Appendix 3

Estimate of Change in Abundance of Fall-run and Late Fall-run Chinook Salmon Available to Killer Whales Due to CVP and SWP Operations

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Changes in production of Central Valley fall-run and late fall-run Chinook salmon emigrating from freshwater due to Project operations were estimated using the tools and data available in each of the rivers and in the Delta. Sacramento River changes were estimated using the Salmod model, which integrates the effects of water temperature, flow, fish density, and distribution on all lifestages present in the river upstream of Red Bluff. Feather River, American River, and Stanislaus River changes were estimated using the Reclamation salmon mortality model. This model uses water temperature and spawning distribution data to estimate early lifestage survival/mortality. Delta changes were estimated using the results of Chinook salmon survival studies described in the Delta effects section of the BO. These have been combined in a spreadsheet model to estimate effects of Delta operations scenarios on Chinook salmon survival. The quantified freshwater mortality sources were combined into an overall change in freshwater mortality attributable to the water operations scenarios. Hatchery production was included in the analysis by using the production goals for each Central Valley Chinook hatchery as the number of hatchery produced fish released each year. In-river mortality was applied to the in-river released hatchery fish and these were then added to the Bay releases for a total number of hatchery fish in the bay. The average ocean abundance (production) of fall and late fall-run Chinook was divided by the number of hatchery and naturally produced fall and late fall-run in the Bay to determine a baseline ocean survival value and number of hatchery and naturally produced Chinook in the ocean. The baseline ocean abundance along with changes in freshwater survival was used to calculate a range of Chinook salmon prey available to Southern Residents under the operational scenarios.

Changes in Production from the Upstream Areas

Sacramento River

The Salmod model was used to estimate the number of fall-run and late fall-run emigrating from the Sacramento River past Red Bluff under current and future conditions. The model calculates juvenile production emigrating downstream past Red Bluff for each run from a starting adult escapement level entering the upper Sacramento River at Red Bluff. Factors in the model affecting production include water temperature affects on each lifestage present in the upper river (adult through emigrating juveniles), flow versus spawning habitat area relative to adult spawner distribution, and flow versus rearing habitat area relative to fish distribution. Figure 1 shows the estimated number of juvenile fall-run emigrants past Red Bluff from an escapement of 59,653 adults. The maximum production from this escapement level is near 35 million emigrants. Many years have lower production. Table 1 shows the mortality calculated in Salmod by causative factor under Study 7.0. These scenarios are "with Project" operations. Production without the Project is harder to estimate because all data available is with Project operations in place. An assumption was made that production without the project could be maintained near the maximum production year with the Project by providing flows and temperatures that target salmonid production. The production estimates do not include effects due to factors such as fish stranding, redd dewatering, or predation. These effects are similar to those described in the BO for winter-run and spring-run Chinook. Stranding and redd dewatering in the Sacramento River is likely of a greater magnitude for fall-run when flows are decreased in the fall as water demands drop off and flows are lowered to provide storage for water releases the next season. These effects have not been quantified for any of the runs. Predation effects on fall-run and late fall-run are similar to those for winter and spring-run. The reduction in production compared to the maximum production year is shown in figure 2 for each operational scenario.

Figure 3 shows late fall-run production past Red Bluff from an escapement of 12,051 adults. Production during most years was around 7 million juveniles, but some years experienced lower production. The reduction in production compared to the maximum production year is shown in figure 4 for each operational scenario.

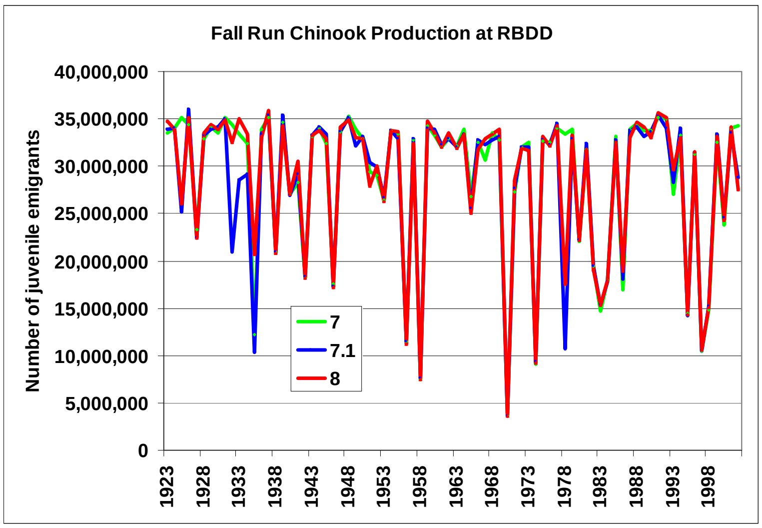

Figure 1. Juvenile fall-run Chinook production emigrating past Red Bluff during each year of the Calsim modeling period by OCAP operational scenario.

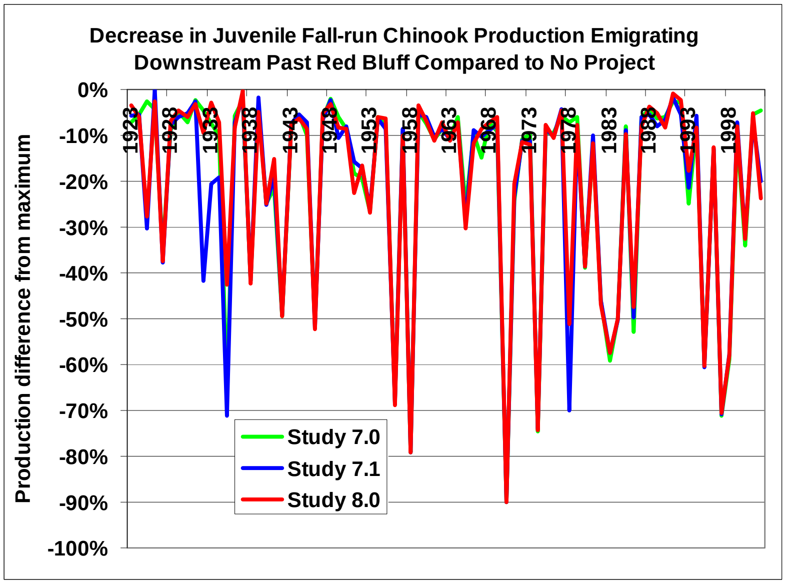

Figure 2. Reduction in upper Sacramento River juvenile fall-run Chinook production during each year of the Calsim modeling relative to the maximum production year.

