Chapter 13 CVP and SWP Delta Effects on Species

Introduction

This chapter deals with the effects the Central Valley Project (CVP) and State Water Project (SWP) may have on delta smelt, and on steelhead, Chinook salmon, and green sturgeon while the latter three species are present in the Delta. The Delta effects on these species are presented in detail in this Chapter in two separate sections for the purpose of clarity and because the effects are significantly different for the resident pelagic species versus migratory species. The first section describes the Delta effects on delta smelt and the second section addresses the effects on steelhead, Chinook salmon and the green sturgeon.

It is important to note that this chapter focuses specifically on the effects of the projects on these species. However, these effects are evaluated in context with the broader factors that influence abundance and distribution as described in Chapter 4 (steelhead) Chapter 6 (Chinook salmon) Chapter 7 (delta smelt) and Chapter 8 (green sturgeon).

In the section discussing delta smelt and referred material in Chapter 7 some of the likely contributing causes of the POD such as toxic effects from agro-chemicals are discussed that may be unrelated to water project operations; however others such as entrainment are in fact directly related. The discussion in this chapter outlines both the direct and indirect potential effects in addition to modeling results related to Delta pumping, in-Delta flows (represented by Old and Middle River flows) and X2 for both current and future conditions.

In the second section, which discusses the Delta effects on steelhead, Chinook salmon, and green sturgeon, the impacts seem to be primarily associated with direct entrainment at various project pumping facilities and fish passage issues at the Suisun Marsh Salinity Control Gates. In addition, this section provides a description of the CVP and SWP monitoring data and modeling results estimating the salvage and loss of fish by species and life stage.

The general approach taken here considers both direct entrainments at the Jones and Banks facilities and indirect effects that may occur elsewhere in the Delta. The objective is to evaluate effects that current and future water project operations may have on each species. Evaluation of the effect of future operations is in each case accomplished by quantitative comparison of relevant variables in models representing future cases with the corresponding variables in the present-operations case. Evaluation of the effects of present operations varies by species. There is substantial uncertainty about the importance of some effects. These uncertainties are usually limited to the magnitude of the effect. Whether an effect is likely harmful or beneficial is usually more certain. It should also be noted that potential effects might be amplified or muted by variation in distribution of fishes in the Delta (which changes from year to year and among months within years), unanticipated secondary biological effects, or by unanticipated effects emerging from climate change. A summary of conclusions drawn from these analyses is presented in Chapter 15.

CVP and SWP Delta Effects on Delta Smelt

Statistical analyses of the long-term delta smelt abundance trends (Manly and Chotkowski 2006) confirm that there has been a long-term decline of delta smelt, with substantial interannual variation. A period of increase in the late 1990s was followed by a rapid and sustained decline beginning about 2000. Current delta smelt numbers are at or near their all-time low since monitoring began (Baxter et al. 2008, DFG unpublished 2008 monitoring results). The 2007 POD Synthesis report posits that delta smelt abundance has been strongly influenced since the start of that decline by adult abundance, habitat conditions, and entrainment (Baxter et al. 2008 and see Chapter 7). Feyrer et al. (2007) found that there has been a significant stock-recruit relationship (i.e., adults affect juvenile production) since 1987; this relationship was improved by including fall habitat conditions (as defined by salinity and turbidity), indicating that habitat also affects abundance. Long-term temperature increases in the Delta (Jassby 2008) may further constrain habitat, particularly in summer (Nobriga et al. 2008). Food availability may also have been historically important to this planktivorous fish as Kimmerer (in review) noted a statistically significant relationship between juvenile smelt survival and zooplankton biomass over the long term. The decline in the mean size of adult delta smelt following the introduction of the overbite clam *Corbula* (Sweetnam 1999; Bennett 2005), which caused declines in key zooplankton prey, is also consistent with food web effects. Feyrer et al. (2007) also found that stock and habitat effects were important when food supply was low following the invasion of *Corbula*. It may also be that the delta smelt population is now at such low levels that large increases in a single year are unlikely, but will require multiple years of successful reproduction and recruitment.

While some of the likely causes of the POD, such as the gradual accumulation of ecologically disruptive exotic species in the Delta, may have developed independently or partially independently of water project operations, other likely contributing causes are clearly related to water project operations. The degree of project effects on delta smelt varies considerably among years and may also vary substantially from month to month, depending on changing distribution of fish, Delta hydrology, and other factors. The POD analysis proposes that changes in water project operational regimes have contributed to the recent decline both directly (via entrainment) and indirectly (via habitat alteration). During some of the recent POD years, increased water project exports during winter resulted in higher losses of adult smelt (Chapter 7), particularly early spawning fish (and their offspring) that may be proportionally more important to the population. By contrast, reduced exports during spring may have increased survival of later-spawned larvae in recent years. Reduced spring exports from the Delta have been partially the result of the Vernalis Adaptive Management Plan (VAMP), a program designed to improve survival of outmigrating juvenile Chinook salmon. VAMP has been operating since 2000.

With respect to an indirect effect, habitat alteration, a long-term upstream shift of X2 during fall has negatively affected delta smelt habitat and has been linked to changes in delta smelt abundance (Feyrer et al. 2007). The steady-state location of the low-salinity zone is a function of total Delta outflow, which under most non-flood conditions is determined primarily by the operations of the CVP and SWP. However, non-CVP and SWP factors such as increased diversions from, and accretions to Delta tributaries may have contributed to the upstream shift of X2 in the fall months. The relative contributions of all factors contributing to the fall shift has not been determined, and probably vary from year to year.

Seasonal Breakdown of Potential Effects

Evidence of a role for each of the factors developed in the POD investigation in the long-term and recent abundance patterns of delta smelt is described in detail below for each season (Baxter et al. 2008). Note that this is a general summary of the broad suite of factors that may affect delta smelt during different seasons; however, the subsequent effects analysis is focused on a subset of these factors known to be related to water project operations.

It is also important to recognize that the present understanding of the factors affecting smelt has many limitations. As described in Baxter et al. (2008), many studies used for the recent POD synthesis are works-in-progress that have not reported final results. Preliminary results from these studies have been provided whenever possible, but peer-reviewed products from these studies may not be available for some time to come. As a consequence, while this review uses such results because they represent the best available science, Baxter et al. (2008) encouraged users of their POD synthesis report to be cautious when evaluating the relative importance of the different factors. Specifically, statements not based on well-developed and peer-reviewed literature should be viewed with more skepticism.

Summer

Summer is the season that usually has the highest primary and secondary productivity in a temperate zone estuary. Given their annual life cycle, summer represents the primary growing season for delta smelt. However, the availability of prey species is strongly affected by food web changes stemming from changes in grazing pressure from the benthos (particularly *Corbula amurensis*). Moreover, in the decade including the early POD years, there has been a further decline in the abundance of calanoid copepods in Suisun Bay and the west Delta (Kimmerer et al., in prep, Mueller-Solger et al., in prep.), part of the core summer habitat of delta smelt (Nobriga et al. 2008). At the same time, these calanoid copepods are being replaced by the small cyclopoid copepod *L. tetraspina* which is presumed to be a less suitable prey species (Bouley and Kimmerer 2006).

The long-term reduction in preferred prey availability has likely resulted in slower growth rates of delta smelt, detectable as a reduction in the mean size of delta smelt in autumn since the early 1990s (Sweetnam 1999; Bennett 2005). The latest POD report (Baxter et al. 2008) proposes that over the long term, reduced summer growth rates have reduced the survival of juvenile delta smelt, perhaps from predation, as smaller fish remain more vulnerable for longer periods (Bennett et al. 1995; Houde 1987). As evidence that changes in prey availability have had survival consequences for this fish species, Kimmerer (in press) found a statistically significant relationship between summer-to-fall delta smelt survival and zooplankton biomass in the low salinity zone from 1972 to 2005. Recent preliminary analyses suggest that total zooplankton biomass may not have changed substantially within the core summer habitat of delta smelt, at least when all species including *L. tetraspina* are included (Mueller-Solger, unpublished data). In 2006, zooplankton biomass, including the biomass of the important food organism *P. forbesi*, even increased substantially in the delta smelt summer habitat, but this was not followed by a recovery of delta smelt. Moreover, summer-to-fall survival since 2000 does not appear to be substantially different from survival for all other years since 1972. Survival since 2000 has actually been somewhat higher than in 1972—1980 when delta smelt abundance indices were much higher than they are now (Mueller-Solger, unpublished data). Finally, summer and fall delta smelt abundance indices have been closely correlated to each other during the POD years. However, while the fall abundance indices since 2000 have spanned almost the full range of delta smelt abundance indices during the previous three decades, the summer abundance indices have remained in the lower portion of the pre-POD summer abundance range.

