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EFFECTS OF THE PROPOSED ACTION

Introduction

The Status of the Species/Environmental Baseline sections described the multitude of factors that affect delta smelt population dynamics including predation, contaminants, introduced species, entrainment, habitat suitability, food supply, aquatic macrophytes, and microcystis. The magnitude of the adverse effects of many of these factors on delta smelt is related to hydrodynamic conditions in the delta, which in turn are controlled to a large extent by CVP and SWP operations. Other sources of water diversion (NBA, CCWD, local agricultural diversions, power plants) adversely affect delta smelt largely through entrainment (see following discussion), but when taken together do not control hydrodynamics conditions throughout the delta to any degree that approaches the influence of the SWP and CVP. So while many of the other stressors that have been identified as adversely affecting delta smelt were not caused by CVP and SWP operations, the likelihood and extent to which they adversely affect delta smelt is highly influenced by how the projects are operated in the context of annual and seasonal hydrologic conditions. So, while research indicates that there is no single primary driver of delta smelt population dynamics, hydrodynamic conditions driven or influenced by project operation in turn influence the dynamics of delta smelt interaction with these other stressors.

The Service is following Bennett and Moyle (1996) and Bennett (2005), and the consensus emerging from the POD investigation (Sommer et al. 2007, Baxter et al. 2008), by assuming that delta smelt abundance trends have been driven by a mixture of factors, some of which are affected or controlled by water project operations and others that are not. The following analysis focuses on the subset of factors that is affected or controlled by water project operations, and includes discussion of other factors to the extent they modulate or otherwise affect the project-related factors affecting delta smelt. Although it is becoming increasingly clear that the long-term decline of delta smelt was very strongly affected by ecosystem changes caused by non-indigenous species invasions and other non-project factors, the water projects have played an important direct role. Further, the water projects have played an indirect role by creating an altered environment in the delta that has fostered the establishment of non-indigenous species and exacerbates these and other indirect effects to delta smelt. This analysis and others show that every day the system is in balanced conditions, the projects are a primary driver of Delta smelt abiotic and biotic habitat suitability, health, and mortality.

This effects analysis diverges from the 2005 biological opinion because it explicitly analyzes the proposed project's effects on three types of effects: entrainment of delta smelt, habitat restriction, and entrainment of *Pseudodiaptomus forbesi*, the primary prey of delta smelt during summer-fall. These types of effects are considered in a life cycle context (Table 1). Thus, a second assumption of this analysis is that the proposed project is affecting delta smelt throughout the year either directly through entrainment or indirectly through influences on food supply and habitat suitability. During December-June, when delta smelt are commonly entrained at Banks and Jones, their habitat and cooccurring food supply also are being entrained, so project effects on habitat and food supply are only examined explicitly during July-December when delta smelt entrainment is rare. Delta smelt entrainment is rare from about mid-July through mid-December each year mainly because environmental conditions in the San Joaquin River and its distributaries are not appropriate to support delta smelt. The water is too warm and clear, so delta smelt actively avoid the central and southern Delta during summer and fall (Feyrer et al. 2007; Nobriga et al. 2008). A third assumption is that any of these three types of effects will adversely affect delta smelt, either alone or in combinations. This approach is also consistent with Rose (2000), who used several different individual based models to show how multiple interacting stressors can result in fish population declines that would not be readily discernable using linear regression-based approaches.

This effects analysis uses a combination of available tools and data. These include the CALSIM II model outputs provided in appendices to the Biological Assessment, historical hydrologic data provided in the DAYFLOW database, statistical summaries derived from 936 unique 90-day particle tracking simulations published by Kimmerer and Nobriga (2008), and statistical summaries and derivative analyses of hydrodynamic and fisheries data published by Feyrer et al. (2007), Kimmerer (2008), and Grimaldo et al. (in press).

Table 1. The distribution of the three types of effects attributed to the Project Description over the life cycle of delta smelt.

Season	Delta smelt entrainment	Pseudodiaptomus entrainment/retention	Habitat suitability
Winter	X (adults)[a]		
Spring	X (larvae/juveniles)[b]		
Summer		X[c]	
Fall			X[d]

[a] Historical hydrodynamic data are DAYFLOW 1967-2007; OMR was measured 1993-2007 and estimated using regression on DAYFLOW variables by Cathy Ruhl (USGS) for 1967-1992; historical delta smelt salvage data are 1993-2007, the period when the data are considered most reliable

[b] Historical hydrodynamic data are DAYFLOW 1967-2007 (except OMR as noted in the previous footnote); direct estimates of larval-juvenile entrainment are 1995-2005 (Kimmerer 2008); Entrainment was estimated statistically for 1967-1994 and 2006-2007

[c] Historical hydrodynamic data (DAYFLOW; except OMR 1988-1992, see footnote a) and Pseudodiaptomus density data (IEP monitoring) are 1988-2006 because Pseudodiaptomus was introduced in 1988

[d] Historical hydrodynamic data are DAYFLOW 1967-2007

Effects Analysis Methods (CALSIM II Modeling)

The CALSIM II model is a mathematical simulation model developed for statewide water planning. It has the ability to estimate water supply, streamflows, and Delta water export capability, keeping within "rules" such as water quality standards that limit model outputs to plausibly achievable system operations. CALSIM II is DWR and USBR's official SWP and CVP planning tool. The CALSIM II model is applied to the SWP, the CVP, and the Sacramento and San Joaquin Delta. The model is used to evaluate the performance of the CVP and SWP systems for: existing or future levels of land development, potential future facilities, and current or alternative operational policies and regulatory environments. Key model output includes reservoir storage, instream river flow, water delivery, Delta exports and conditions, biological indicators such as X2, and operational and regulatory metrics.

CALSIM II simulates 82 years of hydrology for the Central Valley region spanning water years 1922-2003. The model employs an optimization algorithm to find ways to move water through the SWP and CVP in order to meet assumed water demands on a monthly time step. The movement of water in the system is governed by an internal weighting structure that ensures regulatory and operational priorities are met. The Delta is also represented in CALSIM II by DWR's Artificial Neural Network (ANN), which simulates flow and salinity relationships. Delta flow and electrical conductivity are output for key regulatory locations. Details of the level of land development (demands) and hydrology are discussed in Appendix D of the Biological Assessment, as are details of how the model simulates flexible operations like b(2) and EWA allocations. Most of the model data used were directly output from CALSIM II. However, certain Delta flow indicators, most notably OMR flows, were estimated by inputting CALSIM II outputs into DSM-2 HYDRO, which can be used as a "virtual flow meter" for Delta channels.

This effects analysis analyzes outputs from the following subset of studies presented in the BA: 7.0, 7.1, 8.0, and 9.0-9.5. Study 7.0 represents a 2005 level of development with b(2) allocations and a full Environmental Water Account. The full EWA was represented in the CALSIM II framework as up to 50,000 acre-feet of water export reductions during December-February, the VAMP pulse flow, and export reductions following VAMP (mid-May into June) when CALSIM II predicted the EWA had surplus water (i.e., collateral exceeded debt). Study 7.1 also represented a 2005 level of development with b(2) allocations, but with a limited EWA, which as described in the Project Description consists mainly of water from the Yuba Accord. In the limited EWA, there were no export reductions in February and June, but export reductions were possible during December to January and late May. The VAMP pulse flow was modeled in the same way as in the full EWA. Study 8.0 estimated SWP and CVP operations with a 2030 level of development, b(2) allocations and the limited EWA. Note that the 2030 demand was estimated as 100 percent of the CVP's contract deliveries, 100 percent of the SWP's Table A contract deliveries, and no variation in demand among water year types. In other words, 100 percent of contracted quantities were exported in each year of the simulation.

Study 9.1 represents a scenario in which sea level is assumed to be one foot higher than current, resulting in a four inch higher tidal elevation at Martinez, California. Studies 9.2-9.5 represent 'bookends' of climate change scenarios with the 2030 level of development. These bookends cannot be summarized simply except in qualitative terms. The bookends represent 10th and 90th percentiles of predicted changes in precipitation and temperature for 2010 to 2030 relative to 1971 to 2000. Generally, climate change models agree the Central Valley will be warmer in the future, but they do not agree whether precipitation will increase or decrease (e.g., Dettinger 2005). Thus, the climate change bookends include drier and wetter possibilities, but do not include cooler futures relative to current conditions. Thus, the temperature bookends can be called 'less warming' and 'more warming' or 'warmer' and 'warmer still'. Study 9.2 is a wetter and warmer simulation, 9.3 is a wetter and warmer still simulation, 9.4 is a drier and warmer simulation, and 9.5 is a drier and warmer still simulation. Study 9.5 to represents the "worst-case scenario" among all simulations in the biological assessment because drier conditions are expected to result in more frequent conflicts over limited water resources. Further, springtime water temperatures influence the length of the spawning season for delta smelt (Bennett 2005) and summertime water temperature conditions already can be marginal for delta smelt (e.g., Nobriga et al. 2008). Thus, all warmer futures are expected to further stress delta smelt, but the warmer still scenarios have the highest potential for detrimental effects.

Migrating and spawning adults (~ December through March)

Water Diversions and Reservoir Operations

Upstream Reservoirs and diversions

The following Project elements are included in the modeling results and are not specifically discussed in this analysis, rather the effects of these Project elements are included in the Adult Entrainment Effects and the Habitat Suitability Effects sections of the Effects Section: Project effects from the Trinity River Operations, Whiskeytown Operations, Clear Creek Operations, Shasta Lake and Keswick Dam Operations, Red Bluff Diversion Dam Operations, Oroville Dam and Feather River Operations, Folsom and Nimbus Dam Operations, New Melones Reservoir Operations, and Freeport Diversion Operations.

Banks and Jones Pumping Plants

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Entrainment of delta smelt

The entrainment of delta smelt into the Banks and Jones pumping plants is a direct effect of SWP and CVP operations. See Brown et al. (1996) for a description of fish salvage operations. Total entrainment is calculated based upon estimates of the number of fish salvaged (Kimmerer 2008). However, these estimates are indices - most entrained fish are not observed (Table 2), so most of the fish are not salvaged and therefore do not survive. Many, if not most, of the entrained delta smelt that are salvaged likely die due to handling, transport, and predation at release sites (Bennett 2005). Projected diversions through CCWD are included in calculations of E:I ratios used in this effects analysis because they do contribute to reverse flows in Old River. NBA and CCWD effects to delta smelt are presented separately below.

Table 2. Summary of factors that affect the difference between delta smelt entrainment and salvage.

	Adults	Larvae < 20 mm	Larvae > 20 mm and juveniles
Predation prior to encountering fish salvage facilities	unquantified	unquantified	unquantified
Louver efficiency (based on Kimmerer 2008)	Limited data indicate an efficiency of about 13 percent for the CVP facility; no equivalent data are available for the SWP facility	~ 0 percent	Likely < 13 at any size; << 13 percent at less than 30 mm
Collection screens (based on Kimmerer 2008)	~ 100 percent	~ 0 percent	< 100 percent until at least 30 mm
Identification protocols	Identified from subsamples, then expanded in salvage estimates	Not identified	Identified from subsamples, then expanded in salvage estimates
Handling, trucking and release back into the Delta	Study in progress	0 percent	Study in progress

The population-level effects of delta smelt entrainment vary; delta smelt entrainment can best be characterized as a sporadically significant influence on population dynamics. Kimmerer (2008) estimated that annual entrainment of the delta smelt population (adults and their progeny combined) ranged from approximately 10 percent to 60 percent per year from 2002-2006. Major population declines during the early 1980s (Moyle et al. 1992) and during the recent "POD" years (Sommer et al. 2007) were both associated with hydrodynamic conditions that greatly increased delta smelt entrainment losses as indexed by numbers of fish salvaged. However, currently published analyses of long-term associations between delta smelt salvage and subsequent abundance do not support the hypothesis that entrainment is driving population dynamics year in and year out (Bennett 2005; Manly and Chotkowski 2006; Kimmerer 2008).

