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Survival Estimates of Migrant Juvenile Salmonids through Bonneville Dam Using Radio Telemetry, 2004

Final Report of Research

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Executive Summary

During 2004, the USGS evaluated the survival of radio-tagged yearling and subyearling Chinook salmon and steelhead trout through the ice and trash sluiceway and the minimum gap runner (MGR) turbine unit at Bonneville Dam's powerhouse 1. Survival was estimated using paired release-recapture models with paired releases made directly into these passage routes and in the tailrace of Bonneville Dam. For the evaluations of survival through the MGR two separate control release locations were used; one location was directly downstream of the front roll below the turbine unit and the other release location was further downstream of the powerhouse 2 juvenile bypass outfall. During spring and summer releases of radio-tagged fish into the MGR and the ice and trash sluiceway, powerhouse 1 was not continuously operated due to a policy that prioritized the passage of water through powerhouse 2. Because of this policy, powerhouse 1 was only operated sporadically for short time intervals before and after the releases of radio-tagged fish associated with this study.

Using releases of radio-tagged yearling and subyearling Chinook salmon and steelhead trout released at The Dalles Dam, and releases made into the tailrace of Bonneville Dam, we also evaluated survival through Bonneville Dam spillway, powerhouse 1, powerhouse 2 turbines, and the corner collector and juvenile bypass system (JBS) at powerhouse 2. We also estimated dam survival (all routes combined) and project survival (product of pool and dam survival). Further we estimated the survival of fish passing via spillbays at Bonneville Dam with either 7-ft or 14-ft deflectors located above mean sea level using the paired release-recapture model. However, dissimilar to the releases into the ice and trash sluiceway and MGR, the paired release groups were formed post-hoc from releases of radio-tagged fish at The Dalles Dam and Bonneville Dam tailraces.

After the completion of the field component of this study, the Army Corps of Engineers identified a discrepancy between the reported inflow (The Dalles outflow + tributary inflow) and outflow from Bonneville Dam during times of spill. The reported spillway discharge was greater than the actual discharge (as measured downstream of the dam). The magnitude of this discrepancy varied but was on the order of 20 kcfs less than what had been reported (see: Bonneville Lock and Dam, Revision to Fish Passage Plan Spill Patterns FEB2005, Memorandum; Appendix 6). The USGS was to estimate the survival for spring migrants during the Biological Opinion (BIOP) spill operations of 75 kcfs during the day and spill up to 125% of the total dissolved gas cap at night (75 kcfs/TDG). However, due to the discrepancy in reported and actual spillway discharge, the spring spill operation evaluated was on the order of 56 kcfs day/TDG at night. During the summer evaluation of radio-tagged subyearling Chinook salmon, two spill operations were to be examined, 75 kcfs/TDG and 50 kcfs for 24 hour. Again, the actual spill operations evaluated during the summer were approximately 56 kcfs day/TDG night and 23 kcfs for 24 h. This report contains the updated spill values given by the Army Corps of Engineers using methods explained in Bonneville Lock and Dam, Revision to Fish Passage Plan Spill Patterns FEB2005, Memorandum (Appendix 6).

Yearling Chinook salmon

Paired Release-recapture Model

Minimum Gap Runner Turbine Unit

Control group released directly downstream of front roll below turbine unit

The estimated 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 ranged from 0.830 to 1.042 during 2004. The average survival was estimated to be 0.956 (SE = 0.016, 95% confidence interval [0.924, 0.988]).

Control group released below the outfall of the powerhouse 2 juvenile bypass

The estimated 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 powerhouse 2 juvenile bypass outfall ranged from 0.83 to1.02 during 2004. The average survival was estimated to be 0.944 (SE = 0.015, 95% confidence interval [0.913, 0.976]).

Ice and Trash Sluiceway

The estimated 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 JBS) during 2004 ranged from 0.84 to1.15. The average survival was estimated to be 0.947 (SE = 0.018, 95% confidence interval [0.908, 0.986]).

Spillway Flow Deflectors

7-Ft Spillbay Flow Deflectors

The point estimates of the survival for yearling Chinook salmon passing via spillbays with deflectors located 7 feet above mean sea level at Bonneville Dam spillway during daytime 56 kcfs spill operations ranged from 0.780 to 1.010 ($\bar{X} = 0.937;\ SE = 0.018;\ 95\%\,CI = \left[0.898, 0.976\right]$). Survival estimates for yearling Chinook salmon passing via spillbays with 7-ft deflectors during total dissolved gas cap spill operations ranged from 0.780 to 1.077 ($\bar{X} = 0.943;\ SE = 0.026;\ 95\%\,CI = \left[0.886, 1.000\right]$).

14-Ft Spillbay Flow Deflectors

The point estimates of the survival for yearling Chinook salmon passing via spillbays with deflectors located 14 feet above mean sea level at Bonneville Dam spillway during 56 kcfs spill operations ranged from 0.643 to 1.020 ($\bar{X} = 0.773;\ SE = 0.045;\ 95\%\,CI = \left[0.667, 0.879\right]$). Survival estimates for yearling Chinook salmon passing via spillbays with 14-ft deflector during total dissolved gas cap spill operations ranged from 0.845 to 1.087 ($\bar{X} = 0.946;\ SE = 0.018;\ 95\%\,CI = \left[0.907, 0.985\right]$).

Route-specific Survival Model

56 kcfs day/TDG night spill operations

During the 56 kcfs day/TDG night spill operations, the survival of yearling Chinook salmon through Bonneville Dam spillway was estimated to be 0.910 (SE = 0.011, profile likelihood 95% confidence interval [0.888, 0.931]). For yearling Chinook salmon passing via powerhouse 1, the estimated survival was 0.913 (SE = 0.019, profile likelihood 95% confidence interval [0.872, 0.949]) and for yearling Chinook salmon passing via powerhouse 2 turbines the estimated survival was 0.951 (SE = 0.011, profile likelihood 95% confidence interval [0.929, 0.972]). For yearling Chinook salmon passing via the JBS the estimated survival was 0.970 (SE = 0.013, profile likelihood 95% confidence interval [0.943, 0.994]) and passing via the corner collector at powerhouse 2 the estimated survival was 1.016 (SE = 0.008, profile likelihood 95% confidence interval [0.999, 1.032]). Yearling Chinook salmon dam survival through Bonneville Dam was estimated to be 0.951 (SE = 0.008, profile likelihood 95% confidence interval [0.937, 0.966]) and project survival was estimated to be 0.883 (SE = 0.008, profile likelihood confidence interval [0.868, 0.898]).

56 kcfs day spill operations

The survival of yearling Chinook salmon through Bonneville Dam spillway during 56 kcfs day spill operations was estimated to be 0.861 (SE = 0.015, profile likelihood 95% confidence interval [0.831, 0.889]). For yearling Chinook salmon passing via powerhouse 1, the estimated survival was 0.894 (SE = 0.020, profile likelihood 95% confidence interval [0.853, 0.930]) and for yearling Chinook salmon passing via powerhouse 2 turbines, the estimated survival was 0.925 (SE = 0.012, profile likelihood 95% confidence interval [0.902, 0.948]). For yearling Chinook salmon passing via the powerhouse 2 JBS the estimated survival was 0.938 (SE = 0.015, profile likelihood 95% confidence interval [0.906, 0.966]). The survival of yearling Chinook salmon passing via the corner collector at powerhouse 2 was estimated to be 0.993 (SE = 0.008, profile likelihood 95% confidence interval [0.977, 1.008]). Yearling Chinook salmon dam survival through Bonneville Dam was estimated to be 0.925 (SE = 0.008, profile likelihood 95% confidence interval [0.912, 0.941]) and project survival was estimated to be 0.860 (SE = 0.008, profile likelihood 95% confidence interval [0.844, 0.876]).

Total dissolved gas cap night spill operations

The survival of yearling Chinook salmon through Bonneville Dam spillway during total dissolved gas cap night spill operations was estimated to be 0.964 (SE = 0.016, profile likelihood 95% confidence interval [0.932, 0.996]). For yearling Chinook salmon passing via powerhouse 1, the estimated survival was 0.903 (SE = 0.060, profile likelihood 95% confidence interval [0.768, 0.999]) and for yearling Chinook salmon passing via powerhouse 2 turbines, the estimated survival was 0.981 (SE = 0.021, profile likelihood 95% confidence interval [0.937, 1.020]). For yearling Chinook salmon passing via the powerhouse 2 JBS the estimated survival was 1.013 (SE = 0.022, profile likelihood 95% confidence interval [0.964, 1.053]). The estimated survival of yearling Chinook salmon passing via the corner collector at powerhouse 2 was 1.028 (SE = 0.021, profile likelihood 95% confidence interval [0.980, 1.065]). Yearling Chinook salmon dam survival through Bonneville Dam was estimated to be 0.979 (SE = 0.015, profile likelihood 95% confidence interval [0.953, 1.007]) and project survival was estimated to be 0.908 (SE = 0.015, profile likelihood 95% confidence interval [0.881, 0.937]).

Steelhead Trout

Paired Release-recapture Model

Minimum Gap Runner Turbine Unit

Control group released directly downstream of front roll below turbine unit

The estimated survival of 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 ranged from 0.830 to 1.136 during 2004. The average survival was estimated to be 0.952 (SE = 0.024, 95% confidence interval [0.900, 1.003]).

Control group released below the outfall of the powerhouse 2 juvenile bypass

The estimated survival of steelhead trout released into the MGR turbine unit at Bonneville Dam's powerhouse 1 with the control group released in the tailrace below the outfall of the powerhouse 2 juvenile bypass outfall ranged from 0.74 to 1.09 during 2004. The average survival was estimated to be 0.926, (SE = 0.030, 95% confidence interval [0.861, 0.992]).

Ice and Trash Sluiceway

The estimated 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 2004 ranged from 0.76 to1.07. The average survival was estimated to be 0.935 (SE = 0.024, 95% confidence interval [0.884, 0.985]).

Spillway Flow Deflectors

7-Ft Spillbay Flow Deflectors

The point estimates of survival for steelhead trout passing via spillbays with deflectors located 7 feet above mean sea level at Bonneville Dam spillway during 56 kcfs spill operations ranged from 0.667 to 1.064 ($\bar{X} = 0.927;\ SE = 0.046;\ 95\% CI = \left[0.818, 1.036\right]$). Survival estimates for steelhead trout passing via spillbays with 7-ft deflectors during total dissolved gas cap spill operations ranged from 0.926 to 1.143 ($\bar{X} = 1.013;\ SE = 0.016;\ 95\% CI = \left[0.979, 1.047\right]$).

14-Ft Spillbay Flow Deflectors

The point estimates of survival of steelhead trout passing via spillbays with deflectors located 14 feet above sea level at Bonneville Dam spillway during 56 kcfs spill operations ranged from 0.684 to 0.959 ($\bar{X} = 0.850;\ SE = 0.063;\ 95\% CI = \left[0.650, 1.050\right]$). Survival estimates for steelhead trout passing via spillbays with 14-ft deflectors during total dissolved gas cap spill operations ranged from 0.878 to 1.143 ($\bar{X} = 1.012;\ SE = 0.015;\ 95\% CI = \left[0.980, 1.044\right]$).

Route-specific Survival Model

56 kcfs day/TDG night spill operations

The survival of steelhead trout through Bonneville Dam spillway was estimated to be 0.979 (SE = 0.011, profile likelihood 95% confidence interval [0.956, 1.002]). For steelhead trout passing via powerhouse 1 the estimated survival was 0.965 (SE = 0.019, profile likelihood 95% confidence interval [0.926, 0.999]) and for steelhead trout passing via powerhouse 2 turbines, the estimated survival was 0.889 (SE = 0.020, profile likelihood 95% confidence interval [0.848, 0.927]). For steelhead trout passing via the powerhouse 2 JBS the estimated survival was 0.951 (SE = 0.021, profile likelihood 95% confidence interval [0.907, 0.989]). The estimated survival of steelhead trout passing via the powerhouse 2 corner collector was 1.030 (SE = 0.008, profile likelihood 95% confidence interval [1.014, 1.047]). Steelhead trout dam survival through Bonneville Dam was estimated to be 0.991 (SE = 0.008, profile likelihood 95% confidence interval [0.975, 1.008]) and project survival was estimated to be 0.897 (SE= 0.009, profile likelihood 95% confidence interval [0.881, 0.915]).

56 kcfs day spill operations

The survival of steelhead trout through Bonneville Dam spillway during 56 kcfs day spill operations was estimated to be 0.891 (SE = 0.024, profile likelihood 95% confidence interval [0.840, 0.936]). For steelhead trout passing via powerhouse 1, the estimated survival was 0.966 (SE = 0.020, profile likelihood 95% confidence interval [0.922, 1.003]) and for steelhead trout passing via powerhouse 2 turbines the estimated survival was 0.863 (SE = 0.028, profile likelihood 95% confidence interval [0.804, 0.915]). For steelhead trout passing via the powerhouse 2 JBS, the estimated survival was 0.904 (SE = 0.031, profile likelihood 95% confidence interval [0.837, 0.960]). For steelhead trout passing via the powerhouse 2, corner collector, the estimated survival was 1.018 (SE = 0.010, profile likelihood 95% confidence interval [0.9998, 1.039]). Steelhead trout dam survival through Bonneville Dam was estimated to be 0.980 (SE = 0.010, profile likelihood 95% confidence interval [0.962, 1.001]) and project survival was estimated to be 0.888 (SE = 0.010, profile likelihood 95% confidence interval [0.868, 0.909].

Total dissolved gas cap night spill operations

The survival of steelhead trout through Bonneville Dam spillway during total dissolved gas cap spill operations was estimated to be 1.020 (SE = 0.015, profile likelihood 95% confidence interval [0.992, 1.050]). For steelhead trout passing via powerhouse 1, the estimated survival was 0.940 (SE = 0.041, profile likelihood 95% confidence interval [0.850, 1.009]) and for steelhead trout passing via powerhouse 2 turbines the estimated survival was 0.917 (SE = 0.029, profile likelihood 95% confidence interval [0.857, 0.970]). For steelhead trout passing via the powerhouse 2 JBS, the estimated survival was 1.003 (SE = 0.027, profile likelihood 95% confidence interval [0.944, 1.050]). For steelhead trout passing via the powerhouse 2, corner collector the estimated survival was 1.028 (SE = 0.020, profile likelihood 95% confidence interval [0.985, 1.066]). Steelhead trout dam survival through Bonneville Dam was estimated to be 0.998 (SE = 0.014, 95% profile likelihood confidence interval [0.973, 1.027]) and project survival was estimated to be 0.904 (SE = 0.015, profile likelihood confidence interval [0.876, 0.933]).

Subyearling Chinook salmon

Paired Release-recapture Model

Ice and trash sluiceway

We evaluated the survival of subyearling Chinook salmon released into the ice and trash sluiceway from 21 June to 22 July at Bonneville Dam's powerhouse 1. The control group for this evaluation was released in the tailrace below the outfall of the powerhouse 2 juvenile bypass outfall. The estimated survival of subyearling Chinook salmon released into the ice and trash sluiceway ranged from 0.67 to 1.11 during 2004. The average survival was estimated to be 0.925 (SE = 0.019, 95% confidence interval [0.887, 0.962]).

Since there were two dam operations implemented during the summer migration, we also evaluated the survival of subyearling Chinook salmon released into the ice and trash sluiceway during both spill operations. The two spill operations were, 24 h spill with 56 kcfs during the day (0400 to 2200 hrs) and night spill until the total dissolved gas cap of 125% is reached in the tailrace of the dam (56 kcfs day/TDG night) and spill operations of 23 kcfs for 24 h (23 kcfs). The average survival of subyearling Chinook salmon through the ice and trash sluiceway during the 56 kcfs day/TDG night spill operations was estimated to be 0.916 (SE = 0.025, 95% confidence interval [0.862, 0.969]). For subyearling Chinook salmon passing via the ice and trash sluiceway during the 23 kcfs spill operations, the average survival was estimated to be 0.934 (SE = 0.028, 95% confidence interval [0.875, 0.994]). The average survival of subyearling Chinook salmon during 56 kcfs day/TDG night spill operations was not significantly different than survival during 23 kcfs spill operations (two-tailed t-test, P = 0.6234, β =0.077).

Spillway Flow Deflectors

7-ft spillbay flow deflectors during two spill operations

The point estimates of survival of subyearling Chinook salmon passing via spillbays with deflectors located 7 feet above mean sea level at Bonneville Dam spillway during 56 kcfs day and total dissolved gas cap night spill operations ranged from 0.832 to 1.055 ($\bar{X} = 0.920$; $SE = 0.010$; $95\% \, CI = [0.899, 0.941]$). The estimated survival of subyearling Chinook salmon passing via spillbays with 7-ft deflectors during 23 kcfs spill operations ranged from 0.583 to 1.000 ($\bar{X} = 0.822$; $SE = 0.033$; $95\% \, CI = [0.758, 0.886]$).

14-ft spillbay deflectors during two spill operations

The point estimates of survival of subyearling Chinook salmon passing via spillbays with deflectors located 14 feet above mean sea level at Bonneville Dam spillway during 56 kcfs day and total dissolved gas cap night spill operations ranged from 0.552 to 1.066 ($\bar{X} = 0.803$; $SE = 0.026$; $95\% \, CI = [0.749, 0.857]$). The estimated survival of subyearling Chinook salmon passing via spillbays with 14-ft deflectors during 23 kcfs spill operations ranged from 0.553 to 0.913 ($\bar{X} = 0.741$; $SE = 0.027$; $95\% \, CI = [0.683, 0.799]$).

Route-specific Survival Model

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, we generated maximum likelihood estimates of the route-specific passage and survival probabilities for subyearling Chinook salmon through Bonneville Dam during two spill operations from 20 June to 22 July. The two spill operations were, 56 kcfs during the day (0400 to 2200 hrs) and night spill until the total dissolved gas cap of 125% is reached in the tailrace (56 kcfs day/TDG night) and a spill volume of 23 kcfs for 24 h (23 kcfs).

56 kcfs day/TDG night spill operations

During the 56 kcfs day/TDG night spill operations, the survival of subyearling Chinook salmon through the Bonneville Dam spillway was estimated to be 0.877 (SE = 0.013 profile likelihood 95% confidence interval [0.848, 0.902]). For subyearling Chinook salmon passing via powerhouse 1, the estimated survival was 0.827 (SE = 0.061, profile likelihood 95% confidence interval [0.694, 0.937]) and for subyearling Chinook salmon passing via powerhouse 2 turbines, the estimated survival was 0.824 (SE = 0.020, profile likelihood 95% confidence interval [0.782, 0.864]). For subyearling Chinook salmon passing via the powerhouse 2 JBS the estimated survival was 0.927 (SE = 0.027, profile likelihood 95% confidence interval [0.863, 0.976]). For subyearling Chinook salmon passing via the powerhouse 2 corner collector the estimated survival was 0.981 (SE = 0.013, profile likelihood 95% confidence interval [0.951, 1.005]). Subyearling Chinook salmon dam survival through Bonneville Dam was estimated to be 0.891 (SE = 0.010, profile likelihood 95% confidence interval [0.871, 0.910) and project survival was estimated to be 0.768 (SE = 0.010, profile likelihood 95% confidence interval [0.747, 0.788].

56 kcfs day spill operations

During the 56 kcfs day spill operations, the survival of subyearling Chinook salmon through the Bonneville Dam spillway was estimated to be 0.851 (SE = 0.016 profile likelihood 95% confidence interval [0.819, 0.883]). For subyearling Chinook salmon passing via powerhouse 1, the estimated survival was 0.845 (SE = 0.059, profile likelihood 95% confidence interval [0.715, 0.943]) and for subyearling Chinook salmon passing via powerhouse 2 turbines, the estimated survival was 0.834 (SE = 0.021, profile likelihood 95% confidence interval [0.792, 0.873]). For subyearling Chinook salmon passing via the powerhouse 2 JBS the estimated survival was 0.900 (SE = 0.031, profile likelihood 95% confidence interval [0.833, 0.955]). For subyearling Chinook salmon passing via the powerhouse 2 corner collector the estimated survival was 0.966 (SE = 0.014, profile likelihood 95% confidence interval [0.937, 0.991]). Subyearling Chinook salmon dam survival through Bonneville Dam was estimated to be 0.882 (SE = 0.011, 95% confidence interval [0.861, 0.903) and project survival was estimated to be 0.763 (SE = 0.012, profile likelihood 95% confidence interval [0.741, 0.785]).

Total dissolved gas night spill operations

During the TDG night spill operations, the survival of subyearling Chinook salmon through the Bonneville Dam spillway was estimated to be 0.913 (SE = 0.021 profile likelihood 95% confidence interval [0.869, 0.953]). For subyearling Chinook salmon passing via powerhouse 1, the estimated survival was 0.519 (SE = 0.266, profile likelihood 95% confidence interval [0.109, 0.947]) and for subyearling Chinook salmon passing via powerhouse 2 turbines, the estimated survival was 0.696 (SE = 0.062, profile likelihood 95% confidence interval [0.570, 0.810]). For subyearling Chinook salmon passing via the powerhouse 2 JBS the estimated survival was 0.998 (SE = 0.048, profile likelihood 95% confidence interval [0.868, 1.060]). For subyearling Chinook salmon passing via the powerhouse 2 corner collector the estimated survival was 1.009 (SE = 0.041, profile likelihood 95% confidence interval [0.898, 1.063]). Subyearling Chinook salmon dam survival through Bonneville Dam was estimated to be 0.887 (SE = 0.022, profile likelihood 95% confidence interval [0.847, 0.925) and project survival was estimated to be 0.757 (SE = 0.023, profile likelihood 95% confidence interval [0.715, 0.797]).

23 kcfs 24 h spill operations

During the 23 kcfs spill operations, the survival of subyearling Chinook salmon through the Bonneville Dam spillway was estimated to be 0.744 (SE = 0.022, profile likelihood 95% confidence interval [0.700, 0.786]). For subyearling Chinook salmon passing via powerhouse 1, the estimated survival was 0.829 (SE = 0.030, profile likelihood 95% confidence interval [0.767, 0.884]) and for subyearling Chinook salmon passing via powerhouse 2 turbines, the estimated survival was 0.833 (SE = 0.014, profile likelihood 95% confidence interval [0.805, 0.860]). For subyearling Chinook salmon passing via the powerhouse 2 JBS, the estimated survival was 0.958 (SE = 0.019, profile likelihood 95% confidence interval [0.918, 0.991]). For subyearling Chinook salmon passing via the powerhouse 2 corner collector, the estimated survival was 0.954 (SE = 0.013, profile likelihood 95% confidence interval [0.926, 0.978]). Subyearling Chinook salmon survival through Bonneville Dam was estimated to be 0.858 (SE = 0.010, profile likelihood 95% confidence interval [0.840, 0.876]) and project survival was estimated to be 0.736 (SE = 0.010, profile likelihood 95% confidence interval [0.717, 0.754]).

23 kcfs day spill operations

For subyearling Chinook salmon passing during day (0400 to 2200 hrs) 23 kcfs spill operations, survival through the Bonneville Dam spillway was estimated to be 0.725 (SE = 0.025, profile likelihood 95% confidence interval [0.675, 0.773]). For subyearling Chinook salmon passing via powerhouse 1, the estimated survival was 0.826 (SE = 0.033, profile likelihood 95% confidence interval [0.758, 0.886]) and for subyearling Chinook salmon passing via powerhouse 2 turbines, the estimated survival was 0.820 (SE = 0.017, profile likelihood 95% confidence interval [0.785, 0.853]). For subyearling Chinook salmon passing via the powerhouse 2 JBS, the estimated survival was 0.957 (SE = 0.024, profile likelihood 95% confidence interval [0.906, 0.999]) and for passing via the corner collector the estimated survival was 0.955 (SE = 0.015, profile likelihood 95% confidence interval [0.926, 0.983]). Subyearling Chinook salmon dam survival through Bonneville Dam was estimated to be 0.852 (SE = 0.012, profile likelihood 95% confidence interval [0.831, 0.875]) and project survival was estimated to be 0.731 (SE = 0.012, profile likelihood 95% confidence interval [0.710, 0.753]).

23 kcfs night spill operations

For subyearling Chinook salmon passing during the night (2200 to 0400 hrs) 23 kcfs spill operations, survival through the Bonneville Dam spillway was estimated to be 0.830 (SE = 0.045, profile likelihood 95% confidence interval [0.735, 0.909]). For subyearling Chinook salmon passing via powerhouse 1, the estimated survival was 0.863 (SE = 0.077, profile likelihood 95% confidence interval [0.687, 0.982]) and for subyearling Chinook salmon passing via powerhouse 2 turbines, the estimated survival was 0.864 (SE = 0.023, profile likelihood 95%

confidence interval [0.818, 0.907]). For subyearling Chinook salmon passing via the powerhouse 2 JBS, the estimated survival was 0.960 (SE = 0.030, profile likelihood 95% confidence interval [0.891, 1.010]) and for passing via the corner collector the estimated survival was 0.959 (SE = 0.045, profile likelihood 95% confidence interval [0.847, 1.025]). Subyearling Chinook salmon dam survival through Bonneville Dam was estimated to be 0.881 (SE = 0.019, profile likelihood 95% confidence interval [0.847, 0.914]) and project survival was estimated to be 0.755 (SE = 0.020, profile likelihood 95% confidence interval [0.719, 0.791]).

Comparison of estimators generated during 56 kcfs day/TDG night and 23 kcfs spill operations

The estimated survival probabilities for subyearling Chinook salmon passing via the powerhouse 1, powerhouse 2 turbines, and the powerhouse 2 corner collector and JBS were not found to be significantly different between the two spill operations. However, the estimated survival of subyearling Chinook salmon passing via the spillway was significantly different for fish passing during the 56 kcfs day/TDG night spill operations and the 23 kcfs spill operations. The estimated dam survival for fish passing during the two spill operations was also found to be significantly different.

Executive Summary Table 1. The estimated survival probabilities and 95% confidence intervals of radio-tagged, yearling Chinook and subyearling Chinook salmon, and steelhead trout released directly into the Minimum Gap Runner turbine unit (MGR) and ice and trash sluiceway at Bonneville Dam's powerhouse 1 and in the Bonneville Dam tailrace. Also presented are the estimated survival probabilities of fish passing via spillbays with either 7-ft or 14-ft spillbay deflectors at Bonneville Dam spillway estimated from the post-hoc pairing of release groups formulated from fish released at The Dalles Dam (treatment) and Bonneville Dam tailrace (control). Spring spill operations were 56 kcfs during the day and total dissolved gas cap at night (56 kcfs/TDG). Two spill operations were examined in the summer, 56 kcfs/TDG and 23 kcfs for 24 hour.

Paired release-recapture model						
Spill Operations	MGR, downstream control		MGR, front roll control		Ice and trash sluiceway	
	S	95% CI	S	95% CI	S	95% CI
			Yearling Chinook Salmon			
56 kcfs /TDG	0.944	0.913, 0.976	0.956	0.924, 0.988	0.947	0.908, 0.986
			Steelhead trout			
56 kcfs /TDG	0.926	0.861, 0.992	0.952	0.900, 1.003	0.935	0.884, 0.985
			Subyearling Chinook salmon			
56 kcfs /TDG [A]					0.916	0.862, 0.969
23 kcfs 24 h [A]					0.934	0.875, 0.994

Paired release-recapture model				
Spill Operations	7-ft Spillbay		14-ft Spillbay	
	S	95% CI	S	95% CI
		Yearling Chinook Salmon		
56 kcfs Day	0.937	0.898, 0.976	0.773	0.667, 0.879
TDG Night	0.943	0.886, 1.000	0.946	0.907, 0.985
		Steelhead trout		
56 kcfs Day	0.927	0.818, 1.036	0.850	0.650, 1.050
TDG Night	1.013	0.979, 1.047	1.012	0.980, 1.044
		Subyearling Chinook salmon		
56 kcfs /TDG	0.920	0.899, 0.941	0.803	0.749, 0.857
23 kcfs 24 h	0.822	0.751, 0.893	0.741	0.683, 0.799

[A] - No releases were made into the MGR unit in the summer.

Executive Summary Table 2. The route-specific survival probabilities and associated profile likelihood 95% confidence intervals for radio-tagged, yearling Chinook salmon, steelhead trout, and subyearling Chinook salmon passing through Bonneville Dam. Fish were released in The Dalles Dam and Bonneville Dam tailraces. Spring spill operations were 56 kcfs during the day and night spill until the total dissolved gas cap (TDG) of 125% was reached in the tailrace (56 kcfs/TDG). Two spill operations were examined in the summer, 56 kcfs/TDG and 23 kcfs for 24 hour from 20 June to 22 July.

Route-Specific Survival Model						
Spill Operations	Yearling Chinook		Steelhead Trout		Subyearling Chinook	
	S	95% CI	S	95% CI	S	95% CI
			Spillway			
56 kcfs Day	0.861	0.831, 0.889	0.891	0.840, 0.936	0.851	0.819, 0.883
TDG Night	0.964	0.932, 0.996	1.020	0.992, 1.050	0.913	0.869, 0.953
56 kcfs/TDG	0.910	0.888, 0.931	0.979	0.956, 1.002	0.877	0.848, 0.902
23 kcfs Day	NA	NA	NA	NA	0.725	0.675, 0.773
23 kcfs Night	NA	NA	NA	NA	0.830	0.735, 0.909
23 kcfs 24 h	NA	NA	NA	NA	0.744	0.700, 0.786
			Powerhouse 1			
56 kcfs Day	0.894	0.853, 0.930	0.966	0.922, 1.003	0.845	0.715, 0.943
TDG Night	0.903	0.768, 0.999	0.940	0.850, 1.009	0.519	0.109, 0.947
56 kcfs/TDG	0.913	0.872, 0.949	0.965	0.926, 0.999	0.827	0.694, 0.937
23 kcfs Day	NA	NA	NA	NA	0.826	0.758, 0.886
23 kcfs Night	NA	NA	NA	NA	0.863	0.687, 0.982
23 kcfs 24 h	NA	NA	NA	NA	0.829	0.767, 0.884
			Powerhouse 2			
56 kcfs Day	0.925	0.902, 0.948	0.863	0.804, 0.915	0.834	0.792, 0.873
TDG Night	0.981	0.937, 1.020	0.917	0.857, 0.970	0.696	0.570, 0.810
56 kcfs/TDG	0.951	0.929, 0.972	0.889	0.848, 0.927	0.824	0.782, 0.864
23 kcfs Day	NA	NA	NA	NA	0.820	0.785, 0.853
23 kcfs Night	NA	NA	NA	NA	0.864	0.818, 0.907
23 kcfs 24 h	NA	NA	NA	NA	0.833	0.805, 0.860

Executive Summary Table 2 (continued). The route-specific survival probabilities and associated profile likelihood 95% confidence intervals for radio-tagged, yearling Chinook salmon, steelhead trout, and subyearling Chinook salmon passing through Bonneville Dam. Fish were released in The Dalles Dam and Bonneville Dam tailraces. Spring spill operations were 56 kcfs during the day and night spill until the total dissolved gas cap (TDG) of 125% was reached in the tailrace (56 kcfs/TDG). Two spill operations were examined in the summer, 56 kcfs/TDG and 23 kcfs for 24 hour from 20 June to 22 July.

Route-specific Survival Model						
Spill Operations	Yearling Chinook		Steelhead Trout		Subyearling Chinook	
	S	95% CI	S	95% CI	S	95% CI
			Juvenile Bypass System			
56 kcfs Day	0.938	0.906, 0.966	0.904	0.837, 0.960	0.900	0.833, 0.955
TDG Night	1.013	0.964, 1.053	1.003	0.944, 1.050	0.998	0.868, 1.060
56 kcfs/TDG	0.970	0.943, 0.994	0.951	0.907, 0.989	0.927	0.863, 0.976
23 kcfs Day	NA	NA	NA	NA	0.957	0.906, 0.999
23 kcfs Night	NA	NA	NA	NA	0.960	0.891, 1.010
23 kcfs 24 h	NA	NA	NA	NA	0.958	0.918, 0.991
			Corner Collector			
56 kcfs Day	0.993	0.978, 1.008	1.018	0.9998, 1.039	0.966	0.937, 0.991
TDG Night	1.028	0.980, 1.065	1.028	0.985, 1.066	1.009	0.898, 1.063
56 kcfs/TDG	1.016	0.999, 1.032	1.030	1.014, 1.047	0.981	0.951, 1.005
23 kcfs Day	NA	NA	NA	NA	0.955	0.926, 0.983
23 kcfs Night	NA	NA	NA	NA	0.959	0.847, 1.025
23 kcfs 24 h	NA	NA	NA	NA	0.954	0.926, 0.978
			Dam			
56 kcfs Day	0.925	0.912, 0.941	0.980	0.962, 1.001	0.882	0.861, 0.903
TDG Night	0.979	0.953, 1.007	0.998	0.973, 1.027	0.887	0.847, 0.925
56 kcfs/TDG	0.951	0.937, 0.966	0.991	0.975, 1.008	0.891	0.871, 0.910
23 kcfs Day	NA	NA	NA	NA	0.852	0.831, 0.875
23 kcfs Night	NA	NA	NA	NA	0.881	0.847, 0.914
23 kcfs 24 h	NA	NA	NA	NA	0.858	0.840, 0.876
			Project			
56 kcfs Day	0.860	0.844, 0.876	0.888	0.868, 0.909	0.763	0.741, 0.785
TDG Night	0.908	0.881, 0.937	0.904	0.876, 0.933	0.757	0.715, 0.797
56 kcfs/TDG	0.883	0.868, 0.898	0.897	0.881, 0.915	0.768	0.747, 0.788
23 kcfs Day	NA	NA	NA	NA	0.731	0.710, 0.753
23 kcfs Night	NA	NA	NA	NA	0.755	0.719, 0.791
23 kcfs 24 h	NA	NA	NA	NA	0.736	0.717, 0.754

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). Giorgi et al. (2002) noted that survival of salmonid migrants is variable among projects and across species. 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 these research studies that examine migrant salmonid behavior and survival at dams in the Columbia River Basin, management actions are being implemented to improve the survival of juvenile salmonid migrants.

Improved fish marking techniques and development and acceptance of statistical methodologies (see Lebreton et al. 1992) have led scientists to reevaluate past techniques used to assess survival of migrant salmonids in the Columbia River Basin. The development of the passive integrated transponder (PIT) tag, allowed for the unique identification of fish (Prentice et al. 1990), and recent technological advancements in radio-telemetry equipment have decreased the size and increased the life of transmitters allowing for use with juvenile fish passage behavior and survival studies (Skalski et al. 2001, 2002; Counihan et al. 2001, 2002). Consequently, PIT-tag recoveries, radio telemetry capture histories, and release-recapture models (Burnham et al. 1987; Smith et al. 1996) have been used to assess the survival of migrant salmonid smolts through various reaches of the Columbia and Snake Rivers (Muir et al. 1995; Skalski et al. 1998; Smith et al. 1998; Dawley et al. 1998; Skalski et al. 2001, 2002). Results from studies examining simultaneous releases of PIT-tagged and radio-tagged fish in the Snake River and mid Columbia River suggest similar trends in survival between the two groups (Hockersmith et al. 2003). Further, concurrent releases of radio- and PIT-tagged yearling Chinook salmon at The Dalles Dam also indicate that estimates from the two tagging techniques provide comparable estimates (Counihan et al. 2001). Estimates of survival generated from radio-tagged subyearling Chinook salmon were less comparable. However, the large confidence intervals associated with both PIT- and radio-tagged fish were not conducive to a meaningful evaluation of the comparability of the estimates.

Although the two techniques have been shown to produce similar results, there are important considerations with each method. The use of the PIT-tag technique relies on the availability of PIT-tag detectors at hydroelectric dams, which are not present at all locations in the Columbia River Basin (e.g. The Dalles Dam). The absence of PIT-tag detectors at certain dams and areas below Bonneville Dam has precluded or confounded survival estimation in some specific reaches of the Columbia River and limited the spatial scale over which survival estimates can be made. Further, the low detection probabilities associated with this technique requires that large numbers of fish be handled (although minimally) to obtain desired levels of precision in survival estimates (Skalski 1999b). Detection rates of marked fish affect the sample size required for a given level of precision and thus, the reliability of survival estimates (Skalski 1992). The radio-telemetry technique offers high detection rates, observed in migrant salmonid studies at specific project sites and in-river sites in the lower Columbia River, suggesting that the numbers of fish necessary to generate survival estimates with similar or greater precision could be reduced using radio-tagged fish. Further, the flexibility of a radio-telemetry system deployment at hydroelectric projects and in-river locations can increase the geographic area over which estimates are generated (e.g. areas below Bonneville Dam).

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. 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 through tailrace areas, 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 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.

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 during 2000 were made above and below Bonneville Dam 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 paired release-recapture models of Burnham et al. (1987). The original objectives for the 2001 survival evaluation at Bonneville Dam were altered because of the low water conditions present during 2001. The objectives were to provide estimates of survival for fish passing via all routes at Bonneville Dam and to provide estimates of survival of fish passing through the JBS (JBS) at powerhouse 2.

The survival of yearling Chinook salmon passing via all routes at Bonneville Dam (based on detections at Bonneville Dam of fish released near Hood River, OR and in the tailrace of Bonneville Dam) ranged from 0.85 to 1.05. The average dam survival at Bonneville Dam for yearling Chinook salmon was estimated to be 0.937 (SE = 0.014). Dam 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 dam 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 dam survival, 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 dam 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 dam survival of subyearling Chinook salmon ranged from 0.73 to 1.08. The estimated average dam survival was 0.902 (SE = 0.036). The average dam 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 dam 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 survival through the spillway and the first and second powerhouses.

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 downstream migration channel 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 passing via powerhouse 2 the estimated survival was 0.993 (SE = 0.036, profile likelihood 95% confidence interval [0.964, 1.021]). Yearling Chinook salmon dam survival through Bonneville Dam was estimated to be 0.977 (SE = 0.019).

During 2004, the USGS evaluated the survival of radio-tagged yearling 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. Using releases of radio-tagged yearling and subyearling Chinook salmon and steelhead trout released as part of the survival evaluation at The Dalles Dam, and releases made into the tailrace of Bonneville Dam (below the powerhouse 2 JBS outfall), we were able to evaluate survival through the spillway, powerhouses 1 and 2, the corner collector and the JBS at powerhouse 2. These fish were also used in a post-hoc paired release analysis to estimate survival of fish passing the spillway via spillbays with 7-ft or 14-ft flow deflectors.

Methods

Study Area

The study area (zone of inference, see: Peven et al. 2005) 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. All detection arrays spanned the breadth of the river channel. The telemetry system at Bonneville Dam was set up so that passage route could be determined (Evans et al. 2003).

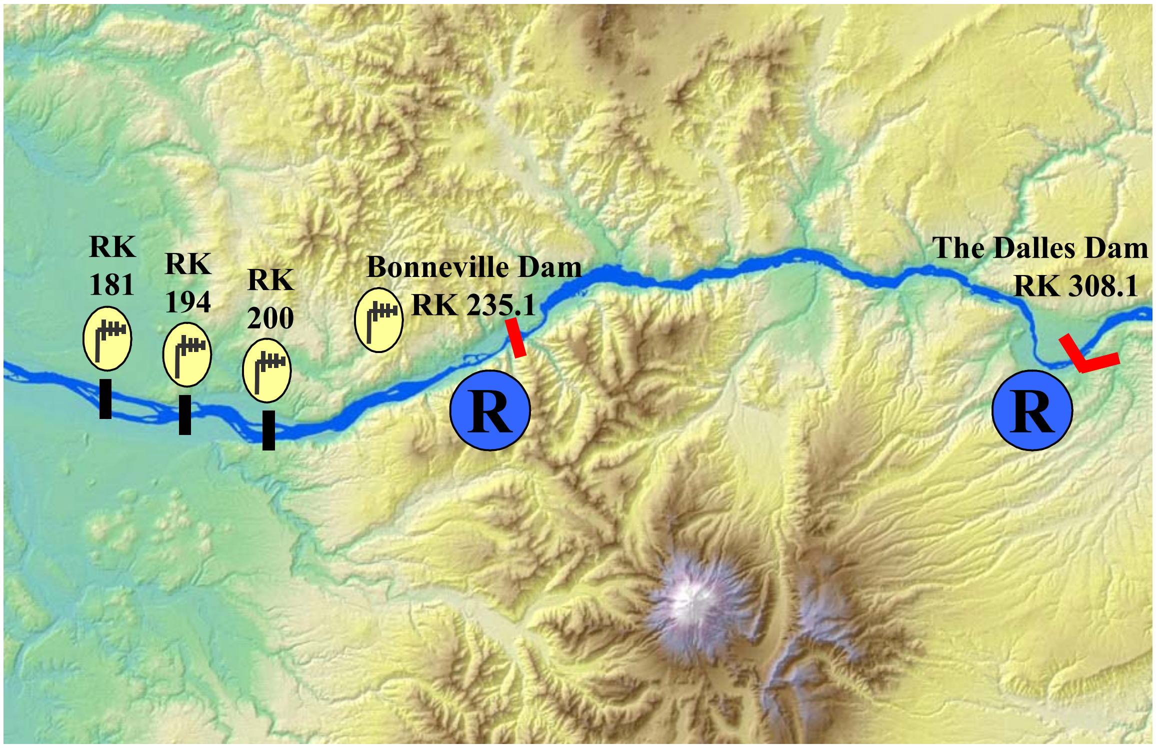


Figure 1. Release and detection locations for Bonneville Dam survival evaluation during 2004. R = release locations, yellow ovals are locations of radio telemetry antenna arrays.

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. At both powerhouses, juvenile fish are guided away from turbines by submersible traveling screens into a fish collection channel. At powerhouse 2, fish enter the JBS, a 1.22 m diameter high-density polyethylene plastic pipe, and are transported downriver 3,530 m to an outfall where fish and water plunge approximately 4 m into the main river channel. At powerhouse 1, the collection channel flows through a monitoring facility within the powerhouse, and then fish and water plunge into the tailrace. Also at powerhouse 2, fish can enter the corner collector channel, located on the southeastern corner of powerhouse 2, where a moveable gate can be raised to allow about 5,000 cfs of water to spill through it. The corner collector channel is a 4.57 m wide by 6.1 m deep concrete trough, and stretches 914.4 m to beyond the western tip of Cascade Island, where fish and water are released into a 15.2 m plunge pool.

System antenna configuration

We used four types of data acquisition equipment to monitor underwater and aerial antennas at Bonneville Dam in 2004. Ninety-seven aerial antennas, 35 stripped coax antennas, and 124 underwater dipole antennas were linked to 34 Lotek SRX-400 receivers (SRX; Lotek

Engineering, Newmarket, Ontario), five 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, DSPs, 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 and survival 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 located in the forebay to detect fish within 100 m of the dam, in the tailrace to confirm fish passage for fish passage efficiency studies, and in the corner collector flume to detect fish passing through the corner collector. 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.

Three MITAS systems were incorporated at B1, B2, and the spillway (Figure 3). The MITAS at B1 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. In addition, two stripped coax antennas and one aerial antenna were placed at the outfall of the sluiceway to confirm sluiceway passage.

The MITAS at B2 was composed of 61 underwater antennas. 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 to the corner collector.

The spillway MITAS consisted of 72 underwater antennas attached to the forebay pier noses. Each spillbay had four antennas; two antennas on each piernose 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.

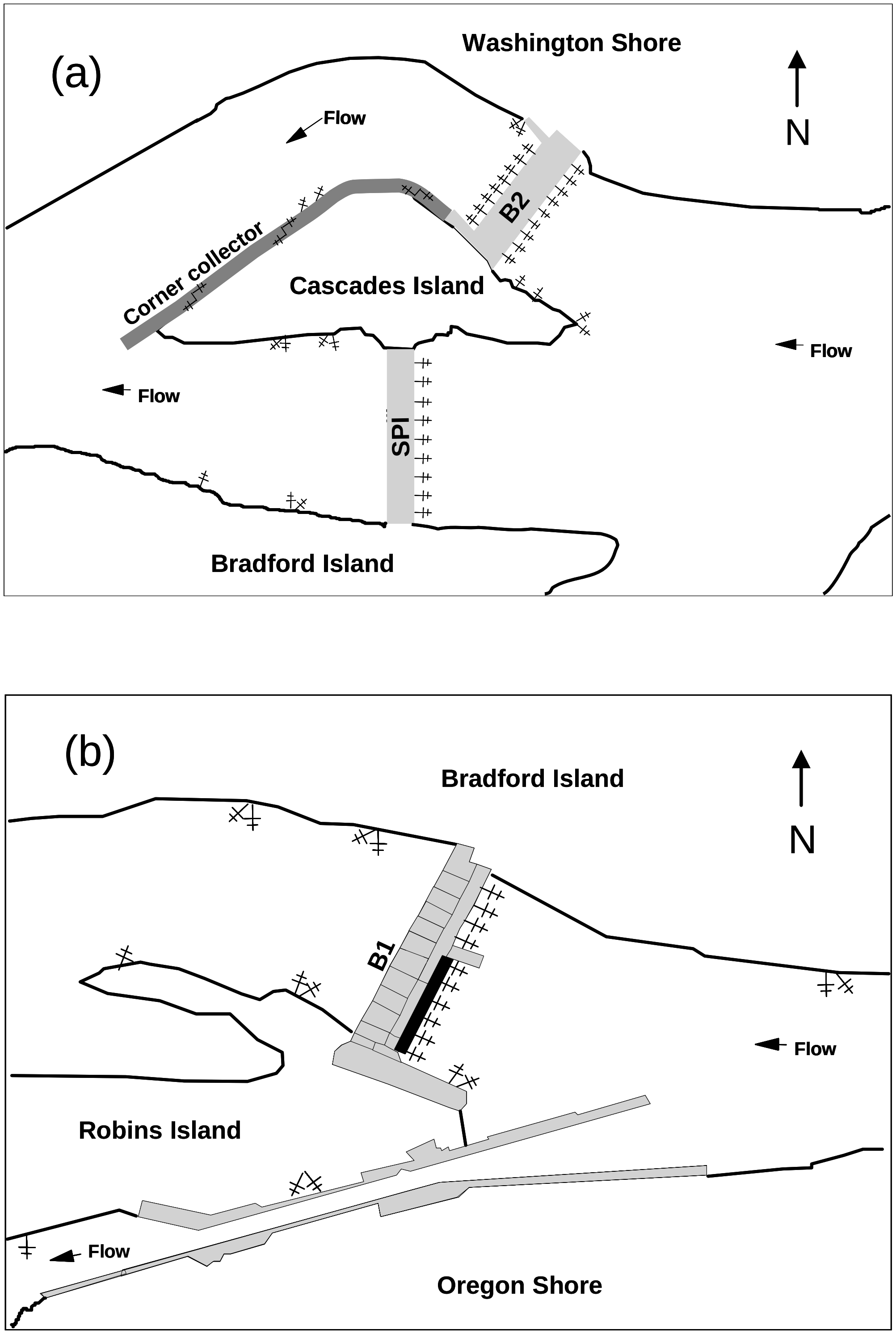


Figure 2. Plan view of aerial antenna coverage during spring 2004 at Bonneville Dam's: (a) second powerhouse (B2) and spillway (SPI); and (b) first powerhouse (B1).

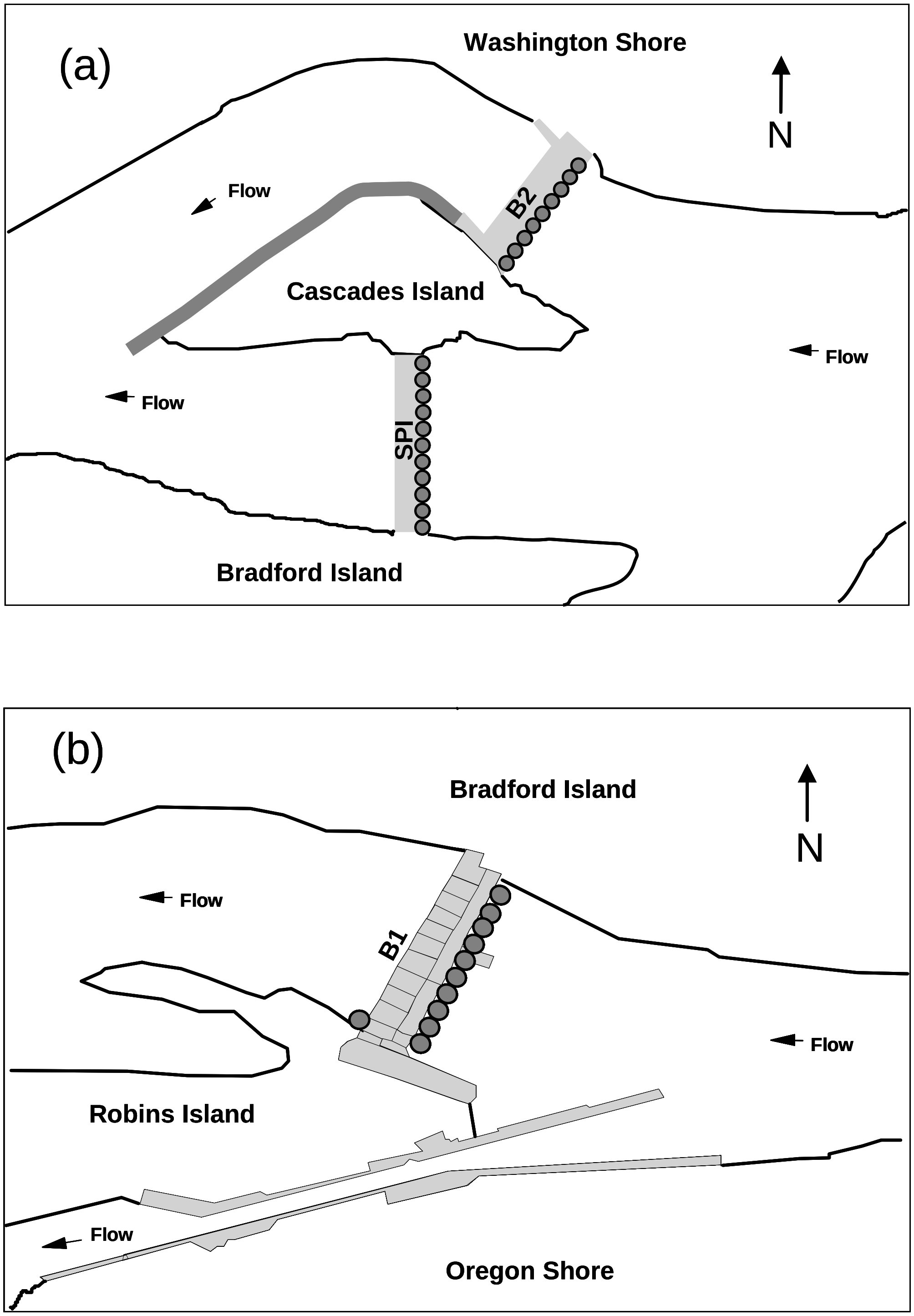


Figure 3. Plan view of underwater antenna coverage during spring 2004 at Bonneville Dam's: (a) second powerhouse (B2) and spillway (SPI); and (b) first powerhouse (B1).

Radio Transmitters

The radio telemetry tags used in this study were pulse-coded transmitters (tags) manufactured by Lotek Engineering, Inc, (Newmarket, Ont.). Transmitters operated at frequencies between 150.280 and 150.800 MHz and used a pulse-coding scheme with 212 unique codes per frequency that allow each individual fish to be recognized. A radio signal was emitted every 2 seconds. 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 1.4 g in air (Lotek Wireless model 3KM). Expected battery life was 8 days for the 3KM tags. Transmitters implanted in subyearling Chinook salmon were 6.3 mm wide x 14.5 mm length x 4.5 mm high and weigh 0.85 g in air (Lotek Model NTC 3-1, expected battery life was 8 days).

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 36 h later. 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 6.5% of a fish weight in air. For yearling Chinook salmon and steelhead trout implanted with a Lotek Wireless model 3KM tag (weight = 1.4 g in air) the minimum weight for tagging was 21.5 g, and for subyearling Chinook salmon implanted with a Lotek Model NTC 3-1, "nanotag" (weight = 0.85 g in air) the minimum weight was 13 g. Transmitters were gastrically implanted using the methods of Martinelli et al. (1998). Fish were held 18 to 28 h after tagging to check for spit tags and mortalities before being released. Fork lengths and weights of the various release groups and number of spit tags and mortalities by release are presented in Appendix 1.

To evaluate survival through the MGR and the ice and trash sluiceway, approximately 25 radio-tagged yearling Chinook salmon and steelhead trout (per release) were released at each location (MGR, MGR front roll tailrace, and ice and trash sluiceway) during 16 releases and 19 subyearling Chinook salmon (per release) into the ice and trash sluiceway during 32 releases (see Appendix 1 for the exact times, dates, and numbers of fish released during the study). Control fish for the MGR evaluation were released from the tailrace deck from a tank connected to a 10 cm diameter flexible tube that extended from the release tank to a barge anchored at the downstream end of the front roll created by the outflow from the turbine. The flexible tube was connected to an aluminum pipe on the barge that terminated 10 ft below the water surface. Water pumped into the tube created a siphon that actively transported fish to the barge where they were discharged into the river channel at the same depth that fish exited the turbine.

To evaluate the route-specific survival and dam survival at Bonneville Dam, radio-tagged fish were released from The Dalles Dam. Radio-tagged fish were released in the The Dalles Dam tailrace from a boat approximately 550 m downriver of the dam beneath the I-197 bridge as well as through and below the ice and trash sluiceway. Releases into The Dalles Dam tailrace occurred twice a day at approximately 1300 and 0100 hrs and releases at The Dalles Dam sluiceway occurred once a day at 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 for exact dates, times and number of fish per release). 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 MGR and ice and trash sluiceway. Bonneville Dam tailrace releases occurred twice a day at approximately 1300 and 0100 hrs. 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 relation between travel time and river discharge was developed by evaluating travel time and discharge data collected during previous studies. For the 2004 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, we also assigned releases equally to spill block treatments at Bonneville Dam. Four-day spill blocks were designed by randomly assigning a 2-day continuous block of 24 h spill with 56 kcfs during the day (0400 to 2200 hrs) and night spill (2200 to 0400 hrs) until the 125% total dissolved gas cap was reached in the tailrace alternating with 23 kcfs for 24 hr for 2-days. Treatment spill conditions were initiated at the dam prior to the start of releases and continued until after the last fish passed Bonneville Dam.

Converting radio signals into detection histories

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

1. Records composed of invalid channel and code combinations, typically a result of erroneous radio transmissions (noise) that overlap with the radio frequencies that we are monitoring.
2. Records logged before a fish’s release.

3. Records below an empirically determined signal strength threshold for each aerial and underwater array 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 5^{th} or greater than the 95^{th} percentiles of past data from a similar flow year, 2) forebay, tailrace, and exit residence times exceeded the 95^{th} 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. Once individual fish histories were verified the capture histories were 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.

Statistical methods

Paired release-recapture model

We used the paired release-recapture models of Burnham et al. (1987) to estimate the survival of yearling Chinook salmon and steelhead trout through an MGR turbine unit and to estimate the survival of yearling and subyearling Chinook salmon through the ice and trash sluiceway at Bonneville Dam's powerhouse 1. The paired release-recapture model was also used to estimate the survival of fish passing via spillbays equipped with flow deflectors located at 7 feet above mean sea level and at 14 feet above mean sea level at Bonneville Dam during the different dam operations. Paired release groups for the spillbay analysis were formed post-hoc from radio-tagged fish released at The Dalles Dam and passing Bonneville Dam spillway (treatment groups) with fish released below the powerhouse 2 JBS outfall (control groups). Spillbays with deflectors at 7 feet above mean sea level were located on the north (bays 1-3) and south (bays 16-18) end of the spillway and spillbays with deflectors at 14 feet above sea level were located in the middle, bays 4-15.

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 1999a). The validity of some of the assumptions listed below can be evaluated using statistical tests and others can be met through careful consideration of fish collection, holding, tagging, and detection techniques. The assumptions are 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.

To evaluate assumption A1, we monitor the timing and lengths of run-of-river fish sampled at the John Day Dam and Bonneville Dam 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. 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. Another factor that may have implications pertaining to these assumptions is the fact that radio-tags have a limited and varied battery life. Therefore, the tag failure rate will affect detection probabilities, depending on travel time and amount of time tags are operational prior to release. To address the probability of tag failure at detection arrays, we performed a tag life study (Appendix 2) to determine the potential for bias in survival estimates caused by tag failure. The assumption A7 is evaluated by releasing dead radio-tagged fish throughout the season with live radio-tagged fish.

Survival was estimated from paired releases by the expression:

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

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

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

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 two additional assumptions for valid survival estimation using the paired release-recapture protocol.

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

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

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

		Release	
		R_1	R_2
Day of detections	1		
	2		
	3		
	⋮		
	D		

For each paired-release (R_1 and R_2), a chi-square test of homogeneity was performed at each downstream array. Tests were performed at $\alpha = 0.10$. 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.