These results suggest that impaired recruitment, growth, and survival before the summer period may also have been important during the POD years. It is possible that summer food limitation was a more important stressor when population densities were higher and that the decline in summer food availability has contributed more to the long-term decline in delta smelt abundance than to its dramatic deterioration in the POD years (Mueller-Solger, unpublished data).

Summer habitat may be more restricted than in the past. Nobriga et al. (2008) noted a complete absence of delta smelt in the southern Delta that coincided with increased water clarity. However, although these changes in turbidity appear to play a role in the longer-term declines in delta smelt, they are unlikely to be an important new cause of the post-2000 declines because delta smelt have not successfully utilized the southern and central Delta in large numbers since the late 1970s. Nobriga et al. also noted that delta smelt distribution is affected by temperature. Moreover, Jassby (2008) found regional increases in water temperature, including areas within the range of delta smelt. Hence, delta smelt may be affected by long-term increases in water temperature in the Estuary.

Direct entrainment effects at the CVP and SWP export facilities in the south Delta are not thought to have been important during most summers because the delta smelt population is north and west of the zone affected strongly by water exports and delta smelt salvage is generally very near zero from July-November (IEP unpublished data). When the toxic blue-green alga *M. aeruginosa* blooms during summer, it occurs primarily upstream of delta smelt, so it is unlikely to have been a major factor in the delta smelt's historical decline. This may have changed in 2007, when *M. aeruginosa* blooms extended into eastern Suisun Bay, well into the historical rearing habitat of delta smelt. Other water quality variables such as contaminants could be important, but are yet to be identified as seasonal stressors for this species.

In summary, there is evidence of bottom-up and habitat suitability effects on delta smelt during the summer over the long-term, but the evidence suggests that since 2000, delta smelt population dynamics have been largely driven by factors occurring in seasons other than summer. Near zero salvage suggests SWP/CVP entrainment effects are minimal during this period under historical flow conditions. Nonetheless, better habitat and food conditions during the summer might improve long-standing effects and increase survival as well as individual fitness of maturing delta smelt.

Fall

Fall represents the time period when the delta smelt year class matures to adulthood. The evidence to date indicates that habitat is a significant issue for delta smelt in fall (Feyrer et al. 2007). Delta smelt presence is strongly associated with low salinity and water clarity, which can be used to index the “environmental quality” of habitat for the species. Feyrer et al. (2007) report that fall environmental quality has declined over the long-term in the core range of delta smelt, including Suisun Bay and the Delta. This decline was largely due to changes in salinity in Suisun Bay and the western Delta, and changes in water clarity within the Delta. There is statistical evidence that these changes have had adverse population-level effects (Feyrer et al. 2007). A multiple linear regression of fall environmental quality in combination with adult abundance provided statistically significant predictions of juvenile production the following year. Hence, both habitat and stock-recruit factors are important issues during fall.

Reduction of habitat area as defined by environmental quality likely interacts with bottom-up and top-down effects. Restricting fish to a smaller geographical area with inadequate food supply would likely maintain or even magnify the bottom up and top down effects already occurring during the summer, although these factors are poorly-understood during fall. Greater mortality due to predation, small adult size by the end of the fall, and the low fecundity of smaller fish likely all contribute to the adult abundance effect observed by Feyrer et al. (2007).

Direct entrainment has not historically been a major stressor during the fall. Delta smelt are usually not salvaged in substantial numbers at the CVP and SWP until late December. However, distribution of suitable habitat (as indexed by salinity and water clarity) affects the location of delta smelt in fall, which may contribute to their subsequent vulnerability to entrainment in winter by advancing them into the geographical area influenced by the pumps. In summary, both bottom-up effects and habitat restriction appear to be important during the fall. Slow growth because of food limitation combined with habitat restriction may also have resulted in higher mortality due to predation. Poor growth in the summer and fall likely contribute to reduced size and fecundity of maturing fish.

Winter

Winter represents the main period of adult delta smelt migration and spawning. Entrainment of adults and larvae (top-down effects) are particularly important to the delta smelt population during this critical season. The increase in salvage of adult delta smelt during winter since 2000 suggests that entrainment levels have been higher as a proportion of the population during the POD years (Baxter et al. 2008; Grimaldo et al. in review). Although in long-term analyses monthly or semi-monthly export volumes explain only 1-3 percent of the variability in same-water year delta smelt abundance (Manly and Chotkowski 2006), these losses may still be important to the population as a component of the total array of pressures on the species. First, this was a long-term analysis. There is a clear coincidence between higher entrainment and population decline in the short period from 2000 (and especially 2002) onward, a period for which there are even now few data with which to fit elaborate statistical models. Moreover, it has been proposed that entrainment losses may manifest effects in the following water year. For example, Bennett (unpublished) has hypothesized that losses of larger females may have a disproportionate effect on the delta smelt population. Specifically, losses of more fecund, early spawning large females and their offspring could eliminate a portion of the cohort most likely to survive to reproductive age, and possibly most likely to be fecund. Winter exports may also have an effect on the number of adults which survive a second year, a possible important factor affecting delta smelt population resilience (Bennett 2005). Manly and Chotkowski (unpublished workshop presentation) note that export effects may not be large during many years, especially very wet years, because exports by the water projects are relatively small compared to Delta inflow and outflow. However, they may be larger in a minority of years when various (at present mostly undescribed) factors affecting the spawning distribution of delta smelt converge to place larger numbers of smelt in areas vulnerable to entrainment.

There is presently no evidence of habitat constriction or food limitation during winter (Baxter et al. 2008); however, no studies have addressed these questions. Contaminant effects are possible during flow pulses, but there is no major evidence yet that these events have caused toxicity to delta smelt. One toxics issue that may have winter-spring effects and is under investigation is the potential role toxic concentrations of free ammonium ion contained in partially treated wastewater discharged into the Sacramento River in the north Delta may have on adult, larvae, and juvenile delta smelt in that region (Werner et al. unpublished data).

Spring

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. Initial otolith studies by Bennett's lab suggest that these spring-spawned fish dominate subsequent recruitment to adult life stages; by contrast, delta smelt spawned prior to the VAMP have been poorly-represented in the adult stock in recent years. He further proposes that the differential fate of winter and spring cohorts may affect sizes of delta smelt in fall because the spring cohorts have a shorter growing season. These results suggest that direct entrainment of larvae and juvenile delta smelt during the spring may be a significant issue in some years. However, Bennett has not published some of his results, and it remains unclear whether his central hypothesis is true. We have therefore not attempted to directly evaluate whether water project operations modeled under the various scenarios differentially affect early-spawning delta smelt.

Because of natural variability and the CVP's and SWP's operations to meet X2 water quality standards, there is no long-term trend in spring salinity (Jassby et al. 1995; Kimmerer 2002a). This suggests there was unlikely to have been a recent change in spring habitat availability or suitability. However, other habitat effects including contaminants or disease could play a role during spring.

Summary of Potential Project Effects

The previous section provided a generalized discussion of the the suite of factors thought to seasonally affect delta smelt. The following summarizes project-specific issues considered relevant for the effects analysis. Note that the following evaluation does not take into account the fact that the climate and geography could be markedly different in the future. A global rise in temperatures, rising sea levels, and changes in streamflow could substantially affect the status of delta smelt including their distribution, population viability, and vulnerability to project effects. There is substantial effort underway to try to model climate conditions 500-100 years away, although the "state of the art" in these simulations is changing almost monthly. Moreover, as the climate-change review in this Biological Assessment indicates, there is no clear prediction whether overall precipitation rates in these watersheds will rise or fall as a result of climate change (see Appendix R). Given these uncertainties, our evaluation focuses on what is known about the current biology and distribution of delta smelt and water project operations.

Direct entrainment of geographically vulnerable delta smelt is likely to occur during a period extending from mid-December through mid-July. Adults are likely to be entrained during their spawning migration from mid-December to April, while juveniles are likely to be entrained from

April until environmental conditions, particularly water temperatures, drive surviving juveniles into the west Delta in June or July. The onset of winter entrainment often coincides with the "first flush" of turbid water through the Delta following early rainstorms in December.