Adult entrainment effects

Adult delta smelt have been salvaged at Banks and Jones as early in the water year as November and as late as June, but most of the recent historical salvage has occurred between mid-December and March (Figure X in the Baseline). Delta smelt salvage usually occurs in a prolonged event that has one major peak. This is evidence that the maturing population makes a spawning migration into the Delta. The migration is cued by pulses of freshwater flow into the estuary, otherwise known as "first flush" events

(Grimaldo et al. in press). Salvage of pre-spawning adults typically begins when river inflows and associated turbidity increase. The magnitude of cumulative annual salvage is best explained by OMR flow, whereby salvage increases with reverse OMR flow (Figure 1). Kimmerer (2008) calculated that entrainment losses of adult delta smelt in the winter removed 1% to 50 % of the estimated population and were proportional to OMR flow, though the high entrainment case might overstate actual entrainment. This effects analysis evaluates the proposed project operations by comparing the long-term trends in OMR flows to OMR flows in the CALSIM II modeling presented in the Biological Assessment. Given the demonstrated relationships between smelt entrainment and salvage with OMR flows (Kimmerer 2008; Grimaldo et al. in review), differences in OMR flows (i.e., modeled from historic) were used to estimate if effects were to be expected. The metric used to estimate effects or entrainment losses (as measured by salvage) was derived by calculating changes in percent differences from historic salvage to predicted salvage using salvage-OMR relationships. The previous year's FMWT Recovery Index (RI) was then used to scale the likely impact of cumulative salvage.

Combined Old and Middle River flow

The median and range of OMR flows were determined for each December to March period for each of the studies and the historic data by water year type (Figure 2). We defined the December to March period to be consistent with recent analyses (Kimmerer 2008, Grimaldo et al. in review) as this is the period when the majority of adults migrate upstream to spawn. We focused the evaluation over the full winter period and not on a month-by-month basis since the timing of migration is variable and because adult delta smelt are not vulnerable to entrainment until they begin to migrate upstream.

We used water years 1967 to 2007 to characterize historical OMR flow since it includes the fullest range of water year types available since the completion of the Banks pumping plant. Historic OMR flow data from 1987-2007 were taken from measured flow stations (Arthur et al. 1996; www.iep.water.ca.gov/dayflow). Historic OMR flow from 1967 to 1987 was modeled from combined Jones and Banks exports and San Joaquin River flow (Ruhl et al. 2006). The median OMR flow for each winter period was derived from daily data values for the historic data and from the monthly values from the CALSIM II model studies.

Methods used to evaluate Project effects

As was done in the Biological Assessment (Reclamation 2008, Chapter 13), we have not attempted to separate the effects of SWP and CVP. The hydrodynamic effects of pumping that cause reverse OMR flow result from the combined action of both facilities. Finally, we have not attempted to estimate total entrainment of delta smelt at the facilities. To date, no studies have been done to evaluate pre-screen losses at the export facilities, and this analytical approach does not support the kind of population-level inferences drawn in Kimmerer (2008) and similar work. Rather, we use salvage as an index of numerical adult smelt entrainment at the facilities.

To quantitatively predict entrainment of delta smelt, we used a linear model (Grimaldo et al. in review) to predict annual winter salvage for each CALSIM II Study. The predictions in this model do not capture the variability (i.e., peaks and valleys) of historical salvage but they it do follow the trend that salvage increases as OMR flows decreases. In part, the variation is not captured because entrainment is not solely explained by OMR flows. Entrainment is also related to the number of adults that migrate into the vicinity of the projects. Although water year type may sometimes affect the spawning distribution (Sweetnam 1999), there is wide, apparently random variation in the use of the central and south delta by spawning delta smelt. For example, there are years when a greater proportion of the smelt population moves into the vicinity of the export facilities, which may lead to larger salvage events. In critical dry years, smelt often migrate into the North Delta (Sweetnam 1999) where entrainment risks would be low in such years when exports are generally small. Leaving aside differences due to spawning migration variability, the approach used here provides an expected salvage given an OMR flow. The percent differences between historic winter salvage and predicted winter salvage from modeled studies were examined for each water year.

To evaluate whether the proposed operations will have adverse impacts on the pre-spawning adult smelt population, we calculated the likelihood that take would exceed thresholds the Smelt Work Group (SWG) has historically regarded as detrimental to the population and the Service has adopted this approach. For this analysis, we calculated the historic median in salvage (1987-2007) with 25th and 75th percentiles and plotted them versus the preceding FMWT RI as the basis for evaluating salvage (Figure 3). The RI provides an indication of the status of the delta smelt population based on distributional and abundance criteria from a subset of September and October FWMT sampling (USFWS 1995). A low RI indicates the delta smelt population is at low levels, whereas a high RI value (~400) indicates a more robust population. We used years 1987 to 2007 as the historic baseline dataset for this analysis because they represent the period after which delta smelt experienced coincident declines in habitat and abundance (Feyrer et al. 2007). The Service has regarded the 25th percentile of recent historic winter salvage (1132 for 1987-2007 data) as a guideline for adverse impact when the previous RI is less than 29 (25th percentile of the RI index value) and the median (2046 fish for 1987-2007 data) when RI is greater than or equal to 29 and less than 71 (Figure 3). Salvage above these levels is likely to lead to large losses of spawners respective of their population size. For example, in 2003 and 2004, the projects salvaged 14,323 and 8,148 delta smelt respectively. These losses are disproportionately high (i.e., greater than the 75th percentile of historical salvage) for their given RI values, 33 (2003) and 101 (2004). According to Kimmerer (2008), 2003 and 2004 were years when entrainment accounted for 50% and 19 % losses of adults from the population.

To estimate whether the historic median (median with 25th and 75th percentiles) would be exceeded under proposed OMR flows, we analyzed historic annual winter salvage and OMR flow data using logistic regression for different levels of exceedance. The event probabilities for each level were plotted against OMR flow and fitted with smoother lines (Figure 4). This graph was used to estimate the probability that the modeled OMR flows will exceed the specified level of salvage. Note, this graph indicates that the probability of salvaging between 0 and 1132 smelt in any year is greater than 90%. In part, this is because some smelt are able to migrate upstream during periods of high total inflow and are entrained even during periods of positive OMR flow (i.e., 1997 and 1998) .

We note that the analysis here uses 1987-2007 data to establish numerical salvage quantiles. This approach does not take into account the overall downtrend in delta smelt abundances that has exists in the historical data. A future version of this analysis will statistically scale the expected salvage range to account for trend, and will include a comparison of impact predictions derived from this analysis with entrainment estimates from Kimmerer (2008), which uses a different method.

CVP and SWP Effects

The median OMR flows from the CalSim-II modeled scenarios were more negative than historic OMR flow for all water year types except critically dry years (Figure 3; see Table 3b for all differences). The most pronounced differences occur during wet years, where median OMR flows are projected to be approximately 400 to 600 % (-7100 to -3678 cfs) higher than historical wet years (-1032 cfs). Correspondingly, this decrease in OMR flow is predicated to cause up to a 65 % increase in smelt salvage and therefore a substantial adverse effect to delta smelt in wet years when salvage levels have been generally low (see years 1995-1999 in Baseline Salvage Figure X). Proposed project operations for studies 7.0, 7.1, 8.0, 9.0, 9.1, 9.4, and 9.5 (median OMR flows -7100 to -5265 cfs) will result in an approximately 50 % probability that salvage will exceed 5000 fish. This level of salvage would cause significant adverse affects to delta smelt given recent RI values have extremely low in recent years (2005=4, 2006 =21, 2007 = 5).

The proposed operation conditions likely to have the greatest impact on delta smelt are those modeled during above normal water years. The modeled OMR flows for the above normal water years ranged between -8155 and -6242 cfs, a 33 to 57% decrease from the historic median of -5178 cfs. Though the predicted salvage would only be about 15-20 % higher than historic salvage during these years (Table 3c), the modeled OMR flows would likely lead to significant population losses. The probability of salvage exceeding 7000 delta smelt would be approximately 48 % at -6242 cfs and approximately 80% at -8155 cfs. Therefore, salvage during above normal water years are projected to cause significant adverse affects to delta smelt for any RI value but particularly substantial given that current RI values have remained less than 22 since 2005.

In below normal and dry water years, proposed OMR flows are also modeled to decrease from historic medians. Predicated salvage levels are likely to increase between 2 and 44 %. More importantly, the modeled median flows from all studies in these water year types range between -5747 and -7438 cfs. Modeled OMR flows at these levels have a greater than 50 % probability of exceeding 5000 fish, and near 75 % probability of exceeding 2000 fish. Given that the population is at near record-low abundance, salvage during below normal and dry water years is likely to range from marginal to significant adverse affects given the current level of RI values.

During critically dry years, the median OMR flows for studies 7.0, 7.1, 8.0, 9.1, 9.4, and 9.5 are less than -5,000 cfs. These studies have predicted salvage lower than historic salvage. Though the event probability is still near a 70 % chance of salvage exceeding 2000 smelt, the models might overestimate salvage during critical dry years when smelt are unlikely to migrate towards the interior delta due to lack of turbidity or first flush. Thus, the effects of critical dry operations on delta smelt take are probably small and lower than estimated.

In summary, adult entrainment is likely to be higher than it has been in the past under most operating scenarios, resulting in lower potential production of early life history stages in the spring in some years. While the largest predicted effects occur in Wet and Above Normal years, there are also likely adverse effects in Below Normal and Dry years. Only Critically Dry years are generally predicted to have lower entrainment than what has occurred in the recent past.