We evaluated *t*-tests to compare the estimated survival of subyearling Chinook salmon released into the ice and trash sluiceway at powerhouse 1, Bonneville Dam during both the 23 kcfs 24 h spill and 56 kcfs Day/TDG Night spill operations. The specific hypothesis tested was:

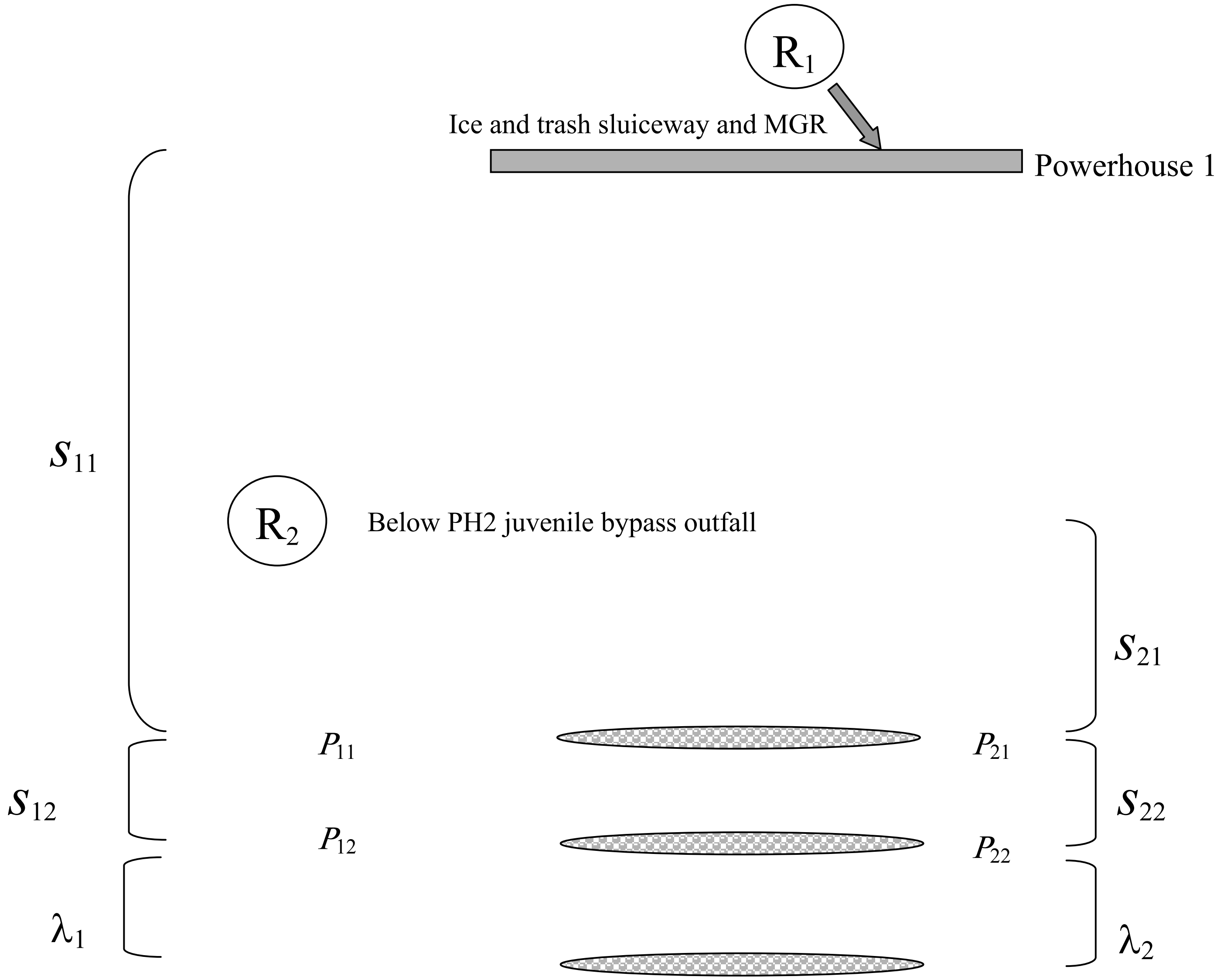
$$H_0 : S_{Ice\ and\ trash\ 24h\ 23\ kcfs} = S_{ice\ and\ trash\ 56\ kcfsDay/TDG\ Night}$$

$$H_A : S_{Ice\ and\ trash\ 24h\ 23\ kcfs} \neq S_{ice\ and\ trash\ 56\ kcfsDay/TDG\ Night}$$

Bartlett’s, Brown-Forsythe, and Levene’s tests for equal variance were evaluated for each comparison and where suggested by the results of these tests, variance weighted *t*-tests were used.

Estimable Parameters

The release and detection schemes used during 2004 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 and MGR: $\hat{S}_{IandTsluice} = \dfrac{\hat{S}_{11}}{\hat{S}_{21}}$

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 turbines primary array detection probability ($q_{B2Turb} = 1 - P_{B2Turb}$); P'_{B2Turb}, the second powerhouse turbines 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 turbines 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:

$$\hat{S}_{DAM} = (1-\hat{E})(1-\hat{P}H2)\ \hat{S}_{PH1} + \hat{E}\,\hat{S}_{SPILL} + (1-\hat{E})(\hat{P}H2)(\hat{B}2CC)\hat{S}_{B2CC} + (1-\hat{E})(\hat{P}H_2)(1-\hat{B}2CC)(1-\hat{B}2JBS)\hat{S}_{B2Turb} + (1-\hat{E})(\hat{P}H_2)(1-\hat{B}2CC)(\hat{B}2JBS)\hat{S}_{B2JBS}$$

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/).

Comparisons of RSSM estimates between treatments

Z-tests were performed to assess the differences of route-specific survival estimates of subyearling Chinook salmon between treatments (i.e. spill operations) for each passage route (John Skalski and Jim Lady, University of Washington, personal communication). The hypotheses tested for subyearling Chinook salmon passing via the powerhouse 1, powerhouse 2 turbines, spillway, powerhouse 2 corner collector and the JBS at powerhouse 2, and through all routes were:

$$H_O : S_{23\ kcfs\ Day/23\ kcfs\ Night} = S_{56\ kcfs\ Day/TDG\ Night}$$

$$H_A : S_{23\ kcfs\ Day/23\ kcfs\ Night} \neq S_{56\ kcfs\ Day/TDG\ Night}$$

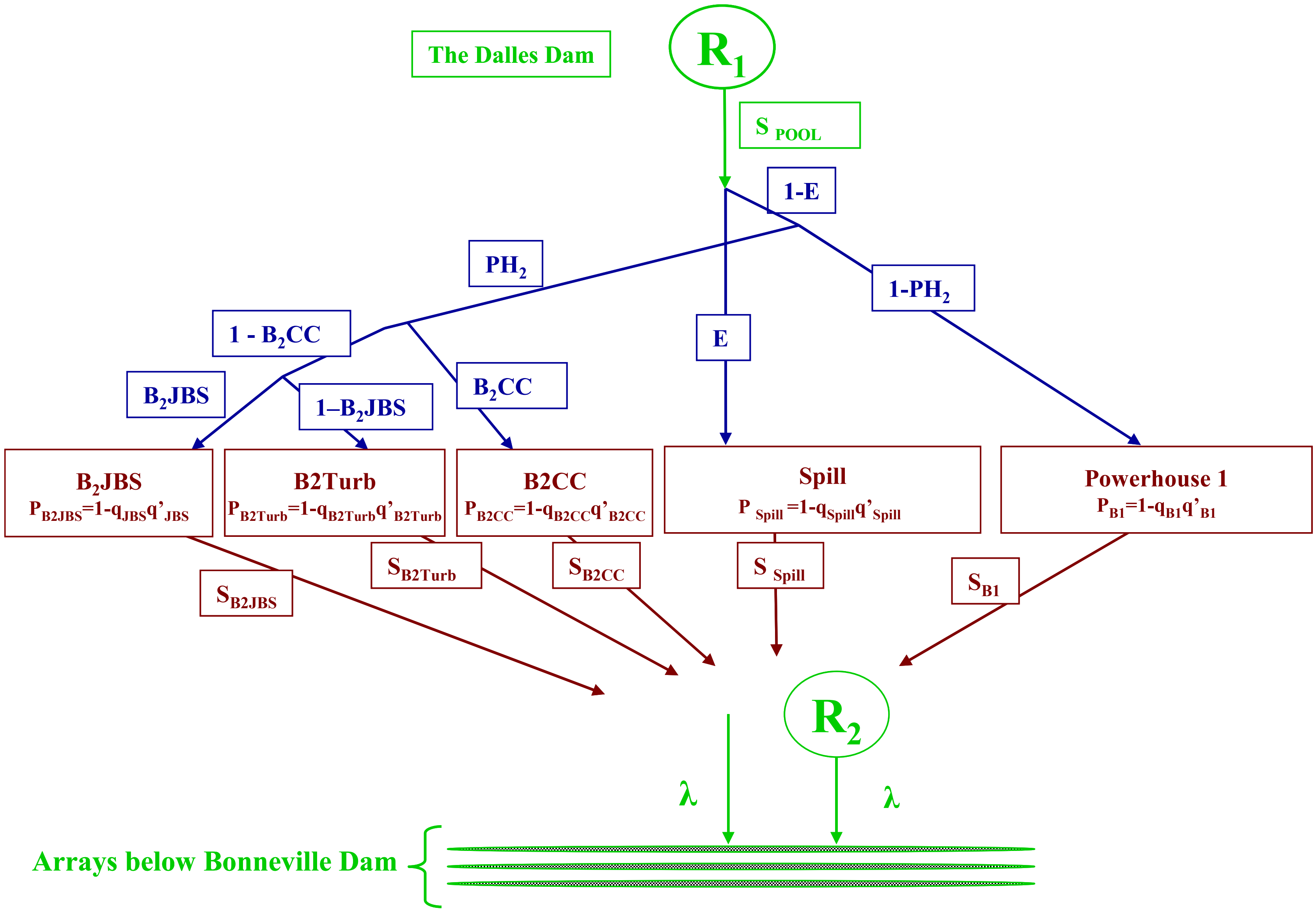


Figure 5. The estimable parameters (see p.49 for definitions) for the route-specific survival model using the proposed release and detection schemes for 2004. Included in the detection scheme is a double radio-telemetry array at Bonneville Dam.

Results

Releases of dead radio-tagged fish

We determined that the standard operating procedure (SOP) for euthanizing fish for planned dead fish releases was not properly implemented. An SOP has been established for the killing and handling of dead fish that requires an overdose of MS-222 for 30 minutes while fish are confined below the water surface with a screen, followed by pithing, prior to release. During the field season there was turnover in the crew that implemented this procedure and the proper steps were not taken to communicate the SOP to all staff thus, the SOP was not consistently implemented. In particular, the screening procedure that prevented fish from gulping air while being subjected to MS-222 was not implemented. Consequently, though several dead fish were detected at the downstream detection arrays, we are unable to determine whether these detections were an artifact of the protocol breach, a result of particular environmental conditions that were more conducive to transporting dead radio-tagged fish past the downstream arrays, or reflect the estimated probability that a dead radio-tagged fish is detected at our downstream arrays. In past years, and for the majority of the release during 2004, dead fish were not detected at the arrays downstream of Bonneville Dam.

As called for in our Quality Assurance Plan, we are implementing corrective measures to ensure this protocol breach does not occur again. Specifically, we have stipulated the nature of staff that implements the protocol (i.e., only shift leaders), we have increased the rigor of the training program for this procedure, have separated the training from the general tagging procedure to be a stand-alone component, and have implemented quality control checks in the field to ensure the procedure is properly implemented. We will evaluate the validity of this assumption during 2005 and if warranted will provide an errata to this report describing our observations.

The detections of dead radio-tagged fish can be grouped into two categories. The first category consists of the detected dead radio-tagged fish with long travel times (Table 1). One of the five dead radio-tagged yearling Chinook salmon had a travel time that was $\geq$ the 99.8th percentile of travel times for fish detected at our furthest downstream detection array and another had the longest travel time (100th percentile) to the first and second detection arrays. The second category is comprised of two dead yearling Chinook (10.1th and 2.9th percentile) and the only dead subyearling Chinook salmon (6.7th percentile) detected that had travel times on the opposite (e.g., fast) end of the distribution (Table 1). That the dead radio-tagged fish could be transported downstream at a slower rate than live fish and eventually be detected seems plausible. However, developing the rationale where the dead radio-tagged fish travel at a rate faster than the live fish through this river reach is more difficult.

To assess the potential effect of this assumption violation on the estimates generated during 2004, we took two approaches. First, to account for the possibility that our detections of radio-tagged fish with long travel times could be dead fish, we eliminated all fish with travel times > the 99.7th percentile and recalculated the estimates (Appendix 2). Further, we generated survival estimates with and without releases that occurred 24 h before or after releases associated with the dead fish detections (see Appendix 2). The rationale for this approach is: since dead fish were not detected consistently throughout the season, then the conditions (i.e., discharge, water velocities, dam operations) present during releases where dead fish were detected (and conservatively ± 24 h of the release) may have been conducive for allowing the transport of dead radio-tagged fish to our detection sites below Bonneville Dam. Thus, all fish passing through the study area during this time (i.e., ± 24 h of the release) were not included in the data set evaluated in the alternate analysis.

Table 1. Summary of the release dates, times and travel times to the radio telemetry detection arrays (Gates) for radio-tagged dead fish detections. The percentile ranking of the dead fish, with respect to the travel time distribution for all live radio-tagged fish released into the Bonneville Dam tailrace below the powerhouse 2 juvenile bypass outfall 2004, is presented for each detection array.

Release			Gate 1	Rank	Gate 2	Rank	Gate 3	Rank
Date	Time	Species	(hours)	(%)	(hours)	(%)	(hours)	(%)
8-May	10:11	Yearling Chinook	111.0	100.0	114.0	100.0	NA	NA
8-May	21:46	Yearling Chinook	NA	NA	NA	NA	73.7	99.8
9-May	10:11	Yearling Chinook	NA	NA	NA	NA	19.0	80.1
14-May	21:59	Yearling Chinook	7.0	14.4	9.1	11.4	12.3	10.1
31-May	00:01	Yearling Chinook	NA	NA	NA	NA	10.7	2.9
22-May	10:55	Steelhead trout	NA	NA	NA	NA	153.0	100.0
5-July	12:59	Subyearling Chinook	7.1	2.9	9.6	4.7	13.7	6.7

Run timing and radio telemetry tagging dates

One assumption of the 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, inexperience of conducting radio-telemetry studies during late-August and at the temperatures commonly seen during this month) 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 6.5% of a fish weight in air. For yearling Chinook salmon and steelhead trout implanted with a Lotek Wireless model 3KM tag (weight = 1.4 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 3-1, “nanotag” (weight = 0.85 g in air) the minimum weight was 13 g (corresponding estimated length of 110 mm). Due to these limitations the resultant data needs to be viewed critically in the context of these assumptions.

In an effort to fulfill 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 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 35% of the run and ended at 90% (Figure 6), and for steelhead trout tagging started at about 18% of the run and ended at 95% of the run (Figure 7). For subyearling Chinook salmon radio telemetry tagging started at approximately 55% of the run and ended near 98% of the run (Figure 8). Approximately 40% of the subyearling Chinook salmon run was composed of hatchery releases which occurred prior to 10 May.

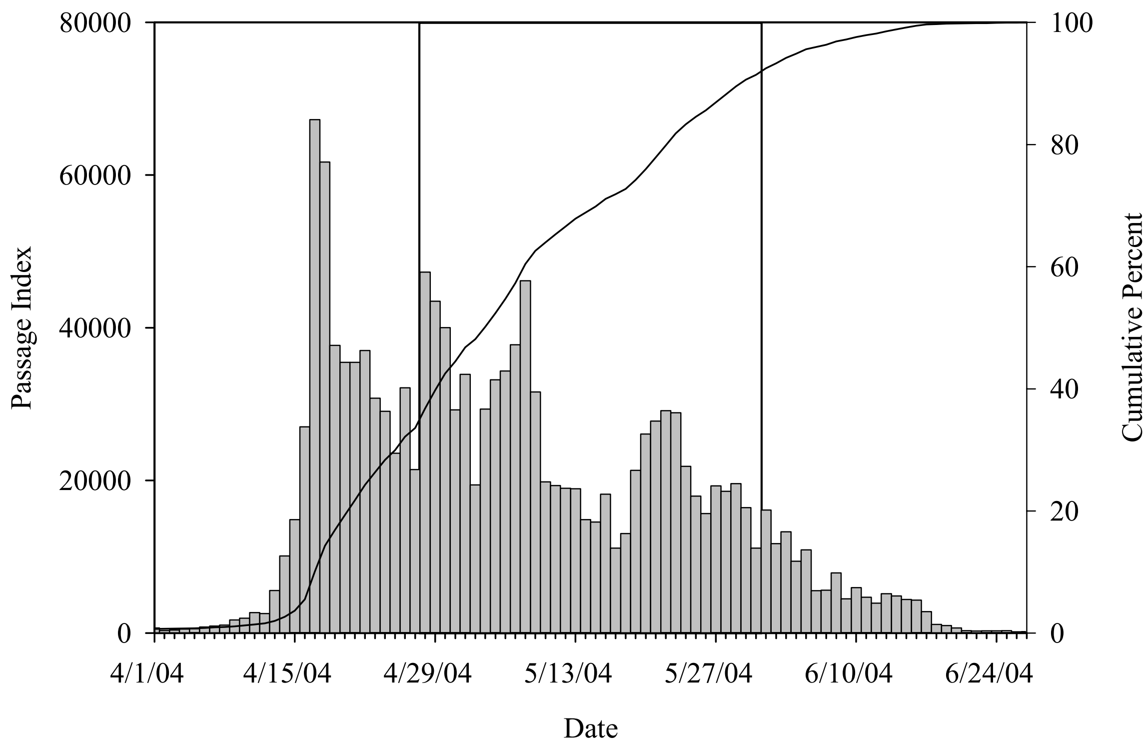


Figure 6. Yearling Chinook salmon daily passage index at Bonneville Dam, powerhouse 2. The vertical bars represent the passage index (see: www.fpc.org) for a given day. Vertical lines represent the start and end dates for radio telemetry tagging.

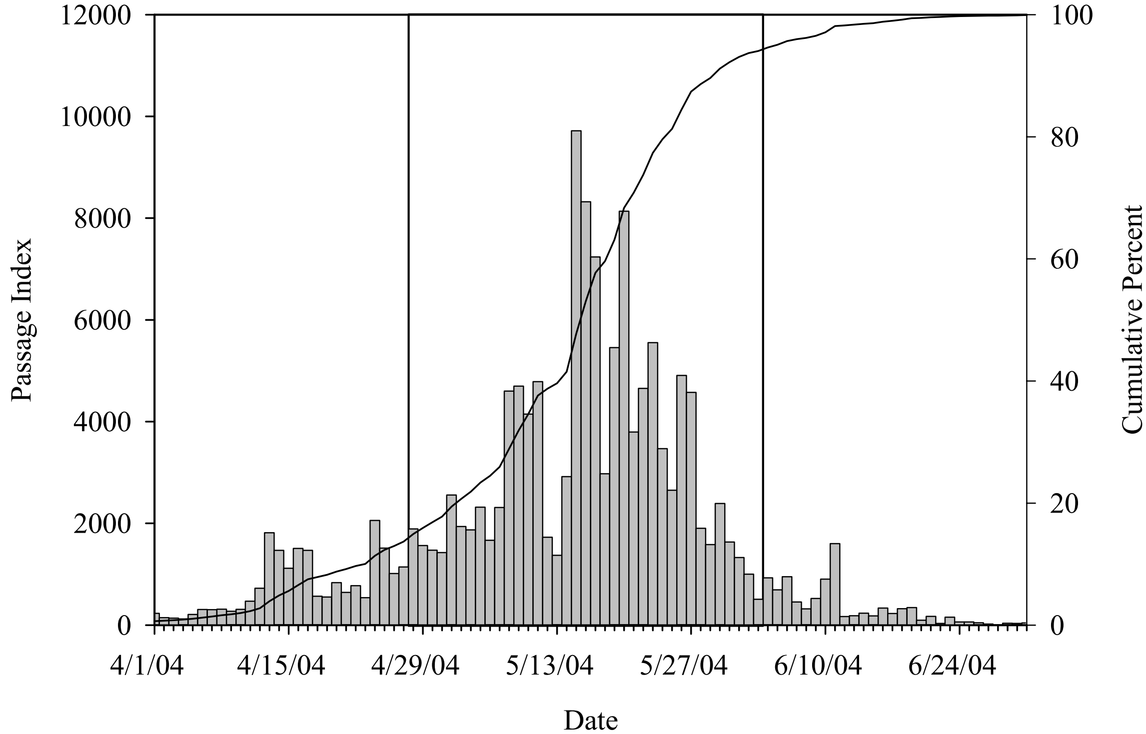


Figure 7. Steelhead trout daily passage index at Bonneville Dam, powerhouse 2 The vertical bars represent the passage index (see: www.fpc.org) for a given day. Vertical lines represent the start and end dates for radio telemetry tagging.

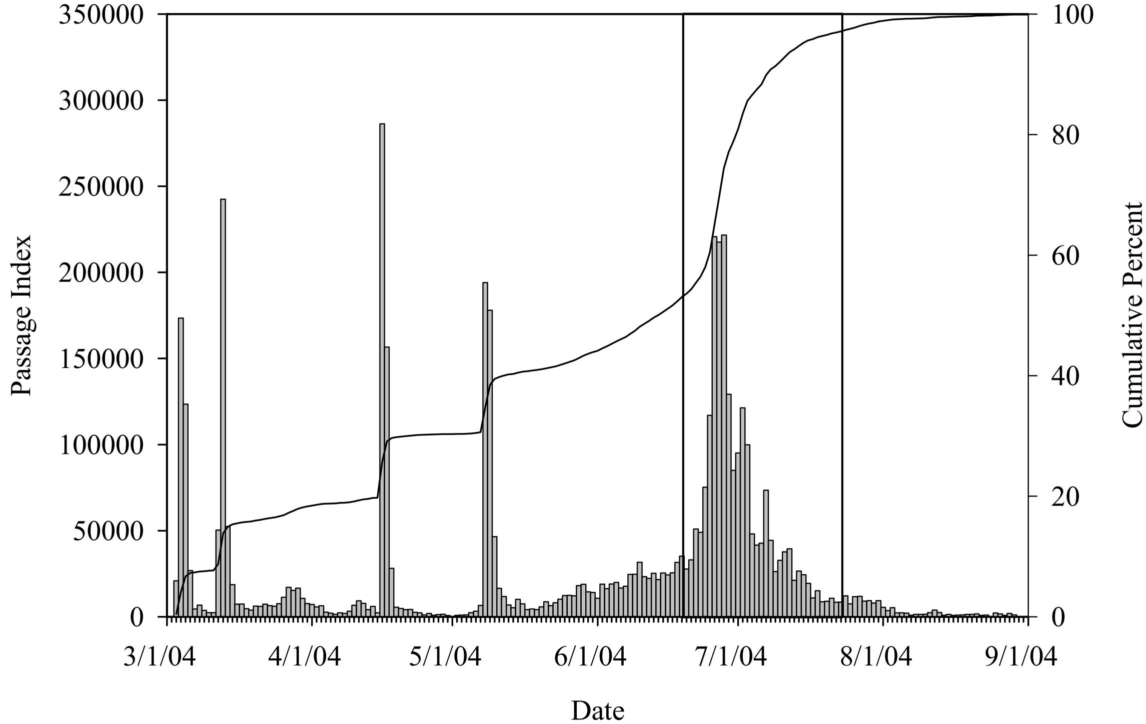


Figure 8. Subyearling Chinook salmon daily passage index at Bonneville Dam, powerhouse 2. The vertical bars represent the passage index (see: www.fpc.org) for a given day. Vertical lines represent the start and end dates for radio telemetry tagging.

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 130 mm size criteria (Figure 10). The average radio-tagged steelhead trout was 12 to 20 mm larger in size than the run-of-river fish. The run-of-river subyearling Chinook salmon were unusually small during the summer of 2004. The mean length at the sampling facilities ranged from 94 to 97 mm from 20 June to 22 July, while the mean radio-tagged fish length was 116 to 117 mm (Figure 11). Furthermore, less than 10% of the run-of-river fish sampled at the facilities were larger than 110 mm.

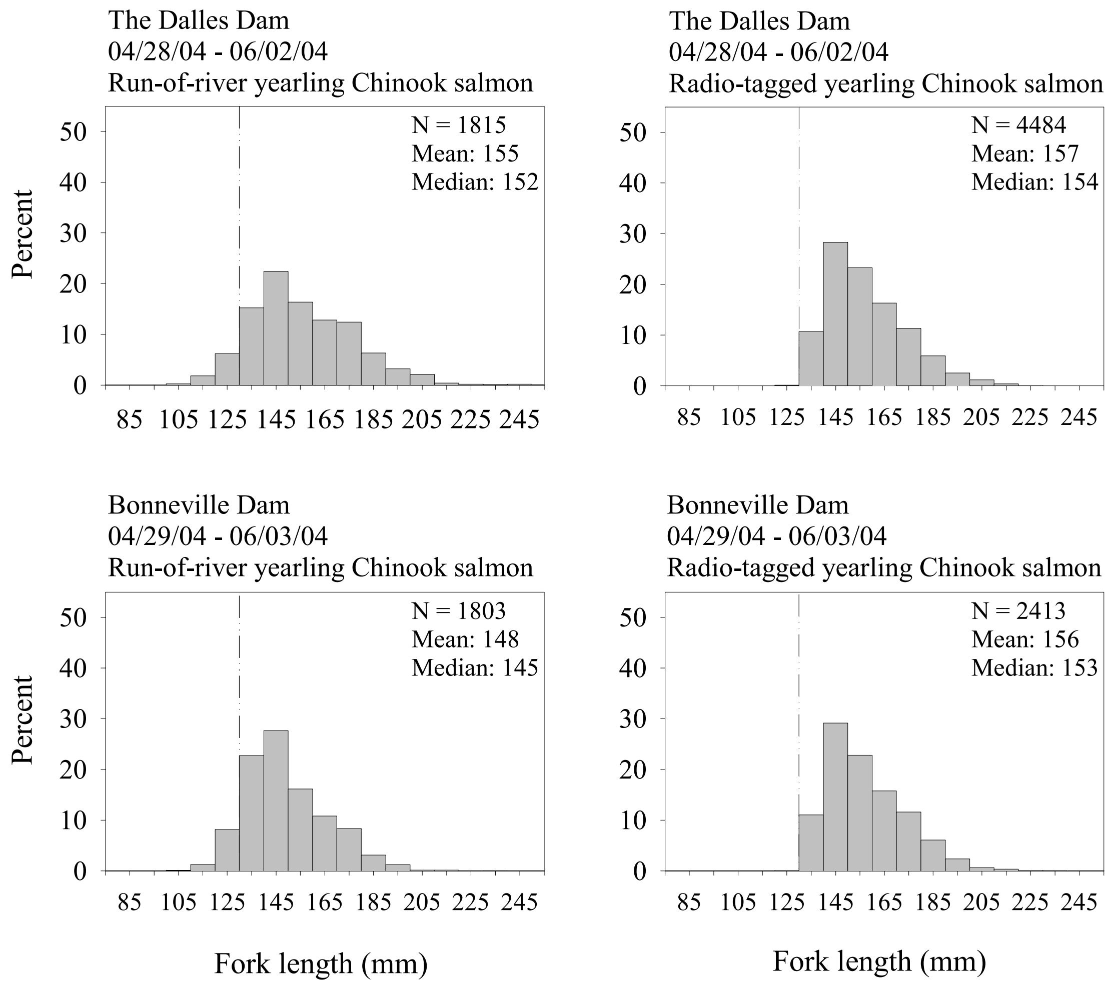


Figure 9. The distribution of fork lengths of run-of-river yearling Chinook salmon that were sampled at the John Day Dam and Bonneville Dam smolt monitoring facilities and fish tagged with MCFT-3KM radio transmitters (Lotek Engineering, Newmarket, Ontario) and released at The Dalles Dam and Bonneville Dam during 2004. 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.

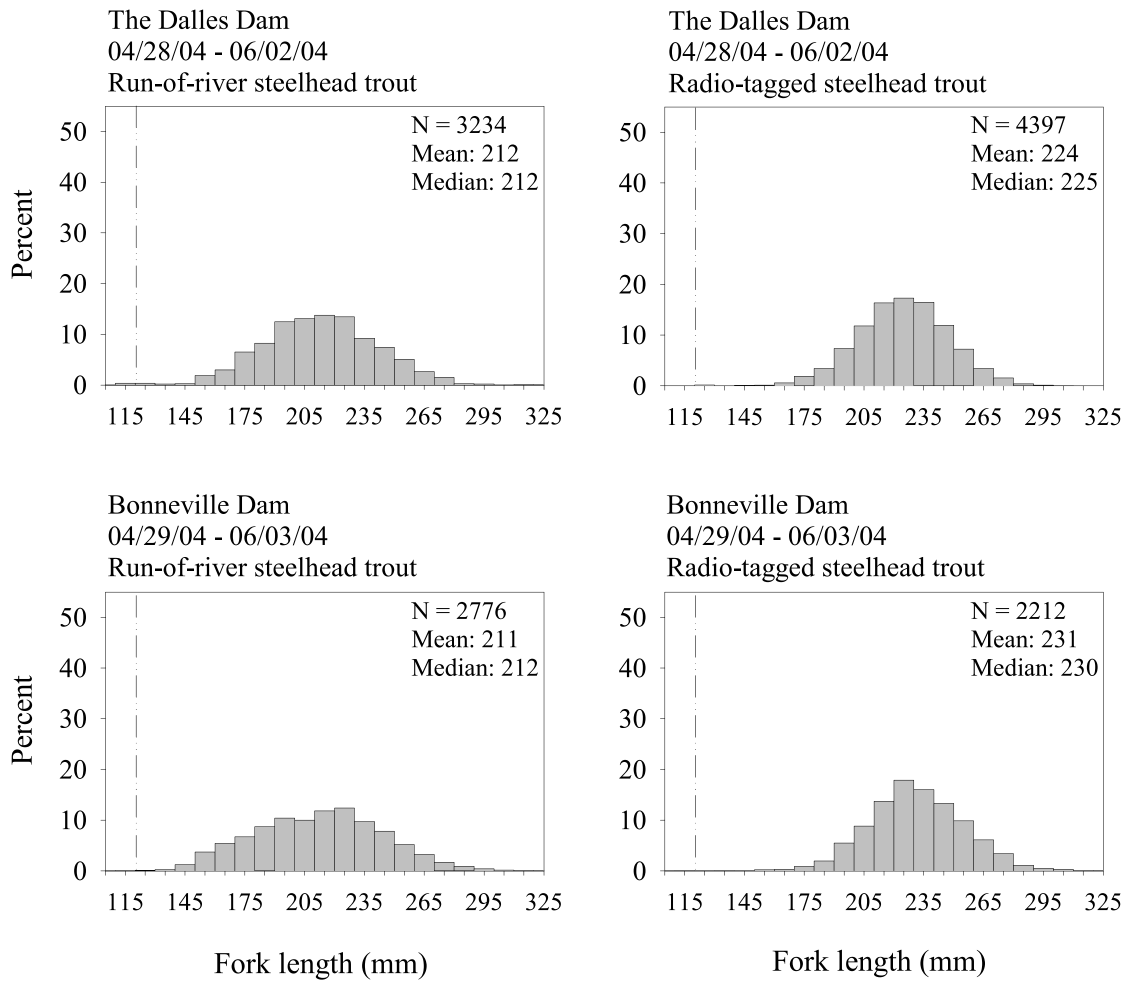


Figure 10. The distribution of fork lengths of run-of-river steelhead trout that were sampled at the John Day Dam and Bonneville Dam smolt monitoring facilities and fish tagged with MCFT-3KM radio transmitters (Lotek Engineering, Newmarket, Ontario) and released at The Dalles Dam and Bonneville Dam during 2004. 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.

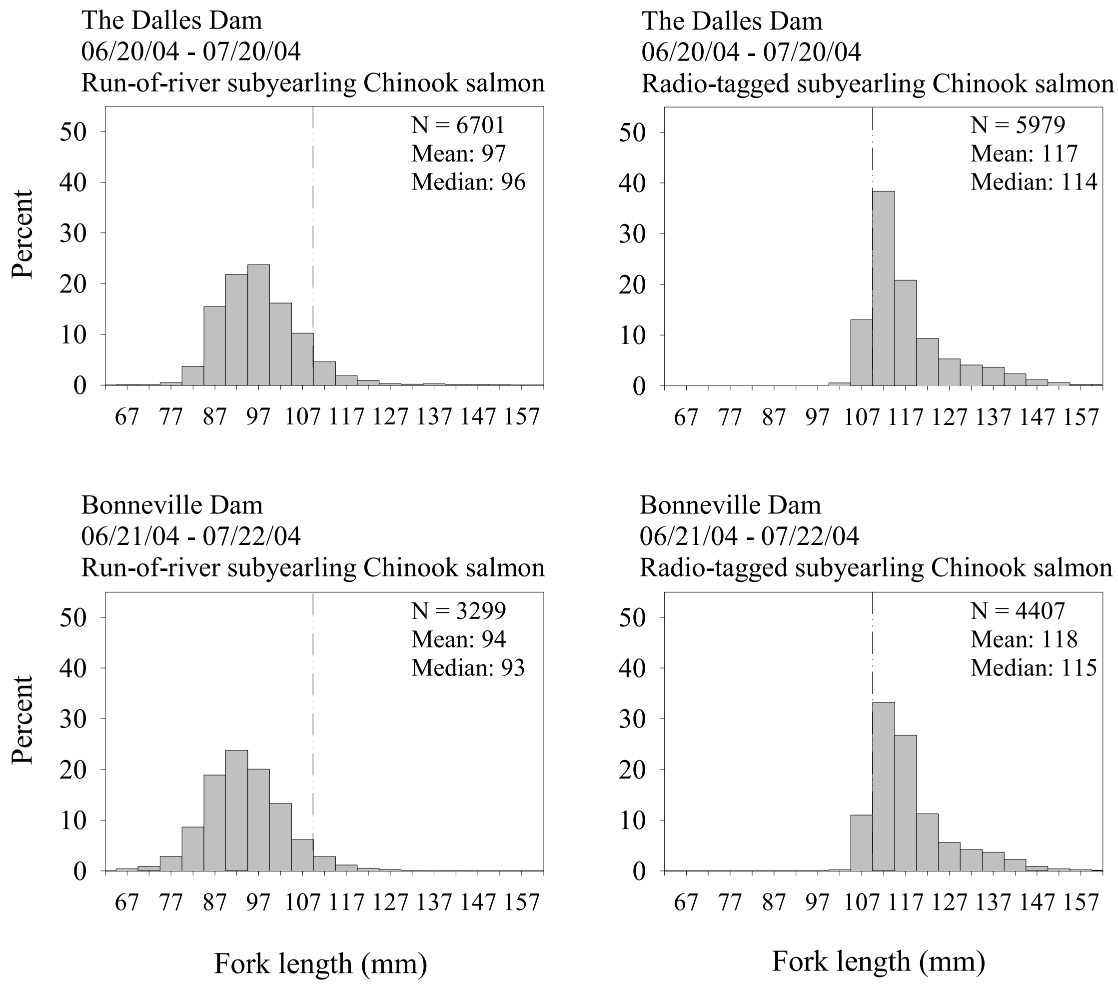


Figure 11. The distribution of fork lengths of run-of-river subyearling Chinook salmon that were sampled at the John Day Dam and Bonneville Dam smolt monitoring facilities and fish tagged with MCFT-3KM radio transmitters (Lotek Engineering, Newmarket, Ontario) and released at The Dalles Dam and Bonneville Dam during 2004. 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 for determining potential bias of survival estimates

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 3) 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).

We determined that the probability of a tag being operational at downstream arrays was high, with all probabilities greater than 99.9% (Table 2). Probabilities were higher for the summer study than for the spring study. The cumulative arrival distributions plotted with the Gompertz model over time shows that tagged juvenile salmonids passed through downstream detection arrays several days before tag-failure was substantial for both fish released from The Dalles Dam tailrace and Bonneville Dam tailrace (Appendix 3, Figure A3.3). Townsend et al. (2004) found that the probability of a tag being operational at downstream detection arrays was 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. Since the probability of a tag being operational at the downstream detection arrays for our survival studies were very close to one (Table 2), thus we did not adjust our survival estimates.

Table 2. Estimated probabilities (mean, SE in parentheses) a radio-tag was operational at Bonneville Dam and the downstream detection arrays for yearling Chinook salmon, steelhead trout, and subyearling Chinook salmon, during 2004.

	Detection Array Locations	
Release Site	Bonneville Dam	Survival Gates
	Yearling Chinook salmon	
The Dalles Dam	0.9996 (3.634×10^{-6})	0.9992 (7.036×10^{-5})
Bonneville Dam	NA	0.9999 (3.474×10^{-6})
	Steelhead trout	
The Dalles Dam	0.9996 (2.152×10^{-5})	0.9993 (3.795×10^{-5})
Bonneville Dam	NA	0.9998 (1.122×10^{-4})
	Subyearling Chinook salmon	
The Dalles Dam	0.9999 (1.604×10^{-5})	0.9999 (2.030×10^{-5})
Bonneville Dam	NA	1.0000 (3.285×10^{-7})

River Discharge and Project Operations

In July of 2004, the U.S. Army Corps of Engineers (ACOE) discovered that the amount of water reported to be spilled at Bonneville Dam was incorrect. An error in the calibration of spill gate openings installed in the early 1970's resulted in up to 30% less water discharged through the spillway than was reported to regional fish and water management officials. In this report we have included the corrected spill discharges and summary discharge statistics as per the revised data set by the Army Corps of Engineers (see: Bonneville Lock and Dam, Revision to Fish Passage Plan Spill Patterns FEB2005, Memorandum; Appendix 6).

During spring 2004 (29 April to 7 June), mean river discharge at Bonneville Dam was 218.4 kcfs, and ranged from 147.6 to 302.2 kcfs (Table 3). Allocation of mean river discharge among dam areas during the spring was 14.3% through powerhouse 1, 35.7% through the spillway and 46.7% through powerhouse 2. Spillway operations evaluated during the spring were supposed to be the NMFS Biological Opinion spill of 75 kcfs during the day with spill up to the total dissolved gas cap at night. However, due to the miscalibration errors, the spill operations were approximately 56 kcfs during the day (0500 to 1959 hrs) and spill up to 125% of the total dissolved gas cap at night (2000 to 0459 hours). During spring day operations the majority of the river discharge passed through powerhouse 2 (51%) with only 27% passing via the spillway, while at night 54% of the mean river discharge passed through the spillway with 37% passing via powerhouse 2 (Table 4).

During summer (21 June to 22 July), mean river discharge was 155.9 kcfs, with a range from 88.4 to 249.4 kcfs (Table 3). The majority of the mean river discharge passed through the powerhouse 2 (56%), with 34% passing via the spillway and 6% through powerhouse 1. Two different spill operations were evaluated during the summer. The NMFS Biological Opinion spill, which was actually 55.8 kcfs day (0400 to 2159 hours), with spill up to the total dissolved gas cap at night and 32 kcfs spill for 24 hours. During summer day operations 61% of the mean river discharge passed via the powerhouse 2, with 29% passing via the spillway, while at night 43% of the river discharge was passed via powerhouse 2 and 49% via the spillway (Table 5).

Table 3. Descriptive statistics for discharge (kcfs) at Bonneville Dam during spring (29 April to 7 June) 2004. Values have been rounded to the nearest tenth and are based on hourly averages.

		Spring			
Dam area	Percentage	Mean	Median	Minimum	Maximum
Powerhouse 1	14.3	33.3	27.75	0.0	100.9
Sluiceway	0.6	1.3	1.2	1.1	1.4
Powerhouse 2	46.7	101.5	103.8	20.3	139.3
Corner collector	2.6	5.6	5.6	5.1	5.9
Spillway	35.7	76.6	56.8	35.3	145.8
Total Discharge	100.0	218.4	219.4	147.6	302.2
		Summer			
Powerhouse 1	5.7	10.5	0.0	0.0	64.9
Sluiceway	0.7	1.1	1.2	0.2	1.4
Powerhouse 2	56.1	86.7	94.2	23.3	127.7
Corner collector	3.6	5.3	5.4	4.1	5.9
Spillway	33.9	52.4	33.1	13.5	161.4
Total Discharge	100.0	155.9	156.0	88.4	249.4

Table 4. Descriptive statistics for discharge (kcfs) during day (0500 to 1959) and night (2000 to 0459 hours) by dam area at Bonneville Dam during spring (29 April to 7 June) 2004. Dam operations were 56 kcfs spill during the day and night spill up to 125% of the total dissolved gas cap (TDG) at night

Period and dam area	Percent (of period)	Mean	Median	Minimum	Maximum
Day, 56 kcfs					
Powerhouse 1	18.8	43.9	43.9	0.0	100.9
Sluiceway	0.6	1.3	1.3	1.1	1.4
Powerhouse 2	51.4	110.7	114.0	77.9	139.3
Corner collector	2.6	5.6	5.6	5.1	5.9
Spillway	26.6	56.4	56.5	35.3	69.5
Total Discharge	100.0	217.9	219.1	147.6	302.2
Night, TDG					
Powerhouse 1	5.5	12.4	8.4	0.0	62.5
Sluiceway	0.6	1.3	1.2	1.1	1.4
Powerhouse 2	37.4	83.3	85.8	20.3	133.1
Corner collector	2.6	5.6	5.6	5.2	5.9
Spillway	53.9	116.8	114.6	57.3	145.8
Total Discharge	100.0	219.3	221.2	157.0	295.9

Table 5. Descriptive statistics for discharge (kcfs) during day (0400 to 2159) and night (2200 to 0359 hours) by dam area at Bonneville Dam during summer (21 June to 22 July) 2004 during. Dam operations were either 56 kcfs day spill with night spill up to 125% of the total dissolved gas cap (TDG) at night or 32 kcfs spill (day and night).

Period and dam area	Percent (of period)	Mean	Median	Minimum	Maximum
Day, 32 kcfs					
Powerhouse 1	9.2	16.6	15.6	0.0	62.1
Sluiceway	0.8	1.1	1.2	0.4	1.4
Powerhouse 2	64.6	97.9	104.4	55.5	127.7
Corner collector	3.7	5.4	5.4	4.4	5.9
Spillway	21.7	31.8	31.8	13.5	56.6
Total Discharge	100.0	152.8	157.5	93.0	224.5
Night, 32 kcfs					
Powerhouse 1	8.3	14.3	8.0	0.0	56.8
Sluiceway	0.8	1.2	1.2	0.4	1.4
Powerhouse 2	66.5	99.0	101.4	69.9	114.9
Corner collector	3.7	5.5	5.6	4.4	5.9
Spillway	20.7	30.7	31.8	16.1	32.6
Total Discharge	100.0	150.7	148.0	106.3	196.6
Day, 56 kcfs					
Powerhouse 1	2.9	6.2	0.0	0.0	64.9
Sluiceway	0.7	1.1	1.2	0.2	1.4
Powerhouse 2	56.3	89.4	91.5	25.4	125.4
Corner collector	3.4	5.3	5.4	4.1	5.9
Spillway	36.7	55.8	56.4	33.5	68.3
Total Discharge	100.0	157.7	153.6	88.4	249.4
Night, TDG					
Powerhouse 1	0.0	6.3	0.0	0.0	5.9
Sluiceway	0.7	1.2	1.2	0.5	1.4
Powerhouse 2	19.7	32.2	26.8	23.3	69.4
Corner collector	3.4	5.4	5.4	4.5	5.9
Spillway	76.1	126.9	136.0	56.4	161.4
Total Discharge	100.0	165.7	174.8	88.4	224.8

Yearling Chinook salmon

Paired Release-recapture Model

Throughout the migration season the MGR and the ice and trash sluiceway, at powerhouse 1 were not operating continuously due to a policy that prioritized the passage of water through powerhouse 2. Because of this policy, powerhouse 1 was only operated sporadically for short time intervals before and after the releases of radio tagged fish associated with this study.

Assumption tests for MGR turbine unit and ice and trash sluiceway

Burnham Tests

The results of the Burnham Tests 2 and 3 testing assumptions A5 and A6 for the following yearling Chinook salmon paired releases: the MGR turbine unit and the control at the MGR front roll, the MGR turbine unit and the control downstream of the outfall of the juvenile bypass at powerhouse 2, and the ice and trash sluiceway with the control downstream of the outfall of the juvenile bypass at powerhouse 2 were mostly 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 4 (Tables A4.1, A4.2, and A4.3).

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 the following paired releases of yearling Chinook salmon: the MGR turbine unit and the control at the MGR front roll, the MGR turbine unit and the control downstream of the outfall of the juvenile bypass at powerhouse 2, and 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 5 Tables A5.1, A5.2, A5.3).

Minimum Gap Runner Turbine Unit Survival Estimation

Control group released directly downstream of front roll turbine unit

We estimated that the 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 ranged from 0.830 to1.042 during 2004 (Table 6). The average survival was estimated to be 0.956 (SE = 0.016, 95% confidence interval [0.924, 0.988]).

Control group released below the outfall of the powerhouse 2 juvenile bypass

We estimated that the 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 powerhouse 2 juvenile bypass outfall ranged from 0.83 to1.02 during 2004 (Table 6). The average survival was estimated to be 0.944 (SE = 0.015, 95% confidence interval [0.913, 0.976]).

Table 6. The estimated survival and standard error (SE) of yearling Chinook salmon released into the minimum gap runner (MGR) turbine unit at Bonneville Dam's powerhouse 1 during 2004. Treatment releases were made directly into the MGR turbine unit and two control releases were evaluated; one directly below the front roll of the turbine unit and one below the powerhouse 2 juvenile bypass system (JBS) outfall at Bonneville Dam. Survival estimates are presented for both paired-release groupings (e.g., the MGR and the control group directly below the turbine unit and MGR and the control group below the powerhouse 2 juvenile bypass outfall). The survival estimates presented are the estimated survival of the release group into the MGR to the release location of the tailrace release group. The specific dates and times of the releases can be referenced in Appendix 1.

	Treatment = MGR, Control = directly below the front roll of the turbine unit		Treatment = MGR, Control = below the powerhouse 2 JBS outfall	
Release	S	SE	S	SE
1	0.97	0.08	1.02	0.08
2	[a]	[a]	0.88	0.10
3	1.00	0.06	0.96	0.04
4	0.88	0.08	0.94	0.11
5[c]	1.01	0.06	1.01	0.07
6[c]	0.99	0.09	0.96	0.08
7	1.00	0.10	1.00	0.10
8[c]	0.91	0.08	0.88	0.07
9	1.04	0.09	1.00	0.12
10	[b]	[b]	[b]	[b]
11	0.97	0.07	0.95	0.07
12	0.97	0.08	0.93	0.07
13	0.83	0.09	0.83	0.08
14	0.94	0.07	0.92	0.09
15	0.93	0.09	0.93	0.06
16[c]	[b]	[b]	[b]	[b]

[a] – Release equipment was not properly working.
[b] – Dam operations were not as specified for treatment conditions.
[c] – Releases within 24 h of detected radio-tagged dead fish

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 2004 ranged from 0.84 to1.15 (Table 7). The average survival was estimated to be 0.947 (SE = 0.018, 95% confidence interval [0.908, 0.986]).

Table 7. The estimated survival and standard error (SE) of yearling Chinook salmon released into the ice and trash sluiceway at Bonneville Dam's powerhouse 1 during 2004. Treatment releases were made into the ice and trash sluiceway and the control release was released below the powerhouse 2, juvenile bypass (JBS) outfall at Bonneville Dam. The survival estimates presented are the estimated survival of the release group into the ice and trash sluiceway to the release location of the tailrace release group. The specific dates and times of the releases can be referenced in Appendix 1.

	Powerhouse 1 Ice and trash sluiceway and downstream tailrace control	
Release	S	SE
1	0.97	0.08
2	0.93	0.09
3	0.89	0.07
4	0.94	0.11
5[a]	1.05	0.06
6[a]	1.01	0.07
7	0.93	0.06
8[a]	0.90	0.06
9	0.92	0.05
10	1.15	0.10
11	0.91	0.08
12	0.97	0.08
13	0.93	0.05
14	0.92	0.08
15	0.89	0.07
16[a]	0.84	0.09

[a] – Releases within 24 h of detected radio-tagged dead fish

Spillway Flow Deflectors

7-ft Spillbay Flow Deflectors

Assumption Tests

Burnham Tests

The results of the Burnham Tests 2 and 3 testing assumptions A5 and A6 for the yearling Chinook passing via spillbays with 7-ft deflectors at Bonneville Dam's spillway and the corresponding tailrace releases below the powerhouse 2 JBS outfall were mostly 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 4, Table A4.8.

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 post-hoc paired releases of yearling Chinook salmon passing via 7-ft deflectors at Bonneville Dam's spillway and the corresponding tailrace releases below the powerhouse 2 JBS outfall indicated that there were few significant differences ($P < 0.0009$, Dunn-Sidak experimentwise error rate) in arrival times between the two release groups (Appendix 5, Table A5.8.).

Survival estimation

We estimated the survival of yearling Chinook salmon passing via spillbays with 7-ft deflectors at Bonneville Dam spillway during daytime 56 kcfs spill operations ranged from 0.780 to 1.010 ($\bar{X} = 0.937$; $SE = 0.018$; $95\% CI = [0.898, 0.976]$; Table 8). Survival estimates for yearling Chinook salmon passing via spillbays with 7-ft deflectors during total dissolved gas cap spill operations ranged from 0.780 to 1.077 ($\bar{X} = 0.943$; $SE = 0.026$; $95\% CI = [0.886, 1.000]$; Table 8).

Table 8. The estimated survival probabilities (S), standard errors (SE), 95% confidence intervals (CI), number released (N; number of fish), and dates associated with paired releases of radio-tagged yearling Chinook salmon passing via spillbays with deflectors located 7 feet above mean sea level during 56 kcfs day (05:00 - 19:59 hrs) spill operations and spill at night (20:00 - 04:59 hrs) up to the total dissolved gas cap of 125% in the tailrace at the Bonneville Dam spillway. The paired release groups were formed post-hoc from fish released into The Dalles Dam tailrace (treatment) and in the Bonneville Dam tailrace (control) during 2004.

	56 kcfs day spill operations						
Release	S	SE	95% CI	Treatment N	Control N	Start Date	End date
1	0.940	0.072	0.798, 1.082	14	75	29-Apr	01-May
2	0.959	0.055	0.852, 1.066	28	78	01-May	03-May
3	0.990	0.061	0.871, 1.108	32	77	03-May	05-May
4	0.938	0.046	0.847, 1.028	66	125	05-May	08-May
5	1.010	0.038	0.937, 1.084	54	98	08-May	10-May
6	0.938	0.046	0.847, 1.028	48	95	10-May	13-May
7	0.908	0.032	0.845, 0.971	85	155	13-May	17-May
8	0.837	0.112	0.617, 1.057	17	82	17-May	19-May
9	0.956	0.063	0.832, 1.080	45	117	19-May	22-May
10	0.780	0.091	0.601, 0.959	22	82	22-May	24-May
11	0.990	0.037	0.916, 1.063	19	81	24-May	26-May
12	0.980	0.101	0.783, 1.177	12	39	26-May	27-May
13	0.959	0.045	0.870, 1.048	48	172	27-May	31-May
	Total dissolved gas cap night operations						
1	0.920	0.072	0.778, 1.062	21	75	29-Apr	01-May
2	0.990	0.045	0.902, 1.078	28	78	01-May	03-May
3	0.875	0.088	0.703, 1.047	23	77	03-May	05-May
4	1.042	0.105	0.836, 1.248	16	125	05-May	08-May
5	0.918	0.085	0.752, 1.083	16	98	08-May	10-May
6	0.896	0.046	0.806, 0.985	23	95	10-May	13-May
7	0.827	0.092	0.646, 1.007	21	155	13-May	17-May
8	1.077	0.075	0.930, 1.224	22	82	17-May	19-May
9	1.055	0.065	0.927, 1.182	21	117	19-May	22-May
10	0.890	0.072	0.748, 1.032	18	82	22-May	24-May
11	1.052	0.076	0.903, 1.201	24	81	24-May	26-May
12	0.780	0.112	0.560, 1.000	17	39	26-May	27-May
13	0.939	0.074	0.794, 1.084	19	172	27-May	31-May

14-ft Spillbay Flow Deflectors

Assumption Tests

Burnham Tests

The results of the Burnham Tests 2 and 3 testing assumptions A5 and A6 for the yearling Chinook salmon passing via spillbays with 14-ft deflectors at Bonneville Dam's spillway and the corresponding tailrace releases below the powerhouse 2 JBS outfall were mostly 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 4, Table A4.8.

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 post-hoc paired releases of yearling Chinook salmon passing via 14-ft deflectors at Bonneville Dam's spillway and the corresponding tailrace releases below the powerhouse 2 JBS outfall indicated that there were some significant differences ($P < 0.0009$, Dunn-Sidak experimentwise error rate) in arrival times between the two release groups (Appendix 5, Table A5.8).

Survival estimation

We estimated the survival of yearling Chinook salmon passing via spillbays with 14-ft deflectors at Bonneville Dam spillway during 56 kcfs spill operations ranged from 0.643 to 1.020 ($\bar{X} = 0.773$; $SE = 0.045$; $95\%\,CI = [0.667, 0.879]$; Table 9). Survival estimates for yearling Chinook salmon passing via spillbays with 14-ft deflector during total dissolved gas cap spill operations ranged from 0.845 to 1.087 ($\bar{X} = 0.946$; $SE = 0.018$; $95\%\,CI = [0.907, 0.985]$; Table 9).

Comparison of yearling Chinook salmon survival estimates for 7-ft and 14-ft Spillbay deflector during two spill operations

Survival estimates for yearling Chinook salmon passing through spillbays 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 56 kcfs day spill operations (Figure 12). At the lower flow spill operation of 56 kcfs day survival estimates of yearling Chinook salmon were much higher for fish passing through spillbays with the 7-ft deflectors than through spillbays with the 14-ft deflectors.

Table 9. The estimated survival probabilities (S), standard errors (SE), 95% confidence intervals (CI), number released (N; number of fish), and dates associated with paired releases of radio-tagged yearling Chinook salmon passing via spillbays with deflectors located 14 feet above mean sea level during 56 kcfs day (05:00 - 19:59 hrs) spill operations and spill at night (20:00 - 04:59 hrs) up to the total dissolved gas cap of 125% in the tailrace at Bonneville Dam spillway. The paired release groups were formed post-hoc from fish released into The Dalles Dam (treatment) and in the Bonneville Dam tailrace (control) during 2004.

	56 kcfs day spill operations						
Release	S	SE	95% CI	Treatment N	Control N	Start date	End date
2	1.020	0.121	0.784, 1.257	13	78	01-May	03-May
4	0.688	0.095	0.502, 0.873	26	125	05-May	08-May
5	0.784	0.135	0.519, 1.048	12	98	08-May	10-May
7	0.816	0.092	0.636, 0.997	20	155	13-May	17-May
8	0.728	0.154	0.426, 1.030	12	82	17-May	19-May
9	0.648	0.112	0.429, 0.868	24	117	19-May	22-May
11	0.854	0.095	0.667, 1.041	20	81	24-May	26-May
13	0.643	0.093	0.461, 0.825	32	172	27-May	31-May
	Total dissolved gas cap night spill operations						
1	0.910	0.072	0.768, 1.052	21	75	29-Apr	01-May
2	0.950	0.058	0.837, 1.063	29	78	01-May	03-May
3	0.917	0.078	0.763, 1.070	23	77	03-May	05-May
4	0.958	0.066	0.830, 1.087	30	125	05-May	08-May
5	1.042	0.068	0.909, 1.174	28	98	08-May	10-May
6	0.865	0.065	0.737, 0.992	46	95	10-May	13-May
7	0.845	0.093	0.663, 1.028	28	155	13-May	17-May
8	0.924	0.082	0.764, 1.084	26	82	17-May	19-May
9	1.087	0.078	0.935, 1.239	27	117	19-May	22-May
10	0.960	0.041	0.879, 1.041	24	82	22-May	24-May
11	0.917	0.065	0.789, 1.045	34	81	24-May	26-May
12	0.970	0.083	0.808, 1.132	15	39	26-May	27-May
13	0.949	0.055	0.842, 1.056	37	172	27-May	31-May

Note- releases were not included where too few fish passed (i.e. < 10)

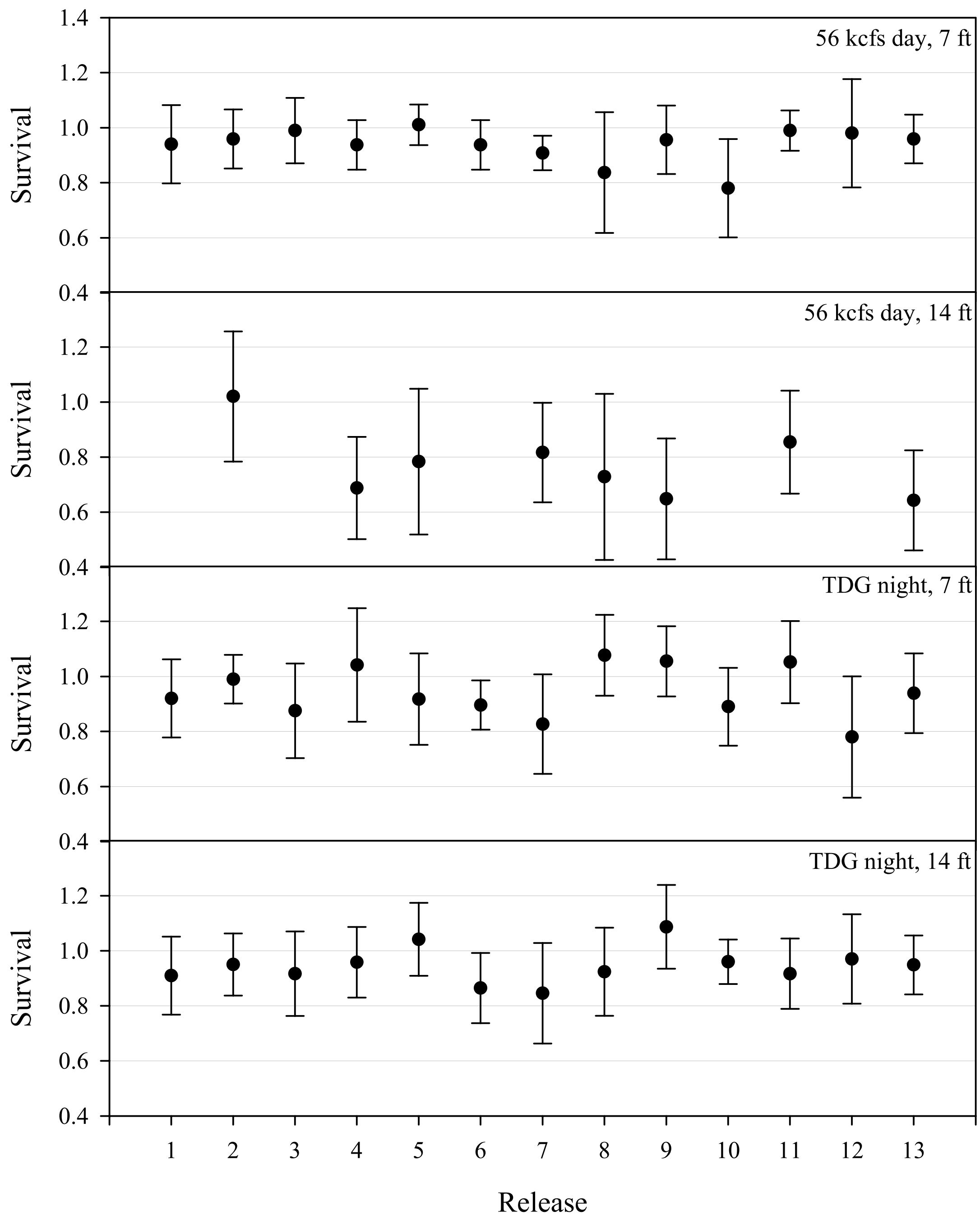


Figure 12. The estimated survival probabilities (95% confidence intervals error bars) from paired releases of radio-tagged yearling Chinook salmon passing through spillbays with deflectors located at either 7-ft or 14-ft above mean sea level at Bonneville Dam under two spill operations (56 kcfs day or total dissolved gas cap(TDG) night) by release. The paired release groupings were formed post-hoc from fish released into The Dalles Dam tailrace and in the Bonneville Dam tailrace during 2004.

