MEMORANDUM

August 11, 2004

FOR: FCRPS Remand File

FROM: Chris Ross, Paul Wagner

SUBJECT: Analytical Approach and Method Used to Calculate Pool Survivals and Develop a Flow/Survival Relationship for Snake River Salmon and Steelhead

Snake River Spring/summer Chinook Salmon

An analysis was conducted to develop a quantitative relationship between flow and reservoir pool survival for listed spring chinook salmon stocks. The method consisted of examining the relationship between pool survival and flow for both the Snake River reach (Lower Granite to Ice Harbor Dam) and the lower Columbia River reach (McNary to Bonneville Dam). The pool survival data were derived from a retrospective SIMPAS modeling analysis. Only empirically derived reach survival estimates were used to calibrate SIMPAS over the 1994-2003 study period. For each year, route-specific dam passage and survival data were used to determine the individual dam survivals for that year. Dividing the empirical reach survival for each project by the dam survival provided a year specific pool survival estimate for each project. The year 1997 was taken out of the flow/survival analysis because high levels of debris at the dams occurred that year, which decreased juvenile fish survival at the dams but not necessarily in the pools. Since pool survival is derived from the reach survival estimate, which includes the dam, exclusion of the year 1997 was deemed appropriate.

The Snake River and lower Columbia River reach pool survival estimates were determined as the product of the four pool survivals of the respective project reaches. Flows used in the retrospective analysis were observed seasonal average flows for the years 1994-2003. Flows used in the reference operations were produced through hydrologic modeling using BPA's HYDSIM model. A regression analysis was performed using PRISM software to develop a relationship between the seasonal average flows and the composite pool survival values for each reach (Figure 1). For both the Snake River and lower Columbia River reaches, the best fit curve was a one-phase exponential association. In this analysis, it was assumed that zero flow equals zero survival when establishing the curve parameters. This assumption forces the curve of the relationship to pass through the 0,0 point on the x-y axis. The shape of the curve indicates there is a sharp rise in survival at a threshold level of flow, after which survival changes little with increasing flow.

The steps used to conduct the analysis follow the sequence of columns in Table 1. The sequence of calculations was:

(1) Using the curve fitting function described above, annual juvenile spring chinook reach survival estimates (pools only) were calculated for both the proposed flows and reference flows for the lower Snake River and lower Columbia River reaches.
(2) Individual pool survival estimates were obtained for the respective reaches by taking the fourth root of the reach survival estimates.
(3) The annual reference operation pool survival values were divided by the proposed hydro operation pool survival values to obtain an adjustment factor for use in SIMPAS pool survival in the gap analysis.