Table 3a. Historic and CALSIM II modeled median winter (Dec-Mar) OMR flows by water year type

Water year type	Historic	7	7.1	8	9	9.1	9.2	9.3	9.4	9.5
Wet	-1033	-5256	-5498	-5699	-5684	-5500	-3999	-3678	-7066	-6100
Above Normal	-5178	-7209	-7923	-8073	-8156	-7595	-6863	-6934	-7861	-7723
Below Normal	-2405	-6461	-7208	-7009	-6599	-6420	-5647	-6736	-6721	-6343
Dry	-5509	-6443	-6931	-6692	-6620	-6353	-6831	-7438	-5785	-5760
Critical	-5037	-4547	-4931	-4980	-5051	-4588	-5320	-5194	-4260	-3845

Table 3b. Winter OMR Flow percent difference from historic median value to CALSIM II model median value

Water year type	7	7.1	8	9	9.1	9.2	9.3	9.4	9.5
Wet	408.92%	432.37%	451.84%	450.36%	432.50%	287.16%	256.13%	584.15%	490.63%
Above Normal	39.21%	53.01%	55.90%	57.49%	46.67%	32.53%	33.91%	51.80%	49.13%
Below Normal	168.62%	199.68%	191.41%	174.35%	166.90%	134.75%	180.05%	179.42%	163.72%
Dry	16.95%	25.81%	21.48%	20.17%	15.32%	24.01%	35.02%	5.01%	4.57%
Critical	-9.74%	-2.12%	-1.14%	0.27%	-8.92%	5.61%	3.11%	-15.44%	-23.68%

Table 3c. Percent difference from historic median salvage to predicated salvage based on Dec-Mar OMR flows from CALSIM II studies

Water year type	Study 7	Study 7.1	Study 8	Study 9	Study 9.1	Study 9.2	Study 9.3	Study 9.4	Study 9.5
Wet	45.64%	48.26%	50.43%	50.26%	48.27%	32.05%	28.59%	65.20%	54.76%
Above Normal	15.15%	20.49%	21.60%	22.22%	18.04%	12.57%	13.10%	20.02%	18.99%
Below Normal	38.17%	45.20%	43.33%	39.46%	37.78%	30.50%	40.76%	40.61%	37.06%
Dry	6.80%	10.36%	8.62%	8.09%	6.15%	9.63%	14.05%	2.01%	1.83%
Critical	-3.70%	-0.81%	-0.43%	0.10%	-3.39%	2.13%	1.18%	-5.87%	-9.00%

Article 21

The CALSIM II modeling, as shown in the biological assessment, does not simulate two major South of the Delta storage facilities, the Kern Water Bank and Diamond Valley Lake. As shown in Table X of the Project Description, both of these facilities have been used to store water moved under Article 21. As such, the full effects of Article 21 pumping are not accurately represented by the modeling. The modeling assumptions assume that Article 21 water demand would be 314 TAF for each month December through March and up to 214 TAF per month in all other months. As shown in the project description in Figure X, there has been an increase in state water pumping corresponding to an increase of the use of Article 21. This increased pumping at the SWP from the year 2000 to present corresponds to the recent declines in the smelt population, currently being studied by the IEP. This pumping is included in the exports at Banks, and the effects to delta smelt are described in the adult entrainment effects section. However, as described above, the modeling under estimates these effects and the amounts of water that would be moved to SOD storage facilities. The previous section showed that the proposed project would result in increased adult entrainment during winter.

The export of Article 21 appears to be one of the factors that increase entrainment in the months of December through March, demonstrated by the large increases of pumping at Banks. The highest amounts of Article 21 water are pumped in the months when adult delta smelt entrainment is also highest. The 2004 OCAP biological assessment and the Service's 2005 biological opinion only considered Article 21 pumping to occur during wet and above normal water years and the analysis stated this would be an infrequent occurrence. However, from 2004 to 2007, Article 21 has been used in more than in the wet years. The effects of pumping of Article 21 water to adult delta smelt would be most severe during below normal and dry years. Even though Article 21 may not be called often in these water types, San Luis Reservoir can be filled in dryer years (for example if the preceding year was wet). It is during these types of years that the increased pumping associated with Article 21 would have the most detrimental effects to delta smelt and significant adult entrainment may occur.

DMC-CA Intertie

As described in the Project Description, the DMC-CA Intertie would provide operational flexibility between the DMC and the CA. In the CALSIM II modeling, Jones pumping capacity increases from 4,200 cfs in Study 7.0 to 4,600 cfs in Study 8.0. While the specific effects of the intertie on delta smelt cannot be separated out from the analysis, the increased capacity of the Jones pumping plant is included in the adult entrainment effects described above and can result in higher entrainment of adult, larval and juvenile delta smelt at Jones. In addition, increase pumping at Jones can have indirect effects to delta smelt by entraining their food source and reducing their available habitat, as described in the habitat suitability section of this effects analysis.

Effects of the NBA

In general, NBA diversions are highest during the winter months. Diversion rates for study 8 in December (64 cfs) were higher than diversion rates for studies 7.0 (43 cfs). The hydrodynamic modeling of NBA diversions indicates that the majority of water diverted originates from Cambell Lake and Calhoun Cut during the winter. As previously mentioned, delta smelt migrate into the Delta during the winter months. However, since the screens on the intakes meet criteria for protecting 25 mm SL delta smelt, adult entrainment is not a concern.

In some years, delta smelt begin spawning in February when temperatures reach about 12°C (Bennett 2005). Thus in some years, delta smelt larvae may be entrained at the NBA diversions. However, since the majority of water diverted originates from Cambell Lake during the winter, this effect is likely to be minimized to Barker Slough near the NBA intakes. During years when the Yolo Bypass floods, the entrainment risk of larvae into the NBA is also probably extremely localized because of a hydrodynamic "plug" that forms between Barker and Lindsay sloughs with Cache Slough. When this happens, hydrodynamic mixing between Cache Slough and Lindsay/Barker sloughs decreases, causing spikes in turbidity and organic carbon in Barker and Lindsay Sloughs (DWR, North Bay Aqueduct Water Quality Report). Entrainment vulnerability would be greatest during dry years when the NBA diversions entrain a large portion of water from Barker and Lindsay Sloughs and are often years when delta smelt spawn in the North Delta (Sweetnam 1999). The fish screen at the NBA diversion was designed to exclude delta smelt larger than 25 mm. However, a study of a fish screen in Horseshoe Bend built to delta smelt standards excluded 99.7 percent of fish from entrainment even though most of these were only 15-25 mm long (Nobriga et al. 2004). Thus, the fish screen at NBA may protect many, if not most of the delta smelt larvae that do hatch and rear in Barker Slough.

CCWD diversions

As described in the Project Description, CCWD diverts water from three different intakes in the Delta. For the proposed project, water demands of the CCWD were anticipated to increase from 135 TAF/year in study 7.0 to 195 TAF/year in study 8.0.

Old River intake

CCWD currently diverts water using the Old River intake for its supplies directly from the Delta. In addition, when salinity is low enough, Los Vaqueros Reservoir is filled at a rate of up to 200 cfs from the Old River Intake. However, since this facility is fully screened to meet delta smelt fish screening criteria, adult entrainment is not a concern.

Rock slough

The Rock Slough Intake is presently unscreened. As described in the Project Description, Reclamation is required to screen this diversion and is seeking an extension for the completion of the fish screen.

Catches of delta smelt at the Rock Slough diversion are low based on sampling conducted using a sieve net three times per week from January through June and twice per week from July through December and using a plankton net at the headworks structure twice per week during times larval delta smelt could be present in the area (generally March through June). The numbers of delta smelt entrained by the facility since 1998 have been extremely low based on this monitoring, with only a single fish taken in February 2005. Most water diversions at the Rock Slough intake now occur during the summer months, so adult delta smelt entrainment is not likely to be high. In addition, Rock Slough is a dead-end slough with poor habitat for delta smelt, so the numbers of delta smelt using Rock Slough are usually low.

Alternative intake

Total entrainment at CCWD's facilities is likely to be reduced when the CCWD's Alternative Intake Project is completed. This diversion is going to be screened according to delta smelt fish screening criteria and will likely reduce unscreened diversions from the unscreened Rock Slough diversion. Because the Alternative Intake diversion is fully screened, adult delta smelt entrainment is not likely to be high.

Suisun Marsh Salinity Control Gates

The SMSCG is generally operated as needed September through May to meet State salinity standards in the marsh. The number of days the SMSCG are operated in any given year varies. Historically, the SMSCG were operated 60-120 days between October and May (1988-2004). With increased understanding of the effectiveness of SMSCG in lowering salinity in Montezuma Slough, salinity standards have been met with less frequent gate operations. In 2006 and 2007, the gates were operated periodically between 10-20 days annually. It is expected that this level of operational frequency (10-20 days per year) will continue in the future.

The SMSCG do not kill delta smelt. It is possible, however, for delta smelt and other fishes to be entrained behind the SMSCG in Montezuma Slough and Suisun Marsh when the SMSCG is closed. Fish may enter Montezuma Slough from the Sacramento River when the gates are open to draw freshwater into the marsh and then may not be able to move back out when the gates are closed. It is not known whether this harms delta smelt in any way, but they could be exposed to predators hovering around the SMSCG or they could have an increased risk of exposure to water diversions in the marsh (Culberson et al. 2004). It is possible that if delta smelt are indeed entrained into Montezuma slough and Suisun Marsh that they may be more vulnerable to water diversion such as DWR's MIDS. Entrainment into MIDS from the Sacramento River may be unlikely based on particle tracking studies have demonstrated low entrainment vulnerability for particles released at random locations throughout Suisun Marsh (3.7 percent), and almost no vulnerability (<0.1 percent) to particles released at Rio Vista (Culberson et al. 2004). Moreover, fish entrainment monitoring at MIDS showed very low entrainment of delta smelt (one larva in 2.3 million m^3 of water sampled over a two-year period) because salinity in Suisun Slough was usually too high for delta smelt when the MIDS diversion needed to operate (Enos et al. 2007). The degree to which movement of delta smelt around the low-salinity zone is constrained by opening and closing the SMSCG is also unknown.

Indirectly, operations of the SMSCG may influence delta smelt habitat suitability and entrainment vulnerability. When the SMSCG are opened, the draw of freshwater into the marsh effectively moves the Suisun Bay salinity field upstream. In some years, the salinity field indexed by X2 may be shifted as far as 3 km upstream. Thus, depending on the tidal conditions during and after gate operations, X2 may be transported upstream nominally about 20 days per year. The consequence of this shift decreases smelt habitat and moves the distribution of smelt upstream (Feyrer et al. 2007; see smelt habitat effects section). Because juvenile smelt production decreases when X2 moves upstream during the fall (Feyrer et al. 2007), any attributable shift in X2 between September to November (December during low outflow years) caused by operations of SMSCG can be a concern. However, a 3-km shift in X2 happening 20 days per year is far less significant than the 10-20 km shifts that have occurred for up to 120 or more days per year during late summer through early winter due to south Delta diversions (see habitat effects section below).

During January through March, most delta smelt move into spawning areas in the Delta. Grimaldo et al (in review) found that prior to spawning entrainment vulnerability of adult delta smelt increased at the SWP and CVP when X2 was upstream of 80 km. Thus, any upstream shift in X2 from SMSCG operations may influence entrainment of delta smelt at the CVP and SWP, especially during years of low outflow or periods of high CVP/SWP exports. However, between January and June the SWP and CVP operate to meet the X2 standards in D-1641, thus the effects of the SMSCG on X2 during this period are negligible. Therefore, SMSCG operations from January to May are not likely to affect entrainment vulnerability. In addition, because delta smelt move upstream between December and March, operations of the SMSCG are unlikely to adversely affect delta smelt habitat suitability during this period.

Larvae and Juvenile Delta Smelt (~ March-June)

Water Diversions and Reservoir Operations

Banks and Jones

Larval and juvenile delta smelt are free-swimming and pelagic; they do not associate strongly with structure or shorelines. Delta smelt use a variety of swimming behaviors to maintain position within suitable habitats – even in regions of strong tidal currents and net seaward flows (Bennett et al. 2002). Since the water exported during spring and early summer (mainly March-June) from the central and south Delta is suitable habitat, young delta smelt do not have a cue to abandon areas where water is flowing toward Banks and Jones. Combinations of Delta inflows and export flows or variables like Delta outflow and OMR are good predictors of larval and young juvenile delta smelt entrainment (Kimmerer 2008). This effects analysis evaluates the proposed project operations by exploring long-term trends in Delta outflow, or X2, and OMR flows during March-June and comparing these to hydrodynamic conditions expected based on CALSIM II modeling presented in the Biological Assessment. The analysis uses the larval-juvenile entrainment estimates provided by Kimmerer (2008) and flow and export projections from the Biological Assessment to estimate the annual percentages of the larval/juvenile delta smelt population expected to be entrained.