Table 1. Mortality of fall-run Chinook salmon by lifestage and causative factor under Study 7.0 operations. Escapement = 59,653; Total potential eggs = 143,160,000

DATE	Adult Females - Temp	Eggs - Invivo	Eggs - Incub	Eggs - Superimp	Adult Males - Temp	Eggs - Temp
9/2/1923	0	0	1,355,033	0	0	2,348
9/2/1924	0	0	1,056,855	0	0	0
9/2/1925	0	0	1,950,682	0	0	79,409
9/2/1926	0	0	1,106,916	0	0	0
9/2/1927	0	10,330	24,531,532	11,730,549	0	15,418
9/2/1928	0	0	1,088,249	0	0	5,382
9/2/1929	0	0	2,031,846	0	0	0
9/2/1930	0	0	1,911,293	6,823,917	0	0
9/2/1931	0	0	2,423,160	0	0	0
9/2/1932	0	833,507	2,040,938	0	0	4,098,693
9/2/1933	0	5,759,899	1,970,342	0	0	12,914,989
9/2/1934	0	9,223,435	1,352,424	0	0	15,314,136
9/2/1935	997	107,002,496	412,359	0	1,049	2,489,833
9/2/1936	0	465,140	1,346,325	0	0	2,238,484
9/2/1937	0	0	1,411,430	0	0	62,325
9/2/1938	0	24,792	14,430,067	35,241,260	0	866,978
9/2/1939	0	0	985,591	0	0	0
9/2/1940	0	10,330	17,863,996	0	0	46,557
9/2/1941	0	0	262,347	36,378,504	0	0
9/2/1942	0	0	17,360,576	46,414,652	0	10,827
9/2/1943	0	0	0	0	0	411
9/2/1944	0	0	797,439	0	0	8,996
9/2/1945	0	24,792	2,274,648	0	0	4,484
9/2/1946	0	0	14,095,915	56,955,428	0	912
9/2/1947	0	0	1,049,049	0	0	713
9/2/1948	0	0	2,005,365	0	0	111,411
9/2/1949	0	0	570,040	0	0	10,180
9/2/1950	0	0	1,238,493	0	0	9,413
9/2/1951	0	0	119,277	30,474,540	0	0
9/2/1952	0	0	0	37,216,136	0	0
9/2/1953	0	0	21,590,690	9,133,086	0	4,992
9/2/1954	0	0	0	0	0	0
9/2/1955	0	0	1,040,882	597,228	0	0
9/2/1956	0	0	28,819,320	58,019,184	0	0
9/2/1957	0	0	78,872	0	0	0
9/2/1958	0	0	67,612,536	11,623,483	0	0
9/2/1959	0	0	563,365	0	0	31,326
9/2/1960	0	10,330	877,475	0	0	576
9/2/1961	0	0	1,538,911	597,388	0	576
9/2/1962	0	0	741,756	0	0	4,148
9/2/1963	0	0	319,205	926,476	0	0
9/2/1964	0	0	1,112,077	3,607,332	0	0
9/2/1965	0	0	1,122,948	46,074,136	0	576
9/2/1966	0	0	14,013	4,417,407	0	0
9/2/1967	0	0	146,414	29,454,212	0	240
9/2/1968	0	0	439,479	0	0	0
9/2/1969	0	0	633,180	2,292,619	0	576
9/2/1970	0	0	59,771,072	42,626,112	0	0
9/2/1971	0	0	802,327	43,982,116	0	0
9/2/1972	0	0	0	0	0	0
9/2/1973	0	0	0	8,108,771	0	0
9/2/1974	0	0	32,677,876	58,815,784	0	0
9/2/1975	0	0	2,330,281	0	0	0
9/2/1976	0	0	933,704	0	0	0
9/2/1977	0	243,837	1,058,867	69,738	0	6,333
9/2/1978	0	2,449,293	2,325,997	89,138	0	7,633,388
9/2/1979	0	0	332,244	0	0	0
9/2/1980	0	24,792	30,256,124	0	0	10,947
9/2/1981	0	0	998,726	0	0	4,675
9/2/1982	0	24,792	8,209,638	59,194,672	0	7,525
9/2/1983	0	0	25,176,900	34,376,600	0	0
9/2/1984	0	0	14,828,150	60,802,992	0	6,382
9/2/1985	0	0	925,812	5,467,326	0	15,905
9/2/1986	0	0	51,773,904	0	0	20,597
9/2/1987	0	236,640	741,322	0	0	129,127
9/2/1988	0	24,792	1,737,881	0	0	507,135
9/2/1989	0	101,234	2,579,201	0	0	766,781
9/2/1990	0	0	2,248,733	0	0	2,628
9/2/1991	0	94,549	2,705,580	0	0	11,787
9/2/1992	0	0	2,333,663	0	0	1,601,324
9/2/1993	13	34,647,664	1,653,405	0	13	14,500,190
9/2/1994	0	0	1,476,255	0	0	1,426
9/2/1995	0	268,311	58,006,608	0	0	1,473,796
9/2/1996	0	0	9,392,018	0	0	5,965
9/2/1997	0	0	27,136,764	61,899,224	0	23,598
9/2/1998	0	0	54,679,996	34,775	0	0
9/2/1999	0	0	73,217	12,828,439	0	170,188
9/2/2000	0	0	27,243,040	0	0	0
9/2/2001	0	0	1,080,853	0	0	85,588
9/2/2002	0	435,735	691,105	8,090,376	0	309,418

Table 1. Continued.