Route-specific Survival Model

Survival estimation

Capture histories were generated for each passage scenario, indicating detection at the release location, detection at the dam, and detection downstream of the dam by assigning a 1 for detection and a 0 for not detected at antenna arrays. Using capture histories from the detections of radio-tagged yearling Chinook salmon released at The Dalles Dam and below the Bonneville Dam powerhouse 2 JBS outfall (Table 10), we generated maximum likelihood estimates of the route-specific passage and survival probabilities through Bonneville Dam (Figure 13). The survival of yearling Chinook salmon through Bonneville Dam spillway was estimated to be 0.910 (SE = 0.011, profile likelihood 95% confidence interval [0.888, 0.931]). For yearling Chinook salmon passing via powerhouse 1, the estimated survival was 0.913 (SE = 0.019, profile likelihood 95% confidence interval [0.872, 0.949]) and for yearling Chinook salmon passing via powerhouse 2 turbines the estimated survival was 0.951 (SE = 0.011, profile likelihood 95% confidence interval [0.929, 0.972]). For yearling Chinook salmon passing via the JBS the estimated survival was 0.970 (SE = 0.013, profile likelihood 95% confidence interval [0.943, 0.994]) and passing via the corner collector at powerhouse 2 the estimated survival was 1.016 (SE = 0.008, profile likelihood 95% confidence interval [0.999, 1.032]). Yearling Chinook salmon dam survival through Bonneville Dam was estimated to be 0.951 (SE = 0.008, profile likelihood 95% confidence interval [0.937, 0.966]) and project survival was estimated to be 0.883 (SE = 0.008, profile likelihood confidence interval [0.868, 0.898]).

Table 10. Counts of radio-tagged yearling Chinook salmon for the releases from The Dalles Dam (*R_1*) and in the tailrace of Bonneville Dam (*R_2*) used in the route-specific survival model during 2004. Detection history recorded as: 1, detected; 0, not detected. For R_1, the first position indicates the release event, the second position indicates detection or not at Bonneville Dam, the third position indicates detection or not at at least one of the arrays below Bonneville Dam. For R_2, the second position indicates the release event and the third position indicates detection or not at at least one of the arrays below 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. B1 is powerhouse 1 and B2 is powerhouse 2 at Bonneville Dam.

				Within-route histories Bonneville Dam		
Release	Detection History	Route	Counts	11	01	10
$R_1 = 4486$	100		326			
	101		70			
	110	Spillway	172	1126	9	203
	111		1166			
	110	B1	43	216	121	5
	111		299			
	110	B2 Turbines	91	511	50	448
	111		918			
	110	B2 Juvenile bypass	37	518	2	2
	111		485			
	110	B2 Corner collector	24	878	0	1
	111		855			
$R_2 = 1276$	010		54			
	011		1222			

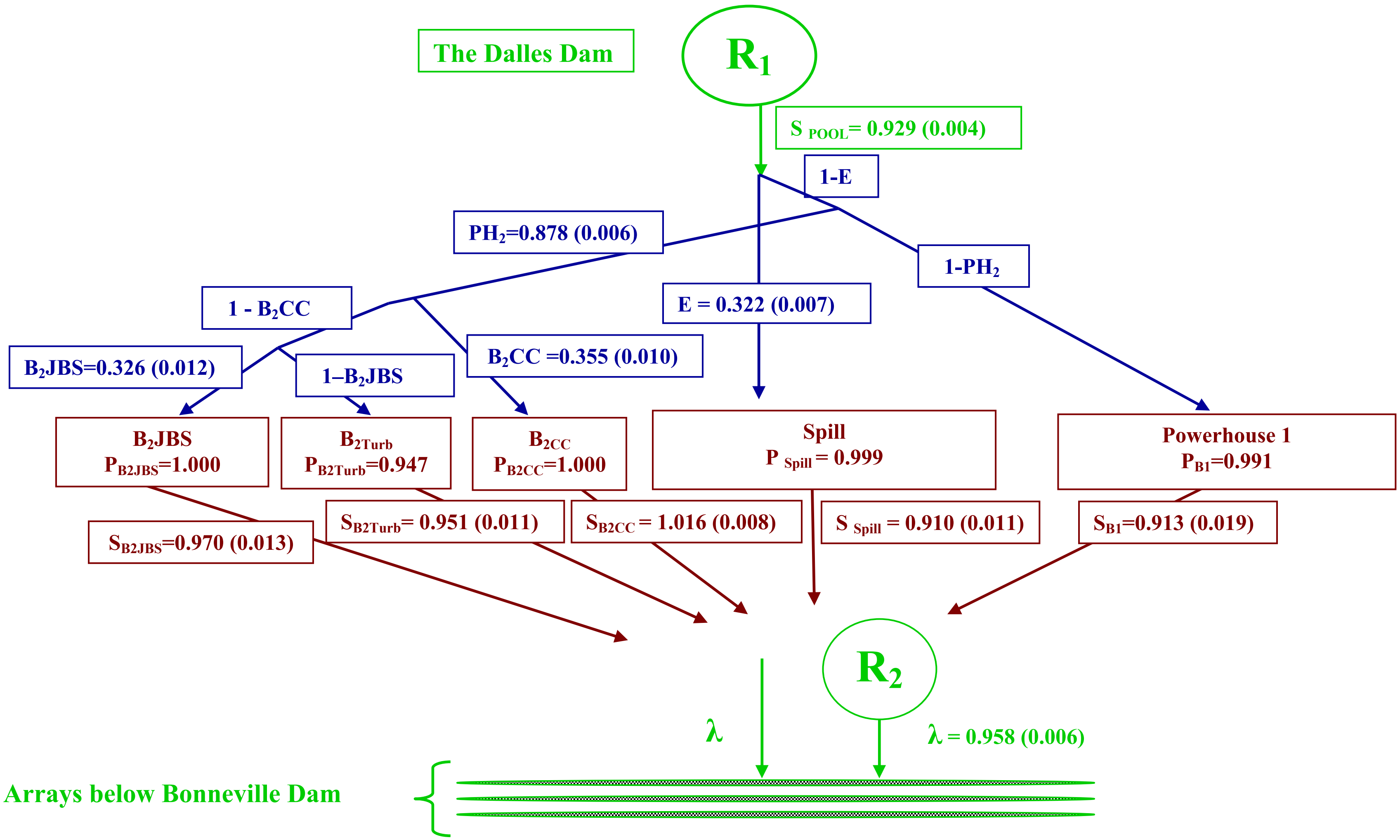


Figure 13. Schematic of estimated route-specific passage and survival parameters for yearling Chinook salmon through Bonneville Dam during 56 kcfs day/total dissolved gas cap night spill operations. Estimated standard errors are in parentheses.

56 kcfs day spill operations

Using capture histories generated from the detections of radio-tagged yearling Chinook salmon released at The Dalles Dam and passing Bonneville Dam between 0500 and 2000 hrs during 56 kcfs spill operations (Table 11), we generated maximum likelihood estimates of the route-specific passage and survival probabilities (Figure 14). The survival of yearling Chinook salmon through Bonneville Dam spillway during 56 kcfs day spill operations was estimated to be 0.861 (SE = 0.015, profile likelihood 95% confidence interval [0.831, 0.889]). For yearling Chinook salmon passing via powerhouse 1, the estimated survival was 0.894 (SE = 0.020, profile likelihood 95% confidence interval [0.853, 0.930]) and for yearling Chinook salmon passing via powerhouse 2 turbines, the estimated survival was 0.925 (SE = 0.012, profile likelihood 95% confidence interval [0.902, 0.948]). For yearling Chinook salmon passing via the powerhouse 2 JBS the estimated survival was 0.938 (SE = 0.015, profile likelihood 95% confidence interval [0.906, 0.966]). The survival of yearling Chinook salmon passing via the corner collector at powerhouse 2 was estimated to be 0.993 (SE = 0.008, profile likelihood 95% confidence interval [0.977, 1.008]). Yearling Chinook salmon dam survival through Bonneville Dam was estimated to be 0.925 (SE = 0.008, profile likelihood 95% confidence interval [0.912, 0.941]) and project survival was estimated to be 0.860 (SE = 0.008, profile likelihood 95% confidence interval [0.844, 0.876]).

Total dissolved gas cap night spill operations

Using capture histories generated from the detections of radio-tagged yearling Chinook salmon released at The Dalles Dam and passing Bonneville Dam between 2000 and 0500 hrs during total dissolved gas cap night spill operations (Table 11), we generated maximum likelihood estimates of the route-specific passage and survival probabilities (Figure 15). The survival of yearling Chinook salmon through Bonneville Dam spillway during total dissolved gas cap night spill operations was estimated to be 0.964 (SE = 0.016, profile likelihood 95% confidence interval [0.932, 0.996]). For yearling Chinook salmon passing via powerhouse 1, the estimated survival was 0.903 (SE = 0.060, profile likelihood 95% confidence interval [0.768, 0.999]) and for yearling Chinook salmon passing via powerhouse 2 turbines, the estimated survival was 0.981 (SE = 0.021, profile likelihood 95% confidence interval [0.937, 1.020]). For yearling Chinook salmon passing via the powerhouse 2 JBS the estimated survival was 1.013 (SE = 0.022, profile likelihood 95% confidence interval [0.964, 1.053]). The survival of yearling Chinook salmon passing via the corner collector at powerhouse 2 was estimated to be 1.028 (SE = 0.021, profile likelihood 95% confidence interval [0.980, 1.065]). Yearling Chinook salmon dam survival through Bonneville Dam was estimated to be 0.979 (SE = 0.015, profile likelihood 95% confidence interval [0.953, 1.007]) and project survival was estimated to be 0.908 (SE = 0.015, profile likelihood 95% confidence interval [0.881, 0.937]).

Table 11. Counts of radio-tagged yearling Chinook salmon for releases from The Dalles Dam (R_1) and in the tailrace of Bonneville Dam (R_2) used in the route-specific survival model during two spill operations: 56 kcfs day (0500-2000) and total dissolved gas cap (TDG) at night in 2004. Detection history recorded as: 1, detected; 0, not detected. For R_1, the first position indicates the release event, the second position indicates detection or not at Bonneville Dam, the third position indicates detection or not at at least one of the arrays below Bonneville Dam. For R_2, the second position indicates the release event and the third position indicates detection or not at at least one of the arrays below 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. B1 is powerhouse 1 and B2 is powerhouse 2 at Bonneville Dam.

56 kcfs day spill operations						
				Within-route histories Bonneville Dam		
Release	Detection History	Route	Counts	11	01	10
R_1 =3100	100		222			
	101		52			
	110	Spillway	106	622	2	63
	111		581			
	110	B1	36	185	107	5
	111		261			
	110	B2 Turbines	68	355	38	353
	111		678			
	110	B2 Juvenile bypass	28	357	2	1
	111		332			
	110	B2 Corner collector	18	735	0	1
	111		718			
R_2 =640	010		11			
	011		629			

TDG night spill operations						
				Within-route histories Bonneville Dam		
Release	Detection History	Route	Counts	11	01	10
R_1 =1386	100		101			
	101		22			
	110	Spillway	66	504	7	140
	111		585			
	110	B1	7	31	14	0
	111		38			
	110	B2 Turbines	23	156	12	95
	111		240			
	110	B2 Juvenile bypass	9	161	0	1
	111		153			
	110	B2 Corner collector	6	143	0	0
	111		137			
R_2 = 636	010		43			
	011		593			

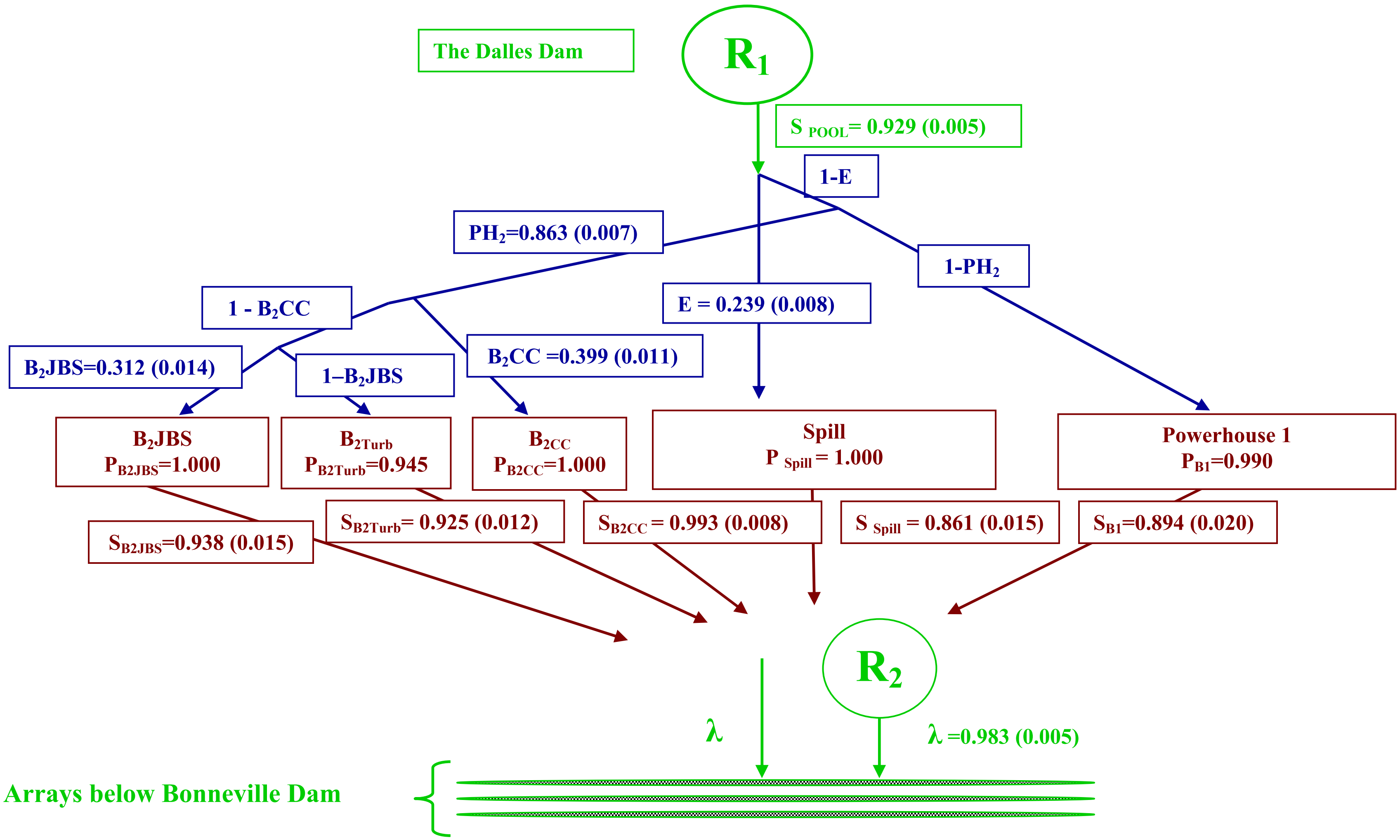


Figure 14. Schematic of estimated route-specific passage and survival parameters for yearling Chinook salmon through Bonneville Dam during 56 kcfs day spill operations. Estimated standard errors are in parentheses.

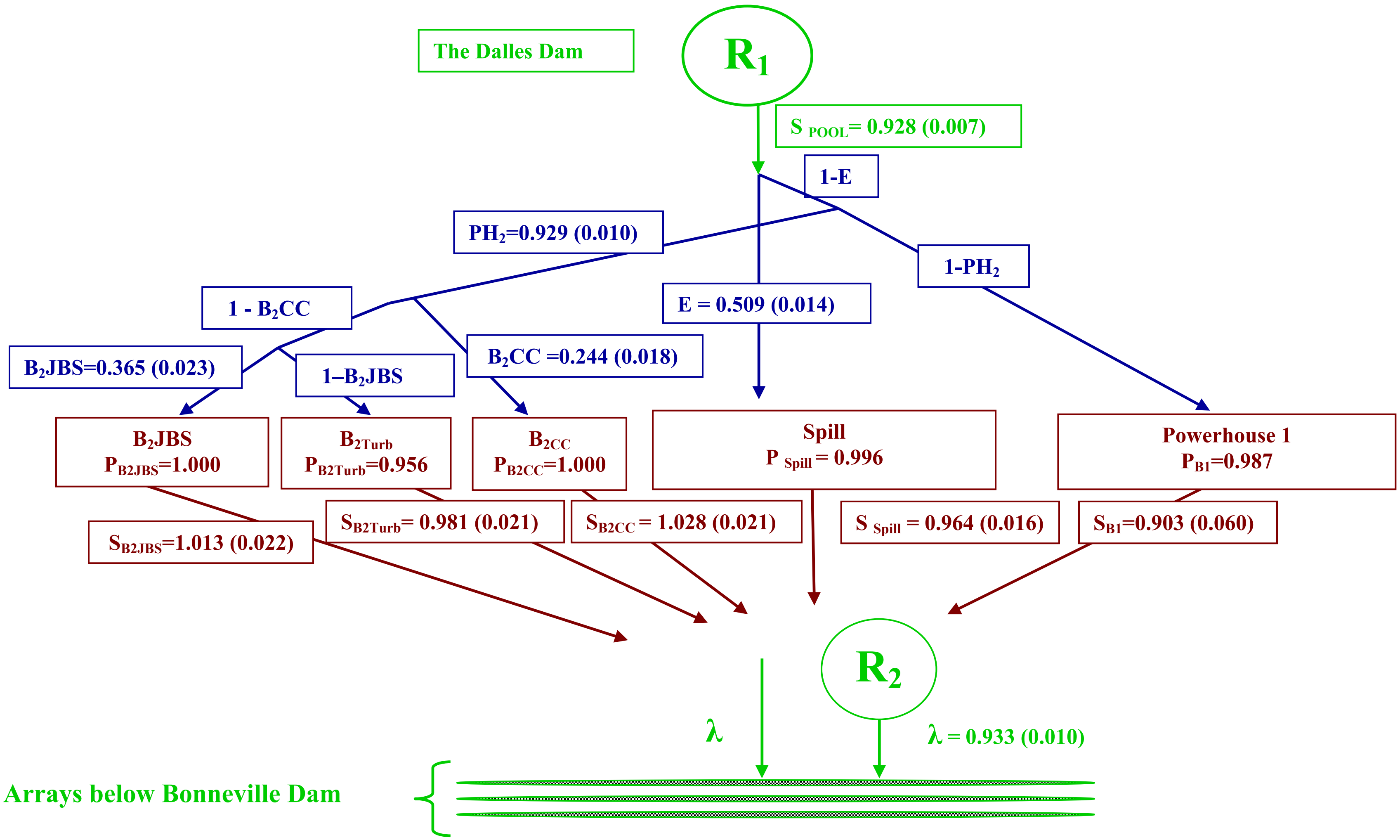


Figure 15. Schematic of estimated route-specific passage and survival parameters for yearling Chinook salmon through Bonneville Dam during total dissolved gas cap night spill operations. Estimated standard errors are in parentheses.

Comparison of survival during 56 kcfs day and TDG night spill operations

The estimated survival probabilities for yearling Chinook salmon passing via the powerhouse 2 turbines, the powerhouse 2 JBS, and the spillway were significantly different between the two spill operations (Table 12). The dam survival was also found to be significantly different between the 56 kcfs day and TDG night spill operations.

Table 12. Summary table of estimated route-specific survival probabilities (S) and their associated standard errors (SE) of yearling Chinook salmon survival through Bonneville Dam (Dam survival) generated from the route-specific survival model. The results of *Z*-tests (i.e., *Z*-statistic) structured to assess whether the estimated survival probabilities during the 56 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.

	56 kcfs day		TDG night		
Passage route	S	SE	S	SE	*Z*
Powerhouse 1	0.894	0.020	0.903	0.060	0.142
Powerhouse 2	0.925	0.012	0.981	0.021	2.315
Corner Collector	0.993	0.008	1.028	0.021	1.557
JBS	0.938	0.015	1.013	0.022	2.817
Spillway	0.861	0.015	0.964	0.016	4.696
Dam Survival	0.925	0.008	0.979	0.015	3.177

Steelhead trout

Paired Release-recapture Model

Assumption tests for the MGR turbine unit and the ice and trash sluiceway

Burnham tests

The results of the Burnham Tests 2 and 3 testing assumptions A5 and A6 for the following steelhead trout paired releases: the MGR turbine unit and the control at the MGR front roll, the MGR turbine unit and the control downstream of the outfall of the juvenile bypass at powerhouse 2, and the ice and trash sluiceway with the control downstream of the outfall of the juvenile bypass at powerhouse 2 were mostly 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 4 (Tables A4.4, A4.5, and A4.6).

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 following paired releases of steelhead trout: the MGR turbine unit and the control at the MGR front roll, the MGR turbine unit and the control downstream of the outfall of the juvenile bypass at powerhouse 2, and 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 5 Tables A5.4, A5.5, A5.6).

Minimum Gap Runner Turbine Unit Survival Estimation

Control group released directly downstream of front roll below turbine unit

We estimated that the survival of 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 ranged from 0.830 to1.136 (Table 13) during 2004. The average survival was estimated to be 0.952 (SE = 0.024, 95% confidence interval [0.900, 1.003]).

Control group released below the outfall of the powerhouse 2 juvenile bypass

We estimated that the survival of steelhead trout released into the MGR turbine unit at Bonneville Dam's powerhouse 1 with the control group released in the tailrace below the outfall of the powerhouse 2 juvenile bypass outfall ranged from 0.74 to1.09 (Table 13) during 2004. The average survival was estimated to be 0.926 (SE = 0.030, 95% confidence interval [0.861, 0.992]).

Table 13. The estimated survival (S) and standard error (SE) of steelhead trout released into the Minimum Gap Runner (MGR) Turbine Unit at Bonneville Dam's powerhouse 1 during 2004. Treatment releases were made directly into the MGR turbine unit and two control releases were evaluated; one directly below the front roll of the turbine unit and one below the powerhouse 2 juvenile bypass system (JBS) outfall at Bonneville Dam. Survival estimates are presented for both paired-release groupings (e.g., the MGR and the control group directly below the turbine unit and MGR and the control group below the powerhouse 2 juvenile bypass outfall). The survival estimates presented are the estimated survival of the release group into the MGR to the release location of the tailrace release group. The specific dates and times of the releases can be referenced in Appendix 1.

	Treatment = MGR, Control = directly below the front roll of the turbine unit		Treatment = MGR, Control = below the powerhouse 2 JBS outfall	
Release	S	SE	S	SE
1	1.14	0.15	1.00	0.14
2	0.83	0.12	0.78	0.10
3	0.87	0.10	0.82	0.08
4	0.92	0.08	0.89	0.06
5	0.91	0.06	0.91	0.08
6	0.88	0.13	1.06	0.21
7	0.90	0.08	0.91	0.09
8	[a]	[a]	[a]	[a]
9	0.93	0.08	0.88	0.07
10	0.93	0.16	0.83	0.07
11	1.14	0.12	1.09	0.07
12	0.99	0.18	0.74	0.10
13	0.96	0.10	1.06	0.09
14	[a]	[a]	[a]	[a]
15	0.95	0.09	0.96	0.09
16	1.00	0.09	1.06	0.13

[a] – Dam operations were not as specified for treatment conditions.

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 2004 ranged from 0.76 to1.07 (Table 14). The average survival was estimated to be 0.935 (SE = 0.024, 95% confidence interval [0.884, 0.985]).

Table 14. The estimated survival and standard error (SE) of steelhead trout released into the ice and trash sluiceway at Bonneville Dam's powerhouse 1 during 2004. Treatment releases were made into the ice and trash sluiceway and the control release was released below the powerhouse 2, juvenile bypass (JBS) outfall at Bonneville Dam. The survival estimates presented are the estimated survival of the release group into the ice and trash sluiceway to the release location of the tailrace release group.

	Powerhouse 1 Ice and trash sluiceway and downstream tailrace control	
Release	S	SE
1	0.78	0.11
2	1.00	0.004
3	0.87	0.07
4	0.79	0.08
5	0.90	0.08
6	0.90	0.22
7	0.76	0.10
8	1.01	0.07
9	0.92	0.06
10	1.02	0.11
11	1.05	0.08
12	1.00	0.06
13	0.95	0.11
14	1.00	0.16
15	0.94	0.10
16	1.07	0.13

Spillbay Flow Deflectors

7-ft Spillbay Flow Deflectors

Assumption Tests

Burnham tests

The results of the Burnham Tests 2 and 3 testing assumptions A5 and A6 for the steelhead trout passing via spillbays with 7-ft deflectors at Bonneville Dam's spillway and the corresponding tailrace releases below the powerhouse 2 JBS outfall were mostly incalculable because of the presence of all zeroes in either rows or columns of the contingency table. Of the tests that were calculated, only 2 of the 49 tests (Test 2) indicated lack of fit ($P < 0.0004$, Dunn-Sidak experimentwise error rate). The results of these tests can be found in Appendix 4, Table A4.12.

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 post-hoc paired releases of steelhead trout indicated that there were some significant differences ($P < 0.0009$, Dunn-Sidak experimentwise error rate) in arrival times between the two release groups (Appendix 5, Table A5.12.).

Survival estimation

We estimated the survival of steelhead trout passing via spillbays with 7-ft deflectors at Bonneville Dam spillway during 56 kcfs spill operations ranged from 0.667 to 1.064 ($\bar{X} = 0.927; SE = 0.046;\ 95\% CI = [0.818, 1.036]$; Table 15). Survival estimates for steelhead trout passing via spillbays with 7-ft deflectors during total dissolved gas cap spill operations ranged from 0.926 to 1.143 ($\bar{X} = 1.013; SE = 0.016;\ 95\% CI = [0.979, 1.047]$; Table 15).

Table 15. The estimated survival probabilities (S), standard errors (SE), 95% confidence intervals, number released (N; number of fish), and dates associated with paired releases of radio-tagged steelhead trout passing via spillbays with deflectors located 7 feet above mean sea level during 56 kcfs day (05:00 - 19:59 hours) spill operations and spill at night (20:00 - 04:59 hrs) up to the total dissolved gas cap of 125% in the tailrace at the Bonneville Dam spillway. The paired release groups were formed post-hoc from fish released at The Dalles Dam (treatment) and in the Bonneville Dam tailrace (control) during 2004.

Release	S	SE	95% CI	Treatment N	Control N	Start date	End date
56 kcfs day spill operations							
5	1.042	0.088	0.869, 1.215	20	90	08-May	12-May
6	0.856	0.115	0.631, 1.080	17	81	12-May	14-May
7	1.064	0.134	0.802, 1.326	12	114	14-May	17-May
8	0.990	0.056	0.880, 1.099	21	136	17-May	20-May
9	0.667	0.157	0.359, 0.974	11	96	20-May	22-May
10	0.989	0.077	0.838, 1.141	14	132	22-May	25-May
13	0.948	0.075	0.802, 1.095	12	88	29-May	31-May
15	0.863	0.107	0.654, 1.073	16	119	01-Jun	04-Jun
Total dissolved gas cap night spill operations							
1	1.075	0.116	0.848, 1.302	16	42	28-Apr	02-May
2	1.000	0.101	0.803, 1.197	20	30	02-May	04-May
3	1.020	0.094	0.836, 1.204	18	47	04-May	06-May
4	0.979	0.066	0.850, 1.108	16	78	06-May	08-May
5	1.042	0.105	0.836, 1.248	16	90	08-May	12-May
6	1.044	0.066	0.916, 1.173	18	81	12-May	14-May
7	0.968	0.067	0.837, 1.100	23	114	14-May	17-May
8	0.927	0.065	0.799, 1.055	26	136	17-May	20-May
9	0.938	0.075	0.790, 1.085	20	96	20-May	22-May
10	1.021	0.048	0.928, 1.115	26	132	22-May	25-May
11	0.926	0.080	0.769, 1.083	23	95	25-May	27-May
12	1.143	0.072	1.001, 1.285	25	90	27-May	29-May
13	1.031	0.078	0.878, 1.184	23	88	29-May	31-May
14	1.087	0.128	0.837, 1.337	15	36	31-May	01-Jun
15	1.000	0.077	0.850, 1.150	15	119	01-Jun	04-Jun

Note- releases were not included where too few fish passed (i.e. < 10)

14-ft Spillbay Flow Deflectors

Assumption Tests

Burnham tests

The results of the Burnham Tests 2 and 3 testing assumptions A5 and A6 for the steelhead trout passing via spillbays with 14-ft deflectors at Bonneville Dam's spillway and the corresponding tailrace releases below the powerhouse 2 JBS outfall were mostly incalculable because of the presence of all zeroes in either rows or columns of the contingency table. Of the tests (Test 2) that were calculated, 2 of 47 tests indicated lack of fit ($P < 0.0004$, Dunn-Sidak experimentwise error rate). The results of these tests can be found in Appendix 4, Table A4.11.

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 post-hoc paired releases of steelhead trout indicated that there were some significant differences ($P < 0.0009$, Dunn-Sidak experimentwise error rate) in arrival times between the two release groups (Appendix 5, Table A5.11).

Survival estimation

We estimated the survival of steelhead trout passing via spillbays with 14-ft deflectors at Bonneville Dam spillway during 56 kcfs spill operations ranged from 0.684 to 0.959 ($\bar{X} = 0.850; SE = 0.063;\ 95\% CI = [0.650, 1.050]$; Table 16). Survival estimates for steelhead trout passing via spillbays with 14-ft deflectors during total dissolved gas cap spill operations ranged from 0.878 to 1.143 ($\bar{X} = 1.012; SE = 0.015;\ 95\% CI = [0.980, 1.044]$; Table 16).

Comparison of steelhead trout survival estimates for 7-ft and 14-ft Spillbay deflector during two spill operations

The point estimates of survival for steelhead trout passing through spillbays with 7-ft and 14-ft deflectors were higher during the total dissolved gas cap night spill operations when flows are typically higher and more fish tend to pass than during the 56 kcfs day spill operations (Figure 16). For the 56 kcfs day spill, the point estimates of survival for steelhead trout were higher for fish passing through spillbays with the 7-ft deflectors than through spillbays with the 14-ft deflectors.

Table 16. The estimated survival probabilities (S), standard errors (SE), 95% confidence intervals, number released (N; number of fish), and dates associated with paired releases of radio-tagged steelhead trout passing via spillbays with deflectors located 14 feet above mean sea level during 56 kcfs day (05:00 - 19:59 hrs) spill operations and spill at night (20:00 - 04:59 hrs) up to the total dissolved gas cap of 125% in the tailrace at the Bonneville Dam spillway. The paired release groups were formed post-hoc from fish released at The Dalles Dam (treatment) and in the Bonneville Dam tailrace (control) during 2004.

Release	S	SE	95% CI	Treatment N	Control N	Start date	End date
56 kcfs day spill operations							
8	0.938	0.096	0.750, 1.125	10	136	17-May	20-May
10	0.819	0.129	0.567, 1.072	13	132	22-May	25-May
13	0.959	0.228	0.513, 1.405	10	88	29-May	31-May
15	0.684	0.159	0.373, 0.995	11	119	01-Jun	04-Jun
Total dissolved gas cap night spill operations							
1	1.022	0.069	0.885, 1.158	19	42	28-Apr	02-May
2	1.000	0.101	0.803, 1.197	20	30	02-May	04-May
3	0.878	0.084	0.714, 1.041	21	47	04-May	06-May
4	1.042	0.082	0.881, 1.202	22	78	06-May	08-May
5	1.000	0.047	0.909, 1.091	25	90	08-May	12-May
6	1.067	0.057	0.955, 1.178	24	81	12-May	14-May
7	1.021	0.048	0.928, 1.115	28	114	14-May	17-May
8	0.979	0.023	0.934, 1.025	32	136	17-May	20-May
9	0.958	0.056	0.849, 1.068	26	96	20-May	22-May
10	0.989	0.057	0.877, 1.101	28	132	22-May	25-May
11	1.011	0.053	0.906, 1.115	35	95	25-May	27-May
12	1.143	0.072	1.001, 1.285	27	90	27-May	29-May
13	1.031	0.059	0.916, 1.146	33	88	29-May	31-May
14	1.043	0.071	0.903, 1.184	25	36	31-May	01-Jun
15	0.989	0.047	0.897, 1.082	32	119	01-Jun	04-Jun

Note- releases were not included where too few fish passed (i.e. < 10)

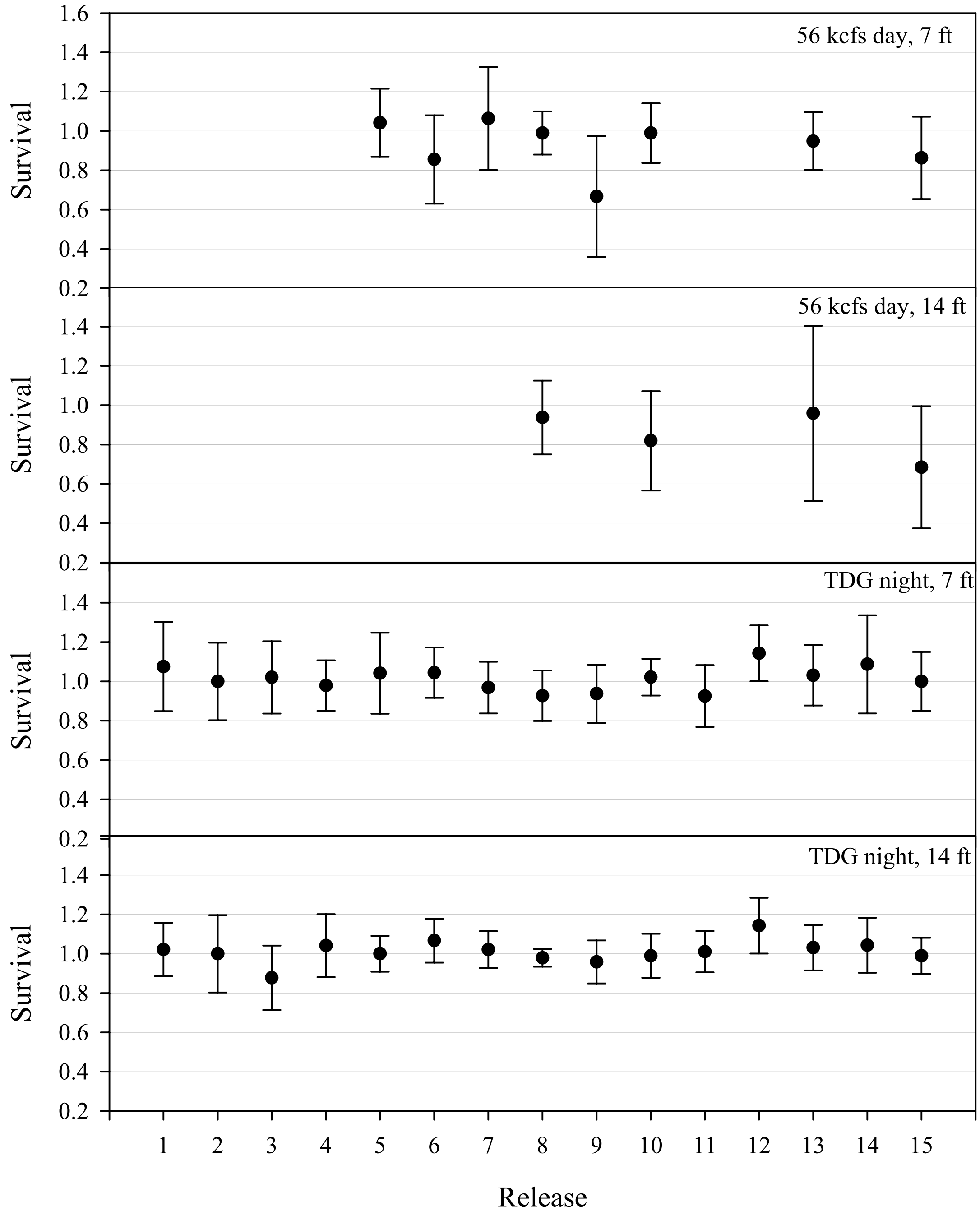


Figure 16. The estimated survival probabilities (95% confidence interval error bars) from paired releases of radio-tagged steelhead trout passing through spillbays with either deflectors located 7 feet or 14 feet above mean sea level at Bonneville Dam under two spill operations (TDG is total dissolved gas cap), by release. The paired release groupings were formed post-hoc from fish released at The Dalles Dam and in the Bonneville Dam tailrace during 2004.

Route-specific Survival Model

Survival estimation

Using capture histories generated from the detections of radio-tagged steelhead trout released at The Dalles Dam and in the tailrace of Bonneville Dam (Table 17), we generated maximum likelihood estimates of the route-specific passage and survival probabilities for steelhead trout through Bonneville Dam (Figure 17). The survival of steelhead trout through the Bonneville Dam spillway was estimated to be 0.979 (SE = 0.011, profile likelihood 95% confidence interval = [0.956, 1.002]). For steelhead trout passing via powerhouse 1 the estimated survival was 0.965 (SE = 0.019, profile likelihood 95% confidence interval [0.926, 0.999]) and for steelhead trout passing via powerhouse 2 turbines the estimated survival was 0.889 (SE = 0.020, profile likelihood 95% confidence interval [0.848, 0.927]). For steelhead trout passing via the powerhouse 2 JBS the estimated survival was 0.951 (SE = 0.021, profile likelihood 95% confidence interval [0.907, 0.989]). The survival of steelhead trout passing via the powerhouse 2 corner collector was estimated to be 1.030 (SE = 0.008, profile likelihood 95% confidence interval [1.014, 1.047]). Steelhead trout dam survival through Bonneville Dam was estimated to be 0.991 (SE = 0.008, profile likelihood 95% confidence interval [0.975, 1.008]) and the project survival was estimated to be 0.897 (SE = 0.009, profile likelihood 95% confidence interval [0.881, 0.915]).

56 kcfs day spill operations

Using capture histories generated from the detections of radio-tagged steelhead trout released at The Dalles Dam and passing Bonneville Dam between 0500 and 2000 hrs during 56 kcfs spill operations (Table 18), we generated maximum likelihood estimates of the route-specific passage and survival probabilities (Figure 18). The survival of steelhead trout through the Bonneville Dam spillway during 56 kcfs day spill operations was estimated to be 0.891 (SE = 0.024, profile likelihood 95% confidence interval [0.840, 0.936]). For steelhead trout passing via powerhouse 1, the estimated survival was 0.966 (SE = 0.020, profile likelihood 95% confidence interval [0.922, 1.003]) and for steelhead trout passing via powerhouse 2 turbines the estimated survival was 0.863 (SE = 0.028, profile likelihood 95% confidence interval [0.804, 0.915]). For steelhead trout passing via the powerhouse 2 JBS, the estimated survival was 0.904 (SE = 0.031, profile likelihood 95% confidence interval [0.837, 0.960]). For steelhead trout passing via the powerhouse 2, corner collector, the estimated survival was 1.018 (SE = 0.010, profile likelihood 95% confidence interval [0.9998, 1.039]). Steelhead trout dam survival through Bonneville Dam was estimated to be 0.980 (SE = 0.010, profile likelihood 95% confidence interval [0.962, 1.001]) and project survival was estimated to be 0.888 (SE = 0.010, profile likelihood 95% confidence interval [0.868, 0.909].

Total dissolved gas cap night spill operations

Using capture histories generated from the detections of radio-tagged steelhead trout released at The Dalles Dam and passed Bonneville Dam between 2000 and 0500 hrs during total dissolved gas cap spill operations (Table 18), we generated maximum likelihood estimates of the route-specific passage and survival probabilities (Figure 19). The survival of steelhead trout through Bonneville Dam spillway during total dissolved gas cap spill operations was estimated to be 1.020 (SE = 0.015, profile likelihood 95% confidence interval [0.992, 1.050]). For steelhead trout passing via powerhouse 1, the estimated survival was 0.940 (SE = 0.041, profile likelihood 95% confidence interval [0.850, 1.009]) and for steelhead trout passing via powerhouse 2 turbines the estimated survival was 0.917 (SE = 0.029, profile likelihood 95% confidence interval [0.857, 0.970]). For steelhead trout passing via the powerhouse 2 JBS, the estimated survival was 1.003 (SE = 0.027, profile likelihood 95% confidence interval [0.944, 1.050]). For steelhead trout passing via the powerhouse 2, corner collector the estimated survival was 1.028 (SE = 0.020, profile likelihood 95% confidence interval [0.985, 1.066]). Steelhead trout dam survival through Bonneville Dam was estimated to be 0.998 (SE = 0.014, 95% profile likelihood confidence interval [0.973, 1.027]) and project survival was estimated to be 0.904 (SE = 0.015, profile likelihood confidence interval [0.876, 0.933]).

Table 17. Counts of radio-tagged steelhead trout for the releases from The Dalles Dam (R_1) and in the tailrace of Bonneville Dam (R_2) used in the route-specific survival model during 2004. Detection history recorded as: 1, detected; 0, not detected. For R_1, the first position indicates the release event, the second position indicates detection or not at Bonneville Dam, the third position indicates detection or not at at least one of the arrays below Bonneville Dam. For R_2, the second position indicates the release event and the third position indicates detection or not at at least one of the arrays below 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. B1 is powerhouse 1 and B2 is powerhouse 2 at Bonneville Dam.

				Within-route histories Bonneville Dam		
Release	Detection History	Route	Counts	11	01	10
R_1 = 4398	100		420			
	101		47			
	110	Spillway	80	792	19	185
	111		916			
	110	B1	30	214	107	0
	111		291			
	110	B2 Turbines	69	260	31	112
	111		334			
	110	B2 Juvenile bypass	29	269	2	2
	111		244			
	110	B2 Corner collector	63	1930	4	4
	111		1875			
R_2 = 1274	010		77			
	011		1197			

Table 18. Counts of radio-tagged steelhead trout for releases from The Dalles Dam (R_1) and in the tailrace of Bonneville Dam (R_2) used in the route-specific survival model during two spill operations: 56 kcfs day (0500-1959) and total dissolved gas cap (TDG) at night in 2004. Detection history recorded as: 1, detected; 0, not detected. For R_1, the first position indicates the release event, the second position indicates detection or not at Bonneville Dam, the third position indicates detection or not at at least one of the arrays below Bonneville Dam. For R_2, the second position indicates the release event and the third position indicates detection or not at at least one of the arrays below 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. B1 is powerhouse 1 and B2 is powerhouse 2 at Bonneville Dam.

56 kcfs day spill operations						
				Within-route histories Bonneville Dam		
Release	Detection History	Route	Counts	11	01	10
$R_1 = 2893$	100		276			
	101		31			
	110	Spillway	40	235	3	25
	111		223			
	110	B1	19	177	59	0
	111		217			
	110	B2 Turbines	38	135	18	45
	111		160			
	110	B2 Juvenile bypass	20	141	2	1
	111		124			
	110	B2 Corner collector	54	1738	3	4
	111		1691			
$R_2 = 671$	010		32			
	011		639			

TDG night spill operations						
				Within-route histories Bonneville Dam		
Release	Detection History	Route	Counts	11	01	10
$R_1 = 1505$	100		144			
	101		16			
	110	Spillway	40	557	16	160
	111		693			
	110	B1	11	37	48	0
	111		74			
	110	B2 Turbines	31	125	13	67
	111		174			
	110	B2 Juvenile bypass	9	128	0	1
	111		120			
	110	B2 Corner collector	9	192	1	0
	111		184			
$R_2 = 603$	010		44			
	011		559			

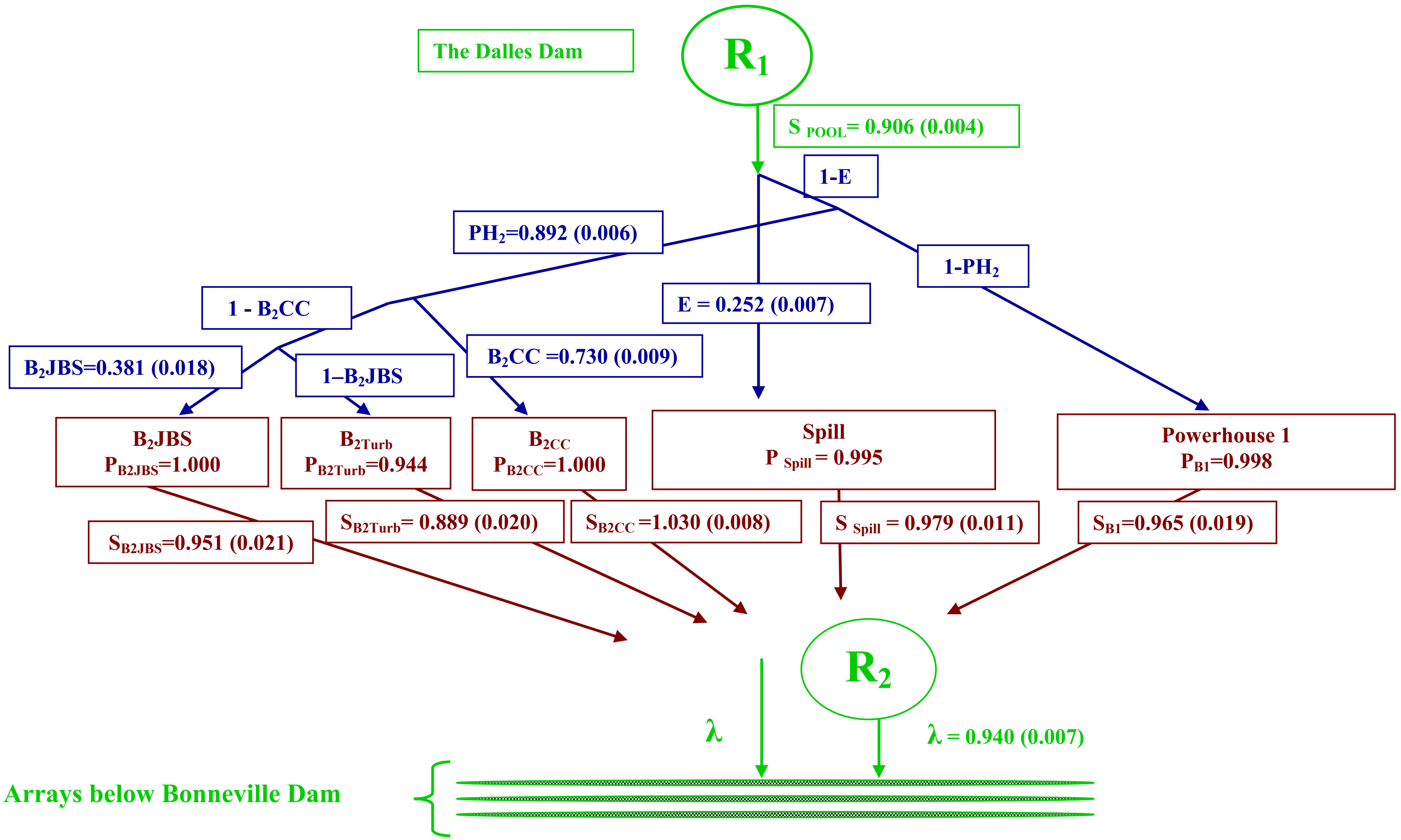


Figure 17. Schematic of estimated route-specific passage and survival parameters for steelhead trout through Bonneville Dam during 2004. Estimated standard errors are in parentheses.

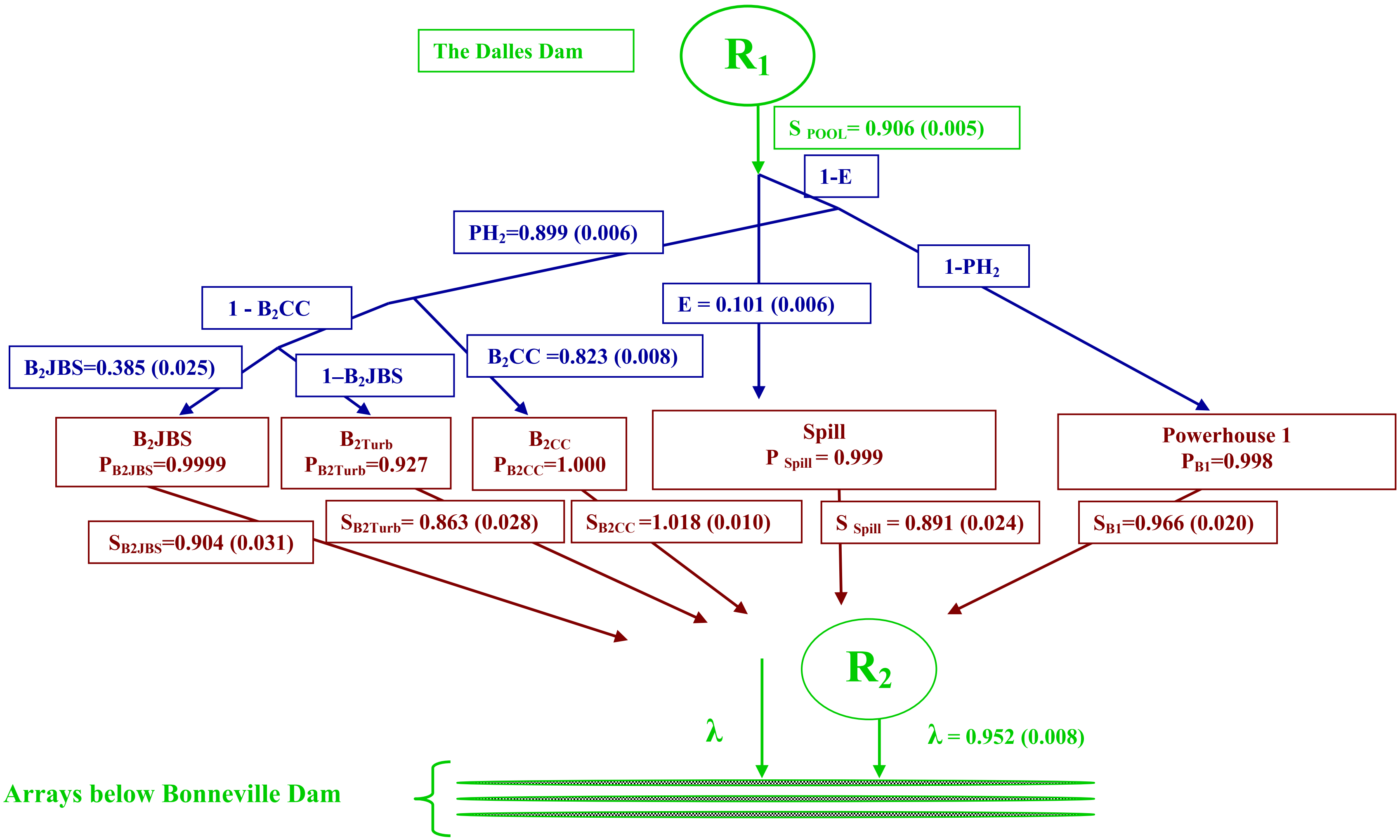


Figure 18. Schematic of estimated route-specific passage and survival parameters for steelhead trout passing during daytime 56 kcfs spill operations through Bonneville Dam 2004. Estimated standard errors are in parentheses.

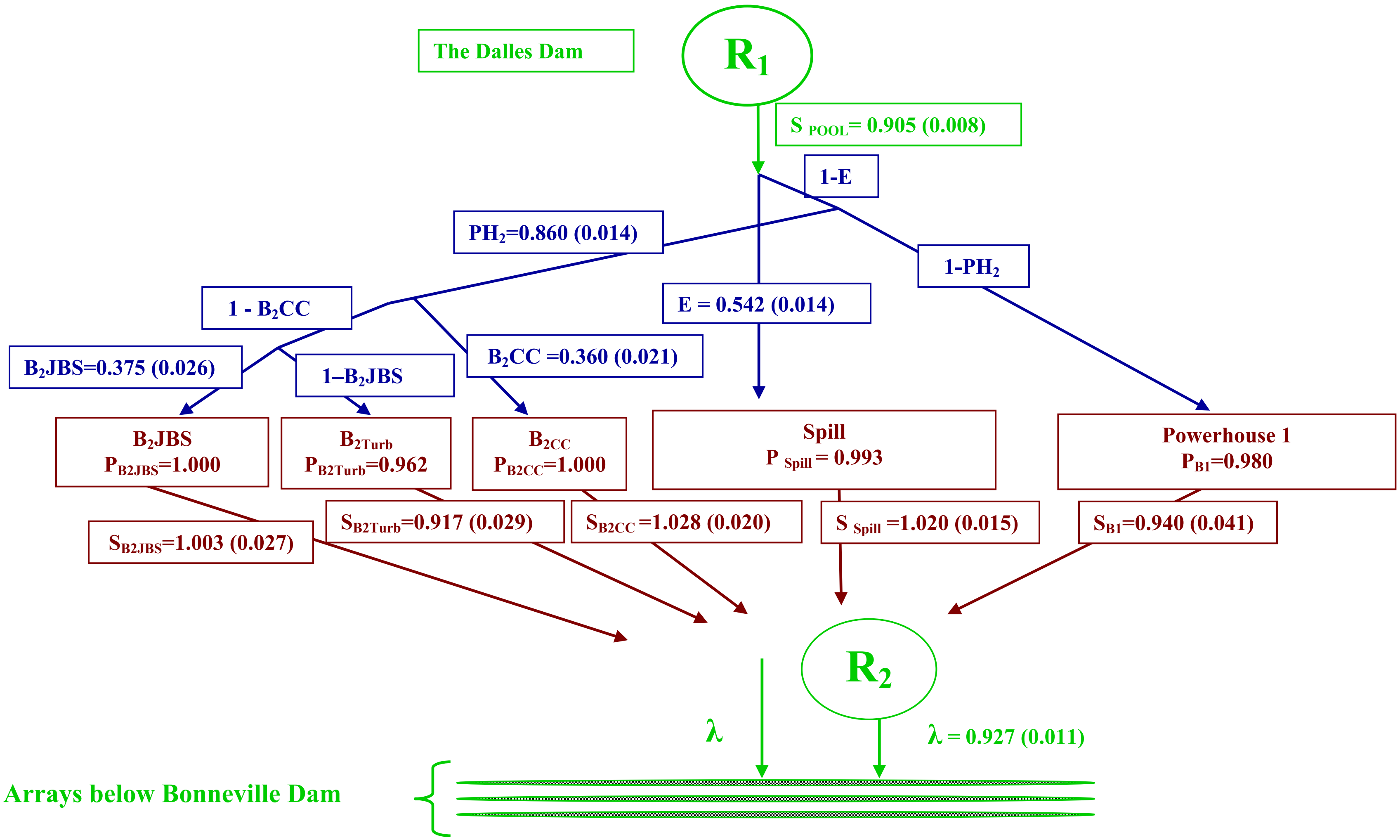


Figure 19. Schematic of estimated route-specific passage and survival parameters for steelhead trout passing during total dissolved gas cap nighttime spill operations through Bonneville Dam 2004. Estimated standard errors are in parentheses.

Comparison of survival during 56 kcfs day and TDG night spill operations

The estimated survival probabilities for steelhead trout passing via the powerhouse 2 JBS and the spillway were found to be significantly different between the two spill operations (Table 19). The dam survival for steelhead trout was not found to be significantly different between 56 kcfs day and TDG night spill operations.

Table 19. Summary table of estimated route-specific survival probabilities (S) and their associated standard errors (SE) of steelhead trout survival through Bonneville Dam (Dam survival) generated from the route-specific survival model. The results of *Z*-tests (i.e., *Z*-statistic) structured to assess whether the estimated survival probabilities during the 56 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.