Direct entrainment risk varies with rate of export pumping, and is also affected by other factors, including atmospheric conditions, the tides, and the Delta's tributary inflows. The rate of export pumping and these other factors jointly determine the geographical boundary of the "zone of entrainment", described as the zone within which passive, neutrally buoyant particles are moved toward, and eventually entrained into, either Clifton Court Forebay and the Banks Pumping Plant in Byron or the Jones Pumping Plant in Tracy (see development of this concept in Kimmerer and Nobriga 2007). Because other factors modulate the effect of export pumping, the actual boundary of this zone is in constant motion. However, with other factors being held constant, the average northward reach of the pumps increases with pumping rate.

In this analysis, we assume that the net change in direct entrainment risk varies linearly with both total export pumping rate and Old and Middle River (OMR) flow. We also assume that actual historical entrainment varied in proportion to empirically measured salvage at the Jones and Banks facilities. In the following discussion, evidence of a linear or quasi-linear relationship between salvage at the Jones and Banks facilities and export pumping or OMR flow is interpreted as evidence of qualitatively similar relationships between actual entrainment and those hydrodynamic variables. It is important to note that salvage imperfectly indexes actual entrainment. The reasons for skepticism include (1) unknown and possibly substantial size-filtering of the incoming fish by the physical screen system, which does not divert fishes of all sizes with equal likelihood; (2) unknown effects of incoming water velocity on the efficiency of the screening system; (3) unknown (for delta smelt) prescreen mortality in Clifton Court Forebay, which presumably depends on the residence time of fish in the forebay before salvage. The assumption of linearity has general support both regressions of salvage against OMR flow (Grimaldo et al. in review; P. E. Smith, unpublished but influential analysis cited in Baxter et al. 2008). We expect the relationship between entrainment and OMR flow to be somewhat cleaner than that between salvage and total export pumping rate because of the variable time delay and other complications created by Clifton Court Forebay. However, that the known salvage-OMR relationship for adult smelt appears to increase faster than linearly at high negative OMR flow suggests that our assumption of linearity will not overstate the increase in risk at higher pumping, and might understate it.

We have not attempted to separately evaluate the effects of Jones and Banks pumping here, because the hydrodynamic effects of pumping, with which we associate fish transport and entrainment, result from the combined effect of pumping at both facilities. Furthermore, incidental take restriction on the export facilities is administered as a combined limit. Finally, the present analysis does not take into account finer scale factors that may have a substantial effect on entrainment risk. As described in Grimaldo et al. (in review), peaks in adult entrainment at the water projects coincide closely with turbidity pulses into the Delta. At present, we do not have the capability to model how different operational scenarios would change the pattern of winter turbidity pulses into the Delta. Future models and monitoring may allow better prediction of these events.

Change in the availability of habitat of the proper low salinity and turbidity and in habitat quality can be caused by water project operations through alteration of Delta outflow and in the sources of water permitted to reach the western Delta. As described above, the disposition of the low salinity zone may be important to delta smelt during the summer, and is likely to be important during the fall. Unlike the fall, the there is no simple linkage between summer Delta salinity and delta smelt abundance (Nobriga et al. 2008). During the winter, turbidity associated with flow pulses may be an important migratory cue for delta smelt (Grimaldo et al. in review). In this analysis, we use the location of the 2 ppt isohaline (hereafter called “X2”) to index the location of the low salinity zone, which in part identifies suitable habitat for post-larval delta smelt. The definition and measurement of X2 is technically complicated, because isohaline location varies with depth and is in constant tidal motion. Regulation of X2 at specific locations between February and June is among the criteria controlling water project operations under Water Rights Decision D-1641 and other authorities. However, it is allowed to vary at other times, including the fall, during which the position of the low salinity zone is useful as an index of environmental quality for delta smelt as described in Chapter 7 and above.

The environmental quality work described above and in Chapter 7 indicates that the historical movement of fall X2 upstream from Suisun Bay is associated with declines in environmental quality for delta smelt during the same period. In particular, movement of the low salinity zone upstream of Collinsville (at River Kilometer Index 81) is associated with a sharp decrease in the quality of delta smelt habitat. In this analysis, we present the projected X2 in each month of the year under the scenarios described in CalSim-II studies 6.1, 7.0, 7.1, and 8.0. In each case, we examine the base X2 in Study 6.1 and departures from that location in the other studies. The data are also binned by hydrology. For October through December, we have used the water-year type of the previous water year; for January through May we used quintiles of the Eight River Index, which represents the unimpaired runoff in the Sacramento and San Joaquin watersheds; for the remaining months, we used the water-year type of the current water year. For convenience the Eight River Index quintiles are represented by the same five labels as the water-year types.

Model Results Used

Most of this analysis of effects on delta smelt is organized around monthly comparisons because the CalSim-II model results, which are presented on a monthly timestep, are the only available simulations representing all the studies considered in this Biological Assessment. In each model case comparison, we have considered (1) changes in total exports at the CVP and SWP export facilities for each month of the year with respect to Study 6.1; (2) predicted net OMR flow during each month; and (3) X2 and changes in it among the studies for each month. Study 6.1 comparisons are provided here in the BA because we believe Study 6.1 is most representative to the operating regime in the years immediately before the POD than the other model cases. Given that changes in water project operations are likely a contributing, or partial, cause of the POD, it is important to provide comparisons that give some indication of differences in water project operations immediately before and after the POD. However, Study 6.1 is not an especially satisfactory representation of pre-POD water project operations. The pre- and post-POD comparisons desirable for these analyses could be performed through additional CalSim-II simulations or using an alternative approach in which statistical models of water project operations during different periods are constructed using actual historical data. The models would then be used for direct comparison of water project characteristics during the pre- and post-POD eras. While we have not adopted an alternative statistical approach in this biological assessment, we believe it would be a useful way to further assess changes in water project operations during the POD era and we recommend that the Service consider such an analysis as further refinement to this BA. We have used OMR flow results generated via DSM2 modeling for studies 7.0, 7.1, and 8.0 because DSM2-based estimates are regarded as more credible for OMR than those derived from the CalSim-II modeling.

The climate change analysis presented here is adapted from Appendix R, which comprises a detailed analysis of the implications of four “bookend” climate change scenarios meant to represent plausible combinations of high or low future precipitation and temperature. The analyses in Appendix R are departures from CalSim-II model case 8.0, and rely on a base assumption of sea level rise. As noted previously, there is great uncertainty how local climate will evolve as global climate change proceeds. The authors of Appendix R caution against assuming that any one of the scenarios in the Appendix is especially likely relative to the others and that key analytical assumptions may have potentially significant uncertainties, and we repeat that caution here.

The CalSim-II output examined here models the base operation of the water projects in each of the Studies. It does not incorporate discretionary adjustments to water operations that might be implemented by the Water Operations Management Team to avoid adverse impacts on listed species, including delta smelt that might be caused by export pumping, Old and Middle River flow, or low salinity zone location. Such operational adjustments would be based on actual conditions at the time. For this reason, actual impacts, where adverse impacts are predicted to occur, might be smaller than the following results indicate.

Analyses and Results

Direct Entrainment at the CVP and SWP

Some delta smelt are entrained by the south Delta export facilities, with most dying in the process. Because the species is migratory, entrainment is seasonal. Adult delta smelt may be present in the south Delta and vulnerable to entrainment from December through April; larvae and juveniles are likely to be present and vulnerable during late March through early July.

Export Pumping

To evaluate the effects of direct entrainment we reviewed the total CVP + SWP pumping (as “Jones” plus “Total Banks”) in the CalSim-II output. Hydrologic data from the years 1921 to 2003 were used to fit the model. For each comparison presented in Table 13-1 through Table 13-12, differences among model cases are presented as average percent change from the average total pumping in Study 6.1. We have not calculated a numerical estimate of the change in salvage of delta smelt, because that is not a necessary step in evaluating the differences in risk among studies. The export pumping numbers represent the average pumping (in cfs) reported in the CalSim-II simulations for a given month and water year type.

It is important to note that the base operating regime simulated in Study 6.1 represents high levels of winter and spring pumping that have been implicated as a likely contributing cause of the Pelagic Organism Decline (see Chapter 7 and introductory discussion of winter pumping above). Hence study comparisons principally serve to indicate where this existing risk might be redistributed, enhanced, or diminished by the assumptions made in studies 7.0, 7.1, and 8.0.

Percentage changes in pumping in studies 7.0, 7.1, and 8.0 represent the average differences between corresponding cases, and we interpret them to represent predicted *average differences in entrainment* during the water-year types and months represented in each table.