DATE	Fry - Temp	Fry - Habitat	Presmolts - Temp	Presmolts - Habitat	Immature Smolts - Temp	Immature Smolts - Habitat
9/2/1923	0	24,738,932	0	677,361	0	41,980
9/2/1924	1,222	25,880,924	79,032	439,578	15,199	94,629
9/2/1925	0	19,315,550	0	103,535	0	6,197
9/2/1926	0	25,340,356	0	586,045	0	50,463
9/2/1927	0	13,002,910	0	129,311	0	4,277
9/2/1928	0	27,163,390	0	295,130	0	15,562
9/2/1929	0	22,693,126	0	116,656	0	8,892
9/2/1930	0	21,761,834	0	373,740	0	21,989
9/2/1931	0	22,674,714	0	892,524	0	85,489
9/2/1932	0	20,543,300	27,561	97,064	17,823	28,910
9/2/1933	25,843	16,362,962	208,862	211,025	40,970	22,578
9/2/1934	0	15,862,240	14,258	806,890	20,189	97,709
9/2/1935	0	1,967,816	0	9,525	0	2,210
9/2/1936	0	24,187,220	0	197,405	0	3,548
9/2/1937	0	23,893,766	0	536,165	0	47,103
9/2/1938	0	9,980,305	0	126,576	0	1,332
9/2/1939	0	23,939,780	0	639,579	0	19,577
9/2/1940	0	22,185,746	0	464,968	0	42,280
9/2/1941	0	11,597,627	0	59,076	0	7,987
9/2/1942	0	6,055,073	0	72,631	0	4,060
9/2/1943	0	28,313,236	0	285,098	0	5,929
9/2/1944	0	27,081,384	0	555,299	0	22,140
9/2/1945	0	25,393,980	0	125,300	0	2,117
9/2/1946	0	4,632,394	0	12,557	0	0
9/2/1947	0	24,306,284	0	256,231	0	5,742
9/2/1948	0	22,249,576	0	397,406	0	7,567
9/2/1949	0	24,818,494	0	141,995	0	1,892
9/2/1950	0	25,238,592	0	156,686	0	521
9/2/1951	0	11,019,869	0	39,763	0	0
9/2/1952	0	7,209,370	0	23,878	0	0
9/2/1953	0	14,379,616	0	183,019	0	2,685
9/2/1954	0	24,419,688	0	197,751	0	145
9/2/1955	0	22,560,040	0	94,968	0	404
9/2/1956	0	3,445,033	0	2,407	0	0
9/2/1957	0	27,526,974	0	153,114	0	1,469
9/2/1958	0	1,711,305	0	5,885	0	562
9/2/1959	0	25,533,198	0	513,082	0	16,091
9/2/1960	0	27,790,126	0	178,595	0	5,011
9/2/1961	0	24,321,764	0	185,244	0	204
9/2/1962	0	23,675,844	0	114,744	0	85
9/2/1963	12,872	28,158,802	55,691	84,314	0	4,257
9/2/1964	0	20,337,984	0	130,324	0	169
9/2/1965	0	5,285,483	0	21,259	0	0
9/2/1966	0	21,635,928	0	95,788	0	0
9/2/1967	0	10,964,281	0	84,035	0	0
9/2/1968	0	25,026,672	0	243,551	0	3,036
9/2/1969	0	20,618,536	0	41,584	0	0
9/2/1970	0	1,033,827	0	992	0	166
9/2/1971	0	6,559,323	0	32,111	0	0
9/2/1972	0	25,443,832	0	68,489	0	22
9/2/1973	0	18,457,044	0	62,161	0	0
9/2/1974	0	4,563,986	0	1,046	0	0
9/2/1975	0	23,868,630	0	125,839	0	963
9/2/1976	0	25,301,760	0	132,673	0	1,254
9/2/1977	0	27,611,638	87,985	151,325	59,554	26,634
9/2/1978	0	16,693,909	0	70,893	0	0
9/2/1979	0	26,350,838	0	248,694	0	11,056
9/2/1980	0	15,395,437	0	92,845	0	1,068
9/2/1981	0	27,658,232	0	205,108	0	3,345
9/2/1982	12,284	4,811,467	25,548	12,358	0	0
9/2/1983	0	8,626,050	0	24,298	0	173
9/2/1984	0	3,903,415	0	21,613	0	60
9/2/1985	0	20,720,376	0	126,952	0	1,477
9/2/1986	0	7,596,313	0	151,531	0	31,377
9/2/1987	0	25,394,978	0	436,705	0	8,174
9/2/1988	0	22,489,604	2,379	150,043	287	4,147
9/2/1989	0	21,465,036	0	241,955	0	1,010
9/2/1990	0	24,333,820	2,255	173,615	1,361	3,225
9/2/1991	0	23,704,040	2,438	367,015	2,624	14,875
9/2/1992	0	22,073,462	3,343	771,156	2,075	44,116
9/2/1993	0	8,588,623	0	37,159	0	0
9/2/1994	0	26,143,564	0	305,511	0	14,864
9/2/1995	0	8,710,445	5,833	18,668	3,466	421
9/2/1996	0	22,979,406	0	143,784	0	14,082
9/2/1997	0	3,503,024	0	8,232	0	428
9/2/1998	0	9,474,753	0	31,695	0	0
9/2/1999	0	19,128,736	0	115,441	0	800
9/2/2000	0	19,552,304	6,792	398,382	10,184	76,633
9/2/2001	0	26,504,828	843	914,254	1,021	34,438
9/2/2002	0	19,872,484	2,279	659,527	1,042	36,331

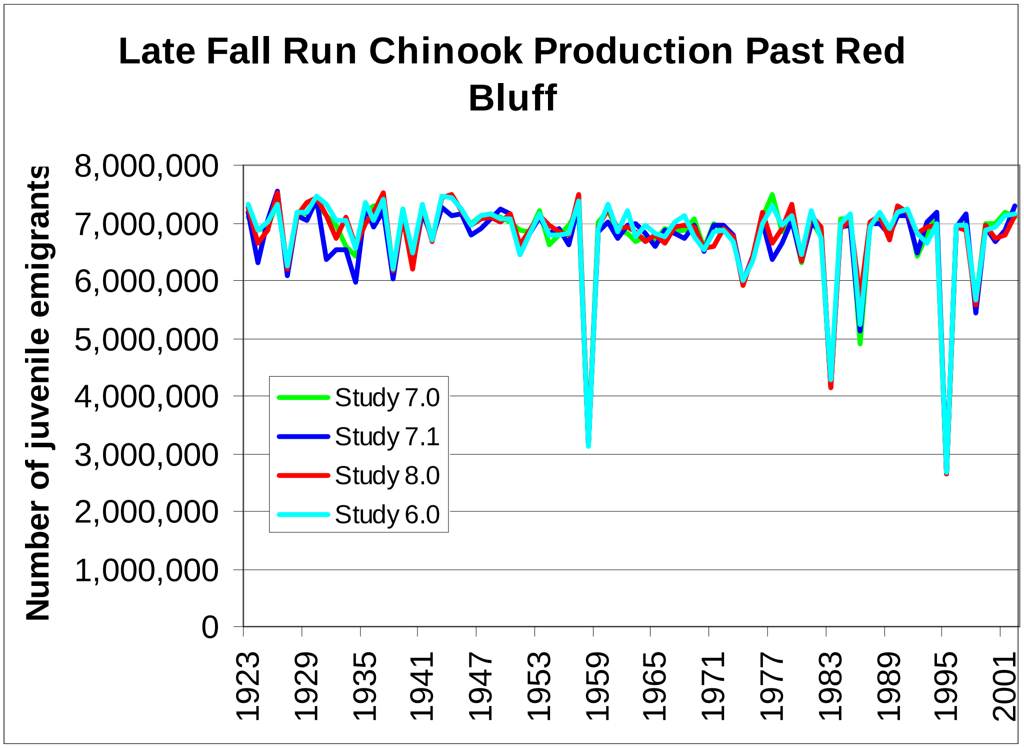

Figure 3. Juvenile late fall-run Chinook salmon production emigrating past Red Bluff during each year of the Calsim modeling period by OCAP operational scenario.