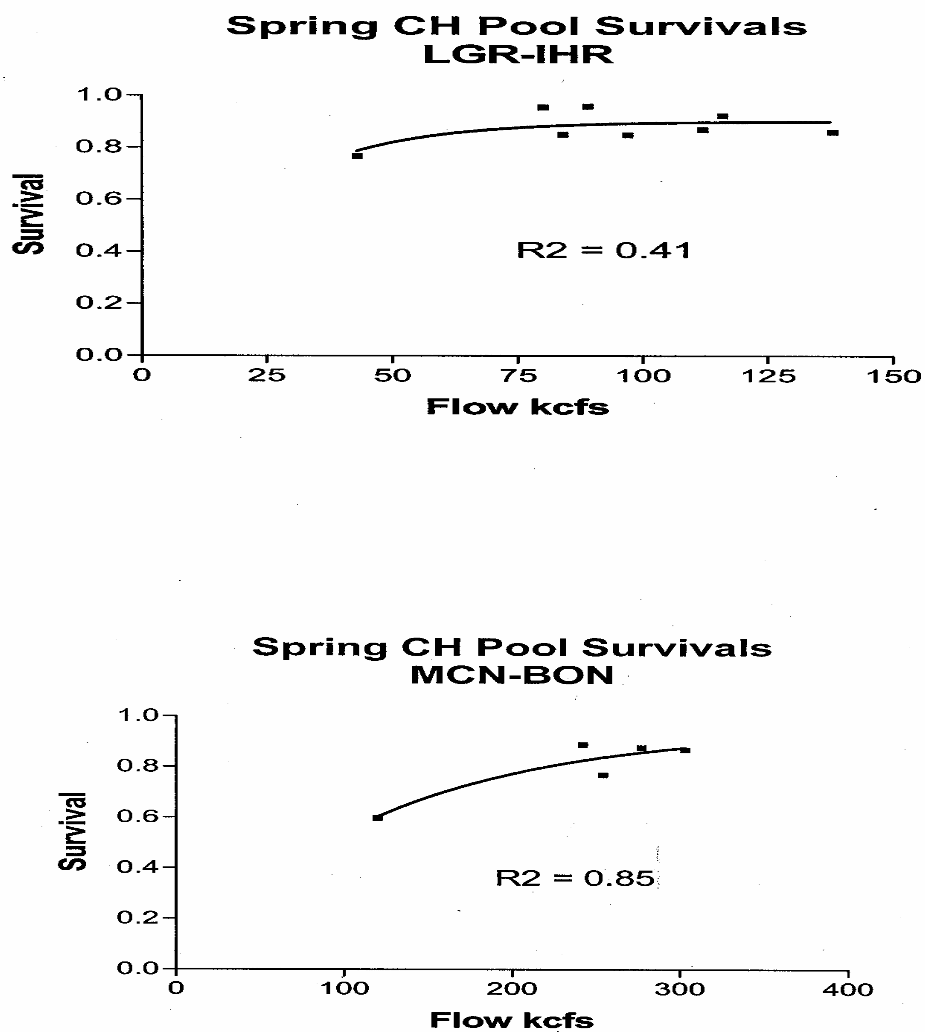


Figure 1. Relationship between flow and survival for juvenile spring chinook salmon through Lower Snake and Columbia River reaches.

Table 1 . Flow and estimated survival (pools by reach and individual pools) of juvenile spring chinook by year for the lower Snake and lower Columbia River reaches. An adjustment to flow was made for the reduced travel time of juvenile migrants by operating John Day pool at elevation 552 feet.

Spring CH **POOL SURVIVALS VS FLOWS** **Spring CH**

Ex. Association **Flows per BPA**

Chris Ross
8/11/04

	L Snake		L Columbia
YMAX	0.901	YMAX	0.9501
K	0.048	K	0.008375
HalfLife	14.44	HalfLife	82.76

Flow L. Snk. R.	**Proposed** Flow L. Col. R.	Survival L. Snk. R.	Survival Lower Col.	Year	Flow L. Snk. R.	**Reference** Flow L. Col. R.	Flow L. Col. Adjusted	Survival L. Snk. R.	Survival L. Col. R.	Survival L. Col. Adjusted	JDA Survival Ratio	**Retrospective** Reach Surv L. Snake River	L. Col. River
58.17	162.54	0.8458	0.7066	1994	60.73	161.39	188.56	0.8522	0.7042	0.7542	1.0711	0.6922	0.5432
95.06	245.74	0.8916	0.8288	1995	95.69	249.22	291.17	0.8919	0.8323	0.8672	1.0420	0.8482	0.7638
126.42	316.30	0.8989	0.8829	1996	126.32	324.57	379.21	0.8989	0.8874	0.9104	1.0259	0.8592	0.6726
145.37	401.32	0.9002	0.9171	1997	147.77	421.76	492.76	0.9003	0.9223	0.9348	1.0135	0.8266	0.6816
106.05	259.25	0.8955	0.8418	1998	107.51	272.17	317.99	0.8958	0.8529	0.8839	1.0363	0.8684	0.7391
114.16	311.02	0.8972	0.8799	1999	114.52	323.44	377.89	0.8973	0.8868	0.9100	1.0261	0.9223	0.8673
82.28	246.60	0.8836	0.8296	2000	82.84	256.18	299.31	0.8841	0.8389	0.8726	1.0402	0.8498	0.7676
56.28	159.90	0.8405	0.7011	2001	56.74	151.82	177.38	0.8419	0.6837	0.7350	1.0751	0.7670	0.5970
87.57	257.74	0.8875	0.8404	2002	86.50	269.32	314.66	0.8868	0.8505	0.8820	1.0370	0.9544	0.8754
75.58	195.89	0.8771	0.7659	2003	76.52	187.13	218.64	0.8781	0.7519	0.7979	1.0611	0.9582	0.8877

