Appendix F, Modeling

Attachment F.7 Change in Abundance Estimate of Central Valley Chinook Salmon Available to Southern Resident Killer Whales

F.7.1 Introduction

This assessment evaluates abundance of Chinook salmon produced from the Central Valley watershed of California and available as adults in the ocean as prey for Southern Resident killer whales. The assessment assumes that age three and older (3+) Chinook salmon would be in the size range most suitable as prey, so the assessment focuses on age 3+ Chinook salmon. The scenarios evaluated are the No Action Alternative representing the last biological opinion operations (NAA) and the four alternatives analyzed in the Environmental Impact Statement with four phases of Alternative 2 that include or exclude TUCP and/or include or exclude the Voluntary Agreements (VA). The four phases of Alternative 2 assessed in this analysis are: without TUCP without VA (ALT2v1woTUCP), with TUCP and without VA (ALT2v1_wTUCP), without TUCP and with Delta VA (ALT2v2_woTUCP), and without TUCP and with systemwide voluntary agreements (ALT2v3_woTUCP).

F.7.2 Modeling Approach

Table F.7-1 depicts portions of life stages differentially affected by the Alternatives and other relevant scenarios that have quantitative models available and are compatible with the CalSim 3 water operations simulation. Unquantified effects are described but not bundled into the evaluation of abundance and assumed to apply equally across scenarios. The quantified freshwater mortality sources are aggregated into an overall change in freshwater survival attributable to the water operations scenarios.

Hatchery Chinook salmon releases are included in the analysis by using the average annual number of Chinook salmon released for all hatcheries and runs combined. Releases are separated by in-river and Bay releases using the proportion of release locations for each hatchery over approximately the past 15 years. Year to year variation in release location and numbers occurs in response to environmental conditions and hatchery management flexibility. For example, recently fry releases occurred in addition to the standard release numbers and these fry releases

were not included here. In-river mortality based on the XT model and the Delta Passage Model 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 scenarios are assumed not to affect hatchery operations or fish so hatchery Chinook abundance entering the ocean is held constant through all scenarios. The past 18-year median ocean Chinook salmon abundance is divided by the hatchery and naturally produced Chinook salmon in the Bay to determine a baseline bay to ocean survival value. The hatchery proportion is based on coded wire tag recovery data in 2011 – 2020 from escapement surveys on the spawning grounds and proportions in the ocean are assumed to be the same. The past 20-year median ocean abundance along with differences in freshwater survival from the No Action Alternative (NAA) was used to calculate a point value of Chinook salmon available as prey to SRKW under each modeled scenario. The NAA was used as a point of reference to operations as they have occurred since the last Endangered Species Act consultation to obtain relative differences in survival between all the scenarios.

Table F.7-1. Rivers and Chinook salmon runs assessed, and models used in the assessment. The "Run" column refers to natural-origin (i.e., spawned in-river) fish unless stated otherwise. The proportions of Central Valley Chinook salmon is the mean 2001-2017 production from each tributary in USFWS 2018 and when summed adds up to 100% of the Central Valley Chinook production.

River	Run	Model	Proportion of Central Valley Chinook salmon	Reach shown in Figure F.7-1
Sacramento (spawning)	Fall	Salmort	0.097	1
Sacramento (RBDD to Delta Cross Channel)	Fall	XT	0.097	2
Sacramento (spawning)	Late Fall	Salmort	0.026	1
Sacramento	Late Fall (RBDD to Delta Cross Channel)	XT	0.026	2
Sacramento	Winter	CVPIA SIT	0.014	CV-wide
Central Valley	Spring	CVPIA SIT	0.02	CV-wide
Clear Creek	Fall	Upstream effects not included	0.023	-
Feather	Fall	Upstream effects not included	0.240	-
American	Fall	Salmort	0.223	3
American (mouth to Delta Cross Channel)	Fall	XT	0.223	4

River	Run	Model	Proportion of Central Valley Chinook salmon	Reach shown in Figure F.7-1
Stanislaus	Fall	Upstream effects not included	0.010	-
Delta	All Chinook salmon from Sacramento River basin	Delta Passage Model	0.936	5
Delta	Fall-run Chinook salmon from San Joaquin River basin and Delta Eastside streams [a]	Unquantified	0.065	-
Hatchery instream releases	All runs	XT model and Delta Passage Model NAA scenario	0.59 of hatchery releases	3,4,5
Hatchery Bay releases	All Bay releases	No project effects assumed	0.41 of hatchery releases	-

[a] "Delta Eastside streams" refers to the Cosumnes River, Mokelumne River, and Calaveras River.

