenile salmonid migrants.

Mitigation efforts in the Columbia River Basin have sought to increase survival of juvenile salmonid migrants through the federal hydrosystem (National Marine Fisheries Service 2000). To facilitate this objective, migrant salmonids are diverted from turbine passage by the development of turbine bypass systems and spill scenarios used to increase spillway passage. While there is a 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). During 1999, tests of the efficacy of different spill scenarios were conducted at both John Day and The Dalles dams and at Bonneville Dam in 2004. The motivation for these evaluations was to identify which spill scenario would increase fish passage efficiency and reduce predation of migrant juvenile salmonids by altering the hydraulic conditions in the forebay environment, shortening travel times, and manipulating passage routes through tailrace areas to divert fish from areas with high predator densities. Ultimately, these actions are designed to increase the survival of migrant salmonids as they migrate through hydroelectric projects in the lower Columbia River. Thus, there continues to be a need to estimate the dam survival and route-specific survival of migrant juvenile salmonids in the lower Columbia River to evaluate the utility of these management actions. Further, given the completion of the new corner collector at Bonneville Dam's powerhouse 2 as a bypass system, a post construction survival program to evaluate dam and route-specific survival at Bonneville Dam will help fish managers understand the effect of this new passage route on migrating juvenile salmonids.

During 2005, we evaluated the survival of radio-tagged yearling and subyearling Chinook salmon and steelhead trout through the Bonneville Dam spillway, powerhouses 1 and 2, the corner collector and juvenile bypass system (JBS) at powerhouse 2, and through all routes collectively using the route-specific survival model. Radio-tagged fish were released at The Dalles Dam and in the tailrace of Bonneville Dam and were interrogated at Bonneville Dam and three radio-telemetry arrays below Bonneville Dam. We also evaluated the survival of radio-tagged yearling and subyearling Chinook salmon and steelhead trout using paired releases through the ice and trash sluiceway at Bonneville Dam's powerhouse 1. Site-specific releases were made directly into the ice and trash sluiceway and in the tailrace of Bonneville Dam below the outfall of the powerhouse 2 juvenile bypass system.

Previous USGS survival studies at Bonneville Dam

Pilot studies

Evaluations conducted during 1999 and 2000 demonstrated the feasibility of using radio telemetry to estimate the survival of juvenile salmonids passing through the John Day, The Dalles, and Bonneville dams (Counihan et al. 2001, 2002a). During 2000, radio-tagged yearling and subyearling Chinook salmon and steelhead trout were released in the lower Columbia River to evaluate fish passage efficiency and estimate survival (Beeman et al. 2001a and 2001b). During 2000, the evaluation of two spill conditions (12 vs. 24 h spill) at John Day Dam, indicated differences in survival for groups passing the dam during each operating scenario. However, further analyses suggest that other environmental conditions were variable within and between the two treatments and that the variability in conditions (including spill percent within treatments) may have affected the survival of both yearling Chinook salmon and steelhead trout and confounded the original intent of the experiment. Releases of yearling Chinook salmon were made above and below Bonneville Dam during 2000 to assess the feasibility of estimating survival at this dam. The results of the pilot study at Bonneville Dam suggested that the high capture probabilities observed in impounded reaches of the Columbia River were also possible in the un-impounded reach below Bonneville Dam.

2001

During 2001, we estimated the survival of yearling and subyearling Chinook salmon at Bonneville Dam (Counihan et al. 2002b). The survival of paired releases of radio-tagged fish was evaluated using the paired release-recapture models of Burnham et al. (1987). The objectives for the 2001 survival evaluation at Bonneville Dam were to provide estimates of survival for fish passing via all routes collectively at Bonneville Dam and to estimate survival of fish passing through the JBS at powerhouse 2.

The survival of yearling Chinook salmon passing through Bonneville Dam, based on detections at Bonneville Dam of fish released near Hood River, Oregon and in the tailrace of Bonneville Dam, ranged from 0.85 to 1.05. The average survival of radio-tagged yearling Chinook salmon through Bonneville Dam was estimated to be 0.937 (SE = 0.014). Survival during the day was estimated to be 0.923 (SE = 0.024) and night survival was estimated to be 0.949 (SE = 0.016). No significant differences were detected between day and night survival (one-tailed t-test, $P = 0.19$); but the power associated with this unplanned test was low ($1 - \beta = 0.22$). No significant relations were detected (linear regression, $P > 0.10$) between the dam survival of yearling Chinook salmon and total river discharge, total turbine discharge, or total powerhouse 2 discharge.

Because of the low water year during 2001, appreciable spill at Bonneville Dam occurred during only the last 7 releases of radio-tagged yearling Chinook salmon. The nature of the 2001 operations allowed us to conduct a post-hoc comparison of the survival of yearling Chinook passing Bonneville Dam during periods of spill and no spill. Prior to the initiation of spill at Bonneville Dam, the survival of yearling Chinook passing through all routes at Bonneville Dam was estimated to be 0.928 (n = 8, SE = 0.023) and after spill was initiated, was 0.946 (n = 7, SE = 0.015). The survival of yearling Chinook salmon passing Bonneville Dam before and after spill was initiated was not statistically different (one tailed t-test, $P = 0.27$). However, the power associated with this unplanned test was again low ($1 - \beta = 0.14$).

The estimated survival of yearling Chinook salmon released through the powerhouse 2 JBS ranged from 0.78 to 1.1. The average estimated survival through the JBS was estimated to be 0.962 (*SE* = 0.023). Survival through the JBS during the day was estimated to be 0.953 (*SE* = 0.039) and night survival was estimated to be 0.971 (*SE* = 0.027). No significant differences were detected between day and night survival through the JBS (one tailed *t*-test, $P = 0.35$) with power ($1 - \beta = 0.10$). Similar to the results for survival through all routes at the dam, no significant relations were detected (linear regression, $P > 0.10$) between the estimated juvenile bypass survival of yearling Chinook salmon and total river discharge, total turbine discharge, or total powerhouse 2 discharge.

We also estimated the survival of guided and unguided yearling Chinook salmon through Bonneville Dam's second powerhouse. The estimated average survival of turbine passed yearling Chinook was 0.929 (*SE* = 0.02) and for non-turbine passed fish was 0.937 (*SE* = 0.02). For turbine passed yearling Chinook, the average survival of fish passing during periods of spill was 0.900 (*SE* = 0.032) and during periods of no spill was 0.954 (*SE* = 0.024). The survival of turbine passed yearling Chinook passing during periods of spill and no spill were significantly different (one-tailed t-test, $P = 0.098$). The average survival of non-turbine passed fish during periods of spill was 0.96 (*SE* = 0.018) and for periods of no spill was 0.91 (*SE* = 0.029). The difference between the average estimated survival during periods of spill and no spill for non-turbine passed fish was found to be significantly different (one-tailed *t*-test, $P = 0.086$).

The survival of subyearling Chinook salmon passing via all routes at Bonneville Dam was based on the same release locations as those used for yearling Chinook salmon. The survival of subyearling Chinook salmon ranged from 0.73 to 1.08. The estimated average survival was 0.902 (*SE* = 0.036). The average survival during day releases was estimated to be 0.895 (*SE* = 0.044) and during night releases was 0.910 (*SE* = 0.066). No significant differences between day and night survival were detected (one-tailed *t*-test, $P = 0.42$). No significant relations (linear regression, $P > 0.10$) between total river discharge, total turbine discharge, and total powerhouse 2 discharge were detected.

Subyearling Chinook salmon were also released through the powerhouse 2 JBS during 2001. Subyearling Chinook salmon JBS survival ranged from 0.62 to 1.28. The average JBS survival was estimated to be 0.90 (*SE* = 0.053). The average JBS survival for the day releases was estimated to be 0.870 (*SE* = 0.089) and for night releases was 0.946 (*SE* = 0.0374). The average survival estimates were not found to be significantly different between day and night releases (variance weighted one-tailed *t*-test, $P = 0.23$). Significant relations (linear regression, $P < 0.1$) between total river discharge, total turbine discharge, and total powerhouse 2 discharge were detected.

2002

Evaluations of radio-tagged yearling Chinook salmon survival through a Minimum Gap Runner (MGR) Turbine Unit and the downstream migration channel (DSM) at Bonneville Dam's powerhouse 1 were conducted during 2002 (Counihan et al. 2003). Using releases of radio-tagged yearling Chinook salmon released as part of the survival evaluation at The Dalles Dam, and releases made below the outfall of the powerhouse 2 JBS, we also evaluated the survival through the spillway and powerhouse 1 and 2.

The average survival of yearling Chinook salmon released into the MGR turbine unit at powerhouse 1, given the control group was released directly below the front roll of the turbine unit was estimated to be 1.06 ([1.00, 1.12] 95% confidence interval) and through the MGR turbine unit at Bonneville Dam's powerhouse 1 given the control release below the powerhouse 2 JBS outfall was 1.01 ([0.98, 1.04] 95% confidence interval) during the 2002 migration season. We estimated that the survival of yearling Chinook salmon released into the DSM at Bonneville Dam's powerhouse 1 (control release below the powerhouse 2 JBS outfall) during 2002 ranged from 0.60 to 1.05. The average survival was estimated to be 0.91 ([0.83, 0.99] 95% confidence interval).

Using capture histories generated from the detections of radio-tagged yearling Chinook salmon released at The Dalles Dam and below the powerhouse 2 JBS outfall, we generated maximum likelihood estimates of the route-specific passage and survival probabilities for yearling Chinook salmon passing Bonneville Dam. The estimated dam and route-specific survival probabilities generated during 2002 differ from those generated during 2001 in that a different survival estimation model (i.e., the Route-specific Survival Model) was used to generate the estimates. The survival of yearling Chinook salmon through the Bonneville Dam spillway was estimated to be 0.977 (*SE* = 0.0135; profile likelihood 95% confidence interval [0.951, 1.000]). For yearling Chinook salmon passing via powerhouse 1, the estimated survival was 0.902 (*SE* = 0.036, profile likelihood 95% confidence interval [0.824, 0.965]) and for yearling Chinook salmon passing via powerhouse 2 the estimated survival was 0.993 (*SE* = 0.036, profile likelihood 95% confidence interval [0.964, 1.021]). The estimated dam survival for Yearling Chinook salmon through Bonneville Dam was estimated to be 0.977 (*SE* = 0.019).

2004

During 2004, we evaluated the survival of radio-tagged yearling and subyearling Chinook salmon and steelhead trout through the Bonneville Dam spillway, powerhouses 1 and 2, the corner collector and the JBS at powerhouse 2 from releases at The Dalles Dam and into the tailrace of Bonneville Dam below the powerhouse 2 JBS outfall. These fish were also used in a post-hoc paired release analysis to estimate survival of fish passing the spillway via spill bays with 7-ft or 14-ft flow deflectors. During the 2004 spring evaluations, the spill operations were approximately 48 kcfs during the day with night spill until the total dissolved gas cap (TDG) was reached in the tailrace. During the summer two spill operations were evaluated: 48 kcfs during the day with spill until the TDG was reached in the tailrace and 23 kcfs for 24 h. We also evaluated the survival of radio-tagged yearling and subyearling Chinook salmon and steelhead trout using paired releases through the ice and trash sluiceway and the MGR turbine unit at Bonneville Dam's powerhouse 1. Site-specific releases were made directly into the ice and trash sluiceway, the MGR turbine unit and in the tailrace at the front roll of the MGR turbine unit at powerhouse 1. Radio-tagged subyearling Chinook salmon survival was also estimated through the ice and trash sluiceway at powerhouse 1.

Route-specific survival estimates for yearling Chinook salmon indicated that the estimated survival through the powerhouse 2, corner collector (1.016, [0.999, 1.032] 95%

profile likelihood confidence interval) was greatest through this route, followed by the powerhouse 2 JBS (0.970, [0.943, 0.994] 95% profile likelihood confidence interval) and powerhouse 2 turbines (0.951, [0.929, 0.972] 95% profile likelihood confidence interval). Survival estimates through the spillway were the lowest (0.910, [0.888, 0.931] 95% profile likelihood confidence interval) of all routes. Reagan et al. (2005) demonstrated that the passage route was influenced by discharge. For the spring migration season 45% of the overall discharge was passed through powerhouse 2, with 40% discharge through the spillway and 15% through powerhouse 1. The passage results from Reagan et al. (2005) indicated that 59% of yearling Chinook salmon passed via powerhouse 2, 33% passed via the spillway, and only 8% passed via the powerhouse 1. For yearling Chinook salmon passage within powerhouse 2, 43% passed via the turbines, 36% via the corner collector, and 21% via the JBS. These results were consistent with our route-specific survival estimates and with the dam survival of 0.951 ([0.936, 0.966] 95% confidence interval), which was likely influenced by the large proportion of fish passing through powerhouse 2.

Similar to yearling Chinook salmon, the estimated survival of steelhead trout was greatest through the powerhouse 2 corner collector (1.030 [1.014, 1.047] 95% profile likelihood confidence interval), followed by the spillway, powerhouse 1, the powerhouse 2 JBS, and finally the powerhouse 2 turbines. Reagan et al. (2005) evaluated passage routes of steelhead trout released at The Dalles Dam and passed at Bonneville Dam. Their results indicated 66% of the steelhead trout passed via powerhouse 2, 25.2% passed via the spillway, and 8.5% passed via the powerhouse 1. These results are again consistent with the overall discharge proportions through each route. Steelhead trout passage via the corner collector was very high at 74% of fish passing powerhouse 2, the other 16% passed through the turbines and 10% through the JBS. The high dam survival estimate of 0.991 ([0.974, 1.007] 95% confidence interval) is likely a result of the high passage proportions and survival estimates through the corner collector.

Route-specific survival for subyearling Chinook salmon at Bonneville Dam was evaluated during two spill operations. In general route-specific survival estimates were higher during the higher spill operation of 48 kcfs day/TDG night spill operations than for the 23 kcfs spill operations for 24 h. In particular we observed significant differences between the survival estimates for the powerhouse 2 corner collector, the spillway, and the overall dam survival between the two spill operations. The differences are likely a result of the different proportions of total discharge through the various routes (i.e. during the 48 kcfs day/TDG night spill operations more fish pass via the spillway, and during the 23 kcfs spill operations more fish pass via powerhouse 2 and the corner collector).

Survival estimates for yearling Chinook salmon and steelhead trout passing through spill bays with 7-ft and 14-ft deflectors were higher during the total dissolved gas cap night spill operations where flows are typically higher and more fish tend to pass than during the 48 kcfs day spill operations. At the lower flow spill operation of 48 kcfs day survival estimates of yearling Chinook salmon and steelhead trout were higher for fish passing through spill bays with the 7-ft deflectors than through spill bays with the 14-ft deflectors. The point estimates of survival for subyearling Chinook salmon passing through the 7-ft deflectors were consistently higher than the survival point estimates for fish passing through the 14-ft deflectors for both spill conditions (48 kcfs day/TDG and 23 kcfs for 24 h). Survival point estimates for subyearling Chinook salmon passing through both the 7-ft and the 14-ft spill bay deflectors were higher during the 48 kcfs day and TDG night spill operations than during the 23 kcfs 24 h spill operations.

The estimated average survival of yearling Chinook salmon released into the MGR turbine unit at Bonneville Dam's powerhouse 1 with the control group released in the tailrace below the MGR unit front roll was 0.956 ([0.924, 0.988], 95% confidence interval) and the average survival for paired releases with the control group below the powerhouse 2 juvenile bypass outfall was 0.996 ([0.962, 1.029], 95% confidence interval). The estimated average survival of yearling Chinook salmon through the ice and trash sluiceway was 1.001 ([0.957, 1.045], 95% confidence interval). The estimated average survival of hatchery steelhead trout released into the MGR turbine unit at Bonneville Dam's powerhouse 1 with the control group released in the tailrace below the MGR unit front roll was 0.952 ([0.900, 1.003] 95% confidence interval) and the average survival for paired releases with the control group below the powerhouse 2 juvenile bypass outfall was 0.974 ([0.893, 1.054] 95% confidence interval). The estimated average survival of hatchery steelhead trout released into the ice and trash sluiceway at Bonneville Dam's powerhouse 1 (control release in the tailrace below the outfall of powerhouse 2 juvenile bypass outfall) was 0.985 ([0.917, 1.052] 95% confidence interval). The average survival of subyearling Chinook salmon released into the ice and trash sluiceway was estimated to be 0.946 ([0.909, 0.984] 95% confidence interval).

Methods

Study Area

The study area extended from The Dalles Dam at river kilometer (RK) 308 downriver to the I-205 Glenn Jackson Bridge (RK 181, Figure 1). Antenna arrays within the study area were located at Bonneville Dam (RK 235), Reed Island, (RK 200), Lady Island near the mouth of the Washougal River (RK 194), and the I-205 Glenn Jackson Bridge. The detection range of all the arrays spanned the breadth of the river channel. Furthermore, the array at Bonneville Dam was set up so that passage route could be determined (Evans et al. 2003).

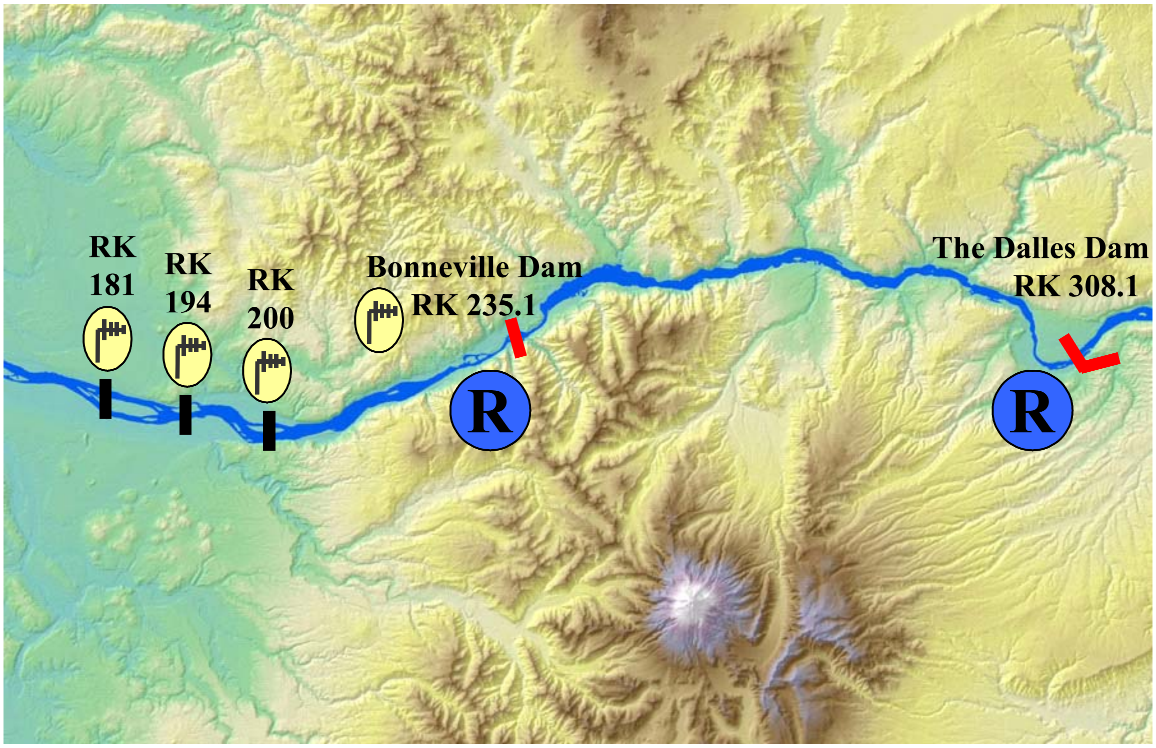


Figure 1. Release and detection locations for Bonneville Dam survival evaluation, during 2005. R = release locations, yellow ovals are locations of radio telemetry antenna arrays.

Bonneville Dam

Bonneville Dam is located on the Columbia River at RK 235. The dam consists of two powerhouses and a single spillway, each separated by an island. Powerhouse 2 consists of eight vertical-axis turbine units, each with three intakes, and is located on the north side of the river, spanning from Cascade Island to the Washington shore. Powerhouse 1 consists of 10 vertical-axis turbines, each with three intakes, and is located on the south side of the river, spanning between Bradford Island and the Oregon shore. The spillway is centrally located between Cascade and Bradford islands and consists of 18 spill bays, each equipped with a tainter gate that allows sub-surface water to pass under the gate and into the tailrace. At both powerhouses, juvenile fish can pass through the turbines, a juvenile bypass system (JBS), or through a surface-debris sluiceway (the corner collector). Fish entering the JBS are guided away from turbines by submersible traveling screens and into a fish collection channel. Fish and water are conveyed around the dam and return to the river via an outfall.

At powerhouse 2, the JBS collection channel is partially dewatered and fish enter a 1.22 m diameter high-density polyethylene plastic conveyance channel and are conveyed downriver 3,530 m. Before re-entering the river, fish and water are diverted to either a low or high outfall, determined by river surface elevation. The outfalls terminate 50 m from shore into the river channel. Fish and water plunge up to 4 m into the river depending on water discharge from the dam and which outfall is in use.

The corner collector of Powerhouse 2 is located on the southeastern corner of the powerhouse. A moveable gate can be raised to allow about 5,000 cfs of water to spill through it. Fish and water are conveyed through the dam via a 4.57 m wide by 6.1 m deep concrete trough 914.4 m to beyond the western tip of Cascade Island, where fish and water are released into a 15.2 m plunge pool.

Water quality, river discharge, and project operations

We monitored water temperature (±0.2ºC), dissolved oxygen (DO; ± 0.2 ppm), and conductivity (EC; 0.5%) throughout the study using a Stevens-Greenspan CS304 multi-parameter sensor (Stevens Water Monitoring Systems, Inc, Beaverton, Oregon). This unit is calibrated prior to installation and data is downloaded and monitored weekly throughout the season. The CS304 was deployed 5 m below the water surface in the forebay of the Bonneville Dam spillway and was programmed to record water temperature, DO, and EC measurements every minute. River discharge and project operations are obtained from the Army Corps of Engineers and are summarized for the study periods. Dam operations during both spring and summer were specified as the National Marine Fisheries Biological Opinion recommended spill of 75 kcfs during the day (0500 to 2100 hrs spring and 0500 to 2200 hrs summer) with night spill until the total dissolved gas cap is reached in the tailrace.

System antenna configuration

Radio-telemetry monitoring equipment was set up at Bonneville Dam and downstream of the dam in order to monitor behavior and passage information for use in fish passage- and guidance-efficiency (Reagan et. al 2005) studies as well as survival studies. We used four types of data acquisition equipment to monitor underwater and aerial antennas at Bonneville Dam in 2005. Eighty-three aerial antennas, 36 stripped coax antennas, and 124 underwater dipole antennas were linked to 34 Lotek SRX-400 receivers (SRX; Lotek Engineering, Newmarket, Ontario), two Lotek DSP-500 digital spectrum processors (DSP; Lotek Engineering, Newmarket, Ontario), three Orion DSP receivers (Grant Systems Engineering, King City, Ontario, Canada), and three Multiprotocol Integrated Telemetry Acquisition Systems (MITAS; Grant Systems Engineering, King City, Ontario, Canada). Each SRX monitored a maximum of six aerial antennas. Orions and MITASs were used to monitor underwater antennas. Orions and DSPs were also used to monitor aerial antennas in some areas. The combination of these technologies allowed us to monitor passage through all routes at Bonneville Dam.

Aerial antennas were positioned in three locations: 1) along the periphery of the forebay, 2) along the tailrace shoreline, and 3) along the corner collector flume (Figure 2). Aerial antennas were connected to SRX receivers programmed to monitor 19 frequencies in random order. Two aerial antenna monitoring configurations were used depending on location: auxiliary/master switching or combined antennas. The auxiliary/master switching configuration was used in the forebay of both powerhouses and at entrance stations where signal acquisition time was longer and more spatial resolution was required. Combined antenna configurations were used in the spillway forebay and all tailraces where signal acquisition time was limited and less spatial resolution was needed. In addition to combining antennas to reduce scan time, the scan time (a function of the number of frequencies being monitored) was reduced by half by using an extra receiver at all locations. Reducing scan time increases the probability of detecting transmitters. Underwater dipole and stripped coax antennas had limited ranges (about 6 m) compared to aerial antennas (100 to 300 m depending on transmitter depth, receiver gain, and number of antenna elements). Underwater antennas allowed us to obtain fine scale fish behavior information by limiting the range of signal detection.

Two SRX receivers in the powerhouse 2 tailrace were each coupled with DSPs. These receivers had essentially no scan time because a DSP acquires signals over a 1 MHz bandwidth almost instantaneously. Using DSPs, rather than a stand-alone SRX, was necessary to document fish behavior in high flow hydraulic environments because signal acquisition time is limited. Three MITASs were incorporated at powerhouse 1, powerhouse 2, and the spillway. Each MITAS was capable of simultaneously monitoring up to 50 inputs with greater multiple transmitter recognition than the SRX, DSP, or Orion. Although each MITAS was limited to a maximum of 50 inputs, each input could be a horizontal or vertical combination of multiple underwater dipole or stripped coax antennas.

The MITAS at powerhouse 1 was composed of 22 underwater stripped coax antennas and one aerial antenna. Twenty stripped coax antennas were positioned mid-channel in the sluiceway, two at each unit, to monitor unit-specific sluiceway entrance and passage through the sluiceway (Figure 3). In addition, two stripped coax antennas and one aerial antenna were placed at the outfall of the sluiceway to monitor sluiceway passage.

The MITAS at powerhouse 2 was composed of 61 underwater antennas (Figure 3). Forty-eight dipole underwater antennas attached to the submersible traveling screens monitored unguided turbine passage: Two dipole antennas were mounted to the bottom of each of three submersible traveling screens in front of each of eight turbine units. Antennas from each of three gatewell slots per unit were combined to provide turbine unit specific passage information. Nine stripped coax antennas placed within the downstream salmonids migrant channel (DSM) monitored guided fish passage. One antenna was located just downstream of each "C-slot" gatewell orifice and one additional antenna was located at the terminus of the DSM. Four dipole underwater antennas monitored approach and entrance of fish into the corner collector.

The spillway MITAS consisted of 72 underwater dipole underwater antennas that were attached to the forebay pier noses to monitor passage (Figure 3). Each spillbay had four antennas; two antennas on each pier nose at about 4.5 m below mean pool level and 2 antennas at about 10.5 m below mean pool level. All four antennas in each spillbay were combined to one input to provide spillbay-specific passage information.

Regardless of the type of monitoring technology used, a standard input signal of known value was used to determine the signal strength reaching each receiver. All aerial antennas were amplified in close proximity to the receiving antenna and transmission line amplification was used as needed to insure signal quality. Underwater antenna transmission lines were amplified as soon as they reached the deck elevation. Over-amplified signals were attenuated down to a standard level. These efforts insured that all antennas within and among arrays were equally sensitive and resulted in a balanced receiving system.