Proposed 4th Root Survival ls	4th Root Survival lc	Year	**Reference** 4th Root Survival ls	4th Root Survival lc	**Retrospective** 4th Root Survival ls	4th Root Survival lc
0.9590	0.9168	1994	0.9608	0.9161	0.9121	0.8585
0.9717	0.9541	1995	0.9718	0.9551	0.9597	0.9349
0.9737	0.9693	1996	0.9737	0.9706	0.9628	0.9056
0.9740	0.9786	1997	0.9741	0.9800	0.9535	0.9086
0.9728	0.9578	1998	0.9729	0.9610	0.9653	0.9272
0.9733	0.9685	1999	0.9733	0.9704	0.9800	0.9650
0.9695	0.9544	2000	0.9697	0.9570	0.9601	0.9360
0.9575	0.9151	2001	0.9579	0.9093	0.9358	0.8790
0.9706	0.9575	2002	0.9704	0.9603	0.9884	0.9673
0.9677	0.9355	2003	0.9680	0.9312	0.9894	0.9707

	Ratio of Reference to Proposed		Ratio of Proposed to Retro	
Year	L. Snake	L. Col.	L. Snake	L. Col.
1994	1.001882	0.99916	1.051391	1.06794
1995	1.000078	1.00105	1.012559	1.02062
1996	0.999997	1.00127	1.011369	1.07039
1997	1.000025	1.00141	1.021544	1.07703
1998	1.000105	1.00328	1.007702	1.03304
1999	1.000018	1.00197	0.993129	1.00361
2000	1.000129	1.00279	1.009801	1.01962
2001	1.000389	0.99373	1.023151	1.04101
2002	0.999801	1.00300	0.981992	0.98984
2003	1.000299	0.99539	0.97812	0.96378

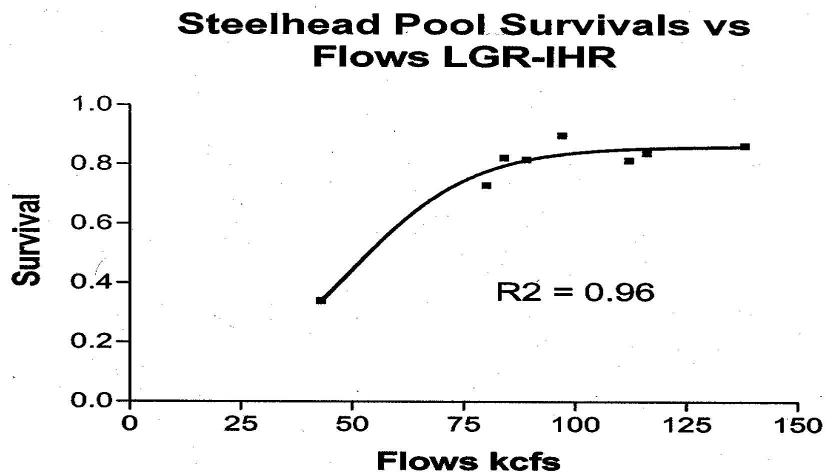
Snake River Steelhead

An analysis was conducted to develop a quantitative relationship between flow and reservoir pool survival for listed steelhead stocks. The method consisted of examining the relationship between pool survival and flow for both the Snake River reach (Lower Granite to Ice Harbor Dam) and the lower Columbia River reach (McNary to Bonneville Dam). The pool survival data were derived from a retrospective SIMPAS modeling analysis. Only empirically derived reach survival estimates were used to calibrate SIMPAS over the 1994-2003 study period. For each year, route-specific dam passage and survival data were used to determine the individual dam survivals for that year. Dividing the empirical reach survival for each project by the dam survival provided a year specific pool survival estimate for each project. The year 1997 was taken out of the flow/survival analysis, because high levels of debris at the dams occurred that year, which decreased juvenile fish survival at the dams but not necessarily in the pools. Since pool survival is derived from the dam survival estimate, exclusion of the year 1997 was deemed appropriate.

The Snake River and lower Columbia River reach pool survival estimates were determined as the product of the four pool survivals of the respective project reaches. Flows used in the retrospective analysis were observed seasonal average flows for the years 1994-2003. Flows used in the reference operations were produced through hydrologic modeling using BPA's HYDSIM model. A regression analysis was performed using PRISM software to fit a curve to the seasonal average flows and the composite pool survival values for each reach (Figure 2). In this analysis, it was assumed that zero flow equals zero survival when establishing the curve parameters. This assumption forces the curve of the relationship to pass through the 0,0 point on the x-y axis. The shape of the curve indicates there is a sharp rise in survival at a threshold level of flow, after which survival changes little with increasing flow. The best fit function for the Snake River and lower Columbia River reaches was a Boltzmann sigmoid curve. The sigmoid curve was considered to be an appropriate model to describe the relationship between flow and survival for this species in Williams *et al.* (2004).