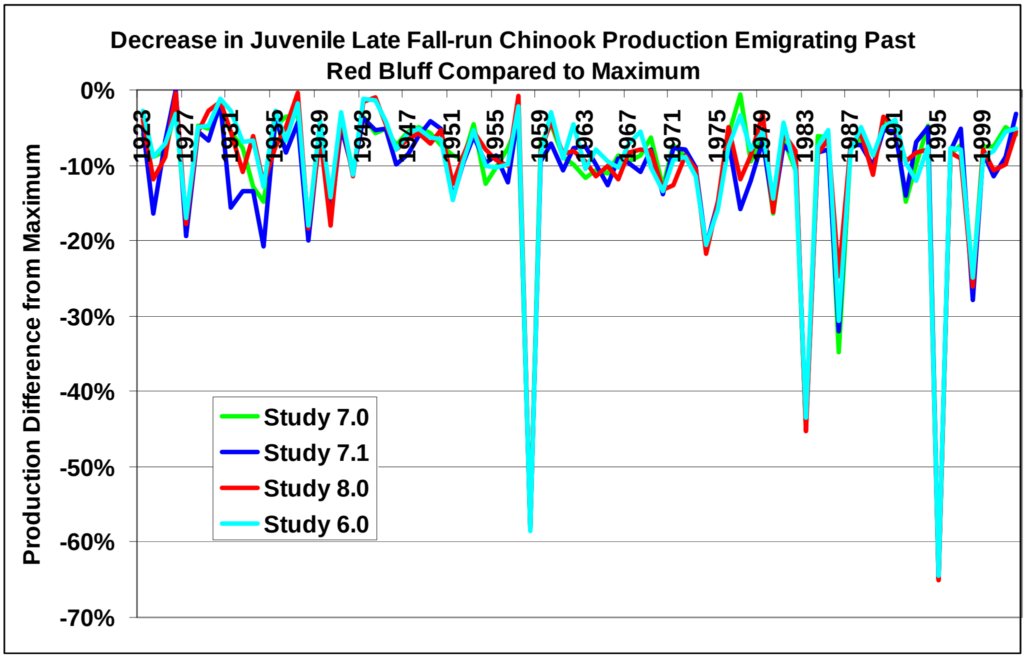

Figure 4. Reduction in upper Sacramento River juvenile late fall-run Chinook salmon production during each year of the Calsim modeling period relative to the maximum production year.

Feather, American, and Stanislaus Rivers

The Reclamation salmon mortality model was used to estimate the change in survival from the Feather, American, and Stanislaus Rivers from changes in early lifestage survival due to water temperature (table 2). Consistent with the Upper Sacramento River, the best survival year was used as a comparison point for what could be attained with no Project operations, but water operations targeted to salmonid production. These mortality model results are the same results summarized and included in figures in the essential fish habitat section of the BA. Additional mortality factors such as fish stranding, redd dewatering, and predation were not included. These additional mortality factors are described in the BO for steelhead, spring-run and winter-run. Stranding occurs in the American River following flow release pulses made to meet Delta water quality standards and following flood control releases (not project effects). Stranding in the Stanislaus River is a less common occurrence and of lower significance. The extent of population effects of stranding and redd dewatering has not been quantified. Project related predation in these rivers is related to water temperatures favoring predator populations and is similar to that described for the other runs.

Table 2. Percent difference in Chinook survival from the Reclamation egg mortality model (Feather, American, and Stanislaus Rivers) and Salmod model (Sacramento River) compared to the highest production/survival year in each river under the OCAP studies.

River	Model	Study 7.0	Study 7.1	Study 8.0	Study 6.0
Sacramento River Fall	Salmod	-19.9	-21.8	-20.4	
Sacramento River Late Fall	Salmod	-10.5	-11.4	-10.4	-10.0
Feather River	Egg Mortality	-2.0	-2.0	-2.0	-2.1
American River	Egg Mortality	-8.8	-8.8	-10.4	-9.0
Stanislaus River	Egg Mortality	-6.4	-6.7	-6.2	-6.2

Average annual fall-run and late fall-run Chinook salmon production from the Central Valley over the last 20 years (1988 – 2007) has been 852,413 as estimated by the CVPIA Anadromous Fish Restoration Program (USFWS 2008). Production is defined as the total number of adults in the ocean and is calculated by adding commercial harvest, recreational harvest, in-river escapement estimates, and hatchery returns. This production number includes a combination of natural- and hatchery-produced fish. The adult production attributed to each river in this analysis is shown in Table 3. The proportion of production from each river (last column) is the proportion of the total Central Valley fall and late fall-run escapement returning to that river averaged over the last 20 years (1988 – 2007).

Table 3. The 20-year average adult fall and late fall-run Chinook salmon production from the Central Valley, present in the ocean, and available to Southern Residents and the proportion of the production originating from each river.

River	20 year average Adult Production 1988-2007	Proportion of Central Valley Production
Sacramento River Fall	159,753	0.19
Sacramento River Late Fall	30,290	0.04
Feather River	181,436	0.21
American River	194,757	0.23
Stanislaus River	7,836	0.01
Total Central Valley adult fall and late fall-run Chinook pı	852,413	1.00

Change in Survival from Central Valley

A summary of the change in salmon survival due to the Project is shown in table 4. The maximum and minimum values refer to the scenario with the maximum (least decrease in survival) and minimum (greatest decrease in survival) number of resulting fish. The Delta mortality is based on a number of survival experiments analyzed by Ken Newman and then extrapolated into Project-related mortality for each OCAP scenario. The Delta mortality estimates are based on Sacramento River origin fish. San Joaquin River Project-related mortality is different and was not quantified. The same mortality factors were applied to fish from both basins. Less than three percent of production originates from the San Joaquin River tributaries, so the effect of different mortality factors on total production is small. See the Delta effects section of the BO for a description of Project-related mortality factors in the Delta

Table 4. Summary of proportional change in fall-run and late fall-run Chinook salmon survival attributed to Project effects by area.

		Method of Calc	**Study 7.0**	Max	Min	**Study 7.1**	Max	Min	**Study 8.0**	Max	Min
Sacramento River Fall		Salmod	-0.199	-0.021	-0.901	-0.218	0.000	-0.901	-0.204	-0.002	-0.901
Sacramento River Late Fall		Salmod	-0.105	-0.007	-0.684	-0.114	0.000	-0.648	-0.104	-0.004	-0.651
Feather River		Egg Mortality	-0.02	-0.003	-0.167	-0.020	-0.003	-0.203	-0.020	-0.002	-0.164
American River		Egg Mortality	-0.088	-0.007	-0.341	-0.088	-0.007	-0.341	-0.104	-0.008	-0.328
Stanislaus River		Egg Mortality	-0.064	-0.0005	-0.169	-0.067	0.000	-0.242	-0.062	0.000	-0.196
Delta		Newman based model	-0.0344	-0.003	-0.1189	-0.0396	-0.0044	-0.1514	-0.0395	-0.0041	-0.147

The total change in survival of fish was scaled by the proportion of Central Valley production originating from the respective river (change in survival from table 4 multiplied by proportion of Central Valley production affected in the specific watershed from table 3). The changes in survival proportions for the project rivers were summed to give an overall upstream survival change (table 5). All juveniles from the upstream rivers pass through the Delta. Overall upstream survival was multiplied by Delta survival to give the total survival from the Central Valley as affected by project operations. The total change in survival of Central Valley fall and late fall-run in freshwater is a 9.8 percent (range 0.9 percent to 39 percent) decrease in survival under study 7.0, a 10.7 percent (range 0.7 percent to 41.9 percent) reduction under study 7.1, and a 10.7 percent (range 0.7 percent to 40.6 percent) reduction under study 8.0 (table 5). Note that the table 5 survival values are survival relative to no project operations. No project operations is represented by a base survival of 1.0 with only background mortality occurring. Background mortality refers to that which occurs with or without the project.