	56 kcfs day		TDG night		
Passage route	S	SE	S	SE	*Z*
Powerhouse 1	0.966	0.020	0.940	0.041	0.570
Powerhouse 2	0.863	0.028	0.917	0.029	1.340
Corner Collector	1.018	0.010	1.028	0.020	0.447
JBS	0.904	0.031	1.003	0.027	2.408
Spillway	0.891	0.024	1.020	0.015	4.558
Dam Survival	0.980	0.010	0.998	0.014	1.046

Subyearling Chinook salmon

Paired Release-recapture Model

Powerhouse 1 Ice and Trash Sluiceway

Throughout the migration season the MGR and the ice and trash sluiceway, at powerhouse 1 were not operating continuously due to a policy that prioritized the passage of water through powerhouse 2. Because of this policy, powerhouse 1 was only operated sporadically for short time intervals before and after the releases of radio tagged fish associated with this study.

Assumption Tests

Burnham Tests

The results of the Burnham Tests 2 and 3 testing assumptions A5 and A6 for subyearling Chinook salmon released into the ice and trash sluiceway at Bonneville Dam's powerhouse 1 and the corresponding tailrace releases below the powerhouse 2 JBS outfall were mostly 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 4, Table A4.9.

Tests of the assumption of mixing of treatment and control groups

The chi-square tests of homogeneity testing for the similarity in arrival times of paired releases of subyearling Chinook salmon indicated that there were no significant differences in arrival times between the two release groups at the downstream radio-telemetry arrays (Appendix 5, Table A5.9).

Survival Estimation

We estimated the survival of subyearling Chinook salmon released into the ice and trash sluiceway from 21 June to 22 July at Bonneville Dam's powerhouse 1. The control group for this evaluation was released in the tailrace below the outfall of the powerhouse 2 juvenile bypass outfall. The estimated survival of subyearling Chinook salmon released into the ice and trash sluiceway ranged from 0.67 to 1.11 (Table 20), during 2004. The average survival was estimated to be 0.925 (SE = 0.019, 95% confidence interval [0.887, 0.963]).

Comparison of 56 kcfs day/TDG night and 23 kcfs spill operations

The survival of subyearling Chinook salmon released into the ice and trash sluiceway during two spill operations, 56 kcfs during the day and night spill until the total dissolved gas cap of 125% is reached in the tailrace of the dam (56 kcfs day/TDG night) and an alternate operation of 23 kcfs for 24 h (23 kcfs), was also estimated. The average survival of subyearling Chinook salmon through the ice and trash sluiceway during the 56 kcfs day/TDG night spill operations was estimated to be 0.916 (SE = 0.025, 95% confidence interval [0.862, 0.969]). For subyearling Chinook salmon passing via the ice and trash sluiceway during the 23 kcfs spill operations the average survival was estimated to be 0.934 (SE = 0.028, 95% confidence interval [0.875, 0.994]). The average survival of subyearling Chinook salmon during 56 kcfs day/TDG night spill operations was not significantly different than during 23 kcfs spill operations (two-tailed *t*-test, $P = 0.6261$, $\beta = 0.076$).

Comparison of 56 kcfs day and 23 kcfs day spill operations

We also compared the survival of subyearling Chinook salmon during daytime passage between 0400 and 2200 hrs during the two spill operations. Survival of subyearling Chinook salmon through the ice and trash sluiceway during the 56 kcfs spill operations was estimated to be 0.944 (SE = 0.034, 95% confidence interval [0.863, 1.024]). For subyearling Chinook salmon passing via the ice and trash sluiceway during the 23 kcfs daytime spill operations the estimated survival was 0.944 (SE = 0.034, 95% confidence interval [0.863, 1.025]). The average survival of subyearling Chinook salmon during 56 kcfs spill operations was not significantly different than the survival during 23 kcfs day spill operations (two-tailed *t*-test, $P = 0.9950$, $\beta = 0.050$).

Comparison of TDG night and 23 kcfs night spill operations

We also compared the survival of subyearling Chinook salmon during nighttime passage between 2200 and 0400 hrs of TDG spill operations to those during 23 kcfs spill operations. Survival of subyearling Chinook salmon through the ice and trash sluiceway during the TDG spill operations was estimated to be 0.888 (SE = 0.037, 95% confidence interval [0.801, 0.974]). For subyearling Chinook salmon passing via the ice and trash sluiceway during the 23 kcfs night spill operations, the estimated survival was 0.924 (SE = 0.046, 95% confidence interval [0.815, 1.033]). The average survival of subyearling Chinook salmon during TDG spill operations was not significantly different than during 23 kcfs night spill operations (two-tailed *t*-test, P = 0.5433, $\beta = 0.090$).

Table 20. 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 two dam operations, summer 2004. Dam operations were 56 kcfs during the day with total dissolved gas cap at night (56 kcfs /TDG) or 23 kcfs for 24 h. 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. The specific dates and times of the releases can be referenced in Appendix 1.

	Powerhouse 1 Ice and trash sluiceway and downstream tailrace control		
Release	Spill Operations	S	SE
1	56 kcfs/TDG	1.01	0.07
2	56 kcfs/TDG	1.05	0.08
3	23 kcfs	0.87	0.08
4	23 kcfs	1.04	0.16
5	23 kcfs	1.04	0.12
6	23 kcfs	0.80	0.09
7	56 kcfs/TDG	0.97	0.06
8	56 kcfs/TDG	0.86	0.09
9	23 kcfs	1.01	0.09
10	23 kcfs	0.72	0.09
11	56 kcfs/TDG	1.07	0.09
12	56 kcfs/TDG	0.89	0.09
13	23 kcfs	0.92	0.06
14	23 kcfs	0.90	0.06
15[a]	56 kcfs/TDG	0.85	0.08
16[a]	56 kcfs/TDG	0.89	0.09
17	56 kcfs/TDG	1.06	0.14
18	56 kcfs/TDG	0.91	0.10
19	23 kcfs	0.75	0.12
20	23 kcfs	0.86	0.11
21	23 kcfs	0.99	0.04
22	23 kcfs	0.93	0.08
23	56 kcfs/TDG	0.83	0.10
24	56 kcfs/TDG	0.89	0.09
25	56 kcfs/TDG	0.89	0.10
26	56 kcfs/TDG	0.94	0.04
27	23 kcfs	1.01	0.06
28	23 kcfs	1.03	0.02
29	56 kcfs/TDG	0.86	0.09
30	56 kcfs/TDG	0.67	0.12
31	23 kcfs	0.96	0.09
32	23 kcfs	1.11	0.08

[a] – Releases within 24 h of detected radio-tagged dead fish

Spillway Flow Deflectors

7-ft spillbay flow deflectors during two spill operations

Assumption Tests

Burnham Tests

The results of the Burnham Tests 2 and 3 testing assumptions A5 and A6 for the yearling Chinook passing via spillbays with 7-ft deflectors at Bonneville Dam's spillway and the corresponding tailrace releases below the powerhouse 2 JBS outfall were inconclusive due to the number of tests that were incalculable because of the presence of all zeroes in either rows or columns of the contingency table. Of the 78 tests (Test 2) that were calculated 5 indicated lack of fit (P<0.0003, Dunn-Sidak experimentwise error rate), while goodness of fit (Test 3) was not rejected in any of the tests. The results of these tests can be found in Appendix 4, Table A4.12.

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 post-hoc paired releases of subyearling Chinook salmon passing via 7-ft deflectors at Bonneville Dam's spillway and the corresponding tailrace releases below the powerhouse 2 JBS outfall, indicated that there were no significant differences (P< 0.0009, Dunn-Sidak experimentwise error rate) in arrival times between the two groups (Appendix 5, Table A5.12).

Survival estimation

The survival of subyearling Chinook salmon passing via spillbays with 7-ft deflectors at Bonneville Dam spillway during 56 kcfs day and total dissolved gas cap night spill operations ranged from 0.832 to 1.055 ($\bar{X} = 0.920;\ SE = 0.010;\ 95\%\,CI = [0.899, 0.941]$; Table 21). The estimated survival of subyearling Chinook salmon passing via spillbays with 7-ft deflectors during 23 kcfs spill operations ranged from 0.583 to 1.000 ($\bar{X} = 0.822;\ SE = 0.033;\ 95\%\,CI = [0.758, 0.886]$; Table 22).

Table 21. The estimated survival probabilities (S), standard errors (SE), 95% confidence intervals, the number released (N), and dates and times associated with paired releases of radio-tagged subyearling Chinook salmon passing via spillbays with deflectors located 7 feet above mean sea level during 24 h spill with 56 kcfs during the day and night spill until the total dissolved gas cap of 125% is reached in the tailrace. The paired release groups were formed post-hoc from fish released at The Dalles Dam (treatment) and in the Bonneville Dam tailrace (control) during 2004.

Release	S	SE	95% CI		Treatment N	Control N	Start date	time	End date	time
1	1.055	0.048	0.961,	1.149	50	112	21-Jun	07:00	22-Jun	07:00
2	0.890	0.041	0.810,	0.970	55	175	25-Jun	19:00	27-Jun	07:00
3	0.980	0.032	0.917,	1.042	35	115	27-Jun	07:00	28-Jun	07:00
4	0.938	0.056	0.828,	1.047	38	189	29-Jun	19:00	01-Jul	07:00
5	0.894	0.077	0.743,	1.044	31	112	01-Jul	07:00	02-Jul	07:00
6	0.889	0.051	0.788,	0.989	53	234	03-Jul	19:00	05-Jul	19:00
7	0.926	0.076	0.777,	1.076	24	111	05-Jul	19:00	06-Jul	19:00
8	0.883	0.067	0.753,	1.013	40	182	06-Jul	19:00	08-Jul	07:00
9	0.897	0.055	0.790,	1.004	44	168	11-Jul	19:00	13-Jul	07:00
10	0.832	0.066	0.703,	0.960	56	120	13-Jul	07:00	14-Jul	07:00
11	0.896	0.065	0.768,	1.024	36	138	14-Jul	07:00	15-Jul	07:00
12	0.837	0.102	0.638,	1.036	21	91	15-Jul	07:00	16-Jul	07:00
13	1.000	0.038	0.926,	1.074	48	150	17-Jul	19:00	18-Jul	19:00
14	0.947	0.061	0.827,	1.067	36	80	18-Jul	19:00	19-Jul	07:00
15	0.948	0.056	0.839,	1.057	41	159	19-Jul	07:00	20-Jul	07:00
16	0.923	0.059	0.808,	1.038	61	253	23-Jul	19:00	24-Jul	19:00
17	0.879	0.062	0.757,	1.001	82	145	24-Jul	19:00	25-Jul	07:00
18	0.925	0.068	0.792,	1.057	35	145	25-Jul	07:00	25-Jul	19:00
19	0.862	0.086	0.694,	1.030	40	141	25-Jul	19:00	26-Jul	07:00
20	0.979	0.057	0.867,	1.091	34	143	26-Jul	07:00	26-Jul	19:00
21	0.913	0.072	0.773,	1.054	36	121	26-Jul	19:00	27-Jul	07:00
22	0.950	0.052	0.848,	1.052	32	121	27-Jul	07:00	27-Jul	19:00
23	0.909	0.085	0.742,	1.076	34	142	27-Jul	19:00	28-Jul	07:00
24	0.927	0.063	0.803,	1.051	31	293	29-Jul	19:00	30-Jul	19:00
25	0.920	0.086	0.753,	1.088	34	147	30-Jul	19:00	01-Aug	07:00

Table 22. The estimated survival probabilities (S), standard errors (SE), 95% confidence intervals, number released (N), and dates and times associated with paired releases of radio-tagged subyearling Chinook salmon passing via spillbays with deflectors located 7 feet above mean sea level during 23 kcfs 24 h spill operations at Bonneville Dam. The paired release groups were formed post-hoc from fish released at The Dalles Dam (treatment) and in the Bonneville Dam tailrace (control) during 2004.

Release	S	SE	95% CI		Treatment N	Control N	Start date	time	End date	time
1	0.824	0.048	0.731,	0.917	16	168	21-Jun	19:00	23-Jun	07:00
2	0.755	0.102	0.555,	0.956	22	176	23-Jun	07:00	24-Jun	19:00
3	1.000	0.030	0.941,	1.059	30	180	24-Jun	19:00	26-Jun	07:00
4	0.866	0.114	0.643,	1.089	12	242	27-Jun	19:00	30-Jun	07:00
5	0.583	0.125	0.338,	0.829	18	231	01-Jul	19:00	04-Jul	07:00
6	0.594	0.115	0.368,	0.820	23	184	08-Jul	07:00	09-Jul	19:00
7	0.698	0.104	0.493,	0.903	24	294	09-Jul	19:00	12-Jul	07:00
8	0.917	0.063	0.793,	1.041	36	299	16-Jul	07:00	18-Jul	07:00
9	0.863	0.086	0.694,	1.032	27	161	19-Jul	19:00	20-Jul	19:00
10	0.813	0.106	0.606,	1.019	18	150	20-Jul	19:00	21-Jul	19:00
11	0.906	0.111	0.689,	1.123	21	136	21-Jul	19:00	22-Jul	19:00
12	0.859	0.089	0.684,	1.033	30	252	22-Jul	19:00	24-Jul	07:00
13	0.909	0.093	0.726,	1.092	24	435	27-Jul	19:00	29-Jul	07:00
14	0.916	0.086	0.746,	1.085	21	285	29-Jul	07:00	30-Jul	07:00

14-ft Flow Spillbay Deflectors during two spill operations

Assumption Tests

Burnham Tests

The results of the Burnham Tests 2 and 3 testing assumptions A5 and A6 for the subyearling Chinook salmon passing via spillbays with 14-ft deflectors at Bonneville Dam's spillway and the corresponding tailrace releases below the powerhouse 2 JBS outfall were mostly incalculable because of the presence of all zeroes in either rows or columns of the contingency table. Of the 74 tests (Test 2) that were calculated 3 tests indicated lack of fit ($P <$ 0.0003, Dunn-Sidak experimentwise error rate) while goodness of fit was not rejected for any of the tests (Test 3). The results of these tests can be found in Appendix 4, Table A4.12.

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 post-hoc paired releases of subyearling Chinook salmon passing via 14-ft deflectors at Bonneville Dam's spillway and the corresponding tailrace releases below the powerhouse 2 JBS outfall, indicated that there were no significant ($P <$ 0.0007, Dunn-Sidak experimentwise error rate) in arrival times between the two groups (Appendix 5, Table A5.12).

Survival estimation

The survival of subyearling Chinook salmon passing via spillbays with 14-ft deflectors at Bonneville Dam spillway during 56 kcfs day and total dissolved gas cap night spill operations ranged from 0.552 to 1.066 ($\bar{X} = 0.803$; $SE = 0.026$; $95\%\, CI = [0.749, 0.857]$; Table 23). The estimated survival of subyearling Chinook salmon passing via spillbays with 14-ft deflectors during 23 kcfs spill operations ranged from 0.553 to 0.913 ($\bar{X} = 0.741$; $SE = 0.027$; $95\%\, CI = [0.683, 0.799]$; Table 24).

Table 23. The estimated survival probabilities (S), standard errors (SE), 95% confidence intervals, number released (N), and dates and times associated with paired releases of radio-tagged subyearling Chinook salmon passing via spillbays with deflectors located 14 feet above mean sea level during 24 h spill with 56 kcfs during the day and night spill until the total dissolved gas cap of 125% is reached in the tailrace. The paired release groups were formed post-hoc from fish released at The Dalles Dam (treatment) and in the Bonneville Dam tailrace (control) during 2004.

Release	S	SE	95% CI		Treatment N	Control N	Start date	time	End date	time
1	1.066	0.048	0.971,	1.160	32	112	21-Jun	07:00	22-Jun	07:00
2	0.880	0.061	0.761,	0.999	30	175	25-Jun	19:00	27-Jun	07:00
3	0.616	0.101	0.418,	0.815	25	115	27Jun	07:00	28-Jun	07:00
4	0.760	0.116	0.534,	0.987	27	189	29-Jun	19:00	01-Jul	07:00
5	0.947	0.067	0.816,	1.078	27	112	01-Jul	07:00	02-Jul	07:00
6	0.566	0.101	0.367,	0.764	27	234	03-Jul	19:00	05-Jul	19:00
7	0.779	0.086	0.611,	0.947	27	111	05-Jul	19:00	06-Jul	19:00
8	0.872	0.077	0.722,	1.023	27	182	06-Jul	19:00	08-Jul	07:00
9	0.845	0.064	0.719,	0.971	38	168	11-Jul	19:00	13-Jul	07:00
10	0.716	0.106	0.507,	0.924	21	120	13-Jul	07:00	14-Jul	07:00
11	0.833	0.075	0.686,	0.980	34	138	14-Jul	07:00	15-Jul	07:00
12	1.033	0.073	0.889,	1.176	17	91	15-Jul	07:00	16-Jul	07:00
13	0.552	0.115	0.326,	0.778	21	150	17-Jul	19:00	18-Jul	19:00
14	0.862	0.089	0.686,	1.037	26	80	18-Jul	19:00	19-Jul	07:00
15	0.896	0.065	0.768,	1.024	35	159	19-Jul	07:00	20-Jul	07:00
16	0.728	0.078	0.576,	0.881	49	253	23-Jul	19:00	24-Jul	19:00
17	0.835	0.082	0.675,	0.995	41	145	24-Jul	19:00	25-Jul	07:00
18	0.946	0.078	0.793,	1.099	23	145	25-Jul	07:00	25-Jul	19:00
19	0.782	0.107	0.572,	0.991	28	141	25-Jul	19:00	26-Jul	07:00
20	0.745	0.087	0.575,	0.914	32	143	26-Jul	07:00	26-Jul	19:00
21	0.903	0.061	0.783,	1.023	48	121	26-Jul	19:00	27-Jul	07:00
22	0.610	0.130	0.355,	0.865	15	121	27-Jul	07:00	27-Jul	19:00
23	0.830	0.095	0.643,	1.016	33	142	27-Jul	19:00	28-Jul	07:00
24	0.708	0.084	0.544,	0.872	33	293	29-Jul	19:00	30-Jul	19:00
25	0.773	0.084	0.608,	0.937	42	174	30-Jul	19:00	01-Aug	07:00

Table 24. The estimated survival probabilities (S), standard errors (SE), 95% confidence intervals, number released (N; number of fish), and dates and times associated with paired releases of radio-tagged subyearling Chinook salmon passing via spillbays with deflectors located 14 feet above mean sea level during 23 kcfs, 24 h spill operations at Bonneville Dam. The paired release groups were formed post-hoc from fish released at The Dalles Dam (treatment) and in the Bonneville Dam tailrace (control) during 2004.

Release	S	SE	95% CI		Treatment N	Control N	Start date	time	End date	time
1	0.846	0.111	0.628,	1.065	17	168	21-Jun	19:00	23-Jun	07:00
2	0.643	0.123	0.403,	0.883	16	176	23-Jun	07:00	24-Jun	19:00
3	0.553	0.086	0.385,	0.722	39	180	24-Jun	19:00	26-Jun	07:00
4	0.680	0.103	0.478,	0.883	23	242	27-Jun	19:00	30-Jun	07:00
5	0.833	0.073	0.689,	0.977	29	286	01-Jul	19:00	04-Jul	07:00
6	0.844	0.085	0.677,	1.011	25	184	08-Jul	07:00	09-Jul	19:00
7	0.781	0.094	0.597,	0.966	24	294	09-Jul	19:00	12-Jul	07:00
8	0.760	0.115	0.535,	0.986	18	299	16-Jul	07:00	18-Jul	07:00
9	0.674	0.117	0.445,	0.902	19	161	19-Jul	19:00	20-Jul	19:00
10	0.688	0.095	0.502,	0.873	26	150	20-Jul	19:00	21-Jul	19:00
11	0.779	0.097	0.589,	0.969	35	136	21-Jul	19:00	22-Jul	19:00
12	0.913	0.058	0.800,	1.026	62	252	22-Jul	19:00	24-Jul	07:00
13	0.648	0.092	0.467,	0.828	41	435	27-Jul	19:00	29-Jul	07:00
14	0.726	0.086	0.559,	0.894	33	285	29-Jul	07:00	30-Jul	07:00

Comparison of subyearling Chinook salmon survival estimates for 7-ft and 14-ft spillbay deflectors during two spill operations

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 (Figures 20 and 21) for both spill conditions. Survival point estimates for subyearling Chinook salmon passing through both the 7-ft and the 14-ft spillbay deflectors were higher during the 56 kcfs day and total dissolved gas cap night spill operations than during the 23 kcfs 24 h spill operations.

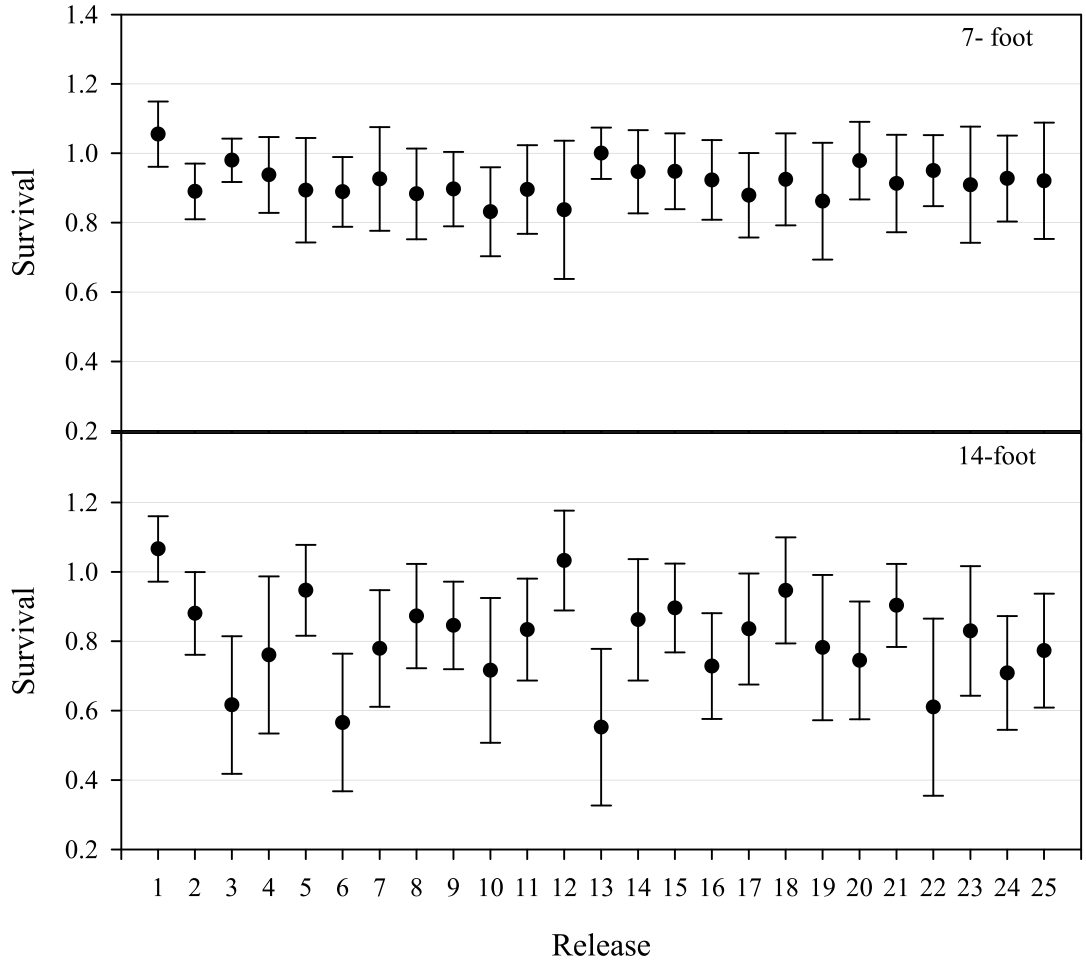


Figure 20. The estimated survival probabilities (95% CI error bars) from paired releases of radio-tagged subyearling Chinook salmon passing through spillbays with either deflectors located at 7 feet or 14 feet above mean sea level at Bonneville Dam under the 56 kcfs day/total dissolved gas night spill operation, by release. The paired release groupings were formed post-hoc from fish released at The Dalles Dam (treatment) and in the Bonneville Dam tailrace (control) during 2004.

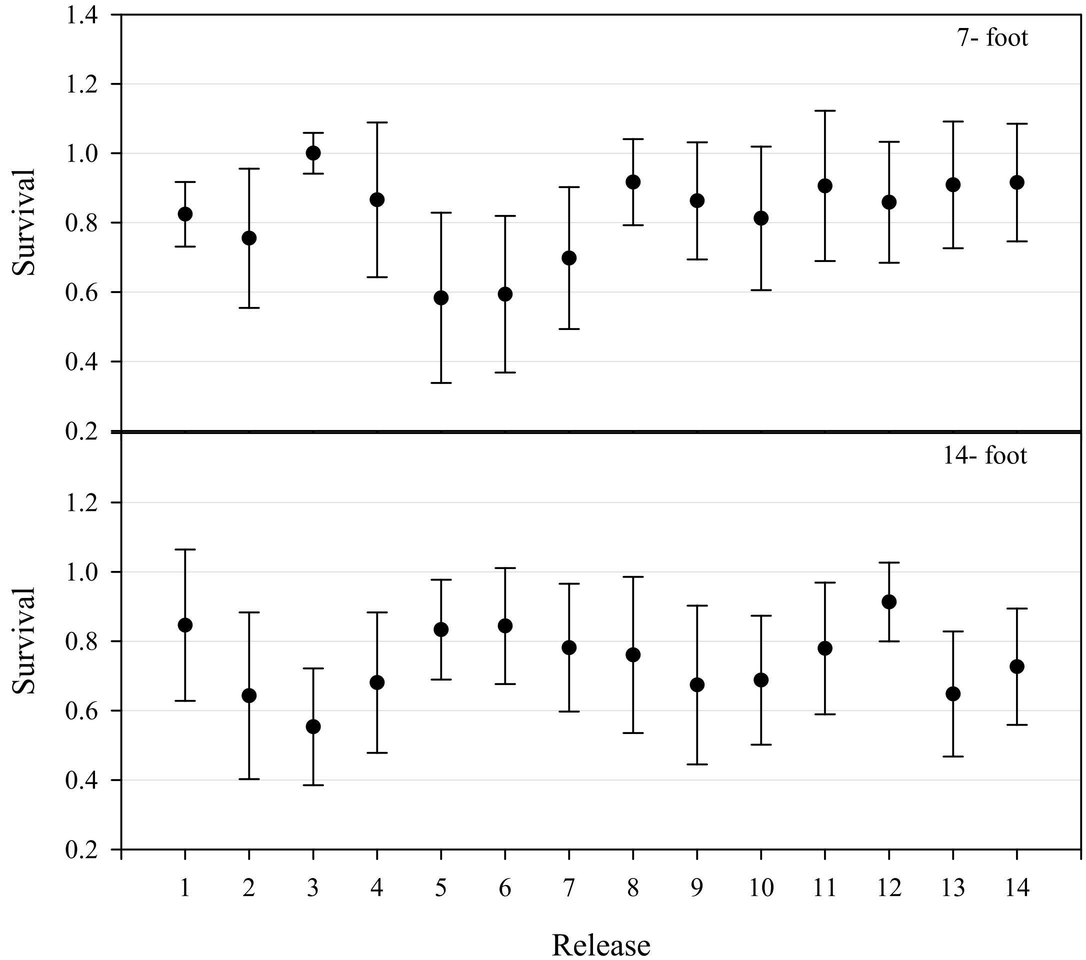


Figure 21. The estimated survival probabilities (95% CI error bars) from paired releases of radio-tagged subyearling Chinook salmon passing through spillbays with either deflectors located at 7 feet or 14 feet above mean sea level at Bonneville Dam under 24 h, 23 kcfs spill, by release. The paired release groupings were formed post-hoc from fish released at The Dalles Dam (treatment) and in the Bonneville Dam tailrace (control) during 2004.

Route-specific Survival Model

Using capture histories generated from the detections of radio-tagged subyearling Chinook salmon (Table 25) released at The Dalles Dam and in the tailrace of Bonneville Dam, we generated maximum likelihood estimates of the route-specific passage and survival probabilities for subyearling Chinook salmon through Bonneville Dam during two spill operations from 20 June to 22 July (Figures 22 and 23). The two spill operations tested were 56 kcfs during the day (0400 to 2200 hrs) and night spill until 125% total dissolved gas cap was reached in the tailrace (56 kcfs day/TDG night) and 24 hr spill operations of 23 kcfs (23 kcfs).

56 kcfs day/TDG night spill operations

During the 56 kcfs day/TDG night spill operations, the survival of subyearling Chinook salmon through the Bonneville Dam spillway was estimated to be 0.877 (SE = 0.013 profile likelihood 95% confidence interval [0.848, 0.902]). For subyearling Chinook salmon passing via powerhouse 1, the estimated survival was 0.827 (SE = 0.061, profile likelihood 95% confidence interval [0.694, 0.937]) and for subyearling Chinook salmon passing via powerhouse 2 turbines, the estimated survival was 0.824 (SE = 0.020, profile likelihood 95% confidence interval [0.782, 0.864]). For subyearling Chinook salmon passing via the powerhouse 2 JBS during the 56 kcfs day/TDG night dam operations, the estimated survival was 0.927 (SE = 0.027, profile likelihood 95% confidence interval [0.863, 0.976]). For subyearling Chinook salmon passing via the powerhouse 2 corner collector the estimated survival was 0.981 (SE = 0.013, profile likelihood 95% confidence interval [0.951, 1.005]). Subyearling Chinook salmon dam survival through Bonneville Dam was estimated to be 0.891 (SE = 0.010, profile likelihood 95% confidence interval [0.871, 0.910) and project survival was estimated to be 0.768 (SE = 0.010, profile likelihood 95% confidence interval [0.747, 0.788].

56 kcfs day spill operations

During the 56 kcfs spill operations the survival of subyearling Chinook salmon through the Bonneville Dam spillway was estimated to be 0.851 (SE = 0.016 profile likelihood 95% confidence interval [0.819, 0.883]). For subyearling Chinook salmon passing via powerhouse 1, the estimated survival was 0.845 (SE = 0.059, profile likelihood 95% confidence interval [0.715, 0.943]) and for subyearling Chinook salmon passing via powerhouse 2 turbines during the 56 kcfs spill operations the estimated survival was 0.834 (SE = 0.021, profile likelihood 95% confidence interval [0.792, 0.873]). For subyearling Chinook salmon passing via the powerhouse 2 JBS the estimated survival was 0.900 (SE = 0.031, profile likelihood 95% confidence interval [0.833, 0.955]). For subyearling Chinook salmon passing via the powerhouse 2 corner collector the estimated survival was 0.966 (SE = 0.014, profile likelihood 95% confidence interval [0.937, 0.991]). Subyearling Chinook salmon dam survival through Bonneville Dam was estimated to be 0.882 (SE = 0.011, 95% confidence interval [0.861, 0.903) and project survival was estimated to be 0.763 (SE = 0.012, profile likelihood 95% confidence interval [0.741, 0.785]).

Total dissolved gas night spill operations

During the TDG spill operations, the survival of subyearling Chinook salmon through the Bonneville Dam spillway was estimated to be 0.913 (SE = 0.021 profile likelihood 95% confidence interval [0.869, 0.953]). For subyearling Chinook salmon passing via powerhouse 1, the estimated survival was 0.519 (SE = 0.266, profile likelihood 95% confidence interval [0.109, 0.947]) and for subyearling Chinook salmon passing via powerhouse 2 turbines the estimated survival was 0.696 (SE = 0.062, profile likelihood 95% confidence interval [0.570, 0.810]). For subyearling Chinook salmon passing via the powerhouse 2 JBS the estimated survival was 0.998 (SE = 0.048, profile likelihood 95% confidence interval [0.868, 1.060]). For subyearling Chinook salmon passing via the powerhouse 2 corner collector the estimated survival was 1.009 (SE = 0.041, profile likelihood 95% confidence interval [0.898, 1.063]). Subyearling Chinook salmon dam survival through Bonneville Dam was estimated to be 0.887 (SE = 0.022, profile likelihood 95% confidence interval [0.847, 0.925) and project survival was estimated to be 0.757 (SE = 0.023, profile likelihood 95% confidence interval [0.715, 0.797]).

23 kcfs 24 h spill operations

During the 23 kcfs spill operations the survival of subyearling Chinook salmon through the Bonneville Dam spillway was estimated to be 0.744 (SE = 0.022, profile likelihood 95% confidence interval [0.700, 0.786]). For subyearling Chinook salmon passing via powerhouse 1 the estimated survival was 0.829 (SE = 0.030, profile likelihood 95% confidence interval [0.767, 0.884]) and for subyearling Chinook salmon passing via powerhouse 2 turbines the estimated survival was 0.833 (SE = 0.014, profile likelihood 95% confidence interval [0.805, 0.860]). For subyearling Chinook salmon passing via the JBS the estimated survival was 0.958 (SE = 0.019, profile likelihood 95% confidence interval [0.918, 0.991]) and passing via the corner collector at powerhouse 2 the estimated survival was 0.954 (SE = 0.013, profile likelihood 95% confidence interval [0.926, 0.978]). Subyearling Chinook salmon survival through Bonneville Dam was estimated to be 0.858 (SE = 0.010, profile likelihood 95% confidence interval [0.840, 0.876]) and project survival was estimated to be 0.736 (SE = 0.010, profile likelihood 95% confidence interval [0.717, 0.754]).

23 kcfs day spill operations

For subyearling Chinook salmon passing during day (0400 to 2200 hrs) 23 kcfs spill operations, survival through the Bonneville Dam spillway was estimated to be 0.725 (SE = 0.025, profile likelihood 95% confidence interval [0.675, 0.773]). For subyearling Chinook salmon passing via powerhouse 1 the estimated survival was 0.826 (SE = 0.033, profile likelihood 95% confidence interval [0.758, 0.886]) and for subyearling Chinook salmon passing via powerhouse 2 turbines, the estimated survival was 0.820 (SE = 0.017, profile likelihood 95% confidence interval [0.785, 0.853]). For subyearling Chinook salmon passing via the powerhouse 2 JBS, the estimated survival was 0.957 (SE = 0.024, profile likelihood 95% confidence interval [0.906, 0.999]). For subyearling Chinook salmon passing via the powerhouse 2 corner collector the estimated survival was 0.955 (SE = 0.015, profile likelihood 95% confidence interval [0.926, 0.983]). Subyearling Chinook salmon dam survival through Bonneville Dam was estimated to be 0.852 (SE = 0.012, profile likelihood 95% confidence interval [0.831, 0.875]) and project survival was estimated to be 0.731 (SE = 0.012, profile likelihood 95% confidence interval [0.710, 0.753]).

23 kcfs night spill operations

For subyearling Chinook salmon passing during the night (2200 to 0400 hrs) 23 kcfs spill operations, survival through the Bonneville Dam spillway was estimated to be 0.830 (SE = 0.045, profile likelihood 95% confidence interval [0.735, 0.909]). For subyearling Chinook salmon passing via powerhouse 1 the estimated survival was 0.863 (SE = 0.077, profile likelihood 95% confidence interval [0.687, 0.982]) and for subyearling Chinook salmon passing via powerhouse 2 turbines, the estimated survival was 0.864 (SE = 0.023, profile likelihood 95% confidence interval [0.818, 0.907]). For subyearling Chinook salmon passing via the powerhouse 2 JBS the estimated survival was 0.960 (SE = 0.030, profile likelihood 95% confidence interval [0.891, 1.010]). For subyearling Chinook salmon passing via the powerhouse 2, corner collector the estimated survival was 0.959 (SE = 0.045, profile likelihood 95% confidence interval [0.847, 1.025]). Subyearling Chinook salmon dam survival through Bonneville Dam was estimated to be 0.881 (SE = 0.019, profile likelihood 95% confidence interval [0.847, 0.914]) and project survival was estimated to be 0.755 (SE = 0.020, profile likelihood 95% confidence interval [0.719, 0.791]).

Table 25. 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 two spill operations: 56 kcfs day/total dissolve gas cap at night (TDG) and 23 kcfs for 24 h used in the route-specific survival model during 2004. Detection history recorded as: 1, detected; 0, not detected. For R_1, the first position indicates the release event, the second position indicates detection or not at Bonneville Dam, the third position indicates detection or not at at least one of the arrays below Bonneville Dam. For R_2, the second position indicates the release event and the third position indicates detection or not at at least one of the arrays below 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. B1 is powerhouse 1 and B2 is powerhouse 2 at Bonneville Dam.

56 kcfs day/TDG night spill operations

Release	Detection History	Route	Counts	Within-route histories Bonneville Dam 11	01	10
R_1 = 2714	100		385			
	101		35			
	110	Spillway	176	863	11	168
	111		866			
	110	B1	11	40	12	0
	111		41			
	110	B2 Turbines	108	251	55	190
	111		388			
	110	B2 Juvenile bypass	20	162	1	2
	111		145			
	110	B2 Corner collector	38	530	2	7
	111		501			
R_2 = 1835	010		94			
	011		1741			

23 kcfs for 24 h spill operations

Release	Detection History	Route	Counts	Within-route histories Bonneville Dam 11	01	10
R_1 = 3269	100		483			
	101		61			
	110	Spillway	146	410	15	71
	111		350			
	110	B1	46	148	67	0
	111		169			
	110	B2 Turbines	225	504	93	478
	111		850			
	110	B2 Juvenile bypass	27	289	1	3
	111		266			
	110	B2 Corner collector	62	625	4	17
	111		584			
R_2 = 1960	010		102			
	011		1858			

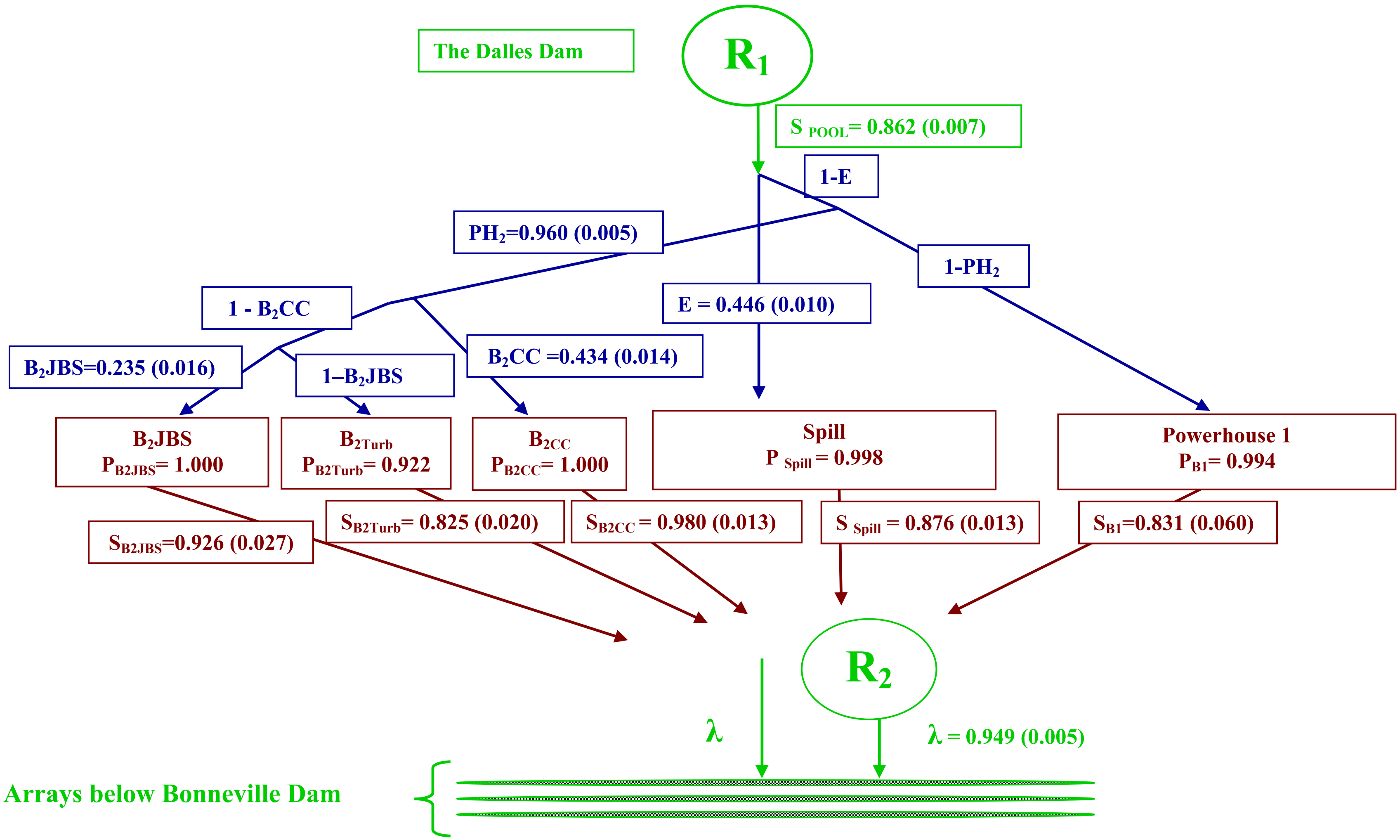


Figure 22. Schematic of estimated route-specific passage and survival parameters for subyearling Chinook salmon through Bonneville dam during 20 June through 22 July, during 56 kcfs day and total dissolved gas cap at night spill operations in 2004. Estimated standard errors are in parentheses.

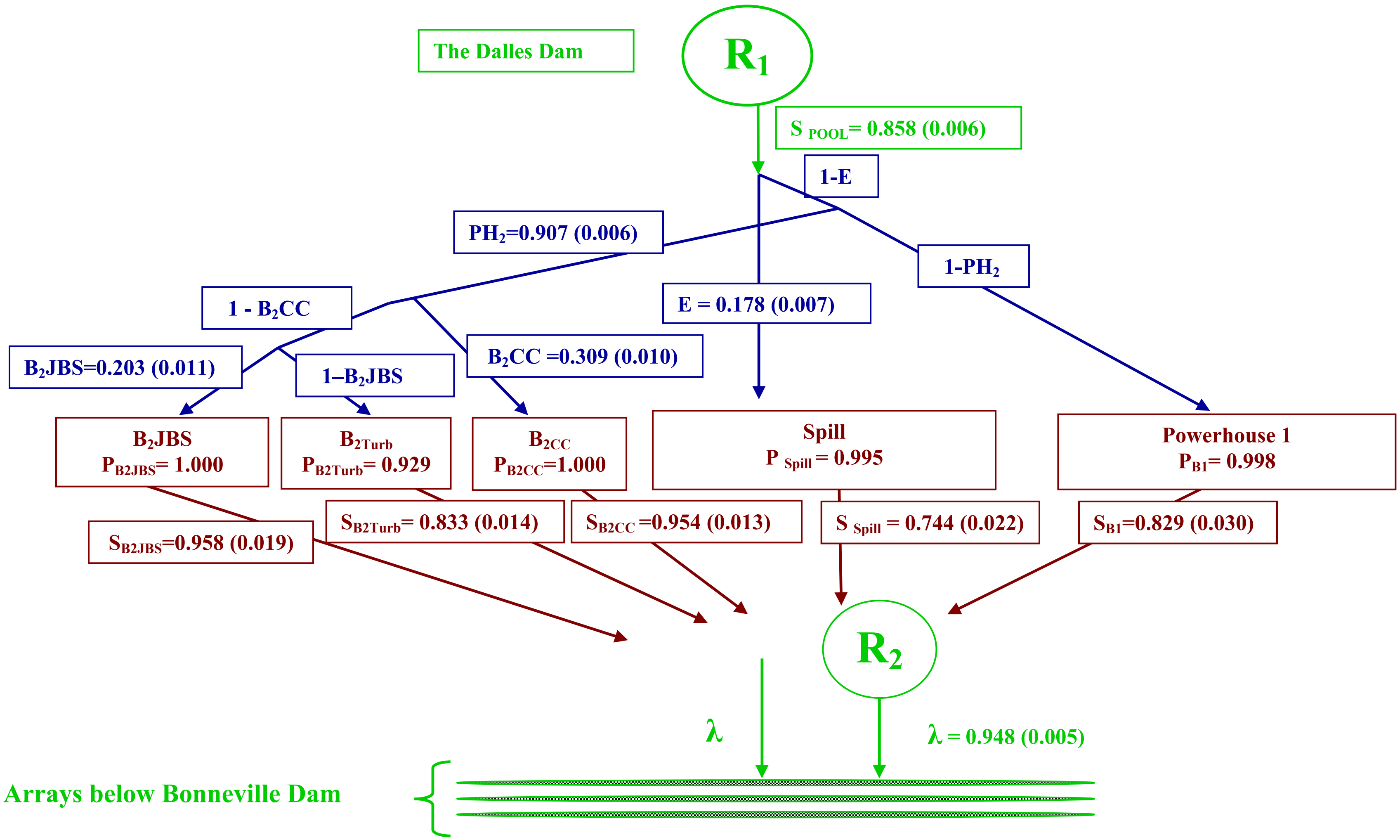


Figure 23. Schematic of estimated route-specific passage and survival parameters for subyearling Chinook salmon through Bonneville dam during 20 June through 22 July, during 23 kcfs 24 h spill operations in 2004. Estimated standard errors are in parentheses.

Comparison of survival during 56 kcfs/TDG and 23 kcfs for 24 h spill operations

The estimated survival probabilities for subyearling Chinook salmon passing via the powerhouse 1 and 2 turbines, and the powerhouse 2 corner collector and JBS were not found to be significantly different between the two spill operations. However, the estimated survival of subyearling Chinook salmon passing via the spillway was significantly different for fish passing during the 56 kcfs day/TDG night spill operations and the 23 kcfs spill operations (Table 26). The estimated dam survival for fish passing during the two spill operations was also found to be significantly different.

Table 26. Summary table of estimated route-specific survival probabilities (S) and their associated standard errors (SE) of subyearling Chinook salmon survival through Bonneville Dam (Dam survival) generated from the route-specific survival model at Bonneville Dam during 20 June to 22 July 2004. The results of *Z*-tests (i.e., *Z*-statistic and *P*-value) structured to assess whether the estimated survival probabilities during the 56 kcfs day/TDG night spill operations were different than the estimated survival probabilities during the 23 kcfs 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.

	56 kcfs day/TDG night		23 kcfs		
Passage route	S	SE	S	SE	*Z*
Powerhouse 1	0.827	0.061	0.829	0.030	0.029
Powerhouse 2	0.824	0.020	0.833	0.014	0.369
Corner Collector	0.981	0.013	0.954	0.013	1.469
JBS	0.927	0.027	0.958	0.019	0.939
Spillway	0.877	0.013	0.744	0.022	5.205
Dam Survival	0.891	0.010	0.858	0.010	2.333

Discussion

During our study, the Army Corps of Engineers identified a discrepancy between the reported inflow (The Dalles outflow + tributary inflow) and outflow from Bonneville Dam during times of spill. The reported spillway discharge was greater than the actual discharge (as measured downstream of the dam). Two issues resulted in this discrepancy. The spillway gate hoist mechanism had been miscalibrated and the spillway rating curve had not been updated when the spill gate lip changed from a rounded to a sharp edged design in the 1970's. The greatest impact of the gate miscalibration was on discharges with small gate openings, magnified by the spill pattern adopted in 2002 that utilized more gates at smaller openings for a given flow. The magnitude of this discrepancy varied but was on the order of 20 kcfs less than what had been reported (see: Bonneville Lock and Dam, Revision to Fish Passage Plan Spill Patterns FEB2005, Memorandum; Appendix 6).

During our evaluation of survival through the MGR and the ice and trash sluiceway at powerhouse 1, the powerhouse 1 was not continuously operated because of a policy that prioritized the passage of water through powerhouse 2. Instead it was operated sporadically for short time intervals before and after the time of our site-specific releases into the MGR turbine unit and the ice and trash sluiceway. Consequently, 14% and 6% of the total discharge during spring and summer study periods passed through 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 higher than for all other passage routes at Bonneville Dam, 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 51% of the overall discharge was passed through powerhouse 2, with 27% discharge through the spillway and 19% 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.

The point estimate of dam survival during 2004 is lower than the estimated dam survival during 2002. The priority to pass water through the powerhouse 2 during 2004 could have effected overall survival through Bonneville Dam. Further, in 2002, an additional day spill condition allowing discharge until the total dissolved gas cap of 125% was reached in the tailrace was evaluated. In 2002, 46% of the overall discharge passed through the spillway, 40% via powerhouse 2, and 14% through powerhouse 1 (Evans et al. 2003). The miscalibration error resulting in spillway discharge during 2004 being less than the recommended BIOP spill may have influenced the relatively low survival observed at the spillway. Despite the higher survival for fish passing via the new powerhouse 2 corner collector, 43% of yearling Chinook salmon at powerhouse 2 still passed unguided via the turbines.

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, the route-specific survival estimates were higher during the higher spill operation of 56 kcfs day/TDG night spill than for the 23 kcfs spill 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 we observed are likely a result of the different proportions of total discharge through the various routes (i.e. during the 56 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 turbines and the corner collector).

Evans et al. (2005) evaluated passage of subyearling Chinook salmon released from John Day Dam and The Dalles Dam and passed at Bonneville Dam, their results indicated 60% fish passed at powerhouse 2, 35% at the spillway, and 5% at powerhouse 1 for the season. This follows the proportion of total discharge through each route of 56% at powerhouse 2, 34% at the spillway, and 6% through powerhouse 1. It was also noted that during the 56 kcfs day/TDG night spill operations 50% of the subyearling Chinook salmon passed via the spillway, where 47% of the total discharge was apportioned. During the 23 kcfs spill operation, 72% of the subyearling Chinook salmon passed via the powerhouse 2, which operated at 65% of the total discharge. Of the subyearling Chinook salmon that passed powerhouse 2 throughout the season, 49% passed via the turbines, 37% passed via the corner collector and 14% passed via the JBS. For subyearling Chinook salmon passing during the 56 kcfs day/TDG night spill operations, the survival estimate through the powerhouse 2, corner collector was highest, followed by the powerhouse 2 JBS, the spillway, powerhouse 1, and powerhouse 2 turbines. During the 23 kcfs spill operations the powerhouse 2 JBS route had the highest survival estimate, followed by the powerhouse 2 corner collector, powerhouse 2 turbines, powerhouse 1, and the lowest survival estimate was through the spillway.

The 2004 dam survival estimate during the 56 kcfs/TDG spill operations (0.891, [0.871, 0.910] profile likelihood 95% confidence interval) is very similar to the 2001 paired release-recapture estimate of 0.902 ([0.831, 0.973] 95% confidence interval) for fish released near Hood River and in the tailrace of Bonneville Dam. The 2004 dam survival estimate for the 23 kcfs spill operations was considerably lower at 0.858 ([0.840, 0.876] profile likelihood 95% confidence interval). During the 2001 study year very little discharge (2.4%) passed through the spillway and the majority of the discharge and fish passed via powerhouse 2 (Evans et al. 2001).

In general we observed that spillway survival was typically lower than the survival estimates through the guided powerhouse 2 routes (corner collector and JBS) and that survival estimates through the spillway were lowest during the lower spill discharge operating conditions. Similarly, it was observed that survival of fish passing via the 7-ft and 14-ft deflector spillbays was higher during higher flow conditions (TDG spill operations versus 48 and 23 kcfs). At the lower spill conditions of 56 kcfs or 23 kcfs the 7-ft spillbay deflector consistently had higher survival estimates than for the 14 ft-spillbay deflector. During the spring migration the mean tail water elevation was 18.1 ft with a range between 14 and 23 ft, and for the summer migration the mean tail water elevation was 13.9 ft, with a range between 9.1 and 19.5 ft above mean sea level. It may be that at the lower tail water elevations and in conjunction with the lower spill discharge operations, the shallower 14 ft deflector was less effective.

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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 2004. Dates, times, numbers of tagged fish released (N), 24 h post-tagging tag loss and mortality, and means, standard deviations (SD) and ranges for fork lengths and weights are presented. Release times are the start of releases and include fish released up to 1 hour later.

						Fork Length (mm)			Weight (g)		
Release	Date	Time	N	Tag loss	Mortality	Mean	SD	Range	Mean	SD	Range
1	30-Apr	12:28	24	1	0	146	10.8	130 - 179	30.7	7.0	23.6 - 51.9
2	3-May	00:05	24	1	0	142	6.3	130 - 155	29.1	4.5	22.9 - 40.1
3	4-May	11:19	25	1	0	141	5.3	132 - 154	32.9	4.1	26.9 - 43.5
4	6-May	23:48	26	0	0	153	12.2	133 - 179	35.8	9.8	25.0 - 65.6
5	8-May	12:14	25	0	0	147	7.6	140 - 165	31.1	5.2	25.2 - 44.8
6	10-May	23:08	23	1	1	147	13.4	134 - 183	30.8	9.4	21.5 - 57.5
7	12-May	12:33	24	1	0	153	13.9	138 - 185	37.1	11.2	25.6 - 64.1
8	14-May	23:50	27	0	0	155	16.7	134 - 192	33.2	10.9	21.7 - 61.7
9	16-May	12:44	25	0	0	167	16.8	135 - 200	45.0	13.6	27.3 - 80.0
10	19-May	01:10	26	0	0	166	17.2	141 - 204	42.1	13.2	25.5 - 71.0
11	20-May	11:58	24	0	1	164	16.3	142 - 194	41.1	13.2	25.8 - 66.0
12	22-May	22:34	24	0	1	163	11.9	142 - 186	40.7	8.8	29.0 - 59.5
13	24-May	10:05	26	0	0	164	11.7	147 - 191	41.2	10.2	27.7 - 68.0
14	26-May	22:13	26	0	0	164	14.7	144 - 210	33.2	10.4	22.3 - 69.4
15	28-May	10:41	24	0	0	162	14.5	146 - 210	34.5	12.4	22.9 - 83.3
16	30-May	22:50	26	0	0	165	16.0	142 - 212	39.1	14.1	24.8 - 87.2
Overall			399	5	3	156	15.8	130 - 212	36.2	11.2	21.5 - 87.2

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

						Fork Length (mm)			Weight (g)		
Release	Date	Time	N	Tag loss	Mortality	Mean	SD	Range	Mean	SD	Range
1	30-Apr	12:06	24	1	0	144	6.5	130 - 156	29.7	3.9	22.7 - 36.7
2	2-May	23:53	24	1	0	140	7.0	130 - 154	27.2	3.6	21.6 - 35.2
3	4-May	11:04	23	1	0	144	12.8	130 - 180	34.5	9.2	24.4 - 65.7
4	6-May	23:25	25	1	0	144	6.7	133 - 161	29.3	5.1	23.5 - 48.0
5	8-May	11:56	26	0	0	148	11.5	135 - 194	32.0	8.0	22.7 - 64.8
6	10-May	22:54	24	0	0	150	16.0	131 - 190	33.1	13.4	21.5 - 66.7
7	12-May	12:19	25	0	0	154	14.9	140 - 194	37.8	12.2	27.1 - 72.1
8	14-May	23:19	24	1	0	153	14.8	134 - 188	31.0	9.3	21.9 - 54.9
9	16-May	12:20	24	1	0	164	14.0	146 - 185	41.3	10.1	28.1 - 59.0
10	19-May	a	a	a	a	a	a	a	a	a	a
11	20-May	11:39	25	0	0	152	17.1	134 - 188	31.4	11.1	21.7 - 56.2
12	22-May	22:06	25	0	0	161	12.2	139 - 183	36.6	8.1	23.0 - 52.1
13	24-May	9:55	24	0	0	165	12.9	138 - 192	41.6	10.1	24.9 - 67.4
14	26-May	21:54	24	0	0	155	12.2	135 - 182	38.0	9.3	23.6 - 58.0
15	28-May	10:28	25	0	0	159	12.9	142 - 186	32.1	8.8	22.4 - 54.5
16	30-May	a	a	a	a	a	a	a	a	a	a
Overall			342	6	0	153	14.6	130 - 194	34.0	9.9	21.5 –72.1

a – Dam operations were different then the specified treatment conditions.

Table A1.3. Summary of yearling Chinook salmon releases at Bonneville Dam in the tailrace directly below the front roll of the powerhouse 1 MGR turbine unit during spring 2004. Dates, times, numbers of tagged fish released (N), 24 h post-tagging tag loss and mortality, and means, standard deviations (SD) and ranges for fork lengths and weights are presented. Release times are the start of releases and include fish released up to 1 hour later.

						Fork Length (mm)			Weight (g)		
Release	Date	Time	N	Tag loss	Mortality	Mean	SD	Range	Mean	SD	Range
1	30-Apr	12:11	22	2	0	145	9.0	133 - 165	29.8	5.9	22.3 - 46.1
2	3-May	00:08	25	0	0	141	5.6	134 - 155	28.5	3.5	23.1 - 35.6
3	4-May	11:09	27	0	0	140	8.8	121 - 164	32.9	6.4	24.8 - 52.9
4	6-May	23:29	25	0	0	147	10.1	137 - 175	31.0	7.1	24.3 - 53.8
5	8-May	12:08	24	0	0	145	9.4	135 - 179	29.0	6.3	22.0 - 52.2
6	10-May	23:01	25	0	0	150	15.6	134 - 190	31.0	11.6	21.5 - 64.9
7	12-May	13:01	25	0	0	159	15.3	143 - 198	41.2	12.5	26.2 - 75.5
8	14-May	23:30	23	0	0	163	21.3	136 - 220	39.3	18.6	22.1 -104.7
9	16-May	12:33	25	0	0	162	18.5	143 - 216	39.7	16.4	24.2 - 97.9
10	19-May	00:37	25	0	0	156	12.7	138 - 176	34.3	9.3	22.4 - 50.2
11	20-May	11:48	22	3	0	158	12.4	137 - 184	31.0	7.2	21.7 - 47.6
12	22-May	22:16	23	1	0	166	13.3	144 - 187	43.6	9.5	29.9 - 60.7
13	24-May	09:51	28	0	0	174	14.2	150 - 206	43.5	12.0	28.0 - 78.5
14	26-May	21:58	26	0	0	159	11.5	140 - 189	29.9	6.2	21.6 - 47.5
15	28-May	10:34	25	0	0	157	9.2	138 - 179	31.8	5.4	22.0 - 48.6
16	30-May	22:41	26	0	0	173	16.7	150 - 206	48.0	14.7	33.7 - 83.5
Overall			396	6	0	156	16.6	121 - 220	35.4	11.9	21.5 -104.7

Table A1.4. 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 2004. Dates, times, numbers of tagged fish released (N), 24 h post-tagging tag loss and mortality, and means, standard deviations (SD) and ranges for fork lengths and weights are presented. Release times are the start of releases and include fish released up to 1 hour later.