The steps used to conduct the analysis follow the sequence of columns in Table 2. The sequence of calculations was:

(1) Using the curve fitting function described above, annual juvenile spring chinook reach survival estimates (pools only) were calculated for both the proposed flows and reference flows for the lower Snake River and lower Columbia River reaches.
(2) Individual pool survival estimates were obtained for the respective reaches by taking the fourth root of the reach survival estimates.
(3) The annual reference operation pool survival values were divided by the proposed hydro operation pool survival values to obtain an adjustment factor for use in SIMPAS pool survival in the gap analysis.



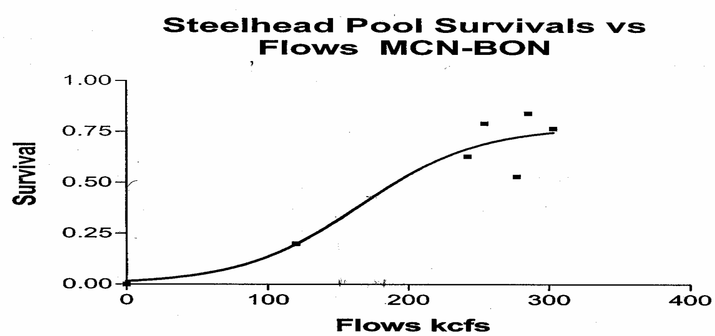


Figure 2. Relationship between flow and survival for juvenile steelhead through Lower Snake River and Lower Columbia River reaches.

Table 2. Flow and estimated survival (pools by reach and individual pools) of juvenile steelhead by year for the lower Snake and lower Columbia River reaches. An adjustment to flow was made for the reduced travel time of juvenile migrants by operating John Day pool at elevation 552 feet.

Steelhead **POOL SURVIVALS VS FLOWS** **Steelhead**

Chris Ross
8/11/04

Boltzmann Sigmoid	**L Snake**	**Boltzmann Sigmoid**	**L Columbia**
Bottom	0	Bottom	0
Top	0.8610	Top	0.7744
V50	49.16	V50	165.5
Slope	14.00	Slope	42.29

Proposed Flow L. Snk. R.	Flow L. Col. R.	Survival L. Snk. R.	Survival Lower Col.	Year	**Reference** Flow L. Snk. R.	Flow L. Col. R.	Flow L. Col. Adjusted	Survival L. Snk. R.	Survival L. Col. R.	Survival L. Col. Adjusted	JDA Survival Ratio	**Retrospective** Reach Survival L. Snake River	L. Col. River
58.17	162.54	0.5644	0.3737	1994	60.73	161.39	188.56	0.5989	0.3684	0.4902	1.3307	0.77227	0.740994
95.06	245.74	0.8297	0.6734	1995	95.69	249.22	291.17	0.8311	0.6804	0.7367	1.0827	0.897826	0.88674
126.42	316.30	0.8576	0.7531	1996	126.32	324.57	379.21	0.8575	0.7568	0.7695	1.0168	0.864072	0.788381
145.37	401.32	0.8601	0.7715	1997	147.77	421.76	492.76	0.8602	0.7726	0.7741	1.0019	0.909146	0.853708
106.05	259.25	0.8465	0.6983	1998	107.51	272.17	317.99	0.8479	0.7169	0.7539	1.0517	0.813498	0.839568
114.16	311.02	0.8528	0.7504	1999	114.52	323.44	377.89	0.8530	0.7563	0.7693	1.0172	0.837917	0.765436
82.28	246.60	0.7871	0.6752	2000	82.84	256.18	299.31	0.7897	0.6932	0.7430	1.0719	0.822026	0.790006
56.28	159.90	0.5377	0.3616	2001	56.74	151.82	177.38	0.5443	0.3251	0.4412	1.3571	0.340105	0.199445
87.57	257.74	0.8089	0.6958	2002	86.50	269.32	314.66	0.8051	0.7132	0.7523	1.0549	0.729446	0.529772
75.58	195.89	0.7477	0.5206	2003	76.52	187.13	218.64	0.7541	0.4841	0.6028	1.2451	0.816204	0.628736