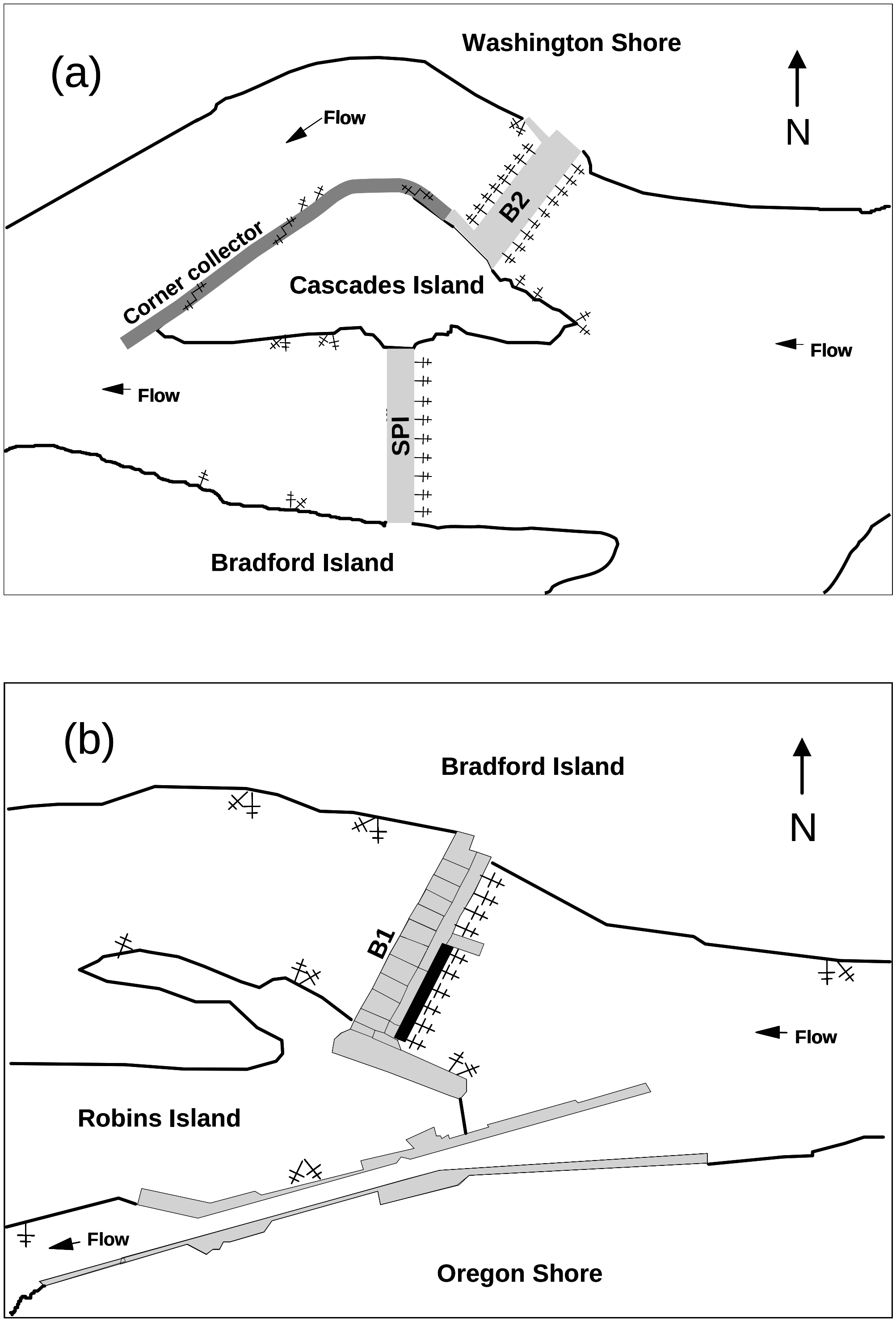


Figure 2. Plan view of aerial antenna coverage during spring 2005 at Bonneville Dam's: (a) second powerhouse (B2) and spillway (SPI); and (b) first powerhouse (B1) during 2005.

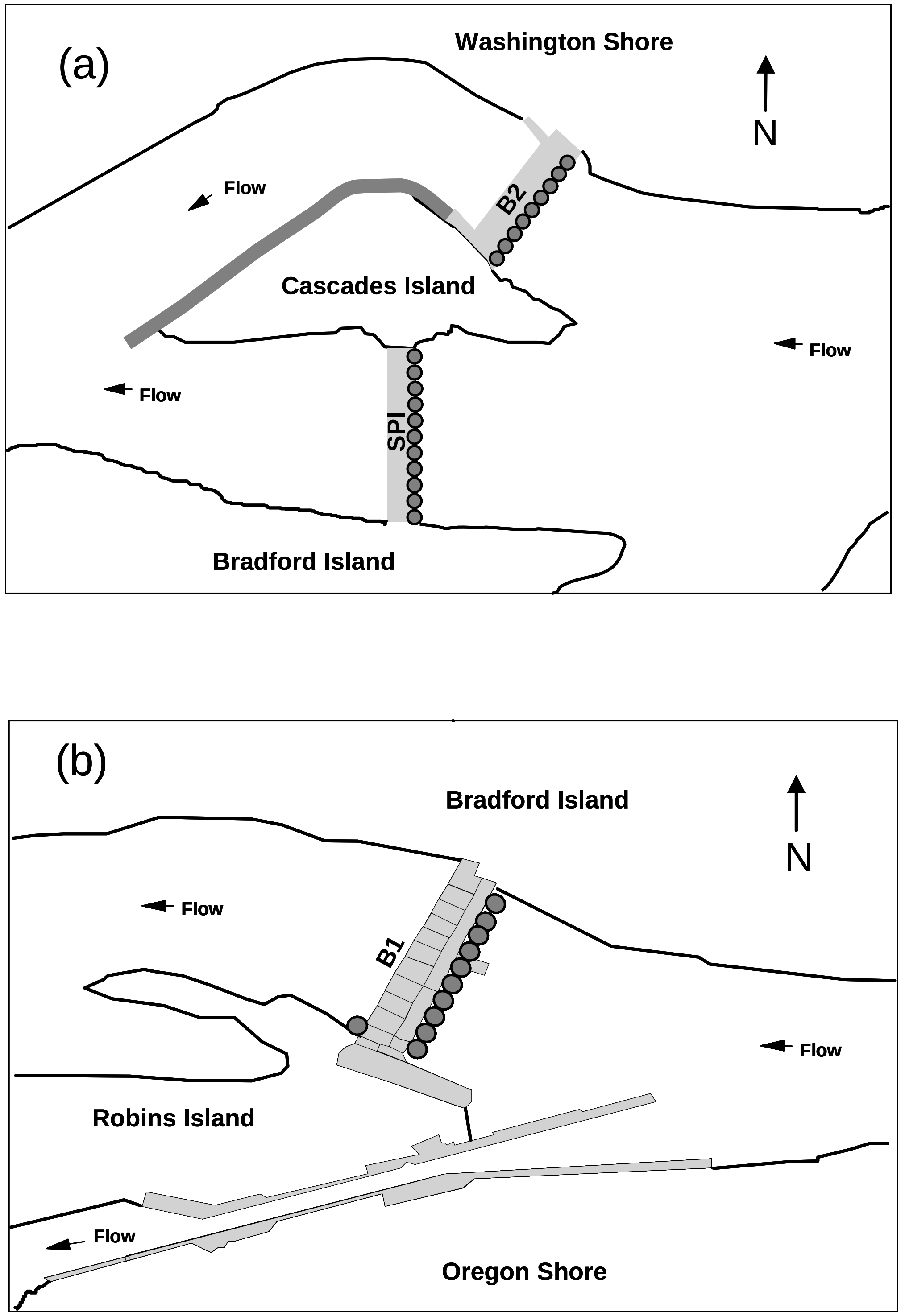


Figure 3. Plan view of underwater antenna coverage during spring 2005 at Bonneville Dam's: a) second powerhouse (B2) and spillway (SPI), and (b) first powerhouse (B1).

Radio Transmitters

The radio telemetry tags used in this study were pulse-coded transmitters (tags) manufactured by Lotek Wireless, Inc, (Newmarket, Ont.). Transmitters operated at frequencies between 150.280 and 150.800 MHz and used a pulse-coding scheme with 521 unique codes per frequency that allow each individual fish to be recognized. A radio signal was emitted every 2 seconds for spring tags and every 2.5 seconds for summer tags. Two sizes of these transmitters were used to accommodate the different sizes of the spring and summer migrants. Transmitters implanted in yearling Chinook salmon and steelhead trout were 7.3 mm in diameter x 18.0 mm in length and weighed approximately 0.98 g in air (volume = 0.60 ml), with an antenna length of 22 cm (Lotek Wireless model NTC-3-1- KMF). Expected battery life was 8 days for the KM tags. Transmitters implanted in subyearling Chinook salmon were 5.6 mm wide x 13.9 mm length x 3.7 mm high and weigh approximately 0.43 g in air (volume = 0.22 ml), with an antenna length of 18 cm (Lotek Wireless Model NTC-M-2, expected battery life was 8.8 d).

Fish tagging and releasing

Juvenile salmonids to be implanted with radio transmitters and released at The Dalles Dam were collected from the juvenile collection and bypass facility at John Day Dam at night and in the morning. After collection, fish were transported to The Dalles Dam and were tagged 12 to 36h later. The minimum 12 h holding time is to attain a post-absorptive state, minimizing stress during the tagging procedure. Juvenile salmonids to be released at Bonneville Dam were collected at Bonneville Dam's powerhouse 2 juvenile bypass monitoring facility and were held approximately 12 to 36 hours prior to tagging. Fish were considered suitable for tagging if they were free of injuries, severe descaling, external signs of gas bubble trauma, or other abnormalities. Fish size criteria were also established such that the radio tag weight in air would not exceed approximately 5% of a fish's weight in air. For yearling Chinook salmon and steelhead trout implanted with a Lotek Wireless model NTC-3-1-KMF tag the minimum weight selected for tagging was 21.5 g, and for subyearling Chinook salmon implanted with a Lotek Model NTC-M-2, the minimum weight was 10 g. Procedures used for gastric implantation were similar to Martinelli et al. (1998). Fish were anesthetized using MS-222 (tricaine methanosulfate) to the point of losing their equilibrium, the fish were moved to a tagging tray where the transmitter was gently pushed into the stomach with a Plexiglass tube (4 mm in diameter). The antenna was crimped prior to implantation so that the portion protruding from the mouth trailed to the posterior. Fish were held 18 to 36 h after tagging to check for spit tags and mortalities before being released. Fork lengths and weights of the various release groups are presented in Appendix 1.

To evaluate survival through the ice and trash sluiceway, approximately 25 radio-tagged yearling Chinook salmon and steelhead trout were released into the ice and trash sluiceway through a hose release mechanism during 16 replicate releases and 19 subyearling Chinook salmon during 32 replicate releases (see Appendix 1, Tables A1.1, A1.4, and A1.7 for exact dates, times, numbers, and fork lengths and weights for fish released). Fish were released from the powerhouse deck into a tank with a 10 cm diameter flexible hose that extended from the tank to the ice and trash sluiceway collection channel. The release tank was filled with river water and tagged fish were placed inside. A knife gate on the tank was raised and fish and water were transported through the hose into the collection channel. Water from the tank created a siphon that actively transported fish through the tube.

To evaluate the route-specific and dam survival at Bonneville Dam during the spring, radio-tagged fish were released into The Dalles Dam tailrace from a boat about 550 m downriver of the dam beneath the I-197 Bridge and into and below the ice and trash sluiceway. Releases were made twice a day into The Dalles Dam tailrace at approximately 1400 and 0000 hrs and once a day into The Dalles Dam sluiceway at approximately 0700, 1300, 1900, and 0100 hrs. The sluiceway releases were randomized and equally allocated among the four release times for the study period. Release times were the midpoints of 6-hour blocks of divergent discharge conditions seen in diel discharge patterns at The Dalles Dam. See Appendix 1 (Tables A1.2 and A1.5) for exact dates, times, numbers, and fork lengths and weights for fish released. A control group was released by boat, mid-channel in the Bonneville Dam tailrace 2 km downstream and below the powerhouse 2 JBS outfall. This control group was also the control group for the paired release-recapture evaluations through the ice and trash sluiceway. Bonneville Dam tailrace releases occurred twice a day at approximately 0800 and 2100 hrs (Appendix 1, Tables A1.3 and A1.6). Releases into the tailrace at Bonneville Dam were timed to approximately coincide with the arrival of fish released in the tailrace at The Dalles Dam. The timing of the releases was determined using a regression equation based on Zabel et al. (1997) to estimate travel times. Specifically travel time for Bonneville reservoir was estimated such that:

$$\text{Travel rate (km/d)} = 49.902 + 0.1309*(\text{Discharge}).$$

The regression equation was formulated using past years radio-telemetry 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 the dam operation and test treatment schedule at each study site to determine our release times. Since fish released from The Dalles Dam tailrace were also part of a survival study at The Dalles Dam, further coordination was necessary to accommodate releases made in the John Day Dam tailrace. During the summer, releases of subyearling Chinook salmon into the tailrace of The Dalles Dam occurred twice a day at approximately 1400 and 0000 and releases through the sluiceway occurred once a day at 0700, 1300, 1900, and 0100 hrs (Appendix 1, Table A1.8). Bonneville Dam tailrace releases for subyearling Chinook salmon occurred twice a day at approximately 1100 and 0000 hrs (Appendix 1, Table A1.9).

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 for each individual fish:

1. Records composed of invalid channel and code combinations, typically a result of erroneous radio transmissions (noise) that overlap with the radio frequencies that we are monitoring.
2. Records logged before a fish's release.
3. Records below an empirically determined signal strength threshold for each aerial and underwater array at the dam.
4. Single records recorded within a 20 min period on an array of nearby adjacent antennas (e.g. entrance, forebay, tailrace, or survival gate arrays).
5. A group of fewer than 3 records within a 60-min interval on an individual entrance, forebay, tailrace, or exit station receiver previously not classified as noise by criteria 1 through 4, that are unsupported by at least two other valid records among these areas during the hour interval of detection or the hour before and after detection.
6. Records not classified as noise by criteria 1 through 4 and detected on an array of nearby antennas in the forebay or tailrace that were recorded more than an hour after the previous valid record at the same antenna array.
7. Records on the MITAS aerial tailrace array over a 3-h interval, not classified as noise by the above criteria, and unsupported by any other valid entrance, forebay, tailrace, or exit detections during the same time period.

Once all times and locations of interest (events) were electronically assigned, individual fish histories were verified using criteria derived from manually-proofed radio-telemetry 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.

Run timing

One assumption of mark-recapture models used in this study is that individuals marked constitute a representative sample from the population of interest. However, there are technological (i.e. tag size and battery life) or logistical (i.e. availability of fish of appropriate sizes) limitations dictating the size of fish tagged and the timing of the study. Fish size criteria (21.5g for spring migrants and 10.0 g minimum for summer migrants) were established such that the radio tag weight in air would not exceed 5.0% of a fish weight in air. Due to this limitation the resultant data needs to be viewed critically in the context of these assumptions. In accordance with this assumption radio-telemetry tagging dates are designed to encompass the run timing for run-of-river fish. The Fish Passage Center (www.fpc.org) maintains passage index data for fish passing Bonneville Dam powerhouse 2. We use these data to provide an assessment of how our releases of radio-tagged fish compare to the run timing of run-of-the-river fish.

Tag-life performance

Another assumption of release-recapture models used to estimate survival is that all live tagged individuals have the same probability of being detected at downstream detection arrays. Since radio-tags have a limited and varied battery life, the tag failure rate may affect detection probabilities, depending on travel time of a tagged fish and the time a tag is on prior to release. Thus, survival estimates may be biased if the radio-tag expires prior to a fish exiting all the detection arrays. We employed the methods of Townsend et al. (2004) to conduct a tag life study to estimate the probability that a tag was functional at our detection arrays (Appendix 2).

The tag-life study entailed activating tags during the 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) during early, middle, and late season for both spring (n =75) and summer (n=75) were taken. The expiration time 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.

Tag-life data was used to model tag survivorship and for calculating the probability of a tag being operational at detection arrays as per Townsend et al. (2004). The tag-life data was fit to a Gompertz distribution (Elandt-Johnson and Johnson 1980). A non-parametric form of the tag survival function was used because travel times of radio-tagged salmonids are typically highly skewed (i.e., data are not normally distributed). Tag-life data were ranked to facilitate the estimation of model parameters. Estimates for model parameters α and β were generated for the tag survival function below and were used to estimate probabilities, where *S* is the probability the radio-tag is operational and *t* is time in days.

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

Travel time 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.

Statistical methods

Paired Release-recapture Model

We used the paired release-recapture models of Burnham et al. (1987) to estimate the survival of yearling and subyearling Chinook salmon and steelhead trout through the ice and trash sluiceway at Bonneville Dam's powerhouse 1.

Model Assumptions

There are assumptions associated with using the paired release-recapture model to estimate survival; some are biological and some pertain to the statistical models (Burnham et al. 1987, Skalski et al. 1998, Skalski 1999). The validity of some of the assumptions listed below can be evaluated using statistical tests and others can be met through careful consideration of fish collection, holding, tagging, and detection techniques. Strict protocols are already in place for tagging techniques, water quality monitoring, field equipment checks, and data collection that will be used in these studies and we will perform further statistical tests where possible to ensure that the assumptions associated with the release-recapture models are met. The assumptions are the following:

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

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

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

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

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

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

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

The first assumption (A1) involves making inferences from the sample to the target population. For instance, if a sample is drawn from a population of fish and the size of the transmitter biases your sample to include only larger members of the population, then non-statistical inferences justifying the similarity between the target population and the sample are necessary. To evaluate assumption A1, we monitor the timing and lengths of run-of-river fish sampled at the John Day and Bonneville dams smolt monitoring facilities. We compare this to our sampling dates and lengths of radio-tagged fish to assess how representative the radio-tagged fish are to run-of -river fish.

Assumption A2 regards making inferences to the target population. If tagging has a detrimental effect on survival, then survival estimates from the tagged fish will be negatively biased (i.e., underestimated). To limit the effects of our tagging methods on our tagged fish we have used the criteria established in Adams et al. (1998).

Assumption A3 stipulates that mortality be negligible in the area near sampling stations so that mortality incorporated into the survival estimates occurs in the river reach in question and not during the sampling event. Our tagged fish spend only a brief amount of time near the antenna array to that spent traveling between detection locations.

The assumption of independence (A4) implies that the fate of any particular fish does not affect the fate of others. This assumption is common to all tagging studies and in a large system, such as the Columbia River, there is no evidence to suggest that it is not true. Violations of A4 have little effect on the point estimate but may bias the variance estimate to be lower than it actually is (Skalski 1999).

Assumption A5 specifies that prior detection has no effect on the subsequent survival of fish. The lack of handling following initial release minimizes the risk that detection influences survival. Assumption A6 could be violated if downstream detections were affected by fish passage routes. Providing adequate coverage of the entire river or placing arrays below mixing zones will reduce the likelihood of violating this assumption. We also conduct statistical tests to evaluate assumptions A5 and A6 using tests developed by Burnham et al. (1987). Burnham et al. (1987) presents a series of tests of assumptions named Test 2 that examine whether upstream or downstream detections affect downstream survival and/or detection. To examine whether upstream capture histories affect downstream survival and/or capture, Burnham et al. (1987) present a series of tests called Test 3.

Assumption A7 implies that fish do not lose their tags and are not misidentified as dead or not captured and that dead fish aren't incorrectly recorded as alive. Tag loss or failure could negatively bias survival estimates of a treatment or control group through a particular reach. Typically, the retention rate of active transmitters is high suggesting that the effects of tag loss on survival estimates would be minimal. For example, with the exception of one fish that became entangled in a tank structure, Adams et al. (1998) did not report any radio tag loss for Chinook salmon with gastric and surgically implanted transmitters during a 21 d laboratory experiment. 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. Conversely, dead fish drifting downstream could result in false-positive detections and upwardly bias survival estimates. However, a prudent selection of detection arrays that are sufficiently spaced would minimize this occurrence. Assumption A7 is evaluated by releasing dead radio-tagged fish throughout the season with live radio-tagged fish.

Survival was estimated from paired-release recapture models from releases of juvenile salmonids into the ice and trash sluiceway and the tailrace at Bonneville Dam by the expression:

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

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

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

where $\hat{S}_{11}$ = survival estimates for fish released above the project of interest or into a particular route and $\hat{S}_{22}$ = fish released below the project, and where

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

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

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

leading to the relationship

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

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

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

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

A10. Releases (R_1) and (R_2) have the same survival probability in the lower river segment (S_{21}).

Assumption A9 stipulates that there is no synergistic relationship between survival processes in the two river segments (i.e., fish released above the dam that survive the first river segment are no more or less susceptible to mortality in the second river segment than fish released below the dam).

Assumption A10 is satisfied if the paired releases mix as they migrate through the second river segment but can also be satisfied if the survival process is stable during passage by the two releases. Under similar flow and spill conditions, a stable survival process should be expected.

To test whether releases within a paired release have similar survival and capture histories, likelihood ratio tests can be performed to compare models H_{1N} and H_{k-1N} and other intermediate scenarios (Burnham et al. 1987). Burnham et al. (1987) also suggest that a 2 x 2 contingency table test be used to determine whether the capture and survival rates for the paired releases are equal at or below the first downstream antenna array as (i.e., $p_{11} = p_{21}$, $S_{11} = S_{21}$, $p_{12} = p_{22}$, etc.) another indication of complete mixing. The 2 x 2 table would be of the form:

	Release	
	R_1	R_2
m_1	m_{11}	m_{21}
Z_1	z_{11}	z_{21}

where m_1 is the number of fish detected at the first downstream array for a given release and Z_1 is the number of fish that were not detected at the first array but were subsequently detected at a downstream array. While the contingency table provides tests of equality of overall recapture for paired releases, it does not provide the resolution of the equal site-specific capture and survival rate for both releases. Thus, inferences regarding mixing will be largely based on the sequential use of likelihood ratio tests.

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

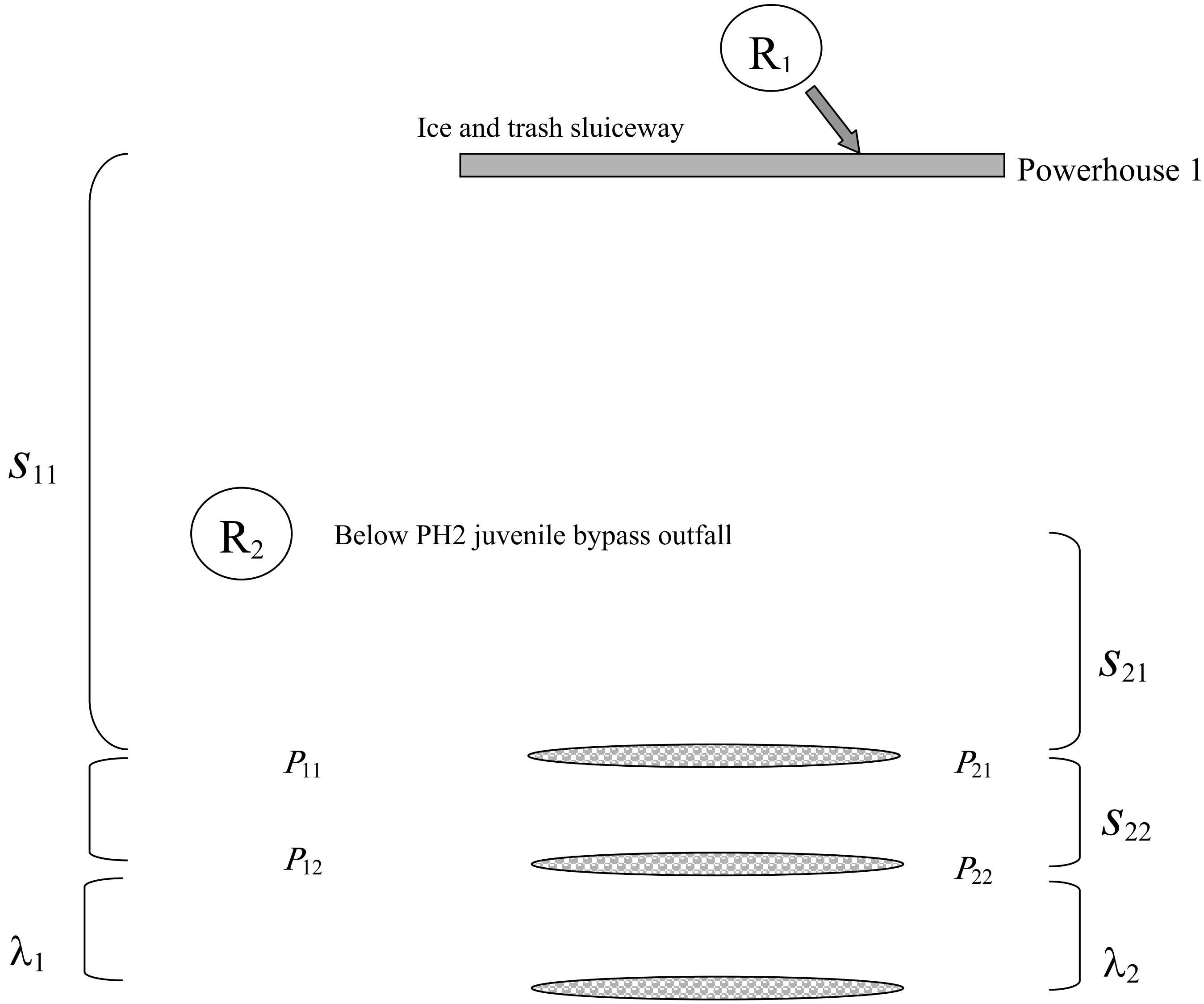
		Release	
		R_1	R_2
Day of detections	1		
	2		
	3		
	⋮		
	D		

For each paired-release (R_1 and R_2), a chi-square test of homogeneity was performed at each downstream array. Tests were performed at $\alpha = 0.10$. Because there were multiple releases and tests across paired releases, the Type I error rates were adjusted for an overall experimental-wise error rate pertaining specifically to each paired release-recapture evaluation conducted at Bonneville Dam (Dunn-Sidak method, Sokal and Rohlf, 1995).

Inferences regarding mixing will be largely based on the sequential use of likelihood ratio tests. In any given survival estimation scenario, a number of potential models will be generated and subsequently evaluated (Burnham et al. 1987, Lebreton et al. 1992). Forward-sequential and reverse-sequential procedures will be used to find the most parsimonious statistical model that adequately describes the downstream survival and capture processes of the paired release. The most efficient estimate of survival will be based on the statistical model for the paired releases that properly share all common parameters between release groups.

Estimable Parameters

The release and detection schemes used during 2005 allowed us to generate the survival and capture probabilities shown in Figure 4 for all site-specific releases at Bonneville Dam.



Survival through the ice and trash sluiceway: $\hat{S}_{IandT\ sluice} = \dfrac{\hat{S}_{11}}{\hat{S}_{21}}$

Figure 4. Schematic of estimable capture and survival probabilities (S = survival estimate, p = capture probability, and $\lambda = S \cdot p$) from site-specific releases (R_{ROUTE}) at Bonneville Dam and in the Bonneville Dam tailrace.

Route-Specific Survival Model

Model Assumptions

The assumptions associated with the Route-Specific Survival Model (RSSM) are described in detail in Skalski et al. (2002) and are similar to those for the paired release-recapture model of Burnham et al. (1987). Assumptions of the RSSM are:

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

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

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

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

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

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

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

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

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

Skalski et al. (2002) identified two additional assumptions associated with the RSSM:

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.

Skalski et al. (2002) suggest that assumption A10 can be qualitatively assessed by examining radio telemetry detection histories to determine whether inconsistencies in individual fish detection histories exist. Skalski et al. (2002) use an example of a situation where a radio-tagged fish is detected in the upstream array of a route and then in the downstream array of another route, resulting in uncertainty in the route taken. That is, they used aerial antennas that monitored the tailrace area to help determine passage. Similar to the radio-telemetry system used in Skalski et al. (2002), the double array we employed at Bonneville 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 JBS and corner collector where underwater antennas were placed at two locations within these structures. However, while we did have a radio-telemetry 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 during this type of study. Rather, they suggest that the detection fields of the primary and secondary arrays should be located in a way that fish detected in one array does not have a higher or lower probability of being detected in the secondary array than the primary array. Further, they suggest that this is best accomplished by having independent receivers for each antenna array and by having the detection field of at least one array encompass the entire passage route. The arrays we deployed at Bonneville Dam powerhouses 1 and 2, the JBS, corner collector, and spillway adhere to these requirements.