							Fork Length (mm)			Weight (g)		
Release	Location	Date	Time	N	Tag loss	Mortality	Mean	SD	Range	Mean	SD	Range
1	Tailrace	28-Apr	01:25	41	6	0	148	10.5	130 - 188	34.8	9.2	23.8 - 76.4
2	Tailrace	28-Apr	12:23	45	0	0	152	7.4	139 - 169	33.2	5.2	25.9 - 44.7
3	Sluiceway	28-Apr	12:29	32	0	0	156	8.8	142 - 180	36.3	6.7	26.0 - 52.1
4	Tailrace	29-Apr	01:49	40	6	1	155	12.1	131 - 185	36.7	9.0	24.5 - 58.2
5	Tailrace	29-Apr	12:30	44	0	0	156	13.0	132 - 200	38.2	9.3	23.4 - 62.2
6	Sluiceway	29-Apr	19:09	44	4	0	154	8.7	142 - 175	36.1	6.5	27.9 - 53.8
7	Tailrace	30-Apr	01:33	38	6	2	152	9.9	135 - 180	35.1	8.0	23.0 - 62.6
8	Tailrace	30-Apr	13:06	47	1	0	153	8.4	133 - 178	35.1	5.6	22.5 - 51.6
9	Tailrace	1-May	00:10	48	0	0	150	7.0	136 - 167	32.9	4.7	24.2 - 50.5
10	Sluiceway	1-May	01:59	43	0	0	154	10.9	136 - 179	35.7	7.9	24.2 - 56.2
11	Sluiceway	1-May	07:05	42	3	1	151	10.0	130 - 173	33.8	6.6	23.5 - 49.7
12	Tailrace	1-May	13:15	45	1	0	153	9.8	137 - 180	35.5	7.4	24.2 - 55.6
13	Tailrace	2-May	00:30	47	0	0	149	7.8	136 - 170	33.0	5.6	24.3 - 48.1
14	Tailrace	2-May	13:38	47	0	0	148	12.4	130 - 178	35.0	7.8	25.4 - 57.5
15	Sluiceway	2-May	13:00	43	3	1	147	12.1	131 - 186	32.7	6.5	22.9 - 55.9
16	Tailrace	3-May	00:48	46	2	0	153	10.5	135 - 186	34.9	7.7	25.1 - 60.0
17	Sluiceway	3-May	07:00	47	1	0	147	10.5	125 - 180	33.7	7.9	21.7 - 58.0
18	Tailrace	3-May	12:30	45	1	0	150	14.2	127 - 192	36.2	10.8	21.5 - 69.5
19	Tailrace	4-May	00:37	44	2	0	149	9.3	137 - 190	33.0	6.4	22.5 - 56.0
20	Tailrace	4-May	12:46	47	1	0	150	9.8	136 - 176	32.5	6.5	23.9 - 54.9
21	Tailrace	5-May	00:33	46	0	1	147	10.2	130 - 176	30.7	8.0	21.8 - 63.3
22	Sluiceway	5-May	01:00	48	0	0	149	11.2	134 - 179	33.1	8.7	22.4 - 55.5
23	Tailrace	5-May	12:28	47	1	0	149	10.8	131 - 191	31.6	7.1	21.7 - 60.8
24	Sluiceway	5-May	19:09	46	1	0	147	9.6	136 - 174	30.6	6.9	21.6 - 52.5

Table A1.4 (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 2004. Dates, times, numbers of tagged fish released (N), 24 h post-tagging tag loss and mortality, and means, standard deviations (SD) and ranges for fork lengths and weights are presented. Release times are the start of releases and include fish released up to 1 hour later.

							Fork Length (mm)			Weight (g)		
Release	Location	Date	Time	N	Tag loss	Mortality	Mean	SD	Range	Mean	SD	Range
25	Tailrace	6-May	00:33	47	0	0	154	13.9	133 - 184	35.4	10.3	21.5 - 59.5
26	Sluiceway	6-May	07:00	47	0	0	151	13.6	131 - 192	33.5	9.9	21.7 - 63.1
27	Tailrace	6-May	12:35	46	1	0	152	12.2	131 - 183	34.0	8.5	21.7 - 58.7
28	Tailrace	7-May	00:19	41	6	0	149	11.7	132 - 177	35.5	8.0	21.8 - 54.1
29	Tailrace	7-May	12:04	45	1	0	152	14.2	130 - 180	34.6	10.2	22.5 - 55.8
30	Tailrace	8-May	00:03	46	2	0	154	10.1	139 - 174	38.9	6.7	27.4 - 54.5
31	Sluiceway	8-May	01:00	46	1	0	158	13.6	136 - 189	43.1	12.1	28.4 - 69.5
32	Tailrace	8-May	12:33	43	2	0	156	10.9	140 - 184	36.0	7.2	25.7 - 55.1
33	Sluiceway	8-May	19:00	43	0	5	152	14.9	122 - 185	35.6	11.1	22.0 - 60.1
34	Tailrace	9-May	00:06	47	0	0	147	12.5	132 - 181	31.8	10.5	21.5 - 77.5
35	Tailrace	9-May	13:01	47	0	0	147	12.5	132 - 205	30.1	9.8	22.0 - 75.1
36	Sluiceway	9-May	13:00	48	0	0	149	9.8	135 - 178	31.8	7.2	23.7 - 58.7
37	Tailrace	10-May	01:30	48	0	0	157	13.3	133 - 192	37.5	9.8	23.6 - 70.2
38	Tailrace	10-May	12:47	47	0	0	154	12.1	134 - 191	35.9	9.3	23.5 - 66.7
39	Sluiceway	10-May	19:00	47	1	0	152	14.8	133 - 205	35.0	13.6	21.9 - 98.6
40	Tailrace	11-May	00:43	48	0	0	149	12.4	133 - 181	32.2	8.5	23.3 - 58.9
41	Tailrace	11-May	12:05	48	0	0	147	11.9	131 - 188	30.3	8.6	21.6 - 62.0
42	Sluiceway	11-May	13:00	47	1	0	150	18.3	130 - 210	33.1	14.1	22.2 - 79.8
43	Tailrace	12-May	00:26	46	1	0	159	18.1	134 - 200	39.4	13.5	22.8 - 74.7
44	Sluiceway	12-May	07:08	48	0	0	156	16.6	129 - 210	37.6	13.6	21.8 - 95.6
45	Tailrace	12-May	12:06	45	2	0	159	14.7	136 - 189	39.2	10.7	23.9 - 64.5
46	Tailrace	13-May	00:31	48	0	0	154	16.9	133 - 190	36.2	12.4	22.6 - 65.4
47	Tailrace	13-May	12:10	48	0	0	163	17.3	131 - 197	42.3	13.8	22.3 - 71.2
48	Tailrace	14-May	00:55	48	0	0	155	15.2	135 - 199	36.1	12.2	21.7 - 76.6

Table A1.4 (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 2004. Dates, times, numbers of tagged fish released (N), 24 h post-tagging tag loss and mortality, and means, standard deviations (SD) and ranges for fork lengths and weights are presented. Release times are the start of releases and include fish released up to 1 hour later.

							Fork Length (mm)			Weight (g)		
Release	Location	Date	Time	N	Tag loss	Mortality	Mean	SD	Range	Mean	SD	Range
49	Sluiceway	14-May	01:00	44	0	1	160	17.8	134 - 203	40.0	13.6	23.4 - 77.4
50	Tailrace	14-May	13:06	48	0	0	159	17.6	136 - 198	38.4	12.4	23.5 - 69.3
51	Tailrace	15-May	01:04	47	0	0	160	18.8	136 - 218	40.7	15.9	22.5 - 94.1
52	Sluiceway	15-May	01:12	48	0	0	166	19.8	132 - 207	45.1	16.4	21.9 - 79.0
53	Sluiceway	15-May	07:00	47	0	1	161	21.0	132 - 220	41.8	18.1	21.6 - 97.3
54	Tailrace	15-May	12:29	47	1	0	161	18.0	135 - 208	40.8	14.8	21.5 - 83.0
55	Tailrace	16-May	00:21	47	1	0	160	19.3	136 - 205	39.7	14.7	21.8 - 72.2
56	Tailrace	16-May	12:40	47	0	0	159	18.6	137 - 200	38.7	14.6	21.8 - 76.9
57	Sluiceway	16-May	19:00	46	1	0	160	17.9	130 - 190	39.4	13.5	22.0 - 69.1
58	Tailrace	17-May	00:39	45	1	2	161	18.2	130 - 200	41.0	13.7	21.6 - 72.9
59	Tailrace	17-May	12:28	48	0	0	161	16.0	134 - 189	40.0	13.1	21.9 - 68.8
60	Sluiceway	17-May	13:00	48	0	0	164	16.9	136 - 205	42.3	14.7	22.8 - 91.1
61	Tailrace	18-May	00:20	46	1	1	160	17.9	138 - 195	40.0	14.3	24.1 - 76.0
62	Tailrace	18-May	12:47	43	4	0	165	17.8	135 - 198	42.7	13.9	22.2 - 73.5
63	Tailrace	19-May	00:10	48	0	0	155	15.6	135 - 194	36.0	11.4	22.2 - 69.6
64	Sluiceway	19-May	01:00	47	1	0	160	15.7	132 - 194	38.5	11.0	22.5 - 67.3
65	Tailrace	19-May	12:19	47	1	0	156	14.6	131 - 191	35.6	9.5	22.0 - 60.3
66	Sluiceway	19-May	13:01	47	1	0	158	14.8	134 - 195	37.5	11.3	22.1 - 64.5
67	Tailrace	20-May	00:04	53	0	0	160	15.9	130 - 197	39.9	11.7	21.6 - 75.9
68	Sluiceway	20-May	07:03	54	0	0	165	14.6	137 - 200	42.1	11.2	23.3 - 73.9
69	Tailrace	20-May	12:40	51	1	0	163	15.3	131 - 205	41.5	11.4	25.2 - 70.3
70	Tailrace	21-May	00:59	52	0	1	160	15.5	133 - 200	39.7	11.1	24.3 - 69.9
71	Tailrace	21-May	12:03	53	0	0	158	15.3	130 - 185	37.1	10.5	21.6 - 58.6
72	Sluiceway	21-May	19:00	54	1	0	156	16.1	130 - 200	36.7	11.3	22.4 - 71.0

Table A1.4 (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 2004. Dates, times, numbers of tagged fish released (N), 24 h post-tagging tag loss and mortality, and means, standard deviations (SD) and ranges for fork lengths and weights are presented. Release times are the start of releases and include fish released up to 1 hour later.

							Fork Length (mm)			Weight (g)		
Release	Location	Date	Time	N	Tag loss	Mortality	Mean	SD	Range	Mean	SD	Range
73	Tailrace	22-May	00:55	53	0	0	160	15.2	131 - 200	39.3	11.7	22.9 - 81.1
74	Tailrace	22-May	12:26	52	0	0	159	13.4	134 - 190	37.4	9.8	22.3 - 67.6
75	Sluiceway	22-May	13:00	55	0	0	161	15.5	133 - 202	39.3	12.0	22.9 - 78.4
76	Tailrace	23-May	00:04	51	2	0	162	14.7	139 - 216	40.2	11.8	24.6 - 91.0
77	Tailrace	23-May	12:20	53	0	0	161	13.6	133 - 191	40.0	9.9	22.3 - 65.8
78	Sluiceway	23-May	19:00	53	0	0	160	13.4	132 - 185	38.0	9.4	22.5 - 59.5
79	Tailrace	24-May	00:36	52	0	0	162	13.8	141 - 205	40.0	11.6	26.4 - 83.6
80	Tailrace	24-May	12:40	48	0	0	160	15.6	135 - 191	39.0	11.5	21.7 - 62.5
81	Tailrace	25-May	00:43	51	2	0	159	16.6	136 - 199	37.7	12.6	23.9 - 70.8
82	Sluiceway	25-May	01:01	52	1	0	166	17.5	135 - 214	43.0	15.6	21.5 - 92.0
83	Sluiceway	25-May	07:01	55	0	0	164	15.3	134 - 200	42.7	12.5	23.4 - 81.2
84	Tailrace	25-May	15:47	51	1	0	162	18.5	135 - 209	42.5	16.0	24.3 - 94.1
85	Tailrace	26-May	00:18	51	1	1	162	18.3	136 - 215	41.0	16.7	22.0 - 100.6
86	Tailrace	26-May	12:40	52	0	1	161	16.8	137 - 205	41.1	14.9	24.7 - 91.7
87	Tailrace	27-May	00:57	53	0	0	163	17.8	135 - 214	41.8	15.7	21.9 - 96.7
88	Sluiceway	27-May	01:02	52	0	2	165	20.0	132 - 215	44.1	18.4	22.3 - 99.0
89	Tailrace	27-May	12:04	53	0	0	161	16.4	135 - 202	40.9	14.2	22.1 - 87.9
90	Sluiceway	27-May	13:03	53	1	0	167	19.1	134 - 214	46.8	17.9	23.7 - 96.8
91	Tailrace	28-May	00:47	44	0	0	168	20.5	134 - 210	48.8	19.5	26.4 - 99.8
92	Sluiceway	28-May	07:00	45	1	0	161	18.2	138 - 210	40.4	16.4	24.6 - 87.6
93	Tailrace	28-May	12:08	47	0	0	169	21.8	133 - 224	48.5	20.9	21.8 - 112.6
94	Tailrace	29-May	01:10	28	0	0	166	21.1	141 - 202	46.5	18.9	26.0 - 84.7
95	Tailrace	29-May	12:10	29	2	0	169	19.3	145 - 212	47.1	19.1	26.5 - 88.0
96	Sluiceway	29-May	19:00	20	0	0	166	20.5	137 - 202	46.3	18.2	25.6 - 85.6
Overall				4486	82	21	157	16.0	122 - 224	38.0	12.6	19.7 - 112.6

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

						Fork Length (mm)			Weight (g)		
Release	Date	Time	N	Tag loss	Mortality	Mean	SD	Range	Mean	SD	Range
1	29-Apr	09:54	20	0	0	148	14.6	135 - 205	31.8	10.9	23.0 - 76.0
2	29-Apr	21:43	18	0	0	145	6.9	135 - 158	30.9	5.0	24.0 - 41.7
3	30-Apr	10:19	17	1	1	147	12.9	135 - 180	31.6	10.1	21.5 - 61.8
4	30-Apr	21:56	20	1	0	148	7.5	135 - 163	32.2	5.1	24.5 - 40.5
5	1-May	10:08	22	0	0	148	8.7	135 - 172	31.8	6.8	23.3 - 54.1
6	1-May	21:45	17	2	0	149	8.6	136 - 163	32.3	5.2	24.6 - 41.1
7	2-May	09:42	21	0	0	148	10.2	132 - 170	32.2	6.8	23.2 - 47.0
8	2-May	22:07	18	2	0	142	6.7	131 - 152	29.3	4.1	23.7 - 38.9
9	3-May	10:00	20	0	0	145	9.0	134 - 166	30.6	6.4	24.7 - 46.0
10	3-May	22:00	19	3	0	147	8.6	136 - 167	31.2	5.7	23.9 - 45.8
11	4-May	09:53	18	2	0	151	10.9	139 - 179	33.9	7.8	26.2 - 56.7
12	4-May	22:01	20	0	0	144	9.1	134 - 160	29.1	6.3	23.0 - 42.3
13	5-May	09:46	20	0	0	142	6.4	130 - 154	27.6	3.4	21.6 - 33.5
14	5-May	21:55	22	0	1	148	13.0	135 - 192	31.3	9.4	22.6 - 65.1
15	6-May	10:11	22	0	0	145	12.3	133 - 181	30.3	9.3	22.0 - 62.3
16	6-May	21:39	20	0	0	151	9.2	138 - 171	33.6	7.5	24.7 - 51.1
17	7-May	10:25	20	0	0	151	8.0	137 - 165	33.4	5.2	27.1 - 46.7
18	7-May	21:51	21	0	0	145	6.4	136 - 157	30.5	5.6	23.9 - 43.6
19	8-May	10:07	19	0	1	145	8.9	131 - 171	29.5	6.7	22.1 - 54.1
20	8-May	21:42	20	0	0	151	12.8	134 - 175	34.3	9.4	23.3 - 58.4
21	9-May	10:12	20	1	0	152	14.3	136 - 199	34.5	10.7	24.1 - 66.1
22	9-May	21:43	19	0	0	145	10.2	130 - 165	28.9	7.1	21.8 - 51.0
23	10-May	09:53	20	0	0	149	11.7	135 - 180	30.6	8.9	22.1 - 53.1
24	10-May	21:59	20	0	0	148	13.2	132 - 187	31.1	11.1	21.7 - 70.2

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

						Fork Length (mm)			Weight (g)		
Release	Date	Time	N	Tag loss	Mortality	Mean	SD	Range	Mean	SD	Range
25	11-May	10:24	19	1	1	148	9.9	135 - 169	30.5	7.7	21.5 - 48.3
26	11-May	22:00	18	1	0	156	10.4	139 - 181	36.5	7.6	26.0 - 57.5
27	12-May	09:23	22	0	0	159	14.7	139 - 190	40.2	14.3	23.2 - 75.4
28	12-May	22:07	16	2	0	168	22.0	141 - 208	46.2	18.6	26.6 - 86.8
29	13-May	10:01	20	0	0	161	17.7	142 - 199	35.7	11.3	23.7 - 63.6
30	13-May	22:00	20	1	0	163	12.7	148 - 191	35.9	8.9	25.2 - 56.8
31	14-May	10:01	19	1	0	167	13.8	147 - 194	38.5	9.9	24.7 - 60.7
32	14-May	21:54	22	0	0	157	12.8	140 - 180	38.3	10.2	24.1 - 57.7
33	15-May	10:25	19	0	1	153	11.9	140 - 178	33.8	7.8	24.9 - 52.3
34	15-May	21:52	19	0	0	157	11.8	141 - 190	34.9	6.8	26.2 - 50.1
35	16-May	10:16	17	3	0	160	11.9	141 - 185	35.6	7.2	24.4 - 51.6
36	16-May	22:08	19	0	1	168	15.0	145 - 199	44.1	12.5	29.1 - 71.9
37	17-May	09:55	21	1	0	174	17.0	146 - 230	50.3	21.2	28.4 - 132.0
38	17-May	22:15	20	0	0	168	11.0	152 - 188	44.6	7.6	31.0 - 61.4
39	18-May	09:52	19	1	0	169	14.0	150 - 198	45.6	11.5	32.4 - 71.1
40	18-May	22:33	22	0	0	157	14.9	139 - 189	35.7	10.8	24.2 - 58.7
41	19-May	10:05	20	0	0	167	14.4	139 - 190	43.4	12.1	22.0 - 62.4
42	19-May	22:35	20	0	0	151	10.5	133 - 168	33.7	7.8	24.7 - 47.6
43	20-May	10:11	21	0	0	155	12.8	135 - 183	33.1	8.6	22.3 - 53.5
44	20-May	21:51	20	0	0	166	10.6	148 - 184	44.3	9.4	28.3 - 61.9
45	21-May	10:01	19	1	0	171	14.0	152 - 200	45.9	11.5	31.6 - 73.7
46	21-May	21:49	17	4	0	174	11.6	151 - 195	47.5	9.4	33.3 - 67.1
47	22-May	10:55	20	0	0	172	11.5	148 - 188	47.8	9.0	31.2 - 65.1
48	22-May	23:49	18	2	0	159	8.2	144 - 172	38.1	6.3	28.9 - 49.6
49	23-May	10:22	20	0	0	167	15.7	146 - 212	42.2	12.8	28.2 - 81.6
50	23-May	22:14	24	0	0	166	12.2	144 - 193	43.1	11.1	29.5 - 75.3
51	24-May	11:21	20	0	0	172	10.7	150 - 191	46.8	9.5	32.1 - 69.7

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

						Fork Length (mm)			Weight (g)		
Release	Date	Time	N	Tag loss	Mortality	Mean	SD	Range	Mean	SD	Range
52	24-May	22:15	22	0	0	167	12.4	149 - 198	43.7	10.6	31.5 - 73.8
53	25-May	09:26	20	0	0	173	13.4	151 - 197	46.5	11.3	29.0 - 67.9
54	25-May	22:06	19	1	0	160	12.5	142 - 185	37.5	8.9	26.0 - 56.6
55	26-May	10:06	20	1	0	165	13.2	144 - 200	39.6	10.1	28.6 - 69.1
56	26-May	23:50	19	1	0	155	18.2	135 - 210	38.7	17.0	24.0 - 98.4
57	27-May	10:35	20	0	0	161	11.0	147 - 185	38.7	8.5	29.4 - 66.7
58	27-May	21:54	20	1	0	156	13.2	141 - 184	36.0	11.7	24.1 - 66.2
59	28-May	12:05	20	0	0	161	11.8	139 - 180	38.4	7.0	27.2 - 54.3
60	28-May	22:08	22	0	0	163	17.8	145 - 225	38.7	14.4	22.9 - 83.0
61	29-May	10:50	21	0	0	166	16.0	143 - 200	43.4	13.6	27.8 - 77.3
62	29-May	22:27	22	0	1	164	12.9	146 - 200	38.9	13.2	26.3 - 78.8
63	30-May	10:59	24	0	0	176	17.4	155 - 215	46.0	16.6	27.2 - 83.7
64	31-May	00:01	23	0	0	174	14.0	150 - 202	50.4	13.0	32.8 - 80.1
Overall			1276	34	7	158	15.8	130 - 230	37.2	9.6	21.5 - 132.0

Table A1.6. Summary of steelhead trout releases at Bonneville Dam ice and trash sluiceway during spring 2004. Dates, times, numbers of tagged fish released (N), 24 h post-tagging tag loss and mortality, and means, standard deviations (SD) and ranges for fork lengths and weights are presented. Release times are the start of releases and include fish released up to 1 hour later.

						Fork Length (mm)			Weight (g)		
Release	Date	Time	N	Tag loss	Mortality	Mean	SD	Range	Mean	SD	Range
1	5-May	23:50	14	3	0	225	18.8	198 - 260	93.2	23.2	63.9 - 153.2
2	6-May	23:48	18	1	1	224	24.1	194 - 265	104.5	34.6	63.0 - 171.0
3	8-May	12:18	23	1	0	227	23.2	200 - 275	101.4	34.6	64.4 - 179.3
4	12-May	12:38	24	3	0	215	26.5	134 - 268	93.4	26.6	49.9 - 155.8
5	13-May	12:10	28	0	0	235	18.5	191 - 265	90.2	23.5	42.3 - 139.3
6	14-May	23:42	13	0	1	223	15.3	208 - 260	91.5	20.6	74.0 - 150.5
7	16-May	12:39	25	0	0	235	21.1	193 - 275	110.3	31.9	57.6 - 172.2
8	19-May	01:01	23	1	1	224	18.3	196 - 259	90.8	20.3	60.4 - 138.1
9	20-May	12:05	23	2	0	211	21.5	161 - 252	73.1	21.5	30.2 - 127.2
10	22-May	22:30	15	0	0	237	24.4	198 - 289	114.4	40.5	63.2 - 221.5
11	24-May	10:12	25	0	0	231	27.9	177 - 295	90.4	33.6	38.4 - 182.8
12	26-May	22:07	23	2	0	239	23.4	179 - 273	95.3	30.2	36.5 - 147.6
13	28-May	10:45	22	3	0	231	17.8	187 - 260	96.1	28.4	51.6 - 165.0
14	30-May	22:53	11	0	0	233	27.9	190 - 274	104.2	39.4	45.3 - 175.7
15	1-Jun	10:20	18	1	0	229	24.4	172 - 282	86.3	32.6	31.2 - 180.3
16	2-Jun	22:05	16	0	0	242	34.7	183 - 293	131.3	52.4	45.8 - 221.5
Overall			321	17	3	229	24.1	134 - 295	96.8	32.8	30.2 - 221.5

Table A1.7. Summary of steelhead trout releases at the Bonneville Dam powerhouse 1 minimum gap runner (MGR) turbine unit during spring 2004. Dates, times, numbers of tagged fish released (N), 24 h post-tagging tag loss and mortality, and means, standard deviations (SD) and ranges for fork lengths and weights are presented. Release times are the start of releases and include fish released up to 1 hour later.

						Fork Length (mm)			Weight (g)		
Release	Date	Time	N	Tag loss	Mortality	Mean	SD	Range	Mean	SD	Range
1	5-May	23:35	16	1	0	227	23.7	193 - 270	102.1	34.0	65.6 - 174.2
2	6-May	23:25	18	1	1	217	11.0	199 - 241	93.7	20.3	66.8 - 155.9
3	8-May	12:01	23	1	1	235	17.6	201 - 270	111.6	29.0	68.0 - 174.4
4	12-May	12:22	26	0	0	231	21.0	188 - 270	104.4	28.2	53.2 - 175.5
5	13-May	11:58	23	1	0	224	15.9	201 - 273	79.1	16.9	54.2 - 130.2
6	14-May	23:24	16	0	0	242	25.4	200 - 305	130.5	53.2	59.5 - 276.1
7	16-May	12:25	22	2	0	235	20.2	210 - 278	107.2	30.5	74.4 - 175.1
8	19-May	a	a	a	a	a	a	a	a	a	a
9	20-May	11:35	25	0	0	229	27.1	177 - 280	104.3	39.1	44.5 - 186.0
10	22-May	22:01	17	0	0	226	22.5	186 - 276	100.7	32.8	51.9 - 178.9
11	24-May	09:52	25	0	0	228	23.1	193 - 267	99.7	30.5	56.4 - 161.1
12	26-May	21:47	24	0	1	232	24.5	180 - 275	107.6	33.2	46.8 - 177.2
13	28-May	10:23	22	1	1	231	21.0	184 - 277	90.8	24.0	45.6 - 141.7
14	30-May	a	a	a	a	a	a	a	a	a	a
15	1-Jun	10:06	20	0	0	231	28.2	163 - 278	94.4	32.4	29.1 - 157.5
16	2-Jun	21:54	15	0	0	233	18.2	205 - 265	108.7	30.9	66.6 - 163.2
Overall			292	7	4	230	22.1	163 - 305	102.0	32.8	29.1 - 276.1

a - Dam operations were different then the specified treatment conditions.

Table A1.8. Summary of steelhead trout releases at Bonneville Dam in the tailrace directly below the front roll of the powerhouse 1 MGR turbine unit during spring 2004. Dates, times, numbers of tagged fish released (N), 24 h post-tagging tag loss and mortality, and means, standard deviations (SD) and ranges for fork lengths and weights are presented. Release times are the start of releases and include fish released up to 1 hour later.

						Fork Length (mm)			Weight (g)		
Release	Date	Time	N	Tag loss	Mortality	Mean	SD	Range	Mean	SD	Range
1	6-May	00:14	17	0	0	227	20.8	179 - 260	100.4	27.7	50.3 - 143.8
2	6-May	23:40	18	2	0	221	19.1	193 - 259	92.4	24.0	61.4 - 149.9
3	8-May	12:03	20	0	0	220	14.6	188 - 241	91.4	19.8	57.5 - 126.7
4	12-May	13:09	25	1	0	238	17.0	209 - 290	118.2	29.8	86.9 - 226.2
5	13-May	12:07	25	1	0	234	14.5	199 - 268	91.4	17.6	69.1 - 136.5
6	14-May	23:34	13	1	1	239	20.3	213 - 278	112.6	31.4	75.0 - 174.1
7	16-May	12:41	23	2	0	229	23.7	190 - 283	99.4	33.4	51.4 - 173.1
8	19-May	00:29	24	1	0	221	14.5	198 - 245	80.4	14.0	58.6 - 117.0
9	20-May	11:56	20	5	0	226	14.3	202 - 251	88.0	17.1	62.3 - 123.8
10	22-May	22:09	17	0	0	227	21.6	186 - 261	95.5	27.4	49.0 - 140.0
11	24-May	10:01	24	1	0	237	34.9	118 - 280	97.3	33.2	39.7 - 168.4
12	26-May	22:09	25	0	0	229	28.8	167 - 304	111.6	42.5	49.0 - 243.8
13	28-May	10:39	25	0	0	238	25.9	182 - 290	97.8	31.0	43.0 - 154.5
14	30-May	22:31	14	0	0	218	33.1	150 - 258	96.0	34.9	39.6 - 149.2
15	1-Jun	10:10	20	0	0	226	31.8	159 - 285	86.0	39.6	25.1 - 169.5
16	2-Jun	22:15	15	0	0	250	20.6	208 - 300	134.9	42.8	63.4 - 251.9
Overall			325	14	1	230	24.0	118 - 304	98.9	32.1	25.1 - 251.9

Table A1.9. Summary of steelhead trout releases at The Dalles Dam tailrace during spring 2004. Dates, times, numbers of tagged fish released (N), 24 h post-tagging tag loss and mortality, and means, standard deviations (SD) and ranges for fork lengths and weights are presented. Release times are the start of releases and include fish released up to 1 hour later.

						Fork Length (mm)			Weight (g)		
Release	Date	Time	N	Tag loss	Mortality	Mean	SD	Range	Mean	SD	Range
1	28-Apr	00:31	21	1	0	216	17.5	178 - 253	86.0	20.6	48.4 - 124.9
2	28-Apr	12:23	17	1	0	218	17.1	190 - 260	80.3	12.6	62.7 - 111.4
3	29-Apr	00:44	30	0	0	225	19.2	189 - 257	88.9	23.0	58.0 - 143.6
4	29-Apr	13:05	27	1	0	227	21.1	193 - 271	90.7	23.9	54.4 - 166.4
5	30-Apr	00:39	33	4	0	228	20.2	182 - 273	103.0	23.6	53.9 - 157.0
6	30-Apr	12:45	40	10	0	221	21.7	144 - 258	83.6	24.0	26.0 - 135.2
7	1-May	01:24	67	4	0	218	18.6	181 - 261	76.1	18.6	50.3 - 144.6
8	1-May	13:12	34	4	0	227	17.3	187 - 250	91.7	24.8	54.4 - 131.1
9	2-May	01:03	62	5	0	232	16.2	201 - 270	107.3	22.9	65.6 - 173.3
10	2-May	13:20	56	4	0	216	22.5	124 - 264	99.3	24.1	50.8 - 181.5
11	3-May	01:23	70	1	0	228	23.3	124 - 270	103.1	24.9	50.7 - 164.6
12	3-May	12:49	64	6	0	218	22.3	129 - 260	101.7	24.0	59.4 - 157.7
13	4-May	01:09	66	3	0	226	19.1	147 - 265	97.6	21.8	56.9 - 147.3
14	4-May	12:29	35	3	0	223	16.9	193 - 262	93.1	21.4	63.2 - 148.5
15	5-May	01:31	25	3	0	227	24.4	169 - 265	100.5	30.1	49.1 - 164.0
16	5-May	12:28	28	0	0	220	16.9	183 - 256	90.7	22.2	51.1 - 138.7
17	6-May	00:33	38	2	0	227	17.8	185 - 268	97.6	23.3	53.5 - 142.3
18	6-May	13:06	40	3	0	226	16.6	190 - 264	98.8	26.5	56.7 - 173.9
19	7-May	00:07	65	5	0	218	21.5	177 - 275	98.2	26.1	53.8 - 174.5
20	7-May	12:37	61	8	1	228	15.7	190 - 260	101.0	22.3	55.1 - 158.4
21	8-May	00:17	70	0	0	223	23.2	161 - 270	100.0	28.6	42.1 - 171.0
22	10-May	00:29	41	0	0	225	23.4	125 - 258	99.6	24.3	53.5 - 150.4
23	10-May	13:02	41	1	0	231	19.1	176 - 275	99.7	24.2	41.5 - 166.7
24	11-May	01:13	70	0	0	230	19.4	173 - 270	100.5	27.8	44.9 - 164.9

Table A1.9 (continued). Summary of steelhead trout releases at The Dalles Dam tailrace during spring 2004. Dates, times, numbers of tagged fish released (N), 24 h post-tagging tag loss and mortality, and means, standard deviations (SD) and ranges for fork lengths and weights are presented. Release times are the start of releases and include fish released up to 1 hour later.

						Fork Length (mm)			Weight (g)		
Release	Date	Time	N	Tag loss	Mortality	Mean	SD	Range	Mean	SD	Range
25	11-May	12:05	68	3	1	232	19.9	176 - 284	102.3	29.7	32.1 - 191.6
26	12-May	00:44	71	0	0	228	18.2	176 - 269	98.6	25.0	44.8 - 154.5
27	12-May	12:26	67	2	1	226	19.0	181 - 275	95.7	26.6	48.4 - 188.7
28	13-May	01:11	72	0	0	230	20.7	177 - 275	99.0	29.4	43.6 - 174.1
29	13-May	12:16	67	4	0	226	19.0	194 - 270	95.7	27.9	56.2 - 197.3
30	14-May	00:23	78	1	1	224	22.4	153 - 278	97.1	27.3	28.2 - 176.9
31	14-May	12:45	75	4	1	223	19.2	176 - 270	89.5	23.2	42.4 - 136.5
32	15-May	00:35	76	0	2	229	22.2	170 - 274	100.7	29.7	46.4 - 184.4
33	15-May	12:08	79	3	0	229	19.2	163 - 268	98.9	25.7	30.0 - 165.9
34	16-May	00:51	77	1	2	228	22.0	115 - 267	97.5	24.9	51.9 - 169.5
35	16-May	12:15	80	2	0	232	23.1	179 - 288	103.2	32.4	47.3 - 195.9
36	17-May	00:02	78	1	3	229	19.6	183 - 271	98.4	25.9	48.1 - 164.5
37	17-May	12:02	70	0	0	221	22.0	126 - 265	90.1	23.1	43.5 - 161.1
38	18-May	00:54	80	0	2	220	20.2	175 - 269	90.5	27.5	41.8 - 180.0
39	18-May	12:11	80	2	0	220	22.0	146 - 277	91.3	27.7	45.1 - 191.4
40	19-May	00:45	74	4	4	221	22.7	166 - 269	93.0	29.8	40.1 - 169.6
41	19-May	12:41	81	1	0	221	21.5	172 - 286	91.1	29.2	40.9 - 217.5
42	20-May	00:30	81	1	0	229	24.1	167 - 288	101.2	31.8	34.6 - 196.5
43	20-May	12:08	77	4	0	219	22.1	143 - 269	91.9	26.6	51.9 - 146.3
44	21-May	00:29	81	0	0	219	23.8	158 - 274	91.0	30.3	32.0 - 172.9
45	21-May	12:18	77	2	2	221	25.2	172 - 300	94.5	36.0	43.1 - 235.8
46	22-May	00:23	77	3	0	214	25.5	162 - 322	84.3	31.4	35.1 - 232.0
47	22-May	12:08	79	3	0	213	20.1	158 - 256	81.1	22.8	33.1 - 142.4
48	23-May	00:39	80	0	1	218	26.3	152 - 271	90.2	33.4	36.6 - 185.6
49	23-May	12:54	77	2	0	217	24.6	174 - 277	90.5	34.4	35.6 - 199.9
50	24-May	00:22	77	2	0	217	23.8	168 - 290	85.6	28.7	39.0 - 201.2
51	24-May	13:07	80	2	0	219	25.2	172 - 298	88.6	29.8	44.9 - 169.3

Table A1.9 (continued). Summary of steelhead trout releases at The Dalles Dam tailrace during spring 2004. Dates, times, numbers of tagged fish released (N), 24 h post-tagging tag loss and mortality, and means, standard deviations (SD) and ranges for fork lengths and weights are presented. Release times are the start of releases and include fish released up to 1 hour later.

						Fork Length (mm)			Weight (g)		
Release	Date	Time	N	Tag loss	Mortality	Mean	SD	Range	Mean	SD	Range
52	25-May	00:10	80	1	1	218	24.1	158 - 278	85.7	29.3	32.2 - 195.3
53	25-May	16:10	81	1	0	218	25.6	160 - 284	88.1	31.5	34.5 - 195.8
54	26-May	00:18	39	1	1	226	27.7	162 - 288	94.9	36.6	31.5 - 200.5
55	26-May	13:08	44	2	0	222	22.1	171 - 280	90.3	27.8	38.4 - 192.7
56	27-May	00:17	79	2	1	229	24.8	133 - 274	99.7	28.6	37.5 - 179.5
57	27-May	12:22	80	1	1	227	22.2	176 - 270	95.6	26.7	46.7 - 159.5
58	28-May	00:14	80	0	2	234	20.9	178 - 281	106.3	28.4	45.4 - 170.6
59	28-May	12:29	79	2	0	224	25.8	166 - 278	95.1	34.7	37.4 - 193.1
60	29-May	00:25	71	1	4	223	24.6	128 - 270	95.8	27.5	40.8 - 162.4
61	29-May	12:10	75	4	2	216	23.3	166 - 277	84.8	30.5	32.3 - 196.6
62	30-May	00:24	78	1	3	220	25.4	160 - 293	91.0	37.1	24.5 - 215.3
63	30-May	12:32	74	6	2	225	20.6	172 - 270	95.6	30.8	38.5 - 186.7
64	31-May	00:31	75	5	2	228	25.6	173 - 300	101.7	38.0	41.9 - 252.2
65	31-May	12:38	78	3	1	230	23.9	173 - 286	105.5	41.4	32.1 - 294.0
66	1-Jun	00:28	76	1	0	227	23.8	179 - 289	99.0	33.4	47.6 - 210.7
67	1-Jun	12:16	78	3	1	231	24.1	174 - 290	105.0	37.5	41.6 - 260.2
68	2-Jun	00:16	71	3	0	227	26.5	168 - 295	97.0	35.2	37.7 - 217.9
Overall			4398	153	42	224	22.7	115 - 322	95.1	29.5	24.5 - 294.0

Table A1.10. Summary of steelhead trout releases at Bonneville Dam tailrace during spring 2004. Dates, times, numbers of tagged fish released (N), 24 h post-tagging tag loss and mortality, and means, standard deviations (SD) and ranges for fork lengths and weights are presented. Release times are the start of releases and include fish released up to 1 hour later.

						Fork Length (mm)			Weight (g)		
Release	Date	Time	N	Tag loss	Mortality	Mean	SD	Range	Mean	SD	Range
1	30-Apr	10:19	16	1	0	224	14.3	195 - 240	99.0	21.1	65.1 - 143.2
2	30-Apr	21:56	13	1	0	234	20.6	205 - 273	112.5	35.4	73.1 - 188.3
3	1-May	10:08	13	3	0	235	20.0	194 - 258	111.1	23.9	66.4 - 144.3
4	2-May	22:07	20	1	0	227	28.0	189 - 320	107.3	47.9	58.6 - 283.6
5	3-May	22:00	10	6	0	225	31.4	179 - 280	103.4	45.2	49.3 - 201.4
6	4-May	09:53	10	0	0	234	15.2	203 - 259	114.9	23.2	76.0 - 154.8
7	4-May	22:01	20	0	0	236	17.5	200 - 265	109.7	23.5	64.0 - 156.9
8	5-May	21:55	17	0	0	234	17.6	205 - 265	106.0	26.4	69.2 - 152.5
9	6-May	10:11	20	1	0	237	23.4	190 - 279	115.1	36.3	51.0 - 182.4
10	6-May	21:39	21	0	0	221	18.2	198 - 257	93.6	23.5	62.4 - 144.5
11	7-May	10:25	22	1	1	224	24.8	187 - 290	96.5	35.9	57.0 - 205.0
12	7-May	21:51	15	3	0	220	16.5	192 - 247	94.3	24.5	53.5 - 132.9
13	8-May	10:07	21	0	0	227	24.2	187 - 280	105.5	40.5	55.6 - 201.4
14	8-May	21:42	26	1	0	227	16.7	200 - 276	99.2	20.3	64.2 - 151.1
15	9-May	10:12	21	0	0	232	26.8	196 - 285	105.8	36.7	62.2 - 194.0
16	11-May	22:00	22	1	0	232	20.8	191 - 266	105.8	27.8	52.3 - 159.7
17	12-May	09:23	24	1	0	231	15.0	208 - 276	105.7	25.1	75.6 - 181.6
18	12-May	22:07	20	2	0	229	21.1	201 - 274	99.0	28.2	64.6 - 167.8
19	13-May	10:01	22	0	0	228	20.9	182 - 260	85.6	23.0	48.4 - 125.4
20	13-May	22:00	15	2	0	222	22.9	184 - 288	80.1	31.0	40.2 - 180.6
21	14-May	10:01	14	0	1	225	13.6	206 - 253	82.4	16.6	60.8 - 117.1
22	14-May	21:54	13	2	1	223	20.7	190 - 255	98.2	25.5	55.2 - 138.8
23	15-May	10:25	16	0	0	224	22.8	181 - 267	96.6	31.7	52.4 - 176.3
24	15-May	21:52	26	1	0	234	21.9	190 - 290	110.0	30.3	66.9 - 206.5

Table A1.10 (continued). Summary of steelhead trout releases at Bonneville Dam tailrace during spring 2004. Dates, times, numbers of tagged fish released (N), 24 h post-tagging tag loss and mortality, and means, standard deviations (SD) and ranges for fork lengths and weights are presented. Release times are the start of releases and include fish released up to 1 hour later.

						Fork Length (mm)			Weight (g)		
Release	Date	Time	N	Tag loss	Mortality	Mean	SD	Range	Mean	SD	Range
25	16-May	10:16	21	3	0	244	23.5	193 - 296	123.8	39.7	49.1 - 221.6
26	16-May	22:08	24	0	0	242	15.6	214 - 278	112.4	27.3	70.3 - 177.1
27	17-May	09:55	23	1	0	244	16.0	207 - 270	117.5	26.2	65.3 - 168.4
28	17-May	22:15	24	1	0	238	14.3	216 - 266	109.5	25.7	77.9 - 163.0
29	18-May	09:52	24	0	0	248	19.8	213 - 302	122.5	29.4	71.5 - 193.5
30	18-May	22:33	21	3	0	229	27.0	178 - 275	97.1	31.9	40.8 - 149.9
31	19-May	10:05	22	0	0	239	23.0	205 - 288	112.7	37.8	62.3 - 213.7
32	19-May	22:35	22	3	1	236	21.3	200 - 274	112.8	34.1	63.1 - 177.5
33	20-May	10:11	23	0	0	237	13.0	206 - 256	108.9	23.4	65.6 - 151.6
34	20-May	21:51	28	1	0	219	24.3	174 - 267	85.4	30.5	27.2 - 163.6
35	21-May	10:01	23	1	0	240	22.4	206 - 293	114.0	38.9	68.1 - 216.2
36	21-May	21:49	22	2	0	236	18.3	205 - 273	108.5	27.2	71.5 - 163.5
37	22-May	10:55	22	3	0	237	21.4	200 - 280	110.8	36.2	63.8 - 193.4
38	22-May	23:49	12	0	0	225	22.2	175 - 255	96.6	27.8	42.4 - 140.7
39	23-May	10:22	30	1	0	227	27.2	184 - 305	97.5	38.0	49.7 - 236.0
40	23-May	22:14	20	3	1	234	29.8	178 - 310	109.6	46.4	47.2 - 261.6
41	24-May	11:21	24	0	0	234	20.9	188 - 265	104.9	28.4	58.1 - 176.4
42	24-May	22:15	24	0	0	231	30.9	174 - 304	110.4	45.3	44.5 - 241.8
43	25-May	09:26	24	0	0	227	22.7	180 - 270	95.2	33.2	44.4 - 172.6
44	25-May	22:06	23	0	0	221	27.1	157 - 263	104.3	39.9	46.4 - 162.5
45	26-May	10:06	24	0	0	219	21.7	181 - 260	83.4	25.2	43.8 - 135.4
46	26-May	23:49	24	0	0	232	31.3	176 - 289	88.8	33.7	43.3 - 158.4
47	27-May	10:35	23	1	0	219	19.4	188 - 255	89.0	33.0	54.7 - 145.7
48	27-May	21:54	22	2	0	229	25.5	190 - 283	98.5	37.3	52.3 - 197.6
49	28-May	12:05	21	4	0	247	21.7	206 - 291	125.2	31.5	65.4 - 181.0
50	28-May	22:08	24	0	0	229	27.7	183 - 274	85.2	30.7	38.5 - 137.6
51	29-May	10:50	24	0	0	230	25.9	178 - 276	102.9	31.1	44.0 - 152.3

Table A1.10 (continued). Summary of steelhead trout releases at Bonneville Dam tailrace during spring 2004. Dates, times, numbers of tagged fish released (N), 24 h post-tagging tag loss and mortality, and means, standard deviations (SD) and ranges for fork lengths and weights are presented. Release times are the start of releases and include fish released up to 1 hour later.

						Fork Length (mm)			Weight (g)		
Release	Date	Time	N	Tag loss	Mortality	Mean	SD	Range	Mean	SD	Range
52	29-May	22:27	23	3	0	224	24.8	190 - 283	81.3	30.0	44.2 - 173.7
53	30-May	10:59	24	0	0	229	27.8	178 - 273	90.6	32.9	43.3 - 165.4
54	31-May	00:01	17	0	0	229	32.5	167 - 300	114.9	51.0	43.2 - 262.4
55	31-May	09:57	16	1	0	230	32.3	178 - 281	101.6	48.1	47.6 - 181.0
56	31-May	22:00	20	0	0	228	30.6	159 - 270	104.8	37.3	31.4 - 150.4
57	1-Jun	11:19	17	0	0	232	26.4	161 - 261	96.2	31.4	32.0 - 139.9
58	1-Jun	21:50	32	0	0	236	27.9	178 - 295	114.3	45.6	46.6 - 231.4
59	2-Jun	10:00	28	0	1	239	22.5	193 - 282	112.0	38.2	24.2 - 192.8
60	2-Jun	22:59	15	2	0	254	22.7	212 - 284	142.5	45.7	71.4 - 206.2
61	3-Jun	10:06	27	3	0	232	22.6	184 - 278	108.0	38.9	48.8 - 195.5
Overall			1274	65	6	231	22.6	157 - 320	104.0	32.6	24.2 - 283.6

Table A1.11. Summary of subyearling Chinook salmon releases at Bonneville Dam ice and trash sluiceway during summer 2004. Dates, times, numbers of tagged fish released (N), 24 h post-tagging tag loss and mortality, and means, standard deviations (SD) and ranges for fork lengths and weights are presented. Release times are the start of releases and include fish released up to 1 hour later.

						Fork Length (mm)			Weight (g)		
Release	Date	Time	N	Tag loss	Mortality	Mean	SD	Range	Mean	SD	Range
1	21-Jun	11:43	17	2	0	122	8.4	111 - 138	18.3	4.3	13.9 - 26.0
2	22-Jun	00:24	16	3	0	124	12.8	112 - 161	20.1	6.3	13.9 - 37.7
3	23-Jun	12:08	21	0	0	121	5.2	115 - 134	18.4	2.5	14.3 - 26.4
4	23-Jun	23:50	20	1	0	120	6.9	108 - 135	17.6	2.7	13.9 - 23.7
5	25-Jun	12:00	19	0	0	118	7.3	110 - 138	16.9	2.9	13.5 - 26.1
6	26-Jun	00:00	20	0	0	119	3.9	110 - 127	17.9	1.7	15.3 - 20.8
7	27-Jun	11:55	19	0	0	120	9.0	109 - 142	16.9	3.6	13.0 - 26.3
8	27-Jun	23:48	19	0	0	116	6.7	110 - 137	15.4	3.7	13.2 - 28.8
9	29-Jun	12:12	14	0	0	118	10.6	109 - 150	17.2	5.4	14.0 - 34.5
10	30-Jun	00:09	24	0	0	116	5.6	110 - 134	16.8	2.5	13.6 - 23.4
11	1-Jul	11:57	19	0	0	115	4.7	106 - 124	15.3	2.1	13.2 - 19.1
12	1-Jul	23:58	19	0	0	115	5.2	109 - 132	15.3	2.4	13.0 - 23.3
13	3-Jul	12:00	24	0	0	117	7.5	107 - 132	16.2	3.0	13.4 - 23.9
14	4-Jul	00:16	19	0	0	116	5.9	105 - 129	15.8	2.8	13.0 - 22.6
15	5-Jul	12:06	24	0	0	117	9.8	105 - 144	17.7	4.7	13.6 - 28.8
16	5-Jul	23:51	19	0	0	114	5.1	106 - 127	15.3	2.4	13.0 - 23.6

Table A1.11 (continued). Summary of subyearling Chinook salmon releases at Bonneville Dam ice and trash sluiceway during summer 2004. Dates, times, numbers of tagged fish released (N), 24 h post-tagging tag loss and mortality, and means, standard deviations (SD) and ranges for fork lengths and weights are presented. Release times are the start of releases and include fish released up to 1 hour later.

						Fork Length (mm)			Weight (g)		
Release	Date	Time	N	Tag loss	Mortality	Mean	SD	Range	Mean	SD	Range
17	7-Jul	12:07	18	0	1	115	5.2	105 - 125	15.6	2.0	13.0- 19.5
18	7-Jul	23:58	19	0	0	113	9.8	103 - 147	15.2	2.3	13.0 - 21.2
19	9-Jul	12:10	19	0	0	112	5.0	105 - 124	15.0	1.9	13.0 - 20.6
20	9-Jul	23:56	18	1	0	113	5.9	105 - 128	15.9	2.6	13.0 - 22.8
21	11-Jul	12:04	18	1	0	114	10.9	105 - 145	17.2	6.7	13.3 - 39.7
22	12-Jul	00:00	19	0	0	118	11.6	108 - 151	17.3	5.6	13.2 - 35.2
23	13-Jul	12:00	19	0	0	120	13.5	108 - 149	18.6	6.3	13.5 - 32.3
24	14-Jul	00:11	19	0	0	122	14.8	107 - 150	20.1	7.0	13.5 - 36.9
25	15-Jul	11:55	19	0	0	116	14.0	105 - 166	17.0	7.6	13.0 - 46.2
26	16-Jul	00:17	19	0	0	117	12.3	105 - 147	17.3	5.0	13.1 - 29.9
27	17-Jul	12:00	19	0	0	116	7.6	106 - 134	17.1	3.3	13.2 - 25.2
28	18-Jul	00:00	18	0	0	115	6.6	105 - 127	17.2	3.1	13.0 - 23.8
29	19-Jul	12:00	19	0	0	125	13.0	108 - 149	21.0	5.7	14.3 - 35.1
30	19-Jul	23:55	19	0	0	119	8.6	110 - 142	16.9	3.4	13.0 - 25.7
31	21-Jul	11:54	18	1	0	115	6.4	108 - 131	16.0	2.9	13.0 - 24.1
32	22-Jul	00:06	19	0	0	113	8.3	104 - 134	16.4	4.4	13.0 - 27.3
Overall			612	9	1	117	9.2	103 - 166	17.0	4.3	13.0 - 46.2

Table A1.12. 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 summer 2004. Dates, times, numbers of tagged fish released (N), 24 h post-tagging tag loss and mortality, and means, standard deviations (SD) and ranges for fork lengths and weights are presented. Release times are the start of releases and include fish released up to 1 hour later.

							Fork Length (mm)			Weight (g)		
Release	Location	Date	Time	N	Tag loss	Mortality	Mean	SD	Range	Mean	SD	Range
1	Tailrace	20-Jun	00:41	117	2	0	119	8.8	106 - 149	18.6	4.1	14.0 - 34.6
2	Sluiceway	20-Jun	07:00	61	1	0	119	7.3	110 - 141	17.8	3.6	13.6 - 27.9
3	Tailrace	20-Jun	12:35	106	1	0	117	6.9	108 - 138	16.6	3.1	13.0 - 26.2
4	Tailrace	21-Jun	00:31	117	2	0	118	6.9	109 - 137	18.1	3.5	13.2 - 28.2
5	Tailrace	21-Jun	12:35	115	4	0	121	8.0	108 - 146	18.4	4.0	13.0 - 33.2
6	Sluiceway	21-Jun	13:21	57	3	0	120	6.6	110 - 135	17.7	3.3	13.3 - 25.8
7	Tailrace	22-Jun	00:23	114	3	0	120	7.6	104 - 141	18.0	3.5	14.1 - 31.0
8	Sluiceway	22-Jun	09:12	61	1	0	117	6.1	108 - 134	16.5	2.7	13.1 - 25.4
9	Tailrace	22-Jun	13:05	65	1	0	119	7.0	111 - 145	17.4	3.1	13.6 - 28.4
10	Tailrace	23-Jun	01:05	116	2	0	119	7.4	109 - 140	18.5	3.2	13.4 - 27.6
11	Tailrace	23-Jun	12:38	118	1	1	118	7.6	109 - 142	17.1	3.4	13.1 - 28.3
12	Sluiceway	23-Jun	19:00	61	1	0	116	5.6	109 - 135	16.9	2.7	13.5 - 26.6
13	Tailrace	24-Jun	00:43	117	2	0	115	4.9	108 - 132	16.5	2.4	13.2 - 24.9
14	Tailrace	24-Jun	13:38	118	1	0	116	7.0	109 - 153	16.4	3.4	13.3 - 38.1
15	Sluiceway	24-Jun	19:00	59	3	0	114	4.8	110 - 142	14.8	2.1	13.0 - 26.7
16	Tailrace	25-Jun	00:35	88	2	0	115	6.3	109 - 142	15.3	3.0	13.0 - 30.9
17	Tailrace	25-Jun	13:13	47	1	0	114	5.5	107 - 137	15.5	3.0	13.0 - 30.1
18	Sluiceway	25-Jun	13:00	58	0	0	116	7.5	108 - 144	16.5	3.6	13.4 - 29.7
19	Tailrace	26-Jun	00:56	89	4	0	115	6.7	108 - 140	15.6	3.2	13.1 - 29.3
20	Sluiceway	26-Jun	07:00	58	0	0	115	8.0	109 - 154	16.3	4.7	13.0 - 42.4
21	Tailrace	26-Jun	13:05	46	3	3	117	9.1	110 - 150	16.5	4.9	13.1 - 35.1
22	Tailrace	27-Jun	01:07	19	1	0	117	6.3	110 - 132	17.2	2.9	13.4 - 24.1
23	Sluiceway	27-Jun	01:02	28	0	0	118	9.6	108 - 145	17.8	4.7	13.7 - 32.8
24	Tailrace	27-Jun	13:04	35	1	0	121	11.4	109 - 153	19.2	6.5	13.4 - 36.1

Table A1.12 (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 summer 2004. Dates, times, numbers of tagged fish released (N), 24 h post-tagging tag loss and mortality, and means, standard deviations (SD) and ranges for fork lengths and weights are presented. Release times are the start of releases and include fish released up to 1 hour later.

							Fork Length (mm)			Weight (g)		
Release	Location	Date	Time	N	Tag loss	Mortality	Mean	SD	Range	Mean	SD	Range
25	Tailrace	28-Jun	01:16	32	0	1	118	9.1	109 - 147	17.5	4.3	13.3 - 32.1
26	Sluiceway	28-Jun	07:06	27	1	0	116	6.3	110 - 136	16.5	3.2	13.0 - 25.7
27	Tailrace	28-Jun	13:12	14	0	0	116	6.1	111 - 135	16.2	3.3	13.0 - 26.3
28	Tailrace	29-Jun	00:45	58	0	0	114	4.4	107 - 134	16.3	2.3	13.2 - 24.9
29	Tailrace	29-Jun	12:53	81	0	0	115	7.0	107 - 146	16.1	3.7	13.0 - 32.3
30	Sluiceway	29-Jun	19:04	25	0	1	114	5.7	109 - 133	15.7	2.7	13.0 - 25.0
31	Tailrace	30-Jun	01:02	28	0	0	117	10.8	106 - 149	17.7	5.4	13.1 - 36.3
32	Sluiceway	30-Jun	01:00	37	0	0	114	5.7	108 - 130	15.8	2.6	13.0 - 24.3
33	Tailrace	30-Jun	12:49	165	2	2	115	7.9	107 - 146	16.2	3.9	13.0 - 34.2
34	Tailrace	1-Jul	00:18	101	2	3	115	7.5	104 - 146	15.5	3.6	13.0 - 31.8
35	Tailrace	1-Jul	12:36	125	1	2	115	7.4	107 - 148	16.5	3.8	13.0 - 35.2
36	Sluiceway	1-Jul	13:16	60	1	0	114	6.9	107 - 148	15.6	3.5	13.1 - 33.0
37	Tailrace	2-Jul	01:12	27	0	2	115	8.3	105 - 138	16.1	4.2	13.1 - 27.1
38	Sluiceway	2-Jul	01:05	34	0	0	116	7.0	109 - 138	15.9	3.1	13.0 - 27.6
39	Tailrace	2-Jul	12:48	53	2	0	115	7.1	107 - 136	16.0	3.5	13.1 - 26.6
40	Tailrace	3-Jul	01:36	73	0	2	115	10.5	102 - 154	16.7	5.6	13.0 - 40.5
41	Tailrace	3-Jul	13:08	50	0	0	115	7.5	107 - 142	16.1	3.9	13.0 - 31.0
42	Sluiceway	3-Jul	19:01	39	1	0	115	6.4	108 - 133	16.0	2.9	13.1 - 27.4
43	Tailrace	4-Jul	00:38	40	0	0	114	6.8	107 - 139	15.9	3.3	13.1 - 27.1
44	Tailrace	4-Jul	13:30	18	0	0	117	8.5	109 - 142	17.3	4.1	13.0 - 28.1
45	Sluiceway	4-Jul	13:05	30	2	0	117	10.6	107 - 142	17.5	5.2	13.2 - 30.1
46	Tailrace	5-Jul	00:46	64	1	0	117	11.1	103 - 150	18.6	5.9	13.2 - 40.0
47	Sluiceway	5-Jul	07:00	32	0	0	116	11.7	104 - 160	17.5	6.4	13.1 - 40.7
48	Tailrace	5-Jul	13:01	27	0	0	116	8.8	107 - 150	16.8	5.1	13.0 - 37.8

Table A1.12 (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 summer 2004. Dates, times, numbers of tagged fish released (N), 24 h post-tagging tag loss and mortality, and means, standard deviations (SD) and ranges for fork lengths and weights are presented. Release times are the start of releases and include fish released up to 1 hour later.