Table 5. Total change in survival of naturally produced Central Valley fall and late fall-run Chinook salmon. Change in survival from individual rivers is expressed as the proportion of the change in total Central Valley survival that the change in the respective river represents.

		Study 7.0			Study 7.1			Study 8.0		
	Method of Calc	Mean	Max fish left	Min fish left	Mean	Max fish	Min fish	Mean	Max fish l	Min fish l
Sacramento River Fall	Salmod	-0.037	-0.004	-0.169	-0.041	0.000	-0.169	-0.038	0.000	-0.169
Sacramento River Late Fall	Salmod	-0.004	0.000	-0.024	-0.004	0.000	-0.023	-0.004	0.000	-0.023
Feather River	Egg Mortality	-0.004	-0.001	-0.036	-0.004	-0.001	-0.043	-0.004	0.000	-0.035
American River	Egg Mortality	-0.020	-0.002	-0.078	-0.020	-0.002	-0.078	-0.024	-0.002	-0.075
Stanislaus River	Egg Mortality	-0.001	0.000	-0.002	-0.001	0.000	-0.002	-0.001	0.000	-0.002
Upstream Survival Change		-0.066	-0.006	-0.308	-0.070	-0.002	-0.315	-0.071	-0.003	-0.304
Upstream Survival		0.934	0.994	0.692	0.930	0.998	0.685	0.929	0.997	0.696
Delta Survival Change	Newman based model	-0.034	-0.003	-0.119	-0.040	-0.004	-0.151	-0.040	-0.004	-0.147
Delta Survival		0.966	0.997	0.881	0.960	0.996	0.849	0.961	0.996	0.853
Survival from Central Valley (not including background mortality)		0.902	0.991	0.610	0.893	0.993	0.581	0.893	0.993	0.594
Change in Survival due to project		-0.098	-0.009	-0.390	-0.107	-0.007	-0.419	-0.107	-0.007	-0.406

The change in survival in each river in table 5 is expressed as the proportion of the total Central Valley population that the survival of the population in the individual river represents. The scaling of survival to the total population enables the upstream survivals to be summed across rivers for a total upstream survival change due to the project. This was converted to upstream survival (survival = 1 – mortality). All salmon from the upstream rivers pass through the Delta so the Delta survival from the Delta effects analysis in the BO was multiplied by the survival of the upstream population (Upstream survival X Delta survival = Survival from the Central Valley). Multiplying the upstream survival by Delta survival accounts for the individuals lost due to the project before reaching the Delta where additional project related mortality occurs. This survival is the relative survival of fish experiencing the effects of the project compared to a survival value of 1.0 representing what would occur without the project. Background mortality from a variety of non-project related factors for salmon is high and occurs with or without the project. This approach assumes no density dependence. For example, when fewer eggs survive to fry there are more resources for the remaining fry so they should survive better, particularly when abundance is high. The Salmod model takes density dependence into account for fall-run and late fall-run in the Sacramento River down to Red Bluff, but the egg mortality model and delta survival make no adjustments for density dependence. These models are the best available tools we have to evaluate project operations in conjunction with the Calsim. Because density dependence is overlooked in the rivers (other than the Sacramento) and in the Delta the estimates of survival are lower than what would occur with compensatory mortality, where it occurs, accounted for. Thus the analysis assumes worst case scenario regarding density dependence.

The scaling to proportion of the production originating from the Sacramento River (19 percent originates from the Sacramento River) results in an overall change in Central Valley fall and late fall-run production of -3.7 percent due to the effect of Project operations on fall-run in the Sacramento River under Study 7.0. All Chinook salmon pass through the Delta, so no scaling was needed for Delta mortality. All fish inhabit the Delta during their migrations, while effects in individual rivers are confined to the proportion of the population inhabiting the respective river.

Effects of Operations on Hatchery and Naturally Produced Smolt Production

The number of hatchery produced Chinook exiting freshwater is affected by in-river survival of the hatchery produced fish released in the rivers upstream of the delta. Those released in the Bay do not experience the in-river survival reduction. We estimated the in-river survival of the hatchery fish and applied this survival to the in-river released hatchery fish to determine the number of fish reaching the Bay (Table 6). Out of a total hatchery release of 34,660,000 (sum of Central Valley Chinook salmon hatchery yearly production goals) about 14,000,000 are released in-river. The in-river releases occur primarily from Coleman, Merced, and Livingston Stone hatcheries. The vast majority come from Coleman Hatchery. Coleman trucked a proportion of their production to the Bay in 2008 and may do the same in 2009 but the future Coleman releases are expected to be primarily in-river. The survival of Coleman fish to the Delta was estimated for 1994 – 2001 using coded wire tags and was 0.53 (Bruce Oppenheim, personal communication). Survival of winter-run released at Caldwell Park was estimated to be 0.547. Chinook are released as smolts and emigrate quickly downriver at release. The mortality that occurs to these fish as they emigrate to the Delta is assumed to be the same with or without project operations (RBDD gates are up at release). Delta mortality varies with project operations as shown in the Delta survival rates in table 6. These survivals are from the model used in the Delta effects analysis in the BO. The freshwater survival (product of in-river and Delta survival) was multiplied by the in-river release number to yield the number in-river released fish reaching the Bay. This was added with the number released in the Bay to yield the total number of hatchery fish in the Bay (24.6 – 27.7 million). Nimbus Hatchery releases four million Chinook downstream of Carquinez Strait each year. The last row of table 6 shows the proportion of Nimbus Hatchery origin fish compared to total hatchery fish in the bay by scenario.

Table 6. Total number of hatchery produced smolts reaching the Bay after correcting for the survival of in-river released fish from the point of release to the Bay.