This section examines the effects of entrainment on larval and juvenile delta smelt during the months of March-June. The analysis is based on comparison of historical trends in OMR, Delta outflow and X2 to the proposed project's predictions of these variables provided in the biological assessment for studies 7.0, 7.1, 8.0, and 9.0-9.5. The hydrologic data are examined in light of recent estimates of larval/juvenile delta smelt entrainment (Kimmerer 2008) that are reproduced well by Delta outflow (or X2) and OMR (Figure 7). All analyses examine two sets of spring months; March-June, which encompasses most of the spawning season and April-May, which encompasses the empirical hatch dates of most fish surviving to the fall in recent years (Bill Bennett, UC Davis, unpublished data). Note that OMR was empirically measured during 1980-2006 using Acoustic Doppler Current Profilers installed in Old and Middle rivers (Oltmann 1998). The OMR values for 1967-1979 and for 2007 were estimated using a regression relationship (Cathy Ruhl, USGS, pers. comm). All Delta outflow and X2 data were retrieved from DAYFLOW.

Kimmerer (2008) proposed a method for estimating the percentage of the larval-juvenile delta smelt population entrained at Banks and Jones each year. These estimates were based on a combination of larval distribution data from the 20 mm survey, estimates of net efficiency in this survey, estimates of larval mortality rates, estimates of spawn timing, particle tracking simulations from DWR's DSM-2 particle tracking model, and estimates of Banks and Jones salvage efficiency for larvae of various sizes. Kimmerer estimated larval-juvenile entrainment for 1995-2005. We used Kimmerer's entrainment estimates to develop multiple regression models to predict percent of the larval-juvenile delta smelt population entrained based on a combination of X2 and OMR. We developed two separate models, one for the March-June averaging period and one for the April-May averaging period. The equations are: March-June percent entrainment = (0.00933*March-June X2) + (0.0000207*March-June OMR) – 0.556 and April-May percent entrainment = (0.00839*April-May X2) + (0.000029*April-May OMR) – 0.487. The adjusted R^2 on these equations are 0.90 and 0.87, respectively. These equations were used to predict historical springtime entrainment (1967-1994 and 2006-2007). Note that 1995 and 1998, which were both very high flow years with 0 percent predicted entrainment were not included in the regression because they resulted in significant nonlinearity. Thus, the resulting equations predict negative entrainment in similarly wet years. The negative estimates were assumed to represent 0 percent entrainment for the analysis.

We also used the above-mentioned regression equations to predict larval-juvenile entrainment based on the hydrologic predictions provided in the Biological Assessment. We used this to compare relative entrainment effect across the CALSIM II studies.

Historical Data (1967-2007)

Combined Old and Middle River flow

There has been no clear long term trend in OMR for either the March-June or April-May averaging periods (Figures 6-7). Since the early 1990s, minimum OMR flows during April-May have been higher (less negative) than 1967-1990 (Figure 7).

Delta outflow

Delta outflows generally declined from 1967-1990, but Delta outflows have generally been higher and comparable to 1970s levels since 1990. This is true for both the March-June and April-May averaging periods (Figures 8-9). Since the early 1990s, minimum Delta outflows flows during April-May have usually been slightly higher than 1967-1990. This is likely due to the combination of the X2 standard and the VAMP pulse flow.

Relationship between Delta outflow and OMR

There is a positive correlation between Delta outflow and OMR, but the relationship is not quite linear (Figures 10-11). Regardless of averaging period, OMR tends to be negative and unresponsive to outflow until outflow exceeds about 50,000 cfs (representing X2 seaward of Roe Island). At outflows higher than 50,000 cfs, the outflow-OMR relationship is approximately linear.

Predicted entrainment

Predicted entrainment is a function of both X2 and OMR, therefore higher flows and lower exports translate into lower entrainment of delta smelt. Predicted larval-juvenile entrainment was often higher prior to the implementation of the X2 standard in 1995 than it has been currently (Figure 16). The predictions for entrainment range from 0 to about 40 percent for 1967-1994 and 0 to about 30 percent for 1995-2007. However, the upper confidence limits reach substantially higher levels, ranging from 0 to about 65 percent between 1967 and 1994 and 0 to about 40 percent during 1995-2007. The effect of the X2 standard on larval-juvenile entrainment can be seen in Figure 17. The frequency of years in which 0 percent-10 percent of the larval-juvenile population was estimated to have been entrained was similar between 1967-1994 and 1995-2005 because wet years have always pushed X2 far downstream resulting in delta smelt distributions distant from the influence of the SWP and CVP diversions. However, there are substantial differences between the 1967-1994 and 1995-2005 time periods in terms of how frequently larger percentages of the larval-juvenile population was entrained. For instance, it is estimated that less than 20 percent of the larval-juvenile population was entrained in 67 percent of years from 1995-2005, but only 44 percent of years from 1967-1994 (Figure 17). Further, predicted entrainment sometimes exceeded 30 percent during 1967-1994, but was never that high during 1995-2005. Note that we did not attempt to carry the confidence limits on entrainment estimates through these calculations. See Figure 16 for estimates of the confidence intervals.

Proposed Project Operations

Combined Old and Middle River flow

The Biological Assessment proposes that Banks and Jones pumping will cause March-June OMR flows to be more negative than 1967-2007 in wet and above normal years and will cause April-May OMR flows to be more negative than 1967-2007 wet years (Figures 12-13). It is also anticipated there will be less variation in OMR during these time periods than there was historically in wet and above normal years. The predicted OMR flows are predicted to be higher (hovering near 0 cfs on average) in dry and critical years. This is true for both averaging periods. These patterns do not change in the climate change scenarios.

X2

Most of the projected operations result in average March-June and average April-May X2 that are further downstream than historical (Figures 14-15). As stated previously, this is likely due to the full implementation of the X2 standard and VAMP export reduction in projected operations. The exception is wet years. In wet years, projected X2 is generally very similar to historical in both averaging periods except that the boxplots indicate no occurrences of X2 further downstream than 50 km. This is probably due to the proposed decreases in wet year OMR flows (Figures 6 and 7). The climate change scenarios predict April and May X2 will be further downstream in dry and critical years, but the differences are modest (< 5 km) and again likely due primarily to the modeling assumptions of meeting the X2 standard and providing an export reduction during VAMP.

Effects of forecasted operations

Note that we did not attempt to carry the confidence limits on entrainment estimates through these calculations. See Figure 16 for estimates of the uncertainty surrounding the following. The Biological Assessment's assumptions of a continued X2 standard and an EWA-related export reduction during April-May, keep the frequency of years with larval-juvenile entrainment higher than 20 percent consistent with 1995-2005 expectations regardless of operational assumptions (Figure 18). However, the proposed project will decrease the frequency of years in which estimated entrainment is ≤ 15 percent. Thus, over a given span of years, the project as proposed will increase larval-juvenile entrainment relative to 1995-2005 levels. This will have an adverse effect on delta smelt based on their current low population levels.

Article 21

See previous effects discussion

VAMP

VAMP which is described in the Project Description and the Status and Baseline Sections, provides benefits to larval and juvenile delta smelt. As described in the Status and Baseline Section of this opinion, Bennett (unpublished analysis) proposes that reduced spring exports resulting from VAMP has selectively enhanced the survival of delta smelt larvae that emerge during VAMP by reducing direct entrainment.

Since VAMP is an experiment, it is only projected to continue until 2009. As described in the Project Description, after VAMP ends, Reclamation has committed to maintaining the export curtailment portion of the VAMP experiment. Since VAMP also contains a San Joaquin River flow component, the maintaining the export curtailment after the end of the VAMP experiment ends is not expected to provide the same benefits as the complete VAMP experiment. In order for delta smelt produced during the VAMP period to survive to the Fall, the export curtailments and the VAMP flows would be needed to protect larval and juvenile delta smelt from becoming entrained.

In the Project Description, DWR will continue the export reductions at Banks as long as there assets available from the Yuba Accord Water Transfer. Because the export reductions may cost more than the Yuba Accord provides, the export curtailments at Banks may be smaller and therefore provide less benefit to larval and juvenile delta smelt. Also, as mentioned above, the export reductions at Jones and Banks are only part of VAMP, and the Vernalis flow is also important for protection of delta smelt.

Intertie

See previous effects discussion

Effects of the NBA

In the modeling, the only difference in NBA diversions during the spring were for April, where study 8.0 had an approximately 20 percent higher diversion rate than study 7.0 (Reclamation 2008). NBA diversions ranged between 30 and 54 cfs during the spring, indicating that the majority of water diverted originates from Campbell Lake at these diversions rates. Thus a 20 percent increase in Study 8 from Study 7.0 may have minimal effects when you account for the source of water diverted. Overall, spring (March –June) represents the period of greatest entrainment risk for delta smelt larvae at the NBA, especially in dry years when delta smelt spawn in the North Delta. As described above, based on Nobriga et al. 2004, the fish screen at NBA may protect many, if not most of the delta smelt larvae that do hatch and rear in Barker Slough.

CCWD diversions

Old River intake

While the Old River diversion is screened to protect adult delta smelt, all CCWD diversions implement additional fishery protection measures to protect larval smelt which may be entrained. These measures consist of a 75-day period during which CCWD does not fill Los Vaqueros Reservoir and a concurrent 30-day period during which CCWD halts all diversions from the Delta, provided that Los Vaqueros Reservoir storage is above emergency levels. The default dates for the no-fill and no-diversion periods are March 15 through May 31 and April 1 through April 30, respectively; the Service, NMFS and DFG can change these dates to best protect the subject species. Larval fish may occur at this facility outside of the no-fill and no-diversion periods, and may be subject to entrainment. However, larval fish monitoring behind the screens has shown very few larval fish become entrained (Reclamation 2008) and as stated above for the NBA, the fish screens at this facility may protect fish smaller than the screens' designs.

Rock Slough

While most water diversions at the Rock Slough intake now occur during the summer months, the Rock Slough diversion is also subject to the no-fill and no-diversion periods that all CCWD diversions are operated under. Like the Old River diversion, larval fish may occur at this facility outside of the no-fill and no-diversion periods, and may be subject to entrainment. Since the Rock Slough diversion is not screened, larval entrainment at this facility may be a concern., However, larval fish monitoring behind the headworks has not shown that large numbers of larval fish become entrained (Reclamation 2008).

Alternative intake

Like the Old River diversion, the Alternative intake is screened to protect adult delta smelt from entrainment. Again, since larval smelt are not protected by these fish screens, the Alternative intake will also operate to the no-fill and no-diversion periods to protect larval fish from entrainment. Like the other two diversions, larval fish may occur at this facility outside of the no-fill and no-diversion periods, and may be subject to entrainment. Larval fish may also become entrained at this facilitiy, but as stated above for the NBA, the fish screens at this facility may protect fish smaller than the screens' designs.

South Delta Temporary Barriers

Hydrodynamic Effects

The TBP does not alter total Delta outflow, or the position of X2. However, the TBP causes changes in the hydraulics of the Delta, which may affect delta smelt. The HORB blocks San Joaquin River flow, which prevents it from entering Old River at that point. This increases the flow toward Banks and Jones from Turner and Columbia cuts, which can increase the predicted entrainment risk for particles in the east and central Delta by up to about 10 percent (Kimmerer and Nobriga 2008). In most instances, net flow is directed towards the Banks and Jones pumps and local agricultural diversions. The directional flow towards the Banks and Jones increases the vulnerability of fish to entrainment. Larval and juvenile delta smelt are especially susceptible to these flows.