							Fork Length (mm)			Weight (g)		
Release	Location	Date	Time	N	Tag loss	Mortality	Mean	SD	Range	Mean	SD	Range
49	Tailrace	6-Jul	00:55	33	0	0	118	11.8	107 - 151	18.7	6.1	13.5 - 38.5
50	Sluiceway	6-Jul	01:00	34	1	1	119	11.7	105 - 145	19.4	6.4	13.2 - 34.2
51	Tailrace	6-Jul	12:31	100	1	0	116	11.4	104 - 168	17.6	6.1	13.0 - 48.2
52	Tailrace	7-Jul	00:46	43	0	0	114	6.9	107 - 137	16.2	3.1	13.0 - 27.4
53	Tailrace	7-Jul	12:49	108	1	2	115	8.8	105 - 147	16.9	4.3	13.1 - 34.0
54	Sluiceway	7-Jul	13:14	76	2	0	117	8.5	105 - 146	17.3	4.0	13.0 - 31.7
55	Tailrace	8-Jul	00:37	82	0	4	114	9.1	103 - 146	16.2	4.4	13.0 - 32.6
56	Tailrace	8-Jul	13:01	79	1	0	113	8.2	101 - 144	15.7	3.6	13.0 - 32.2
57	Sluiceway	8-Jul	19:00	26	0	0	116	10.6	104 - 148	17.1	5.2	13.1 - 35.7
58	Tailrace	9-Jul	01:00	11	0	1	122	13.0	108 - 145	19.6	6.7	13.5 - 30.1
59	Sluiceway	9-Jul	01:00	25	0	0	118	13.5	105 - 146	18.3	6.3	13.0 - 32.5
60	Tailrace	9-Jul	13:03	39	0	0	111	6.4	105 - 142	15.3	2.8	13.0 - 29.4
61	Tailrace	10-Jul	00:49	78	0	0	115	10.7	103 - 149	17.6	5.1	13.1 - 36.1
62	Tailrace	10-Jul	12:47	42	0	3	119	14.8	103 - 156	18.6	7.7	13.0 - 41.0
63	Sluiceway	10-Jul	13:22	50	0	2	117	10.5	107 - 151	17.4	5.6	13.0 - 36.7
64	Tailrace	11-Jul	00:34	58	1	1	124	13.9	106 - 159	21.3	7.5	13.1 - 49.8
65	Sluiceway	11-Jul	07:00	55	0	0	124	12.6	106 - 151	20.3	6.4	13.0 - 37.3
66	Tailrace	11-Jul	13:10	60	0	2	127	17.4	105 - 169	22.9	10.5	13.0 - 50.2
67	Tailrace	12-Jul	00:38	50	0	1	120	12.9	105 - 158	19.6	6.9	13.0 - 42.8
68	Sluiceway	12-Jul	01:02	51	1	1	120	13.8	104 - 156	20.0	7.4	13.0 - 45.0
69	Tailrace	12-Jul	12:46	59	0	2	119	12.2	105 - 163	18.7	6.4	13.0 - 47.0
70	Tailrace	13-Jul	00:28	63	1	1	125	15.8	105 - 162	21.6	9.2	13.0 - 48.8
71	Tailrace	13-Jul	13:12	49	0	0	125	16.8	106 - 168	21.4	8.5	13.1 - 50.5
72	Sluiceway	13-Jul	19:00	42	0	1	133	16.5	107 - 167	25.6	9.8	13.3 - 52.2

Table A1.12 (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 summer 2004. Dates, times, numbers of tagged fish released (N), 24 h post-tagging tag loss and mortality, and means, standard deviations (SD) and ranges for fork lengths and weights are presented. Release times are the start of releases and include fish released up to 1 hour later.

							Fork Length (mm)			Weight (g)		
Release	Location	Date	Time	N	Tag loss	Mortality	Mean	SD	Range	Mean	SD	Range
73	Tailrace	14-Jul	01:10	25	0	1	129	14.5	109 - 162	23.1	8.6	13.7 - 47.4
74	Sluiceway	14-Jul	07:07	47	1	0	128	15.1	105 - 164	22.5	8.6	13.0 - 50.2
75	Tailrace	14-Jul	13:10	21	0	0	120	11.8	104 - 142	18.1	4.9	13.1 - 27.9
76	Tailrace	15-Jul	01:08	92	0	1	117	10.1	104 - 156	17.3	4.7	13.0 - 38.6
77	Sluiceway	15-Jul	01:02	70	0	1	119	11.8	105 - 154	18.4	5.8	13.3 - 42.1
78	Tailrace	15-Jul	12:46	62	0	0	119	11.3	107 - 145	17.6	4.6	13.0 - 30.1
79	Tailrace	16-Jul	00:40	68	0	2	118	10.3	105 - 149	17.5	4.7	13.0 - 35.5
80	Tailrace	16-Jul	12:54	59	0	2	118	12.2	104 - 150	18.1	5.5	13.2 - 36.9
81	Sluiceway	16-Jul	13:11	51	2	3	118	10.0	105 - 150	17.6	4.8	13.0 - 35.6
82	Tailrace	17-Jul	00:18	101	2	1	121	14.1	104 - 165	19.6	7.6	13.1 - 49.9
83	Tailrace	17-Jul	12:40	106	1	1	121	12.2	105 - 153	19.1	5.9	13.0 - 41.9
84	Sluiceway	17-Jul	19:00	56	1	0	115	6.7	105 - 129	16.5	2.5	13.0 - 21.2
85	Tailrace	18-Jul	00:44	79	0	2	114	8.4	104 - 147	16.9	4.7	13.1 - 43.8
86	Tailrace	18-Jul	13:08	108	4	1	118	10.5	105 - 161	17.8	5.6	13.1 - 47.2
87	Sluiceway	18-Jul	13:10	59	0	0	117	9.1	103 - 149	17.4	4.3	13.1 - 35.6
88	Tailrace	19-Jul	00:29	162	2	0	115	8.5	103 - 157	16.5	3.7	13.1 - 43.1
89	Sluiceway	19-Jul	07:00	67	0	1	113	5.6	105 - 135	16.0	2.0	13.0 – 23.0
90	Tailrace	19-Jul	13:11	158	0	2	116	9.5	103 - 160	17.2	5.0	13.1 - 46.0
91	Tailrace	20-Jul	00:34	106	0	1	113	7.5	103 - 138	16.1	2.9	13.0 - 28.8
92	Sluiceway	20-Jul	01:06	60	0	2	113	7.3	103 - 144	16.0	3.0	13.1 - 30.9
Overall				5980	75	60	117	10.0	101 - 169	17.4	5.1	13.0 - 52.2

Table A1.13. Summary of subyearling Chinook salmon releases at Bonneville Dam tailrace during summer 2004. Dates, times, numbers of tagged fish released (N), 24 h post-tagging tag loss and mortality, and means, standard deviations (SD) and ranges for fork lengths and weights are presented. Release times are the start of releases and include fish released up to 1 hour later.

						Fork Length (mm)			Weight (g)		
Release	Date	Time	N	Tag loss	Mortality	Mean	SD	Range	Mean	SD	Range
1	21-Jun	13:04	56	4	0	119	6.2	106 - 134	17.5	2.7	14.2 - 26.4
2	22-Jun	01:28	56	4	0	122	7.8	109 - 143	18.6	3.7	13.7 - 30.1
3	22-Jun	13:29	55	3	0	120	6.8	109 - 145	17.9	3.2	14.3 - 29.7
4	23-Jun	01:22	57	3	0	122	9.0	106 - 146	19.1	4.4	13.6 - 33.0
5	23-Jun	13:21	58	2	0	123	8.3	110 - 141	18.7	4.0	14.3 - 30.9
6	24-Jun	01:05	58	4	0	121	9.7	108 - 156	18.4	4.6	13.3 - 32.7
7	24-Jun	13:13	60	4	0	119	5.6	109 - 136	17.3	2.3	13.6 - 25.0
8	25-Jun	01:06	59	1	0	120	6.2	110 - 135	18.0	2.9	14.6 - 27.9
9	25-Jun	13:01	62	0	0	119	6.9	108 - 145	17.2	3.2	13.8 - 34.3
10	26-Jun	00:56	59	3	0	122	9.7	110 - 153	19.2	4.6	14.7 - 34.3
11	26-Jun	13:01	59	2	0	123	8.4	112 - 143	18.5	3.8	14.0 - 28.5
12	27-Jun	00:57	57	2	0	116	6.5	106 - 141	15.5	3.0	13.1 - 29.4
13	27-Jun	12:55	59	0	0	118	7.4	107 - 140	16.0	3.2	13.0 - 28.5
14	28-Jun	01:05	56	3	0	119	10.2	105 - 145	17.1	5.2	13.0 - 37.4
15	28-Jun	13:05	60	1	0	118	8.0	109 - 155	16.6	3.8	13.1 - 32.1
16	29-Jun	01:18	38	1	0	121	10.7	109 - 155	19.0	5.3	13.5 - 34.9
17	29-Jun	13:07	38	1	0	119	8.4	106 - 146	17.8	4.9	13.1 - 41.0
18	30-Jun	01:05	50	1	0	116	5.8	105 - 135	15.6	2.3	13.0 - 23.3
19	30-Jun	13:00	76	0	0	117	7.5	106 - 145	15.8	3.2	13.2 - 29.0
20	1-Jul	01:00	63	0	0	117	6.6	108 - 143	16.0	3.4	13.0 - 30.0
21	1-Jul	12:49	57	1	0	118	9.4	107 - 151	16.7	4.4	13.0 - 33.5
22	2-Jul	00:54	55	0	0	115	4.5	105 - 133	15.2	2.3	13.0 - 24.5
23	2-Jul	12:52	71	0	0	116	6.9	108 - 139	16.3	3.5	13.0 - 30.9
24	3-Jul	01:01	59	0	4	116	9.3	105 - 150	16.2	3.9	13.0 - 30.0

Table A1.13 (continued). Summary of subyearling Chinook salmon releases at Bonneville Dam tailrace during summer 2004. Dates, times, numbers of tagged fish released (N), 24 h post-tagging tag loss and mortality, and means, standard deviations (SD) and ranges for fork lengths and weights are presented. Release times are the start of releases and include fish released up to 1 hour later.

						Fork Length (mm)			Weight (g)		
Release	Date	Time	N	Tag loss	Mortality	Mean	SD	Range	Mean	SD	Range
25	3-Jul	12:53	44	2	0	116	5.0	110 - 135	15.7	2.6	13.0 - 23.5
26	4-Jul	01:10	57	1	2	114	4.6	107 - 132	15.2	2.5	13.0 - 26.8
27	4-Jul	13:08	50	2	1	114	4.7	106 - 133	14.8	1.9	13.0 - 22.0
28	5-Jul	00:55	68	1	1	114	6.1	105 - 143	15.4	2.8	13.0 - 30.0
29	5-Jul	12:58	59	1	0	116	7.8	106 - 143	16.5	4.0	13.0 - 34.7
30	6-Jul	00:56	61	3	1	116	8.0	109 - 152	15.9	3.8	13.0 - 34.2
31	6-Jul	13:00	50	1	0	115	7.5	105 - 144	15.7	3.9	13.0 - 29.7
32	7-Jul	00:56	64	1	0	114	8.1	104 - 143	16.4	4.2	13.0 - 35.1
33	7-Jul	12:58	54	0	1	113	6.9	105 - 140	15.1	3.4	13.0 - 26.8
34	8-Jul	00:56	64	1	0	114	8.4	102 - 143	16.6	3.9	13.0 - 30.2
35	8-Jul	13:09	65	1	0	115	7.5	106 - 146	16.1	3.4	13.0 - 29.3
36	9-Jul	00:53	59	1	0	116	8.8	104 - 146	16.8	4.3	13.0 - 31.4
37	9-Jul	13:18	60	0	0	116	7.5	107 - 141	16.7	3.8	13.0 - 29.3
38	10-Jul	00:54	60	1	0	113	5.6	105 - 138	15.1	2.2	13.0 - 24.3
39	10-Jul	13:00	65	1	0	114	5.6	105 - 130	16.2	3.1	13.1 - 32.1
40	11-Jul	00:57	51	0	1	118	8.1	106 - 145	17.5	3.9	13.0 - 31.8
41	11-Jul	12:53	62	1	0	113	6.0	105 - 141	15.5	2.6	13.0 - 27.1
42	12-Jul	00:52	56	2	0	117	8.3	106 - 145	16.8	3.9	13.2 - 30.5
43	12-Jul	12:58	58	0	2	119	11.0	104 - 146	17.7	4.7	13.0 - 31.9
44	13-Jul	01:05	54	1	1	118	11.9	105 - 143	18.2	5.1	13.2 - 31.6
45	13-Jul	12:53	61	1	0	121	12.5	106 - 152	19.2	6.0	13.2 - 35.8
46	14-Jul	01:05	59	0	0	121	11.3	107 - 145	19.5	5.1	13.8 - 30.3
47	14-Jul	12:55	59	2	1	119	11.5	107 - 145	17.9	5.2	13.1 - 30.2
48	15-Jul	00:45	79	1	1	115	9.8	105 - 150	16.3	4.5	13.0 - 36.3
49	15-Jul	12:57	33	1	0	116	11.3	105 - 164	16.7	6.4	13.1 - 48.0
50	16-Jul	01:23	58	3	1	117	9.8	106 - 146	17.1	4.5	13.0 - 32.7
51	16-Jul	13:14	55	0	1	116	10.8	105 - 155	16.5	5.1	13.0 - 38.9

Table A1.13 (continued). Summary of subyearling Chinook salmon releases at Bonneville Dam tailrace during summer 2004. Dates, times, numbers of tagged fish released (N), 24 h post-tagging tag loss and mortality, and means, standard deviations (SD) and ranges for fork lengths and weights are presented. Release times are the start of releases and include fish released up to 1 hour later.

						Fork Length (mm)			Weight (g)		
Release	Date	Time	N	Tag loss	Mortality	Mean	SD	Range	Mean	SD	Range
52	17-Jul	00:37	83	2	1	117	11.4	105 - 158	17.9	5.8	13.0 - 46.2
53	17-Jul	13:05	82	0	0	117	9.0	106 - 152	17.8	4.2	13.2 - 38.9
54	18-Jul	00:47	79	0	2	120	11.3	106 - 157	19.0	5.3	13.0 - 41.1
55	18-Jul	13:00	71	0	1	116	9.2	105 - 150	17.2	4.1	13.1 - 33.0
56	19-Jul	00:54	80	0	2	122	10.9	108 - 164	19.0	5.4	13.0 - 43.7
57	19-Jul	12:58	78	1	1	123	14.7	105 - 172	20.6	8.3	13.3 - 57.4
58	20-Jul	00:58	81	0	0	121	9.7	106 - 144	18.6	4.1	13.1 - 29.7
59	20-Jul	13:05	80	1	0	121	11.3	105 - 157	20.4	6.4	13.0 - 44.5
60	21-Jul	00:57	73	2	2	116	7.8	105 - 141	16.7	3.5	13.2 - 27.9
61	21-Jul	12:55	77	0	1	117	9.9	105 - 155	17.1	4.7	13.0 - 35.5
62	22-Jul	01:00	68	0	0	115	7.3	105 - 138	16.7	3.2	13.1 - 27.0
Overall			3795	75	28	118	9.2	102 - 172	17.2	4.4	13.0 - 57.4

Appendix 2: Dead fish analysis

We generated survival estimates without releases that occurred 24 h before or after releases associated with the dead fish detections. The rationale for this approach is: since dead fish were not detected consistently throughout the season, then the conditions (i.e., discharge, water velocities, dam operations) present during releases where dead fish were detected (and conservatively ± 24 h of the release) may have been conducive for allowing the transport of dead radio-tagged fish to our detection sites below Bonneville. Thus, all fish passing through the study area during this time (i.e., ± 24 h of the release) were not included in the alternate analysis. In addition, to account for the possibility that our detections of radio-tagged fish with long travel times could be dead fish, we eliminated all fish with travel times > the 99.7th percentile and recalculated the estimates.

Yearling Chinook salmon

Paired Release-recapture Model

We generated survival estimates without releases that occurred 24 h before or after releases associated with the dead fish detections.

Minimum Gap Runner Turbine Unit

Control group released directly downstream of front roll below MGR turbine unit

Survival Estimation with removal of releases within 24 h of detected dead fish

We removed releases 5, 6, 8, and 16 (Appendix 1, Table A1.2 and A1.3) and estimated that the average survival of yearling Chinook salmon into the MGR turbine unit 4A at Bonneville Dam's powerhouse 1 with the control group released in the tailrace below the MGR unit front roll was 0.952 (SE = 0.012, 95% confidence interval [0.907, 0.997].

Control group released below the outfall of the powerhouse 2 juvenile bypass outfall

Survival estimation with removal of releases within 24 h of detected dead fish

We removed releases 5, 6, 8, and 16 (Appendix 1, Table A1.2) and estimated that the average survival of yearling Chinook salmon into the MGR turbine unit 4A at Bonneville Dam's powerhouse 1 with the control group released in the tailrace below the powerhouse 2 juvenile bypass outfall was 0.995 (SE = 0.020, 95% confidence interval [0.951, 1.039].

Powerhouse 1 Ice and Trash Sluiceway

Survival estimation with removal of releases within 24 h of detected dead fish

We removed releases 5, 6, 8, and 16 (Appendix 1, Table A1.1) and estimated that the average 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) was 1.004 (SE = 0.026, 95% confidence interval [0.947, 1.061]).

Route-specific Survival Model

Survival estimation with removal of releases within 24 h of detected dead fish

We also generated maximum likelihood estimates of the route-specific passage and survival probabilities through Bonneville Dam using capture histories (Table A2.1) with the removal of fish detected within 24 h of the detected radio-tagged dead fish (Figure A2.1). The survival of yearling Chinook salmon through Bonneville Dam spillway using this analysis method was estimated to be 0.910 (SE = 0.012, profile likelihood 95% confidence interval [0.886, 0.934]). For yearling Chinook salmon passing via powerhouse 1 the estimated survival was 0.922 (SE = 0.021, profile likelihood 95% confidence interval [0.878, 0.960]) and for yearling Chinook salmon passing via powerhouse 2 turbines the estimated survival was 0.947 (SE = 0.012, profile likelihood 95% confidence interval [0.922, 0.970]). For yearling Chinook salmon passing via the JBS the estimated survival was 0.968(SE = 0.015, profile likelihood 95% confidence interval [0.937, 0.995]) and passing via the corner collector at powerhouse 2 the estimated survival was 1.019 (SE = 0.009, profile likelihood 95% confidence interval [1.001, 1.038]). Yearling Chinook salmon dam survival through Bonneville Dam was estimated to be 0.951 (SE = 0.009, 95% confidence intervals [0.933, 0.968].

Survival estimation with removal of fish with travel times > 99.7th percentile

We generated maximum likelihood estimates of the route-specific passage and survival probabilities through Bonneville Dam using capture histories (Table A2.2) with the removal of fish with travel times > 99.7th percentile (Figure A2.2). The survival of yearling Chinook salmon through Bonneville Dam spillway using this analysis method was estimated to be 0.910 (SE = 0.011, profile likelihood 95% confidence interval [0.888, 0.931]). For yearling Chinook salmon passing via powerhouse 1 the estimated survival was 0.912 (SE = 0.020, profile likelihood 95% confidence interval [0.872, 0.948]) and for yearling Chinook salmon passing via powerhouse 2 turbines the estimated survival was 0.951 (SE = 0.011, profile likelihood 95% confidence interval [0.929, 0.972]). For yearling Chinook salmon passing via the JBS the estimated survival was 0.970 (SE = 0.013, profile likelihood 95% confidence interval [0.943, 0.994]) and passing via the corner collector at powerhouse 2 the estimated survival was 1.016 (SE = 0.008, profile likelihood 95% confidence interval [0.999, 1.032]). Yearling Chinook salmon dam survival through Bonneville Dam was estimated to be 0.951 (SE = 0.008, 95% confidence intervals [0.936, 0.966].

Table A2.1. Counts of radio-tagged yearling Chinook salmon with the removal of fish within 24 h of detected dead fish for the releases from The Dalles Dam (R_1) and in the tailrace of Bonneville Dam (R_2) used in the route-specific survival model during 2004. Detection history recorded as: 1, detected; 0, not detected. For R_1, the first position indicates the release event, the second position indicates detection or not at Bonneville Dam, the third position indicates detection or not at at least one of the arrays below Bonneville Dam. For R_2, the second position indicates the release event and the third position indicates detection or not at at least one of the arrays below 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. B1 is powerhouse 1 and B2 is powerhouse 2 at Bonneville Dam.

				Within-route histories Bonneville Dam		
Release	Detection History	Route	Counts	11	01	10
R_1 = 3773	100		274			
	101		59			
	110	Spillway	145	936	9	172
	111		972			
	110	B1	34	173	112	2
	111		253			
	110	B2 Turbines	83	430	41	398
	111		786			
	110	B2 Juvenile bypass	33	441	1	2
	111		411			
	110	B2 Corner collector	18	722	0	1
	111		705			
R_2 = 990	010		43			
	011		947			

Table A2.2. Counts of radio-tagged yearling Chinook salmon, with the removal of fish with travel times > 99.7th percentile, from The Dalles Dam (R_1) and in the tailrace of Bonneville Dam (R_2) used in the route-specific survival model during 2004. Detection history recorded as: 1, detected; 0, not detected. For R_1, the first position indicates the release event, the second position indicates detection or not at Bonneville Dam, the third position indicates detection or not at at least one of the arrays below Bonneville Dam. For R_2, the second position indicates the release event and the third position indicates detection or not at at least one of the arrays below 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. B1 is powerhouse 1 and B2 is powerhouse 2 at Bonneville Dam.

				Within-route histories Bonneville Dam		
Release	Detection History	Route	Counts	11	01	10
$R_1 = 4481$	100		326			
	101		70			
	110	Spillway	172	1125	9	203
	111		1165			
	110	B1	43	214	121	5
	111		297			
	110	B2 Turbines	91	511	50	448
	111		918			
	110	B2 Juvenile bypass	37	516	2	2
	111		483			
	110	B2 Corner collector	24	878	0	1
	111		855			
$R_2 = 1273$	010		54			
	011		1219			

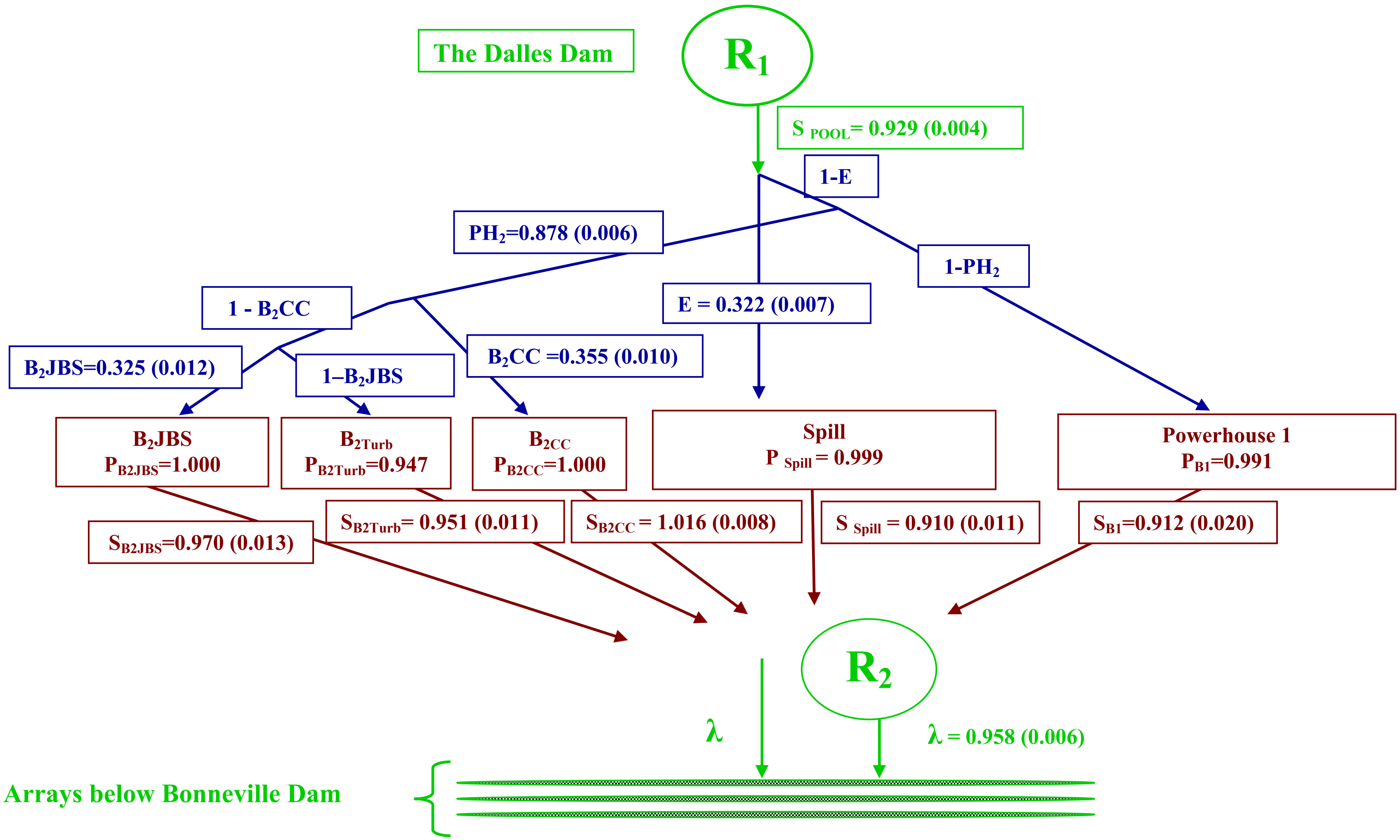


Figure A2.1. Schematic of estimated route-specific passage and survival parameters for yearling Chinook salmon through Bonneville Dam with the removal of fish with travel times > 99.7. Estimated standard errors are in parentheses.

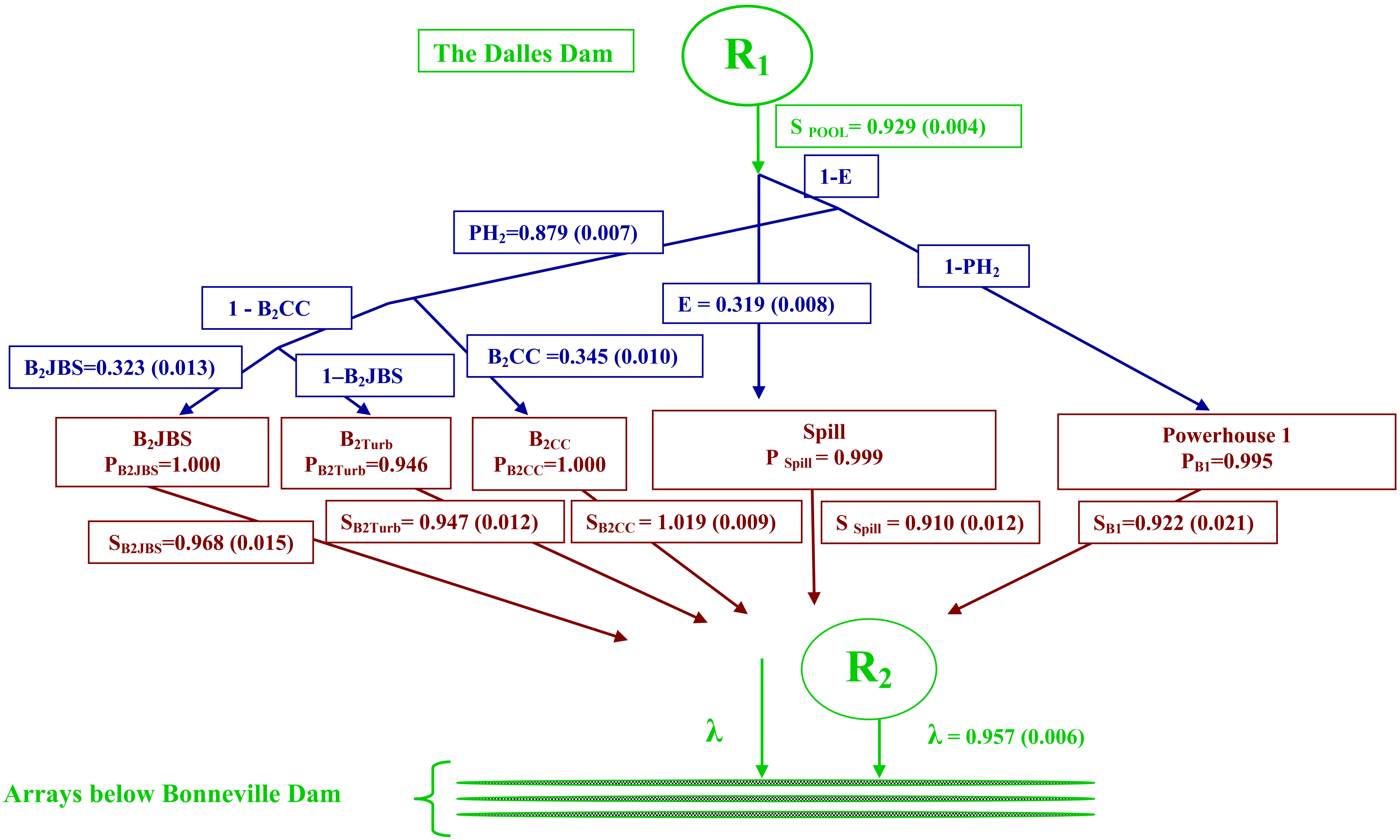


Figure A2.2. Schematic of estimated route-specific passage and survival parameters for yearling Chinook salmon through Bonneville Dam with the removal of fish within 24 h of detected dead fish. Estimated standard errors are in parentheses.

Subyearling Chinook salmon

Paired Release-recapture Model

Powerhouse 1 Ice and Trash Sluiceway

Survival estimation with removal of releases within 24 h of detected dead fish

We removed releases 15 and 16 (Appendix 1, Table A1.11) and estimated that the average survival of subyearling Chinook salmon released into the ice and trash sluiceway from 21 June to 22 July at Bonneville Dam's powerhouse 1 (control release in the tailrace below the outfall of powerhouse 2 JBS outfall) was 0.950 (SE = 0.019, 95% confidence interval [0.911, 0.989]).

56 kcfs/TDG spill operations with removal of fish within 24 h of dead fish detections

We also generated maximum likelihood estimates of the route-specific passage and survival probabilities through Bonneville Dam using capture histories (Table A2.3) with the removal of fish detected within 24 h of the detected radio-tagged dead fish (Figure A2.3). The survival of subyearling Chinook salmon through Bonneville Dam spillway using this analysis method was estimated to be 0.887 (SE = 0.014, profile likelihood 95% confidence interval [0.860, 0.914]). For subyearling Chinook salmon passing via powerhouse 1 the estimated survival was 0.837 (SE = 0.062, profile likelihood 95% confidence interval [0.700, 0.940]) and for subyearling Chinook salmon passing via powerhouse 2 turbines the estimated survival was 0.835 (SE = 0.020, profile likelihood 95% confidence interval [0.795, 0.874]). For subyearling Chinook salmon passing via the JBS the estimated survival was 0.925(SE = 0.029, profile likelihood 95% confidence interval [0.861, 0.976]) and passing via the corner collector at powerhouse 2 the estimated survival was 0.976 (SE = 0.014, profile likelihood 95% confidence interval [0.946, 1.003]). Subyearling Chinook salmon dam survival through Bonneville Dam was estimated to be 0.895 (SE = 0.011, 95% confidence intervals [0.874, 0.916]. Since this analysis did not indicate any major changes in the survival estimates we did not generate survival estimates by day and night spill operations.

32 kcfs spill operations with removal of fish within 24 h of dead fish detections

We also generated maximum likelihood estimates of the route-specific passage and survival probabilities through Bonneville Dam using capture histories (Table A2.4) with the removal of fish detected within 24 h of the detected radio-tagged dead fish (Figure A2.4). The survival of subyearling Chinook salmon through Bonneville Dam spillway using this analysis method was estimated to be 0.744 (SE = 0.022, profile likelihood 95% confidence interval [0.700, 0.786]). For subyearling Chinook salmon passing via powerhouse 1 the estimated survival was 0.829 (SE = 0.030, profile likelihood 95% confidence interval [0.767, 0.884]) and for subyearling Chinook salmon passing via powerhouse 2 turbines the estimated survival was 0.833 (SE = 0.014, profile likelihood 95% confidence interval [0.805, 0.859]). For subyearling Chinook salmon passing via the JBS the estimated survival was 0.958 (SE = 0.019, profile likelihood 95% confidence interval [0.918, 0.991]) and passing via the corner collector at powerhouse 2 the estimated survival was 0.954 (SE = 0.013, profile likelihood 95% confidence interval [0.926, 0.978]). Subyearling Chinook salmon dam survival through Bonneville Dam was estimated to be 0.858 (SE = 0.010, 95% confidence intervals [0.838, 0.877]. Since this analysis did not indicate any major changes in the survival estimates we did not generate survival estimates by day and night spill operations.

Table A2.3. Counts of radio-tagged subyearling Chinook salmon released from The Dalles Dam (R_1) and the tailrace of Bonneville Dam (R_2) during 56 kcfs day/TDG night spill operations with removal of fish within 24 h of deadfish detections used in the route-specific survival model during 2004. Detection history recorded as: 1, detected; 0, not detected. For R_1, the first position indicates the release event, the second position indicates detection or not at Bonneville Dam, the third position indicates detection or not at at least one of the arrays below Bonneville Dam. For R_2, the second position indicates the release event and the third position indicates detection or not at at least one of the arrays below 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. B1 is powerhouse 1 and B2 is powerhouse 2 at Bonneville Dam.

				Within-route histories Bonneville Dam		
Release	Detection History	Route	Counts	11	01	10
$R_1 = 2440$	100		356			
	101		34			
	110	Spillway	149	772	8	151
	111		782			
	110	B1	10	37	11	0
	111		38			
	110	B2 Turbines	100	243	53	182
	111		378			
	110	B2 Juvenile bypass	18	142	1	2
	111		127			
	110	B2 Corner collector	34	445	2	1
	111		414			
$R_2 = 1597$	010		85			
	011		1512			

Table A2.4. Counts of radio-tagged subyearling Chinook salmon released from The Dalles Dam (R_1) and the tailrace of Bonneville Dam (R_2) during 32 kcfs spill operations with removal of fish within 24 h of deadfish detections used in the route-specific survival model during 2004. Detection history recorded as: 1, detected; 0, not detected. For R_1, the first position indicates the release event, the second position indicates detection or not at Bonneville Dam, the third position indicates detection or not at at least one of the arrays below Bonneville Dam. For R_2, the second position indicates the release event and the third position indicates detection or not at at least one of the arrays below 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. B1 is powerhouse 1 and B2 is powerhouse 2 at Bonneville Dam.

				Within-route histories Bonneville Dam		
Release	Detection History	Route	Counts	11	01	10
$R_1 = 3252$	100		468			
	101		59			
	110	Spillway	146	410	15	71
	111		350			
	110	B1	46	148	67	1
	111		169			
	110	B2 Turbines	225	504	93	478
	111		850			
	110	B2 Juvenile bypass	27	289	1	3
	111		266			
	110	B2 Corner collector	62	625	4	17
	111		584			
$R_2 = 1960$	010		102			
	011		1858			

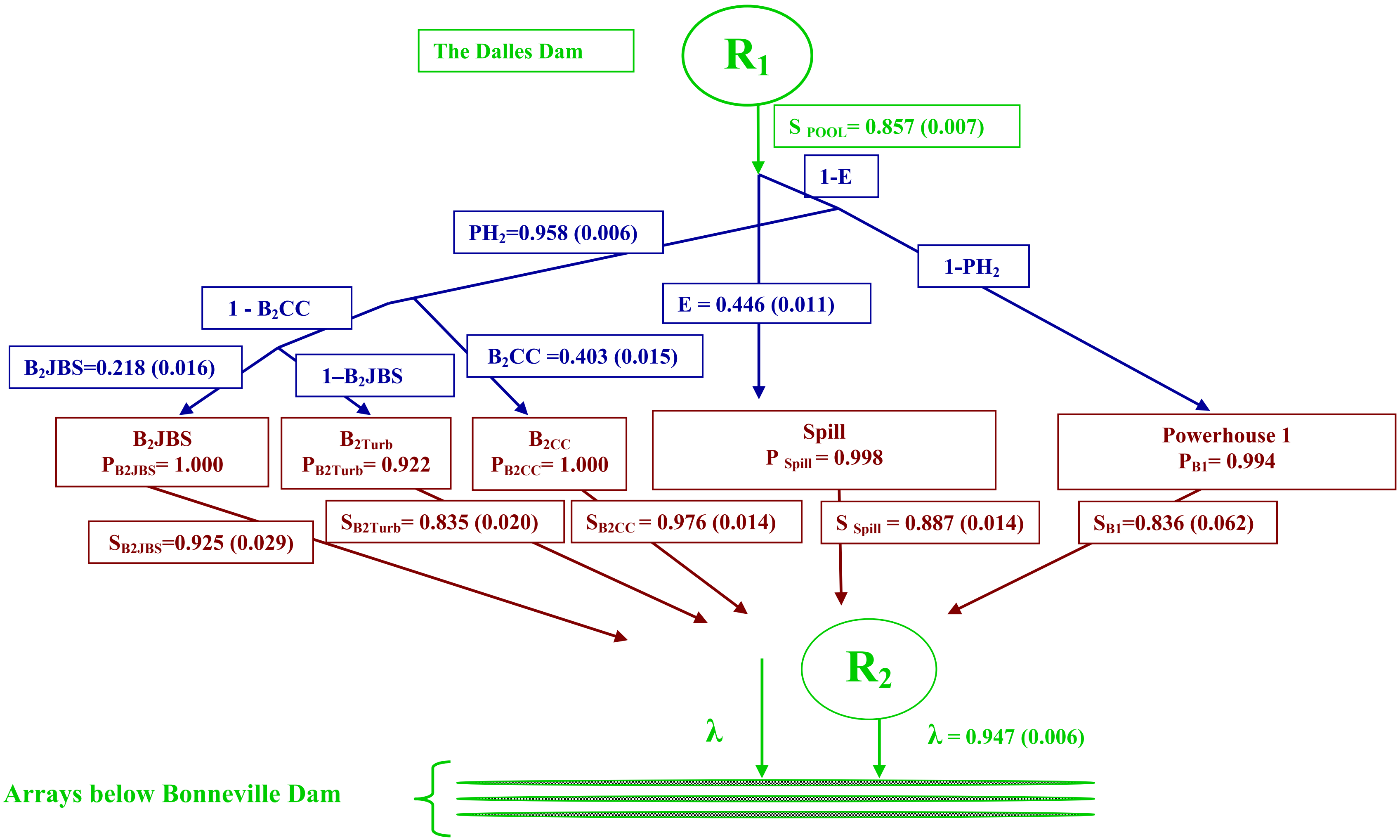


Figure A2.3. Schematic of estimated route-specific passage and survival parameters using an analysis with the removal of fish contacted within 24 h of detected dead fish, for subyearling Chinook salmon through Bonneville dam during 20 June through 22 July, at 56 kcfs day and total dissolved gas cap at night spill operations in 2004. Estimated standard errors are in parentheses.

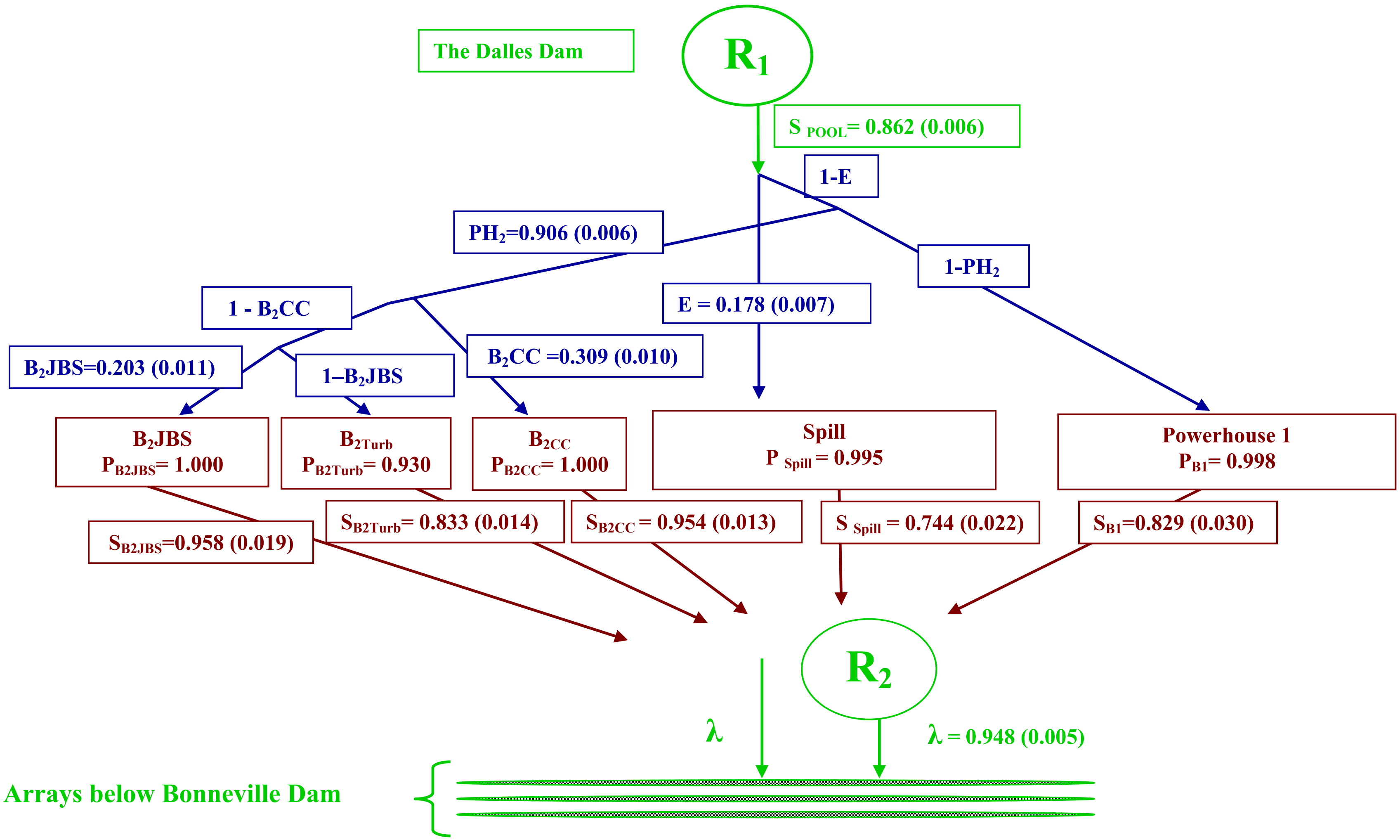


Figure A2.4. Schematic of estimated route-specific passage and survival parameters using an analysis with the removal of fish contacted within 24 h of detected dead fish, for subyearling Chinook salmon through Bonneville dam during 20 June through 22 July, at 32 kcfs spill operations in 2004. Estimated standard errors are in parentheses.

Appendix 3: Tag-Life Performance for Determining Potential Bias of Survival Estimates

Introduction

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 a 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 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).

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

To assess the probability of tag failure at detection arrays, a tag life study was performed. Our objectives were to: 1) estimate the probability a radio-tag was operational over time, 2) model the probability a radio-tag was operational, and 3) estimate the probability radio-tags were operational at detection arrays.

Methods

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

Our analytical approach was as per Townsend et al. (2004). Tag-life data was used to model tag survivorship and for calculating the probability of a tag being operational at detection arrays. The tag-life data was fit to a Gompertz distribution (Elandt-Johnson and Johnson 1980) for each season. A non-parametric form of the tag survival function was used because arrival times for radio-tagged salmonids had a non-normal distribution (Figure A3.1). This involved ranking tag-life data for calculating model parameters. Estimates for model parameters α and β

were generated for the tag survival function below and were used to calculate probabilities, where S is the probability the radio-tag is operational and t is time in days.

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

The tag-life studies for spring and summer were analyzed for generating model parameters of the Gompertz distribution and calculating probabilities that radio-tags were 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 A3.2, Table A3.1).

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

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 probably change even less after correction. Since the probability of a tag being operational at the downstream detection arrays for our survival studies were very close to one (Table A3.2), we did not adjust our survival estimates.

References

Cowen, L. and C. J. Schwarz. 2005. Capture-recapture studies using radio telemetry with premature radio-tag failure. Biometrics 61:657-664.

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

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

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

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

Table A3.2. Estimated probabilities (mean, SE in parentheses) a radio-tag was operational at Bonneville Dam and other downstream detection arrays for yearling Chinook salmon, hatchery steelhead trout, and subyearling Chinook salmon, during 2004.

	Detection Array Locations	
Release Site	Bonneville Dam	Survival Gates
Yearling Chinook salmon		
The Dalles Dam	0.9996 (3.634×10^{-6})	0.9992 (7.036×10^{-5})
Bonneville Dam	NA	0.9999 (3.474×10^{-6})
Hatchery steelhead trout		
The Dalles Dam	0.9996 (2.152×10^{-5})	0.9993 (3.795×10^{-5})
Bonneville Dam	NA	0.9998 (1.122×10^{-4})
Subyearling Chinook salmon		
The Dalles Dam	0.9999 (1.604×10^{-5})	0.9999 (2.030×10^{-5})
Bonneville Dam	NA	1.0000 (3.285×10^{-7})

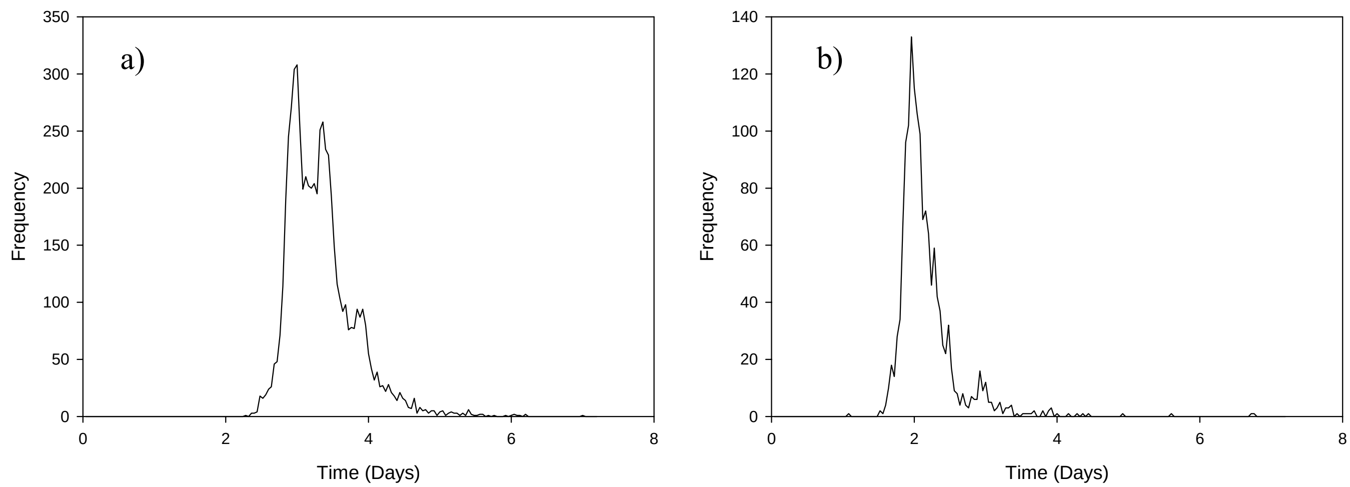


Figure A3.1. Arrival distributions of treatment fish for the, a) Bonneville Dam and b) The Dalles Dam survival assessment during summer of 2004 for subyearling Chinook salmon.

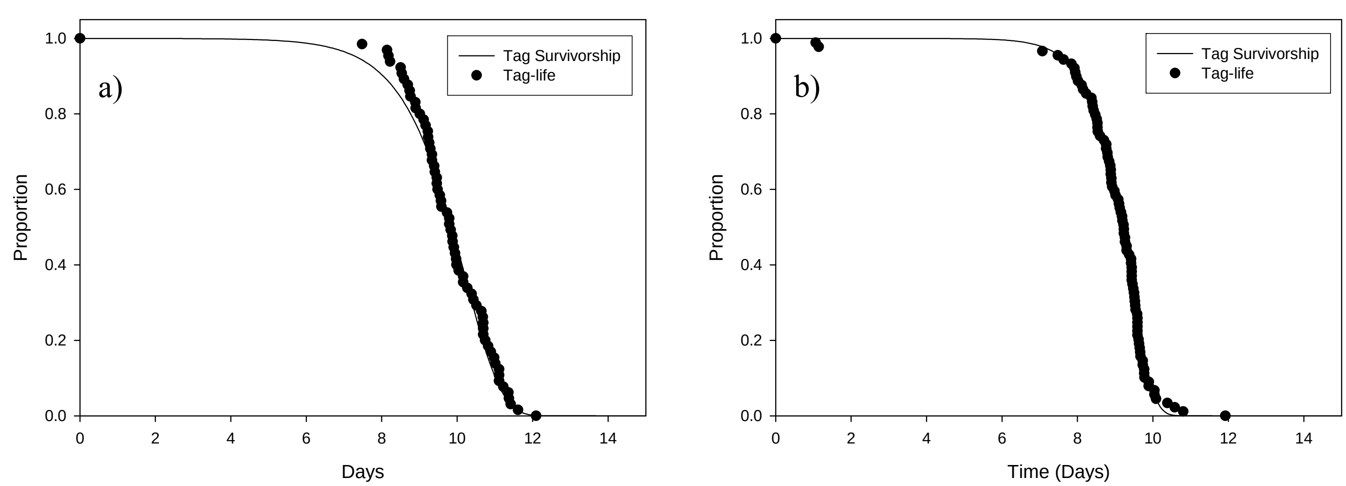
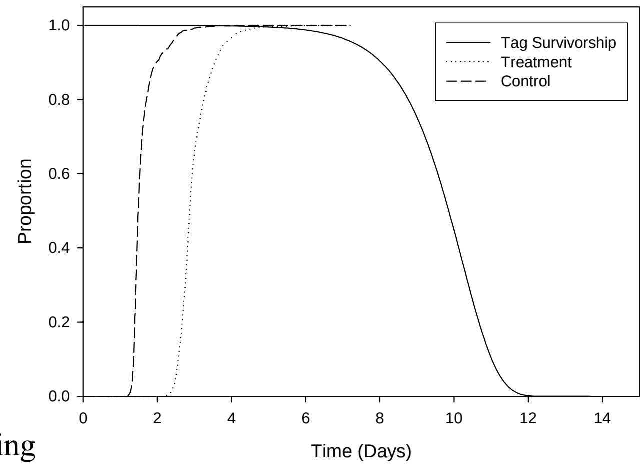
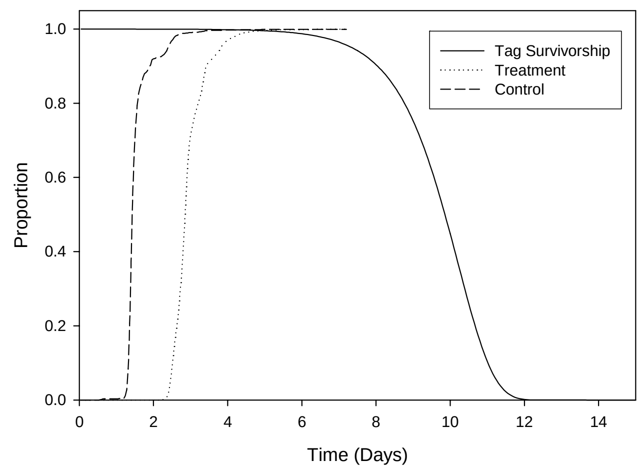


Figure A3.2. Fitted Gompertz model with tag-life data for a) spring and b) summer studies.

a) Yearling Chinook salmon, Spring



b) Hatchery steelhead trout, Spring



c) Subyearling Chinook salmon, Summer

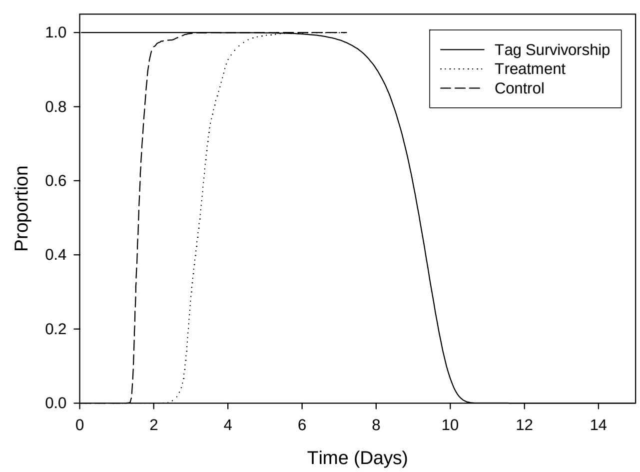


Figure A3.3. Probability distributions (a-c) for radio-tags being operational over time with cumulative arrival distributions at downstream survival gates for the Bonneville Dam survival assessment during 2004.

Appendix 4: Burnham Tests 2 and 3

Table A4.1. Summary statistics for goodness-of-fit tests (tests 2 and 3, Burnham et al. 1987) for paired releases of yearling Chinook salmon, spring 2004. Treatment fish were released into the minimum gap runner (MGR) turbine 4A at Bonneville Dam powerhouse 1 and control fish were released directly downstream of the front roll below the (MGR) turbine unit at Bonneville Dam powerhouse 1.

		Test 2			Test 3		
Release	Population	Df	χ^2	P	df	χ^2	P
1	Treatment	1	0.00	0.95	a	a	a
	Control	1	0.05	0.83	a	a	a
2	Treatment	1	0.01	0.92	a	a	a
	Control	1	1.47	0.23	a	a	a
3	Treatment	1	0.20	0.66	a	a	a
	Control	1	0.54	0.46	a	a	a
4	Treatment	1	1.72	0.19	1	0.04	0.83
	Control	1	2.08	0.15	1	0.77	0.38
5	Treatment	1	1.67	0.20	1	0.03	0.87
	Control	1	0.32	0.57	1	0.98	0.32
6	Treatment	1	0.01	0.94	1	0.36	0.55
	Control	1	0.34	0.56	a	a	a
7	Treatment	1	0.16	0.69	a	a	a
	Control	1	0.07	0.79	1	0.00	0.95
8	Treatment	1	0.39	0.53	1	0.17	0.68
	Control	1	0.35	0.56	1	0.41	0.52
9	Treatment	1	0.25	0.62	a	a	a
	Control	a	a	a	1	0.00	1.00
10	Treatment	b	b	b	b	b	b
	Control	b	b	b	b	b	b
11	Treatment	1	0.06	0.81	1	0.21	0.65
	Control	1	0.29	0.59	1	0.00	0.96
12	Treatment	1	0.71	0.40	a	a	a
	Control	1	0.39	0.53	a	a	a
13	Treatment	1	0.24	0.63	a	a	a
	Control	1	3.25	0.07	1	0.06	0.81
14	Treatment	1	0.20	0.65	1	1.12	0.29
	Control	1	0.10	0.75	1	0.22	0.64
15	Treatment	1	2.23	0.14	1	0.10	0.75
	Control	1	0.02	0.90	a	a	a
16	Treatment	b	b	b	b	b	b
	Control	b	b	b	b	b	b

[a] - Chi-square statistic was not calculable for these tests due to the presence of only zeroes in rows or columns in the contingency tables. [b] – Dam operations were not appropriate for prescribed test conditions.

Table A4.2. Summary statistics for goodness-of-fit tests (tests 2 and 3, Burnham et al. 1987) for paired releases of yearling Chinook salmon, spring 2004. Treatment fish were released into the minimum gap runner turbine 4A at Bonneville Dam powerhouse 1 and control fish were released below the Bonneville Dam powerhouse 2 juvenile bypass outfall.