	No Projec	**Study 7.0**			**Study 7.1**			**Study 8.0**		
		Mean	**Max fish lef**	**Min fish left**	**Mean**	**Max fish left**	**Min fish lef**	**Mean**	**Max fish lef**	**Min fish lef**
Survival to Delta	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53
Delta Survival	0.9165	0.882	0.964	0.609	0.869	0.963	0.533	0.869	0.963	0.546
Freshwater Survival	0.49	0.47	0.51	0.32	0.46	0.51	0.28	0.46	0.51	0.29
In-river released surviving to Bay	6,878,149	6,619,984	7,233,877	4,571,174	6,522,422	7,223,370	4,002,310	6,523,172	7,225,621	4,093,868
Hatchery Bay release	20,500,000	20,500,000	20,500,000	20,500,000	20,500,000	20,500,000	20,500,000	20,500,000	20,500,000	20,500,000
Hatchery total in Bay	27,378,149	27,119,984	27,733,877	25,071,174	27,022,422	27,723,370	24,502,310	27,023,172	27,725,621	24,593,868
Nimbus Proportion	**15%**	**15%**	**14%**	**16%**	**15%**	**14%**	**16%**	**15%**	**14%**	**16%**

Table 7 shows the number of smolts in the Bay under each scenario broken down by naturally produced and hatchery produced smolts. Analysis of Chinook salmon otoliths in 1999 and 2002 found that the contribution of hatchery-produced fish made up approximately 90 percent of the ocean fishery off the central California coast from Bodega Bay to Monterey Bay. Natural contribution was 10 percent ± 6 percent (Barnett-Johnson *et al*. 2007). The number of naturally produced smolts was estimated by assuming 10 percent of the smolts were naturally produced and 90 percent were hatchery produced based on the Barnett-Johnson et al. (2007). The known hatchery production was divided by 0.9 under Study 7.0 in the average scenario. Number of smolts under no project operations was then calculated from the survival of natural fish in Study 7.0 and the hatchery release numbers from table 6. The number of smolts in all other scenarios in table 6 was calculated using the in-river survival of naturally produced and hatchery fish applied to the smolt numbers shown in the no project operations scenario of table 7.

A smolt to adult survival rate was calculated using the total hatchery and natural smolt numbers compared to the 20-year average adult production of 852,413 (1998 – 2007 average), assumed to occur under Study 7.0 in average conditions. This smolt-to-adult survival rate was 2.8%.

Table 7. Total number of smolts in the Bay under each scenario. Freshwater survival of naturally produced fish relative to no project operations, survival of hatchery fish, and smolt to adult survival are also shown.

	No Project	Study 7.0			Study 7.1			Study 8.0		
		Mean	Max fish	Min fish	Mean	Max fish	Min fish	Mean	Max fish	Min fish
Hatchery smolts	27,378,149	27,119,984	27,733,877	25,071,174	27,022,422	27,723,370	24,502,310	27,023,172	27,725,621	24,593,868
Natural smolts	3,341,122	3,013,332	3,309,690	2,036,639	2,984,563	3,318,971	1,941,515	2,982,850	3,318,205	1,984,606
Total smolts	30,719,271	30,133,316	31,043,567	27,107,813	30,006,985	31,042,341	26,443,825	30,006,023	31,043,826	26,578,474
Survival of natural fish		0.902	0.991	0.610	0.893	0.993	0.581	0.893	0.993	0.594
Survival in-river hatchery	0.49	0.47	0.51	0.32	0.46	0.51	0.28	0.46	0.51	0.29
Smolt to adult survival	2.83%	2.83%	2.83%	2.83%	2.83%	2.83%	2.83%	2.83%	2.83%	2.83%

Adult Chinook Production

The production of adults in the ocean was estimated for each scenario by applying the smolt-to-adult survival rate to the number of smolts from table 7 (table 8). An assumption was that the smolt-to-adult survival rate is the same for hatchery and natural fish present in the Bay. If naturally produced fish survive at a higher rate in the ocean than hatchery fish then the number of naturally produced smolts would be lower than shown in table 7. Table 8 also shows the percent change in number of adults in comparison with no project operations. The percent change in the number of adults is the same as the percent change in number of smolts in the Bay. The no project operations scenario is an average so in some years (maximum fish scenarios under each study in table 8) the fish production with project operations can be higher than what would occur on average without project operations. The proportion of total production originating from Nimbus Hatchery was calculated by dividing the yearly Nimbus production (4,000,000) by the total number of hatchery fish in the Bay as shown in table 7. The Nimbus Hatchery proportion of total adults varies by scenario and ranges from 13% to 15.1%. The effect of operations on average numbers of naturally produced fall and late fall-run Chinook in comparison with no project operations ranges from a 9.8% to 10.7% reduction and the maximum and minimum changes range from reductions of 0.7% to 41.9%.

Table 8. Number of adult Central Valley fall and late fall-run Chinook estimated to occur in the ocean under each scenario. The "% difference in total adults" row shows percent difference in annual fish production compared to no project operations and the "% difference in naturally produced" row shows the percent difference in naturally produced fish compared to no project operations.

Adult Fish in Ocean

	No Project	Study 7.0			Study 7.1			Study 8.0		
		Mean	Max fish	Min fish	Mean	Max fish	Min fish	Mean	Max fish	Min fish
Hatchery	774,475	767,172	784,538	709,215	764,412	784,240	693,123	764,433	784,304	695,713
Natural	94,514	85,241	93,625	57,613	84,427	93,887	54,922	84,379	93,866	56,141
Total	868,989	852,413	878,162	766,827	848,839	878,128	748,044	848,812	878,170	751,853
% difference in total adults		-1.9%	1.1%	-11.8%	-2.3%	1.1%	-13.9%	-2.3%	1.1%	-13.5%
Nimbus Hatchery proportion of total	13.0%	13.3%	12.9%	14.8%	13.3%	12.9%	15.1%	13.3%	12.9%	15.0%
% difference in naturally produced		-9.8%	-0.9%	-39.0%	-10.7%	-0.7%	-41.9%	-10.7%	-0.7%	-40.6%

Climate Change

The effect of water operations on salmon production under the climate change scenarios was assessed in the same general way as described in the previous sections. Results of the climate change effects analysis should not be compared directly to the results in the previous analysis because the reference condition was different for the climate change scenarios. Unlike the non-climate change analysis, the background hydrology is different between the climate change scenarios so project related versus non-project related effects are more problematic to separate out. Effects in the rivers were assessed using the Reclamation egg mortality model for all rivers. Salmod was not run for all Sacramento River climate change scenarios. We applied the Salmod model to the Sacramento River for the dryer more warming scenario, Study 9.5, to estimate a maximum climate change effect scenario. The maximum fish production year in Study 9.5 was used as the reference condition for no project operations and all other years were compared to that year. The maximum survival year in Study 9.5 under the egg mortality model runs for each river was used as the no project reference condition in the egg mortality runs. Results of Study 9.5 effects on Chinook production are presented in the figures and tables below as an estimate of worst case scenario under the climate change analysis (Figures 5 and 6 and Tables 9 – 13).

This analysis assumes the distribution of fish production between watersheds would remain the same under the climate change scenarios as under current conditions. The change in hydrology in the climate change scenarios would change conditions for fish in all tributary watersheds, not just those affected by the project. Therefore the proportion of fish production between different watersheds would likely change.

Delta survival was not estimated for the climate change scenarios so the survival relationship under the worst case regular scenario (Study 7.1) was applied to all climate change scenarios. Therefore differences displayed between the climate change scenarios are due to differences in upstream conditions.