Survival through the Delta

The Delta Passage Model results from Figure F.7-11 and Figure F.7-12 are aggregated for all rivers and runs from the Sacramento Basin passing through the delta (Table F.7-10). Results are multiplied by the upstream survival for each river for an aggregate freshwater survival. Results from each river are scaled by the proportion of Central Valley production from each area to allow summing results across rivers for an aggregate freshwater survival as a proportion of NAA survival (Table F.7-11).

F.7.3.1.7 Hatchery Produced Chinook Salmon

Hatchery produced Chinook salmon releases are included in the analysis by using the average release of hatchery juveniles for 2007 – 2013 (from Palmer-Zwahlen et al. 2019 and 2018, and Palmer Zwahlen and Kormos 2015) as the number of hatchery produced fish released each year for all Central Valley Chinook salmon runs combined (average total of 35,059,237 and range of 30,455,664 to 38,510,728). The proportion of hatchery fish released in-river and in San Francisco Bay varies from year to year based on water year conditions and other factors. The general release goals and release locations based on recent trends over the last 15 years (Table F.7-12) were used to estimate an average in-river release proportion of 0.59.

Table F.7-12. Central Valley Chinook salmon hatchery release goals and proportion released in-river and in Bay areas.

Hatchery Annual Chinook Releases	General Goal	Proportion Bay	Proportion In-River	Number In-River
Coleman Fall	12,000,000	0	1	12,000,000
Coleman Late Fall	1,000,000	0	1	1,000,000
LSNFH Winter	200,000	0	1	200,000
Feather Fall	6,000,000	0.7	0.3	1,800,000
Feather Spring	2,000,000	0.5	0.5	1,000,000
Feather Enhancement	2,000,000	1	0	0
Nimbus	4,000,000	0.33	0.67	2,680,000
Mokelumne	5,000,000	0.7	0.3	1,500,000
Mokelumne Enhancement	2,000,000	1	0	0
Merced	300,000	0	1	300,000
Total Release	34,500,000			
In-River Release	20,480,000			
Proportion Released In-River	0.59			

In-river mortality was applied to all the in-river released hatchery fish using a static river survival value across all alternatives. We assumed no difference in hatchery fish survival between alternatives because hatcheries have ability to modify practices as needed to meet their performance measures. A survival of 0.096 from the median NAA scenario of the XT model was applied to Coleman and Livingston Stone hatchery in-river releases. A survival of 0.96 from the XT model difference between RBDD to DCC and RBDD to American River was applied to in-river releases for the American River, Mokelumne River, Feather River, and Merced River hatcheries. The Delta Passage Model survival of 0.17 was applied to all the hatchery fish passing through the Delta. We assumed that the Mokelumne and Merced hatchery survival through the Delta (along with their in-river survival) would be similar to the Delta Passage Model survival for Sacramento River origin Chinook salmon. The in-river released hatchery Chinook salmon surviving through the Delta were added to the Bay releases for a total number of hatchery fish in the Bay (Table F.7-13).

Table F.7-13. Calculation of hatchery Chinook salmon in the San Francisco Bay under the NAA scenario.