The risk of entrainment depends not only on export pumping rates, but also on the discharge of delta tributaries and the distribution of fish. The distribution of delta smelt may vary substantially from year to year and between months. For example, in years which do not have a significant "first flush" event in December or early January, adult smelt might not be in the central Delta, and might therefore be at lower risk of entrainment during that period. The pumping values and differences reported below should be used to infer an average level or average difference in entrainment.

Results: During October through December, total pumping in studies 7.0, 7.1, and 8.0 is generally 2-10 percent lower than in Study 6.1 (Table 13-1 through Table 13-3). These reductions would be expected to reduce losses of delta smelt; however, salvage is typically low prior to the "first flush" that often occurs late in this period, so the reductions are likely to make little difference in terms of direct losses of delta smelt. Exceptions include Below Normal, Dry, and Critically Dry years in studies 7.1 and 8.0, which featured 2.8-9.4 percent increases in pumping over Study 6.1 in December.

Table 13-1 Comparison of total export pumping in studies 7.0, 7.1, and 8.0 with Study 6.1 for October.

OCTOBER	Study 6.1	Study 7.0		Study 7.1		Study 8.0	
WY Type	CFS	CFS	Change	CFS	Change	CFS	Change
Wet	9360	9054	-3.3%	8915	-4.8%	9083	-3.0%
Above Normal	8141	7982	-1.9%	7362	-9.6%	7722	-5.2%
Below Normal	8623	8100	-6.1%	7717	-10.5%	7729	-10.4%
Dry	7603	8111	6.7%	7325	-3.7%	7567	-0.5%
Critically Dry	6868	6799	-1.0%	6460	-5.9%	6468	-5.8%

Table 13-2 Comparison of total export pumping in studies 7.0, 7.1, and 8.0 with Study 6.1 for November.

NOVEMBER	Study 6.1	Study 7.0		Study 7.1		Study 8.0	
WY Type	CFS	CFS	Change	CFS	Change	CFS	Change
Wet	10247	10503	2.5%	10743	4.8%	10699	4.4%
Above Normal	8198	8414	2.6%	8581	4.7%	8422	2.7%
Below Normal	9077	8851	-2.5%	8829	-2.7%	8922	-1.7%
Dry	7628	7416	-2.8%	7717	1.2%	7748	1.6%
Critically Dry	6424	6278	-2.3%	6391	-0.5%	5801	-9.7%

Table 13-3 Comparison of total export pumping in studies 7.0, 7.1, and 8.0 with Study 6.1 for December.

DECEMBER	Study 6.1	Study 7.0		Study 7.1		Study 8.0	
WY Type	CFS	CFS	Change	CFS	Change	CFS	Change
Wet	11000	10438	-5.1%	11515	4.7%	11585	5.3%
Above Normal	10085	8870	-12.1%	10012	-0.7%	9662	-4.2%
Below Normal	9260	8770	-5.3%	9829	6.1%	9876	6.7%
Dry	9548	8924	-6.5%	9816	2.8%	9817	2.8%
Critically Dry	7183	7107	-1.1%	7855	9.4%	7522	4.7%

During January and February, most of the differences in pumping are reductions in 7.0, 7.1, and 8.0 with respect to 6.1 (Table 13-4 through Table 13-6). These reductions make 7.0, 7.1, and 8.0 more protective of delta smelt than 6.1 in January and February. In March, though, there are consistently substantial (3.1 percent to 15.7 percent) increases in 7.0, 7.1, and 8.0 over 6.1 in Wet and Above Normal water years. These increases would be expected to increase losses of delta smelt. Salvage is often low during these wetter years, although the hydrograph can have a substantial effect on the magnitude and timing of losses. Hence, it is difficult to assess the relative importance of the higher March export levels. It is important to note that the base pumping in Study 6.1 during these months may have contributed to excessive winter and spring delta smelt entrainment during the POD years.

Table 13-4 Comparison of total export pumping in studies 7.0, 7.1, and 8.0 with Study 6.1 for January.

JANUARY	Study 6.1	Study 7.0		Study 7.1		Study 8.0	
WY Type	CFS	CFS	Change	CFS	Change	CFS	Change
Wet	11007	10668	-3.1%	11537	4.8%	11425	3.8%
Above Normal	11679	10074	-13.7%	11433	-2.1%	11539	-1.2%
Below Normal	10996	9908	-9.9%	10815	-1.6%	10960	-0.3%
Dry	10041	8410	-16.2%	9584	-4.5%	9682	-3.6%
Critically Dry	7899	7224	-8.5%	7646	-3.2%	7986	1.1%

Table 13-5 Comparison of total export pumping in studies 7.0, 7.1, and 8.0 with Study 6.1 for February.

FEBRUARY	Study 6.1	Study 7.0		Study 7.1		Study 8.0	
WY Type	CFS	CFS	Change	CFS	Change	CFS	Change
Wet	10361	10295	-0.6%	10507	1.4%	10617	2.5%
Above Normal	10951	10143	-7.4%	10728	-2.0%	11062	1.0%
Below Normal	9802	9759	-0.4%	9625	-1.8%	9171	-6.4%
Dry	8533	8322	-2.5%	7982	-6.5%	8137	-4.6%
Critically Dry	5620	5154	-8.3%	6061	7.9%	5853	4.2%

Table 13-6 Comparison of total export pumping in studies 7.0, 7.1, and 8.0 with Study 6.1 for March.

MARCH	Study 6.1	Study 7.0		Study 7.1		Study 8.0	
WY Type	CFS	CFS	Change	CFS	Change	CFS	Change
Wet	8729	10099	15.7%	9138	4.7%	9524	9.1%
Above Normal	9374	10386	10.8%	9660	3.1%	10138	8.2%
Below Normal	8328	8692	4.4%	8387	0.7%	8472	1.7%
Dry	7235	7367	1.8%	7270	0.5%	7188	-0.6%
Critically Dry	4449	3798	-14.6%	4316	-3.0%	4241	-4.7%

During April through May most of the differences between 6.1 and the other studies represent lower pumping in the other studies, including substantially proportionately lower pumping in some cases, particularly in Study 7.0 (Table 13-7 through Table 13-9). However, in June there are large increases (up to 134 percent, representing an increase of about 2000 cfs in average export pumping) in Dry and Critically Dry years in 7.0, 7.1, and 8.0. The net result of these changes is that losses of larvae and early juveniles should be lower in early spring, but with increased losses of juveniles in the late spring of drier years.

Table 13-7 Comparison of total export pumping in studies 7.0, 7.1, and 8.0 with Study 6.1 for April.

APRIL	Study 6.1	Study 7.0		Study 7.1		Study 8.0	
WY Type	CFS	CFS	Change	CFS	Change	CFS	Change
Wet	7155	6226	-13.0%	6944	-2.9%	6987	-2.3%
Above Normal	6262	5488	-12.4%	6173	-1.4%	6226	-0.6%
Below Normal	5460	4472	-18.1%	4737	-13.2%	4708	-13.8%
Dry	3532	2716	-23.1%	3329	-5.7%	3339	-5.5%
Critically Dry	1891	1780	-5.9%	2035	7.6%	1893	0.1%

Table 13-8 Comparison of total export pumping in studies 7.0, 7.1, and 8.0 with Study 6.1 for May.

MAY	Study 6.1	Study 7.0		Study 7.1		Study 8.0	
WY Type	CFS	CFS	Change	CFS	Change	CFS	Change
Wet	7160	6114	-14.6%	6950	-2.9%	6924	-3.3%
Above Normal	5544	4174	-24.7%	5193	-6.3%	5011	-9.6%
Below Normal	4746	3069	-35.3%	4149	-12.6%	4051	-14.7%
Dry	3769	2222	-41.0%	3259	-13.5%	3073	-18.5%
Critically Dry	1783	1595	-10.5%	1751	-1.8%	1644	-7.8%

Table 13-9 Comparison of total export pumping in studies 7.0, 7.1, and 8.0 with Study 6.1 for June.