Numbers of naturally produced fish decrease in the dryer more warming scenario, Study 9.5, by an average of 16.7% (range 4.4% to 51.7% reduction). The change in total fish numbers was estimated to be an average reduction of 3% (range 0.6% to 14.9%) but the total fish numbers are fairly uncertain due to the number of ecosystem changes that may occur under climate change scenarios.

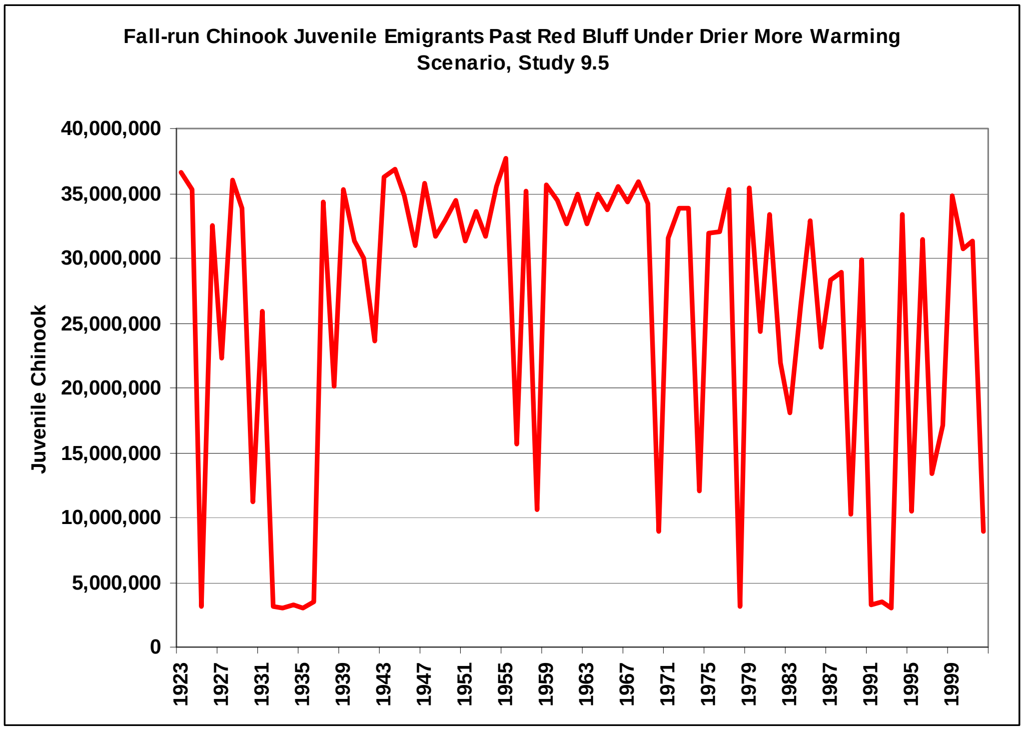

Figure 5. Fall-run Chinook juvenile production at Red Bluff under the dryer more warming scenario, Study 9.5, from an adult escapement of 59,653.

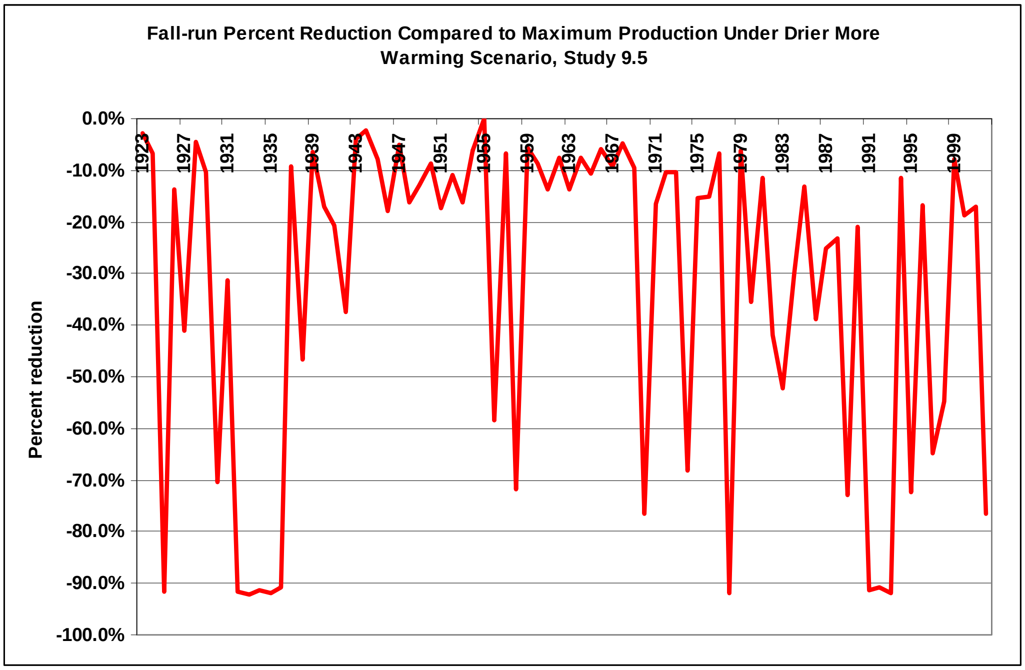

Figure 6. Reduction in upper Sacramento River juvenile fall-run Chinook production during each year of the Calsim modeling relative to the maximum production year under the dryer more warming scenario, Study 9.5.

Table 9. Summary of change in fall-run and late fall-run Chinook salmon survival attributed to Project effects by area under the dryer more warming climate change scenario.

Summary of Change in slamon production compare			Study 9.5 Drier, More Warming		
		Method of Calc	**9.5**	**Max**	**Min**
Sacramento River Fall		Salmod	-0.315	-0.106	-0.921
Sacramento River Late Fall		Salmod	-0.167	-0.007	-0.769
Feather River		Egg Mortality	-0.071	-0.006	-0.341
American River		Egg Mortality	-0.224	-0.082	-0.676
Stanislaus River		Egg Mortality	-0.143	-0.015	-0.388
Delta (used worst case, Study 7.1)		Newman based model	-0.040	-0.004	-0.151

Table 10. Total change in survival of naturally produced Central Valley fall and late fall-run Chinook salmon under the dryer more warming climate change scenario. Change in survival from individual rivers is expressed as the proportion of the change in total Central Valley survival that the change in the respective river represents.

		Study 9.5 Drier, More Warming		
	Method of Calc	Mean	Max	Min
Sacramento River Fall	Salmod	-0.059	-0.020	-0.173
Sacramento River Late Fall	Salmod	-0.006	0.000	-0.027
Feather River	Egg Mortality	-0.015	-0.001	-0.073
American River	Egg Mortality	-0.051	-0.019	-0.154
Stanislaus River	Egg Mortality	-0.001	0.000	-0.004
Upstream Survival Change		-0.133	-0.040	-0.431
Upstream Survival		0.867	0.960	0.569
Delta Survival Change	Newman based model	-0.040	-0.004	-0.151
Delta Survival		0.960	0.996	0.849
Survival from Central Valley		0.833	0.956	0.483
(not including background mortality)				
Change in Survival due to project		-0.167	-0.044	-0.517

Table 11. Total number of hatchery produced smolts reaching the Bay after correcting for the survival of in-river released fish from the point of release to the Bay.