Total Hatchery Release	35,059,237
Proportion Released In-River	0.59
Coleman and LSNFH Hatchery Survival to Delta from XT Model NAA	0.096
Feather, American, Mokelumne, and Merced River Hatchery Survival to Delta (using interpolated value for American River from XT model)	0.96
Hatchery Fish Surviving to Delta	8,263,280
NAA DPM Survival	0.17
NAA Hatchery Fish to Bay	1,410,488
Hatchery Bay Release	14,247,261
Hatchery Total in Bay NAA	15,657,749
Hatchery Proportion	0.74
Total Fish in Bay	21,159,121
Natural Fish in Bay NAA	5,501,371

F.7.3.1.8 Hatchery and Natural Proportions and Ocean Abundance

Because release and recovery coded wire tag data are available and more reliable for the hatchery component of the runs, the smolt to adult survival rate was estimated for the hatchery component and applied to the whole population (hatchery and natural) of smolts in the bay. First it was necessary to estimate ocean abundance of all the central valley Chinook runs and then apply a hatchery proportion. This is because the ocean abundance estimates for the largest Central Valley run, Sacramento River fall-run Chinook, is estimated for the combined natural and hatchery origin fish.

The hatchery and natural area escapement proportions of Central Valley Chinook salmon were estimated using data from the Central Valley coded wire tag recovery reports for run years 2011-2022 (Palmer-Zwahlen et al. 2019, Palmer-Zwahlen et al. 2018, and Palmer-Zwahlen and Kormos 2015, 2020, Letvin et al. 2021a, Letvin et al. 2021b, Dean and Lindley 2023). The hatchery proportion over the eleven years of available data averaged 0.74 (range 0.57 – 0.88). A separate 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 (Barnett-Johnson et al. 2007), however the more recent Central Valley coded wire tag-derived value of 0.74 overall Central Valley hatchery proportion was used for this analysis.

The ocean abundance, hatchery releases, and hatchery proportions are values regularly estimated with greater confidence than the abundance of naturally produced Chinook salmon entering the ocean from the Central Valley. Therefore, the median ocean abundance for the period 2001 – 2022 of 233,349 (Table F.7-14) along with the hatchery proportion of 0.74 and median number of hatchery produced fish in San Francisco Bay in the NAA scenario (15,657,749 from Table F.7-13) was used to estimate the smolt in the bay-to adult survival rate of 0.011[1]. Mortality sources other than that quantified in the fisheries (e.g. predation on adults by marine mammals) are not included in this estimate. Back calculating using the median ocean abundance, smolt to adult survival, and 0.74 hatchery proportion gives a NAA value for estimated number of naturally produced juvenile Chinook salmon in the San Francisco Bay of 5,501,371 juveniles (Table F.7-13).

F.7.3.2 Ocean Abundance and Biomass of Adult (Age 3+) Chinook Salmon

The Sacramento River Index was used as the annual production of fall-run Chinook salmon from the Central Valley. This index is the sum of the annual (September 1 to August 31) Sacramento River fall-run Chinook salmon ocean harvest South of Cape Falcon (~Columbia River mouth), fall-run Chinook salmon impacts from non-retention (released fish), recreational harvest of Sacramento River fall-run Chinook salmon in the Sacramento River Basin, and the Sacramento River fall-run Chinook salmon spawner escapement (Pacific Fishery Management Council 2023a). The ocean abundance of late fall-run, San Joaquin fall-run Chinook salmon, Sacramento River winter-run Chinook salmon, and Central Valley spring-run Chinook salmon was estimated from annual escapement estimates as presented in PFMC (2023b) plus an estimated ocean harvest. Each year's ocean harvest rate for late fall-run and spring-run Chinook salmon was assumed to be the same as the year's rate for fall-run Chinook salmon. Winter-run Chinook salmon abundance assumed an annual harvest rate of 8.5 percent based on harvest management goals. Jacks, as enumerated in PFMC (2023b), were excluded from the ocean abundance estimate for all runs because they were assumed to be too small to contribute significantly to Southern Residents killer whale prey.