			Test 2			Test 3	
Release	Population	df	χ^2	P	Df	χ^2	P
1	Treatment	1	0.00	0.95	[a]	[a]	[a]
	Control	1	1.53	0.22	[a]	[a]	[a]
2	Treatment	1	0.01	0.92	[a]	[a]	[a]
	Control	1	1.00	0.32	[a]	[a]	[a]
3	Treatment	1	0.20	0.66	[a]	[a]	[a]
	Control	1	0.44	0.51	1	0.44	0.51
4	Treatment	1	1.72	0.19	1	0.04	0.83
	Control	1	6.79	0.01	[a]	[a]	[a]
5	Treatment	1	1.67	0.20	1	0.03	0.87
	Control	1	0.00	0.95	[a]	[a]	[a]
6	Treatment	1	0.01	0.94	1	0.36	0.55
	Control	1	0.04	0.84	1	0.36	0.55
7	Treatment	1	0.16	0.69	[a]	[a]	[a]
	Control	1	0.11	0.73	1	0.19	0.66
8	Treatment	1	0.39	0.53	1	0.17	0.68
	Control	1	1.18	0.28	1	1.09	0.30
9	Treatment	1	0.25	0.62	[a]	[a]	[a]
	Control	1	0.01	0.92	1	0.19	0.66
10	Treatment	[b]	[b]	[b]	[b]	[b]	[b]
	Control	[b]	[b]	[b]	[b]	[b]	[b]
11	Treatment	1	0.06	0.81	1	0.21	0.65
	Control	1	1.02	0.31	1	0.01	0.92
12	Treatment	1	0.71	0.40	[a]	[a]	[a]
	Control	1	0.15	0.70	[a]	[a]	[a]
13	Treatment	1	0.24	0.63	[a]	[a]	[a]
	Control	1	0.21	0.65	[a]	[a]	[a]
14	Treatment	1	0.20	0.65	1	1.12	0.29
	Control	1	0.06	0.81	[a]	[a]	[a]
15	Treatment	1	2.23	0.14	1	0.10	0.75
	Control	1	0.56	0.46	1	0.02	0.89
16	Treatment	[b]	[b]	[b]	[b]	[b]	[b]
	Control	[b]	[b]	[b]	[b]	[b]	[b]

[a] - Chi-square statistic was not calculable for these tests due to the presence of only zeroes in rows or columns in the contingency tables.
[b] – Dam operations were not appropriate for prescribed test conditions.

Table A4.3. Summary statistics for goodness-of-fit tests (tests 2 and 3, Burnham et al. 1987) for paired releases of yearling Chinook salmon, spring 2004. Treatment fish were released at the top of the ice and trash sluiceway at Bonneville Dam powerhouse 1 and control fish were released below the Bonneville Dam powerhouse 2 juvenile bypass outfall.

			Test 2			Test 3	
Release	Population	df	χ^2	P	Df	χ^2	P
1	Treatment	1	0.59	0.44	1	0.10	0.76
	Control	1	1.53	0.22	[a]	[a]	[a]
2	Treatment	1	0.44	0.51	[a]	[a]	[a]
	Control	1	1.00	0.32	[a]	[a]	[a]
3	Treatment	1	1.06	0.30	1	0.10	0.75
	Control	1	0.44	0.51	1	0.44	0.51
4	Treatment	1	0.04	0.84	1	0.10	0.76
	Control	1	6.79	0.01	[a]	[a]	[a]
5	Treatment	1	0.13	0.72	1	0.00	0.96
	Control	1	0.00	0.95	[a]	[a]	[a]
6	Treatment	1	0.37	0.54	1	0.04	0.85
	Control	1	0.04	0.84	1	0.36	0.55
7	Treatment	1	0.00	0.98	[a]	[a]	[a]
	Control	1	0.11	0.73	1	0.19	0.66
8	Treatment	1	0.02	0.90	1	0.17	0.68
	Control	1	1.18	0.28	1	1.09	0.30
9	Treatment	1	0.42	0.52	1	0.03	0.87
	Control	1	0.01	0.92	1	0.19	0.66
10	Treatment	1	0.33	0.57	1	0.04	0.83
	Control	1	0.22	0.64	1	0.30	0.58
11	Treatment	[a]	[a]	[a]	[a]	[a]	[a]
	Control	1	1.02	0.31	1	0.01	0.92
12	Treatment	1	0.11	0.74	[a]	[a]	[a]
	Control	1	0.15	0.70	[a]	[a]	[a]
13	Treatment	1	0.35	0.55	1	0.45	0.50
	Control	1	0.21	0.65	[a]	[a]	[a]
14	Treatment	1	0.62	0.43	1	3.48	0.06
	Control	1	0.06	0.81	[a]	[a]	[a]
15	Treatment	1	0.20	0.65	1	1.35	0.25
	Control	1	0.56	0.46	1	0.02	0.89
16	Treatment	1	3.05	0.08	1	1.00	0.32
	Control	1	0.82	0.37	[a]	[a]	[a]

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

Table A4.4. Summary statistics for goodness-of-fit tests (tests 2 and 3, Burnham et al. 1987) for paired releases of hatchery steelhead trout, spring 2004. Treatment fish were released into the minimum gap runner (MGR) turbine 4A at Bonneville Dam powerhouse 1 and control fish were released directly downstream of the front roll below the (MGR) turbine unit at Bonneville Dam powerhouse 1.

		Test 2			Test 3		
Release	Population	df	χ^2	P	df	χ^2	P
1	Treatment	[a]	[a]	[a]	[a]	[a]	[a]
	Control	[a]	[a]	[a]	[a]	[a]	[a]
2	Treatment	[a]	[a]	[a]	[a]	[a]	[a]
	Control	[a]	[a]	[a]	[a]	[a]	[a]
3	Treatment	1	0.14	0.71	[a]	[a]	[a]
	Control	1	0.04	0.84	1	0.68	0.41
4	Treatment	1	3.49	0.06	1	0.47	0.49
	Control	1	0.13	0.71	[a]	[a]	[a]
5	Treatment	1	1.01	0.31	1	0.93	0.34
	Control	1	1.34	0.25	[a]	0.28	0.60
6	Treatment	[a]	[a]	[a]	[a]	[a]	[a]
	Control	[a]	[a]	[a]	[a]	[a]	[a]
7	Treatment	1	2.48	0.12	[a]	[a]	[a]
	Control	1	0.19	0.66	1	00.0	0.96
8	Treatment	[b]	[b]	[b]	[b]	[b]	[b]
	Control	[b]	[b]	[b]	[b]	[b]	[b]
9	Treatment	1	2.12	0.15	1	0.21	0.65
	Control	1	2.73	0.10	[a]	[a]	[a]
10	Treatment	[a]	[a]	[a]	[a]	[a]	[a]
	Control	[a]	[a]	[a]	[a]	[a]	[a]
11	Treatment	1	5.10	0.02	1	1.75	0.19
	Control	1	1.87	0.17	[a]	[a]	[a]
12	Treatment	[a]	[a]	[a]	[a]	[a]	[a]
	Control	1	3.99	0.05	1	1.50	0.22
13	Treatment	1	0.00	0.97	1	0.31	0.58
	Control	[a]	[a]	[a]	[a]	[a]	[a]
14	Treatment	[b]	[b]	[b]	[b]	[b]	[b]
	Control	[b]	[b]	[b]	[b]	[b]	[b]
15	Treatment	1	0.85	0.36	[a]	[a]	[a]
	Control	1	0.00	0.96	[a]	[a]	[a]
16	Treatment	[a]	[a]	[a]	[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.
[b] – Dam operations were not appropriate for prescribed test conditions.

Table A4.5. Summary statistics for goodness-of-fit tests (tests 2 and 3, Burnham et al. 1987) for paired releases of hatchery steelhead trout, spring 2004. Treatment fish were released into the minimum gap runner turbine 4A at Bonneville Dam powerhouse 1 and control fish were released below the Bonneville Dam powerhouse 2 juvenile bypass outfall.

		Test 2			Test 3		
Release	Population	df	χ^2	P	Df	χ^2	P
1	Treatment	[a]	[a]	[a]	[a]	[a]	[a]
	Control	[a]	[a]	[a]	[a]	[a]	[a]
2	Treatment	[a]	[a]	[a]	[a]	[a]	[a]
	Control	[a]	[a]	[a]	[a]	[a]	[a]
3	Treatment	1	0.14	0.71	[a]	[a]	[a]
	Control	[a]	[a]	[a]	[a]	[a]	[a]
4	Treatment	1	3.49	0.06	1	0.47	0.49
	Control	1	0.83	0.36	1	0.77	0.38
5	Treatment	1	1.01	0.31	1	0.93	0.34
	Control	1	2.00	0.16	[a]	[a]	[a]
6	Treatment	[a]	[a]	[a]	[a]	[a]	[a]
	Control	1	1.98	0.16	[a]	[a]	[a]
7	Treatment	1	2.48	0.12	[a]	[a]	[a]
	Control	1	0.01	0.93	[a]	[a]	[a]
8	Treatment	[b]	[b]	[b]	[b]	[b]	[b]
	Control	[b]	[b]	[b]	[b]	[b]	[b]
9	Treatment	1	2.12	0.15	1	0.21	0.65
	Control	1	0.77	0.38	1	1.18	0.28
10	Treatment	[a]	[a]	[a]	[a]	[a]	[a]
	Control	[a]	[a]	[a]	[a]	[a]	[a]
11	Treatment	1	5.10	0.02	1	1.75	0.19
	Control	1	2.12	0.15	1	2.00	0.16
12	Treatment	[a]	[a]	[a]	[a]	[a]	[a]
	Control	[a]	[a]	[a]	[a]	[a]	[a]
13	Treatment	1	0.00	0.97	1	0.31	0.58
	Control	1	0.17	0.68	1	0.13	0.72
14	Treatment	[b]	[b]	[b]	[b]	[b]	[b]
	Control	[b]	[b]	[b]	[b]	[b]	[b]
15	Treatment	1	0.85	0.36	[a]	[a]	[a]
	Control	1	0.30	0.58	[a]	[a]	[a]
16	Treatment	[a]	[a]	[a]	[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.
[b] – Dam operations were not appropriate for prescribed test conditions.

Table A4.6. Summary statistics for goodness-of-fit tests (tests 2 and 3, Burnham et al. 1987) for paired releases of hatchery steelhead trout, spring 2004. Treatment fish were released at the top of the sluiceway at Bonneville Dam powerhouse 1 and control fish were released below the Bonneville Dam powerhouse 2 juvenile bypass outfall.

		Test 2			Test 3		
Release	Population	df	χ^2	P	Df	χ^2	P
1	Treatment	[a]	[a]	[a]	[a]	[a]	[a]
	Control	[a]	[a]	[a]	[a]	[a]	[a]
2	Treatment	[a]	[a]	[a]	[a]	[a]	[a]
	Control	[a]	[a]	[a]	[a]	[a]	[a]
3	Treatment	1	1.01	0.31	1	0.50	0.48
	Control	[a]	[a]	[a]	[a]	[a]	[a]
4	Treatment	1	0.00	0.96	1	0.68	0.41
	Control	1	0.83	0.36	1	0.77	0.38
5	Treatment	1	0.13	0.72	[a]	[a]	[a]
	Control	1	2.00	0.16	[a]	[a]	[a]
6	Treatment	1	[a]	[a]	[a]	[a]	[a]
	Control	1	1.98	0.16	[a]	[a]	[a]
7	Treatment	1	0.19	0.67	[a]	[a]	[a]
	Control	1	0.01	0.93	[a]	[a]	[a]
8	Treatment	[a]	[a]	[a]	[a]	[a]	[a]
	Control	[a]	[a]	[a]	[a]	[a]	[a]
9	Treatment	1	0.02	0.88	1	0.41	0.52
	Control	1	0.77	0.38	1	1.18	0.28
10	Treatment	[a]	[a]	[a]	[a]	[a]	[a]
	Control	[a]	[a]	[a]	[a]	[a]	[a]
11	Treatment	1	0.04	0.85	1	0.65	0.42
	Control	1	2.12	0.15	1	2.00	0.16
12	Treatment	1	4.49	0.03	[a]	[a]	[a]
	Control	[a]	[a]	[a]	[a]	[a]	[a]
13	Treatment	[a]	[a]	[a]	1	0.50	0.48
	Control	1	0.17	0.68	1	0.13	0.72
14	Treatment	[a]	[a]	[a]	[a]	[a]	[a]
	Control	[a]	[a]	[a]	[a]	[a]	[a]
15	Treatment	1	0.01	0.94	[a]	[a]	[a]
	Control	1	0.30	0.58	[a]	[a]	[a]
16	Treatment	[a]	[a]	[a]	[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 A4.7. 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 2004. Treatment fish were released at the ice and trash sluiceway of Bonneville Dam powerhouse 1 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
1	Treatment	1	1.37	0.24	[a]	[a]	[a]
	Control	1	2.60	0.11	1	0.00	0.98
2	Treatment	1	0.13	0.71	[a]	[a]	[a]
	Control	1	10.99	0.00	1	0.41	0.52
3	Treatment	1	0.05	0.83	[a]	[a]	[a]
	Control	1	0.11	0.74	1	0.00	1.00
4	Treatment	1	0.83	0.36	[a]	[a]	[a]
	Control	1	0.28	0.59	1	0.07	0.79
5	Treatment	1	0.17	0.68	[a]	[a]	[a]
	Control	1	0.12	0.73	1	0.09	0.77
6	Treatment	1	0.57	0.45	[a]	[a]	[a]
	Control	1	3.62	0.06	1	0.08	0.78
7	Treatment	1	0.10	0.75	1	0.00	1.00
	Control	1	0.10	0.76	1	0.03	0.86
8	Treatment	1	0.06	0.81	[a]	[a]	[a]
	Control	1	2.16	0.14	1	0.31	0.58
9	Treatment	1	0.36	0.55	1	0.21	0.65
	Control	1	0.01	0.93	[a]	[a]	[a]
10	Treatment	1	0.23	0.63	[a]	[a]	[a]
	Control	1	0.10	0.75	[a]	[a]	[a]
11	Treatment	1	0.03	0.85	[a]	[a]	[a]
	Control	1	2.34	0.13	1	0.07	0.79
12	Treatment	1	0.60	0.44	[a]	[a]	[a]
	Control	1	0.04	0.83	1	2.81	0.09
13	Treatment	1	0.02	0.88	1	0.06	0.81
	Control	1	1.24	0.26	1	0.00	0.98
14	Treatment	1	0.11	0.74	[a]	[a]	[a]
	Control	1	0.35	0.55	1	1.96	0.16
15	Treatment	1	0.00	1.00	[a]	[a]	[a]
	Control	1	0.01	0.93	1	0.07	0.79
16	Treatment	1	0.37	0.55	1	0.04	0.85
	Control	1	0.08	0.78	1	0.04	0.83

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

Table A4.7 (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 2004. Treatment fish were released at the ice and trash sluiceway of Bonneville Dam powerhouse 1 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	0.58	0.45	[a]	[a]	[a]
	Control	1	1.00	0.32	[a]	[a]	[a]
18	Treatment	1	0.00	1.00	1	0.52	0.47
	Control	1	0.11	0.75	1	0.55	0.46
19	Treatment	1	0.06	0.81	1	0.07	0.78
	Control	1	10.42	0.00	1	0.06	0.81
20	Treatment	1	0.07	0.80	1	0.00	1.00
	Control	1	0.01	0.94	1	0.00	0.97
21	Treatment	1	0.03	0.86	1	0.18	0.67
	Control	1	0.02	0.88	1	0.01	0.93
22	Treatment	1	0.00	0.98	[a]	[a]	[a]
	Control	1	0.03	0.86	1	0.07	0.78
23	Treatment	1	0.01	0.91	1	0.01	0.92
	Control	1	0.19	0.67	1	0.52	0.47
24	Treatment	1	0.02	0.90	[a]	[a]	[a]
	Control	1	6.13	0.01	1	0.02	0.88
25	Treatment	[a]	[a]	[a]	1	0.07	0.79
	Control	1	0.01	0.93	[a]	[a]	[a]
26	Treatment	1	0.02	0.90	1	0.05	0.83
	Control	1	0.42	0.51	1	0.86	0.36
27	Treatment	1	0.00	1.00	[a]	[a]	[a]
	Control	1	1.20	0.27	1	0.10	0.75
28	Treatment	1	0.10	0.91	1	0.03	0.85
	Control	1	0.24	0.62	1	0.13	0.72
29	Treatment	1	0.60	0.44	[a]	[a]	[a]
	Control	1	0.00	0.98	1	0.03	0.85
30	Treatment	1	0.15	0.70	[a]	[a]	[a]
	Control	1	0.13	0.72	1	0.34	0.56
31	Treatment	1	0.00	0.94	1	0.00	1.00
	Control	1	0.63	0.43	1	0.42	0.52
32	Treatment	1	0.94	0.33	1	0.26	0.61
	Control	1	8.99	0.00	1	0.11	0.75

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

Table A4.8. Summary statistics for goodness-of-fit tests (tests 2 and 3, Burnham et al. 1987) for releases used to estimate survival of yearling Chinook salmon through spillbays with deflectors at 7-ft and 14-ft, spring 2004. Treatment fish were released in The Dalles Dam tailrace and control fish were released into the tailrace of Bonneville Dam.

Release		Deflector Ht	Population	Test 2 df	Test 2 χ^2	Test 2 P	Test 3 df	Test 3 χ^2	Test 3 P
1	Day	7	Treatment	1	0.36	0.55	[a]	[a]	[a]
			Control	1	0.17	0.68	[a]	[a]	[a]
		14	Treatment	1	0.00	1.00	[a]	[a]	[a]
			Control	1	0.17	0.68	[a]	[a]	[a]
	Night	7	Treatment	1	0.00	0.98	1	0.06	0.81
			Control	1	0.17	0.68	[a]	[a]	[a]
		14	Treatment	1	0.17	0.68	[a]	[a]	[a]
			Control	1	0.17	0.68	[a]	[a]	[a]
2	Day	7	Treatment	1	0.06	0.81	1	0.03	0.87
			Control	1	1.23	0.27	1	0.00	0.99
		14	Treatment	1	0.02	0.88	[a]	[a]	[a]
			Control	1	1.23	0.27	1	0.00	0.99
	Night	7	Treatment	1	0.07	0.79	[a]	[a]	[a]
			Control	1	1.23	0.27	1	0.00	0.99
		14	Treatment	1	0.51	0.47	[a]	[a]	[a]
			Control	1	1.23	0.27	1	0.00	0.99
3	Day	7	Treatment	1	1.41	0.23	1	0.01	0.93
			Control	1	0.00	0.96	1	0.00	0.96
		14	Treatment	1	0.00	1.00	[a]	[a]	[a]
			Control	1	0.00	0.96	1	0.00	0.96
	Night	7	Treatment	1	0.44	0.51	1	0.09	0.77
			Control	1	0.00	0.96	1	0.00	0.96
		14	Treatment	1	0.04	0.84	[a]	[a]	[a]
			Control	1	0.00	0.96	1	0.00	0.96
4	Day	7	Treatment	1	0.01	0.93	1	0.28	0.60
			Control	1	7.87	0.01	1	0.09	0.77
		14	Treatment	1	0.23	0.63	[a]	[a]	[a]
			Control	1	7.87	0.01	1	0.09	0.77
	Night	7	Treatment	1	0.27	0.61	1	0.00	1.00
			Control	1	7.87	0.01	1	0.09	0.77
		14	Treatment	1	0.22	0.64	[a]	[a]	[a]
			Control	1	7.87	0.01	1	0.09	0.77
5	Day	7	Treatment	1	0.03	0.85	1	0.02	0.88
			Control	1	0.26	0.61	1	0.13	0.72
		14	Treatment	1	0.06	0.81	[a]	[a]	[a]

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

Table A4.8 (continued). Summary statistics for goodness-of-fit tests (tests 2 and 3, Burnham et al. 1987) for releases used to estimate survival of yearling Chinook salmon through spillbays with deflectors at 7-ft and 14-ft, spring 2004. Treatment fish were released in The Dalles Dam tailrace and control fish were released into the tailrace of Bonneville Dam.

Release		Deflector Ht	Population	Test 2 df	Test 2 χ^2	Test 2 P	Test 3 df	Test 3 χ^2	Test 3 P
	Day	14	Control	1	0.26	0.61	1	0.13	0.72
	Night	7	Treatment	1	0.29	0.59	[a]	[a]	[a]
			Control	1	0.26	0.61	1	0.13	0.72
		14	Treatment	1	2.10	0.15	1	0.00	0.96
			Control	1	0.26	0.61	1	0.13	0.72
6	Day	7	Treatment	1	0.39	0.53	1	0.25	0.62
			Control	1	0.03	0.87	1	0.37	0.54
		14	Treatment	[a]	[a]	[a]	[a]	[a]	[a]
			Control	1	0.03	0.87	1	0.37	0.54
	Night	7	Treatment	1	0.01	0.92	[a]	[a]	[a]
			Control	1	0.03	0.87	1	0.37	0.54
		14	Treatment	1	2.31	0.13	[a]	[a]	[a]
			Control	1	0.03	0.87	1	0.37	0.54
7	Day	7	Treatment	1	0.79	0.37	[a]	[a]	[a]
			Control	1	1.00	0.32	1	2.77	0.10
		14	Treatment	1	0.33	0.57	1	0.02	0.88
			Control	1	1.00	0.32	1	2.77	0.10
	Night	7	Treatment	1	0.00	0.97	1	0.14	0.71
			Control	1	1.00	0.32	1	2.77	0.10
		14	Treatment	1	0.12	0.73	[a]	[a]	[a]
			Control	1	1.00	0.32	1	2.77	0.10
8	Day	7	Treatment	1	0.22	0.64	[a]	[a]	[a]
			Control	1	0.51	0.47	1	0.30	0.58
		14	Treatment	1	0.38	0.54	[a]	[a]	[a]
			Control	1	0.51	0.47	1	0.30	0.58
	Night	7	Treatment	1	4.70	0.03	1	0.36	0.55
			Control	1	0.51	0.47	1	0.30	0.58
		14	Treatment	1	1.44	0.23	1	0.26	0.61
			Control	1	0.51	0.47	1	0.30	0.58
9	Day	7	Treatment	1	1.59	0.21	[a]	[a]	[a]
			Control	1	6.65	0.01	1	0.12	0.73
		14	Treatment	1	0.60	0.44	[a]	[a]	[a]
			Control	1	6.65	0.01	1	0.12	0.73
	Night	7	Treatment	1	0.01	0.93	[a]	[a]	[a]
			Control	1	6.65	0.01	1	0.12	0.73
		14	Treatment	1	0.02	0.90	[a]	[a]	[a]
			Control	1	6.65	0.01	1	0.12	0.73

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

Table A4.8 (continued). Summary statistics for goodness-of-fit tests (tests 2 and 3, Burnham et al. 1987) for releases used to estimate survival of yearling Chinook salmon through spillbays with deflectors at 7-ft and 14-ft, spring 2004. Treatment fish were released in The Dalles Dam tailrace and control fish were released into the tailrace of Bonneville Dam.

Release		Deflector Ht	Population	Test 2 df	Test 2 χ^2	Test 2 P	Test 3 df	Test 3 χ^2	Test 3 P
10	Day	7	Treatment	1	0.01	0.92	[a]	[a]	[a]
			Control	1	1.49	0.22	1	0.01	0.91
		14	Treatment	1	0.31	0.58	[a]	[a]	[a]
			Control	1	1.49	0.22	1	0.01	0.91
	Night	7	Treatment	1	0.10	0.76	[a]	[a]	[a]
			Control	1	1.49	0.22	1	0.01	0.91
		14	Treatment	1	1.89	0.17	[a]	[a]	[a]
			Control	1	1.49	0.22	1	0.01	0.91
11	Day	7	Treatment	1	4.43	0.04	[a]	[a]	[a]
			Control	1	3.93	0.05	[a]	[a]	[a]
		14	Treatment	1	0.27	0.61	1	0.08	0.78
			Control	1	3.93	0.05	[a]	[a]	[a]
	Night	7	Treatment	1	0.09	0.77	[a]	[a]	[a]
			Control	1	3.93	0.05	[a]	[a]	[a]
		14	Treatment	1	0.16	0.69	[a]	[a]	[a]
			Control	1	3.93	0.05	[a]	[a]	[a]
12	Day	7	Treatment	1	0.33	0.56	[a]	[a]	[a]
			Control	1	0.01	0.94	1	0.20	0.66
		14	Treatment	[a]	[a]	[a]	[a]	[a]	[a]
			Control	1	0.01	0.94	1	0.20	0.66
	Night	7	Treatment	1	0.17	0.68	1	0.75	0.39
			Control	1	0.01	0.94	1	0.20	0.66
		14	Treatment	1	0.01	0.94	[a]	[a]	[a]
			Control	1	0.01	0.94	1	0.20	0.66
13	Day	7	Treatment	1	0.23	0.63	1	0.00	0.97
			Control	1	7.17	0.01	1	0.00	0.97
		14	Treatment	1	0.04	0.84	1	0.02	0.88
			Control	1	7.17	0.01	1	0.00	0.97
	Night	7	Treatment	1	0.51	0.47	[a]	[a]	[a]
			Control	1	7.17	0.01	1	0.00	0.97
		14	Treatment	1	2.89	0.09	[a]	[a]	[a]
			Control	1	7.17	0.01	1	0.00	0.97

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

Table A4.9. Summary statistics for goodness-of-fit tests (tests 2 and 3, Burnham et al. 1987) for releases used to estimate survival of hatchery steelhead trout through spillbays with deflectors at 7-ft and 14-ft, spring 2004. Treatment fish were released in The Dalles Dam tailrace and control fish were released into the tailrace of Bonneville Dam.

Release		Deflector Ht	Population	Test 2 df	Test 2 χ^2	Test 2 P	Test 3 df	Test 3 χ^2	Test 3 P
1	Day	7	Treatment	1	0.05	0.82	[a]	[a]	[a]
			Control	1	0.04	0.84	[a]	[a]	[a]
		14	Treatment	[a]	[a]	[a]	[a]	[a]	[a]
			Control	1	0.04	0.84	[a]	[a]	[a]
	Night	7	Treatment	[a]	[a]	[a]	[a]	[a]	[a]
			Control	1	0.04	0.84	[a]	[a]	[a]
		14	Treatment	1	0.85	0.36	[a]	[a]	[a]
			Control	1	0.04	0.84	[a]	[a]	[a]
2	Day	7	Treatment	1	0.00	1.00	[a]	[a]	[a]
			Control	[a]	[a]	[a]	[a]	[a]	[a]
		14	Treatment	[a]	[a]	[a]	[a]	[a]	[a]
			Control	[a]	[a]	[a]	[a]	[a]	[a]
	Night	7	Treatment	1	1.87	0.17	1	1.75	0.19
			Control	[a]	[a]	[a]	[a]	[a]	[a]
		14	Treatment	[a]	[a]	[a]	[a]	[a]	[a]
			Control	[a]	[a]	[a]	[a]	[a]	[a]
3	Day	7	Treatment	1	2.13	0.14	[a]	[a]	[a]
			Control	1	5.00	0.03	[a]	[a]	[a]
		14	Treatment	1	0.00	1.00	[a]	[a]	[a]
			Control	1	5.00	0.03	[a]	[a]	[a]
	Night	7	Treatment	[a]	[a]	[a]	[a]	[a]	[a]
			Control	1	5.00	0.03	[a]	[a]	[a]
		14	Treatment	1	0.08	0.77	[a]	[a]	[a]
			Control	1	5.00	0.03	[a]	[a]	[a]
4	Day	7	Treatment	1	0.00	1.00	[a]	[a]	[a]
			Control	1	0.20	0.65	1	1.36	0.24
		14	Treatment	[a]	[a]	[a]	[a]	[a]	[a]
			Control	1	0.20	0.65	1	1.36	0.24
	Night	7	Treatment	[a]	[a]	[a]	[a]	[a]	[a]
			Control	1	0.20	0.65	1	1.36	0.24
		14	Treatment	[a]	[a]	[a]	[a]	[a]	[a]
			Control	1	0.20	0.65	1	1.36	0.24
5	Day	7	Treatment	1	0.49	0.48	1	0.97	0.32

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

Table A4.9 (continued). Summary statistics for goodness-of-fit tests (tests 2 and 3, Burnham et al. 1987) for releases used to estimate survival of hatchery steelhead trout through spillbays with deflectors at 7-ft and 14-ft, spring 2004. Treatment fish were released in The Dalles Dam tailrace and control fish were released into the tailrace of Bonneville Dam.

Release		Deflector Ht	Population	Test 2 df	Test 2 χ^2	Test 2 P	Test 3 df	Test 3 χ^2	Test 3 P
			Control	1	0.29	0.59	1	0.95	0.33
		14	Treatment	[a]	[a]	[a]	[a]	[a]	[a]
			Control	1	0.29	0.59	1	0.95	0.33
	Night	7	Treatment	1	0.13	0.71	[a]	[a]	[a]
			Control	1	0.29	0.59	1	0.95	0.33
		14	Treatment	1	1.26	0.26	[a]	[a]	[a]
			Control	1	0.29	0.59	1	0.95	0.33
6	Day	7	Treatment	1	1.41	0.23	1	0.50	0.48
			Control	1	0.47	0.49	1	0.99	0.32
		14	Treatment	1	0.70	0.40	[a]	[a]	[a]
			Control	1	0.47	0.49	1	0.99	0.32
	Night	7	Treatment	[a]	[a]	[a]	[a]	[a]	[a]
			Control	1	0.47	0.49	1	0.99	0.32
		14	Treatment	[a]	[a]	[a]	[a]	[a]	[a]
			Control	1	0.47	0.49	1	0.99	0.32
7	Day	7	Treatment	1	0.01	0.94	[a]	[a]	[a]
			Control	1	0.00	0.95	1	1.29	0.26
		14	Treatment	[a]	[a]	[a]	[a]	[a]	[a]
			Control	1	0.00	0.95	1	1.29	0.26
	Night	7	Treatment	1	4.49	0.03	[a]	[a]	[a]
			Control	1	0.00	0.95	1	1.29	0.26
		14	Treatment	[a]	[a]	[a]	[a]	[a]	[a]
			Control	1	0.00	0.95	1	1.29	0.26
8	Day	7	Treatment	1	1.27	0.26	1	0.60	0.44
			Control	1	4.54	0.03	1	0.99	0.32
		14	Treatment	1	0.08	0.78	[a]	[a]	[a]
			Control	1	4.54	0.03	1	0.99	0.32
	Night	7	Treatment	1	1.18	0.28	[a]	[a]	[a]
			Control	1	4.54	0.03	1	0.99	0.32
		14	Treatment	[a]	[a]	[a]	1	1.84	0.18
			Control	1	4.54	0.03	1	0.99	0.32
9	Day	7	Treatment	[a]	[a]	[a]	[a]	[a]	[a]
			Control	1	0.11	0.74	1	0.13	0.72

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

Table A4.9 (continued). Summary statistics for goodness-of-fit tests (tests 2 and 3, Burnham et al. 1987) for releases used to estimate survival of hatchery steelhead trout through spillbays with deflectors at 7-ft and 14-ft, spring 2004. Treatment fish were released in The Dalles Dam tailrace and control fish were released into the tailrace of Bonneville Dam.

Release		Deflector Ht	Population	Test 2 df	Test 2 χ^2	Test 2 P	Test 3 df	Test 3 χ^2	Test 3 P
		14	Treatment	1	0.19	0.67	[a]	[a]	[a]
			Control	1	0.11	0.74	1	0.13	0.72
	Night	7	Treatment	[a]	[a]	[a]	[a]	[a]	[a]
			Control	1	0.11	0.74	1	0.13	0.72
		14	Treatment	1	0.79	0.37	[a]	[a]	[a]
			Control	1	0.11	0.74	1	0.13	0.72
10	Day	7	Treatment	1	1.86	0.17	[a]	[a]	[a]
			Control	1	9.50	0.00	1	3.93	0.05
		14	Treatment	1	0.63	0.43	[a]	[a]	[a]
			Control	1	9.50	0.00	1	3.93	0.05
	Night	7	Treatment	1	0.13	0.72	[a]	[a]	[a]
			Control	1	9.50	0.00	1	3.93	0.05
		14	Treatment	1	0.96	0.33	1	1.42	0.23
			Control	1	9.50	0.00	1	3.93	0.05
11	Day	7	Treatment	1	0.39	0.53	[a]	[a]	[a]
			Control	1	0.02	0.89	1	0.10	0.75
		14	Treatment	[a]	[a]	[a]	[a]	[a]	[a]
			Control	1	0.02	0.89	1	0.10	0.75
	Night	7	Treatment	[a]	[a]	[a]	1	4.24	0.04
			Control	1	0.02	0.89	1	0.10	0.75
		14	Treatment	1	1.39	0.24	1	6.43	0.01
			Control	1	0.02	0.89	1	0.10	0.75
12	Day	7	Treatment	[a]	[a]	[a]	[a]	[a]	[a]
			Control	1	0.01	0.91	1	0.03	0.87
		14	Treatment	1	0.00	1.00	[a]	[a]	[a]
			Control	1	0.01	0.91	1	0.03	0.87
	Night	7	Treatment	1	1.34	0.25	1	2.25	0.13
			Control	1	0.01	0.91	1	0.03	0.87
		14	Treatment	1	0.38	0.54	[a]	[a]	[a]
			Control	1	0.01	0.91	1	0.03	0.87
13	Day	7	Treatment	1	0.14	0.71	[a]	[a]	[a]
			Control	1	0.76	0.38	1	2.76	0.10
		14	Treatment	1	0.11	0.74	1	0.19	0.67
			Control	1	0.76	0.38	1	2.76	0.10

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

Table A4.9 (continued). Summary statistics for goodness-of-fit tests (tests 2 and 3, Burnham et al. 1987) for releases used to estimate survival of hatchery steelhead trout through spillbays with deflectors at 7-ft and 14-ft, spring 2004. Treatment fish were released in The Dalles Dam tailrace and control fish were released into the tailrace of Bonneville Dam.

Release		Deflector Ht	Population	Test 2 df	Test 2 χ^2	Test 2 P	Test 3 df	Test 3 χ^2	Test 3 P
	Night	7	Treatment	[a]	[a]	[a]	[a]	[a]	[a]
			Control	1	0.76	0.38	1	2.76	0.10
		14	Treatment	1	2.09	0.15	1	2.01	0.16
			Control	1	0.76	0.38	1	2.76	0.10
14	Day	7	Treatment	1	0.19	0.67	[a]	[a]	[a]
			Control	1	0.65	0.42	[a]	[a]	[a]
		14	Treatment	1	0.00	1.00	[a]	[a]	[a]
			Control	1	0.65	0.42	[a]	[a]	[a]
	Night	7	Treatment	[a]	[a]	[a]	[a]	[a]	[a]
			Control	1	0.65	0.42	[a]	[a]	[a]
		14	Treatment	1	0.11	0.74	[a]	[a]	[a]
			Control	1	0.65	0.42	[a]	[a]	[a]
15	Day	7	Treatment	1	0.22	0.64	[a]	[a]	[a]
			Control	1	0.34	0.56	1	0.47	0.49
		14	Treatment	1	0.26	0.61	[a]	[a]	[a]
			Control	1	0.34	0.56	1	0.47	0.49
	Night	7	Treatment	1	0.00	1.00	[a]	[a]	[a]
			Control	1	0.34	0.56	1	0.47	0.49
		14	Treatment	[a]	[a]	[a]	1	1.20	0.27
			Control	1	0.34	0.56	1	0.47	0.49

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

Table A4.10. Summary statistics for goodness-of-fit tests (tests 2 and 3, Burnham et al. 1987) for releases used to estimate survival of subyearling Chinook through spillbays with deflectors at 7-ft and 14-ft, summer 2004. Treatment fish were released in The Dalles Dam tailrace and control fish were released into the tailrace of Bonneville Dam. BIOP spill = 56 kcfs day/total dissolved gas cap at night.

Release	Spill	Deflector Ht	Population	Test 2 df	Test 2 χ^2	Test 2 P	Test 3 df	Test 3 χ^2	Test 3 P
1	BIOP	7	Treatment	1	0.51	0.48	1	0.07	0.79
			Control	1	12.66	0.00	1	0.13	0.72
		14	Treatment	1	0.00	0.97	[a]	[a]	[a]
			Control	1	12.66	0.00	1	0.13	0.72
2	KCFS50	7	Treatment	1	0.27	0.60	1	0.05	0.83
			Control	1	11.96	0.00	1	0.45	0.50
		14	Treatment	1	0.01	0.94	[a]	[a]	[a]
			Control	1	11.96	0.00	1	0.45	0.50
3	KCFS50	7	Treatment	1	0.25	0.62	1	1.33	0.25
			Control	1	0.27	0.60	1	0.45	0.50
		14	Treatment	1	0.05	0.83	[a]	[a]	[a]
			Control	1	0.27	0.60	1	0.45	0.50
4	KCFS50	7	Treatment	1	0.00	0.96	[a]	[a]	[a]
			Control	1	6.13	0.01	1	0.31	0.58
		14	Treatment	1	0.36	0.55	1	0.00	1.00
			Control	1	6.13	0.01	1	0.31	0.58
5	BIOP	7	Treatment	1	2.94	0.09	[a]	[a]	[a]
			Control	1	4.56	0.03	1	0.09	0.77
		14	Treatment	1	0.18	0.67	[a]	[a]	[a]
			Control	1	4.56	0.03	1	0.09	0.77
6	BIOP	7	Treatment	1	0.18	0.67	[a]	[a]	[a]
			Control	1	1.32	0.25	1	0.10	0.75
		14	Treatment	1	0.04	0.85	[a]	[a]	[a]
			Control	1	1.32	0.25	1	0.10	0.75
7	KCFS50	7	Treatment	1	0.21	0.65	1	0.14	0.71
			Control	1	1.15	0.28	1	0.00	0.95
		14	Treatment	1	0.22	0.64	[a]	[a]	[a]
			Control	1	1.15	0.28	1	0.00	0.95
8	BIOP	7	Treatment	1	1.66	0.20	[a]	[a]	[a]
			Control	1	0.02	0.88	1	1.50	0.22
		14	Treatment	1	0.00	1.00	1	0.27	0.60

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

Table A4.10 (continued). Summary statistics for goodness-of-fit tests (tests 2 and 3, Burnham et al. 1987) for releases used to estimate survival of subyearling Chinook through spillbays with deflectors at 7-ft and 14-ft, summer 2004. Treatment fish were released in The Dalles Dam tailrace and control fish were released into the tailrace of Bonneville Dam. BIOP spill = 56 kcfs day/total dissolved gas cap at night.

Release	Spill	Deflector Ht	Population	Test 2 df	Test 2 χ^2	Test 2 P	Test 3 df	Test 3 χ^2	Test 3 P
9	BIOP	7	Control	1	0.02	0.88	1	1.50	0.22
			Treatment	1	0.35	0.56	1	0.13	0.72
		14	Control	1	0.35	0.55	1	0.50	0.48
			Treatment	1	0.53	0.47	1	0.01	0.91
10	KCFS50	7	Control	1	0.35	0.55	1	0.50	0.48
			Treatment	1	0.00	1.00	[a]	[a]	[a]
		14	Control	1	0.08	0.78	1	1.07	0.30
			Treatment	1	0.17	0.68	1	0.10	0.75
11	BIOP	7	Control	1	0.00	0.95	1	3.66	0.06
			Treatment	1	1.73	0.19	1	0.24	0.62
		14	Control	1	3.62	0.06	1	0.43	0.51
			Treatment	1	0.02	0.90	[a]	[a]	[a]
12	BIOP	7	Control	1	3.62	0.06	1	0.43	0.51
			Treatment	1	0.01	0.93	1	0.56	0.45
		14	Control	1	0.08	0.78	1	0.00	1.00
			Treatment	1	1.05	0.30	1	0.17	0.68
13	BIOP	7	Control	1	0.08	0.78	1	0.00	1.00
			Treatment	1	0.36	0.55	1	0.00	0.97
		14	Control	1	0.67	0.41	1	0.12	0.73
			Treatment	1	0.58	0.45	1	0.03	0.87
14	KCFS50	7	Control	1	0.67	0.41	1	0.12	0.73
			Treatment	1	0.00	0.94	[a]	[a]	[a]
		14	Control	1	6.36	0.01	1	0.31	0.58
			Treatment	[a]	[a]	[a]	1	1.40	0.24
15	KCFS50	7	Control	1	6.36	0.01	1	0.31	0.58
			Treatment	1	0.17	0.68	1	0.01	0.92
		14	Control	1	0.37	0.54	1	1.29	0.26
			Treatment	1	0.22	0.64	1	0.00	0.94
16	BIOP	7	Control	1	0.37	0.54	1	1.29	0.26
			Treatment	1	0.13	0.72	[a]	[a]	[a]
		14	Control	1	0.21	0.65	1	0.03	0.86
			Treatment	1	0.86	0.35	1	0.28	0.60
17	BIOP	7	Control	1	0.21	0.65	1	0.03	0.86
			Treatment	1	0.02	0.88	1	0.14	0.70

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

Table A4.10 (continued). Summary statistics for goodness-of-fit tests (tests 2 and 3, Burnham et al. 1987) for releases used to estimate survival of subyearling Chinook through spillbays with deflectors at 7-ft and 14-ft, summer 2004. Treatment fish were released in The Dalles Dam tailrace and control fish were released into the tailrace of Bonneville Dam. BIOP spill = 56 kcfs day/total dissolved gas cap at night.

Release	Spill	Deflector Ht	Population	Test 2 df	Test 2 χ^2	Test 2 P	Test 3 df	Test 3 χ^2	Test 3 P
			Control	1	4.18	0.04	1	0.01	0.91
		14	Treatment	1	1.07	0.30	1	0.86	0.35
			Control	1	4.18	0.04	1	0.01	0.91
18	BIOP	7	Treatment	1	0.16	0.69	[a]	[a]	[a]
			Control	1	0.26	0.61	1	0.93	0.33
		14	Treatment	1	1.71	0.19	1	0.00	0.96
			Control	1	0.26	0.61	1	0.93	0.33
19	BIOP	7	Treatment	1	0.00	1.00	1	0.02	0.89
			Control	1	0.51	0.48	1	0.85	0.36
		14	Treatment	1	0.57	0.45	1	0.00	1.00
			Control	1	0.51	0.48	1	0.85	0.36
20	KCFS50	7	Treatment	1	1.95	0.16	1	0.05	0.82
			Control	1	8.67	0.00	1	0.18	0.67
		14	Treatment	1	0.43	0.51	[a]	[a]	[a]
			Control	1	8.67	0.00	1	0.18	0.67
21	BIOP	7	Treatment	1	0.00	1.00	1	0.00	0.97
			Control	1	1.20	0.27	1	0.13	0.72
		14	Treatment	[a]	[a]	[a]	1	0.09	0.77
			Control	1	1.20	0.27	1	0.13	0.72
22	BIOP	7	Treatment	1	0.07	0.79	[a]	[a]	[a]
			Control	1	0.01	0.94	1	1.20	0.27
		14	Treatment	1	0.07	0.79	1	0.37	0.54
			Control	1	0.01	0.94	1	1.20	0.27
23	BIOP	7	Treatment	1	0.17	0.68	1	0.08	0.77
			Control	1	0.18	0.67	1	1.20	0.27
		14	Treatment	1	0.07	0.80	[a]	[a]	[a]
			Control	1	0.18	0.67	1	1.20	0.27
24	KCFS50	7	Treatment	1	0.23	0.63	[a]	[a]	[a]
			Control	1	0.62	0.43	1	0.67	0.41
		14	Treatment	1	0.08	0.78	1	0.03	0.86
			Control	1	0.62	0.43	1	0.67	0.41
25	KCFS50	7	Treatment	1	0.07	0.80	[a]	[a]	[a]
			Control	1	0.56	0.45	1	0.41	0.52
		14	Treatment	1	0.03	0.85	1	0.02	0.90
			Control	1	0.56	0.45	1	0.41	0.52
26	KCFS50	7	Treatment	1	0.48	0.49	1	0.29	0.59

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

Table A4.10 (continued). Summary statistics for goodness-of-fit tests (tests 2 and 3, Burnham et al. 1987) for releases used to estimate survival of subyearling Chinook through spillbays with deflectors at 7-ft and 14-ft, summer 2004. Treatment fish were released in The Dalles Dam tailrace and control fish were released into the tailrace of Bonneville Dam. BIOP spill = 56 kcfs day/total dissolved gas cap at night.

		Deflector			Test 2			Test 3	
Release	Spill	Ht	Population	df	χ^2	P	df	χ^2	P
			Control	1	1.99	0.16	1	0.01	0.91
		14	Treatment	1	2.27	0.13	[a]	[a]	[a]
			Control	1	1.99	0.16	1	0.01	0.91
27	KCFS50	7	Treatment	1	0.11	0.74	1	1.80	0.18
			Control	1	9.97	0.00	1	0.01	0.91
		14	Treatment	1	0.88	0.35	1	0.53	0.47
			Control	1	9.97	0.00	1	0.01	0.91
28	BIOP	7	Treatment	1	1.96	0.16	1	3.59	0.06
			Control	1	7.30	0.01	1	0.01	0.90
		14	Treatment	1	0.87	0.35	1	0.01	0.94
			Control	1	7.30	0.01	1	0.01	0.90
29	BIOP	7	Treatment	1	0.11	0.75	1	1.02	0.31
			Control	1	1.12	0.29	1	0.00	0.95
		14	Treatment	1	0.25	0.62	1	0.24	0.63
			Control	1	1.12	0.29	1	0.00	0.95
30	BIOP	7	Treatment	1	0.38	0.54	1	0.00	1.00
			Control	1	0.24	0.63	1	0.09	0.76
		14	Treatment	[a]	[a]	[a]	1	0.17	0.68
			Control	1	0.24	0.63	1	0.09	0.76
31	BIOP	7	Treatment	1	0.06	0.81	1	2.07	0.15
			Control	1	0.03	0.87	1	0.08	0.77
		14	Treatment	1	0.01	0.93	1	0.36	0.55
			Control	1	0.03	0.87	1	0.08	0.77
32	BIOP	7	Treatment	1	0.00	0.95	[a]	[a]	[a]
			Control	1	0.00	0.98	1	0.69	0.41
		14	Treatment	1	0.08	0.77	1	0.21	0.65
			Control	1	0.00	0.98	1	0.69	0.41
33	BIOP	7	Treatment	1	0.38	0.54	1	0.59	0.44
			Control	1	6.94	0.01	1	1.29	0.26
		14	Treatment	1	0.04	0.85	1	0.05	0.82
			Control	1	6.94	0.01	1	1.29	0.26
34	BIOP	7	Treatment	1	0.20	0.65	[a]	[a]	[a]
			Control	1	0.01	0.92	1	0.18	0.67
		14	Treatment	[a]	[a]	[a]	[a]	[a]	[a]
			Control	1	0.01	0.92	1	0.18	0.67
35	BIOP	7	Treatment	1	2.22	0.14	1	0.31	0.58

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

Table A4.10 (continued). Summary statistics for goodness-of-fit tests (tests 2 and 3, Burnham et al. 1987) for releases used to estimate survival of subyearling Chinook through spillbays with deflectors at 7-ft and 14-ft, summer 2004. Treatment fish were released in The Dalles Dam tailrace and control fish were released into the tailrace of Bonneville Dam. BIOP spill = 56 kcfs day/total dissolved gas cap at night.

Release	Spill	Deflector Ht	Population	Test 2 df	Test 2 χ^2	Test 2 P	Test 3 df	Test 3 χ^2	Test 3 P
			Control	1	0.23	0.63	1	0.03	0.87
		14	Treatment	1	0.75	0.39	1	0.23	0.63
			Control	1	0.23	0.63	1	0.03	0.87
36	KCFS50	7	Treatment	1	0.03	0.87	1	0.06	0.81
			Control	1	1.59	0.21	1	0.04	0.85
		14	Treatment	1	0.02	0.88	[a]	[a]	[a]
			Control	1	1.59	0.21	1	0.04	0.85
37	KCFS50	7	Treatment	1	1.60	0.21	[a]	[a]	[a]
			Control	1	1.46	0.23	1	0.89	0.34
		14	Treatment	1	0.06	0.80	1	0.04	0.83
			Control	1	1.46	0.23	1	0.89	0.34
38	BIOP	7	Treatment	1	0.03	0.86	[a]	[a]	[a]
			Control	1	2.62	0.11	1	0.06	0.81
		14	Treatment	1	0.37	0.54	1	0.01	0.92
			Control	1	2.62	0.11	1	0.06	0.81
39	BIOP	7	Treatment	1	0.19	0.66	[a]	[a]	[a]
			Control	1	0.89	0.35	1	1.23	0.27
		14	Treatment	1	0.01	0.93	1	0.80	0.37
			Control	1	0.89	0.35	1	1.23	0.27

[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 5: Homogeneity of Arrival Times

Table A5.1. Summary of chi-square tests for homogeneity of arrival times of yearling Chinook salmon released into the minimum gap runner (MGR) turbine unit at Bonneville Dam powerhouse 1 and directly downstream of the front roll below the MGR turbine unit and detected at river kilometers 200, 194, and 181, spring 2004.

	River Kilometer 200			River Kilometer 194			River Kilometer 181		
Release	DF	Chi-square	P	DF	Chi-square	P	DF	Chi-square	P
1	3	3.60	0.308	2	0.97	0.616	3	3.24	0.356
2	0	0	[a]	0	0	[a]	1	0.76	0.385
3	0	0	[a]	1	0.81	0.368	1	0.86	0.353
4	0	0	[a]	0	0	[a]	0	0	[a]
5	0	0	[a]	1	0.05	0.823	1	0.01	0.923
6	0	0	[a]	1	1.10	0.294	1	0.89	0.345
7	0	0	[a]	0	0	[a]	0	0	[a]
8	1	1.35	0.245	1	1.10	0.295	1	1.03	0.311
9	1	1.33	0.249	1	1.12	0.291	1	0.94	0.333
10[b]									
11	0	0	[a]	0	0	[a]	0	0	[a]
12	0	0	[a]	1	1.20	0.274	1	1.02	0.311
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[b]									

[a] - All fish arrived on the same day at this detection array.
[b] - Release did not occur due to failure with release mechanism

Table A5.2. Summary of chi-square tests for homogeneity of arrival times of yearling Chinook salmon released from a minimum gap runner (MGR) turbine at Bonneville Dam powerhouse 1 and in the Bonneville Dam tailrace below the juvenile bypass outfall at powerhouse 2 and detected at river kilometers 200, 194, and 181, spring 2004.

	River Kilometer 200			River Kilometer 194			River Kilometer 181		
Release	DF	Chi-square	P	DF	Chi-square	P	DF	Chi-square	P
1	3	3.52	0.318	3	1.49	0.685	3	3.45	0.327
2	0	0	[a]	0	0	[a]	1	1.80	0.180
3	0	0	[a]	1	1.31	0.253	0	0	[a]
4	0	0	[a]	0	0	[a]	0	0	[a]
5	0	0	[a]	1	0.76	0.383	1	0.77	0.381
6	1	0.97	0.325	0	0	[a]	1	0.92	0.336
7	0	0	[a]	0	0	[a]	0	0	[a]
8	1	1.51	0.219	1	1.35	0.245	1	1.08	0.300
9	1	0.82	0.366	1	0.61	0.435	1	0.68	0.408
10[b]									
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[b]									

[a] - All fish arrived on the same day at this detection array.
[b] - Release was not analyzed due to dam operations not as specified in test conditions.

Table A5.3. 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 2004.

	River Kilometer 200			River Kilometer 194			River Kilometer 181		
Release	DF	Chi-square	P	DF	Chi-square	P	DF	Chi-square	P
1	2	2.18	0.336	2	4.13	0.127	3	5.82	0.121
2	0	0	[a]	0	0	[a]	1	0.83	0.362
3	0	0	[a]	1	1.37	0.241	0	0	[a]
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]

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

Table A5.4. Summary of chi-square tests for homogeneity of arrival times of hatchery steelhead trout released into a minimum gap runner (MGR) turbine unit at Bonneville Dam powerhouse 1 and directly downstream of the front roll below the MGR turbine unit and detected at river kilometers 200, 194, and 181, spring 2004.

	River Kilometer 200			River Kilometer 194			River Kilometer 181		
Release	DF	Chi-square	P	DF	Chi-square	P	DF	Chi-square	P
1	1	2.00	0.157	1	2.00	0.157	2	2.14	0.343
2	1	1.25	0.263	1	1.35	0.245	1	1.35	0.245
3	2	1.64	0.441	2	1.10	0.576	2	2.43	0.296
4	1	4.17	0.041	2	3.56	0.169	2	4.02	0.134
5	0	0	[a]	0	0	[a]	1	1.19	0.276
6	1	1.14	0.286	1	1.13	0.288	1	1.13	0.288
7	3	2.16	0.539	3	2.01	0.571	2	1.33	0.513
8	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]
9	1	0.72	0.396	1	0.83	0.362	0	0	[a]
10	0	0	[a]	0	0	[a]	0	0	[a]
11	2	3.26	0.196	2	3.26	0.196	2	2.68	0.261
12	2	2.13	0.346	2	2.26	0.323	2	2.13	0.344
13	1	1.51	0.220	1	1.28	0.258	1	1.17	0.280
14	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]
15	1	0.97	0.326	1	1.03	0.310	1	1.08	0.298
16	1	1.04	0.309	1	1.04	0.309	1	1.04	0.309

[a]- All fish arrived on the same day at this detection array.
[b]- Release did not occur due to failure with release mechanism.

Table A5.5. Summary of chi-square tests for homogeneity of arrival times of hatchery steelhead trout released from a minimum gap runner (MGR) turbine at Bonneville Dam powerhouse 1 and the Bonneville Dam tailrace below the juvenile bypass outfall at powerhouse 2 and detected at river kilometers 200, 194, and 181, spring 2004.

	River Kilometer 200			River Kilometer 194			River Kilometer 181		
Release	DF	Chi-square	P	DF	Chi-square	P	DF	Chi-square	P
1	2	1.03	0.596	2	1.03	0.596	2	1.11	0.574
2	1	1.47	0.225	1	1.59	0.208	1	1.59	0.208
3	1	0.44	0.509	1	0.46	0.498	1	0.29	0.589
4	2	4.46	0.107	3	5.76	0.124	3	4.09	0.252
5	0	0	[a]	0	0	[a]	1	1.13	0.287
6	0	0	[a]	1	1.51	0.219	1	1.36	0.244
7	3	3.54	0.315	2	2.26	0.323	2	1.09	0.581
8	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]
9	1	0.98	0.323	2	2.00	0.367	1	0.89	0.347
10	0	0	[a]	0	0	[a]	0	0	[a]
11	2	3.42	0.181	2	3.58	0.167	2	2.81	0.245
12	2	1.46	0.483	2	1.41	0.494	2	1.41	0.494
13	1	0.79	0.374	1	0.92	0.336	1	0.88	0.348
14	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]
15	1	0.83	0.362	1	0.85	0.356	1	0.86	0.354
16	1	0.82	0.366	1	0.89	0.345	1	0.89	0.345

[a]- All fish arrived on the same day at this detection array.
[b]- Release was not analyzed due to dam operations not as specified in test conditions.

Table A5.6. 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 2004.

	River Kilometer 200			River Kilometer 194			River Kilometer 181		
Release	DF	Chi-square	P	DF	Chi-square	P	DF	Chi-square	P
1	1	0.71	0.398	1	0.71	0.398	1	0.71	0.398
2	2	2.65	0.266	2	2.35	0.309	2	2.35	0.309
3	1	0	1.000	1	0.31	0.579	1	0.26	0.612
4	3	3.73	0.293	3	3.57	0.311	3	3.69	0.297
5	2	2.00	0.367	2	2.23	0.328	2	2.81	0.245
6	1	1.20	0.274	1	0	1.00	1	0.53	0.466
7	1	0.67	0.413	0	0	[a]	1	0.92	0.336
8	0	0	[a]	0	0	[a]	0	0	[a]
9	0	0	[a]	1	0.79	0.373	1	0.89	0.347
10	0	0	[a]	0	0	[a]	0	0	[a]
11	0	0	[a]	0	0	[a]	0	0	[a]
12	1	0.93	0.334	1	0.93	0.335	1	0.98	0.323
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]

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

Table A5.7. Summary of chi-square tests for homogeneity of arrival times of subyearling 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, summer 2004.

	River Kilometer 200			River Kilometer 194			River Kilometer 181		
Release	DF	Chi-square	P	DF	Chi-square	P	DF	Chi-square	P
1	0	0	[a]	0	0	[a]	0	0	[a]
2	0	0	[a]	0	0	[a]	0	0	[a]
3	1	0.35	0.552	0	0	[a]	0	0	[a]
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	1	44.00	3.284×10^{-11}	1	79.00	0	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]	1	0.31	0.576
15	0	0	[a]	0	0	[a]	1	2.89	0.089
16	0	0	[a]	0	0	[a]	0	0	[a]
17	1	0.505	0.477	1	0.85	0.357	1	0.99	0.320
18	0	0	[a]	0	0	[a]	0	0	[a]
19	1	3.85	0.050	1	3.90	0.048	0	0	[a]
20	0	0	[a]	0	0	[a]	0	0	[a]
21	1	4.12	0.042	1	4.29	0.038	1	3.99	0.046
22	0	0	[a]	1	0.27	0.605	2	0.67	0.714
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]	1	3.88	0.049	1	3.12	0.077
27	0	0	[a]	0	0	[a]	0	0	[a]
28	0	0	[a]	1	0.26	0.612	1	0.24	0.623
29	0	0	[a]	0	0	[a]	0	0	[a]
30	0	0	[a]	0	0	[a]	0	0	[a]
31	0	0	[a]	0	0	[a]	0	0	[a]
32	0	0	[a]	0	0	[a]	0	0	[a]

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

Table A5.8. Summary of chi-square tests for homogeneity of arrival times of yearling Chinook salmon released and used to estimate survival through spillbays with deflectors at 7-ft and 14-ft, spring 2004. Treatment fish were released in The Dalles Dam tailrace and control fish were released into the tailrace of Bonneville Dam and detected at river kilometers 200, 194, and 181.