The varying operational configurations of the TBP, natural variations in fish distribution, and a number of other physical and environmental variables limit statistical confidence in assessing fish salvage when the TBP is operational versus when it is not. In 1996, the installation of the spring HORB caused a sharp reversal of net flow in the south Delta to the upstream direction. Coincident with this change was a strong peak in delta smelt salvage (Nobriga et al. 2000). This observation indicates that short-term salvage can significantly increase when the HORB is installed in such a manner that it causes a sharp change or reversal of positive net daily flow in the south and central Delta. The physical presence of the TBP may attract piscivorous fishes and influence predation on delta smelt. However, past studies by the DFG TBP Fish Monitoring Program indicated that predation is negligible (DWR 2000a).

Vulnerability to Local Agricultural Diversions

Fish that may become trapped upstream of the TBP agricultural barriers may suffer increased vulnerability to local agricultural diversions. However, the risk of entrainment (Kimmerer and Nobriga 2008) or death from unsuitable water quality (as inferred from lack of occurrence in the south Delta during summer; Nobriga et al. 2008) is so high for delta smelt trapped in the south Delta that loss to irrigation diversions in this region is moot.

Effects to Potential Fish Prey Items

The extent to which the distribution and abundance of delta smelt prey organisms is influenced by the conditions posed by the TBP is difficult to determine. Because the TBP does not influence the position of X2, organisms that exhibit a strong abundance-X2 relationship (i.e. mysid shrimp) (Jassby and others 1995), will not be affected. However, the barriers might influence the flux of *Pseudodiaptomus* from the Delta to the low-salinity zone.

South Delta Permanent Operable Gates

Hydrodynamic Effects

As described in the Project Description, the South Delta Permanent Operable Gates (Operable Gates) are expected to be constructed in late 2012. The Operable Gates are expected to operate during similar time periods as the TBP, with the gate closing starting in April and operating thorough the winter. The Head of Old River Gate would operate in April and May and in the fall.

The effects of the Operable Gates are expected to be similar to the effects of the TBP. The Operable Gates will open daily to maintain water levels at 0.0 foot mean sea level in Old River near the Jones pumping plant, and these daily openings would provide passage for delta smelt. Like the TBP, the operations of the Operable Gates are not expected to decrease Delta outflows, but the increase in entrainment risk at Banks and Jones is expected to remain the same. Also, OMR flows would be affected by the Operable Gates and may result in more negative OMR flows which could further lead to entrainment.

If the Operable Gates are operated during periods when the TBP have not been installed, additional effects to delta smelt could occur. For example, if the Operable Gates are closed during the winter (December through March), flow cues from the San Joaquin River may be disrupted and may affect adult delta smelt migration into the Delta. Also, if the Operable Gates are closed during this period, the available habitat for delta smelt would be reduced. The south Delta can be suitable habitat for delta smelt in some years; if this habitat is inaccessible to the delta smelt due to the Operable Gates being closed, adverse effects to the delta smelt and their habitat would occur.

Vulnerability to Local Agricultural Diversions

Delta smelt would be affected similarly as with the TBP although delta smelt may be less susceptible to entrainment at local agricultural diversion since the Operable Gates are likely to be opened more often. As described above, the risk of entrainment or death from unsuitable water quality is so high for delta smelt trapped in the south Delta that loss to irrigation diversions in this region is moot.

Effects to Potential Fish Prey Items

These effects would be the similar as for the TBP, but may be 1less affected since the Operable Gates will be open more than the TBP.

Suisun Marsh Control Gates

See previous effects discussion

American River Demands

In Study 8.0, total American River Division annual demands on the American and Sacramento Rivers are estimated to increase from about 324,000 acre-feet in 2005 to 605,000 acre-feet in 2030, without the Freeport Regional Water project maximum of 133,000 acre-feet during drier years. These increases in demands and diversions are included in the modeling results and are therefore included in the Habitat Suitability sections.

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Delta Cross Channel

The DCC will be closed for fishery protection as described in the Project Description. These actions are not expected to change in the future. The effects of the DCC are included in the CALSIM II modeling results and are included in the Habitat Suitability section.

Juveniles and adults (~ July-December)

Entrainment of *Pseudodiaptomus forbesi*

Entrainment of *Pseudodiaptomus forbesi* (June-September)

Historically, the diet of juvenile delta smelt during summer was dominated by the copepod *Eurytemora affinis* and the mysid shrimp *Neomysis mercedis* (Moyle et al. 1992; Feyrer et al. 2003). These prey bloomed from within the estuary's low-salinity zone and were decimated by the overbite clam *Corbula amurensis* (Kimmerer and Orsi 1996), so delta smelt switched their diet to other prey. *Pseudodiaptomus forbesi* has been the dominant summertime prey for delta smelt since it was introduced into the estuary in 1988 (Lott 1998; Nobriga 2002; Hobbs et al. 2006). Unlike *Eurytemora* and *Neomysis*, *Pseudodiaptomus* blooms originate in the freshwater Delta (John Durand San Francisco State University, oral presentation at 2006 CALFED Science Conference). This freshwater reproductive strategy provides a refuge from overbite clam grazing, but *Pseudodiaptomus* has to be transported to the low-salinity zone (LSZ) during summer to co-occur with most of the delta smelt population. This might make *Pseudodiaptomus* more vulnerable to pumping effects from the export facilities than *Eurytemora* and *Neomysis* were. Therfore, the projects have more effect on the food supply available to delta smelt than they did before the overbite clam changed the low-salinity zone food web.

There is statistical evidence suggesting that the co-occurrence of delta smelt and *Pseudodiaptomus forbesi* has a strong statistical influence on the survival of young delta smelt from summer to fall (Miller 2007). In addition, recent histopathological evaluations of delta smelt have shown evidence of heat stress/food limitation in delta smelt during the summer (Bennett 2005 and Bennett et al. 2008 as summarized by Nobriga and Herbold 2008).

Most quantitative sections of this effects analysis use OMR as a predictor variable. This analysis evaluates the proposed project operations by comparing the long-term trends in the E:I ratio during June-September relative to conditions expected based on CalSim II modeling. The E:I ratio is a useful metric of factors like entrainment risk and residence time that reflect the transport of particles among regions of the Delta (Kimmerer and Nobriga 2008). A recent study of tidal and daytime versus nighttime movements of fish and zooplankton in Old River did not find any evidence that *Pseudodiaptomus* used behaviors in Old River that would prevent its entrainment or render particle tracking model outputs based on simulations using neutrally-buoyant particles inappropriate to predict the relative effect of proposed operations (Lenny Grimaldo, USBR, unpublished data).

The Interagency Ecological Program's Environmental Monitoring Program has conducted zooplankton surveys in the estuary since 1974. We used these data, along with data on historic project operations, to investigate whether there has been a demonstrable effect of the water projects on *P. forbesi* availability to delta smelt during the summer. During summer delta smelt occur mainly in the LSZ near the Sacramento-San Joaquin River confluence (Nobriga et al. 2008). Due to retention and entrainment of *P. forbesi* to the south Delta by the export pumps, we expected an inverse relationship between E:I and the abundance of *P. forbesi* in Suisun Bay during the summer.

We determined the average monthly catch per unit effort (CPUE) for *P. forbesi* for June-September 1988-2006 at each station in two regions, Suisun Bay (stations NZD 06, NZO 28, NZO 32, NZS 42, NZO 42, and NZO 48) and the south Delta (NZM 10, NZD 28, NZO 86, and NZO 92). The monthly average CPUEs were then grouped into regional average CPUEs. We expected to see two things in the data. First, that *Pseudodiaptomus* densities would be higher in the south Delta region than in Suisun Bay because the Delta is the production region, and second, that *Pseudodiaptomus* densities in Suisun Bay would be inversely related to the summertime E:I ratio because it represents hydrodynamic influence on particle residence time and entrainment (Kimmerer and Nobriga 2008).

The summertime density of *Pseudodiaptomus* is generally higher in the south Delta than in Suisun Bay. The ratio of south Delta *Pseudodiaptomus* density to Suisun Bay *Pseudodiaptomus* density was greater than one in 73 percent of the collections from June-September 1988-2006. The average value of this ratio is 22, meaning that on average summer *Pseudodiaptomus* density has been 22 times higher in the south Delta than Suisun Bay. Densities in the two regions are not correlated ($P > 0.30$). This demonstrates that the presence of high copepod densities in the south Delta do not necessarily occur simultaneously in Suisun Bay. The density of *Pseudodiaptomus* appears to be reduced when E:I exceeds about 0.5 (Figure 19). The data for 1989 weaken this relationship, but the Service interprets the 1989 values as an initial "explosion" of the *Pseudodiaptomus* population following its introduction in 1988. This pattern of population explosion is commonly seen when species invade new ecosystems (Simberloff and Gibbons 2003).

The decline in *Pseudodiaptomus* density that occurs when E:I ratios exceed 0.5 does not occur where the *Pseudodiaptomus* bloom originates in the Delta (Figure 20). This is consistent with the hypothesis that high E:I ratios retain *Pseudodiaptomus* in the Delta, impairing its flux to delta smelt's summertime rearing habitat. This finding is also consistent with Kimmerer and Nobriga's (2008) analyses of particle entrainment risk in different regions of the Delta. As E:I increases, the probability that a particle will be entrained into the export facilities increases. Residence times from some locations also increase as E:I ratios increase. Both of these effects can reduce the flux of Pseudodiaptomus from the Delta to the low-salinity zone.

Proposed Operations

During June and July the projected monthly E:I ratios resulting from proposed project operations do not diverge dramatically from historic conditions and for the most part, do not surpass 0.5 (Figures 21-22). One exception occurs in June of critical years, when proposed project operations would reduce E:I relative to historic conditions. During July, in above normal through critical years, monthly E:I occasionally surpasses 0.5 for proposed project operations, whereas the actual monthly E:I has exceeded 0.5 only in dry years since 1988. This would likely further decrease the flux of *Pseudodiaptomus* to the low-salinity zone compared to current operations.

In August, a clear change in monthly E:I is projected for proposed project operations relative to historic conditions for wet and above normal WYTs (Figure 23). E:I ratios greater than 0.5 are proposed in most years. Historically, wetter years rarely had E:I ratios exceeding 0.5 and above normal years did so only occasionally. The occurrence of only a single below normal WYT makes it difficult to assess potential changes between historic and proposed conditions. Dry years commonly have a projected August E:I greater than 0.5 for proposed operations, but this is not a change relative to historic conditions.

The proposed September operations resemble August operations in that E:I ratios will increase relative to historic conditions (Figure 24). Note that an important difference between September and August is that the projected E:I ratios are much higher in September in most above normal, below normal, dry, and critical water years. Projected E:I ratios in September are generally above 0.5 in all but critical water years, and frequently exceed 0.6. This operation will likely decrease the flux of *Pseudodiaptomus* to the low-salinity zone.

Water transfers

Water transfers would increase Delta exports by 0 to 360,000 acre-feet (af) in most years (the wettest 80 percent of years) and by up to 600,000 af in Critical and some Dry years (approximately the driest 20 percent years). Most transfers will occur at Banks (SWP) because reliable capacity is not likely to be available at Jones except in the driest 20 percent of years. Although transfers can occur at any time of year, the exports for transfers described in this assessment would occur only in the months July-September. Delta smelt are rarely present in the Delta in these months, so no increase in salvage due to water transfers during these months is anticipated.