Parameter Estimation

The double radio-telemetry array systems that we deployed at Bonneville 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 Bonneville Dam: S_{POOL}, survival from the release location at The Dalles Dam; E, probability that fish will pass via the spillway; PH2, conditional probability of passing via the second powerhouse, given that fish were going to either the first or second powerhouse; B2CC, conditional probability of passing via the corner collector, given that fish were going to powerhouse 2; B_2JBS, conditional probability of passing via the JBS, given that fish were going to powerhouse 2; $P_{B2CC,}$ the corner collector primary array detection probability ($q_{B2CC} = 1 - P_{B2CC}$); $P'_{B2CC,}$ the corner collector secondary array detection probability ($q'_{B2CC} = 1 – P'_{B2CC}$); $P_{B2JBS,}$ the JBS primary array detection probability ($q_{B2JBS} = 1- P_{B2JBS}$); $P'_{B2JBS,}$ the JBS secondary array detection probability ($q'_{B2JBS} = 1- P'_{B2JBS}$); P_{B2Turb}, the second powerhouse primary array detection probability ($q_{B2Turb} = 1 - P_{B2Turb}$); P'_{B2Turb}, the second powerhouse secondary array detection probability ($q'_{B2Turb} = 1-P'_{B2Turb}$); P_{PH1}, the first powerhouse primary array detection probability ($q_{PH1} = 1 - P_{PH1}$); P'_{PH1}, the first powerhouse secondary array detection probability ($q'_{PH1} = 1 - P'_{PH1}$); P_{SPILL}, spillway primary array detection probability ($q_{SPILL} = 1 - P_{SPILL}$); P'_{SPILL}, spillway secondary array detection probability ($q'_{SPILL} = 1 - P'_{SPILL}$); S_{SPILL}, spillway survival probability; S_{B2CC}, the corner collector survival probability; S_{B2JBS}, the JBS survival probability; S_{B2Turb}, the second powerhouse survival probability; S_{PH1}, the first powerhouse survival probability; λ, the joint probability of surviving and being detected at the arrays below Bonneville Dam. The releases made at The Dalles Dam (R_1) and the releases made below the second powerhouse JBS outfall (R_2) were interrogated at three arrays below Bonneville Dam, the furthest downriver being an array deployed on the I-205 Bridge (Figure 1). A branching process was used to model the migration and survival of releases R_1 and R_2 (Figure 5). 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 Bonneville dam was estimated from the expression:

$$S_{DAM} = (1-E)(1-PH2)\ S_{PH1} + E\ S_{SPILL} + (1-E)(PH2)(B2CC)S_{B2CC} +$$
$$(1-E)(PH_2)(1-B2CC)(1-B2JBS)S_{B2Turb} + (1-E)(PH_2)(1-B2CC)(B2JBS)S_{B2JBS}$$

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 with the USER (User Specified Estimation Routine) software developed at the University of Washington (Lady et al. 2003; see: http://www.cqs.washington.edu/paramEst/USER/).

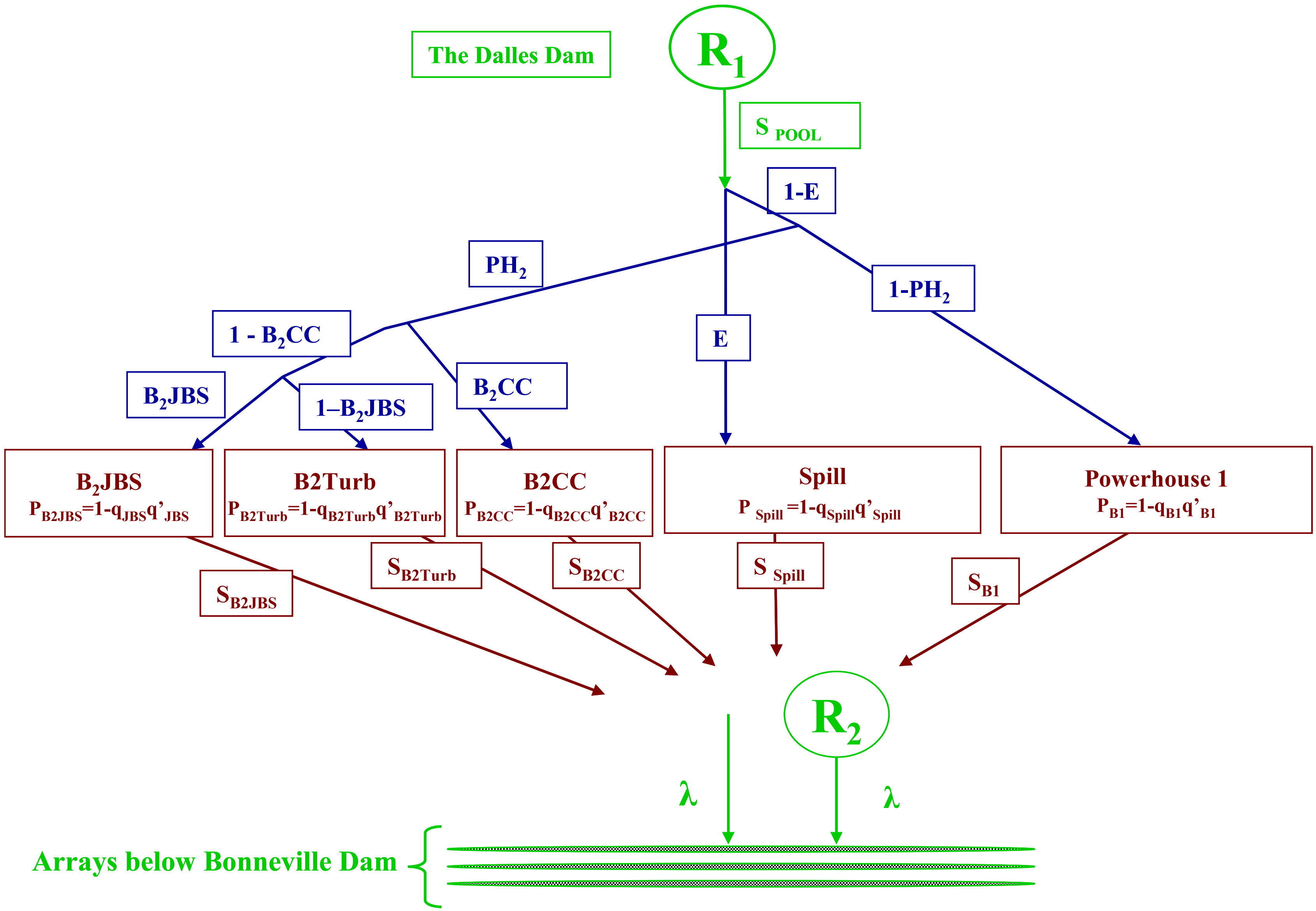


Figure 5. The estimable parameters (see text p. 23 for parameter definitions) for the route-specific survival model using the proposed release and detection schemes for 2005. Included in the detection scheme is a double radio-telemetry array at Bonneville Dam.

Results

Water quality, river discharge, and project operations

During the spring water temperature in the spillway forebay increased over the course of the study, averaging 14.2 ºC and ranging from 11.0 to 16.5 ºC. Dissolved oxygen in the spillway forebay gradually decreased over the course of the study, averaging 9.66 ppm and ranging from 8.61 to 10.68 ppm. Electrical conductivity increased gradually over the study, averaging 150.8 µS/cm and ranging from 126.5 to 189.1 µS/cm. During the summer, water temperature in the spillway forebay increased, averaging 19.5 ºC and ranging from 16.2 to 22.4 ºC. Dissolved oxygen in the spillway forebay gradually decreased, averaging 8.19 ppm and ranging from 7.45 to 8.85 ppm. Electrical conductivity increased gradually, averaging 169.3 µS/cm and ranging from 129.8 to 229.6 µS/cm.

Prescribed dam operations during 2005 were 75 kcfs spill during the day (0500 to 2100 hrs spring and 0500 to 2200 hrs summer) and night spill until the total dissolved gas cap was reached in the tailrace. However, these operations were not consistently achieved throughout the study period. From 04 May at 2100 to 08 May at 1200 spill operations were below even the daytime minimum for the entire time block, with spill averaging 66 kcfs. During the spring study period the mean river discharge at Bonneville Dam was 219.3 kcfs, and ranged from 157.6 to 279.2 kcfs. Allocation of mean river discharge among dam areas during the study period was, 13% through powerhouse 1, 47% through powerhouse 2, and 39% through the spillway (Table 1). During the summer, mean river discharge at Bonneville Dam was 177.4 kcfs, and ranged from 143.1 to 213.2 kcfs. Allocation of mean river discharge among dam areas during the study period was, 3% through powerhouse 1, 45% through powerhouse 2, and 52% through the spillway (Table 1).

Table 1. Summary of daily discharge by dam area at Bonneville Dam during spring (30 April to 7 June) and summer (16 June to 19 July) study periods, 2005. Dam operations were 75 kcfs spill during the day (0500 to 2100 hrs spring and 0500 to 2200 hrs summer) and night spill until the total dissolved gas cap was reached in the tailrace.

		Spring River Discharge (kcfs)		
Dam area	Percent	Mean	Max	Min
Powerhouse 1	13	28.9	70.5	0.9
Powerhouse 2	48	104.0	125.4	76.0
Spillway	39	86.4	105.4	65.1
Total	100	219.3	279.2	157.6
		Summer River Discharge (kcfs)		
Powerhouse 1	3	5.5	21.8	0.9
Powerhouse 2	45	79.2	100.4	50.2
Spillway	52	92.6	97.2	84.1
Total	100	177.4	213.2	143.1

Run timing and radio telemetry tagging dates

One assumption of mark-recapture models used in this study is that individuals marked constitute a representative sample from the population of interest. However, there are technological (i.e. tag size and battery life) or logistical (i.e. availability of fish of appropriate sizes) limitations dictating the size of fish tagged and the timing of the study. Fish size criteria were established such that the radio tag weight in air would not exceed approximately 5% of a fish weight in air. For yearling Chinook salmon and steelhead trout implanted with a Lotek Wireless model NTC-3-1-KMF tag (weight = 0.98 g in air) the minimum weight for tagging was 21.5 g (corresponding estimated length of 130 mm), and for subyearling Chinook salmon implanted with a Lotek Model NTC-M-2 (weight = 0.43 g in air) the minimum weight was 10 g (corresponding estimated length of 100 mm). Due to these limitations the resultant data needs to be viewed critically in the context of these assumptions.

In accordance with this assumption, radio-telemetry tagging dates are designed to encompass the run timing for run-of-river fish. The Fish Passage Center (see: www.fpc.org) maintains daily passage index data for fish passing Bonneville Dam powerhouse 2. 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. For yearling Chinook salmon radio telemetry tagging started at approximately 38% of the run and ended at 98% (Figure 6), and for steelhead trout tagging started at about 25% of the run and ended at 98% of the run (Figure 7). For subyearling Chinook salmon radio telemetry tagging started at approximately 50% of the run and ended near 95% of the run (Figure 8). Approximately 40% of the subyearling Chinook salmon run was composed of hatchery releases which occurred prior to 5 May.

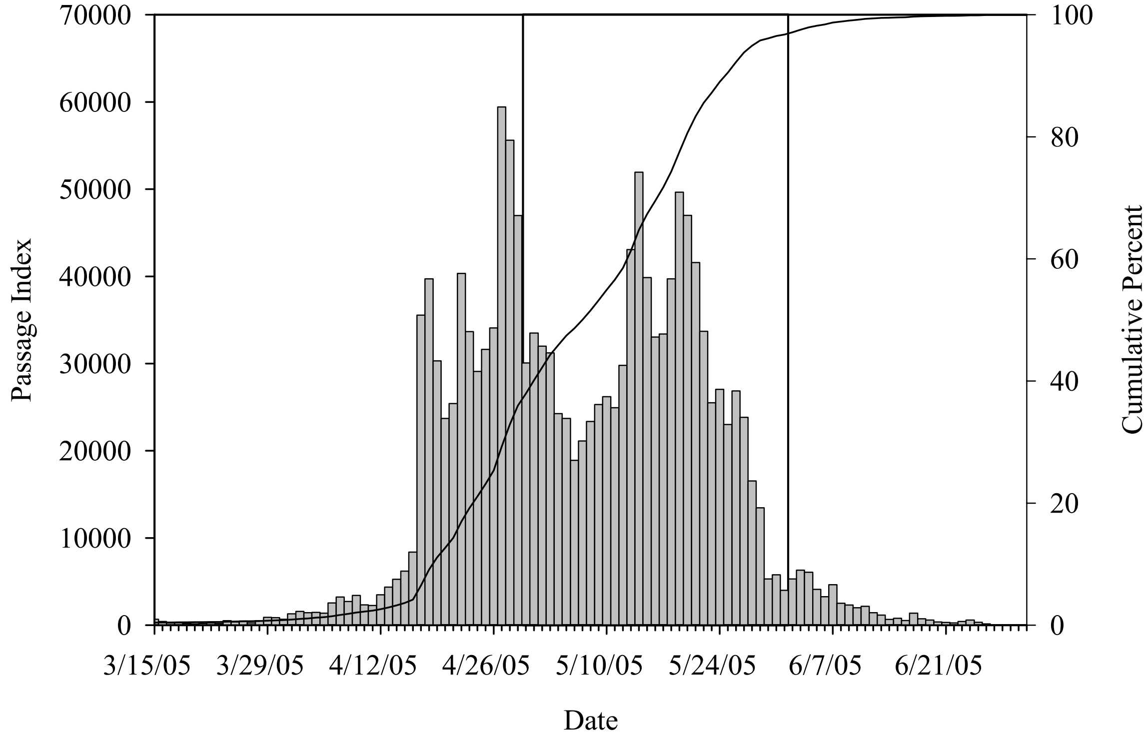


Figure 6. Yearling Chinook salmon daily passage index and cumulative percent passage at Bonneville Dam, powerhouse 2. The vertical bars represent the passage index (see: www.fpc.org) for a given day. Vertical lines represent the start and end dates for radio telemetry tagging.

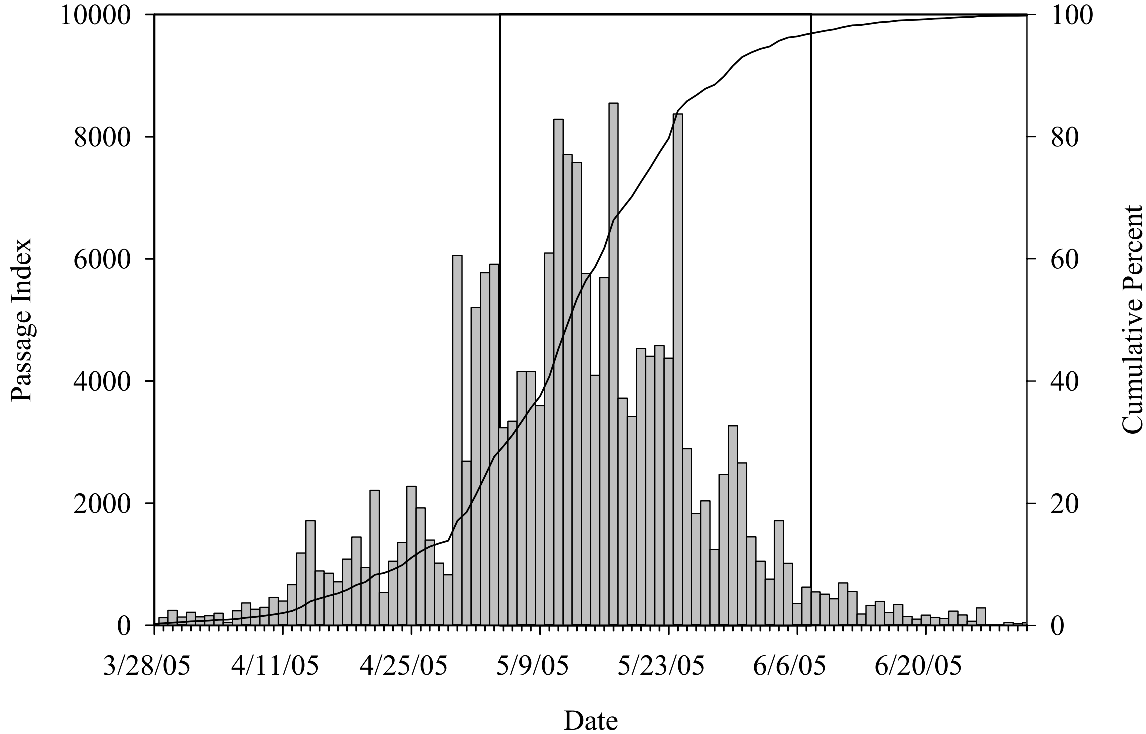


Figure 7. Steelhead trout daily passage index and cumulative percent passage at Bonneville Dam, powerhouse 2. The vertical bars represent the passage index (see: www.fpc.org) for a given day. Vertical lines represent the start and end dates for radio telemetry tagging.

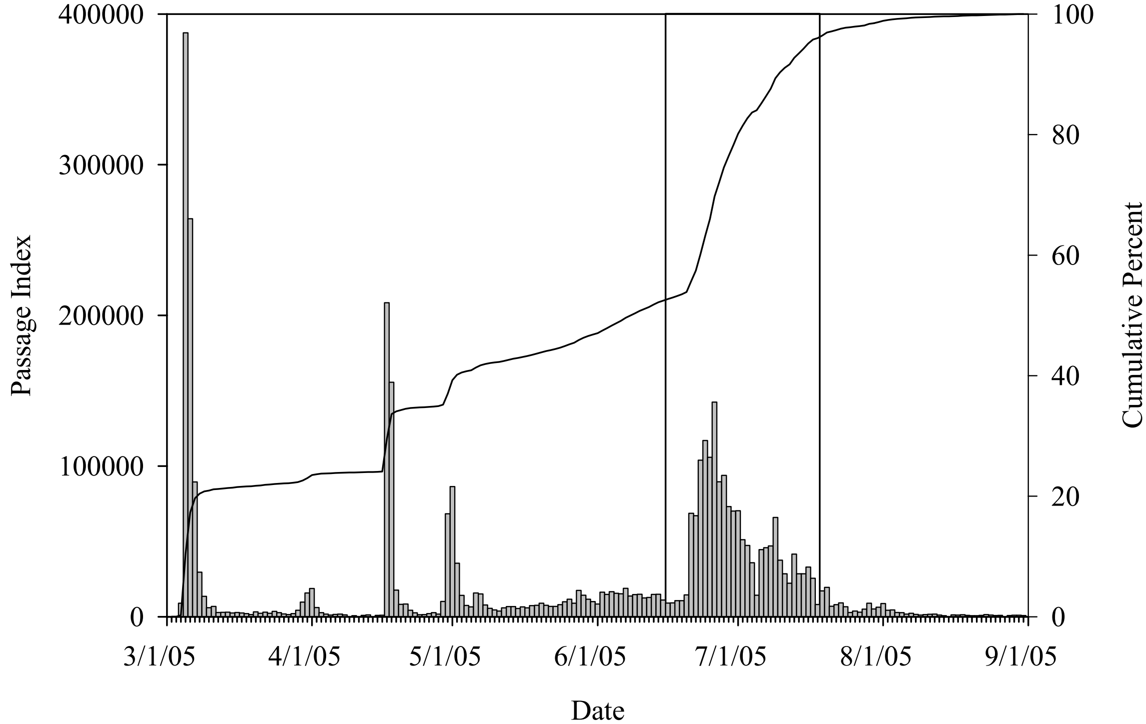


Figure 8. Subyearling Chinook salmon daily passage index and cumulative percent passage at Bonneville Dam, powerhouse 2. The vertical bars represent the passage index (see: www.fpc.org) for a given day. Vertical lines represent the start and end dates for radio telemetry tagging.

Radio-tagged fish size relative to run-of-river fish

We obtained fork length data for run-of-river fish sampled at the John Day Dam and Bonneville Dam smolt monitoring facilities and compared it to fork length data for radio-tagged fish obtained from each of these sites. For yearling Chinook salmon the radio-tagged fish were of very similar sizes to the run-of-river fish (Figure 9). We observed that less than 10% of the sampled run was below the 130 mm size criteria throughout the season. For steelhead trout very few run-of-river fish fell below the minimum size criteria (Figure 10). The average radio-tagged steelhead trout was 15 to 17 mm larger in size than the run-of-river fish. For the subyearling Chinook salmon the mean length at the sampling facilities ranged from 96 to 99 mm, while the mean radio-tagged fish length was 108 mm (Figure 11). Approximately 55-60% of the run-of-river subyearling Chinook salmon sampled at The Dalles and Bonneville dams were less than 100 mm.

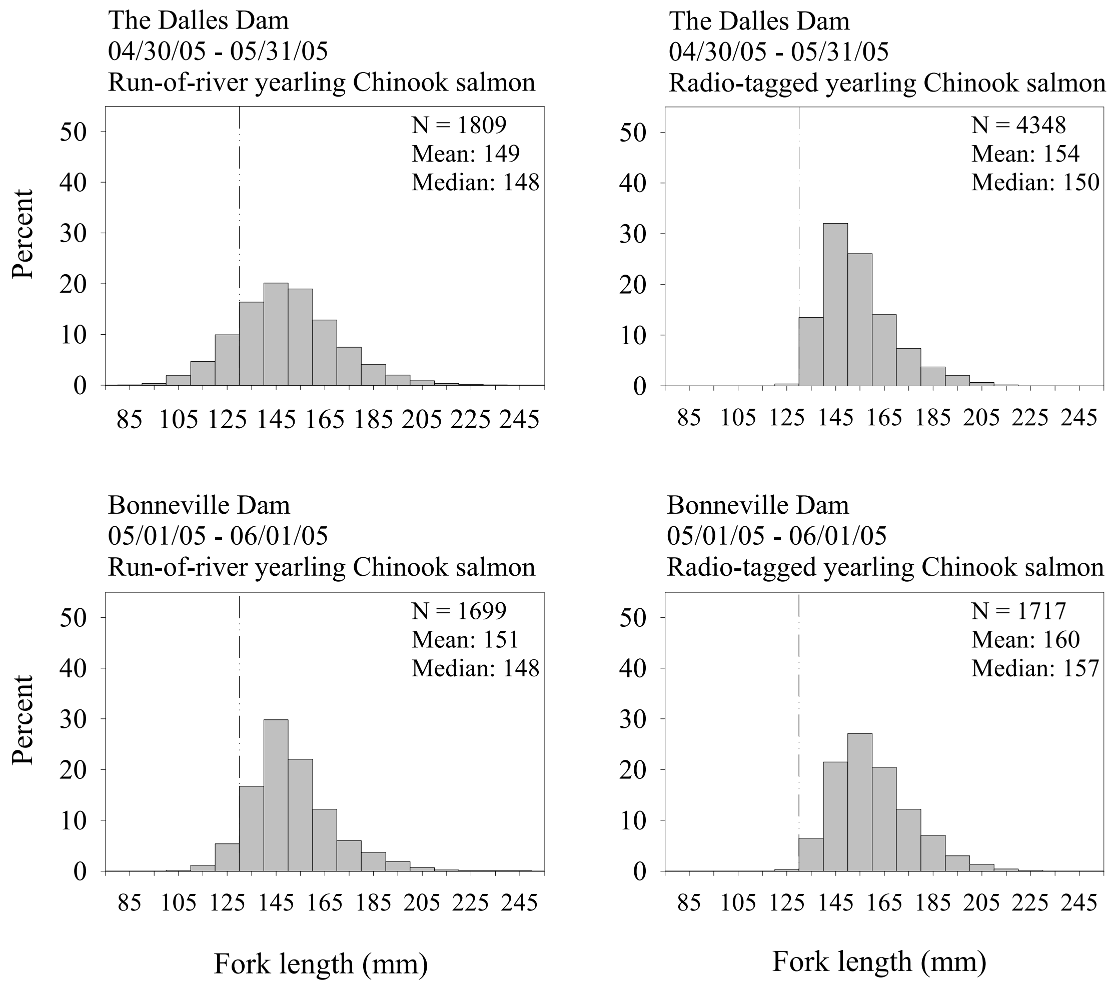


Figure 9. The distribution of fork lengths of run-of-river yearling Chinook salmon that were sampled at the John Day Dam and Bonneville Dam smolt monitoring facilities and fish tagged with NCT-3-1-KMF radio transmitters (Lotek Engineering, Newmarket, Ontario) and released at The Dalles Dam and Bonneville Dam during 2005. Based on length to weight regression equations and tag weight to fish weight criterion, fish to the left of the dashed lines were too small to be tagged with the transmitters.

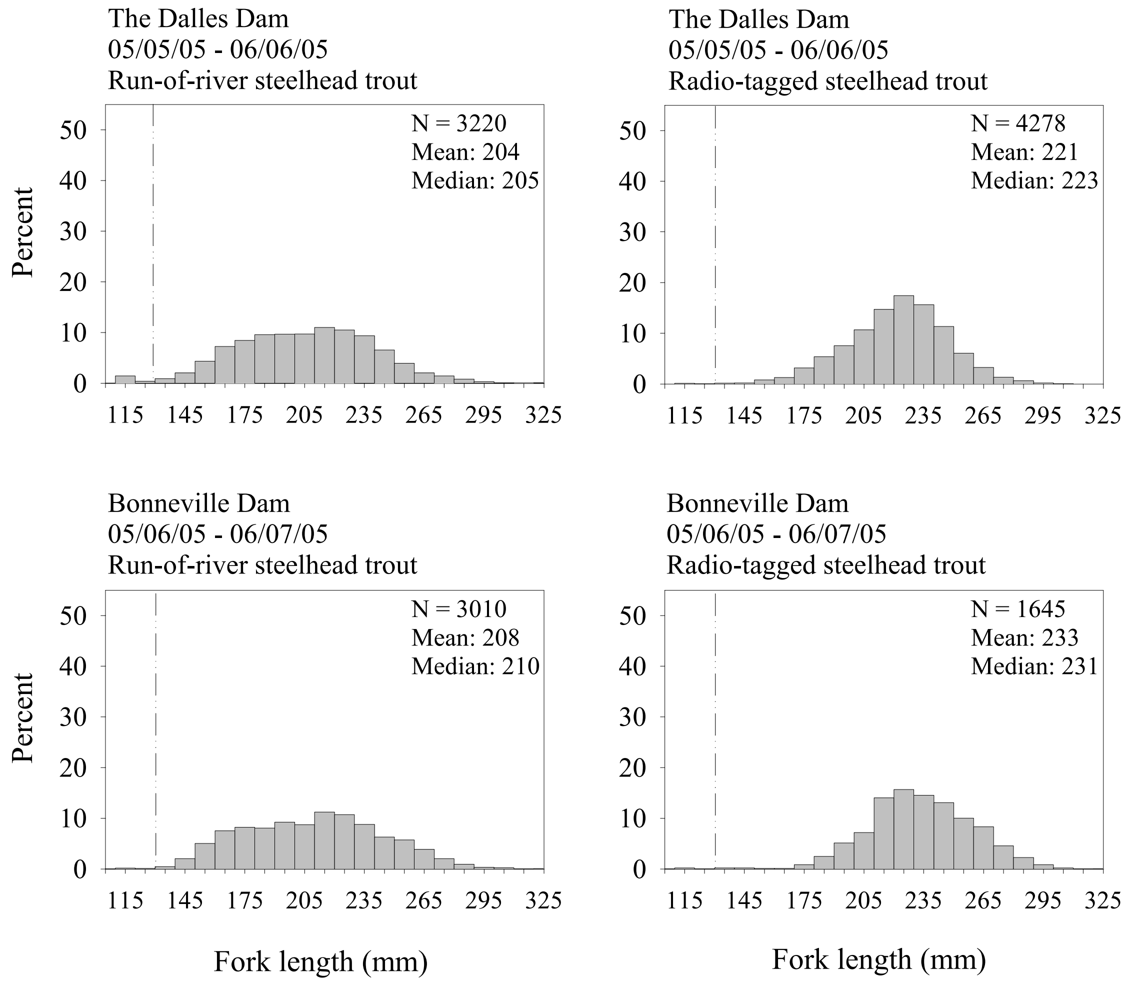


Figure 10. The distribution of fork lengths of run-of-river steelhead trout that were sampled at the John Day Dam and Bonneville Dam smolt monitoring facilities and fish tagged with NCT-3-1-KMF radio transmitters (Lotek Engineering, Newmarket, Ontario) and released at The Dalles Dam and Bonneville Dam during 2005. Based on length to weight regression equations and tag weight to fish weight criterion, fish to the left of the dashed lines were too small to be tagged with the transmitters.