			River Kilometer 200			River Kilometer 194			River Kilometer 181		
Release		Deflector	DF	Chi-square	P	DF	Chi-square	P	DF	Chi-square	P
1	Day	7	3	4.09	0.252	3	2.68	0.443	3	3.96	0.266
		14	3	0.87	0.832	3	0.34	0.951	3	1.46	0.691
	Night	7	3	1.23	0.745	3	11.46	0.009	3	21.32	0.000
		14	3	2.10	0.551	3	7.85	0.049	3	15.87	0.001
2	Day	7	2	0.51	0.773	3	5.04	0.169	3	10.86	0.012
		14	2	1.12	0.571	3	1.24	0.743	3	2.29	0.515
	Night	7	2	4.10	0.129	3	6.29	0.099	3	5.03	0.170
		14	2	3.19	0.203	3	6.65	0.084	3	6.12	0.106
3	Day	7	2	7.51	0.023	2	3.56	0.169	2	5.83	0.054
		14	2	0.14	0.935	2	0.36	0.834	2	0.47	0.792
	Night	7	2	10.78	0.005	2	15.86	0.000	2	17.68	0.000
		14	2	10.78	0.005	2	15.86	0.000	2	17.68	0.000
4	Day	7	4	4.80	0.308	4	6.14	0.189	3	8.50	0.037
		14	3	0.96	0.812	3	4.09	0.252	3	3.26	0.353
	Night	7	3	17.53	0.001	3	15.27	0.002	3	21.26	0.000
		14	3	18.63	0.000	3	15.23	0.002	3	15.48	0.001
5	Day	7	2	0.56	0.757	2	2.17	0.338	2	0.06	0.969
		14	2	3.49	0.175	2	2.55	0.279	2	0.48	0.789
	Night	7	2	3.66	0.160	2	9.26	0.010	2	4.66	0.098
		14	2	7.86	0.020	2	8.82	0.012	2	7.22	0.027
6	Day	7	2	9.88	0.007	2	10.48	0.005	2	7.29	0.026
		14	2	8.95	0.011	2	7.07	0.029	2	10.63	0.005
	Night	7	2	11.70	0.003	2	8.41	0.015	2	9.61	0.008
		14	2	11.73	0.003	2	10.52	0.005	2	11.52	0.003
7	Day	7	4	24.92	0.000	4	14.87	0.005	4	20.85	0.000
		14	4	8.73	0.068	4	3.81	0.432	4	10.27	0.036
	Night	7	4	19.99	0.001	4	27.78	0.000	4	36.40	0.000
		14	4	30.09	0.000	4	29.16	0.000	4	41.62	0.000
8	Day	7	2	11.09	0.004	2	8.20	0.017	2	10.35	0.006
		14	1	6.69	0.010	2	3.40	0.183	2	5.59	0.061
	Night	7	1	7.31	0.007	2	6.84	0.033	2	8.84	0.012
		14	1	7.72	0.005	2	4.03	0.133	2	7.53	0.023
9	Day	7	2	3.82	0.148	2	1.86	0.395	2	8.63	0.013
		14	2	8.45	0.015	2	2.94	0.230	2	5.07	0.079
	Night	7	2	5.69	0.058	2	8.89	0.012	2	10.56	0.005
		14	2	8.17	0.017	2	12.06	0.002	2	19.53	0.000
10	Day	7	1	0.65	0.422	1	0.10	0.750	1	2.01	0.156
		14	1	0.20	0.651	1	2.62	0.106	1	3.53	0.060
	Night	7	1	0.01	0.905	1	0.32	0.570	1	1.17	0.279
		14	1	0.73	0.392	1	0.01	0.933	1	0.06	0.801
11	Day	7	1	1.79	0.181	1	5.43	0.020	1	1.64	0.200
		14	1	1.79	0.181	1	3.36	0.067	1	3.28	0.070
	Night	7	1	2.37	0.124	1	4.44	0.035	1	9.99	0.002
		14	1	0.33	0.564	1	6.23	0.013	1	9.71	0.002

Table A5.8 (continued). Summary of chi-square tests for homogeneity of arrival times of yearling Chinook salmon released and used to estimate survival through spillbays with deflectors at 7-ft and 14-ft, spring 2004. Treatment fish were released in The Dalles Dam tailrace and control fish were released into the tailrace of Bonneville Dam and detected at river kilometers 200, 194, and 181.

			River Kilometer 200			River Kilometer 194			River Kilometer 181		
Release		Deflector	DF	Chi-square	P	DF	Chi-square	P	DF	Chi-square	P
12	Day	7	0	0.00	[a]	1	0.47	0.493	1	0.47	0.493
		14	0	0.00	[a]	1	0.08	0.779	1	0.08	0.779
	Night	7	0	0.00	[a]	1	0.68	0.411	1	0.68	0.411
		14	0	0.00	[a]	1	0.68	0.411	1	0.68	0.411
13	Day	7	3	19.07	0.000	3	12.11	0.007	3	16.74	0.001
		14	4	20.94	0.000	3	15.82	0.001	4	32.65	0.000
	Night	7	3	37.32	0.000	3	41.01	0.000	3	57.79	0.000
		14	3	37.17	0.000	3	39.37	0.000	3	63.76	0.000

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

Table A5.9. Summary of chi-square tests for homogeneity of arrival times of hatchery steelhead trout used to estimate survival through spillbays with deflectors at 7-ft and 14-ft, spring 2004. Releases were in The Dalles Dam tailrace and in the tailrace of Bonneville Dam and detected at river kilometers 200, 194, and 181, spring 2004.

			River Kilometer 200			River Kilometer 194			River Kilometer 181		
Release		Deflector	DF	Chi-square	P	DF	Chi-square	P	DF	Chi-square	P
1	Day	7	1	2.55	0.110	3	32.71	0.000	3	28.93	0.000
		14	1	0.68	0.410	2	1.84	0.399	2	2.17	0.337
	Night	7	2	12.52	0.002	3	13.65	0.003	3	19.47	0.000
		14	2	12.27	0.002	3	23.36	0.000	3	27.85	0.000
2	Day	7	1	13.43	0.000	2	4.52	0.104	2	6.01	0.049
		14	1	4.85	0.028	1	5.51	0.019	1	5.51	0.019
	Night	7	1	3.06	0.080	1	1.73	0.189	1	3.39	0.066
		14	1	3.06	0.080	1	3.06	0.080	1	4.25	0.039
3	Day	7	2	14.80	0.001	2	12.50	0.002	2	8.81	0.012
		14	2	3.01	0.222	2	3.01	0.222	2	1.37	0.505
	Night	7	2	4.85	0.089	2	4.85	0.089	2	4.85	0.089
		14	2	4.85	0.089	2	4.85	0.089	2	4.85	0.089
4	Day	7	2	24.42	0.000	2	26.12	0.000	2	18.29	0.000
		14	2	15.56	0.000	2	14.88	0.001	2	14.88	0.001
	Night	7	2	1.13	0.568	2	0.54	0.763	2	0.86	0.652
		14	2	3.32	0.190	2	2.20	0.332	2	2.62	0.269
5	Day	7	5	27.48	0.000	5	35.28	0.000	5	29.41	0.000
		14	5	10.53	0.062	5	9.29	0.098	5	5.19	0.393
	Night	7	5	11.40	0.044	5	10.62	0.060	5	10.14	0.071
		14	5	18.94	0.002	5	26.76	0.000	5	28.22	0.000
6	Day	7	3	22.54	0.000	3	20.15	0.000	3	18.55	0.000
		14	3	6.41	0.093	3	6.00	0.111	3	4.75	0.191
	Night	7	3	1.65	0.648	3	1.36	0.716	3	1.12	0.772
		14	3	1.77	0.622	3	1.81	0.614	3	1.69	0.640
7	Day	7	4	75.51	0.000	3	70.64	0.000	4	75.22	0.000
		14	4	33.46	0.000	3	32.43	0.000	4	35.64	0.000
	Night	7	4	12.07	0.017	3	14.78	0.002	4	15.70	0.003
		14	4	17.21	0.002	3	14.46	0.002	4	17.37	0.002
8	Day	7	3	38.20	0.000	3	46.96	0.000	3	41.96	0.000
		14	2	14.57	0.001	2	17.77	0.000	3	12.48	0.006
	Night	7	2	18.93	0.000	2	24.65	0.000	3	24.18	0.000
		14	2	23.26	0.000	2	25.63	0.000	3	28.43	0.000
9	Day	7	1	15.48	0.000	1	15.32	0.000	1	16.08	0.000
		14	1	13.69	0.000	1	15.49	0.000	2	16.13	0.000
	Night	7	1	3.80	0.051	1	2.27	0.132	1	2.61	0.106
		14	1	3.94	0.047	1	5.89	0.015	1	5.20	0.023
10	Day	7	3	38.30	0.000	3	41.52	0.000	3	27.56	0.000
		14	3	26.89	0.000	3	26.61	0.000	3	25.95	0.000
	Night	7	3	21.28	0.000	3	20.78	0.000	3	21.45	0.000
		14	3	19.32	0.000	3	21.37	0.000	3	22.04	0.000
11	Day	7	2	18.05	0.000	2	14.57	0.001	2	10.46	0.005
		14	2	13.30	0.001	2	12.81	0.002	2	13.30	0.001
	Night	7	2	10.76	0.005	2	11.77	0.003	2	12.52	0.002
		14	2	14.35	0.001	2	9.14	0.010	2	12.75	0.002
12	Day	7	1	6.62	0.010	1	12.95	0.000	1	11.37	0.001
		14	1	6.28	0.012	1	7.27	0.007	1	3.80	0.051
	Night	7	1	0.10	0.756	1	0.02	0.881	1	0.35	0.553
		14	1	1.54	0.215	1	2.77	0.096	1	0.84	0.358

Table A5.9 (continued). Summary of chi-square tests for homogeneity of arrival times of hatchery steelhead trout used to estimate survival through spillbays with deflectors at 7-ft and 14-ft, spring 2004. Releases were in The Dalles Dam tailrace and in the tailrace of Bonneville Dam and detected at river kilometers 200, 194, and 181, spring 2004.

			River Kilometer 200			River Kilometer 194			River Kilometer 181		
Release		Deflector	DF	Chi-square	P	DF	Chi-square	P	DF	Chi-square	P
13	Day	7	1	6.62	0.010	2	9.51	0.009	2	8.15	0.0017
		14	1	11.48	0.001	2	11.15	0.004	2	9.37	0.009
	Night	7	2	3.52	0.172	2	2.70	0.259	2	3.02	0.220
		14	1	6.23	0.013	2	7.55	0.023	2	9.69	0.008
14	Day	7	2	0.23	0.890	2	0.23	0.890	2	0.23	0.890
		14	2	0.35	0.839	2	0.35	0.839	2	0.35	0.839
	Night	7	1	0.45	0.501	1	0.45	0.501	2	0.92	0.630
		14	2	0.77	0.682	2	1.52	0.467	2	5.49	0.064
15	Day	7	2	1.75	0.417	2	2.46	0.293	2	2.09	0.352
		14	2	2.76	0.252	2	4.87	0.088	2	4.27	0.118
	Night	7	2	1.36	0.506	2	5.34	0.069	2	7.57	0.023
		14	2	3.83	0.147	2	5.60	0.061	2	5.74	0.057

Table A5.10. Summary of chi-square tests for homogeneity of arrival times of subyearling Chinook salmon used to estimate survival through spillbays with deflectors at 7-ft and 14-ft, summer 2004. Treatment fish were released in The Dalles Dam tailrace and control fish were in the tailrace of Bonneville Dam and detected at river kilometers 200, 194, and 181. BIOP spill =56 kcfs day/total dissolved gas cap at night.

			River Kilometer 200			River Kilometer 194			River Kilometer 181		
Release	Spill	Deflector	DF	Chi-square	P	DF	Chi-square	P	DF	Chi-square	P
1	BIOP	7	1	0.45	0.503	1	0.01	0.926	1	2.81	0.094
		14	1	0.91	0.341	1	3.50	0.061	1	2.80	0.095
2	KCFS 50	7	1	2.14	0.144	1	1.74	0.187	1	2.47	0.116
		14	1	0.00	0.986	1	0.04	0.843	1	0.00	0.977
3	KCFS 50	7	1	1.57	0.211	1	0.24	0.627	1	0.04	0.832
		14	1	2.98	0.084	1	6.83	0.009	1	7.74	0.005
4	KCFS 50	7	1	0.86	0.353	1	4.75	0.029	1	5.67	0.017
		14	1	3.42	0.064	1	5.34	0.021	1	8.93	0.003
5	BIOP	7	1	6.49	0.011	1	0.86	0.353	1	4.73	0.030
		14	1	0.65	0.420	1	9.39	0.002	1	9.12	0.003
6	BIOP	7	0	0	[a]	1	0.31	0.580	1	1.25	0.263
		14	0	0	[a]	1	0.22	0.640	1	1.57	0.210
7	KCFS 50	7	2	1.86	0.394	2	1.98	0.372	2	3.88	0.144
		14	2	4.84	0.089	2	3.60	0.166	2	5.50	0.064
8	BIOP	7	1	2.97	0.085	1	0.47	0.494	1	0.09	0.760
		14	1	0.02	0.897	2	7.11	0.029	2	7.43	0.024
9	BIOP	7	1	0.28	0.598	1	3.63	0.056	2	3.91	0.142
		14	0	0	[a]	1	4.18	0.041	1	0.24	0.622
10	KCFS 50	7	1	2.07	0.151	3	0.91	0.824	3	0.77	0.856
		14	2	2.29	0.319	3	7.44	0.059	4	11.63	0.020
11	BIOP	7	1	1.49	0.222	1	4.34	0.037	2	3.81	0.149
		14	1	0.56	0.455	1	1.51	0.220	2	2.89	0.236
12	BIOP	7	1	0.44	0.508	0	0	[a]	1	0.22	0.641
		14	1	1.19	0.274	1	4.14	0.042	1	1.19	0.274
13	BIOP	7	1	5.17	0.023	1	0.42	0.520	1	0.73	0.394
		14	1	0.87	0.352	1	0.40	0.528	2	7.86	0.020
14	KCFS 50	7	1	4.39	0.036	1	0.32	0.573	1	0.42	0.516
		14	1	0.91	0.339	1	0.56	0.453	1	0.00	0.978
15	KCFS 50	7	2	3.53	0.171	3	2.96	0.398	4	5.72	0.221
		14	2	7.50	0.023	3	0.86	0.835	4	0.77	0.942
16	BIOP	7	1	0.01	0.912	2	1.09	0.580	2	1.35	0.508
		14	1	3.25	0.071	2	3.81	0.149	2	5.64	0.060
17	BIOP	7	1	1.88	0.170	1	0.68	0.409	1	1.75	0.186
		14	1	0.35	0.551	1	0.72	0.396	1	1.29	0.256
18	BIOP	7	2	0.53	0.768	1	0.80	0.372	1	1.62	0.203
		14	2	0.75	0.687	1	1.53	0.216	1	0.02	0.891
19	BIOP	7	0	0	[a]	1	0.71	0.399	1	0.96	0.328
		14	1	0.19	0.664	1	1.40	0.237	1	1.28	0.259
20	KCFS 50	7	2	2.03	0.362	3	1.18	0.757	3	1.87	0.600
		14	1	1.54	0.214	2	5.14	0.077	3	4.10	0.251
21	BIOP	7	1	0.00	0.960	1	0.81	0.367	1	0.67	0.415
		14	1	0.87	0.351	1	0.27	0.600	1	2.99	0.084
22	BIOP	7	0	0	[a]	0	0	[a]	0	0	[a]
		14	0	0	[a]	0	0	[a]	0	0	[a]

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

Table A5.10 (continued). Summary of chi-square tests for homogeneity of arrival times of subyearling Chinook salmon used to estimate survival through spillbays with deflectors at 7-ft and 14-ft, summer 2004. Treatment fish were released in The Dalles Dam tailrace and control fish were in the tailrace of Bonneville Dam and detected at river kilometers 200, 194, and 181. BIOP spill =56 kcfs day/total dissolved gas cap at night.

			River Kilometer 200			River Kilometer 194			River Kilometer 181		
Release	Spill	Deflector	DF	Chi-square	P	DF	Chi-square	P	DF	Chi-square	P
23	BIOP	7	1	3.90	0.048	1	0.31	0.579	1	0.00	0.978
		14	0	0	[a]	1	1.40	0.237	1	9.18	0.002
24	KCFS 50	7	0	0	[a]	1	0.17	0.681	1	0.38	0.540
		14	0	0	[a]	1	0.12	0.730	1	0.36	0.548
25	KCFS 50	7	1	1.63	0.201	0	0	[a]	1	8.38	0.004
		14	0	0	a	1	5.80	0.016	1	5.80	0.016
26	KCFS 50	7	1	0.08	0.773	1	1.02	0.313	2	1.29	0.525
		14	1	1.88	0.170	1	2.19	0.139	2	5.75	0.056
27	BIOP	7	2	1.23	0.542	1	3.94	0.047	2	5.22	0.074
		14	2	1.50	0.471	1	0.25	0.620	2	0.27	0.874
28	BIOP	7	0	0	[a]	0	0	[a]	1	1.78	0.183
		14	0	0	[a]	0	0	[a]	0	0	[a]
29	BIOP	7	0	0	[a]	0	0	[a]	0	0	[a]
		14	0	0	[a]	0	0	[a]	0	0	[a]
30	BIOP	7	0	0	[a]	0	0	[a]	0	0	[a]
		14	0	0	[a]	0	0	[a]	0	0	[a]
31	BIOP	7	0	0	[a]	0	0	[a]	0	0	[a]
		14	0	0	[a]	0	0	[a]	0	0	[a]
32	BIOP	7	0	0	[a]	0	0	[a]	0	0	[a]
		14	0	0	[a]	0	0	[a]	0	0	[a]
33	BIOP	7	0	0	[a]	0	0	[a]	0	0	[a]
		14	0	0	[a]	0	0	[a]	0	0	[a]
34	BIOP	7	0	0	[a]	0	0	[a]	0	0	[a]
		14	1	4.33	0.037	1	4.33	0.037	1	4.33	0.037
35	KCFS 50	7	1	0.02	0.897	2	0.41	0.815	2	0.45	0.797
		14	2	12.14	0.002	2	2.13	0.345	2	0.10	0.951
36	KCFS 50	7	2	0.30	0.861	1	0.92	0.337	2	0.23	0.891
		14	2	0.47	0.791	1	7.89	0.005	2	7.34	0.025
37	BIOP	7	1	0.76	0.384	1	0.00	0.962	1	0.21	0.644
		14	1	0.05	0.821	1	3.03	0.082	1	2.65	0.104
38	BIOP	7	0	0	[a]	1	4.35	0.037	1	8.74	0.003
		14	1	3.52	0.061	1	3.52	0.061	1	3.52	0.061

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

Appendix 6: Bonneville Lock and Dam, Revision to Fish Passage Plan Spill Patterns FEB2005

CENWP-EC-HD 25FEB2005
MEMORANDUM FOR THE RECORD

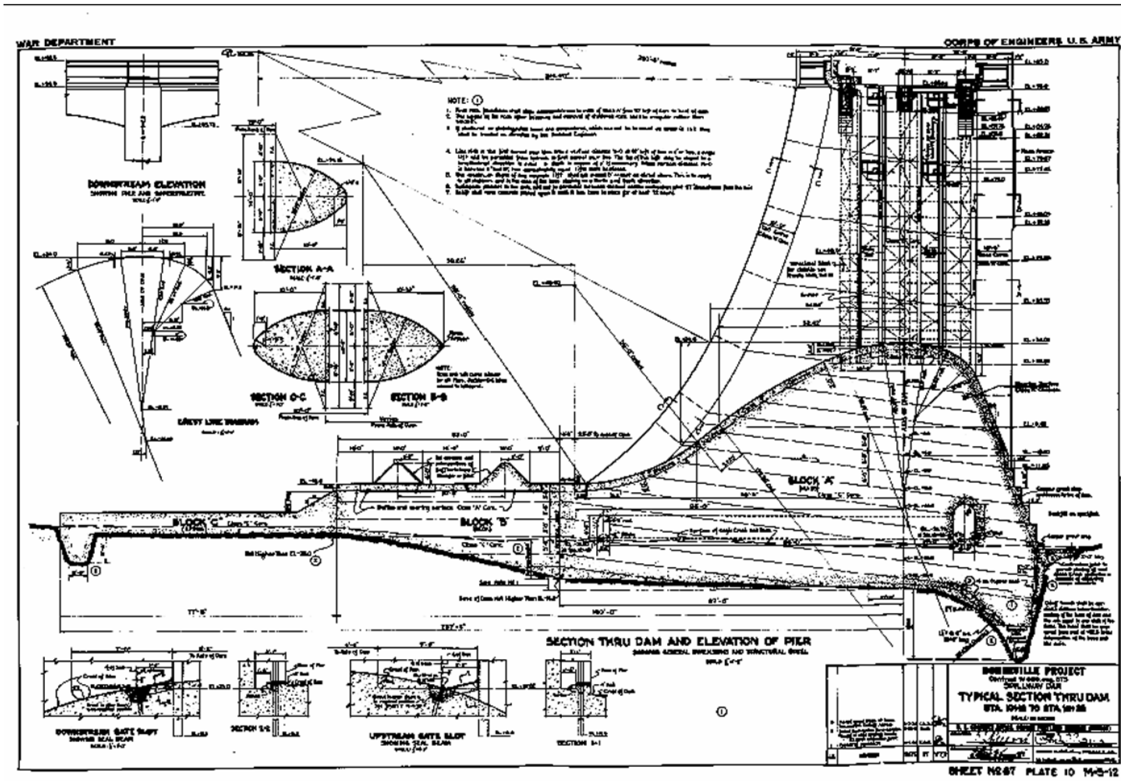
Subject:
Bonneville Lock and Dam, Revision to Fish Passage Plan Spill Patterns FEB2005

1. Introduction/Background:

Location: Bonneville Dam and Lake, Columbia River Basin

General Overview of Project

View of Spillway



Cross Section View of Spillway

Since additional flow deflectors were installed at Bonneville Dam Spillway (immediately prior to the 2002 spill season) a discrepancy between the computed inflow (The Dalles Outflow + tributary inflow) and outflow from Bonneville Dam was identified. This discrepancy occurred during times of spill. The reported spillway discharge turned out to be greater than the actual discharge (as measured downstream of the project). The magnitude of this discrepancy varied but was on the order of 20 Kcfs.

It has been determined that there are two major issues that have resulted in this flow discrepancy. One is a mis-calibration in the gate opening mechanism. The other is an out of date rating curve that gives the relationship between gate opening and flow.

During July 2004, it was discovered that the spillway gate hoist controller (GDACS) at Bonneville had been mis-calibrated and actual gate openings were up to 4 inches less than was reported. The greatest impact of this mis-calibration was on discharges at smaller gate openings. This effect was magnified by the new spill pattern developed for the new flow deflectors, which utilizes a larger number of gates at smaller openings for a given total spillway flow as compared to previous patterns.

The calibration errors would be significant primarily when the project was trying to meet a target discharge such as the 75 Kcfs daytime spill. When the project discharges to the gas cap the gas concentration downstream determines the spill volume that can be passed. The actual volume may have been misreported but the volume was set to meet the water quality requirements downstream. When the total river flows exceed the powerhouse capacity, the excess flow is also discharged through the spillway, increasing the 75 Kcfs daytime spill. In this case the spill is governed by total inflow and not increasing the forebay elevation.

During the investigation of the flow discrepancy between The Dalles (TDA) and Bonneville (BON) the spillway rating curves for both projects were scrutinized. Upon review the original TDA spillway-rating curve is consistent with current EM guidance. In addition the TDA discharge is verified by using a USGS gauging station just downstream of the TDA project. The BON spillway-rating curve is based on the orifice equation with the discharge coefficient determined from the original design physical model studies. In the 1970s the gate lip design was changed to reduce gate vibration. The lip changed from a rounded to a sharp edge design that also reduced the gate effeciency, especially at lower discharges. However, it does not appear that the rating curve was updated, and operation continued with the original rating curve. With older spill patterns, this difference was not particularly noticeable.

This memorandum will document the recommended BON spillway-rating curve and provide a relationship between actual spill in 2002 through 2004 given the reported spill in the Columbia River Operational Hydromet Management System (CROHMS) database for that same period. The relationship will not be exact but will provide a reasonable estimate of the actual spill volumes during the 2002, 2003 and 2004 spill season.

2. Rating Curve Revision:

The original Bonneville Spillway Rating Curve is based on the following orifice equation (HDC 311-1):

$$Q = C_d A\sqrt{2gH}$$

Where:

Q is the discharge in cfs

C_d is the discharge coefficient

A is the area of the opening in ft^2

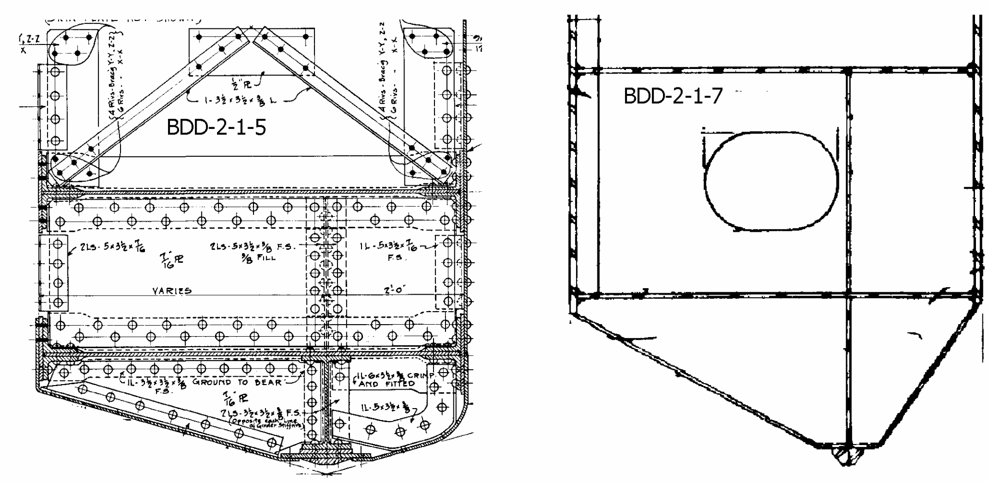
A = B*Height of opening

B is the width of the opening in ft

g = gravity (32.2 ft/sec^2)

H is the height of water from centerline of the opening to the surface

Physical model work conducted during the original design phase has been used to compute the discharge coefficient, C_d. The discharge coefficient from the original model work ranged from 1.1 for small gate openings to 0.7 for large gate openings (greater than 5 ft). For small gate openings the discharge coefficient appears to be unusually high. Typical discharge coefficients range from 0.65 to 0.75 for tainter gates, 0.7 to 0.85 for regulating gates and 1.0 for very efficient tube orifices. It is most likely that the original gate lip may have been extremely efficient for small gate openings where as the current gate lip may be more typical of vertical sluice gates. Another possible factor is that gate leakage in the model may have adversely affected the flow measurements.



Original Rounded Gate Lip

Current Sharp Edge Gate Lip

Comparison of original and current Bonneville Spillway gate lips

Discharge under high head vertical lift gates can be computed using the standard orifice equation (HDC 311-1) or using a relationship between gate-controlled discharge to free discharge (HDC 312). A spillway-rating curve was developed using both methods and they are presented in Figure 1. Included in Figure 1 is the original spillway-rating curve. The discharge coefficient for small gate openings is set equal to 0.80 in the rating curve called “Corrected Orifice Equation”. The original rating curve falls above the other two rating curves for small gate openings. For this application a discharge coefficient of 0.80 was assumed for small gate openings. For example, for a 74.0 ft forebay, a gate opening equivalent to 1 dog, or 1.06 ft, yield a coefficient of 1.01 under the old rating curve for a flow of 3047 cfs, while the new rating curve would fix the coefficient at 0.80 for a flow of 2411 cfs. For a single bay this is a difference of 636 cfs, and across 18 bays the difference would be on the order of 11000 cfs (assuming for this example that all bays are open 1.06 ft). As the gate opening increases, the coefficients match up better, and the differences themselves become less signifigant.

Thus the recommended rating curve for the Bonneville Spillway is documented in Table 2, which details a full rating curve for a full range of forebays (70 ft NGVD to 77 ft NGVD) and gate openings in both dogs and feet up to 12 dogs, or 22.15 ft.

Note that this will allow GDACS to compute the spillway discharge given the reported gate openings. The spill patterns recommended in the Fish Passage Plan and incorporated into the GDACS system at Bonneville need to have the discharge associated with a specific set of gate openings (the pattern) updated using the revised rating curve.

Relationship Between Reported and Actual Spill

Using the spill patterns detailed in the Fish Passage Plan and incorporating the revised rating curve and the actual gate openings, the following comparison can be made for reported versus actual spill volumes. This assumes a Bonneville forebay elevation of 74.0 feet NGVD. The relationship would vary slightly for different forebay elevations and the impact of forebay elevation can be seen in Table 2. The results in Table 1 are presented in Figure 3 and a trend line has been fitted through the data points where:

$$ActualSpill = 0.001x^2 + 0.8788x - 23.45$$

Where:

x = reported spill

For example, if the reported spill from the CROHMS database showed 89 kcfs, using the *ActualSpill* formula the spill would actually be 63 kcfs.

Table 1 Comparison for spill patterns used since 2002, both ratings corrected for gate opening Assumed correction applied to all gates to determine "Actual Gate Opening" All values based on a Bonneville Forebay Elevation of 74.0 ft NGVD							
		Gate Corrected Only			Gate and Gate Coefficient Corrected		
Nominal Spill	Reported Spill	PRE2005 Ratinge Curve Flow	Difference	% Difference	FEB2005 Rating Curve Flow	Difference	% Difference
kcfs	kcfs				kcfs	kcfs	%
50	49.9	33.4	16.5	33.0	23.1	26.8	53.8
75	74.6	62.8	11.8	15.9	47.6	27.0	36.2
100	100.2	91.1	9.1	9.1	74.8	25.4	25.4
125	125.2	117.1	8.1	6.5	102.4	22.8	18.2
150	150.2	142.1	8.1	5.4	131.1	19.1	12.7

For a given requested spill, the spill pattern that closest matched was selected from the Fish Passage Plan. Table 1 shows the impact of the gate opening correction and the gate opening correction in conjunction with the gate coefficient correction.

3. Recommendations:

As of this writing (FEB2005) the GDACS system has been properly calibrated (see MFR “Bonneville Spillway Recalibration Field Trip Report”, 18OCT2004) by the project and reports an accurate gate opening. As of this writing the rating curve in GDACS has not been updated.

Recommended Actions:

- GDACS system used to control the spillway needs to be updated with the revised rating curves
- The Fish Passage Plan needs to be updated with the revised rating curves in the Bonneville Spill Pattern, it is recommended that the FEB2005 rating curve for a 74.0 ft NGVD forebay be used

- GDACS gate calibration should be confirmed prior to spill season and documented. Due to mechanical issues the hoists in general and the gantry operated bays in particular may loose calibration over time, and may do so to varying degrees (see MFR "Bonneville Spillway Recalibration Field Trip Report", 18OCT2004)

- Spill should be monitored during the 2005 spill season to determine if discrepancy has been corrected to an acceptable level, if not, a field test may be required to update the rating curve due to the non-standard lip design.

4. References:

"Spillway Flow Discrepancy, Executive Summary", 15 pgs, Prepared by David B. Smith, Bonneville Project, dated 27JUL2004.

"Bonneville Spillway Recalibration Field Trip Report", 18oct2004bonnswrecal-1, written by HIGA, Nathan T., dated 18OCT2004, EC-HD files.

"Hydraulic Design Criteria" (HDC), US Army Corps of Engineers Waterways Experiment Station, 1988.

Written by
HIGA, Nathan T.
Engineer, Hydraulic Design Section

Technical Review, Approval: ____________________
Laurie L. Ebner, P.E.

CF: CENWP-EC-HD Files

Bonneville Spillbay 17, looking across top of gate towards right pier, the markings shown correspond to dogs. However the dogs match the old 50 ft tall gates, and not the current 60 ft tall gates. Calibrating to the dogs resulted in the gates being open approximately 0.3 ft lower than reported by the hoisting equipment.


Local gate control with front panel open during recalibration process.

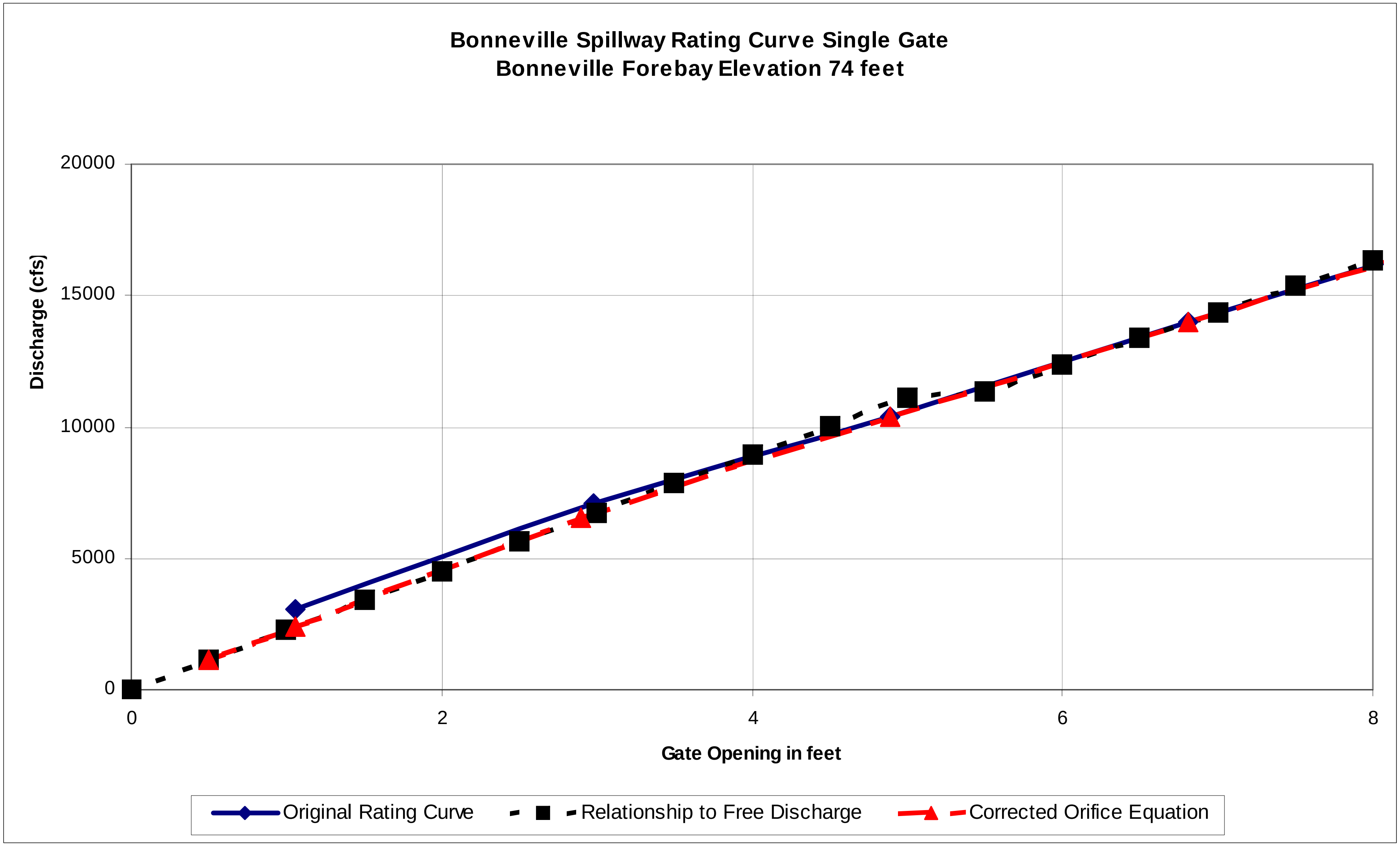


Figure 1. Bonneville Spillway Rating Curve Single Gate, Bonneville Forebay Elevation 74 ft.

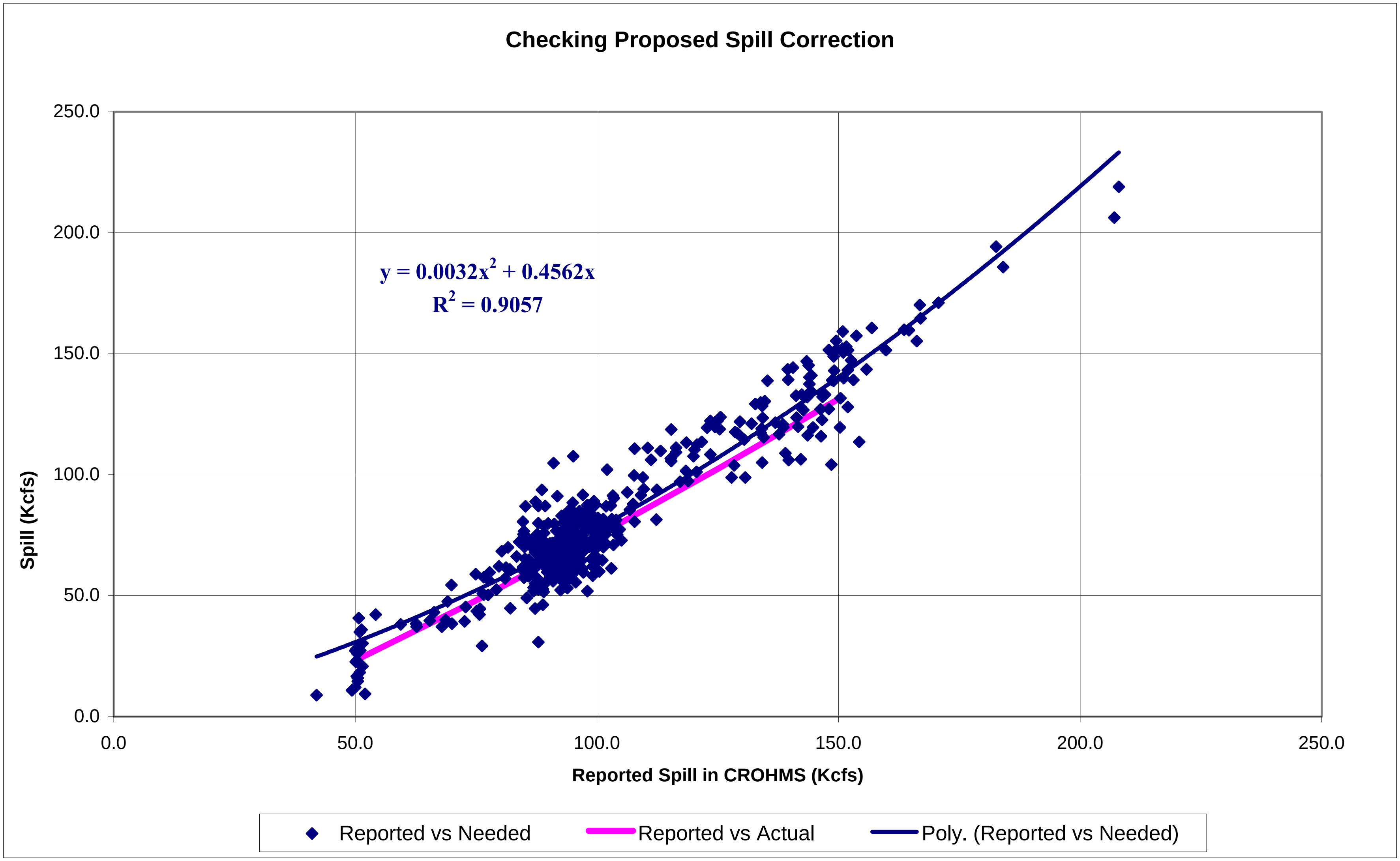


Figure 2. Checking Proposed Spill Correction.

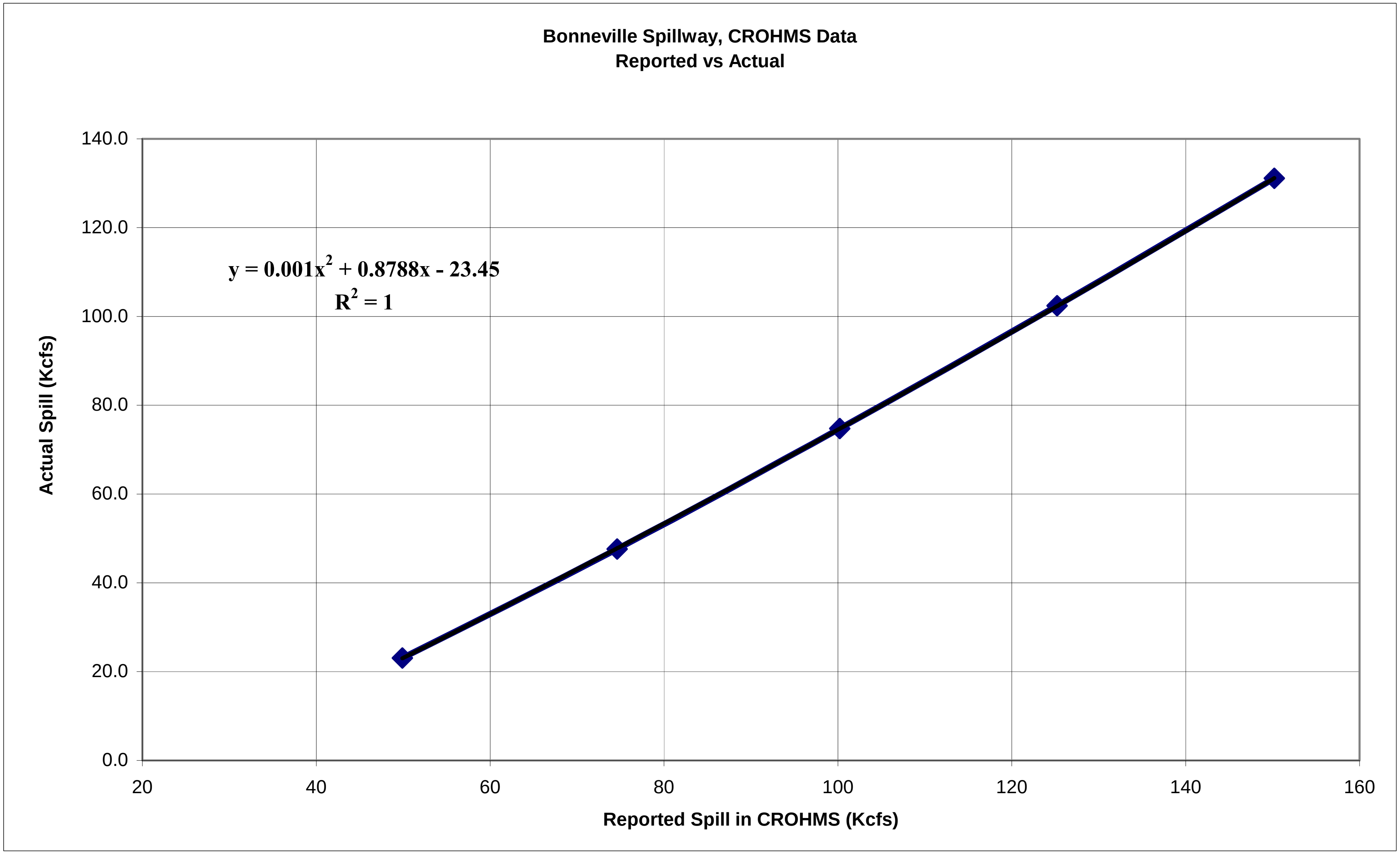


Figure 3. Bonneville Spillway, CROHMS Data, Reported vs Actual Flow.

Table 2 Bonneville Spill from a single bay with respect to Opening in Dogs (& feet) and Lake Elevation, flow in CFS. 60 foot Gate

Computed by LLE on February 11, 2005

Backed checked and compared to work by NTkH on 09FEB2005

Forebay Elevation	Gate Opening																
FB	dogs	0			1				2					3			
ft	feet	0	0.5	1	1.06	1.5	2	2.5	2.9	3	3.5	4	4.5	4.89	5	5.5	6
70		0	1102	2179	2307	3233	4265	5275	6069	6265	7235	8187	9120	9837	10037	10938	11824
70.2		0	1104	2184	2312	3240	4274	5287	6082	6279	7251	8205	9141	9859	10060	10963	11851
70.4		0	1106	2188	2317	3247	4283	5298	6095	6293	7267	8223	9161	9881	10083	10988	11878
70.6		0	1109	2193	2322	3254	4293	5310	6109	6306	7283	8241	9182	9903	10105	11012	11904
70.8		0	1111	2198	2327	3261	4302	5321	6122	6320	7299	8260	9202	9925	10128	11037	11931
71		0	1113	2202	2331	3268	4311	5333	6135	6334	7315	8278	9222	9947	10150	11062	11958
71.2		0	1116	2207	2336	3275	4320	5344	6148	6347	7331	8296	9243	9969	10172	11086	11985
71.4		0	1118	2212	2341	3282	4330	5356	6162	6361	7347	8314	9263	9991	10195	11111	12011
71.6		0	1120	2216	2346	3289	4339	5367	6175	6375	7363	8332	9283	10013	10217	11135	12038
71.8		0	1123	2221	2351	3296	4348	5378	6188	6388	7378	8350	9303	10035	10239	11160	12064
72		0	1125	2226	2356	3303	4357	5390	6201	6402	7394	8368	9323	10057	10262	11184	12091
72.2		0	1127	2230	2361	3309	4366	5401	6214	6415	7410	8386	9343	10078	10284	11208	12117
72.4		0	1130	2235	2366	3316	4375	5412	6227	6429	7426	8403	9363	10100	10306	11232	12144
72.6		0	1132	2239	2371	3323	4384	5424	6240	6442	7441	8421	9383	10121	10328	11257	12170
72.8		0	1134	2244	2375	3330	4393	5435	6253	6456	7457	8439	9403	10143	10350	11281	12196
73		0	1137	2248	2380	3337	4402	5446	6266	6469	7472	8457	9423	10165	10372	11305	12222
73.2		0	1139	2253	2385	3344	4411	5457	6279	6483	7488	8474	9443	10186	10394	11329	12248
73.4		0	1141	2258	2390	3350	4420	5469	6292	6496	7504	8492	9462	10207	10416	11353	12274
73.6		0	1143	2262	2395	3357	4429	5480	6305	6509	7519	8510	9482	10229	10438	11377	12300
73.8		0	1146	2267	2400	3364	4438	5491	6318	6523	7534	8527	9502	10250	10459	11401	12326
74		0	1148	2271	2404	3371	4447	5502	6331	6536	7550	8545	9522	10271	10481	11424	12352
74.2		0	1150	2276	2409	3377	4456	5513	6344	6549	7565	8562	9541	10293	10503	11448	12378
74.4		0	1153	2280	2414	3384	4465	5524	6356	6562	7581	8580	9561	10314	10524	11472	12404
74.6		0	1155	2285	2419	3391	4474	5535	6369	6576	7596	8597	9580	10335	10546	11496	12430
74.8		0	1157	2289	2423	3398	4483	5546	6382	6589	7611	8615	9600	10356	10568	11519	12455
75		0	1159	2294	2428	3404	4492	5557	6395	6602	7627	8632	9619	10377	10589	11543	12481
75.2		0	1162	2298	2433	3411	4501	5568	6407	6615	7642	8649	9639	10398	10611	11566	12507
75.4		0	1164	2303	2438	3418	4509	5579	6420	6628	7657	8667	9658	10419	10632	11590	12532
75.6		0	1166	2307	2442	3424	4518	5590	6433	6641	7672	8684	9677	10440	10653	11613	12558
75.8		0	1168	2312	2447	3431	4527	5601	6445	6654	7687	8701	9697	10461	10675	11637	12583
76		0	1170	2316	2452	3437	4536	5612	6458	6667	7702	8718	9716	10482	10696	11660	12608
76.2		0	1173	2320	2456	3444	4545	5623	6471	6680	7718	8735	9735	10503	10717	11683	12634
76.4		0	1175	2325	2461	3451	4553	5634	6483	6693	7733	8753	9754	10524	10739	11707	12659
76.6		0	1177	2329	2466	3457	4562	5645	6496	6706	7748	8770	9773	10544	10760	11730	12684
76.8		0	1179	2334	2470	3464	4571	5656	6508	6719	7763	8787	9793	10565	10781	11753	12709
77		0	1182	2338	2475	3470	4579	5666	6521	6732	7778	8804	9812	10586	10802	11776	12734

Table 2 Bonneville Spill from a single bay with respect to Opening in Dogs (& feet) and Lake Elevation in CFS. 60 foot Gate

Computed by LLE on February 11, 2005

Backed checked and compared to work by NTkH on 09FEB2005

Forebay Elevation	Gate Opening																
FB	dogs		4					5					6				
ft	feet	6.5	6.81	7	7.5	8	8.5	8.73	9	9.5	10	10.5	10.64	11	11.5	12	12.5
70		12695	13228	13553	14398	15231	16053	16428	16865	17668	18462	19248	19467	20028	20801	21568	22331
70.2		12724	13259	13584	14431	15267	16091	16467	16905	17710	18506	19295	19514	20076	20851	21621	22386
70.4		12753	13289	13615	14465	15302	16129	16505	16945	17752	18550	19341	19561	20125	20902	21674	22441
70.6		12782	13319	13646	14498	15338	16166	16544	16985	17794	18594	19387	19608	20173	20952	21726	22495
70.8		12811	13350	13677	14531	15373	16204	16582	17024	17836	18638	19433	19654	20221	21003	21779	22550
71		12840	13380	13708	14564	15408	16241	16621	17064	17877	18682	19479	19701	20269	21053	21831	22605
71.2		12869	13410	13739	14597	15443	16278	16659	17103	17919	18726	19525	19747	20317	21103	21883	22659
71.4		12898	13440	13770	14630	15478	16316	16697	17143	17960	18769	19570	19793	20365	21153	21935	22713
71.6		12926	13470	13801	14663	15513	16353	16735	17182	18001	18813	19616	19840	20412	21203	21987	22767
71.8		12955	13500	13832	14696	15548	16390	16773	17221	18043	18856	19661	19886	20460	21252	22039	22821
72		12983	13530	13862	14729	15583	16427	16811	17260	18084	18899	19707	19932	20507	21302	22091	22875
72.2		13012	13560	13893	14761	15618	16464	16849	17299	18125	18942	19752	19977	20555	21351	22143	22929
72.4		13040	13589	13924	14794	15653	16500	16887	17338	18166	18985	19797	20023	20602	21401	22194	22983
72.6		13069	13619	13954	14827	15687	16537	16924	17377	18207	19028	19842	20069	20649	21450	22245	23036
72.8		13097	13649	13984	14859	15722	16574	16962	17415	18247	19071	19887	20114	20696	21499	22297	23090
73		13125	13678	14015	14891	15756	16610	16999	17454	18288	19114	19932	20160	20743	21548	22348	23143
73.2		13153	13708	14045	14924	15791	16647	17037	17492	18329	19157	19977	20205	20790	21597	22399	23196
73.4		13182	13737	14075	14956	15825	16683	17074	17531	18369	19199	20021	20250	20837	21646	22450	23249
73.6		13210	13767	14105	14988	15859	16719	17111	17569	18410	19242	20066	20295	20883	21695	22501	23302
73.8		13238	13796	14135	15020	15894	16756	17149	17607	18450	19284	20110	20340	20930	21743	22551	23355
74		13266	13825	14165	15052	15928	16792	17186	17646	18490	19326	20155	20385	20976	21792	22602	23407
74.2		13294	13854	14195	15084	15962	16828	17223	17684	18530	19369	20199	20430	21023	21840	22652	23460
74.4		13321	13883	14225	15116	15996	16864	17260	17722	18570	19411	20243	20475	21069	21888	22703	23512
74.6		13349	13912	14255	15148	16030	16900	17297	17760	18610	19453	20287	20520	21115	21936	22753	23565
74.8		13377	13941	14285	15180	16063	16936	17333	17798	18650	19495	20331	20564	21161	21984	22803	23617
75		13405	13970	14315	15212	16097	16971	17370	17835	18690	19536	20375	20609	21207	22032	22853	23669
75.2		13432	13999	14344	15243	16131	17007	17407	17873	18730	19578	20419	20653	21253	22080	22903	23721
75.4		13460	14028	14374	15275	16164	17043	17443	17911	18770	19620	20462	20697	21298	22128	22953	23773
75.6		13487	14057	14403	15307	16198	17078	17480	17948	18809	19661	20506	20741	21344	22176	23002	23824
75.8		13515	14085	14433	15338	16231	17114	17516	17986	18849	19703	20550	20785	21389	22223	23052	23876
76		13542	14114	14462	15369	16265	17149	17552	18023	18888	19744	20593	20829	21435	22271	23101	23928
76.2		13569	14143	14491	15401	16298	17184	17589	18060	18927	19786	20636	20873	21480	22318	23151	23979
76.4		13597	14171	14521	15432	16331	17220	17625	18098	18966	19827	20679	20917	21525	22365	23200	24030
76.6		13624	14200	14550	15463	16365	17255	17661	18135	19006	19868	20723	20961	21570	22412	23249	24081
76.8		13651	14228	14579	15494	16398	17290	17697	18172	19045	19909	20766	21004	21615	22459	23298	24133
77		13678	14256	14608	15525	16431	17325	17733	18209	19084	19950	20809	21048	21660	22506	23347	24184

Table 2 Bonneville Spill from a single bay with respect to Opening in Dogs (& feet) and Lake Elevation, flow in CFS. 60 foot Gate

Computed by LLE on February 11, 2005 3/3

Backed checked and compared to work by NTkH on 09FEB2005

Forebay Elevation	Gate Opening																
FB	dogs	7				8					9					10	
ft	feet	12.56	13	13.5	14	14.48	14.5	15	15.5	16	16.4	16.5	17	17.5	18	18.31	18.5
70		22422	23089	23844	24597	25318	25348	26097	26846	27595	28195	28345	29096	29850	30606	31076	31365
70.2		22477	23146	23904	24659	25382	25412	26164	26915	27666	28268	28419	29172	29928	30687	31159	31449
70.4		22532	23204	23963	24720	25446	25476	26230	26983	27737	28341	28492	29248	30006	30768	31241	31532
70.6		22587	23261	24023	24782	25509	25539	26296	27052	27808	28413	28565	29324	30084	30848	31323	31615
70.8		22642	23317	24082	24843	25573	25603	26362	27120	27879	28486	28638	29399	30162	30928	31405	31698
71		22697	23374	24141	24904	25636	25667	26427	27188	27949	28558	28711	29474	30240	31009	31487	31781
71.2		22752	23431	24199	24965	25699	25730	26493	27256	28019	28630	28783	29549	30317	31088	31568	31863
71.4		22806	23487	24258	25026	25762	25793	26558	27324	28089	28702	28856	29624	30395	31168	31650	31945
71.6		22861	23544	24317	25087	25825	25856	26624	27391	28159	28774	28928	29699	30472	31248	31731	32027
71.8		22915	23600	24375	25148	25888	25919	26689	27459	28229	28846	29000	29773	30548	31327	31812	32109
72		22969	23656	24433	25208	25951	25981	26754	27526	28298	28917	29072	29847	30625	31406	31892	32191
72.2		23023	23712	24491	25268	26013	26044	26819	27593	28368	28988	29144	29921	30702	31485	31973	32272
72.4		23077	23768	24549	25329	26075	26106	26883	27660	28437	29059	29215	29995	30778	31564	32053	32353
72.6		23131	23823	24607	25389	26137	26169	26948	27726	28506	29130	29286	30069	30854	31642	32133	32434
72.8		23184	23879	24665	25449	26199	26231	27012	27793	28575	29201	29358	30142	30930	31721	32213	32515
73		23238	23934	24722	25508	26261	26293	27076	27859	28643	29271	29429	30216	31006	31799	32292	32596
73.2		23291	23989	24780	25568	26323	26354	27140	27926	28712	29342	29499	30289	31081	31877	32372	32676
73.4		23345	24045	24837	25627	26385	26416	27204	27992	28780	29412	29570	30362	31156	31954	32451	32756
73.6		23398	24100	24894	25687	26446	26478	27268	28058	28849	29482	29641	30435	31232	32032	32530	32836
73.8		23451	24154	24951	25746	26507	26539	27331	28124	28917	29552	29711	30507	31307	32109	32609	32916
74		23504	24209	25008	25805	26568	26600	27395	28189	28984	29622	29781	30580	31381	32187	32688	32996
74.2		23557	24264	25065	25864	26629	26661	27458	28255	29052	29691	29851	30652	31456	32264	32766	33075
74.4		23609	24318	25122	25923	26690	26722	27521	28320	29120	29761	29921	30724	31531	32340	32844	33154
74.6		23662	24373	25178	25981	26751	26783	27584	28385	29187	29830	29991	30796	31605	32417	32923	33233
74.8		23714	24427	25235	26040	26811	26844	27647	28450	29254	29899	30060	30868	31679	32493	33001	33312
75		23767	24481	25291	26098	26872	26904	27710	28515	29321	29968	30129	30940	31753	32570	33078	33391
75.2		23819	24535	25347	26156	26932	26965	27772	28580	29388	30036	30199	31011	31827	32646	33156	33469
75.4		23871	24589	25403	26215	26992	27025	27835	28644	29455	30105	30268	31082	31900	32722	33233	33548
75.6		23923	24643	25459	26273	27052	27085	27897	28709	29522	30173	30336	31154	31974	32797	33310	33626
75.8		23975	24697	25515	26330	27112	27145	27959	28773	29588	30242	30405	31224	32047	32873	33387	33704
76		24027	24750	25570	26388	27172	27205	28021	28837	29655	30310	30474	31295	32120	32948	33464	33781
76.2		24078	24804	25626	26446	27232	27265	28083	28901	29721	30378	30542	31366	32193	33024	33541	33859
76.4		24130	24857	25681	26503	27291	27324	28144	28965	29787	30446	30610	31436	32266	33099	33618	33936
76.6		24181	24910	25736	26561	27351	27384	28206	29029	29853	30513	30679	31507	32338	33174	33694	34014
76.8		24232	24963	25792	26618	27410	27443	28268	29093	29919	30581	30746	31577	32411	33248	33770	34091
77		24284	25016	25847	26675	27469	27502	28329	29156	29984	30648	30814	31647	32483	33323	33846	34168