	No Project	Study 9.5 dryer warmer		
		Mean	Max	Min
Survival to Delta	0.53	0.53	0.53	0.53
Delta Survival (7.1)	0.9165	0.869	0.963	0.533
Freshwater Survival	0.49	0.46	0.51	0.28
In-river released surviving to Bay	6,878,149	6,522,422	7,223,370	4,002,310
Hatchery Bay release	20,500,000	20,500,000	20,500,000	20,500,000
Hatchery total in Bay	27,378,149	27,022,422	27,723,370	24,502,310
Nimbus Proportion	**15%**	**15%**	**14%**	**16%**

Table 12. Total number of smolts in the Bay under the dryer more warming climate change scenario.. Freshwater survival of naturally produced fish relative to no project operations, survival of hatchery fish, and smolt to adult survival are also shown.

Smolt Production

	Study 9.5 Drier, More Warming		
	Mean	Max	Min
Hatchery smolts	27,022,422	27,723,370	24,502,310
Natural smolts	2,745,636	3,149,288	1,592,752
Total smolts	29,768,058	30,872,658	26,095,062
Survival of natural fish	0.833	0.956	0.483
Survival in-river hatchery fish	0.46	0.51	0.28
Smolt to adult survival	2.84%	2.84%	2.84%

Table 13. Number of adult Central Valley fall and late fall-run Chinook estimated to occur in the ocean under the dryer more warming climate change scenario. The "% difference in total adults" row shows percent difference in annual fish production compared to no project operations and the "% difference in naturally produced" row shows the percent difference in naturally produced fish compared to no project operations.

	Study 9.5 Drier, More Warming		
	Mean	Max	Min
Hatchery	767,172	787,072	695,625
Natural	77,949	89,409	45,219
Total	845,121	876,481	740,844
% difference in total adults	-3.0%	0.6%	-14.9%
Nimbus Hatchery proportion of total	13.4%	13.0%	15.3%
% difference in naturally produced	-16.7%	-4.4%	-51.7%

Areas Not Included in this Analysis

Clear Creek

Clear Creek production changes were not included because no spawning distribution information was available to run the mortality model in Clear Creek. Clear Creek contributes about 1.6 percent of the Central Valley production. Changes in Clear Creek will not substantially affect the overall estimated change in prey availability.

Trinity River

CVP water operations in the Trinity River affect coho salmon and Chinook salmon populations in the Klamath/Trinity River watershed. The implementation of the Trinity River Record of Decision has provided increased flows down the Trinity River and stream habitat improvement projects. These actions should positively affect salmonid production from the Klamath/Trinity River watershed as described in the OCAP Biological Assessment and Trinity River Restoration Program EIS. Therefore no adverse effect on Chinook salmon in the ocean originating from the Trinity River will occur from the project. Reclamation funds the Trinity River Hatchery as mitigation for Trinity Dam. Trinity River Hatchery produces 3,000,000 Chinook salmon smolts (1,000,000 spring-run, 2,000,000 fall-run) and 1,300,000 Chinook salmon yearlings (400,000 spring-run, 900,000 fall-run) and releases them all at the hatchery. This production is expected to remain the same for the foreseeable future. Figure 7 shows the natural and hatchery components of the Chinook salmon escapement. The average hatchery proportion from 1991 – 2006 has been 57% and the average Chinook escapement over this period has been 52,933.

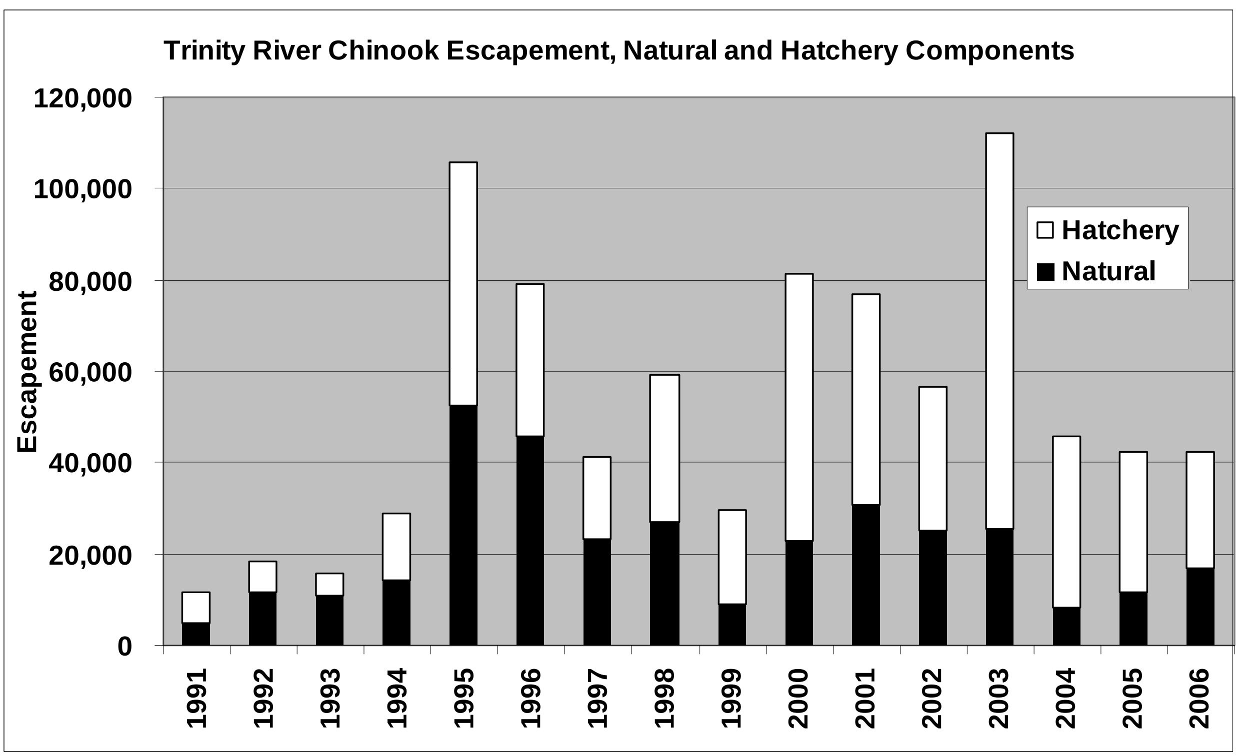

Figure 7. Trinity River Chinook salmon escapement upstream of the Willow Creek weir (fall-run) and Junction City weir (spring-run). Spring-run and fall-run are combined.

References

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