Post-processing of Model Data for Transfers

This section shows results from post-processed available pumping capacity at Banks and Jones for the Study 8.0 (Future Conditions - 2030). These results are used for illustration purposes. Results from the Existing Conditions CVP-OCAP study alternatives do not differ greatly from those of Study 8.0, and produce similar characteristics and tendencies regarding the opportunities for transfers over the range of study years. The assumptions for the calculations are:

- Capacities are for the Late-Summer period July through September total.
- The pumping capacity calculated is up to the allowable E:I ratio and is limited by either the total physical or permitted capacity, and does not include restrictions due to ANN salinity requirements with consideration of carriage water costs.

- The quantities displayed on the graph do not include the additional 500 cfs of pumping capacity at Banks (up to 7,180 cfs) that is proposed to offset reductions previously taken for fish protection. This could provide up to a maximum about 90 taf of additional capacity for the July-September period, although 60 taf is a better estimate of the practical maximum available from that 500 cfs of capacity, allowing for some operations contingencies.

- Figure XX and Figure XX in the Project Description show the available export capacity from Study 8.0 (Future Conditions-2030) at Banks and Jones, respectively, with the 40-30-30 water year type on the x-axis and the water year labeled on the bars. The SWP allocation or the CVP south of Delta Agriculture allocation is the allocation from CalSim-II output from the water year.

From Figure XX of the Project Description, Banks will have the most ability to move water for transfers in Critical and certain Dry years (driest 20 percent of study years) which generally have the lowest water supply allocations, and reflect years when transfers may be higher to augment water supply to export contractors. For all other study years (generally the wettest 80 percent) the available capacity at Banks for transfer ranges from about 0 to 500 taf (not including the additional 60 taf accruing from the proposed permitted increase of 500 cfs at Banks. But, over the course of the three months July-September other operations constraints on pumping and occasional contingencies would tend to reduce capacity for transfers. In consideration of those factors, proposed transfers would be up to 360 taf in most years when capacity is limiting. In Critical and some Dry years, when capacity would not be a limiting factor, exports for transfers could be up to 600 taf (at Banks and Jones combined). Transfers at Jones (Figure XX of the biological assessment) are probably most likely to occur only in the driest of years (Critical years and some Dry years) when there is available capacity and low allocations.

Limitations

The analysis of transfer capacity available derived from the CalSim-II study results shows the capacity at the export pumps and does not reflect the amount of water available from willing sellers or the ability to move through the Delta. The available capacity for transfer at Banks and Jones is a calculated quantity that should be viewed as an indicator, rather than a precise estimate. It is calculated by subtracting the respective project pumping each month from that project's maximum pumping capacity. That quantity may be further reduced to ensure compliance with the Export/Inflow ratio required. In actual operations, other contingencies may further reduce or limit available capacity for transfers: for example, maintenance outages, changing Delta outflow requirements, limitations on upstream operations, water level protection criteria in the south Delta, and fishery protection criteria. For this reason, the available capacity should be treated as an indicator of the maximum available for use in transfers under the assumed study conditions.

Proposed Exports for Transfers

In consideration of the estimated available capacity for transfers, and in recognition of the many other operations contingencies and constraints that might limit actual use of available capacity, for this assessment proposed exports for transfers (months July-September only) are as follows:

Water Year class	Maximum Amount of Transfer
Critical	up to 600 kaf
Consecutive Dry	up to 600 kaf
Dry after Critical	up to 600 kaf
All other Years	up to 360 kaf

Therefore, effects of water transfers are not expected to have direct entrainment effects to adult delta smelt since the proposed transfer window is a time when delta smelt are distributed the western Delta. However, water transfers could have adverse effects to delta smelt habitat or food items by increased pumping during the summer or fall. These habitat effects are captured in CALSIM II modeling and the habitat suitability section.

JPOD

JPOD, as described in the Project Description and included in the SWRCB's D-1641, gives Reclamation and DWR the ability to use/exchange each Project's diversion capacity capabilities to enhance the beneficial uses of both Projects. There are a number of requirements outlined in D-1641 that the Projects that restrict JPOD to protect Delta water quality and fisheries resources. The effects of JPOD are included in the CALSIM II modeling results and in the habitat suitability section.

500 cfs at Banks

Under the 500 cfs increased diversion, the maximum allowable daily diversion rate into CCF during the months of July, August, and September would increase from 13,870 AF up to 14,860 AF and three-day average diversions would increase from 13,250 AF up to 14,240 AF. This increased diversion over the three-month period would result in an amount not to exceed 90,000 AF each year. Maximum average monthly SWP exports during the three-month period from Banks Pumping Plant would increase to 7,180 cfs. Variations to hydrologic conditions coupled with regulatory requirements may limit the ability of the SWP to fully utilize the proposed increased diversion rate. Also, facility capabilities may limit the ability of the SWP to fully utilize the proposed increased diversion rate

Effects of the NBA

The summer pumping rates of NBA diversions in study 7.0 (average 42 cfs) were 12 percent lower than the pumping in study 8.0 (average 48 cfs) (Reclamation 2008). Hydrodynamic modeling results from the Solano County Water Agency (SCWA) indicate that at a 42 cfs pumping rate, the major water source pumped by the NBA during normal water years origins from Cambell Lake, a small non-tidal lake north of Barker Slough. Thus under most summer-time conditions the entrainment effects are likely to be low, especially since delta smelt move downstream by July (Nobriga et al. 2008). In dry seasons, the NBA entrains water from Barker and Lindsay sloughs (SCWA), indicating a potential entrainment risk for delta smelt. Historically, delta smelt densities have been low in Barker and Lindsay sloughs but the modeling data suggest that delta smelt could exhibit some level of entrainment vulnerability during dry years. But it should be noted, that these effects are likely to be small since most delta smelt reach 20 mm SL by June (http://www.delta.dfg.ca.gov/data/NBA/) and are therefore protected by the fish screens on the NBA intakes designed to protect smelt this size.

Field Code Changed

NBA diversions are lowest in the fall (Chapter 12) only averaging 18 cfs in study 7.0, and 23 in study 8.0. Overall, there was no difference in fall diversions rates among the studies. As discussed previously, delta smelt reside in the Suisun Bay to Sherman Island region during the fall months and are not at sizes vulnerable to NBA entrainment at this time. Thus, there are no expected direct effects of the NBA on delta during this period. Because pumping rates are low and the hydrodynamic models indicate only a small percentage of water entrained enters from Barker Slough, it is unlikely the NBA has any measurable indirect effects during this period.

CCWD diversions
See previous effects discussion

Temp Ag barriers
See previous effects discussion

Permanent barriers
See previous effects discussion

American River Demands
See previous effects discussion

Delta Cross Channel
See previous effects discussion

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Entrainment Effects

Water Diversions and Reservoir Operations

Banks and Jones

Entrainment effects during July through November are not expected to be significant. Delta smelt are not present during this time of year, so direct entrainment during this time of year is not likely a concern.

Intertie
See previous effects discussion

Suisun Marsh Control Gates
See previous effects discussion

Habitat suitability

Delta smelt distribution is highly constricted near the Sacramento-San Joaquin river confluence during periods of low river flow into the estuary when the population gets "pinned" in between saline water in Suisun Bay and warm, high transparency water in the Delta. It was recently shown that there has been a long-term decline in delta smelt habitat suitability during fall (Feyrer et al. 2007). In this analysis, the Service shows that X2 is an indicator of fall habitat suitability. Therefore, this analysis assumes that whenever the water projects are in balanced conditions, they are a primary driver of delta smelt habitat suitability.

This analysis is based on fall X2 and how it reflects the surface area of suitable abiotic habitat for delta smelt, and how that likely effects delta smelt abundance given current delta smelt population dynamics. Supporting background material on the effect of fall X2 on the amount of suitable abiotic habitat and delta smelt abundance is available from Feyrer et al. (2007, 2008). During fall when delta smelt are nearing adulthood, the amount of suitable abiotic habitat for delta smelt is positively associated with X2. This results from the effects of delta outflow on salinity distribution throughout the estuary. Fall X2 also has a measurable effect on recruitment of juveniles the following summer in that it has been a significant covariate in delta smelt's stock-recruit relationship since the invasion of the overbite clam. Potential mechanisms for the observed effect are several fold. First, positioning X2 seaward during fall provides a larger habitat area which presumably lessens the likelihood of density-dependent effects (e.g., food availability) on the delta smelt population. Second, a more confined distribution may increase the probability of stochastic events that increase mortality rates of adults. For delta smelt, this includes predation and anthropogenic effects such as contaminants and entrainment (Sommer et al. 2007).

This evaluation of habitat suitability considered three elements: X2 position, total area of suitable abiotic habitat, and predicted effect on delta smelt abundance the following summer. Effects of the proposed project operations were determined by comparing X2, area of suitable abiotic habitat, and effect on delta smelt abundance across the operational scenarios characterized by the CALSIM II model runs, and also as they compare to actual historic values from 1967 to the present. The modeled scenarios include: Study 7.0, Study 7.1, Study 8.0, and Studies 9.0-9.5. The section concludes with additional observations of the historic and modeled data with a discussion of the potential underlying mechanisms.

X2

The first step of the evaluation examined the effect of project operations on X2 (km) during fall, as determined by the CALSIM II model results. These model results are presented in a monthly time step and are provided in the appendices to the Biological Assessment. In order to be consistent with previous analyses (Feyrer 2007, 2008), X2 during fall was calculated as the average of the monthly X2 values from September through December obtained from the CALSIM II model results. The data were also differentiated by water year type according to that of the previous spring.

The median X2 across the CALSIM II modeled scenarios were 10-15 percent further upstream than actual historic X2 (Figure 25). Median historic fall X2 was 79km, while median values for the CALSIM II modeled scenarios ranged from 87 to 91km. The CALSIM II modeled scenarios all had an upper range of X2 at about 90km. The consistent upper cap on X2 shows that water quality requirements for the Delta ultimately constrain the upper limit of X2 in the simulations. These results were also consistent across water year types (Figure 25) with the differences becoming much more pronounced as years became drier. Thus, the proposed project operations will affect X2 by shifting it upstream in all years, and the effect is exacerbated in drier years.

Area of suitable abiotic habitat

The second step of the evaluation used the modeled X2 to estimate the total surface area of suitable abiotic habitat available for delta smelt. Feyrer et al. (2008) examined three different definitions of habitat suitability for delta smelt that were subsequently used to generate the hectares (ha) of suitable abiotic habitat. The three habitat criteria examined by Feyrer et al. (2008) were based on the statistical probability of delta smelt occurring in a sample due to water salinity and clarity characteristics at the time of sampling. The probabilities of occurrence they examined and compared were $\geq$ 10 percent, $\geq$ 25 percent, and $\geq$ 40 percent. This evaluation applied their intermediate definition of 25 percent to avoid potentially over- or under-estimating the effect. The quantitative model relating X2 to area of suitable abiotic habitat is presented in Figure 26.

The median amounts of suitable abiotic habitat based upon X2 values generated across the CALSIM II modeled scenarios were 49-57 percent smaller than that predicted by actual historic X2 (Figure 27). The median historic amount of suitable abiotic habitat was 9,164 ha, while median values for the CALSIM II modeled scenarios ranged from 3,995 to 4,631 ha. These results were also consistent across water year types (Figure 27), with the differences becoming much more pronounced in drier years. Thus, the proposed project operations affect the amount of suitable abiotic habitat by decreasing it as a result of moving X2 upstream, and the effect is exacerbated in drier years.