JUNE	Study 6.1	Study 7.0		Study 7.1		Study 8.0	
WY Type	CFS	CFS	Change	CFS	Change	CFS	Change
Wet	7930	8414	6.1%	8635	8.9%	8616	8.7%
Above Normal	6937	7344	5.9%	7961	14.8%	7802	12.5%
Below Normal	6296	6480	2.9%	6988	11.0%	6890	9.4%
Dry	4429	5621	26.9%	6212	40.3%	6118	38.1%
Critically Dry	1513	3540	133.9%	2754	82.0%	2416	59.7%

The trend of higher pumping in June is continued in July, with substantial (14 percent to 179 percent) increases in pumping in all water year types. These increases would cause correspondingly higher juvenile smelt entrainment in some years. In August there is higher (9.4 percent to 95.9 percent) pumping in all water year types Study 7.0, with corresponding increases in Wet, Above Normal, and Below Normal years in studies 7.1 and 8.0. In September most changes were small, with only Critically Dry years standing out (+24 percent) in Study 7.0 and Dry years in 7.1 and 8.0 (-17 percent and -19 percent, respectively) being substantial different from Study 6.1. Since delta smelt entrainment tends to be very low in August and September, these changes in late summer are not expected to have significant population effects.

Table 13-10 Comparison of total export pumping in studies 7.0, 7.1, and 8.0 with Study 6.1 for July.

JULY	Study 6.1	Study 7.0		Study 7.1		Study 8.0	
WY Type	CFS	CFS	Change	CFS	Change	CFS	Change
Wet	8898	10154	14.1%	10773	21.1%	10875	22.2%
Above Normal	6936	8899	28.3%	10037	44.7%	9736	40.4%
Below Normal	7907	10476	32.5%	11111	40.5%	10641	34.6%
Dry	6747	10593	57.0%	10539	56.2%	10123	50.0%
Critically Dry	1887	5270	179.3%	3675	94.8%	3359	78.0%

Table 13-11 Comparison of total export pumping in studies 7.0, 7.1, and 8.0 with Study 6.1 for August.

AUGUST	Study 6.1	Study 7.0		Study 7.1		Study 8.0	
WY Type	CFS	CFS	Change	CFS	Change	CFS	Change
Wet	10010	11549	15.4%	11491	14.8%	11627	16.2%
Above Normal	8969	11474	27.9%	11082	23.6%	11168	24.5%
Below Normal	8676	10514	21.2%	9814	13.1%	9717	12.0%
Dry	6958	7611	9.4%	5720	-17.8%	5277	-24.2%
Critically Dry	2156	4224	95.9%	2020	-6.3%	1880	-12.8%

Table 13-12 Comparison of total export pumping in studies 7.0, 7.1, and 8.0 with Study 6.1 for September.

SEPTEMBER	Study 6.1	Study 7.0		Study 7.1		Study 8.0	
WY Type	CFS	CFS	Change	CFS	Change	CFS	Change
Wet	10804	11469	6.2%	11249	4.1%	11315	4.7%
Above Normal	10320	10498	1.7%	10325	0.1%	10710	3.8%
Below Normal	9998	10128	1.3%	9755	-2.4%	9924	-0.7%
Dry	8475	8571	1.1%	7024	-17.1%	6838	-19.3%
Critically Dry	4706	5828	23.8%	4922	4.6%	4777	1.5%

Old and Middle River Flow

Old and Middle River flow provides an alternative approach to estimating entrainment risk. It provides a direct measure of the strength of the transport process responsible for the movement of delta smelt to the export facilities (Grimaldo et al. in review), and is thus somewhat “cleaner” than analyses relying solely on export pumping. As with X2 and the boundary of the zone of entrainment, OMR flow is in a constant state of flux because of the tides, wind, river flows, operation of the South Delta Temporary Barriers, and export pumping. The relevant quantity for analyzing the transport of fish is the tidally averaged net OMR flow. It is not possible to accurately predict OMR flow from CalSim-II output. Here we use DSM2-based OMR flow predictions provided by CDWR instead of CalSim-II. Only cases representing studies 7.0, 7.1, and 8.0 were provided.

The net velocity of water in Old and Middle River scales a transport process that can affect delta smelt survival, reproduction, and dispersal in two ways. First, upstream flow may directly deliver delta smelt larvae, juveniles, and adults to the threshold of the water project export facilities, where they become entrained. Second, upstream flow may indirectly affect adult delta smelt by creating confusing or adverse migratory conditions at locations remote from the export facilities. A discussion of evidence for both direct and indirect effects is presented in Chapter 7.

Both the direct and indirect effects associated with upstream, or negative OMR flow increase in severity or likelihood with the magnitude of the upstream flow, as discussed in Chapter 7. As with export pumping, we assume (following P.E. Smith, unpublished analysis; Grimaldo et al. in review) that *entrainment escalates at least in proportion to the magnitude of average net upstream OMR flow, and at high OMR flow escalates faster*. As Smith's analysis showed, downstream OMR flow is usually associated with almost nonexistent entrainment risk to delta smelt that are north of Old and Middle Rivers. The assumption of a linear relationship between entrainment and OMR flow only works for upstream OMR flow less than about 4000 cfs. Plots that include historical data for periods of strong upstream flow reveal that the entrainment/OMR flow relationship is in reality exponential, and entrainment increases much faster than negative OMR flow. However, at low upstream OMR flow rates a line fits the relationship reasonably well. Whether the rapid increase in entrainment at higher flow rates is due to changes in the size or disposition of the zone of entrainment or to other characteristics of the transport process itself, or both, is uncertain.

In this analysis, we summarized the median OMR flow for each month, binned by water year type. Data from the years 1975 to 1991 were used to fit the model. The figures represent medians computed over full months. Because there are only 16 years of data, water year types are consolidated into Wet + Above Normal, Below Normal + Dry, and Critically Dry. According to DWR (Aaron Miller, pers. Comm..), there are strong antecedent effects from the boundary conditions used to frame each monthly time period that may skew the results to some extent.

The Smelt Work Group (SWG, formerly the Delta Smelt Work Group) used DSM2-based particle tracking methods to analyze the effects of OMR on the limits of the zone of entrainment during the winter and spring of 2008 (See also Kimmerer and Nobriga 2008 for a more general exposition). The SWG concluded that under hydrodynamic conditions prevailing during March and April 2008 a daily net upstream OMR flow no greater than 2000±500 cfs effectively prevented entrainment of simulated particles injected into the San Joaquin River as far southeast as the mouth of Potato Slough (a fish monitoring location known as "Station 815"). In this analysis, we consider upstream flow of 2000 cfs to be a rough indicator of the limit beyond which increasingly negative OMR flow causes the zone of entrainment to expand beyond the south Delta into the San Joaquin River at Station 815 and farther downstream under operational circumstances similar to those existing in spring 2008. Furthermore, we regard upstream flow of 4000 cfs to be a rough benchmark value separating the linear domain from the exponential domain of the entrainment/flow relationship, and upstream flows exceeding 4000 cfs are likely to be associated with substantially larger entrainment, all other things being equal.

In the following tables, two blocks of months are presented: December through March, representing the period of adult delta smelt vulnerability to entrainment, and April through July, representing juvenile vulnerability.

In Wet + Above Normal years, the results suggest median OMR flows are usually downstream during the winter months (Table 13-13). However, they become negative in June (-3506 to -3869 cfs) and strongly so in July (-6652 to -7996 cfs) (Table 13-14). This suggests that losses of adult delta smelt and early juveniles would result in very low levels of losses. Negative flows during later months would result in more substantial losses of juvenile delta smelt from the central Delta and north of it, including higher losses in years when fish are still within reach of the pumps in July.

Table 13-13 Projected monthly net OMR flow for Wet + Above Normal years during months of adult delta smelt entrainment vulnerability

WYTS: W/AN Study	December	January	February	March	Average
OCAP 7.0	1437	206	2759	5819	2555
OCAP 7.1	-127	-713	5719	8029	3227
OCAP 8.0	-152	-506	5860	7713	3229

Table 13-14 Projected monthly net OMR flow for Wet + Above Normal years during months of juvenile delta smelt entrainment vulnerability

WYTS:W/AN Study	April	May	June	July	Average
OCAP 7.0	3666	931	-3869	-6652	-1481
OCAP 7.1	3469	75	-3666	-7647	-1942
OCAP 8.0	3444	42	-3506	-7996	-2004

In Below Normal + Dry years, the results indicate strong negative OMR flows (-4645 cfs to -6793 cfs) for the months of December through March (Table 13-15). Moderately negative flows in April and May (-897 cfs to -2845 cfs) are followed by strong negative flows in June (-5551 cfs to -6644 cfs) and even stronger negative flows in July (-9028 cfs to -11014 cfs) (Table 13-16). Analyses of particle tracking (see above) and salvage data (Grimaldo et al., in review) indicate that winter losses of adults would likely occur in these drier years, but losses of early larvae and juveniles would likely be relatively low in spring. Strong negative flows in June and July would be expected to result in substantial losses of juveniles from the central Delta and probably the lower Sacramento River in these drier years.