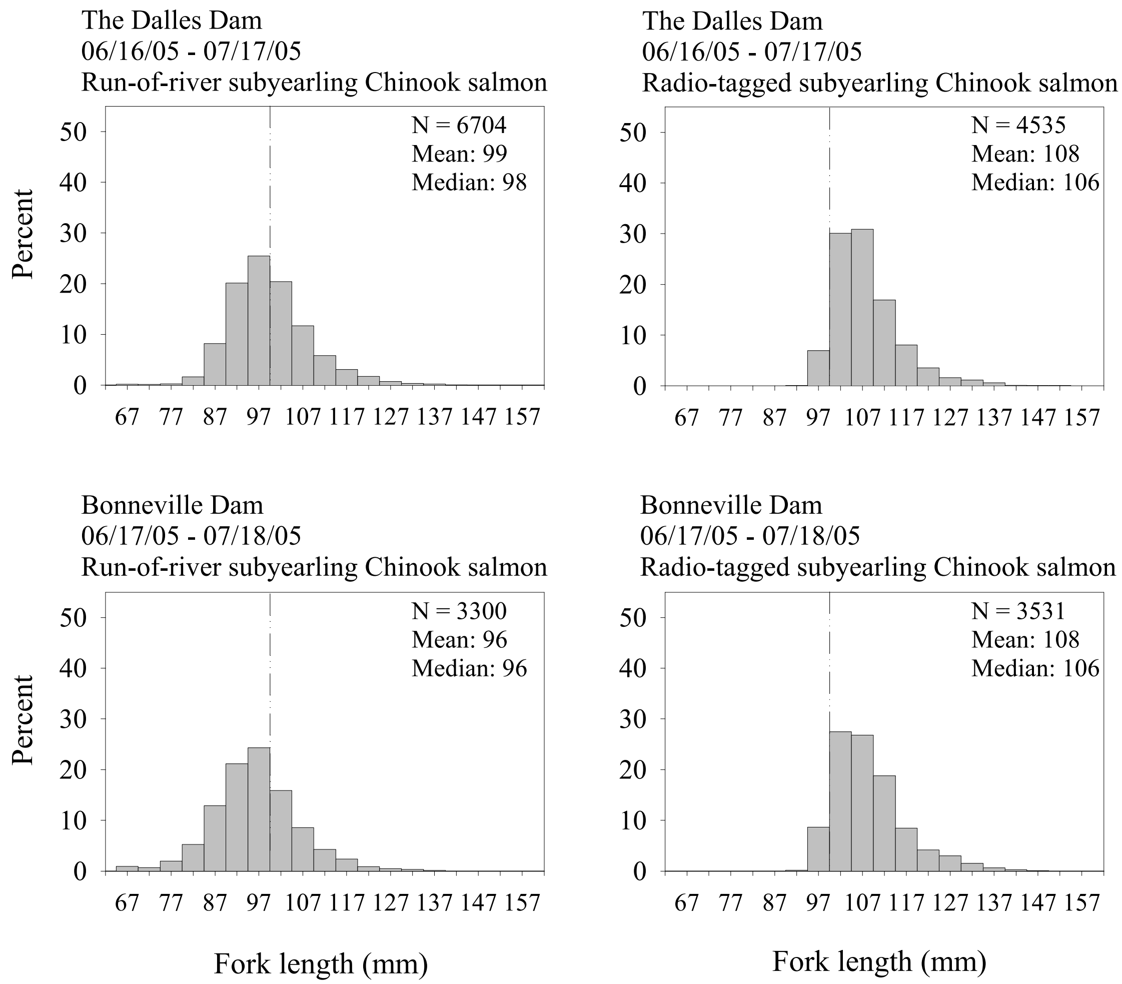


Figure 11. The distribution of fork lengths of run-of-river subyearling Chinook salmon that were sampled at the John Day Dam and Bonneville Dam smolt monitoring facilities and fish tagged with NCT-M-2 radio transmitters (Lotek Engineering, Newmarket, Ontario) and released at The Dalles Dam and Bonneville Dam during 2005. Based on length to weight regression equations and tag weight to fish weight criterion, fish to the left of the dashed lines were too small to be tagged with the transmitters.

Tag-life performance

An assumption of release-recapture models used to estimate survival is that all live tagged individuals have the same probability of being detected at downstream detection arrays. A factor that may influence this assumption is that radio-tags have a limited and varied battery life. Therefore, the tag failure rate will affect detection probabilities depending on travel time of a tagged fish and the time a tag is on prior to release. Thus, 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 equipment malfunction, extended travel time of fish during periods of low discharge, or extended length of time tag was on prior to release. Information obtained by a tag-life study (see Appendix 2) can be used to adjust survival estimates using the probability that a tag will expire prior to fish exiting the study area (Townsend et al. 2004, Cowen and Schwarz 2005).

The tag-life studies for spring and summer were analyzed for generating model parameters of the Gompertz distribution and calculating probabilities radio-tags were alive 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 (Table 2).

We determined that the probability of a tag being operational at downstream arrays was high, with all probabilities greater than 99.9% (Table 3). Probabilities were higher for the summer study than for the spring study. The cumulative arrival distributions plotted with the Gompertz model over time shows that tagged juvenile salmonids passed through downstream detection arrays several days before tag-failure was substantial for both fish released from The Dalles Dam tailrace and Bonneville Dam tailrace (Appendix 2, Figure A2.1 and A2.2). Since the probability of a tag being operational at the downstream detection arrays for our survival studies was very close to one (Table 3), we did not adjust our survival estimates.

Table 2. Parameter estimates for tag-life study using the Gompertz model during spring and summer during 2005, model estimates and standard errors (given in parentheses).

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

Recovery period tag loss and mortality

After tagging, fish were held for approximately 18 to 36 h for recovery. After the holding period, before being released, any dead fish or regurgitated transmitters were removed. For radio-tagged yearling Chinook salmon, for all releases combined, mortality was 0.1% and tag loss was 3.2%. For radio-tagged steelhead trout, for all releases combined, mortality was 0.2% and tag loss was 3.9%. For radio-tagged subyearling Chinook salmon, for all releases combined, mortality was 0.3% and tag loss was 1.2%. Recovery period mortality and tag loss by individual release can be found in Appendix 1.

Table 3. Estimated probabilities (mean, *SE* in parentheses) a radio-tag was operational at Bonneville Dam and the downstream detection arrays for yearling Chinook salmon, hatchery steelhead trout, and subyearling Chinook salmon, during 2005.

	Detection Array Locations	
Release Site	Bonneville Dam	Survival Gates
	Yearling Chinook salmon	
The Dalles Dam	1.000 (1.272×10^{-5})	0.9999 (1.401×10^{-5})
Bonneville Dam	NA	1.000 (4.327×10^{-6})
	Hatchery steelhead trout	
The Dalles Dam	1.000 (1.337×10^{-5})	0.9999 (3.518×10^{-5})
Bonneville Dam	NA	1.0000 (8.403×10^{-6})
	Subyearling Chinook salmon	
The Dalles Dam	0.9999 (1.093×10^{-6})	0.9997 (2.082×10^{-5})
Bonneville Dam	NA	1.0000 (2.661×10^{-7})

Releases of dead radio-tagged fish

We detected two dead radio-tagged yearling Chinook salmon, one steelhead trout, and one subyearling Chinook salmon at the downstream detection arrays suggesting that it was possible to detect marked animals that were not alive. For all other releases during 2005, dead fish were not detected at arrays downstream of Bonneville Dam. We estimate the probabilities for detecting dead radio-tagged yearling Chinook to be 0.0206 (0.0025, 0.0725; 95% CI), the probability of detecting steelhead trout to be 0.0103 (0.0003, 0.0561; 95% CI), and subyearling Chinook salmon to be 0.0102 (0.0003, 0.0555, 95% CI) at the current set of detection arrays below Bonneville Dam. All of the contacted dead radio-tagged fish had long travel times (Table 4) and often only two antenna contacts. Furthermore, one of the dead fish contacts also had very low power readings. Thus, we propose to perform a sensitivity analysis on the survival estimates generated by removing all fish: below a specified power criteria, fish with travel times beyond a specified percent of the overall distribution, and fish with only two antenna records. We will also consider alternate ways of estimating the probability of detecting dead fish. For instance the estimates we provide may be an overestimate. That is the actual probability could be estimated as the product of the probability of detection and the probability of having a certain travel time of power level.

Table 4. Summary of release dates, times, and travel times (hrs) to survival gates and percent of the travel time distribution of all radio-tagged fish for dead radio-tagged fish contacted at survival detection gates below Bonneville Dam, 2005. Each dead fish was contacted only at the Gate specified in the travel time to Gate column.

Release			Travel time to	Travel time distribution
Date	Time	Species	Gate (hrs)	to Gate
3-May	08:20	Yearling Chinook	164 to Gate 1	100.0%
17-May	21:08	Steelhead trout	83.9 to Gate 2	99.6%
29-May	08:07	Yearling Chinook	27.5 to Gate 3	93.5%
4-July	10:54	Subyearling Chinook	14.9 to Gate 1	98.0%

Yearling Chinook salmon

Route-specific Survival Model

Survival estimation

Capture histories are generated for each passage scenario, indicating detection at the release location, detection at the dam, and detection down stream of the dam by assigning a 1 for detection and a 0 for not detected at antenna arrays. Using capture histories generated from the detections of radio-tagged yearling Chinook salmon released at The Dalles Dam and in the tailrace of Bonneville Dam and monitored at the downstream antenna arrays (Tables 5 and 6), we generated maximum likelihood estimates of the route-specific passage and survival probabilities for yearling Chinook salmon through Bonneville Dam during spill operations of 75 kcfs during the day (0500 to 2100 hrs) and night spill until the total dissolved gas cap is reached (Table 7).

Table 5. Counts of radio-tagged yearling Chinook salmon released from The Dalles Dam (R_1) and in the tailrace of Bonneville Dam (R_2) during the 75 kcfs day/total dissolved gas cap night spill operations and used in the route-specific survival model, 2005. B1 is powerhouse 1 and B2 is powerhouse 2 turbines at Bonneville Dam. Within-route histories refer to whether a fish was detected on both antenna arrays (11), the first antenna array only (10), or the second antenna array only (01) within the passage route.

				Within-route histories Bonneville Dam [A]		
Release	Detection History [A]	Route	Counts	11	01	10
$R_1 = 4351$	100		168			
	101		85			
	110	Spillway	152	1277	143	134
	111		1402			
	110	B1	21	135	119	0
	111		233			
	110	B2 Turbines	63	815	40	145
	111		937			
	110	B2 Juvenile bypass	13	499	0	116
	111		602			
	110	B2 Corner collector	6	646	27	2
	111		669			
$R_2 = 1331$	010		38			
	011		1293			

[A] - Detection history recorded as: 1, detected; 0, not detected

Table 6. Counts of radio-tagged yearling Chinook salmon released from The Dalles Dam (R_1) and in the tailrace of Bonneville Dam (R_2) and passing during two spill operations: 75 kcfs day (0500 to 2100 hrs) and TDG (total dissolved gas cap) night in 2005. B1 is powerhouse 1 and B2 is powerhouse 2 turbines at Bonneville Dam. Within-route histories refer to whether a fish was detected on both antenna arrays (11), the first antenna array only (10), or the second antenna array only (01) within the passage route.

75 kcfs day spill operations						
				Within-route histories Bonneville Dam [A]		
Release	Detection History [A]	Route	Counts	11	01	10
$R_1 = 2686$	100		98			
	101		42			
	110	Spillway	101	708	55	69
	111		731			
	110	B1	15	100	88	0
	111		173			
	110	B2 Turbines	35	448	28	46
	111		487			
	110	B2 Juvenile bypass	8	314	0	83
	111		389			
	110	B2 Corner collector	5	582	23	2
	111		602			
$R_2 = 662$	010		13			
	011		649			

TDG night spill operations						
				Within-route histories Bonneville Dam [A]		
Release	Detection History [A]	Route	Counts	11	01	10
$R_1 = 1665$	100		70			
	101		43			
	110	Spillway	51	569	88	65
	111		671			
	110	B1	6	35	31	0
	111		60			
	110	B2 Turbines	28	367	12	99
	111		450			
	110	B2 Juvenile bypass	5	185	0	33
	111		213			
	110	B2 Corner collector	1	64	4	0
	111		67			
$R_2 = 669$	010		25			
	011		644			

[A] - Detection history recorded as: 1, detected; 0, not detected

Table 7. Summary of estimated passage, detection, lambda (joint survival and detection parameter), and survival probabilities for yearling Chinook salmon used in the route-specific survival model at Bonneville Dam, 2005. E, is the probability that fish will pass via the spillway; PH2, conditional probability of passing via the second powerhouse, given fish did not pass via the spillway; B_2CC, conditional probability of passing via the corner collector and B_2JBS, conditional probability of passing via the juvenile bypass system, given that fish were going to powerhouse 2. Detection probabilities by route: P_{B2CC}, the corner collector; P_{B2JBS}, the juvenile bypass system; P_{B2Turb}, the second powerhouse; P_{PH1}, the first powerhouse; P_{SPILL}, spillway; λ, the joint probability of surviving and being detected at arrays below Bonneville Dam. Survival parameters are as follows: S_{PH1}, the first powerhouse survival probability; S_{B2Turb}, survival through turbine units at the second powerhouse; S_{B2CC}, the corner collector survival probability; S_{B2JBS}, the second powerhouse juvenile bypass system survival probability; S_{SPILL}, spillway survival probability; S_{DAM}, the dam survival; S_{POOL}, survival from the release location at The Dalles Dam. Dam operations were 75 kcfs day (0500 to 2100 hrs) and total dissolved gas cap (TDG) at night.

	Spill Operations					
	75 kcfs day/TDG night		75 kcfs day		TDG night	
Parameters	Probability	95% CI	Probability	95% CI	Probability	95% CI
E	0.379	0.364, 0.394[A]	0.326	0.307, 0.344[A]	0.465	0.440, 0.492[A]
PH2	0.888	0.873, 0.901[A]	0.878	0.861, 0.893[A]	0.904	0.877, 0.930[A]
B_2CC	0.293	0.274, 0.311[A]	0.396	0.372, 0.421[A]	0.088	0.070, 0.110[A]
B_2JBS	0.377	0.354, 0.401[A]	0.430	0.398, 0.462[A]	0.310	0.277, 0.345[A]
P_{B2CC}	0.9999	0.9997, 1.000	0.9999	0.9997, 1.000	0.999	0.997, 1.001
P_{B2JBS}	0.9995	0.999, 1.000	0.999	0.997, 1.001	0.999	0.997, 1.001
P_{B2Turb}	0.991	0.987, 0.995	0.994	0.990, 0.997	0.991	0.986, 0.997
P_{PH1}	0.928	0.890, 0.966	0.934	0.901, 0.966	0.882	0.773, 0.991
P_{SPILL}	0.988	0.985, 0.991	0.993	0.990, 0.995	0.983	0.977, 0.989
λ	0.971	0.962, 0.980[A]	0.980	0.968, 0.989[A]	0.963	0.946, 0.975[A]
S_{PH1}	0.950	0.912, 0.980[A]	0.943	0.900, 0.977[A]	0.953	0.870, 1.007[A]
S_{B2Turb}	0.965	0.947, 0.982[A]	0.952	0.926, 0.975[A]	0.978	0.951, 1.004[A]
S_{B2CC}	1.020	1.008, 1.032[A]	1.012	0.999, 1.026[A]	1.024	0.972, 1.049[A]
S_{B2JBS}	1.008	0.992, 1.022[A]	0.999	0.980, 1.017[A]	1.015	0.985, 1.039[A]
S_{SPILL}	0.930	0.912, 0.947[A]	0.897	0.872, 0.921[A]	0.966	0.942, 0.990[A]
S_{DAM}	0.966	0.952, 0.980	0.955	0.939, 0.971	0.978	0.961, 0.996
S_{POOL}	0.962	0.956, 0.968[A]	0.964	0.957, 0.971[A]	0.959	0.949, 0.968[A]

[A] - Profile likelihood confidence intervals

Comparison of estimators generated during 75 kcfs day and TDG night spill operations

The estimated survival probabilities for yearling Chinook salmon were higher during the TDG night spill operations than during the 75 kcfs day operations for fish passing via all routes and for the dam. The estimated survival probabilities for yearling Chinook salmon passing via the powerhouse 1, the powerhouse 2 turbines, the powerhouse 2 corner collector and JBS, were not found to be significantly different between 75 kcfs day and TDG night spill operations (Table 8). The estimated spillway survival and the overall dam survival were found to be significantly different between the two spill operations.

Table 8. Summary table of estimated route-specific survival probabilities (S) and their associated standard errors (*SE*) of yearling Chinook salmon survival through Bonneville Dam during two spill operations, 2005. The results of *Z*-tests (i.e., *Z*-statistic) structured to assess whether the estimated survival probabilities during the 75 kcfs day spill operations were different than the estimated survival probabilities during the total dissolved gas cap (TDG) night spill operations. Significant results are indicated where $Z \geq 1.645$ given a two-tailed test and $\alpha = 0.10$. The JBS refers to the juvenile bypass system at powerhouse 2.

	75 kcfs day		TDG night		
Passage Route	$\hat{S}$	*SE*	$\hat{S}$	*SE*	*Z*
Powerhouse 1	0.943	0.020	0.953	0.035	0.248
Powerhouse 2	0.952	0.012	0.978	0.013	1.470
Corner Collector	1.012	0.007	1.024	0.017	0.163
JBS	0.999	0.009	1.015	0.013	1.012
Spillway	0.897	0.013	0.966	0.012	3.900
Dam	0.955	0.008	0.978	0.009	1.910

Paired Release-recapture Model

Assumption tests for the ice and trash sluiceway

Burnham Tests

The results of the Burnham Tests 2 and 3 testing assumptions A5 and A6 for yearling Chinook salmon paired releases at the ice and trash sluiceway with the control downstream of the outfall of the juvenile bypass at powerhouse 2 were all inconclusive due to the number of tests that were incalculable because of the presence of all zeroes in either rows or columns of the contingency table. The results of these tests can be found in Appendix 3 (Tables A3.1).

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

The chi-square tests of homogeneity testing for the similarity in arrival times of the paired releases of yearling Chinook salmon at the ice and trash sluiceway with the control downstream of the outfall of the juvenile bypass at powerhouse 2 indicated that there were no significant differences in arrival times between the two release groups at the downstream radio telemetry arrays (Appendix 4 Tables A4.1).

Powerhouse 1 Ice and Trash Sluiceway Survival Estimation

We estimated that the survival of yearling Chinook salmon released into the ice and trash sluiceway at Bonneville Dam's powerhouse 1 (control release in the tailrace below the outfall of powerhouse 2 juvenile bypass outfall) during 2005 ranged from 0.778 to 1.00 (Table 9). The average survival was estimated to be 0.919 (*SE* =0.016, 95% confidence interval [0.885, 0.954]).

Table 9. The estimated survival (S) and standard error (*SE*) of yearling Chinook salmon released into the ice and trash sluiceway at Bonneville Dam's powerhouse 1 during spring 2005. Dam operations were 75 kcfs during the day with total dissolved gas cap at night. Releases were made directly into the ice and trash sluiceway with the control release below the powerhouse 2 juvenile bypass (JBS) outfall at Bonneville Dam. The survival estimates are for the fish released directly into the ice and trash sluiceway to the release location of the tailrace release group.

	Powerhouse 1 Ice and Trash Sluiceway Estimates	
Release	S	*SE*
1	0.885	0.065
2	0.956	0.044
3	0.963	0.039
4	0.910	0.056
5	0.913	0.059
6	0.958	0.043
7	0.960	0.039
8	0.958	0.041
9	0.962	0.038
10	0.840	0.073
11	1.000	0.108
12	0.778	0.085
13	0.960	0.039
14	0.958	0.097
15	0.914	0.059
16	0.792	0.095

Steelhead trout

Route-specific Survival Model

Survival estimation

Using capture histories generated from the detections of radio-tagged hatchery steelhead trout released at The Dalles Dam and in the tailrace of Bonneville Dam (Table 10 and 11), we generated maximum likelihood estimates of the route-specific passage and survival probabilities for yearling Chinook salmon through Bonneville Dam during spill operations of 75 kcfs during the day (0500 to 2100 hrs) and night spill until the total dissolved gas cap is reached at night (Table 12).

Table 10. Counts of radio-tagged hatchery steelhead trout for the releases from The Dalles Dam (R_1) and in the tailrace of Bonneville Dam (R_2) during the 75 kcfs day/total dissolved gas cap night spill operations and used in the route-specific survival model, 2005. B1 is powerhouse 1 and B2 is powerhouse 2 turbines at Bonneville Dam. Within-route histories refer to whether a fish was detected on both antenna arrays (11), the first antenna array only (10), the second antenna array only (01) within the passage route.

				Within-route histories Bonneville Dam [A]		
Release	Detection History [A]	Route	Counts	11	01	10
$R_1 = 4278$	100		302			
	101		84			
	110	Spillway	107	1242	194	79
	111		1408			
	110	B1	30	136	168	3
	111		277			
	110	B2 Turbines	65	330	33	54
	111		352			
	110	B2 Juvenile bypass	18	212	0	46
	111		240			
	110	B2 Corner collector	25	1345	46	4
	111		1370			
$R_2 = 1279$	010		34			
	011		1245			

[A] - Detection history recorded as: 1, detected; 0, not detected

Table 11. Counts of radio-tagged hatchery steelhead trout released from The Dalles Dam (R_1) and in the tailrace of Bonneville Dam (R_2) and passing during two spill operations: 75 kcfs day (0500 to 2100 hrs) and TDG (total dissolved gas cap) night in 2005. B1 is powerhouse 1 and B2 is powerhouse 2 turbines at Bonneville Dam. Within-route histories refer to whether a fish was detected on both antenna arrays (11), the first antenna array only (10), the second antenna array only (01) within the passage route.

75 kcfs day spill operations						
				Within-route histories Bonneville Dam [A]		
Release	Detection History [A]	Route	Counts	11	01	10
$R_1 = 2402$	100		177			
	101		36			
	110	Spillway	62	390	42	15
	111		385			
	110	B1	17	95	65	2
	111		145			
	110	B2 Turbines	37	138	20	7
	111		128			
	110	B2 Juvenile bypass	10	99	0	21
	111		110			
	110	B2 Corner collector	22	1247	44	4
	111		1273			
$R_2 = 637$	010		16			
	011		621			
TDG night spill operations						
				Within-route histories Bonneville Dam [A]		
Release	Detection History [A]	Route	Counts	11	01	10
$R_1 = 1876$	100		125			
	101		48			
	110	Spillway	45	852	152	64
	111		1023			
	110	B1	13	41	103	1
	111		132			
	110	B2 Turbines	28	192	13	47
	111		224			
	110	B2 Juvenile bypass	8	113	0	25
	111		130			
	110	B2 Corner collector	3	98	2	0
	111		97			
$R_2 = 642$	010		18			
	011		624			

[A] - Detection history recorded as: 1, detected; 0, not detected

Table 12. Summary of estimated passage, detection, lambda (joint survival and detection parameter), and survival probabilities for hatchery steelhead trout used in the route-specific survival model at Bonneville Dam, 2005. E, is the probability that fish will pass via the spillway; PH2, conditional probability of passing via the second powerhouse, given fish did not pass via the spillway; B_2CC, conditional probability of passing via the corner collector and B_2JBS, conditional probability of passing via the juvenile bypass system, given that fish were going to powerhouse 2. Detection probabilities by route: P_{B2CC}, the corner collector; P_{B2JBS}, the juvenile bypass system; P_{B2Turb}, the second powerhouse; P_{PH1}, the first powerhouse; P_{SPILL}, spillway; λ, the joint probability of surviving and being detected at arrays below Bonneville Dam. Survival parameters are as follows: S_{PH1}, the first powerhouse survival probability; S_{B2Turb}, survival through turbine units at the second powerhouse; S_{B2CC}, the corner collector survival probability; S_{B2JBS}, the second powerhouse juvenile bypass system survival probability; S_{SPILL}, spillway survival probability; S_{DAM}, the dam survival; S_{POOL}, survival from the release location at The Dalles Dam. Dam operations were 75 kcfs day (0500 to 2100) and total dissolved gas cap (TDG) at night.

	Spill Operations					
	75 kcfs day/TDG night		75 kcfs day		TDG night	
Parameters	Probability	95% CI	Probability	95% CI	Probability	95% CI
E	0.386	0.371, 0.402[A]	0.202	0.186, 0.219[A]	0.618	0.594, 0.641
PH2	0.851	0.836, 0.866[A]	0.891	0.875, 0.905[A]	0.738	0.702, 0.774[A]
B_2CC	0.671	0.650, 0.691[A]	0.818	0.799, 0.837[A]	0.202	0.168, 0.239[A]
B_2JBS	0.377	0.341, 0.414[A]	0.419	0.363, 0.477[A]	0.350	0.304, 0.399[A]
P_{B2CC}	0.9999	0.9998, 1.000	0.9999	0.9998, 1.000	0.9998	0.999, 1.000
P_{B2JBS}	0.999	0.997, 1.001	0.998	0.993, 1.002	0.998	0.995, 1.002
P_{B2Turb}	0.985	0.978, 0.992	0.993	0.986, 0.999	0.986	0.978, 0.995
P_{PH1}	0.898	0.867, 0.928	0.913	0.882, 0.944	0.864	0.805, 0.924
P_{SPILL}	0.991	0.988, 0.993	0.996	0.993, 0.998	0.989	0.985, 0.992
λ	0.973	0.964, 0.981[A]	0.975	0.961, 0.985[A]	0.972	0.957, 0.983[A]
S_{PH1}	0.933	0.897, 0.963[A]	0.927	0.876, 0.968[A]	0.941	0.887, 0.982[A]
S_{B2Turb}	0.868	0.830, 0.903[A]	0.797	0.727, 0.858[A]	0.915	0.870, 0.953[A]
S_{B2CC}	1.009	0.997, 1.021[A]	1.008	0.995, 1.025[A]	0.998	0.950, 1.027[A]
S_{B2JBS}	0.956	0.919, 0.985[A]	0.940	0.880, 0.985[A]	0.969	0.919, 1.005[A]
S_{SPILL}	0.955	0.939, 0.971[A]	0.884	0.848, 0.917[A]	0.986	0.968, 1.005[A]
S_{DAM}	0.963	0.950, 0.976	0.957	0.941, 0.972	0.970	0.953, 0.987
S_{POOL}	0.931	0.923, 0.938[A]	0.927	0.916, 0.937[A]	0.935	0.923, 0.946[A]

[A] - Profile likelihood confidence intervals

Comparison of estimators generated during 75 kcfs day and TDG night spill operations

The estimated survival probabilities for steelhead trout passing via the powerhouse 1, the powerhouse 2 JBS and corner collector were not found to be significantly different between the two spill operations (Table 13). The estimated survival for steelhead trout passing via the powerhouse 2 turbines and the spillway were found to be significantly different. The dam survival for steelhead trout was not found to be significantly different between 75 kcfs day and TDG night spill operations.

Table 13. Summary table of estimated route-specific survival probabilities (S) and their associated standard errors (*SE*) of steelhead trout survival through Bonneville Dam during two spill operations, 2005. The results of *Z*-tests (i.e., *Z*-statistic) structured to assess whether the estimated survival probabilities during the 75 kcfs day spill operations were different than the estimated survival probabilities during the total dissolved gas cap (TDG) night spill operations. Significant results are indicated where $Z \geq 1.645$ given a two-tailed test and $\alpha = 0.10$. The JBS refers to the juvenile bypass system at powerhouse 2.

	75 kcfs day		TDG night		
Passage route	$\hat{S}$	*SE*	$\hat{S}$	*SE*	*Z*
Powerhouse 1	0.927	0.023	0.941	0.024	0.421
Powerhouse 2	0.797	0.034	0.915	0.021	2.953
Corner Collector	1.008	0.007	0.998	0.019	0.494
JBS	0.940	0.027	0.969	0.021	0.848
Spillway	0.884	0.018	0.986	0.009	5.068
Dam	0.957	0.008	0.970	0.009	1.080

Paired Release-recapture Model

Assumption tests for the ice and trash sluiceway

Burnham tests

The results of the Burnham Tests 2 and 3 testing assumptions A5 and A6 for hatchery steelhead trout paired releases through the ice and trash sluiceway with the control downstream of the outfall of the juvenile bypass at powerhouse 2 were all inconclusive due to the number of tests that were incalculable because of the presence of all zeroes in either rows or columns of the contingency table. The results of these tests can be found in Appendix 3 (Tables A3.2).

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

The chi-square tests of homogeneity testing for the similarity in arrival times of paired releases of hatchery steelhead trout through the ice and trash sluiceway with the control downstream of the outfall of the juvenile bypass at powerhouse 2 indicated that there were no significant differences in arrival times between the two release groups at the downstream radio telemetry arrays (Appendix 4 Tables A4.2).