Effect on delta smelt abundance

The third step of the evaluation was to use the modeled X2 to estimate the effect on delta smelt abundance. The model relating X2 to delta smelt abundance was updated from that developed by Feyrer et al. (2008) by adding the most recent year of available data (Figure 28). This model incorporates X2 as a covariate in the standard stock-recruit (FMWT index-TNS index the following year; Bennett (2005)) relationship for delta smelt. The model is based on data available since 1987 and therefore represents current delta smelt population dynamics (Feyrer et al. 2007). Note that although the regression model is highly significant and explains 56 percent of the variability in the data set, the residuals are not normally distributed. The pattern of the residuals suggests that some type of transformation of the data would help to define a better fitting model (Figure 28). This analysis did not explore different data transformations. For generating predictions, the FMWT values in the model were held constant at 280, the median value over which the model was built. This was done for all iterations in order to make the results comparable across the scenarios examined. In plots that show "historic" TNS categories, the values are those predicted with the model using actual historic X2 values from 1967 to the present. This approach was necessary in order to examine the likely effects of the different scenarios on present-day delta smelt population dynamics.

The median values for the predicted TNS index based upon X2 values generated across the CALSIM II modeled scenarios were 60-80 percent smaller than those predicted from actual historic X2 (Figure 29). The median value for the TNS index predicted based upon historic X2 was 5, while median values predicted from X2 values generated from the CALSIM II modeled scenarios ranged from 1 to 2. These results were also consistent across water year types (Figure 29) with the differences becoming much more pronounced as years became drier. Thus, the proposed project operations are likely to negatively affect the abundance of delta smelt.

Additional long-term trends and potential mechanisms

There has been a long-term shift upstream for actual X2 during fall that is associated with a similar upstream shift in the E:I ratio (Figure 30). X2 is largely determined by Delta outflow, which in turn is largely determined by the difference between total delta inflow and the total amount of water exported, commonly referred to as the E:I ratio. During fall, the E:I ratio directly affects X2, slightly less so when the E:I ratio reaches approximately 0.45 (Figure 30). The leveling off is due to the need to meet D-1641 salinity standards. Thus, the long-term positive trend in X2 and the associated negative affects on area of suitable abiotic habitat and predicted delta smelt abundance appear to be related to the long-term positive trend in E:I ratio. X2 in the time series for each of the CALSIM II model runs is even greater than the peak of the actual historic values (Figure 31). Based on the proposed operations, the upstream X2 shift will persist.

While the above results demonstrate the likely effects of project operations on X2 averaged over the fall period, the modeling scenarios indicate that X2 in individual months will vary by water year type classification and by the specific modeling scenario (Figure 32). In wetter years of Studies 7.0, 7.1, and 8.0 (wet and above average water year types), X2 tends to diverge from historic conditions in that it shifts upstream in September, October, and November, and shifts downstream in December. This pattern is much less pronounced in the climate change scenarios, Studies 9.0-9.5. In all model studies there is also a general decrease in interannual variability across all of the months. In drier years (below normal to critical water year types), the model scenarios indicate that for all months X2 will generally be shifted upstream and that much of the interannual historic variability will be lost.

The effects of project operations outlined above on X2 during the fall months have considerably altered the hydrodynamics of the estuary in two important ways other than which have already been described. First, the long-term upstream shift in fall X2 has created a situation where all fall seasons regardless of water year type now resemble dry or critical years (Figure 33). Second, the effects have also manifested in a divergence between X2 during fall and X2 during the previous spring (April-July spring averaging period), and the modeling studies indicate this condition will persist in the future (Figure 34). With one exception in 1967, the historic X2 during fall was always less than 10km upstream of X2 during the spring, regardless of water year type (Figure 35). However, since 1993, X2 during fall has moved considerably further upstream than X2 during spring in wet and above normal years. In wet and above normal years, fall X2 was, on average, 3km upstream of spring X2 from 1967 to 1992, while it was 19km upstream from 1993 to 2007.

Combined, these effects of project operations on X2 will have important direct and indirect effects on delta smelt. Directly, these changes will substantially alter the amount of suitable abiotic habitat for delta smelt, which in turn has the possibility of affecting delta smelt abundance. Delta smelt is probably not currently habitat limited given its extremely low abundance. However, it is clear that delta smelt has become increasingly habitat limited over time and that this has contributed to the population declining to record-low abundance levels (Bennett 2005; Baxter et al. 2008; Feyrer et al. 2007, 2008; Nobriga et al. 2008). Therefore, the continued loss and constriction of habitat proposed under future project operations significantly threatens the ability of a self-sustaining delta smelt population to recover and persist in the estuary at abundance levels higher than the current record-lows. Indirectly, changes such as the extremely stable low outflow conditions resembling dry or critical years proposed for the fall across all water year types will likely a) contribute to higher water toxicity (Werner et al. 2008) because the proposed flows are always low in all water year types, b) contribute to the potential suppression of phytoplankton production by ammonia entering the system from wastewater treatment plants (Wilkerson et al. 2006; Dugdale et al. 2007) because diluting flows are minimal, c) increase the reproductive success of overbite clams allowing them to establish year-round populations further east because salinity is consistently high with low variability (Jan Thompson, USGS, unpublished data), d) correspond with high E:I ratios resulting in elevated entrainment of lower trophic levels, e) increase the frequency with which delta smelt encounter unscreened agricultural irrigation diversions in the Delta (Kimmerer and Nobriga 2008) because the eastward movement of X2 will shift the distribution of delta smelt upstream, and provide environmental conditions for nonnative fishes that thrive in stable conditions (Nobriga et al. 2005). Although there is no single driver of delta smelt population dynamics (Baxter et al. 2008), these indirect effects will exacerbate any direct effects on delta smelt and hinder the ability of the population to recover and maintain higher levels of abundance in the future (Bennett and Moyle 1996; Bennett 2005; Feyrer et al. 2007).

Water transfers
See previous effects discussion

American River Demands
See previous effects discussion

Delta Cross Channel
See previous effects discussion

Komeen Treatment

The Department of Boating and Waterways (DBW) prepared an Environmental Impact Report (2001) for a two-year Komeen research trial in the Delta. They determined there were potential effects to fish from Komeen treatment despite uncertainty as to the likelihood of occurrence. Uncertainties exist as to the direct impact that Komeen and Komeen residues may have on fish species. "The target concentration of Komeen is lower than that expected to result in mortality to most fish species, including delta smelt" (Huang and Guy 1998). However, there is evidence that, at target concentrations, Komeen could adversely impact some fish species. The possibility exists that Komeen concentrations could be lethal to some fish species, especially during the first nine hours following application. Although no tests have examined the toxicity of Komeen to Chinook salmon or steelhead, LC50 data for rainbow trout suggest that salmonids would not be affected by use of Komeen at the concentrations proposed for the research trials. No tests have been conducted to determine the effect of Komeen on splittail, green sturgeon, pacific lamprey or river lamprey." (DBW, 2001) or delta smelt.

In 2005, no fish mortality or stressed fish were reported during or after the treatment. The contractor, Clean Lakes, Inc was looking for dead fish during the Komeen application. In addition, no fish mortality was reported in any of the previous Komeen or Nautique applications. In 2005, catfish were observed feeding in the treatment zone at about 3 pm on the day of the application (Scott Schuler, SePro). No dead fish were observed. DWR complied with the NPDES permit that requires visual monitoring assessment. Due to the uncertainty of the impact of Komeen on fish that may be in the Forebay, we will assume that all delta smelt in the Forebay at the time of application are taken. The daily loss values vary greatly within treatments, between months and between years. Figure XX illustrates the presence of delta smelt in the Forebay during treatments. There are no loss estimates for delta smelt, so the relationship between salvage and true loss of delta smelt in the Forebay in unknown.

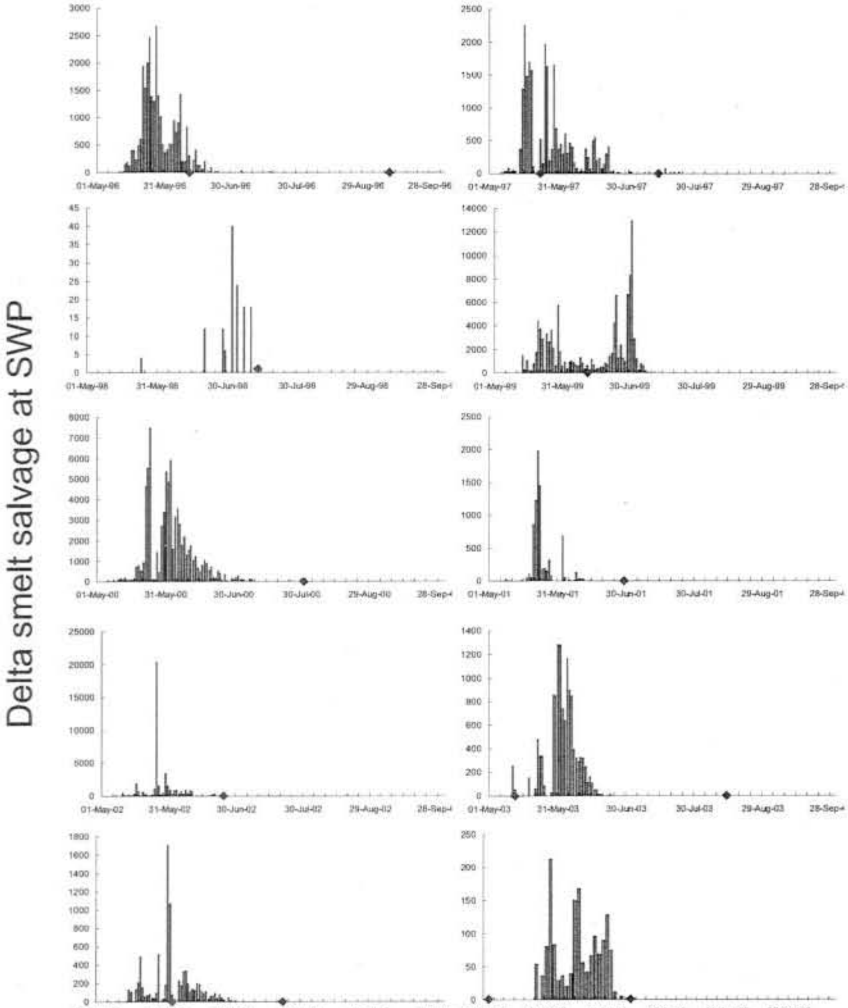

Figure XX May-September delta smelt salvage at the SWP Banks Pumping Plant, 1996-2005, with the start and end dates of Komeen or Nautique aquatic weed treatment indicated by the red diamonds.

Studies at Banks and Jones fish facilities

A number of studies are conducted at the Banks and Jones fish facilities to evaluate the efficiency of these facilities and to study if there are operational modifications that can increase these efficiencies.

Effects to Delta Smelt Critical Habitat

The Service's primary objective in designating critical habitat was to identify the key components of delta smelt habitat that support successful spawning, larval and juvenile transport, rearing, and adult migration. The Service identified the following primary constituent elements as essential to the conservation of the species: physical habitat, water, river flow, and salinity concentrations required to conserve the species. These conditions may occur in different regions of the Delta at different times, and provide habitat for different life stages, but these conditions must be present when needed, and have sufficient connectivity to provide for the flow of energy, materials and organisms among the habitat components. The entire legal Delta plus Honker, Grizzly and Suisun Bay and Marsh and Carquinez Straight to the confluence with the Napa River is designated as critical habitat; over the course of a year, different life stages occupy all the critical habitat.