Proposed 4th Root	4th Root	Year	**Reference** 4th Root	4th Root	**Retrospective** 4th Root Survival ls	4th Root Survival lc
0.8668	0.7818	1994	0.8797	0.7791	0.9374	0.9278
0.9544	0.9059	1995	0.9548	0.9082	0.9734	0.9704
0.9623	0.9316	1996	0.9623	0.9327	0.9641	0.9423
0.9630	0.9372	1997	0.9631	0.9375	0.9765	0.9612
0.9592	0.9141	1998	0.9596	0.9201	0.9497	0.9572
0.9610	0.9307	1999	0.9610	0.9326	0.9568	0.9354
0.9419	0.9065	2000	0.9427	0.9125	0.9522	0.9428
0.8563	0.7755	2001	0.8589	0.7551	0.7637	0.6683
0.9484	0.9133	2002	0.9472	0.9190	0.9242	0.8531
0.9299	0.8494	2003	0.9319	0.8341	0.9505	0.8905

Year	Ratio of Reference to Proposed: L. Snake	L. Col.	Ratio of Proposed to Retro: L. Snake	L. Col.
1994	1.014928	0.996455	0.92462	0.84268
1995	1.000397	1.002592	0.980478	0.93351
1996	0.999993	1.001225	0.998111	0.98862
1997	1.000041	1.000362	0.986234	0.97500
1998	1.00042	1.006573	1.009976	0.95499
1999	1.000061	1.001985	1.004408	0.99504
2000	1.000835	1.006604	0.989207	0.96150
2001	1.003027	0.973759	1.121342	1.16038
2002	0.99881	1.006173	1.026198	1.07054
2003	1.002137	0.981998	0.978335	0.95392

Snake River Fall Chinook Salmon

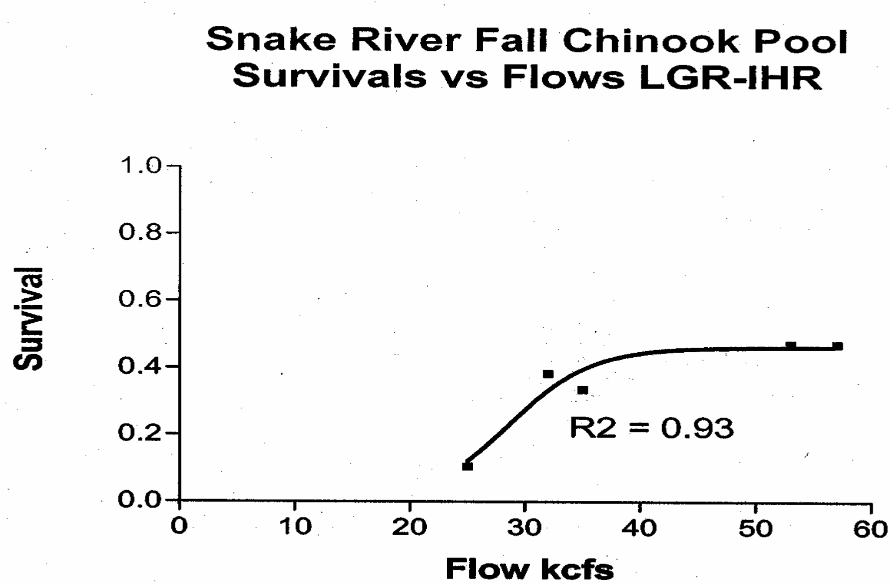
An analysis was conducted to develop a quantitative relationship between flow and reservoir pool survival for listed fall chinook salmon stocks. The method consisted of examining the relationship between pool survival and flow for both the Snake River reach (Lower Granite to Ice Harbor Dam) and the lower Columbia River reach (McNary to Bonneville Dam). The pool survival data were derived from a retrospective SIMPAS modeling analysis. Only empirically derived reach survival estimates for the Snake River reach were used to calibrate SIMPAS over the 1995-2001 and 2003 study period. Empirical reach survival estimates were not available for 1994 or 2002 for either reach. For each remaining year, route-specific dam passage and survival data were used to determine the individual dam survivals for that year. Dividing the empirical reach survival for each project by the dam survival provided a year-specific pool survival estimate for each project. No empirical reach survival data were available below Lower Monumental Dam in 1995 and 1996. Therefore, these years were not included in the lower Snake River section of the analysis. No empirical survival data were available in the lower Columbia River reach for any year. Thus, to complete the system-wide analysis, the lower Snake River survival rates were extrapolated from the lower Columbia reach using a survival-per-mile method. In addition, the year 1997 was taken out of the flow/survival analysis for both the lower Snake and lower Columbia reaches, because there were high levels of debris at the dams that year, which decreased juvenile fish survival at the dams but not necessarily in the pools. Since pool survival is derived from the dam survival estimate, exclusion of the year 1997 was deemed appropriate.