Powerhouse 1 Ice and Trash Sluiceway Survival Estimation

We estimated that the survival of steelhead trout released into the ice and trash sluiceway at Bonneville Dam's powerhouse 1 (control release in the tailrace below the outfall of powerhouse 2 juvenile bypass outfall) during 2005 ranged from 0.750 to 1.074 (Table 14). The average survival was estimated to be 0.910 (*SE* =0.021, 95% confidence interval [0.864, 0.956]).

Table 14. The estimated survival (S) and standard error (*SE*) for hatchery steelhead trout released into the ice and trash sluiceway at Bonneville Dam's powerhouse 1 during spring 2005. Dam operations were 75 kcfs during the day with total dissolved gas cap at night. Releases were made directly into the ice and trash sluiceway with the control release below the powerhouse 2 juvenile bypass (JBS) outfall at Bonneville Dam. The survival estimates are for the fish released directly into the ice and trash sluiceway to the release location of the tailrace release group.

	Powerhouse 1 Ice and Trash Sluiceway Estimates	
Release	S	*SE*
1	0.958	0.041
2	1.074	0.102
3	0.955	0.044
4	0.910	0.056
5	0.932	0.059
6	0.958	0.041
7	0.833	0.076
8	1.000	0.112
9	1.000	0.101
10	0.962	0.038
11	0.750	0.097
12	0.889	0.060
13	0.824	0.100
14	0.876	0.111
15	0.829	0.107
16	0.810	0.086

Subyearling Chinook salmon

Route-specific Survival Model

Survival estimation

Using capture histories generated from the detections of radio-tagged subyearling Chinook salmon released at The Dalles Dam and in the tailrace of Bonneville Dam (Tables 15 and 16), we generated maximum likelihood estimates of the route-specific passage and survival probabilities for yearling Chinook salmon through Bonneville Dam during spill operations of 75 kcfs during the day (0500 to 2200 hrs) and night spill until the total dissolved gas cap is reached at night (Table 17).

Table 15. Counts of radio-tagged subyearling Chinook salmon for the releases from The Dalles Dam (R_1) and in the tailrace of Bonneville Dam (R_2) during the 75 kcfs day/total dissolved gas cap night spill operations and used in the route-specific survival model, 2005. B1 is powerhouse 1 and B2 is powerhouse 2 turbines at Bonneville Dam. Within-route histories refer to whether a fish was detected on both antenna arrays (11), the first antenna array only (10), the second antenna array only (01) within the passage route.

				Within-route histories Bonneville Dam [A]		
Release	Detection History [A]	Route	Counts	11	01	10
$R_1 = 4536$	100		468			
	101		191			
	110	Spillway	265	1485	359	119
	111		1698			
	110	B1	6	43	10	0
	111		47			
	110	B2 Turbines	106	472	90	139
	111		595			
	110	B2 Juvenile bypass	18	265	0	13
	111		260			
	110	B2 Corner collector	33	830	2	50
	111		849			
$R_2 = 2930$	010		146			
	011		2784			

[A] - Detection history recorded as: 1, detected; 0, not detected

Table 16. Counts of radio-tagged subyearling Chinook salmon released from The Dalles Dam (R_1) and in the tailrace of Bonneville Dam (R_2) and passing during two spill operations: 75 kcfs day (0500 to 2200 hrs) and TDG (total dissolved gas cap) night in 2005. B1 is powerhouse 1 and B2 is powerhouse 2 turbines at Bonneville Dam. Within-route histories refer to whether a fish was detected on both antenna arrays (11), the first antenna array only (10), the second antenna array only (01) within the passage route.

75 kcfs day spill operations						
				Within-route histories Bonneville Dam [A]		
Release	Detection History [A]	Route	Counts	11	01	10
$R_1 = 3405$	100		347			
	101		128			
	110	Spillway	219	1143	180	8
	111		1112			
	110	B1	6	40	8	0
	111		42			
	110	B2 Turbines	89	401	66	103
	111		481			
	110	B2 Juvenile bypass	13	174	0	12
	111		173			
	110	B2 Corner collector	32	752	2	41
	111		763			
$R_2 = 1466$	010		58			
	011		1408			

TDG night spill operations						
				Within-route histories Bonneville Dam [A]		
Release	Detection History [A]	Route	Counts	11	01	10
$R_1 = 1131$	100		121			
	101		63			
	110	Spillway	46	342	179	111
	111		586			
	110	B1	0	3	2	0
	111		5			
	110	B2 Turbines	17	71	24	36
	111		114			
	110	B2 Juvenile bypass	5	91	0	1
	111		87			
	110	B2 Corner collector	1	78	0	9
	111		86			
$R_2 = 1464$	010		88			
	011		1376			

[A] - Detection history recorded as: 1, detected; 0, not detected

Table 17. Summary of estimated passage, detection, lambda (joint survival and detection parameter), and survival probabilities for subyearling Chinook salmon used in the route-specific survival model at Bonneville Dam, 2005. E, is the probability that fish will pass via the spillway; PH2, conditional probability of passing via the second powerhouse, given fish did not pass via the spillway; B_2CC, conditional probability of passing via the corner collector and B_2JBS, conditional probability of passing via the juvenile bypass system, given that fish were going to powerhouse 2. Detection probabilities by route: $P_{B2CC,}$ the corner collector; $P_{B2JBS,}$ the juvenile bypass system; P_{B2Turb}, the second powerhouse; P_{PH1}, the first powerhouse; P_{SPILL}, spillway; λ, the joint probability of surviving and being detected at arrays below Bonneville Dam. Survival parameters are as follows: S_{PH1}, the first powerhouse survival probability; S_{B2Turb}, survival through turbine units at the second powerhouse; S_{B2CC}, the corner collector survival probability; S_{B2JBS}, the second powerhouse juvenile bypass system survival probability; S_{SPILL}, spillway survival probability; S_{DAM}, the dam survival; S_{POOL}, survival from the release location at The Dalles Dam. Dam operations were 75 kcfs day (0500 to 2200) and total dissolved gas cap (TDG) at night.

	Spill Operations					
	75 kcfs day/TDG night		75 kcfs day		TDG night	
Parameters	Probability	95% CI	Probability	95% CI	Probability	95% CI
E	0.491	0.475, 0.531[A]	0.434	0.417, 0.452[A]	0.677	0.646, 0.706[A]
PH2	0.915	0.897, 0.985[A]	0.909	0.892, 0.925[A]	0.980	0.954, 0.992[A]
B_2CC	0.464	0.441, 0.487[A]	0.504	0.479, 0.529[A]	0.271	0.224, 0.321[A]
B_2JBS	0.273	0.245, 0.301[A]	0.238	0.209, 0.269[A]	0.392	0.329, 0.457[A]
P_{B2CC}	0.9999	0.9997, 1.000	0.9999	0.9997, 1.000	0.999	0.996, 1.001
P_{B2JBS}	0.9998	0.999, 1.000	0.9996	0.999, 1.000	0.9999	0.9996, 1.000
P_{B2Turb}	0.957	0.945, 0.969	0.967	0.955, 0.978	0.916	0.879, 0.953
P_{PH1}	0.469	0.393, 0.546	0.480	0.407, 0.553	0.901	0.702, 1.101
P_{SPILL}	0.984	0.980, 0.987	0.999	0.998, 0.9998	0.917	0.902, 0.932
λ	0.950	0.942, 0.958[A]	0.960	0.950, 0.970[A]	0.940	0.927, 0.951[A]
S_{PH1}	0.976	0.904, 1.023[A]	0.959	0.881, 1.009[A]	0.886	0.474, 1.055[A]
S_{B2Turb}	0.895	0.866, 0.923[A]	0.880	0.847, 0.911[A]	0.926	0.856, 0.981[A]
S_{B2CC}	1.013	0.997, 1.028[A]	0.999	0.981, 1.016[A]	1.052	1.010, 1.073[A]
S_{B2JBS}	0.984	0.949, 1.012[A]	0.968	0.923, 1.003[A]	1.006	0.943, 1.046[A]
S_{SPILL}	0.911	0.893, 0.928[A]	0.870	0.847, 0.892[A]	0.986	0.960, 1.011[A]
S_{DAM}	0.938	0.924, 0.952	0.916	0.901, 0.931	0.985	0.964, 1.005
S_{POOL}	0.900	0.891, 0.909[A]	0.901	0.890, 0.911[A]	0.898	0.879, 0.916[A]

[A] - Profile likelihood confidence intervals

Comparison of estimators generated during 75 kcfs day and TDG night spill operations

The estimated survival probabilities were higher during the TDG night spill operations than for the 75 kcfs day operations for subyearling Chinook salmon passing via all routes except powerhouse 1. The estimated survival probabilities for subyearling Chinook salmon passing via the powerhouse 1, powerhouse 2 turbines, and the JBS were not found to be significantly different between the two spill operations (Table 18). The estimated survival probabilities for subyearling Chinook salmon passing via the corner collector, the spillway and the dam survival were all found to be significantly different between spill operations.

Table 18. Summary table of estimated route-specific survival probabilities (S) and their associated standard errors (*SE*) of yearling Chinook salmon survival through Bonneville Dam during two spill operations, 2005. The results of *Z*-tests (i.e., *Z*-statistic) structured to assess whether the estimated survival probabilities during the 75 kcfs day spill operations were different than the estimated survival probabilities during the total dissolved gas cap (TDG) night spill operations. Significant results are indicated where $Z \geq 1.645$ given a two-tailed test and $\alpha = 0.10$. The JBS refers to the juvenile bypass system at powerhouse 2.

	75 kcfs day		TDG night		
Passage route	$\hat{S}$	*SE*	$\hat{S}$	*SE*	*Z*
Powerhouse 1	0.959	0.033	0.886	0.162	0.442
Powerhouse 2	0.880	0.016	0.926	0.032	1.286
Corner Collector	0.999	0.009	1.052	0.014	3.185
JBS	0.968	0.020	1.006	0.026	1.158
Spillway	0.870	0.012	0.986	0.013	6.557
Dam	0.916	0.008	0.985	0.011	5.073

Paired Release-recapture Model

Assumption tests for the ice and trash sluiceway

Burnham tests

The results of the Burnham Tests 2 and 3 testing assumptions A5 and A6 for subyearling Chinook salmon paired releases through the ice and trash sluiceway with the control downstream of the outfall of the juvenile bypass at powerhouse 2 were all inconclusive due to the number of tests that were incalculable because of the presence of all zeroes in either rows or columns of the contingency table. The results of these tests can be found in Appendix 3 (Tables A3.3).

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

The chi-square tests of homogeneity testing for the similarity in arrival times of paired releases of subyearling Chinook salmon through the ice and trash sluiceway with the control downstream of the outfall of the juvenile bypass at powerhouse 2 indicated that there was one significant difference in arrival times between the two release groups at the downstream radio telemetry arrays (Appendix 4 Tables A4.3).

Powerhouse 1 Ice and Trash Sluiceway Survival Estimation

We estimated that the survival of subyearling Chinook salmon released into the ice and trash sluiceway at Bonneville Dam's powerhouse 1 (control release in the tailrace below the outfall of powerhouse 2 juvenile bypass outfall) during 2005 ranged from 0.836 to 1.263 (Table 19). The average survival was estimated to be 0.976 (*SE* =0.018, 95% confidence interval [0.938, 1.013]).

Table 19. The estimated survival (S) and standard error (*SE*) of subyearling Chinook salmon released into the ice and trash sluiceway at Bonneville Dam's powerhouse 1 during summer 2005. Dam operations were 75 kcfs during the day with total dissolved gas cap at night. Releases were made directly into the ice and trash sluiceway with the control release below the powerhouse 2 juvenile bypass (JBS) outfall at Bonneville Dam. The survival estimates are for the fish released directly into the ice and trash sluiceway to the release location of the tailrace release group.

	Powerhouse 1 Ice and Trash Sluiceway Estimates	
Release	S	*SE*
1	0.930	0.079
2	1.204	0.106
3	0.924	0.102
4	0.888	0.093
5	0.919	0.106
6	1.026	0.024
7	0.911	0.107
8	1.029	0.075
9	1.263	0.117
10	0.964	0.022
11	0.849	0.114
12	0.908	0.078
13	0.960	0.039
14	0.990	0.068
15	1.012	0.023
16	0.836	0.099
17	1.126	0.074
18	1.180	0.127
19	0.928	0.103
20	0.900	0.000
21	0.837	0.111
22	0.970	0.054
23	0.970	0.052
24	0.986	0.064
25	0.935	0.079
26	0.964	0.056
27	0.924	0.087
28	0.907	0.068
29	0.974	0.057
30	1.140	0.143
31	0.948	0.074
32	0.922	0.061

Discussion

We evaluated route-specific survival estimates for juvenile salmonids through Bonneville Dam. The route-specific survival estimates were highest for yearling Chinook salmon passing via the corner collector and the JBS at powerhouse 2, followed by the powerhouse 2 turbines, powerhouse 1, and the spillway. This trend is consistent with the 2004 route-specific results. In general, route-specific survival estimates and the overall dam survival for yearling Chinook salmon were higher in 2005 than in 2004.

As seen in past years, passage route was influenced by river discharge through an area. In 2005, during the spring migrant season, 47% of the river discharge passed through the powerhouse 2, 39% passed through the spillway, and 13% passed through powerhouse 1. Reagan et al. (*In Preparation*) indicated that 55% of radio-tagged yearling Chinook salmon passed via the powerhouse 2, 38% passed via the spillway, and only 7% passed via powerhouse 1. Therefore, dam survival estimates for yearling Chinook salmon are weighted heavily by the higher proportion of radio-tagged fish passing through the powerhouse 2 routes (corner collector, JBS, and turbines).

For steelhead trout, Reagan et al. (*In Preparation*) indicated that 52% of the radio-tagged steelhead passed via the powerhouse 2, 40% passed via the spillway and 8% passed via powerhouse 1. Of the steelhead that went to powerhouse 2, 64% passed via the corner collector. Route-specific survival estimates for steelhead trout were highest through the corner collector, followed by the JBS and the spillway and lastly powerhouse1 and powerhouse 2 turbines. Therefore steelhead survival through Bonneville Dam was weighted by the high proportion of steelhead passing via the corner collector at powerhouse 2. Overall dam survival for steelhead was lower in 2005 than in 2004. This is likely a result of a higher proportion of water passing through the spillway in 2005 than in 2004, causing a trade-off of steelhead passing via the spillway (lower route-specific survival) instead of through the powerhouse 2 corner collector (higher route-specific survival).

From 04 May to 08 May, periods of lower spill that deviated from the prescribed spill operations were observed, but had little effect on the estimated survival for the spring migrant study period. The average discharge through the spillway during this period was 66 kcfs. During these spill operations, 490 yearling Chinook salmon (11% of entire season) and 144 steelhead trout (3.4%) passed the dam. For yearling Chinook salmon passing during this period, the estimated survival through the spillway was lower than for all other prescribed dam operations (0.853; 95% profile likelihood confidence interval 0.772, 0.926). However, when we compared the survival estimates for the entire study period to the estimated survival excluding the fish passing Bonneville Dam from 04 May to 08 May, dam survival was 0.001 higher and spillway survival was 0.005 higher when the fish passing during the lower spill operations were excluded from the analyses. Too few steelhead trout passed the individual routes during this period to estimate survival using the route-specific model. We were able to estimate survival excluding steelhead trout passing during the 66 kcfs spill operations. Survival estimates through the spillway did not differ between the two spill operation groupings but the estimated dam survival was 0.002 lower when fish passing during the 66 kcfs spill operations were excluded from the analyses.

For the spring migrants the estimated survival through the ice and trash sluiceway was lower than the estimates in 2004. For yearling Chinook salmon they were very similar to the 2002 estimates. However, in 2002, releases were made during a shorter time interval (primarily from 22 May to 8 June). For subyearling Chinook salmon the estimated survival of fish passing through the ice and trash sluiceway at powerhouse 1, was higher in 2005 than in 2004. Two alternating dam operations (48 kcfs day with night spill to the total dissolved gas cap and 23 kcfs for 24 h) occurred during summer 2004, and resulted in lower spill discharge than during 2005, which could have an effect on downstream egress and survival below the ice and trash sluiceway.

During the 2005 summer migration season, the dam operations were the same as the spring, however the majority of the river discharge passed through the spillway (52%), with 45% passing via the powerhouse 2, and 3% passing via powerhouse 1. For subyearling Chinook salmon, Farley et al. (*In Preparation*) indicated that 48% of radio-tagged fish passed via powerhouse 2, 51% passed via the spillway, and 1% passed via powerhouse 1. For subyearling Chinook salmon route-specific survival was estimated to be highest for fish passing via the corner collector, followed by the JBS. There were some day/night differences between survival estimates through the spillway. At night this route has the third highest survival, however during the day survival for fish passing via powerhouse 1 was higher. Since very few fish passed powerhouse 1 during the season this route had very little impact on dam survival. During 2005, the dam survival estimates were higher than during the 2004 study year.

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

Table A1.1. Summary of yearling Chinook salmon releases at Bonneville 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	2-May	09:24	25	0	0	146	8.1	130 - 162	30.6	4.8	23.3 - 39.4
2	4-May	22:07	22	3	0	141	8.6	130 - 162	30.8	5.5	24.6 - 46.1
3	6-May	08:59	25	0	0	145	13.6	122 - 182	32.2	9.3	22.4 - 64.9
4	8-May	22:29	24	1	0	151	10.1	138 - 181	36.2	8.8	26.1 - 65.5
5	10-May	09:19	23	2	0	151	10.8	132 - 170	34.8	6.3	26.3 - 48.6
6	12-May	22:10	23	3	0	160	14.2	144 - 190	39.5	10.9	28.1 - 63.3
7	14-May	09:36	25	1	0	161	15.9	137 - 205	41.4	13.2	26.4 - 80.3
8	16-May	22:34	24	3	0	167	18.3	143 - 211	45.5	14.2	28.8 - 85.6
9	18-May	09:08	26	0	0	162	15.4	139 - 204	41.9	11.1	26.5 - 69.9
10	20-May	22:20	25	1	0	168	12.8	146 - 198	45.2	9.8	30.2 - 67.4
11	22-May	09:18	24	0	0	163	12.0	145 - 195	41.4	12.9	29.0 - 89.2
12	24-May	22:10	27	0	0	164	10.8	147 - 190	45.2	8.9	32.0 - 68.4
13	26-May	09:25	25	0	0	168	15.9	142 - 196	49.3	13.4	30.9 - 72.2
14	28-May	22:18	24	0	0	163	8.4	148 - 180	40.4	6.4	32.4 - 54.8
15	30-May	08:54	23	1	0	158	13.4	133 - 184	39.4	9.3	27.5 - 60.1
16	1-Jun	22:02	25	0	0	166	13.2	146 - 200	47.6	12.1	29.3 - 83.2
Overall			390	15	0	158	15.2	122 - 211	40.2	11.5	22.4 - 89.2

Table A1.2. Summary of yearling Chinook salmon releases at The Dalles Dam ice and trash sluiceway (Sluiceway), and the tailrace 550 m downstream of the spillway beneath the I-197 bridge (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	Location	Date	Time	N	Tag loss	Mortality	Mean	SD	Range	Mean	SD	Range
1	Tailrace	30-Apr	00:35	42	5	0	154	7.6	138 - 177	35.5	6.2	24.7 - 58.4
2	Tailrace	30-Apr	14:18	47	0	0	152	6.9	138 - 168	33.1	5.1	23.0 - 43.8
3	Sluiceway	30-Apr	19:03	46	1	0	154	9.8	139 - 178	34.8	6.8	24.4 - 56.2
4	Tailrace	1-May	00:12	47	0	0	151	8.3	135 - 175	33.0	6.3	23.5 - 54.2
5	Sluiceway	1-May	06:53	47	1	0	155	11.2	137 - 182	35.9	8.5	23.7 - 60.8
6	Tailrace	1-May	13:56	46	1	0	154	9.0	140 - 176	34.6	5.7	24.6 - 49.6
7	Tailrace	2-May	00:04	38	8	0	152	8.9	136 - 173	33.7	7.4	23.4 - 61.4
8	Sluiceway	2-May	13:08	47	1	0	154	9.5	140 - 182	34.9	7.2	24.9 - 56.8
9	Tailrace	2-May	14:21	43	4	0	149	8.3	135 - 175	31.4	5.6	23.0 - 54.6
10	Tailrace	3-May	00:04	45	2	0	150	11.8	131 - 187	33.9	8.8	21.8 - 70.5
11	Sluiceway	3-May	01:00	46	2	0	152	13.4	129 - 204	35.0	10.9	21.5 - 84.9
12	Tailrace	3-May	14:00	45	1	0	147	11.3	126 - 188	32.5	9.2	22.2 - 69.2
13	Tailrace	4-May	00:08	43	3	1	152	13.4	135 - 197	37.1	11.1	25.4 - 83.4
14	Tailrace	4-May	13:59	45	2	0	152	9.0	135 - 175	34.3	6.5	24.4 - 52.5
15	Sluiceway	4-May	18:57	41	7	0	150	12.8	130 - 184	34.3	9.8	22.4 - 64.3
16	Tailrace	5-May	00:08	42	5	0	148	7.1	127 - 160	32.6	4.3	23.0 - 41.6
17	Sluiceway	5-May	00:59	46	2	0	151	11.7	134 - 185	35.2	9.7	22.1 - 70.3
18	Tailrace	5-May	13:53	43	3	0	149	10.7	134 - 178	32.7	7.2	23.1 - 54.6
19	Tailrace	6-May	00:04	45	2	0	150	9.9	131 - 179	33.9	7.1	24.4 - 55.4
20	Sluiceway	6-May	13:00	45	2	0	149	8.5	135 - 174	34.2	6.2	24.5 - 56.0
21	Tailrace	6-May	14:45	45	2	0	150	13.6	129 - 205	35.4	10.8	21.9 - 82.8
22	Tailrace	7-May	00:01	37	10	0	154	11.3	130 - 181	38.4	9.0	22.4 - 60.3
23	Sluiceway	7-May	07:10	46	2	0	152	10.5	137 - 179	36.2	8.6	24.2 - 58.6
24	Tailrace	7-May	14:27	37	10	0	150	9.8	135 - 180	34.9	6.7	24.3 - 57.0

Table A1.2 (continued). Summary of yearling Chinook salmon releases at The Dalles Dam ice and trash sluiceway (Sluiceway), and the tailrace 550 m downstream of the spillway beneath the I-197 bridge (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	Location	Date	Time	N	Tag loss	Mortality	Mean	SD	Range	Mean	SD	Range
25	Tailrace	7-May	23:45	43	4	0	152	14.2	131 - 198	36.4	11.4	23.8 - 80.0
26	Sluiceway	8-May	13:00	46	1	1	153	10.1	138 - 181	35.4	7.6	26.2 - 63.4
27	Tailrace	8-May	14:22	44	3	0	151	10.4	131 - 183	33.1	7.9	22.3 - 58.6
28	Tailrace	9-May	00:06	44	2	0	152	12.9	131 - 193	34.8	9.2	23.1 - 68.0
29	Sluiceway	9-May	01:16	43	5	0	152	10.6	135 - 180	34.8	7.7	24.5 - 58.6
30	Tailrace	9-May	14:02	43	3	0	154	11.0	137 - 186	36.0	8.7	25.0 - 65.2
31	Tailrace	10-May	00:14	46	1	0	146	7.4	135 - 173	30.8	4.9	23.8 - 51.7
32	Tailrace	10-May	14:08	41	5	0	149	13.3	130 - 183	33.8	9.6	21.9 - 66.7
33	Sluiceway	10-May	18:53	47	1	0	152	16.5	126 - 204	35.5	12.4	21.6 - 81.5
34	Tailrace	11-May	00:13	43	2	0	149	14.4	130 - 191	33.6	11.3	21.8 - 70.1
35	Sluiceway	11-May	07:02	44	3	0	151	12.3	135 - 180	34.3	8.6	22.4 - 60.2
36	Tailrace	11-May	14:06	43	4	0	153	17.9	127 - 210	37.0	14.2	22.3 - 81.8
37	Tailrace	12-May	00:12	44	0	0	154	14.8	131 - 208	37.2	12.3	23.0 - 92.2
38	Tailrace	12-May	14:08	44	2	0	152	13.1	131 - 187	35.5	10.6	23.2 - 67.2
39	Sluiceway	12-May	19:00	46	2	0	155	14.9	136 - 189	36.7	10.6	23.3 - 63.3
40	Tailrace	12-May	23:51	45	2	0	156	16.6	130 - 200	38.2	13.2	22.7 - 81.3
41	Sluiceway	13-May	01:00	45	2	0	159	16.3	133 - 191	40.6	12.4	23.0 - 64.0
42	Tailrace	13-May	14:07	44	0	0	149	11.6	130 - 179	33.2	8.7	23.0 - 57.4
43	Tailrace	14-May	00:03	43	4	0	152	13.8	130 - 188	35.0	10.2	21.8 - 65.0
44	Sluiceway	14-May	13:04	45	2	1	150	12.8	133 - 209	32.5	9.4	22.1 - 82.5
45	Tailrace	14-May	14:23	47	0	0	152	10.9	133 - 173	34.5	7.7	23.7 - 53.2
46	Tailrace	14-May	23:53	46	0	0	152	14.8	129 - 195	36.6	10.1	22.9 - 62.3
47	Sluiceway	15-May	06:58	47	0	0	149	11.8	128 - 191	32.2	8.1	21.8 - 66.9
48	Tailrace	15-May	14:09	46	1	0	151	17.0	132 - 206	34.9	13.5	21.5 - 81.3

Table A1.2 (continued). Summary of yearling Chinook salmon releases at The Dalles Dam ice and trash sluiceway (Sluiceway), and the tailrace 550 m downstream of the spillway beneath the I-197 bridge (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	Location	Date	Time	N	Tag loss	Mortality	Mean	SD	Range	Mean	SD	Range
49	Tailrace	16-May	00:12	47	0	0	156	12.7	132 - 185	36.9	9.0	25.5 - 63.1
50	Sluiceway	16-May	06:59	48	0	0	151	10.8	130 - 179	34.6	7.1	22.5 - 54.3
51	Tailrace	16-May	13:52	46	0	0	152	12.6	133 - 190	35.0	9.0	22.6 - 61.4
52	Tailrace	17-May	00:10	46	1	0	152	15.5	130 - 214	35.1	12.5	21.8 - 97.7
53	Sluiceway	17-May	01:10	47	0	0	156	13.8	130 - 193	37.4	10.5	22.2 - 68.2
54	Tailrace	17-May	13:57	46	0	0	155	16.2	130 - 197	37.7	12.3	21.5 - 75.9
55	Tailrace	18-May	00:09	45	0	2	155	17.6	131 - 210	37.6	13.8	21.6 - 86.4
56	Tailrace	18-May	13:51	47	0	0	154	15.7	132 - 199	37.0	11.9	22.5 - 76.7
57	Sluiceway	18-May	18:58	47	0	0	153	14.5	128 - 186	36.2	11.2	22.4 - 62.3
58	Tailrace	19-May	00:03	47	0	0	152	14.3	134 - 195	34.7	10.4	23.2 - 66.6
59	Sluiceway	19-May	13:00	48	0	0	150	10.7	131 - 178	34.3	7.5	22.2 - 55.2
60	Tailrace	19-May	13:59	46	0	0	153	14.1	129 - 185	35.9	9.9	21.9 - 57.8
61	Tailrace	20-May	00:05	45	1	0	157	19.2	130 - 205	39.2	15.0	21.8 - 83.2
62	Sluiceway	20-May	00:58	48	0	0	152	17.9	130 - 211	36.4	14.5	21.8 - 97.0
63	Tailrace	20-May	13:58	46	1	0	155	15.7	133 - 189	36.0	11.0	21.9 - 66.0
64	Tailrace	21-May	00:14	46	0	0	150	14.9	131 - 186	33.4	10.7	21.7 - 60.8
65	Tailrace	21-May	13:56	46	0	1	150	16.2	130 - 203	32.7	12.0	21.6 - 77.0
66	Sluiceway	21-May	18:58	48	0	0	150	17.9	130 - 204	33.7	13.7	22.1 - 79.2
67	Tailrace	22-May	00:03	46	0	0	154	21.1	130 - 215	36.7	17.1	21.6 - 96.3
68	Sluiceway	22-May	06:59	46	0	1	147	14.0	130 - 195	30.9	10.2	21.7 - 66.6
69	Tailrace	22-May	14:02	46	1	0	153	18.4	131 - 200	35.9	13.1	22.8 - 71.9
70	Tailrace	23-May	00:02	47	0	0	154	18.1	129 - 210	36.6	14.8	21.6 - 96.7
71	Sluiceway	23-May	12:59	48	0	0	154	19.6	130 - 200	37.3	15.5	22.2 - 77.0
72	Tailrace	23-May	14:16	46	0	0	154	18.9	132 - 205	37.3	15.4	21.5 - 78.5