The primary constituent elements (PCEs) are affected by water project operations that have altered seasonal flows in the Delta. Springtime flows are decreased relative to the natural hydrograph, as reservoir operations change over from flood management to water storage. Further, summer and early fall flows may be increased over the natural hydrograph as reservoirs release stored water to support export operations (Kimmerer 2004). Changes in inflow affect the location of the highly-productive low-salinity zone, affecting habitat volume and quality. Within the Delta, water diversions alter water circulation patterns and flushing times and change salinity fields. The combined influence of recent hydrologic and other changes upon changes imposed in the 1980s and earlier has had the effect of moving the distribution of delta smelt to areas that are generally upstream of where they once occurred. The effects to delta smelt critical habitat are discussed largely in terms of how the proposed project will affect the location of X2. The location of X2 varies both between and within years, according to hydrology and project operations.

Whether considered a surrogate variable for freshwater flow or an indicator of habitat conditions, changing the location of X2 changes physical conditions in the upper estuary (Kimmerer 2004). The strategic placement of X2 is intended to have two benefits for delta smelt (1) improvement of environmental quality and (2) minimization of entrainment into the Banks and Jones export facilities. Temperature, turbidity and specific conductance (a surrogate for salinity) have been used as variables to describe favorable environmental conditions in the Delta; as such, they have been shown to be statistically significant predictors of fish occurrence (Feyrer et al. 2007). Long-term trend analysis has shown that environmental quality has declined across a broad geographical range, but most dramatically in the western, eastern and southern regions of the Delta, leaving only a relatively restricted area around the confluence of the Sacramento and San Joaquin Rivers with the least habitat alteration, compared to the rest of the upper estuary. This reduced condition may contribute to the observed decline in delta smelt abundance by shrinking suitable physical habitat and by altering feeding conditions (availability of prey and efficiency of feeding). Improved inflow conditions associated with moving X2 westward may maintain the nutrient input that supports primary productivity (Jassby 2008; Cloern 2007) and the turbidity that delta smelt need to successfully forage and, in turn, to elude predators. Recent modeling indicates that the risk of entrainment is related to distribution and to hydrology (Kimmerer and Nobriga 2008; Culberson et al 2004). In the fall, delta smelt tend to occur in the low-salinity zone or just seaward of X2, and as they mature, move into freshwater to spawn. Moving X2 westward in the fall therefore reduces the risk of entrainment by increasing the geographic and hydrologic distance of delta smelt from the influence of the Project facilities.

Spawning. The PCEs required for spawning habitat are physical habitat, water, river flow and salinity. Changes to delta smelt spawning habitat include human alteration from a shallow, seasonally-brackish complex of low islands and marshes to armored islands surrounded by dredged channels kept artificially fresh; invasive species; contaminant loading; and altered hydrology. There is presently no evidence of habitat constriction during the spawning season (Baxter et al 2008), although no studies have addressed this question. Construction and subsequent maintenance of flow control "gates" in the South Delta would permanently modify areas that may function as delta smelt spawning habitat; however, since the footprint of the disturbance is likely to be minimal and the location is such that entrainment into the export facilities is all but assured, construction and maintenance of the gates may have minimal impact on the population overall. During the January to April period, when the bulk of spawning occurs in most years, inflow to the Delta is expected to remain similar to present conditions; however, Delta outflow is expected to decrease, with the biggest differences occurring in below-normal, dry and critical years.

Larval and juvenile transport. The PCEs required for larval and juvenile transport are water, river flow and salinity. Changes to delta smelt larval and juvenile transport habitat include water diversions that create net reverse flows in the Delta that entrain larval and juvenile delta smelt and prevent their transport to rearing areas, permanent and temporary barrier installation and operation that alters Delta hydrology and salinity fields, and diminished river inflows that change the relative location of the low-salinity zone. Both the current and proposed project operations affect larval and juvenile transport by flow disruption and by interception (entrainment) of fish. Under the proposed project, X2 will usually be located further downstream than historically in March through June, except in wet years (*see* Effects Analysis). Larval and juvenile delta smelt move from the areas where they are spawned and must leave the Delta before water temperatures reach their critical thermal maximum of 25.4^0C. Flows must be adequate during the period when larvae and juveniles are being transported. The location of X2 must be west of the confluence of the Sacramento and San Joaquin Rivers when juveniles are being transported, to ensure that suitable rearing habitat is available. Flow regulation has resulted in an overall decrease in riverine sediment load, as sediment is lost to upstream reservoirs (Arthur and Ball 1979). A turbid environment (>25 NTU) is necessary to elicit a first feeding response (Baskerville-Bridges et al. 2000; Baskerville-Bridges 2004). Successful feeding seems to depend on high density of food organisms and turbidity, and increases with stronger light conditions (Baskerville-Bridges *et al.* 2000; Mager et al. 2004; Baskerville-Bridges *et al.* 2004). Reduced frequency and magnitude of inflow events under the proposed project will decrease turbidity and affect feeding behaviors.

Rearing habitat. The PCEs required for larval and juvenile transport are water, river flow and salinity. Changes to delta smelt rearing habitat include altered flow regimes which result in seasonally-reduced freshwater inflow; invasive species; and contaminant loading. For delta smelt, environmental quality as indexed by water temperature, transparency and salinity is an important predictor of delta smelt occurrence and abundance (Feyrer et al 2007, Feyrer et al 2008). The position of the two-parts-per-thousand isohaline, X2, determines the amount of suitable abiotic habitat for delta smelt. River flow is the primary driver for the position of the low-salinity zone (Jassby et al 1995). The location of the low-salinity zone (indexed by X2) is a function of total Delta outflow, which under most conditions is determined primarily by the operations of the SWP and CVP. Reduced river inflows under the proposed project will shift the median location of X2 10 percent to 15 percent further upstream over historic conditions, shrinking the areal extent of suitable abiotic habitat by 49 percent to 57 percent, with the effect most pronounced in drier years. To provide a productive, food-rich environment, and protect rearing delta smelt from entrainment, X2 must be located within an area extending eastward from Carquinez Straight up the Sacramento River to Three-Mile Slough, and south along the San Joaquin River, including Big Break, potentially from February through the summer.

Adult migration. The PCEs required for larval and juvenile transport are water, river flow and salinity. Adult migration habitat has been affected by changes in quantity and pattern (timing) of inflow to the Delta. The proposed project will likely have the greatest effect on adult migration habitat in wetter years, as a relatively greater proportion of inflow is diverted for export. During the December through March period, when most adult migration takes place, Delta outflows are expected to decrease relative to present conditions. During January, when the freshets that cue adult migration are expected, Delta outflow is expected to decrease in all but critically dry years, which may affect the timing, magnitude and duration of attraction flows.

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Cumulative Effects

Cumulative effects include the effects of future State, Tribal, local, or private actions affecting listed species that are reasonably certain to occur in the area considered in this biological assessment. Future Federal actions not related to this proposed action are not considered in determining the cumulative effects, because they are subject to separate consultation requirements pursuant to section 7 of the Act.

Any continuing or future non-Federal diversions of water that may entrain adult or larval fish are not subject to ESA Section 7 and might contribute to cumulative effects to the smelt. Water diversions might include municipal and industrial uses, as well as diversions through intakes serving numerous small, private agricultural lands contribute to these cumulative effects. However, a recent study by Nobriga et al. (2005) suggested that these diversions entrain few delta smelt. Nobriga et al. reasoned that the littoral location and low-flow operational characteristics of these diversions reduced their risks. A study of the Morrow Island Distribution System by DWR produced similar results, with one demersal species and one species that associates with structural environmental features together accounting for 97-98 percent of entrainment, and only one delta smelt observed during the two years of the study (DWR 2007).

State or local levee maintenance may also destroy or adversely modify spawning or rearing habitat and interfere with natural long term habitat-maintaining processes. Operation of flow-through cooling systems on electrical power generating plants that draw water from and discharge into the area considered in this biological assessment may also contribute to cumulative effects to the smelt.

Additional cumulative effects result from the effects of point and non-point source chemical contaminant discharges. These contaminants include but are not limited to free ammonium ion, selenium, and numerous pesticides and herbicides, as well as oil and gasoline products associated with discharges related to agricultural and urban activities. Implicated as potential sources of mortality for smelt, these contaminants may adversely affect fish reproductive success and survival rates.

Two wastewater treatment plants, one located on the Sacramento River near Freeport and the other on the San Joaquin River near Stockton have received special attention because of their discharge of ammonia. The Sacramento Regional County Sanitation District wastewater treatment facility near Freeport discharges more than 500,000 cubic meters of treated wastewater containing more than 10 tonnes of ammonia into the Sacramento River each day (http://www.sacbee.com/378/story/979721.html). Preliminary studies commissioned by the IEP POD investigation and the Central Valley Regional Water Quality Control Board are evaluating the potential for elevated levels of Sacramento River ammonia associated with the discharge to adversely affect delta smelt and their trophic support. The Freeport location of the SRCSD discharge places it upstream of the confluence of Cache Slough and the mainstem Sacramento River, a location where delta smelt have been observed to congregate in recent years during the spawning season. The potential for exposure of a substantial fraction of delta smelt spawners to elevated ammonia levels has heightened the importance of this investigation. Ammonia discharge concerns have also been expressed with respect to the City of Stockton Regional Water Quality Control Plant, but its remoteness from the parts of the estuary frequented by delta smelt suggest that it is more a potential issue for migrating salmonids than for delta smelt. Other cumulative effects could include: the dumping of domestic and industrial garbage may present hazards to the fish because they could become trapped in the debris, injure themselves, or ingest the debris; golf courses reduce habitat and introduce pesticides and herbicides into the environment; oil and gas development and production may affect habitat and may introduce pollutants into the water; agricultural activities including burning or removal of vegetation on levees reduce riparian and wetland habitats; and grazing activities may degrade or reduce suitable habitat, which could reduce vegetation in or near waterways.

The effects of the proposed action are not expected to alter the magnitude of cumulative effects of the above described actions upon the critical habitat's conservation function for the smelt.

Table XX. Summary of expected effects to critical habitat.

Components of the Proposed Action	Primary Constituent Element			
	Physical Habitat	Water	River Flow	Salinity Concentration
SWP and CVP Operations	Small	- Changes to biotic elements of habitat and changes to extent and quality of physical pelagic habitat - Further spread of *Microcystis*	-Interception and entrainment of fish - Disruption of adult migratory behavior - Disruption of larval fish distribution - Enhancement of non-indigenous species - Concentration of environmental toxins	-Changes in quality, extent, and location of physical pelagic habitat
Intertie Between DMC and CA	Small	Small	-Interception and entrainment of fish	Small
Article 21	Small	Small	-Interception and entrainment of fish - Disruption of adult migratory behavior - Disruption of larval fish distribution	Small
North Bay Aqueduct	Small	Small	Small	Small

Freeport Regional Water Project	Small	Small	Small	Small
South Delta Temporary Barriers	Small	Small	-Interception and entrainment of fish - Disruption of adult migratory behavior - Disruption of larval fish distribution	Small
South Delta Permanent Operable Gates	Small	Small	-Interception and entrainment of fish - Disruption of adult migratory behavior - Disruption of larval fish distribution	Small
Suisun Marsh Salinity Control Gates	Small	Small	Small	-Changes in quality, extent, and location of physical pelagic habitat
CCWD Diversions	Small	Small	Small	Small
Water Transfers	Small	- Changes to biotic elements of habitat and changes to extent and quality of physical pelagic habitat - Further spread of *Microcystis*	-Interception and entrainment of fish - Disruption of adult migratory behavior - Disruption of larval fish distribution - Enhancement of non-indigenous species - Concentration of environmental toxins	-Changes in quality, extent, and location of physical pelagic habitat

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