The Snake River and lower Columbia River reach survival estimates were determined as the product of the four pool survivals of the respective river reaches. Flows used in the retrospective analysis were observed seasonal average flows for the years 1995-2001 and 2003. Flows used in the reference operations were produced through hydrologic modeling using BPA's HYDSIM model. A regression analysis was performed using PRISM software to fit a curve to the seasonal average flows and reach survival values (Figure 3). For the Columbia River reach, the best fit curve was a one-phase exponential association. The assumption that zero flow equals zero survival was used when establishing the curve parameters. This assumption forces the curve of the relationship to pass through the 0,0 point on the x-y axis. The shape of the curve indicates there is a sharp rise in survival at a threshold level of flow, after which survival changes little with increasing flow. The best fit function for the Snake River reach was a Boltzmann sigmoid curve. The Sigmoid curve was considered to be an appropriate model to describe the flow-survival relationship for subyearling fall chinook salmon in the lower Snake River (Smith *et al.* 2002).

This analysis was specific to juvenile fall chinook that exhibit a subyearling life history. Both a yearling and subyearling life history have been demonstrated by juvenile Snake River fall chinook salmon (Smith *et al*. 2002). Little specific information is known about the yearling life history of these fish at this time. However, it appears that those fish that exhibit the yearling life history make up a substantial percentage of the adult returns to Lower Granite Dam (Connor *et al*. 2004). Given the existence of the yearling life history, the empirical reach survival data for Snake River fall Chinook could be providing conservative survival estimates, because it assumes that fish not observed at downstream projects are mortalities, when these fish could have survived and moved downstream later as yearling migrants.

The steps used to conduct the analysis follow the sequence of columns in Table 3. The sequence of calculations was:

(1) Using the curve fitting function described above, annual juvenile fall chinook reach survival estimates (pools only) were calculated for both the proposed flows and reference flows for the lower Snake and Columbia River reaches.
(2) Individual pool survival estimates were obtained for the respective reaches by taking the fourth root of the reach survival estimates.
(3) The annual reference operation pool survival values were divided by the proposed hydro operation pool survival values to obtain an adjustment factor for use in SIMPAS pool survival in the "gap" analysis.



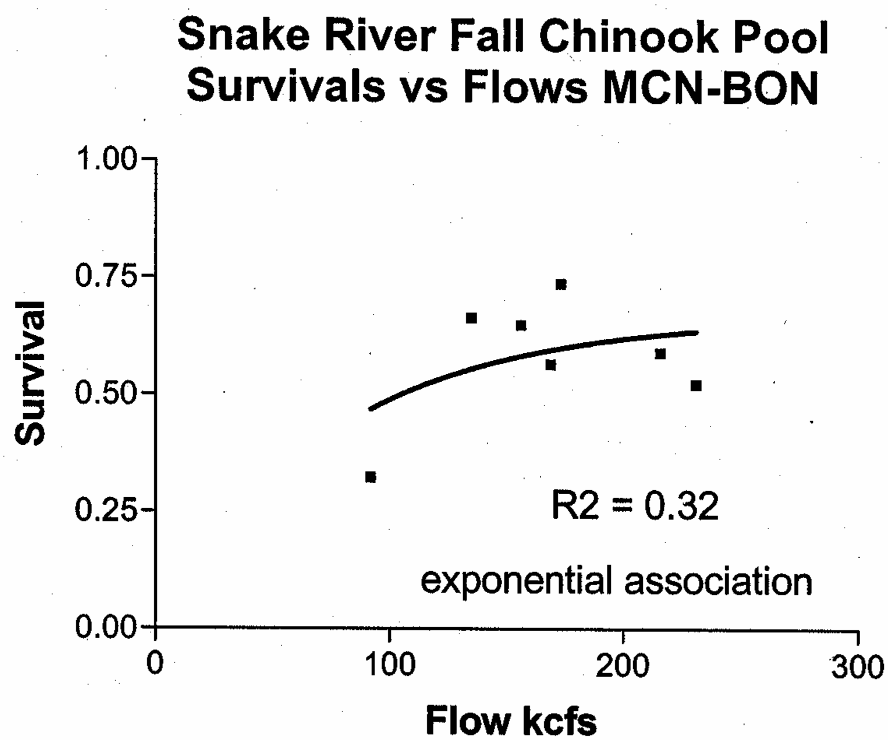


Figure 3. Relationship between flow and survival for juvenile Snake River fall chinook salmon through lower Snake River and lower Columbia River reaches.