Table 13-15 Projected monthly net OMR flow for Below Normal + Dry years during months of adult delta smelt entrainment vulnerability

WYTS: BN/D Study	December	January	February	March	Average
OCAP 7.0	-5203	-4645	-6763	-6146	-5689
OCAP 7.1	-6212	-6104	-5660	-4692	-5667
OCAP 8.0	-6793	-5759	-6207	-4756	-5879

Table 13-16 Projected monthly net OMR flow for Below Normal + Dry years during months of juvenile delta smelt entrainment vulnerability

WYTS: BN/D Study	April	May	June	July	Average
OCAP 7.0	-897	-1258	-5551	-9028	-4183
OCAP 7.1	-2199	-2845	-6644	-11014	-5676
OCAP 8.0	-2181	-2676	-6654	-10908	-5605

In Critically Dry years, strong negative OMR flows in December (-4637 cfs to -6419 cfs) are followed by moderately to weakly negative flows (-837 cfs to -1594 cfs) in January through March (Table 13-17). April and May (-1335 cfs to -1698 cfs) feature moderately negative OMR flows, while June and July (-3195 cfs to -5490 cfs) feature moderate to strong flows (Table 13-18). Analyses of particle tracking (see above) and salvage data (Grimaldo et al., in review) indicate that losses of adults would occur December of Critically Dry years, with much lower losses in the later winter months. Losses of early larvae and juveniles would be expected to be relatively low in spring. Strong negative flows in June and July would be expected to result in substantial losses of juveniles in these very dry years.

Table 13-17 Projected monthly net OMR flow for Critically Dry years during months of adult delta smelt entrainment vulnerability

WYTS: C Study	December	January	February	March	Average
OCAP 7.0	-5829	-1000	-1040	-825	-2173
OCAP 7.1	-6419	-1031	-2022	-976	-2612
OCAP 8.0	-4637	-1525	-1594	-1087	-2211

Table 13-18 Projected monthly net OMR flow for Critically Dry years during months of juvenile delta smelt entrainment vulnerability

WYTS: C Study	April	May	June	July	Average
OCAP 7.0	-1335	-1574	-4493	-5490	-3223
OCAP 7.1	-1642	-1698	-3195	-3573	-2527
OCAP 8.0	-1655	-1509	-2354	-3350	-2217

X2

We used projected monthly X2 from the CalSim-II simulations to estimate X2 in each model case for each of the 12 months. These are presented as Figure 13-1 through Figure 13-36. Each figure consists of five panels representing hydrologic classification as described above. Months using an Eight Rivers Index classification use the same bin names for consistency. In all panels the “x” axis represents X2 in kilometers in Study 6.1, while the “y” axis represents the departure from that X2 in another study. The dashed lines in each figure are smooth. A full set of monthly figures for studies 7.0, 7.1, and 8.0 is presented, but the months of greatest potential significance for delta smelt are, as discussed above, those falling in the summer and fall seasons.

The general disposition of X2 in Study 6.1 varies by month and hydrology. Early and late in the water year, X2 tends to be compressed into a narrow range between approximately 83 and 90 km in drier years, while in wet years values range from the low 70s to the high 80s. In the middle of the water year, X2 varies considerably in all hydrologic categories, depending on the weather. This means that in drier years, especially during the summer and fall months, X2 in Study 6.1 is usually above Collinsville (RKI 81), often by as much as 5 km. Analyses of historical data indicates that habitat conditions are relatively poor and contribute to delta smelt producing fewer offspring in years when X2 is located above Collinsville during autumn (Feyrer et al. 2007). The effects in summer are less clear, with no simple correlation between Delta salinity (a surrogate for X2) and delta smelt abundance during summer (Nobriga et al. 2008).

Summer X2 Deviation in Studies 7.0, 7.1, and 8.0

In Wet and Above Normal years, July X2 is usually similar to Study 6.1, though there is some scatter both below and above parity (Figures 13-10, 22, 34). Below Normal, Dry, and Critically Dry years show progressively greater upstream deviation from Study 6.1, though it is usually of less than 5 km. This pattern is repeated in August, with a small positive offset in all hydrologic categories (Figures 13-11, 23, 35). The upstream X2 deviation in a Dry or Critically Dry August is usually 3-5 km. These results suggest little consistent pattern in the amount of habitat (based on salinity) available to delta smelt during summer for the different studies, except in very dry years. Note that this result is congruent with the finding that there is no long-term trend in summer X2 (Kimmerer 2002). Moreover, there is no simple linkage between summer Delta salinity and delta smelt abundance (Nobriga et al. 2008).

Fall X2 Deviation in Studies 7.0, 7.1, and 8.0

Although Most of September properly belongs to the summer, it is included here for consistency with Feyrer's habitat analysis. In September, studies 7.0, 7.1, and 8.0 all feature substantial upstream shifts of X2 in all five hydrologic categories, with most differences being approximately 5 km (Figures 13-12, 24, 36). In October and November, studies 7.0, 7.1, and 8.0 all feature substantial (5+ km) upstream shifts of X2 in the the four driest year categories (Figures 13-1, 2, 13, 14, 25 & 26). In December, there is a general tendency for X2 in studies 7.0, 7.1, and 8.0 to deviate farther upstream than Study 6.1 in years where Study 6.1 X2 was 70 km or greater (Figures 13-3, 15 & 27). Below that, deviations were generally negative except for very low Study 6.1 X2 (less than approx. 55 km). Hence, the effects changes in X2 on delta smelt habitat and juvenile production would be mixed, depending on Delta outflow.

Based on analyses for the entire autumn (Feyrer et al. 2007), the consistent upstream shift in X2 during September through November (and December in years with high X2) relative to Study 6.1 and high absolute X2 would be expected to reduce the amount of habitat for delta smelt and subsequent production of juveniles. The movement of X2 upstream by several km during drier years might also shift the distribution of delta smelt far enough east that adult entrainment might begin to occur in Fall under circumstances of high export pumping, or at least to occur earlier than it would otherwise. Similarly, it may also position delta smelt geographically closer to the export pumps at the time of "first flush" and make them more vulnerable to entrainment.