Table A1.2 (continued). Summary of yearling Chinook salmon releases at The Dalles Dam ice and trash sluiceway (Sluiceway), and the tailrace 550 m downstream of the spillway beneath the I-197 bridge (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	Location	Date	Time	N	Tag loss	Mortality	Mean	SD	Range	Mean	SD	Range
73	Tailrace	24-May	00:01	47	0	0	160	18.6	126 - 200	40.6	14.5	21.6 - 82.9
74	Sluiceway	24-May	12:56	48	0	0	155	19.7	130 - 204	37.5	16.9	22.1 - 89.5
75	Tailrace	24-May	14:20	45	1	0	153	18.0	131 - 212	35.0	14.6	21.6 - 82.0
76	Tailrace	25-May	00:04	47	0	0	160	17.4	135 - 197	42.0	14.5	22.8 - 72.1
77	Sluiceway	25-May	07:02	48	0	0	160	15.4	134 - 187	40.2	12.0	21.8 - 65.8
78	Tailrace	25-May	14:00	46	1	0	160	18.8	131 - 196	40.7	14.4	21.7 - 74.4
79	Tailrace	25-May	23:52	42	0	0	160	18.9	133 - 203	41.7	15.4	21.9 - 81.3
80	Sluiceway	26-May	01:00	42	0	1	155	15.4	133 - 195	37.8	11.4	22.3 - 69.6
81	Tailrace	26-May	13:53	46	1	0	160	15.1	137 - 196	40.1	11.8	21.9 - 70.5
82	Tailrace	27-May	00:01	44	3	0	156	15.5	132 - 201	38.6	12.4	22.0 - 75.0
83	Tailrace	27-May	14:03	47	0	0	157	16.4	133 - 197	38.4	11.6	22.2 - 71.3
84	Sluiceway	27-May	19:00	47	0	0	163	16.6	133 - 197	42.3	13.3	22.5 - 77.7
85	Tailrace	28-May	00:07	46	1	0	157	15.1	131 - 190	38.5	10.6	23.3 - 63.1
86	Tailrace	28-May	13:59	45	2	0	165	16.1	139 - 209	45.6	14.3	27.3 - 96.6
87	Sluiceway	28-May	19:00	47	0	0	156	11.7	138 - 188	38.6	9.8	24.3 - 67.0
88	Tailrace	28-May	23:45	47	0	0	158	17.0	127 - 220	39.9	13.4	22.1 - 97.9
89	Sluiceway	29-May	01:00	47	0	0	158	14.0	129 - 197	38.9	10.3	22.5 - 70.0
90	Tailrace	29-May	14:51	47	0	0	160	19.8	130 - 205	42.2	16.2	22.4 - 83.2
91	Tailrace	29-May	23:54	47	0	0	155	16.0	130 - 199	37.7	11.6	21.9 - 76.6
92	Sluiceway	30-May	06:59	47	0	0	156	14.3	131 - 206	37.6	10.1	22.9 - 77.3
93	Tailrace	30-May	14:07	47	0	0	157	16.3	133 - 200	38.4	13.2	23.7 - 77.7
94	Tailrace	31-May	00:02	47	0	0	158	16.2	132 - 211	40.8	13.4	22.1 - 92.1
95	Sluiceway	31-May	12:58	47	1	0	153	13.5	128 - 190	36.7	10.0	21.6 - 64.6
96	Tailrace	31-May	14:15	47	0	0	157	15.1	134 - 198	39.4	10.9	23.7 - 70.3
Overall				4351	139	8	154	14.6	126 - 220	36.3	11.3	21.5 - 97.9

Table A1.3. Summary of yearling Chinook salmon releases at Bonneville 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	1-May	08:09	21	0	0	157	11.3	139 - 175	39.3	8.8	27.6 - 59.3
2	1-May	21:09	21	0	0	148	9.4	132 - 168	34.0	6.7	24.3 - 49.6
3	2-May	07:59	21	0	0	146	9.8	131 - 165	31.5	5.3	23.4 - 41.1
4	2-May	21:01	21	0	0	147	9.4	135 - 170	31.7	6.8	24.8 - 49.7
5	3-May	08:20	20	2	0	147	14.2	132 - 190	32.0	10.3	23.6 - 66.9
6	3-May	21:01	21	0	0	146	8.5	134 - 168	30.9	5.5	21.5 - 42.3
7	4-May	07:59	20	1	0	149	11.6	131 - 180	33.7	8.7	22.1 - 61.6
8	4-May	21:03	19	2	0	148	8.1	131 - 162	32.7	5.1	24.3 - 41.2
9	5-May	08:06	20	0	0	146	9.2	137 - 171	31.4	6.3	24.7 - 49.2
10	5-May	21:00	21	0	0	144	11.5	129 - 181	32.2	10.0	22.8 - 70.7
11	6-May	07:59	20	1	0	143	7.9	130 - 165	29.4	5.3	22.9 - 46.0
12	6-May	21:00	21	0	0	148	8.4	129 - 164	34.0	5.8	23.1 - 47.2
13	7-May	07:55	21	0	0	145	7.4	131 - 157	31.7	4.1	23.9 - 40.4
14	7-May	21:07	20	1	0	147	14.7	134 - 204	32.4	11.5	24.3 - 78.9
15	8-May	08:00	20	1	0	148	7.7	138 - 175	32.0	5.7	23.7 - 50.8
16	8-May	20:50	21	0	0	155	12.4	138 - 190	36.8	9.3	25.1 - 66.3
17	9-May	07:58	18	3	0	150	14.5	135 - 195	34.2	9.3	25.9 - 66.0
18	9-May	21:21	20	1	0	152	12.1	132 - 176	33.8	8.3	23.3 - 52.5
19	10-May	07:59	19	1	1	148	10.1	130 - 170	32.6	5.8	22.0 - 48.4
20	10-May	21:00	21	0	0	158	12.0	145 - 190	37.7	8.0	27.9 - 56.3
21	11-May	08:02	20	1	0	161	13.9	144 - 186	41.7	12.4	28.0 - 65.5
22	11-May	20:55	23	0	0	155	11.8	138 - 188	36.0	9.1	26.2 - 64.2
23	12-May	08:10	21	1	0	157	17.2	142 - 209	41.1	15.7	28.2 - 89.9
24	12-May	21:01	21	0	0	167	22.1	136 - 215	46.0	19.9	27.7 - 101.6

Table A1.3 (continued). Summary of yearling Chinook salmon releases at Bonneville 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
25	13-May	08:10	20	4	0	151	8.5	139 - 168	34.8	6.6	24.9 - 48.5
26	13-May	21:01	20	3	0	159	14.8	139 - 185	39.6	11.6	24.8 - 64.0
27	14-May	08:06	23	0	0	155	12.3	140 - 185	37.7	9.5	28.2 - 60.8
28	14-May	21:20	20	1	0	162	16.6	135 - 194	42.1	11.5	26.1 - 64.1
29	15-May	08:23	21	2	0	161	13.5	140 - 187	39.4	8.7	25.9 - 57.1
30	15-May	20:59	19	1	0	160	11.4	140 - 179	40.5	8.2	27.5 - 55.1
31	16-May	08:02	19	3	0	161	11.0	145 - 182	40.0	7.7	29.4 - 54.5
32	16-May	21:04	21	0	0	164	11.4	145 - 184	42.7	9.4	29.0 - 63.1
33	17-May	08:12	19	1	0	163	12.4	136 - 184	41.7	9.5	23.5 - 61.5
34	17-May	21:08	21	0	0	165	11.4	150 - 198	42.9	9.1	30.6 - 68.4
35	18-May	07:52	20	4	0	167	13.6	146 - 190	44.2	12.1	26.5 - 72.8
36	18-May	21:00	23	0	0	170	15.2	133 - 205	46.5	11.2	28.6 - 79.4
37	19-May	07:57	21	2	0	164	10.2	148 - 189	42.5	8.8	31.7 - 66.6
38	19-May	21:00	21	0	0	166	15.0	145 - 206	43.4	12.7	26.3 - 81.6
39	20-May	07:58	22	0	0	168	15.4	148 - 196	44.1	12.7	29.0 - 72.7
40	20-May	21:00	20	1	0	163	10.8	148 - 183	40.4	7.7	31.4 - 56.1
41	21-May	08:13	23	1	0	173	18.0	146 - 210	48.0	16.9	28.1 - 90.7
42	21-May	21:01	21	0	0	162	17.8	139 - 204	40.3	11.7	26.0 - 68.7
43	22-May	08:01	20	1	0	168	19.4	145 - 204	47.8	19.4	29.2 - 92.0
44	22-May	20:55	19	2	0	163	12.7	145 - 184	41.8	9.7	29.7 - 63.1
45	23-May	07:59	23	0	0	160	11.5	145 - 188	40.0	10.8	27.5 - 67.7
46	23-May	20:51	21	0	0	169	8.6	157 - 185	47.1	8.3	36.6 - 63.6
47	24-May	08:00	23	0	0	172	15.2	150 - 210	48.2	12.8	30.2 - 84.2
48	24-May	20:50	23	0	0	170	13.8	149 - 197	46.7	12.6	28.7 - 74.0
49	25-May	07:58	7	0	0	159	10.5	151 - 176	39.0	7.3	32.6 - 52.3
50	25-May	20:53	20	2	0	169	14.8	151 - 205	47.1	12.3	31.7 - 82.4
51	26-May	08:00	22	0	0	180	16.8	152 - 211	56.0	14.7	35.2 - 86.1

Table A1.3 (continued). Summary of yearling Chinook salmon releases at Bonneville 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
52	26-May	21:00	21	0	0	162	12.8	144 - 187	40.5	8.8	29.0 - 58.8
53	27-May	08:18	22	1	0	166	18.8	139 - 223	42.5	17.2	28.5 - 107.6
54	27-May	20:53	20	1	0	172	15.6	154 - 208	49.0	13.5	33.3 - 81.2
55	28-May	08:16	24	1	0	166	12.0	145 - 195	44.6	9.2	31.1 - 67.2
56	28-May	21:00	23	0	0	166	18.6	136 - 210	42.9	14.8	29.6 - 81.8
57	29-May	08:07	25	0	0	161	10.6	141 - 185	41.1	8.1	28.2 - 61.7
58	29-May	21:04	20	2	0	162	11.5	145 - 193	43.7	8.9	32.3 - 68.5
59	30-May	07:50	23	0	0	163	16.2	142 - 199	41.5	12.1	26.8 - 70.0
60	30-May	20:57	21	0	0	167	10.5	148 - 182	45.6	8.6	32.8 - 62.1
61	31-May	07:51	22	0	0	167	13.4	149 - 207	45.5	10.9	32.4 - 80.3
62	31-May	20:58	21	0	0	171	12.7	149 - 198	48.7	11.0	33.5 - 72.5
63	1-Jun	07:56	22	0	0	173	18.0	151 - 222	49.7	14.4	35.7 - 96.2
64	1-Jun	20:50	24	1	0	172	16.4	154 - 226	50.6	18.2	33.6 - 120.9
Overall			1331	49	1	160	15.9	129 - 226	40.5	12.2	21.5 - 120.9

Table A1.4. Summary of steelhead trout releases at Bonneville 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	8-May	22:23	24	1	0	226	25.6	152 - 280	112.7	37.4	68.7 - 209.7
2	10-May	09:19	23	2	0	234	26.0	198 - 286	117.1	40.2	64.2 - 216.3
3	12-May	22:10	22	3	0	230	22.9	193 - 305	112.0	49.0	60.5 - 267.4
4	14-May	09:36	24	3	0	220	14.0	200 - 258	93.3	18.7	69.4 - 155.9
5	16-May	22:34	26	1	0	228	18.4	200 - 270	106.3	28.6	68.2 - 170.4
6	18-May	09:08	24	3	0	238	22.6	210 - 284	114.7	33.5	69.0 - 189.1
7	20-May	22:20	24	0	0	235	25.4	193 - 283	111.4	37.7	58.9 - 202.9
8	22-May	09:18	22	2	0	218	31.6	136 - 276	89.4	33.8	46.5 - 172.1
9	24-May	22:10	24	2	1	230	27.7	165 - 267	105.5	30.6	60.8 - 153.3
10	26-May	09:25	26	0	0	225	28.7	178 - 281	99.1	39.3	51.1 - 199.2
11	28-May	22:18	20	1	0	229	27.6	176 - 299	101.5	44.1	42.6 - 252.1
12	30-May	08:54	27	0	0	225	23.6	185 - 272	96.3	29.2	55.1 - 155.2
13	1-Jun	22:02	23	1	0	245	27.2	180 - 304	128.6	45.1	53.3 - 221.9
14	2-Jun	08:53	17	0	0	240	29.5	161 - 280	130.5	32.6	65.2 - 179.4
15	3-Jun	09:00	19	0	0	245	21.3	205 - 286	137.1	38.5	74.1 - 203.8
16	3-Jun	22:03	21	2	0	243	23.7	199 - 280	134.9	43.1	63.1 - 201.6
Overall			366	21	1	231	25.8	136 - 305	111.0	38.6	42.6 - 267.4

Table A1.5. Summary of steelhead trout 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	5-May	14:17	64	4	0	221	20.4	139 - 273	94.3	23.4	48.1 - 189.3
2	6-May	00:30	64	3	0	220	21.0	119 - 270	92.4	20.3	54.1 - 153.9
3	6-May	14:14	17	0	0	224	21.6	187 - 257	96.5	25.2	61.8 - 134.5
4	7-May	00:24	52	4	0	224	16.1	187 - 259	94.8	22.4	54.3 - 166.9
5	7-May	14:36	48	2	1	229	14.4	200 - 273	104.4	24.3	58.7 - 189.0
6	8-May	00:36	63	4	0	223	21.0	175 - 272	99.1	27.5	51.2 - 170.9
7	8-May	14:29	65	5	0	222	27.4	107 - 276	96.9	31.3	22.6 - 203.0
8	9-May	00:15	65	3	0	225	30.4	118 - 284	107.6	38.9	44.0 - 206.5
9	9-May	14:27	64	4	0	226	18.5	180 - 269	103.0	28.0	48.9 - 169.6
10	10-May	00:24	64	6	0	226	23.1	153 - 270	106.8	34.9	48.1 - 192.3
11	10-May	14:48	62	1	0	228	19.0	178 - 266	105.2	28.9	49.2 - 176.0
12	11-May	00:13	66	2	0	233	19.7	179 - 284	112.8	31.7	47.7 - 208.8
13	11-May	14:26	62	8	0	220	28.0	122 - 283	100.2	30.1	46.7 - 209.2
14	12-May	00:31	61	7	1	225	25.5	166 - 288	102.8	37.3	37.1 - 234.1
15	12-May	14:31	65	3	2	223	24.0	141 - 286	100.2	29.5	53.3 - 188.3
16	13-May	00:05	67	3	0	223	23.1	170 - 279	100.5	33.4	38.8 - 190.1
17	13-May	14:24	65	4	0	220	25.4	151 - 276	92.3	31.4	32.2 - 199.4
18	14-May	00:26	65	2	1	221	24.0	171 - 286	95.7	33.7	42.4 - 210.0
19	14-May	14:48	66	3	0	228	21.3	172 - 274	107.2	32.5	44.2 - 190.4
20	15-May	00:00	65	4	0	223	22.7	166 - 274	95.2	28.4	39.1 - 173.8
21	15-May	14:23	67	3	0	221	25.7	160 - 269	96.0	33.3	38.0 - 167.9
22	16-May	00:12	68	2	0	222	23.1	158 - 270	95.5	29.1	43.6 - 174.8
23	16-May	14:05	66	3	0	217	30.5	93 - 284	93.8	28.5	46.5 - 178.2
24	17-May	00:10	67	2	0	225	24.5	144 - 294	98.4	33.9	27.4 - 240.3

Table A1.5 (continued). Summary of steelhead trout 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
25	17-May	14:02	68	1	0	223	20.0	176 - 274	95.0	26.4	49.7 - 163.2
26	18-May	00:26	68	1	0	216	25.8	97 - 264	86.5	25.7	33.8 - 146.7
27	18-May	13:57	67	3	0	223	21.9	159 - 259	94.8	25.9	35.4 - 147.6
28	19-May	00:23	69	0	0	223	21.2	184 - 277	92.9	30.3	32.9 - 190.1
29	19-May	14:07	67	2	0	223	20.9	159 - 257	94.0	25.2	30.1 - 140.5
30	20-May	00:05	70	0	0	220	24.0	162 - 275	88.8	30.3	34.0 - 176.6
31	20-May	14:05	66	4	0	218	23.3	147 - 265	86.3	28.0	26.9 - 170.5
32	21-May	00:14	70	0	0	223	24.3	163 - 276	91.0	30.3	30.7 - 166.5
33	21-May	14:16	67	3	0	221	25.0	149 - 260	90.6	28.9	26.6 - 150.0
34	22-May	00:20	70	0	0	217	21.0	175 - 265	84.7	26.2	31.7 - 162.1
35	22-May	13:09	62	2	0	220	21.7	169 - 273	88.4	27.8	41.5 - 179.3
36	23-May	00:13	67	3	0	216	23.9	160 - 262	83.6	28.7	32.3 - 161.5
37	23-May	14:23	66	3	0	221	22.6	139 - 268	91.6	26.8	28.9 - 168.8
38	24-May	00:08	65	4	0	220	26.5	144 - 278	91.6	33.1	25.3 - 196.7
39	24-May	14:26	66	3	0	221	22.6	150 - 266	87.9	26.4	25.9 - 156.6
40	25-May	00:10	67	1	0	218	26.8	152 - 290	85.7	31.4	28.9 - 193.7
41	25-May	14:08	68	0	0	220	22.8	163 - 266	90.1	29.0	32.3 - 157.9
42	26-May	00:06	67	2	0	219	24.8	161 - 277	90.3	30.8	38.4 - 190.5
43	26-May	13:53	88	1	0	216	22.5	153 - 275	83.9	26.6	29.3 - 161.1
44	27-May	00:14	81	3	0	221	29.4	154 - 290	90.6	35.5	26.9 - 210.8
45	27-May	14:15	90	2	0	217	22.6	159 - 284	85.3	25.1	37.0 - 175.0
46	28-May	00:12	82	2	0	217	24.2	157 - 265	85.4	28.4	31.7 - 148.2
47	28-May	14:21	91	1	0	223	24.4	155 - 278	94.6	30.0	32.7 - 186.8
48	29-May	00:18	84	1	0	216	28.8	118 - 290	86.1	31.5	37.6 - 221.5
49	29-May	14:06	88	1	1	222	26.2	160 - 291	93.0	33.2	35.4 - 206.9
50	30-May	00:04	83	2	0	220	30.8	154 - 280	90.8	39.2	27.0 - 185.6
51	30-May	14:18	87	4	0	223	25.1	158 - 283	93.3	31.5	29.4 - 181.8

Table A1.5 (continued). Summary of steelhead trout 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
52	31-May	00:13	82	2	1	215	28.2	149 - 279	81.7	30.9	26.4 - 161.8
53	31-May	14:30	89	3	0	219	27.1	155 - 283	87.9	31.3	30.4 - 180.2
54	1-Jun	00:05	72	0	0	214	28.8	148 - 264	82.8	31.2	27.5 - 147.2
55	1-Jun	14:02	77	2	0	227	27.6	166 - 296	99.7	38.5	37.3 - 245.8
56	2-Jun	00:00	48	0	0	214	30.2	158 - 282	84.1	33.5	38.5 - 170.6
57	2-Jun	14:12	57	2	0	214	33.6	130 - 278	86.1	35.8	29.9 - 163.1
58	3-Jun	00:05	52	0	0	207	31.2	148 - 290	75.1	35.5	23.7 - 222.6
59	3-Jun	14:00	50	0	0	220	26.1	169 - 279	89.2	32.9	31.2 - 192.7
60	3-Jun	23:59	37	0	0	218	32.4	158 - 301	89.0	41.7	32.9 - 233.3
61	4-Jun	13:58	48	3	0	223	28.2	154 - 268	93.0	32.9	29.5 - 155.9
62	5-Jun	00:07	75	1	2	224	33.3	153 - 307	94.4	40.7	29.6 - 256.4
63	5-Jun	14:19	75	1	0	231	23.2	175 - 285	100.4	29.9	42.8 - 192.0
64	6-Jun	00:11	54	3	0	217	35.6	136 - 288	90.8	39.8	30.4 - 186.0
Overall			4278	148	9	221	25.3	93 - 307	93.0	31.6	22.6 - 256.4

Table A1.6. Summary of steelhead trout releases at Bonneville 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	6-May	20:57	20	1	0	225	36.1	117 - 296	119.7	42.7	69.0 - 246.0
2	7-May	07:55	17	0	0	221	27.8	178 - 272	101.3	35.9	52.1 - 173.6
3	7-May	21:07	20	2	1	235	17.7	195 - 258	112.6	28.5	65.2 - 162.8
4	8-May	08:00	21	1	0	222	23.0	181 - 271	95.5	34.7	49.8 - 181.5
5	8-May	20:50	19	1	0	220	35.7	115 - 295	98.1	27.7	51.6 - 159.3
6	9-May	07:58	18	3	0	230	26.7	174 - 308	107.3	39.6	53.1 - 245.8
7	9-May	21:21	19	2	0	227	26.4	185 - 294	108.3	44.0	61.3 - 227.6
8	10-May	07:59	18	3	0	240	21.8	199 - 279	121.2	34.2	63.8 - 186.2
9	10-May	21:00	19	2	0	234	23.7	190 - 280	115.7	37.5	58.0 - 202.4
10	11-May	08:02	24	0	0	239	23.8	193 - 284	121.3	39.1	69.2 - 210.9
11	11-May	20:55	22	0	1	229	15.6	198 - 258	104.6	27.8	63.1 - 160.3
12	12-May	08:10	18	3	0	228	19.0	201 - 270	109.4	31.0	70.4 - 179.4
13	12-May	21:01	21	1	1	235	22.4	197 - 280	118.9	37.3	57.8 - 191.1
14	13-May	08:10	18	3	0	239	23.0	197 - 283	123.2	37.3	65.2 - 210.4
15	13-May	21:01	19	2	0	234	23.4	189 - 276	115.2	37.0	51.0 - 178.9
16	14-May	08:06	24	0	0	225	22.4	186 - 275	102.4	32.8	56.6 - 178.1
17	14-May	21:20	20	1	0	227	17.8	198 - 260	106.6	30.3	66.4 - 170.4
18	15-May	08:23	21	1	0	230	16.0	204 - 264	102.3	26.2	71.3 - 158.9
19	15-May	20:59	20	3	0	230	25.2	195 - 280	110.7	39.0	71.2 - 200.5
20	16-May	08:02	23	0	0	214	28.0	147 - 265	96.3	31.0	58.7 - 164.7
21	16-May	21:04	20	2	0	224	21.7	180 - 276	98.6	37.6	45.9 - 197.8
22	17-May	08:12	21	4	0	233	24.4	197 - 296	113.0	37.5	63.9 - 219.9
23	17-May	21:08	17	3	0	225	20.9	178 - 260	97.2	25.9	44.6 - 146.9
24	18-May	07:52	21	1	0	230	20.7	194 - 269	119.7	42.7	69.0 - 246.0

Table A1.6 (continued). Summary of steelhead trout releases at Bonneville 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
25	18-May	21:00	22	0	0	231	23.5	182 - 288	102.8	27.0	64.3 - 151.9
26	19-May	07:57	20	3	0	230	31.3	179 - 296	101.5	36.7	43.8 - 207.3
27	19-May	21:00	24	1	0	232	32.6	131 - 299	109.2	44.4	47.9 - 212.7
28	20-May	07:58	21	0	0	228	25.2	180 - 284	112.0	41.2	55.5 - 221.2
29	20-May	21:00	21	1	0	235	22.0	203 - 280	100.7	37.2	47.0 - 215.5
30	21-May	08:13	20	1	0	229	14.6	193 - 248	104.4	33.3	64.0 - 194.1
31	21-May	21:01	24	0	0	234	26.0	173 - 285	92.5	15.7	57.5 - 114.4
32	22-May	08:01	20	3	0	232	28.4	192 - 287	103.7	34.5	45.9 - 180.4
33	22-May	20:55	21	3	0	219	31.3	118 - 258	101.9	41.0	59.8 - 207.9
34	23-May	07:59	23	1	0	227	27.1	170 - 273	93.6	26.7	42.0 - 156.0
35	23-May	20:51	20	1	0	231	24.6	182 - 276	98.7	35.1	38.6 - 168.6
36	24-May	08:00	22	1	0	231	25.2	191 - 291	102.9	33.0	46.1 - 170.6
37	24-May	20:50	23	0	0	232	22.0	183 - 271	100.3	36.7	55.4 - 199.1
38	25-May	07:58	23	1	0	228	29.2	144 - 272	101.4	32.6	45.5 - 176.1
39	25-May	20:53	21	0	0	230	23.6	185 - 269	108.6	34.7	61.6 - 192.2
40	26-May	08:00	23	0	0	235	24.7	183 - 285	99.2	33.3	48.3 - 180.9
41	26-May	21:00	23	1	0	246	24.2	218 - 324	104.8	34.8	49.2 - 203.2
42	27-May	08:18	21	1	0	235	31.8	132 - 277	122.7	36.9	84.2 - 252.2
43	27-May	20:53	23	0	0	232	28.0	174 - 270	114.6	24.8	64.3 - 157.4
44	28-May	08:16	24	0	0	237	25.1	195 - 287	102.4	31.3	45.7 - 156.9
45	28-May	21:00	18	1	0	232	24.5	172 - 272	110.1	35.3	52.1 - 196.0
46	29-May	08:07	19	1	0	225	27.1	180 - 278	101.7	33.9	44.6 - 163.5
47	29-May	21:04	20	0	0	238	26.0	190 - 285	103.4	40.7	48.1 - 180.3
48	30-May	07:50	20	0	0	234	27.4	155 - 269	123.1	45.5	58.6 - 223.4
49	30-May	20:57	18	2	0	238	19.3	194 - 270	109.0	34.2	36.7 - 162.2
50	31-May	07:51	20	2	0	234	30.1	187 - 288	118.3	37.2	63.4 - 192.2
51	31-May	20:58	18	1	0	248	22.5	196 - 280	113.9	45.9	53.6 - 210.2

Table A1.6 (continued). Summary of steelhead trout releases at Bonneville 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
52	1-Jun	07:56	19	2	0	240	23.8	198 - 283	111.8	32.7	60.4 - 170.7
53	1-Jun	20:50	20	1	0	241	30.4	170 - 290	117.6	39.3	41.8 - 175.8
54	2-Jun	07:53	17	0	0	230	25.8	190 - 270	96.8	30.6	53.2 - 153.1
55	2-Jun	20:36	17	2	0	255	19.8	221 - 291	144.5	42.1	84.3 - 215.2
56	3-Jun	07:59	21	0	0	233	27.4	180 - 281	116.8	44.4	48.8 - 209.2
57	3-Jun	20:56	16	2	0	249	29.8	175 - 298	140.8	48.1	41.9 - 217.1
58	4-Jun	07:57	9	0	0	254	28.0	211 - 289	148.1	48.6	85.2 - 217.6
59	4-Jun	20:47	20	0	0	246	22.1	188 - 275	135.6	38.0	57.2 - 211.0
60	5-Jun	08:00	13	0	1	248	27.7	205 - 290	148.4	53.1	68.7 - 241.5
61	5-Jun	20:43	19	0	0	245	22.7	194 - 278	129.1	34.2	58.9 - 185.4
62	6-Jun	07:58	20	0	0	248	29.2	198 - 290	120.9	41.0	62.9 - 190.2
63	6-Jun	20:47	18	2	0	249	28.3	198 - 295	134.6	52.4	62.0 - 233.2
64	7-Jun	07:59	18	1	0	230	34.2	141 - 269	107.0	44.9	22.9 - 185.3
Overall			1279	74	4	233	26.2	115 - 324	110.7	37.8	22.9 - 252.2