The average size of adult Chinook salmon in the ocean varies from year to year and is likely a function of the prey availability and current age distribution. The seasonal average dressed weight at the time of harvest in the commercial troll fishery ranged from 9.6 to 15.1 pounds from 2001 through 2022 (Pacific Fishery Management Council 2023b). The dressed weight (assumed to be gutted, head off) was converted to live weight using a 1.33 conversion factor (National Marine Fisheries Service 1980) resulting in live weight range of 14.4 to 20.1 pounds. Abundance and biomass have varied substantially from year to year with cohort replacement rates for all runs combined ranging from 0.28 to 3.58 (Figure F.7-13 and Table F.7-14).

[1] (233,349 adult Chinook in the ocean *0.74 hatchery proportion)/ 15,657,749 hatchery fish in the bay = 0.011 bay smolt to ocean adult survival (not including enumerated jacks)

F.7.3.3 Abundance of Central Valley Chinook Salmon Available as Prey for Southern Resident Killer Whales

The estimated natural and hatchery juvenile Chinook salmon abundance in the Bay from Table F.7-13 were combined for a total juvenile Chinook salmon in the Bay estimate (Table F.7-15). A static Bay smolt to adult survival rate of 0.011 was applied to all scenarios to arrive at an estimate of age 3+ adults present in the ocean and available as prey for southern resident killer whales. The adult abundance under the NAA of 232,750 comes from the estimated juvenile abundance in the San Francisco Bay in the NAA multiplied by the smolt to adult survival of 0.011. Ocean adult abundance under the alternatives ranged from 232,722 in Alt2v2_woTUCP to 232,931 under Alternative 3, an abundance range of 728 adult Chinook among all alternatives. Based on an adult weight of 15.015 pounds the Chinook biomass ranges from 3,494,314 pounds to 3,505,241 pounds.

The year to year Chinook salmon abundance and biomass fluctuations shown in Figure F.7-13 and Table F.7-14 are significantly greater than the within year potential differences estimated to be attributable to changes in water operations. The hatchery proportion of 0.74, potentially a low estimate, and the higher contribution of hatchery Bay releases in comparison with instream releases and naturally produced Chinook salmon suggests that naturally produced Chinook salmon from the Central Valley, in aggregate, are in a depressed state in all scenarios. Hatchery-produced Chinook salmon likely supply the bulk of the Chinook salmon available to SRKW. Given the hatchery release scenarios (i.e. Bay releases and high fish numbers) that seem to be needed to support desired harvests of Chinook salmon in the fisheries, unquantified behavioral and genetic effects to naturally produced Chinook salmon (e.g. age at return, stray rates, hatchery/wild fish spawning together) (Davison and Satterthwaite 2017) may continue to exacerbate the depressed state of naturally produced Chinook salmon with potential consequent effects on distribution and abundance of southern resident killer whale prey in the ocean. Based on this analysis the operational alternatives have little difference in effect on abundance and biomass. The difference in quality of the Chinook salmon, nutrition wise, by the time they reach a size usable by killer whales is likely negligible between hatchery and naturally produced Chinook.

Table F.7-15. Abundance of Central Valley Chinook salmon available as prey for SRKW under the LTO scenarios. Biomass is converted using a median adult weight of 15.015 pounds.

Statistic	NAA	ALT1	Alt2v1_woTUCP	Alt2v1_wTUCP	Alt2v2_woTUCP	Alt2v3_woTUCP	ALT3	ALT4
Natural Chinook (all runs combined) in Bay by scenario	5,501,371	5,516,308	5,499,042	5,499,541	5,498,754	5,517,763	5,564,911	5,506,961
Hatchery Chinook in Bay = same in all scenarios	15,657,749	15,657,749	15,657,749	15,657,749	15,657,749	15,657,749	15,657,749	15,657,749
Total Juvenile Chinook in Bay	21,159,120	21,174,058	21,156,792	21,157,291	21,156,503	21,175,512	21,222,661	21,164,710
Bay to ocean adult survival	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011
Ocean Adult Chinook Abundance	232,750	232,915	232,725	232,730	232,722	232,931	233,449	232,812
Ocean Adult Chinook Biomass**	3,494,746	3,497,213	3,494,361	3,494,444	3,494,314	3,497,453	3,505,241	3,495,669

F.7.4 References

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