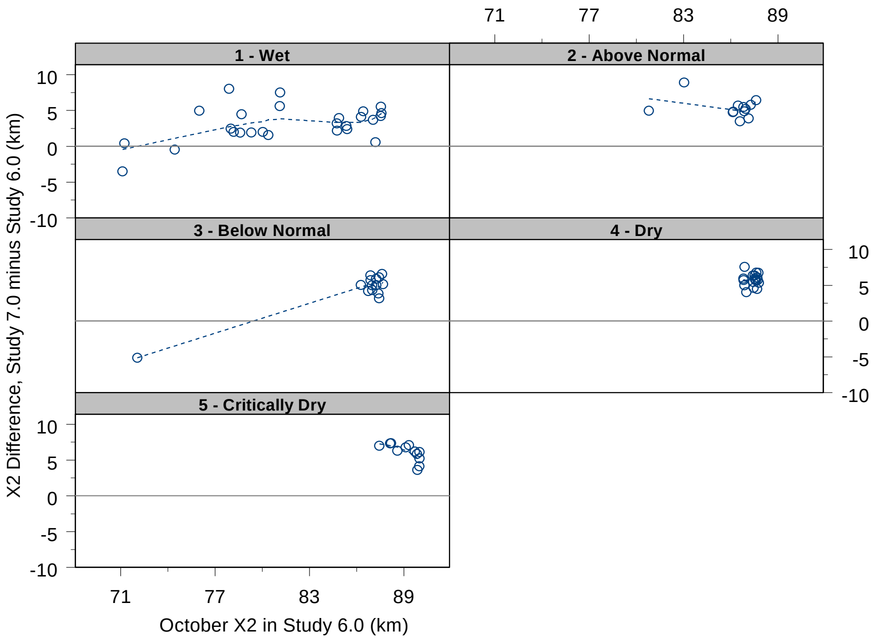


Figure 13-1 Variation in X2 in Study 7.0 with respect to Study 6.1 in October

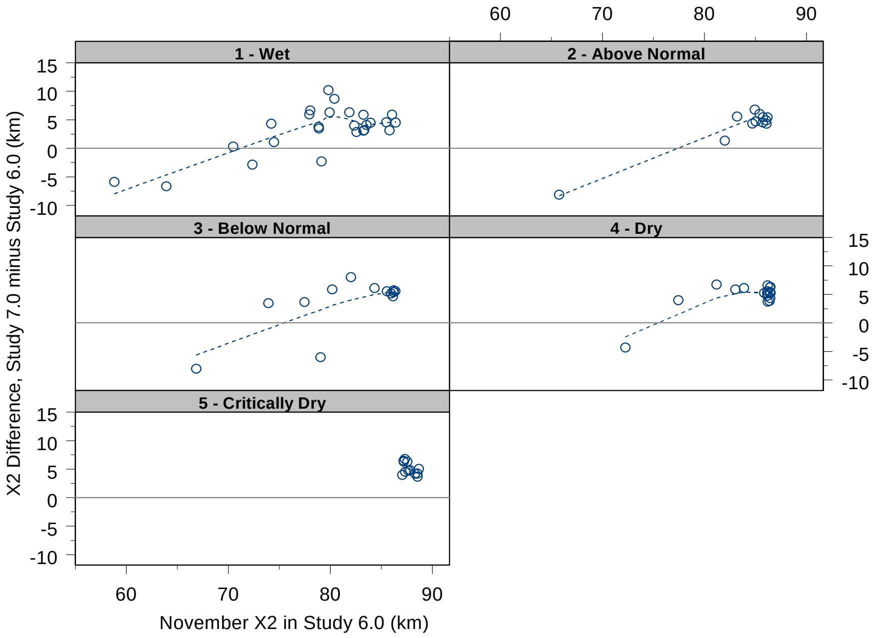


Figure 13-2 Variation in X2 in Study 7.0 with respect to Study 6.1 in November

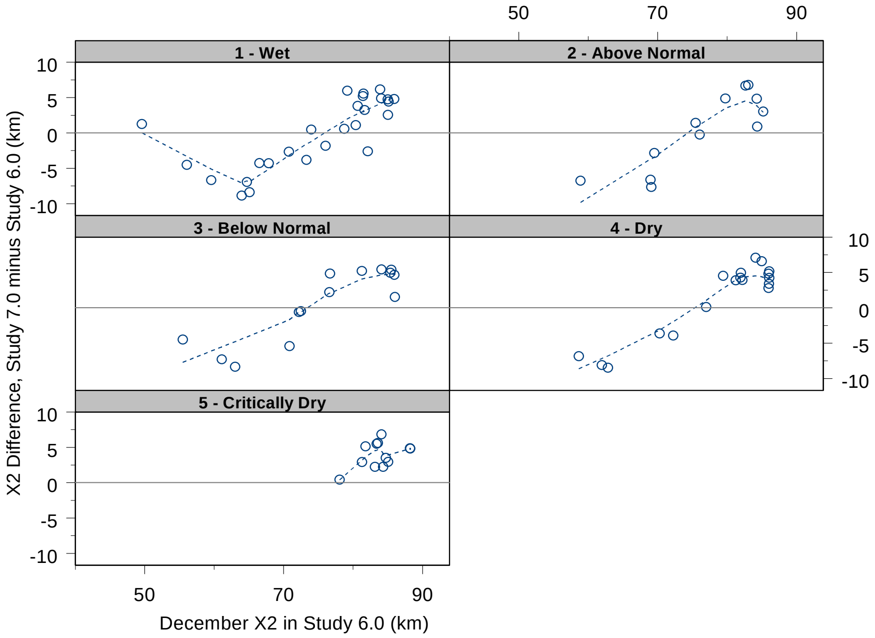


Figure 13-3 Variation in X2 in Study 7.0 with respect to Study 6.1 in December

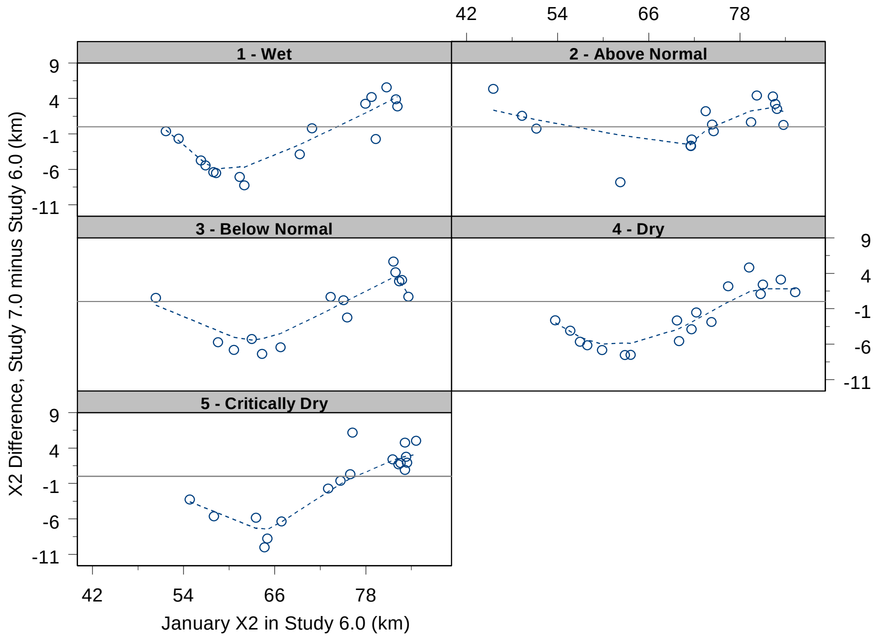


Figure 13-4 Variation in X2 in Study 7.0 with respect to Study 6.1 in January

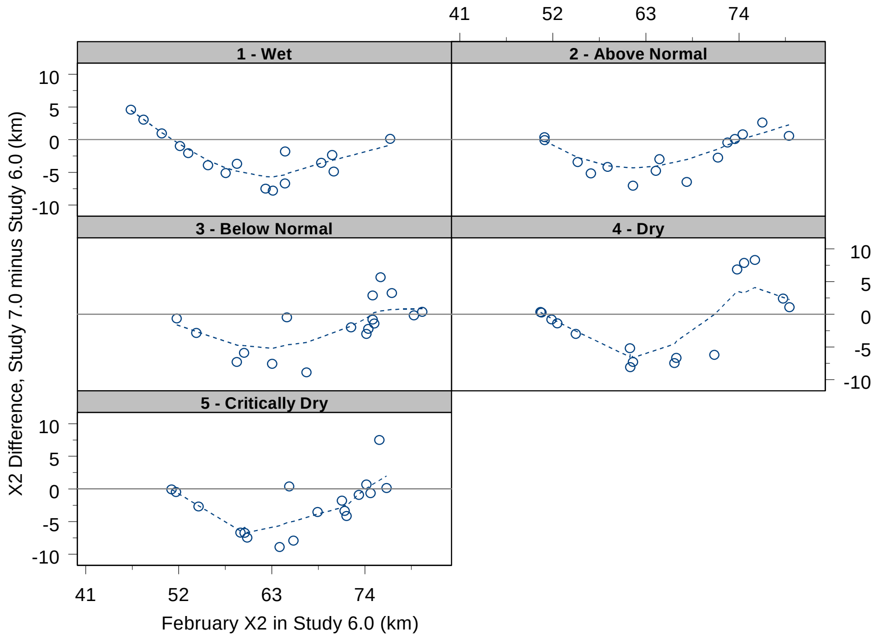


Figure 13-5 Variation in X2 in Study 7.0 with respect to Study 6.1 in February