Table A1.7. Summary of subyearling Chinook salmon releases at Bonneville 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	17-Jun	22:56	19	0	0	105	9.1	96 - 128	13.5	4.1	10.0 - 25.6
2	18-Jun	09:48	19	0	0	105	5.0	98 - 116	13.0	2.1	10.3 - 17.9
3	19-Jun	21:44	19	0	0	107	6.1	99 - 121	14.0	2.8	10.2 - 20.9
4	20-Jun	09:55	19	0	0	109	5.9	98 - 120	14.9	3.4	10.5 - 24.6
5	21-Jun	22:53	18	0	0	112	5.7	105 - 128	16.3	3.1	12.4 - 26.4
6	22-Jun	09:57	18	0	0	110	6.8	96 - 125	14.5	2.6	10.4 - 20.2
7	23-Jun	22:45	18	1	0	115	7.4	105 - 132	15.4	3.1	11.1 - 23.4
8	24-Jun	09:45	18	1	0	112	4.2	105 - 121	13.8	1.7	10.6 - 17.7
9	25-Jun	22:53	19	0	0	106	5.8	99 - 119	13.0	2.6	10.3 - 18.5
10	26-Jun	09:54	17	2	0	106	4.7	97 - 112	12.9	1.6	10.3 - 15.9
11	27-Jun	22:57	18	1	0	106	4.0	100 - 112	12.9	1.5	10.8 - 16.4
12	28-Jun	09:44	18	1	0	107	5.8	100 - 120	13.8	2.1	11.3 - 18.4
13	29-Jun	22:53	19	0	0	107	5.1	100 - 120	13.3	2.0	10.3 - 17.7
14	30-Jun	09:49	19	2	0	105	2.6	99 - 110	13.3	1.4	11.0 - 15.5
15	1-Jul	22:48	21	0	0	103	5.5	94 - 119	12.3	2.6	10.0 - 22.1
16	2-Jul	09:51	20	0	0	105	6.1	98 - 120	13.6	2.6	10.8 - 20.8

Table A1.7 (continued). Summary of subyearling Chinook salmon releases at Bonneville 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
17	3-Jul	22:47	19	0	0	104	4.9	98 - 115	12.1	1.8	10.3 - 16.4
18	4-Jul	09:51	19	0	0	104	6.3	96 - 123	13.1	2.7	10.2 - 21.4
19	5-Jul	22:53	19	0	0	105	6.5	98 - 128	14.5	3.2	11.2 - 24.2
20	6-Jul	09:49	19	0	1	108	5.4	98 - 116	13.9	2.0	11.1 - 18.0
21	7-Jul	22:34	18	0	0	107	3.9	101 - 112	13.4	1.8	10.6 - 17.6
22	8-Jul	09:47	20	1	0	113	9.0	100 - 130	16.8	3.5	12.2 - 25.3
23	9-Jul	22:52	19	0	0	107	7.2	97 - 120	14.5	2.9	10.7 - 20.6
24	10-Jul	09:49	18	0	1	108	6.7	96 - 121	14.3	2.3	10.8 - 18.3
25	11-Jul	22:47	19	0	0	107	7.2	99 - 126	13.0	2.8	10.3 - 20.8
26	12-Jul	09:43	19	0	0	109	5.5	100 - 119	13.8	2.2	10.8 - 18.2
27	13-Jul	22:47	17	1	1	112	12.6	95 - 148	15.9	6.4	10.0 - 38.2
28	14-Jul	09:52	20	0	0	114	10.4	101 - 140	16.8	4.4	12.1 - 26.6
29	15-Jul	22:51	19	0	0	103	7.5	97 - 126	12.5	2.9	10.4 - 23.0
30	16-Jul	09:45	20	0	0	108	9.5	102 - 143	13.4	4.5	10.5 - 31.6
31	17-Jul	22:47	21	0	0	113	6.9	102 - 127	16.7	2.4	12.7 - 20.5
32	18-Jul	10:04	17	2	0	115	6.3	102 - 130	16.9	2.8	11.4 - 24.7
Overall			602	12	3	108	7.5	94 - 148	14.1	3.2	10.0 - 38.2

Table A1.8. Summary of subyearling Chinook salmon releases at The Dalles Dam ice and trash sluiceway (Sluiceway), and the tailrace 550 m downstream of the spillway beneath the I-197 bridge (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	Location	Date	Time	N	Tag loss	Mortality	Mean	SD	Range	Mean	SD	Range
1	Tailrace	16-Jun	00:04	39	1	1	108	6.3	99 - 125	14.2	2.7	10.4 - 23.3
2	Sluiceway	16-Jun	01:00	60	2	0	109	8.2	98 - 138	14.3	4.1	10.1 - 32.4
3	Tailrace	16-Jun	14:02	40	0	0	108	5.5	98 - 123	14.1	2.4	10.4 - 20.6
4	Tailrace	17-Jun	00:02	40	1	0	112	5.6	100 - 123	15.1	2.4	11.3 - 20.3
5	Sluiceway	17-Jun	06:56	61	0	1	110	7.6	101 - 135	14.7	3.2	11.2 - 23.2
6	Tailrace	17-Jun	13:56	41	0	0	112	7.0	101 - 132	15.2	2.9	11.1 - 24.5
7	Tailrace	18-Jun	00:06	41	0	0	112	5.8	100 - 126	15.2	2.5	10.4 - 23.1
8	Tailrace	18-Jun	14:05	40	0	1	111	6.7	102 - 125	15.7	3.5	10.6 - 25.4
9	Sluiceway	18-Jun	19:00	62	0	0	107	5.8	100 - 125	13.3	2.0	10.8 - 18.7
10	Tailrace	19-Jun	00:02	41	0	0	109	6.4	101 - 132	14.2	2.9	10.1 - 26.0
11	Sluiceway	19-Jun	13:00	61	1	0	110	5.3	100 - 122	14.4	2.7	10.8 - 20.7
12	Tailrace	19-Jun	14:14	41	0	0	113	6.5	104 - 130	15.3	3.0	11.4 - 23.2
13	Tailrace	20-Jun	00:00	39	1	0	111	6.0	102 - 130	15.0	2.8	11.9 - 24.2
14	Sluiceway	20-Jun	06:59	61	0	0	110	5.9	104 - 133	14.5	3.0	12.0 - 27.8
15	Tailrace	20-Jun	13:58	41	0	0	111	5.2	104 - 133	14.9	2.7	12.0 - 25.4
16	Tailrace	20-Jun	23:53	41	0	0	108	4.6	99 - 122	13.5	1.8	10.8 - 19.4
17	Tailrace	21-Jun	13:57	41	0	0	108	5.0	101 - 119	14.2	2.2	11.3 - 19.9
18	Sluiceway	21-Jun	18:59	58	0	0	104	3.9	96 - 114	12.1	1.3	10.0 - 15.6
19	Tailrace	22-Jun	00:01	38	0	0	106	4.7	98 - 119	12.6	1.8	10.0 - 19.7
20	Sluiceway	22-Jun	00:59	60	0	0	106	5.0	100 - 124	13.0	2.1	10.4 - 20.0
21	Tailrace	22-Jun	14:10	40	0	0	107	3.7	101 - 117	12.2	1.3	10.3 - 16.6
22	Tailrace	23-Jun	00:01	40	1	0	109	6.1	100 - 131	14.0	3.0	10.0 - 25.2
23	Sluiceway	23-Jun	13:00	62	0	0	107	4.3	100 - 117	12.5	1.5	10.1 - 16.7
24	Tailrace	23-Jun	14:17	41	0	0	108	5.8	100 - 128	13.0	2.4	10.1 - 22.5

Table A1.8 (continued). Summary of subyearling Chinook salmon releases at The Dalles Dam ice and trash sluiceway (Sluiceway), and the tailrace 550 m downstream of the spillway beneath the I-197 bridge (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	Location	Date	Time	N	Tag loss	Mortality	Mean	SD	Range	Mean	SD	Range
25	Tailrace	24-Jun	00:05	40	1	0	108	5.2	100 - 125	13.2	1.9	10.5 - 19.2
26	Sluiceway	24-Jun	07:00	62	0	0	107	6.5	100 - 133	13.1	3.1	10.8 - 25.6
27	Tailrace	24-Jun	14:13	40	1	0	107	6.6	101 - 135	12.8	2.6	10.1 - 23.6
28	Tailrace	25-Jun	00:01	38	2	1	107	7.1	100 - 134	14.2	3.3	10.6 - 26.7
29	Tailrace	25-Jun	14:05	41	0	0	110	7.1	99 - 125	14.8	3.5	10.4 - 24.3
30	Sluiceway	25-Jun	19:05	60	2	0	105	4.2	95 - 114	12.4	1.4	10.5 - 15.4
31	Tailrace	26-Jun	00:07	40	1	0	107	6.5	100 - 134	13.3	2.9	10.8 - 29.1
32	Sluiceway	26-Jun	13:00	62	0	0	107	4.0	99 - 119	14.0	2.4	11.2 - 22.2
33	Tailrace	26-Jun	14:12	39	1	0	107	4.7	99 - 121	14.2	2.7	10.8 - 21.4
34	Tailrace	27-Jun	00:04	41	0	0	109	9.3	100 - 150	13.9	4.7	10.4 - 38.0
35	Sluiceway	27-Jun	00:00	62	0	0	107	4.3	101 - 119	13.1	2.0	10.3 - 18.9
36	Tailrace	27-Jun	13:59	41	0	0	108	4.6	99 - 118	14.2	2.2	10.5 - 19.7
37	Tailrace	28-Jun	00:02	29	2	0	105	5.2	96 - 123	12.4	2.8	10.0 - 23.1
38	Sluiceway	28-Jun	07:00	61	1	0	104	5.2	96 - 121	12.5	2.2	10.0 - 21.0
39	Tailrace	28-Jun	14:00	41	0	0	103	5.0	97 - 122	12.0	1.9	10.0 - 19.2
40	Tailrace	29-Jun	00:00	40	1	0	108	6.9	100 - 134	13.4	3.2	10.8 - 27.5
41	Tailrace	29-Jun	13:58	40	0	0	106	5.0	99 - 119	13.0	2.0	10.4 - 19.4
42	Sluiceway	29-Jun	18:58	62	0	0	105	3.4	100 - 114	12.3	1.5	10.4 - 16.3
43	Tailrace	30-Jun	00:00	41	0	0	104	3.7	99 - 112	12.1	1.5	10.0 - 16.3
44	Sluiceway	30-Jun	12:56	61	0	0	106	5.3	98 - 126	12.0	1.8	10.0 - 20.2
45	Tailrace	30-Jun	14:04	40	0	1	107	5.0	100 - 123	12.4	2.2	10.0 - 20.8
46	Tailrace	30-Jun	23:51	40	0	1	109	6.1	102 - 127	15.1	3.4	11.0 - 25.6
47	Sluiceway	1-Jul	00:57	61	0	0	109	6.1	99 - 129	15.7	3.5	11.0 - 25.8
48	Tailrace	1-Jul	14:00	40	1	0	106	7.1	95 - 136	13.4	3.4	10.5 - 29.4

Table A1.8 (continued). Summary of subyearling Chinook salmon releases at The Dalles Dam ice and trash sluiceway (Sluiceway), and the tailrace 550 m downstream of the spillway beneath the I-197 bridge (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	Location	Date	Time	N	Tag loss	Mortality	Mean	SD	Range	Mean	SD	Range
49	Tailrace	2-Jul	00:06	40	1	0	106	6.8	95 - 125	13.8	3.3	10.1 - 23.7
50	Sluiceway	2-Jul	07:00	62	0	0	111	8.4	101 - 141	14.3	4.3	10.6 - 32.2
51	Tailrace	2-Jul	13:59	41	0	0	110	8.9	100 - 138	14.2	4.2	10.3 - 30.4
52	Tailrace	3-Jul	00:01	40	1	0	108	7.3	100 - 132	15.2	3.3	11.9 - 26.5
53	Sluiceway	3-Jul	12:54	60	2	0	111	7.1	104 - 133	15.4	4.0	11.8 - 29.6
54	Tailrace	3-Jul	14:08	41	0	0	109	6.9	100 - 128	15.2	2.8	11.8 - 23.9
55	Tailrace	4-Jul	00:01	40	1	0	106	5.5	97 - 120	13.1	2.1	10.5 - 19.5
56	Tailrace	4-Jul	13:55	40	1	0	106	8.0	98 - 138	13.9	4.0	11.0 - 30.2
57	Sluiceway	4-Jul	19:02	61	0	1	111	10.0	98 - 136	15.2	4.9	10.9 - 29.8
58	Tailrace	5-Jul	00:01	40	1	0	110	8.8	99 - 135	15.0	4.0	10.7 - 26.6
59	Sluiceway	5-Jul	01:03	61	1	0	107	8.1	96 - 129	14.0	3.4	10.5 - 25.0
60	Tailrace	5-Jul	14:06	40	0	1	112	8.8	100 - 135	15.8	4.1	11.1 - 27.5
61	Tailrace	6-Jul	00:02	40	1	0	108	8.0	97 - 133	14.7	3.6	10.6 - 27.5
62	Sluiceway	6-Jul	12:55	62	0	0	107	6.5	99 - 127	13.9	2.7	10.8 - 22.4
63	Tailrace	6-Jul	14:07	41	0	0	110	6.2	99 - 126	14.7	2.2	11.0 - 19.4
64	Tailrace	6-Jul	23:56	41	0	0	107	6.5	100 - 131	15.0	3.0	11.9 - 26.4
65	Sluiceway	7-Jul	07:00	61	0	0	108	9.3	99 - 144	14.1	4.7	10.5 - 34.7
66	Tailrace	7-Jul	14:01	40	1	0	110	8.5	97 - 136	14.9	4.0	10.7 - 29.7
67	Tailrace	8-Jul	00:00	41	0	0	108	7.6	97 - 123	15.2	3.1	10.8 - 22.8
68	Sluiceway	8-Jul	00:59	62	0	0	105	5.5	97 - 120	13.9	2.0	11.1 - 19.3
69	Tailrace	8-Jul	14:02	41	0	0	105	8.6	96 - 142	13.2	3.9	10.4 - 32.4
70	Tailrace	9-Jul	00:04	39	2	0	104	6.5	97 - 129	13.0	2.7	10.3 - 24.8
71	Tailrace	9-Jul	13:56	40	0	1	107	9.2	97 - 138	14.7	4.0	10.2 - 28.9
72	Sluiceway	9-Jul	18:56	62	0	0	107	7.9	97 - 125	13.7	3.0	10.0 - 20.2

Table A1.8 (continued). Summary of subyearling Chinook salmon releases at The Dalles Dam ice and trash sluiceway (Sluiceway), and the tailrace 550 m downstream of the spillway beneath the I-197 bridge (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	Location	Date	Time	N	Tag loss	Mortality	Mean	SD	Range	Mean	SD	Range
73	Tailrace	10-Jul	00:00	40	1	0	106	6.8	97 - 131	13.1	2.8	10.3 - 25.2
74	Sluiceway	10-Jul	00:57	60	0	2	104	4.7	100 - 118	12.4	1.8	10.5 - 18.9
75	Tailrace	10-Jul	14:09	41	0	0	106	8.9	96 - 132	13.7	3.6	10.0 - 24.7
76	Tailrace	11-Jul	00:00	39	0	2	105	5.9	96 - 123	13.5	2.1	10.8 - 20.4
77	Sluiceway	11-Jul	07:00	59	2	1	108	10.0	97 - 139	15.5	4.8	10.1 - 31.5
78	Tailrace	11-Jul	13:58	41	0	0	108	8.4	97 - 136	15.2	3.8	10.4 - 26.6
79	Tailrace	12-Jul	00:00	40	0	0	108	9.9	98 - 135	14.4	4.0	10.7 - 26.4
80	Sluiceway	12-Jul	12:57	60	2	0	103	5.0	97 - 120	12.6	2.4	10.3 - 21.6
81	Tailrace	12-Jul	14:20	39	2	0	105	6.4	98 - 124	13.2	2.6	10.3 - 21.6
82	Tailrace	13-Jul	00:04	39	1	1	106	10.8	96 - 138	13.9	4.6	10.0 - 28.1
83	Tailrace	13-Jul	14:01	41	0	0	106	10.8	96 - 148	14.3	5.5	10.2 - 40.2
84	Sluiceway	13-Jul	18:52	61	0	0	109	12.2	96 - 151	15.0	5.8	10.4 - 40.5
85	Tailrace	13-Jul	23:56	40	1	0	108	10.6	95 - 147	14.9	5.0	10.3 - 37.9
86	Sluiceway	14-Jul	06:58	61	0	0	103	5.3	96 - 115	12.4	2.0	10.2 - 17.4
87	Tailrace	14-Jul	13:57	41	0	0	107	8.5	97 - 134	13.7	3.6	10.3 - 25.6
88	Tailrace	15-Jul	00:10	40	0	1	106	7.0	94 - 125	13.9	2.3	10.7 - 18.7
89	Tailrace	15-Jul	13:53	42	0	0	109	8.2	98 - 131	14.3	3.2	10.5 - 25.4
90	Sluiceway	15-Jul	19:00	63	0	1	111	8.3	92 - 131	15.8	3.7	10.0 - 24.4
91	Tailrace	16-Jul	00:02	40	1	1	109	6.9	96 - 121	15.2	3.5	10.0 - 22.2
92	Sluiceway	16-Jul	01:02	63	0	0	107	6.8	97 - 121	14.3	3.0	10.7 - 20.5
93	Tailrace	16-Jul	13:58	42	0	0	110	9.6	95 - 134	14.8	3.7	10.1 - 26.9
94	Tailrace	17-Jul	00:10	45	0	0	107	8.8	98 - 126	14.1	3.5	10.2 - 22.4
95	Sluiceway	17-Jul	12:57	63	3	1	104	8.1	94 - 132	12.8	3.1	10.4 - 25.3
96	Tailrace	17-Jul	14:13	49	0	0	104	6.7	95 - 127	12.8	3.0	10.1 - 22.2
Overall				4536	45	19	108	7.3	92 - 151	14.0	3.3	10.0 - 40.5

Table A1.9. Summary of subyearling Chinook salmon releases at Bonneville 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	17-Jun	10:51	46	0	0	110	7.3	99 - 132	14.6	3.3	10.9 - 27.8
2	18-Jun	00:04	46	0	0	108	7.4	94 - 127	14.2	2.8	10.5 - 21.9
3	18-Jun	10:48	45	2	0	105	8.2	94 - 130	13.6	3.8	10.0 - 25.6
4	18-Jun	23:59	45	2	0	107	7.3	96 - 128	13.8	3.1	10.2 - 25.3
5	19-Jun	10:47	43	3	0	106	8.7	96 - 132	13.8	3.4	10.0 - 24.6
6	19-Jun	23:54	45	0	0	108	6.4	99 - 128	14.6	2.3	11.1 - 21.7
7	20-Jun	10:58	43	2	0	108	8.0	94 - 130	14.6	3.9	10.1 - 27.9
8	20-Jun	23:50	45	0	0	111	4.9	102 - 124	15.4	2.4	11.5 - 22.5
9	21-Jun	10:58	45	1	0	109	6.0	98 - 130	14.3	2.5	11.0 - 24.6
10	22-Jun	00:00	43	1	0	109	5.7	101 - 125	15.1	2.8	11.8 - 24.6
11	22-Jun	10:57	45	0	0	110	7.3	98 - 130	14.5	3.2	10.2 - 26.6
12	22-Jun	23:56	46	1	0	109	6.1	98 - 136	14.3	2.6	11.8 - 25.7
13	23-Jun	10:59	49	0	0	114	8.3	100 - 135	15.7	3.4	10.4 - 25.1
14	23-Jun	23:56	47	0	0	112	4.7	100 - 125	14.2	1.9	11.2 - 19.7
15	24-Jun	10:54	49	0	0	116	7.8	102 - 140	15.3	3.7	11.0 - 30.7
16	24-Jun	23:49	47	0	0	110	8.7	97 - 132	13.5	3.2	10.2 - 21.5
17	25-Jun	11:01	46	3	0	110	6.1	99 - 130	14.9	2.9	10.2 - 23.9
18	26-Jun	00:03	46	1	0	105	5.7	96 - 120	12.4	2.1	10.0 - 19.2
19	26-Jun	10:50	45	1	0	105	3.3	97 - 117	12.8	1.6	10.3 - 19.0
20	26-Jun	23:58	46	1	0	105	6.1	97 - 129	12.4	2.4	10.0 - 24.0
21	27-Jun	10:56	46	1	0	105	6.0	97 - 134	12.8	2.4	10.1 - 25.0
22	28-Jun	00:02	47	0	0	107	5.7	98 - 125	13.2	2.2	10.3 - 22.6
23	28-Jun	10:48	47	0	0	108	4.5	100 - 122	14.3	1.8	10.5 - 20.1
24	28-Jun	23:59	46	1	0	104	4.3	97 - 119	12.5	1.7	10.3 - 18.9

Table A1.9 (continued). Summary of subyearling Chinook salmon releases at Bonneville 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
25	29-Jun	11:04	45	2	0	108	8.2	99 - 149	14.6	4.5	11.2 - 41.4
26	29-Jun	23:56	47	0	0	107	5.3	98 - 125	13.3	2.2	10.5 - 20.0
27	30-Jun	10:55	47	1	0	105	5.9	98 - 132	13.9	2.5	10.5 - 24.5
28	30-Jun	23:49	48	0	0	106	6.1	98 - 137	12.9	2.5	10.3 - 27.0
29	1-Jul	10:53	47	1	0	105	5.2	96 - 125	13.5	2.2	10.4 - 22.2
30	1-Jul	23:50	48	0	0	103	4.9	94 - 116	12.3	1.7	10.2 - 19.1
31	2-Jul	10:56	47	1	0	104	6.3	97 - 123	13.2	2.4	10.3 - 20.9
32	2-Jul	23:49	47	1	0	102	5.6	95 - 128	12.1	2.1	10.0 - 22.6
33	3-Jul	10:55	46	0	0	105	6.3	96 - 120	12.8	2.5	10.1 - 20.0
34	3-Jul	23:48	44	1	0	105	8.0	95 - 130	13.0	3.3	10.0 - 24.0
35	4-Jul	10:54	46	1	0	106	8.6	96 - 132	14.0	3.6	10.1 - 24.8
36	4-Jul	23:06	46	1	0	105	5.5	97 - 126	14.0	2.5	10.0 - 23.3
37	5-Jul	10:54	45	0	1	111	10.6	96 - 139	16.2	5.2	10.5 - 36.5
38	5-Jul	23:50	43	3	0	105	7.2	95 - 128	14.0	3.1	10.4 - 24.5
39	6-Jul	10:50	46	0	0	111	9.1	100 - 133	14.7	4.0	10.8 - 26.2
40	7-Jul	00:00	47	0	0	106	6.8	96 - 130	13.6	2.9	10.0 - 25.7
41	7-Jul	10:47	46	1	0	106	8.9	96 - 134	13.6	3.4	10.0 - 23.4
42	7-Jul	23:49	42	4	0	110	9.1	98 - 133	15.1	3.6	10.7 - 24.7
43	8-Jul	10:57	47	0	0	114	9.0	97 - 140	17.0	3.9	11.0 - 29.6
44	9-Jul	00:04	44	1	0	108	6.8	96 - 132	15.1	3.4	10.5 - 27.5
45	9-Jul	10:47	46	0	0	108	7.4	96 - 127	14.5	2.8	10.6 - 22.8
46	10-Jul	00:00	47	0	0	103	6.9	95 - 127	13.0	2.9	10.6 - 25.2
47	10-Jul	10:48	48	0	0	108	8.8	95 - 131	14.1	3.5	10.0 - 26.8
48	10-Jul	23:58	46	0	0	111	10.3	99 - 139	15.8	4.3	10.9 - 28.7
49	11-Jul	10:59	47	0	0	118	9.4	102 - 139	18.4	4.4	12.9 - 28.9
50	11-Jul	23:59	48	0	0	108	6.9	96 - 125	13.4	2.9	10.0 - 20.1
51	12-Jul	10:53	47	0	0	110	9.0	95 - 136	15.2	4.1	10.0 - 29.3

Table A1.9 (continued). Summary of subyearling Chinook salmon releases at Bonneville 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
52	12-Jul	23:46	46	0	0	112	8.2	100 - 137	14.7	3.4	11.4 - 28.0
53	13-Jul	10:51	47	0	0	113	8.8	100 - 135	15.3	3.6	11.0 - 25.3
54	13-Jul	23:55	48	0	0	107	7.9	98 - 137	13.6	3.2	10.4 - 26.3
55	14-Jul	10:51	45	1	0	110	9.6	99 - 143	15.3	4.6	11.0 - 32.7
56	14-Jul	23:50	48	0	0	111	9.6	98 - 142	15.6	4.5	10.3 - 33.9
57	15-Jul	10:56	46	0	0	115	8.5	100 - 134	16.5	3.6	10.9 - 24.6
58	16-Jul	00:00	47	0	0	107	10.1	95 - 143	14.0	4.1	10.0 - 30.4
59	16-Jul	11:00	45	1	0	109	8.8	100 - 140	13.4	3.3	10.3 - 26.0
60	16-Jul	23:50	44	0	2	110	9.5	96 - 134	16.4	3.7	11.0 - 26.8
61	17-Jul	11:04	46	0	0	108	6.9	93 - 125	13.8	2.3	10.1 - 21.1
62	17-Jul	23:57	45	0	0	111	7.5	99 - 132	15.8	3.2	10.7 - 27.0
63	18-Jul	10:59	38	0	1	111	7.4	98 - 127	15.4	3.1	10.9 - 22.6
64	18-Jul	23:56	40	1	0	112	10.7	97 - 135	16.2	4.5	11.0 - 26.8
Overall			2930	41	4	108	8.2	93 - 149	14.3	3.4	10.0 - 41.4

Appendix 2: Tag-Life Performance for Determining Potential Bias of Survival Estimates

Introduction

An assumption of release-recapture models used to estimate survival of juvenile salmonids is that all tagged individuals that are alive, have the same probability of being detected at downstream arrays. A factor that may have implications pertaining to this assumption is that radio-tags have a limited and varied battery-life. Therefore, the tag failure rate will affect detection probabilities, depending on the travel time and the amount of time tags are operational prior to release.

To address the probability of tag failure at detection arrays, a tag life study was performed for determining potential bias of survival estimates. 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

The tag-life study entailed activating tags during spring and summer of 2005 at the John Day Dam, and observing tag failure over time. A random sub-sample of tags during early, middle, and late season for both spring (n=75) and summer (n=75) survival studies were taken. Transmitters were held underwater at ambient water temperatures and monitored over time. The expiration time of each tag was noted at the time at which transmission ceased. The Lotek Wireless Model NTC-3-1 KMF (7.3 mm in diameter x 18.0 mm in length, 0.98 g weight in air, 2 second pulse rate) transmitters were used during the spring tag-life study and the Lotek model NTC-M-2 (5.6 mm wide x 13.9 mm length x 3.7 mm high, 0.43 g weight in air, 2.5 second pulse rate) transmitters were used during the summer tag-life study corresponding to what was used for survival studies.

Our analytical approach was modeled after Townsend et al. (2004). Tag-life data was used to model tag survivorship and for calculating the probability of a tag being operational at detection arrays. The tag-life data generated from the above study 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 a non-normal distribution. 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 used to calculate probabilities, where S is the probability the radio-tag is operational and t is time in days.

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

Travel time 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, tag-failure began around 8 days and continued until about day 13, at which all tags (Model NTC-3-1 KMF) were not operational having an average tag-life of 9.62 days, although, most tags were not operational by day 11 (Figure A2.1). 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, although, most tags were not operational by day 12 of the study. 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 radio-tags were alive 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, all probabilities being greater than 99.9% (Table A2.2). The cumulative arrival distributions plotted along with the Gompertz model over time shows that tagged juvenile salmonids in our study passed through downstream detection arrays several days before tag-failure was substantial for both treatment and control fish at Bonneville and The Dalles Dam (Figure A2.2).