Table 3. Flow and estimated survival (pools by reach and individual pools) of juvenile fall chinook by year for the lower Snake and lower Columbia River reaches. An adjustment to flow was made for the reduced travel time of juvenile migrants by operating John Day pool at elevation 552 feet.

POOL SURVIVALS VS FLOWS SR Fall CH

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8/12/2004

Boltzmann Sigmoid	L Snake
Bottom	0
Top	0.4632
V50	28.68
Slope	3.568

Exponential Association	L Columbia
YMAX	0.6671
K	0.01319

Proposed Flow L. Snk. R.	Flow L. Col. R.	Survival L. Snk. R.	Survival Lower Col.	Year	**Reference** Flow L. Snk. R.	Flow L. Col. R.	Flow L. Col. Adjusted	Survival L. Snk. R.	Survival L. Col. R.	Survival L. Col Adjusted	JDA Survival Ratio	**Retrospective** Reach Surv L. Snake River	L. Col. River
43.4	139.1	0.4558	0.5606	1995	47.2	178.7	208.78	0.4606	0.6039	0.6246	1.0343	0.538663	0.564634
54	188.1	0.4628	0.6113	1996	57.9	213.4	249.32	0.4631	0.6271	0.6422	1.0241	0.394608	0.589709
59.7	196.3	0.4631	0.6170	1997	64.8	220.0	257.04	0.4632	0.6305	0.6446	1.0225	0.134569	0.311685
44.1	136.1	0.4571	0.5563	1998	47.6	177.7	207.61	0.4609	0.6031	0.6240	1.0346	0.472394	0.737158
47.9	182.4	0.4611	0.6069	1999	54.5	209.6	244.88	0.4629	0.6251	0.6407	1.0250	0.471207	0.522399
35.2	131	0.3990	0.5486	2000	37.8	177.3	207.15	0.4298	0.6027	0.6237	1.0347	0.336511	0.64903
27.3	115.1	0.1874	0.5209	2001	26.9	166.0	193.95	0.1750	0.5924	0.6154	1.0389	0.105733	0.323188
35.6	128.9	0.4050	0.5453	2003	39	175.2	204.69	0.4369	0.6009	0.6223	1.0355	0.383993	0.663918

Proposed 4th Root Survival ls	4th Root Survival lc	Year	**Reference** 4th Root Survival ls	4th Root Survival lc	**Retrospective** 4th Root Survival ls	4th Root Survival lc
0.8217	0.8653	1995	0.8238	0.8815	0.8567	0.8668
0.8248	0.8842	1996	0.8249	0.8899	0.7926	0.8763
0.8249	0.8863	1997	0.8250	0.8911	0.6057	0.7472
0.8223	0.8636	1998	0.8240	0.8812	0.8290	0.9266
0.8240	0.8826	1999	0.8248	0.8892	0.8285	0.8502
0.7948	0.8606	2000	0.8097	0.8811	0.7616	0.8976
0.6579	0.8496	2001	0.6468	0.8773	0.5702	0.7540
0.7977	0.8593	2003	0.8130	0.8805	0.7872	0.9027

Year	**Ratio of Reference to Proposed** L. Snake	L. Col.	**Ratio of Proposed to Retro** L. Snake	L. Col.
1995	1.002621	1.018789	0.95912011	0.998206
1996	1.000138	1.006414	1.04066466	1.009027
1997	1.000032	1.005404	1.36203315	1.186165
1998	1.002058	1.020397	0.99182263	0.932043
1999	1.000962	1.007389	0.9945885	1.038210
2000	1.018773	1.023819	1.04351657	0.958837
2001	0.983079	1.032666	1.15376527	1.126759
2003	1.019126	1.024609	1.01338786	0.951966

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