Townsend et al. (2004) found that the probability of a tag being operational at downstream detection arrays was quite high (>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; therefore we did not adjust our estimates.

References

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

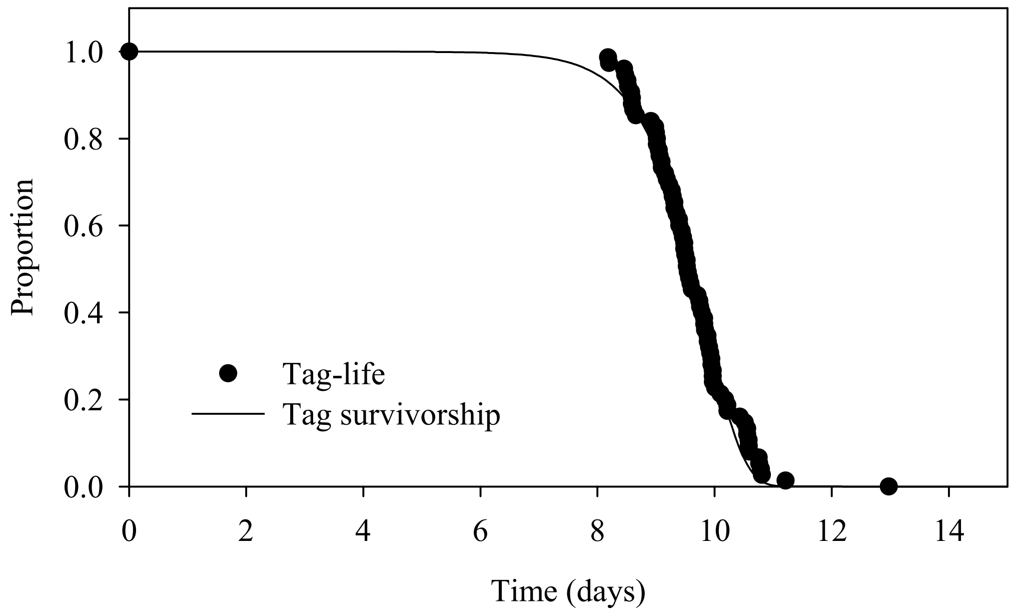
Townsend, R.L., Skalski, J.R., Dillingham, P. & Steig, T.W. 2004. Correcting bias in survival estimation resulting from tag failure in acoustic and radio telemetry studies. Report prepared for the Bonneville Power Administration, Contract No. 00012494.

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

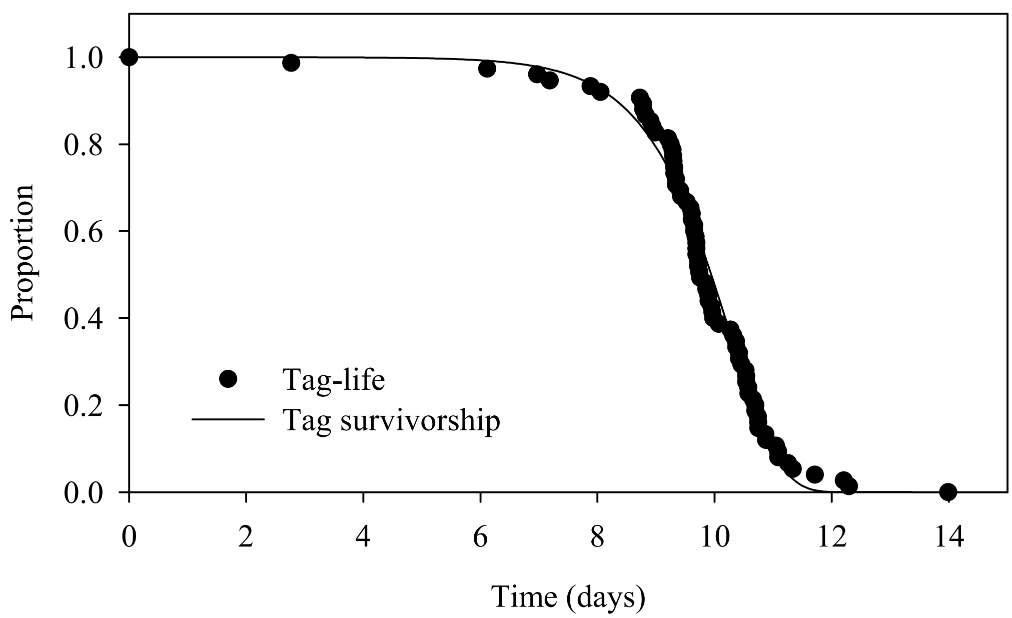
Tag-life Study	N	α	β	R^2
Spring	75	1.5648 (0.1346)	3.136×10^{-7} (3.813×10^{-7})	0.9556
Summer	75	1.1618 (0.0962)	7.747×10^{-6} (6.856×10^{-6})	0.9554

Table A2.2. Estimated probabilities (mean, *SE* in parentheses) a radio-tag was operational at Bonneville Dam and other downstream detection arrays for yearling Chinook salmon, hatchery steelhead trout, and subyearling Chinook salmon, during 2005.

	Detection Array Locations	
Release Site	Bonneville Dam	Survival Gates
	Yearling Chinook salmon	
The Dalles Dam	1.000 (1.272×10^{-5})	0.9999 (1.401×10^{-5})
Bonneville Dam	NA	1.000 (4.327×10^{-6})
	Hatchery steelhead trout	
The Dalles Dam	1.000 (1.337×10^{-5})	0.9999 (3.518×10^{-5})
Bonneville Dam	NA	1.000 (8.403×10^{-6})
	Subyearling Chinook salmon	
The Dalles Dam	0.9999 (1.093×10^{-6})	0.9997 (2.082×10^{-5})
Bonneville Dam	NA	1.000 (2.661×10^{-7})

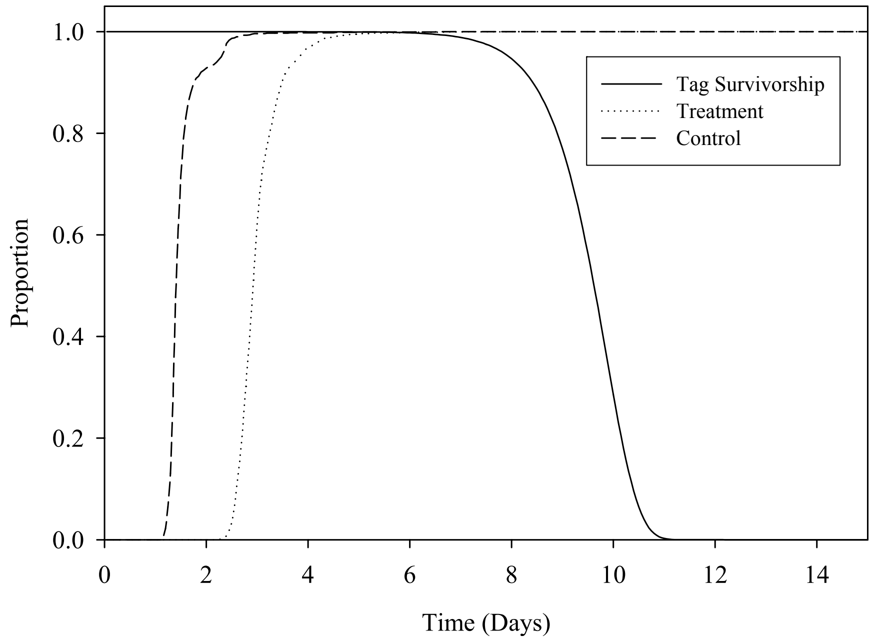


A) Spring

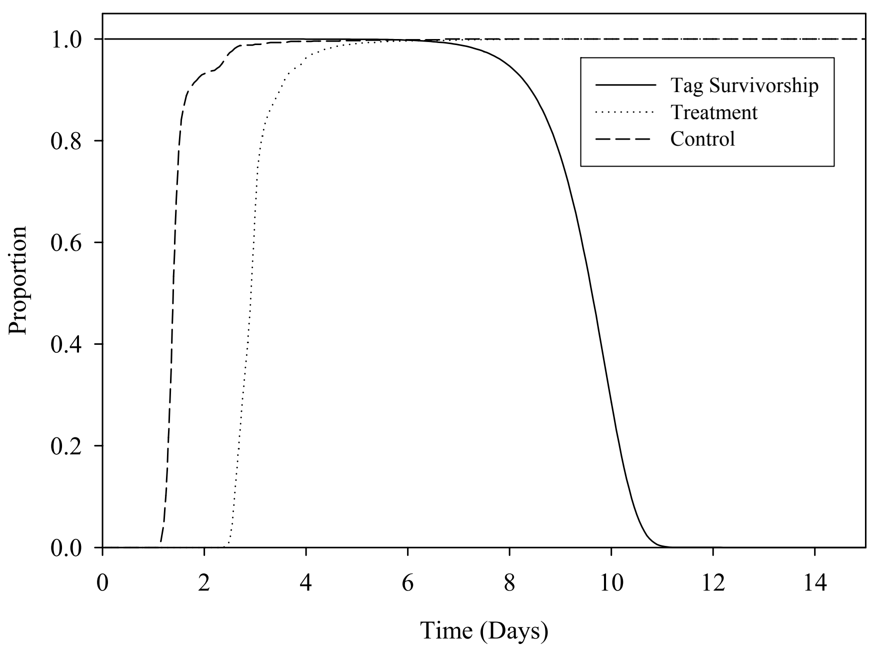


B) Summer

Figure A2.1 Fitted Gompertz model with tag-life data for A) spring and B) summer studies.

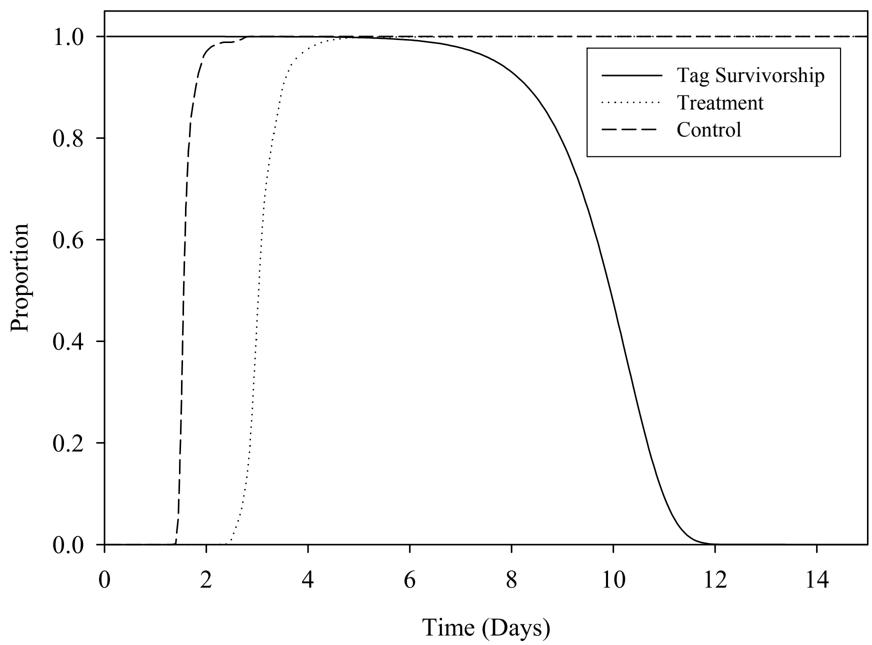


A) Yearling Chinook salmon, Spring



B) Hatchery Steelhead, Spring

Figure A2.2. Probability distributions (A-C) for radio-tags being operational over time with cumulative arrival distributions at downstream survival gates for the Bonneville Dam survival assessment during 2005.



C) Subyearling Chinook salmon, Summer

Figure A2.2. (Continued) Probability distributions (A-C) for radio-tags being operational over time with cumulative arrival distributions at downstream survival gates for the Bonneville Dam survival assessment during 2005.

Appendix 3: Burnham Tests 2 and 3

Table A3.1. Summary statistics for goodness-of-fit tests (tests 2 and 3, Burnham et al. 1987) for each of 16 paired releases of yearling Chinook salmon, 2005. Treatment fish were released into the ice and trash sluiceway of powerhouse 1 and control fish were released below the powerhouse 2 juvenile bypass outfall at Bonneville Dam. Tests are considered significant at α = 0.0033 (Dunn-Sidak experimentwise error rate).

		Test 2			Test 3		
Release	Population	df	χ^2	P	df	χ^2	P
1	Treatment	1	4.49	0.03	1	1.75	0.19
	Control	1	1.87	0.17	1	1.75	0.19
2	Treatment	1	1.09	0.30	1	0.01	0.93
	Control	1	0.50	0.48	[a]	[a]	[a]
3	Treatment	1	0.09	0.77	[a]	[a]	[a]
	Control	[a]	[a]	[a]	1	4.49	0.03
4	Treatment	[a]	[a]	[a]	[a]	[a]	[a]
	Control	1	0.02	0.88	1	0.68	0.41
5	Treatment	1	2.00	0.16	1	0.17	0.68
	Control	[a]	[a]	[a]	[a]	[a]	[a]
6	Treatment	[a]	[a]	[a]	[a]	[a]	[a]
	Control	1	1.87	0.17	1	3.99	0.05
7	Treatment	[a]	[a]	[a]	[a]	[a]	[a]
	Control	1	0.46	0.50	[a]	[a]	[a]
8	Treatment	[a]	[a]	[a]	[a]	[a]	[a]
	Control	[a]	[a]	[a]	[a]	[a]	[a]
9	Treatment	[a]	[a]	[a]	[a]	[a]	[a]
	Control	1	0.35	0.55	[a]	[a]	[a]
10	Treatment	[a]	[a]	[a]	[a]	[a]	[a]
	Control	1	0.59	0.44	1	0.14	0.71
11	Treatment	[a]	[a]	[a]	[a]	[a]	[a]
	Control	1	0.07	0.80	[a]	[a]	[a]
12	Treatment	[a]	[a]	[a]	[a]	[a]	[a]
	Control	1	0.11	0.74	1	0.06	0.81
13	Treatment	1	0.03	0.86	[a]	[a]	[a]
	Control	1	0.18	0.67	[a]	[a]	[a]
14	Treatment	[a]	[a]	[a]	[a]	[a]	[a]
	Control	[a]	[a]	[a]	1	4.49	0.03
15	Treatment	1	0.00	0.97	1	3.48	0.06
	Control	[a]	[a]	[a]	[a]	[a]	[a]
16	Treatment	1	0.93	0.34	[a]	[a]	[a]
	Control	1	0.03	0.86	1	1.37	0.24

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

Table A3.2. Summary statistics for goodness-of-fit tests (tests 2 and 3, Burnham et al. 1987) for each of 16 paired releases of hatchery steelhead trout, 2005. Treatment fish were released into the ice and trash sluiceway of powerhouse 1 and control fish were released below the powerhouse 2 juvenile bypass outfall at Bonneville Dam. Tests are considered significant at α = 0.0033 (Dunn-Sidak experimentwise error rate).

		Test 2			Test 3		
Release	Population	df	χ^2	P	df	χ^2	P
1	Treatment	[a]	[a]	[a]	1	2.25	0.13
	Control	[a]	[a]	[a]	[a]	[a]	[a]
2	Treatment	[a]	[a]	[a]	[a]	[a]	[a]
	Control	[a]	[a]	[a]	1	0.68	0.41
3	Treatment	[a]	[a]	[a]	[a]	[a]	[a]
	Control	[a]	[a]	[a]	[a]	[a]	[a]
4	Treatment	[a]	[a]	[a]	1	0.73	0.39
	Control	[a]	[a]	[a]	[a]	[a]	[a]
5	Treatment	[a]	[a]	[a]	[a]	[a]	[a]
	Control	[a]	[a]	[a]	[a]	[a]	[a]
6	Treatment	1	5.06	0.02	[a]	[a]	[a]
	Control	[a]	[a]	[a]	[a]	[a]	[a]
7	Treatment	[a]	[a]	[a]	[a]	[a]	[a]
	Control	[a]	[a]	[a]	[a]	[a]	[a]
8	Treatment	1	4.99	0.03	[a]	[a]	[a]
	Control	[a]	[a]	[a]	[a]	[a]	[a]
9	Treatment	[a]	[a]	[a]	[a]	[a]	[a]
	Control	[a]	[a]	[a]	1	2.25	0.13
10	Treatment	1	0.63	0.43	[a]	[a]	[a]
	Control	1	0.01	0.91	[a]	[a]	[a]
11	Treatment	[a]	[a]	[a]	[a]	[a]	[a]
	Control	[a]	[a]	[a]	[a]	[a]	[a]
12	Treatment	1	0.83	0.36	1	0.04	0.84
	Control	[a]	[a]	[a]	[a]	[a]	[a]
13	Treatment	[a]	[a]	[a]	[a]	[a]	[a]
	Control	[a]	[a]	[a]	1	0.14	0.71
14	Treatment	[a]	[a]	[a]	[a]	[a]	[a]
	Control	[a]	[a]	[a]	[a]	[a]	[a]
15	Treatment	[a]	[a]	[a]	[a]	[a]	[a]
	Control	1	4.49	0.03	[a]	[a]	[a]
16	Treatment	1	3.74	0.05	[a]	[a]	[a]
	Control	[a]	[a]	[a]	[a]	[a]	[a]

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

Table A3.3. Summary statistics for goodness-of-fit tests (tests 2 and 3, Burnham et al. 1987) for each of 32 paired releases of subyearling Chinook salmon, 2005. Treatment fish were released into the ice and trash sluiceway of powerhouse 1 and control fish were released below the powerhouse 2 juvenile bypass outfall at Bonneville Dam. Tests are considered significant at $\alpha = 0.0016$ (Dunn-Sidak experimentwise error rate).

			Test 2			Test 3	
Release	Population	df	χ^2	P	df	χ^2	P
1	Treatment	1	2.43	0.12	1	1.98	0.16
	Control	1	0.96	0.33	[a]	[a]	[a]
2	Treatment	1	0.22	0.64	[a]	[a]	[a]
	Control	1	2.51	0.11	1	4.74	0.03
3	Treatment	[a]	[a]	[a]	[a]	[a]	[a]
	Control	1	0.34	0.56	[a]	[a]	[a]
4	Treatment	1	1.16	0.28	[a]	[a]	[a]
	Control	1	0.05	0.83	[a]	[a]	[a]
5	Treatment	1	0.00	0.95	[a]	[a]	[a]
	Control	1	0.01	0.90	[a]	[a]	[a]
6	Treatment	1	0.77	0.38	[a]	[a]	[a]
	Control	1	0.01	0.92	[a]	[a]	[a]
7	Treatment	1	0.09	0.76	[a]	[a]	[a]
	Control	1	0.11	0.74	1	0.96	0.33
8	Treatment	1	0.02	0.88	1	0.01	0.91
	Control	1	0.64	0.42	1	1.73	0.19
9	Treatment	1	0.37	0.55	[a]	[a]	[a]
	Control	1	2.22	0.14	1	0.39	0.53
10	Treatment	1	0.08	0.77	1	0.50	0.48
	Control	1	0.45	0.50	1	0.52	0.47
11	Treatment	[a]	[a]	[a]	[a]	[a]	[a]
	Control	1	0.15	0.69	1	1.62	0.20
12	Treatment	[a]	[a]	[a]	[a]	[a]	[a]
	Control	1	0.29	0.59	1	0.83	0.36
13	Treatment	1	0.38	0.54	[a]	[a]	[a]
	Control	1	0.02	0.89	[a]	[a]	[a]
14	Treatment	1	0.08	0.77	[a]	[a]	[a]
	Control	1	0.03	0.87	1	0.09	0.76
15	Treatment	1	0.44	0.51	[a]	[a]	[a]
	Control	1	0.81	0.37	[a]	[a]	[a]
16	Treatment	1	2.56	0.11	[a]	[a]	[a]
	Control	1	0.98	0.32	1	0.03	0.86

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

Table A3.3 (continued). Summary statistics for goodness-of-fit tests (tests 2 and 3, Burnham et al. 1987) for each of 32 paired releases of subyearling Chinook salmon, summer 2005. Treatment fish were released at the ice and trash sluiceway of powerhouse 1 at Bonneville Dam and control fish were released below the powerhouse 2 juvenile bypass outfall at Bonneville Dam.

			Test 2			Test 3	
Release	Population	df	χ^2	P	df	χ^2	P
17	Treatment	1	0.41	0.52	[a]	[a]	[a]
	Control	1	0.44	0.51	[a]	[a]	[a]
18	Treatment	1	0.24	0.62	[a]	[a]	[a]
	Control	1	0.01	0.93	1	0.68	0.41
19	Treatment	1	0.02	0.89	[a]	[a]	[a]
	Control	1	0.02	0.88	[a]	[a]	[a]
20	Treatment	1	0.11	0.74	1	0.01	0.92
	Control	1	0.00	0.99	1	0.58	0.45
21	Treatment	[a]	[a]	[a]	[a]	[a]	[a]
	Control	1	0.94	0.33	1	2.87	0.09
22	Treatment	1	0.14	0.71	[a]	[a]	[a]
	Control	[a]	[a]	[a]	1	0.73	0.39
23	Treatment	1	0.00	1.00	[a]	[a]	[a]
	Control	1	4.15	0.04	1	3.37	0.07
24	Treatment	[a]	[a]	[a]	[a]	[a]	[a]
	Control	1	0.30	0.58	1	0.00	0.96
25	Treatment	1	0.00	1.00	1	0.24	0.62
	Control	1	1.93	0.16	1	1.12	0.29
26	Treatment	[a]	[a]	[a]	1	0.06	0.81
	Control	1	0.09	0.77	1	1.12	0.29
27	Treatment	1	2.11	0.15	[a]	[a]	[a]
	Control	1	0.00	0.96	1	3.50	0.06
28	Treatment	1	0.56	0.45	1	0.57	0.45
	Control	1	0.00	0.98	1	1.03	0.31
29	Treatment	1	3.09	0.08	1	1.12	0.29
	Control	1	0.06	0.80	1	0.05	0.82
30	Treatment	1	1.16	0.28	[a]	[a]	[a]
	Control	1	0.01	0.91	1	0.40	0.53
31	Treatment	1	0.17	0.68	[a]	[a]	[a]
	Control	1	0.78	0.38	1	1.92	0.17
32	Treatment	1	0.27	0.60	[a]	[a]	[a]
	Control	1	0.11	0.75	1	0.01	0.94

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

Appendix 4: Homogeneity of Arrival Times

Table A4.1. Summary of chi-square tests for homogeneity of arrival times of yearling Chinook salmon released into the ice and trash sluiceway of powerhouse 1 at Bonneville Dam and below Bonneville Dam juvenile bypass outfall at powerhouse 2 and detected at river kilometers 200, 194, and 181, spring 2005.

	River Kilometer 200			River Kilometer 194			River Kilometer 181		
Release	DF	Chi-square	P	DF	Chi-square	P	DF	Chi-square	P
1	1	0.129	0.720	1	0	1.000	4	3.642	0.457
2	1	2.003	0.157	2	2.775	0.250	2	1.099	0.577
3	0	0	[a]	0	0	[a]	1	0.846	0.358
4	0	0	[a]	0	0	[a]	0	0	[a]
5	0	0	[a]	0	0	[a]	0	0	[a]
6	0	0	[a]	0	0	[a]	0	0	[a]
7	0	0	[a]	0	0	[a]	0	0	[a]
8	0	0	[a]	0	0	[a]	0	0	[a]
9	0	0	[a]	0	0	[a]	0	0	[a]
10	0	0	[a]	0	0	[a]	0	0	[a]
11	0	0	[a]	0	0	[a]	0	0	[a]
12	0	0	[a]	0	0	[a]	0	0	[a]
13	0	0	[a]	0	0	[a]	0	0	[a]
14	1	1.076	0.300	0	0	[a]	0	0	[a]
15	0	0	[a]	0	0	[a]	0	0	[a]
16	0	0	[a]	0	0	[a]	0	0	[a]

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

Table A4.2. Summary of chi-square tests for homogeneity of arrival times of hatchery steelhead trout released into the ice and trash sluiceway of powerhouse 1 at Bonneville Dam and below Bonneville Dam juvenile bypass outfall at powerhouse 2 and detected at river kilometers 200, 194, and 181, spring 2005.

	River Kilometer 200			River Kilometer 194			River Kilometer 181		
Release	DF	Chi-square	P	DF	Chi-square	P	DF	Chi-square	P
1	1	0.812	0.368	2	1.879	0.391	2	2.379	0.304
2	3	3.097	0.377	3	3.600	0.308	3	3.011	0.390
3	1	1.024	0.311	2	2.327	0.312	2	2.002	0.367
4	2	2.002	0.367	2	0.935	0.626	4	4.105	0.392
5	2	1.735	0.420	2	1.735	0.420	2	1.722	0.423
6	0	0	[a]	1	0.975	0.323	1	0.004	0.947
7	0	0	[a]	1	1.076	0.300	1	1.134	0.287
8	0	0	[a]	0	0	[a]	0	0	[a]
9	0	0	[a]	1	0.846	0.358	1	0.004	0.950
10	1	1.121	0.290	1	0.746	0.388	1	1.066	0.302
11	0	0	[a]	0	0	[a]	0	0	[a]
12	0	0	[a]	0	0	[a]	0	0	[a]
13	0	0	[a]	0	0	[a]	0	0	[a]
14	0	0	[a]	0	0	[a]	0	0	[a]
15	0	0	[a]	0	0	[a]	0	0	[a]
16	1	1.032	0.310	1	1.032	0.310	1	1.255	0.263

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

Table A4.3. Summary of chi-square tests for homogeneity of arrival times of subyearling Chinook released into the ice and trash sluiceway of powerhouse 1 at Bonneville Dam and below Bonneville Dam juvenile bypass outfall at powerhouse 2 and detected at river kilometers 200, 194, and 181, summer 2005.

	River Kilometer 200			River Kilometer 194			River Kilometer 181		
Release	DF	Chi-square	P	DF	Chi-square	P	DF	Chi-square	P
1	1	0.350	0.554	1	1.518	0.218	1	2.419	0.120
2	1	2.515	0.113	1	0.125	0.724	1	0.394	0.530
3	0	0	[a]	0	0	[a]	1	2.545	0.111
4	0	0	[a]	0	0	[a]	0	0	[a]
5	0	0	[a]	0	0	[a]	0	0	[a]
6	0	0	[a]	0	0	[a]	0	0	[a]
7	0	0	[a]	0	0	[a]	0	0	[a]
8	0	0	[a]	0	0	[a]	0	0	[a]
9	0	0	[a]	0	0	[a]	0	0	[a]
10	0	0	[a]	0	0	[a]	0	0	[a]
11	0	0	[a]	0	0	[a]	0	0	[a]
12	0	0	[a]	0	0	[a]	0	0	[a]
13	0	0	[a]	0	0	[a]	0	0	[a]
14	0	0	[a]	0	0	[a]	0	0	[a]
15	0	0	[a]	0	0	[a]	0	0	[a]
16	0	0	[a]	0	0	[a]	0	0	[a]
17	1	48.53	0.000	1	17.00	0.000	1	51.39	0.000
18	0	0	[a]	1	0.457	0.499	0	0	[a]
19	0	0	[a]	0	0	[a]	0	0	[a]
20	0	0	[a]	0	0	[a]	0	0	[a]
21	1	2.624	0.105	1	2.208	0.137	1	2.827	0.093
22	1	2.420	0.120	1	2.690	0.101	1	2.353	0.125
23	0	0	[a]	0	0	[a]	0	0	[a]
24	0	0	[a]	0	0	[a]	0	0	[a]
25	0	0	[a]	0	0	[a]	0	0	[a]
26	0	0	[a]	0	0	[a]	0	0	[a]
27	0	0	[a]	0	0	[a]	0	0	[a]
28	0	0	[a]	0	0	[a]	0	0	[a]
29	0	0	[a]	0	0	[a]	0	0	[a]
30	0	0	[a]	0	0	[a]	0	0	[a]
31	0	0	[a]	0	0	[a]	0	0	[a]
32	0	0	[a]	0	0	[a]	0	0	[a]

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