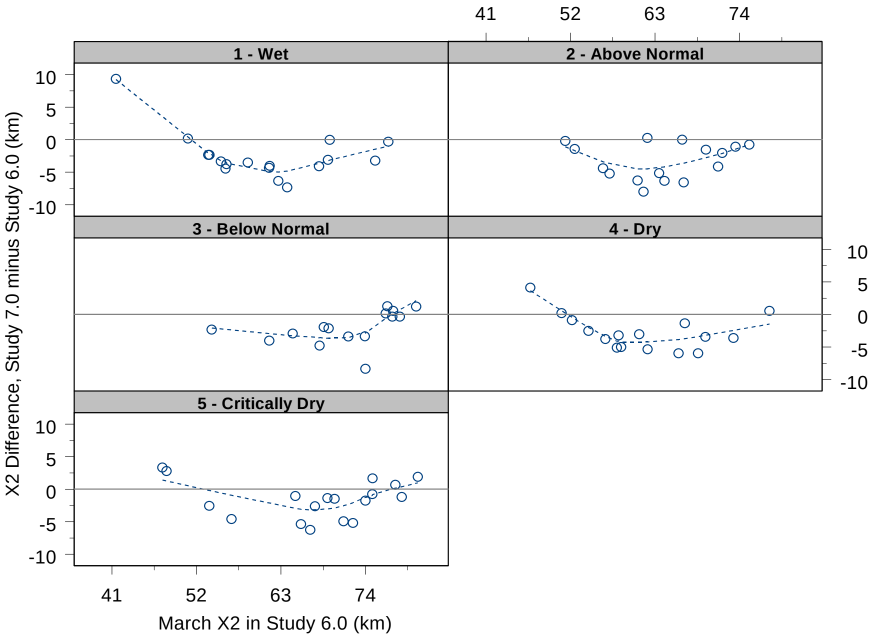


Figure 13-6 Variation in X2 in Study 7.0 with respect to Study 6.1 in March

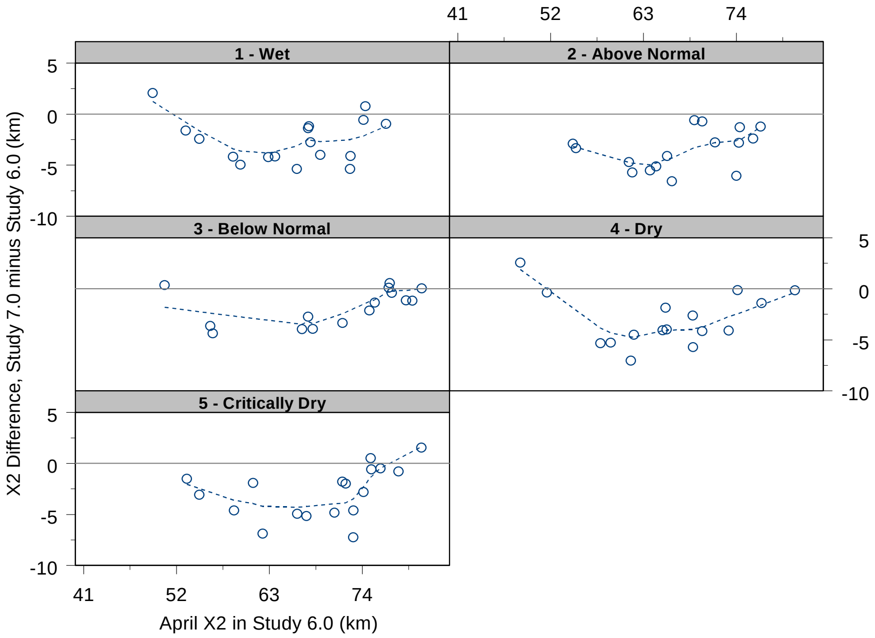


Figure 13-7 Variation in X2 in Study 7.0 with respect to Study 6.1 in April

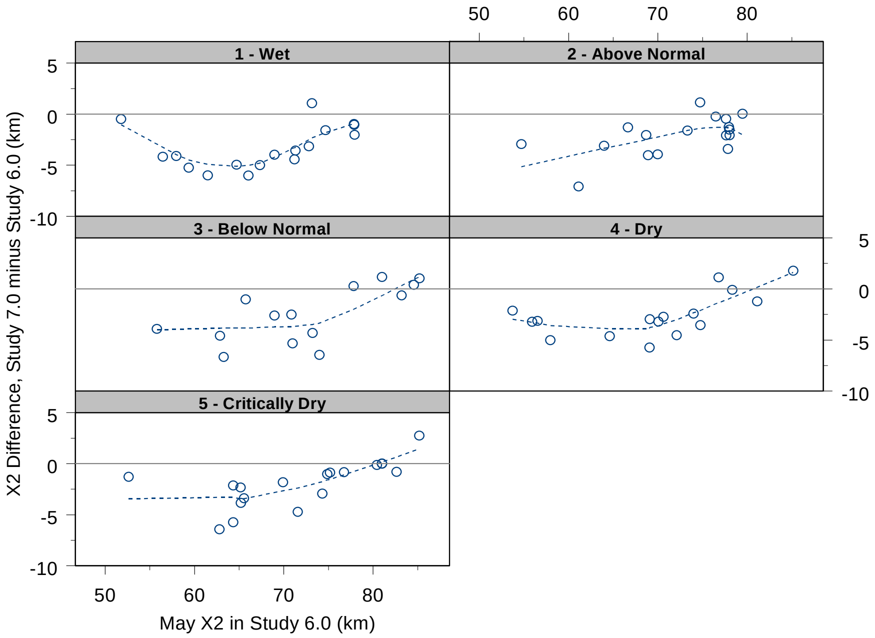


Figure 13-8 Variation in X2 in Study 7.0 with respect to Study 6.1 in May

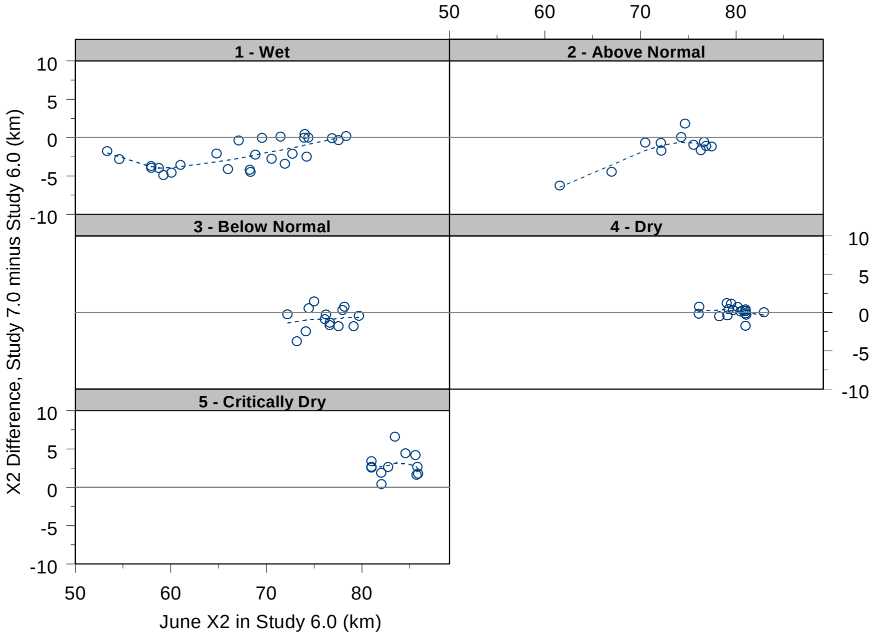


Figure 13-9 Variation in X2 in Study 7.0 with respect to Study 6.1 in June

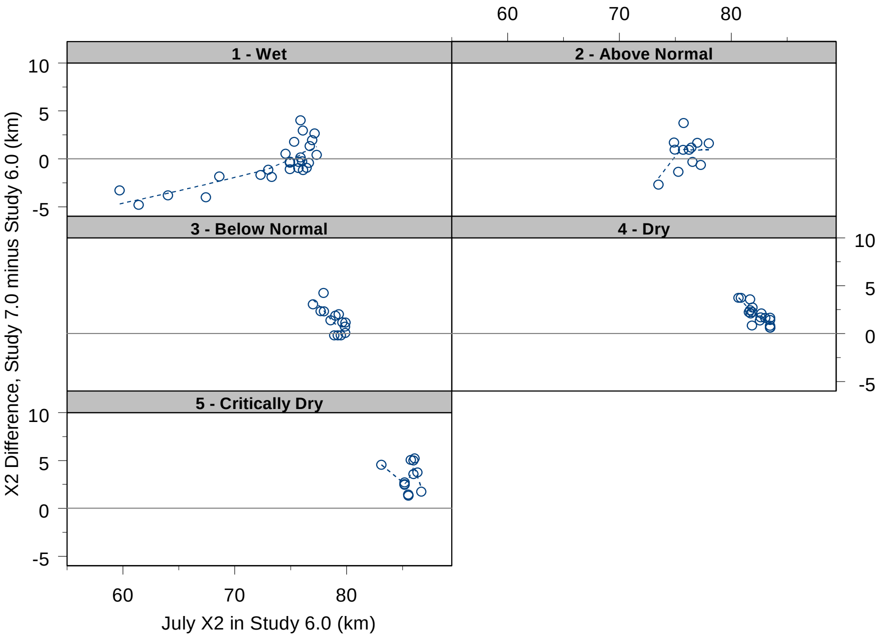


Figure 13-10 Variation in X2 in Study 7.0 with respect to Study 6.1 in July

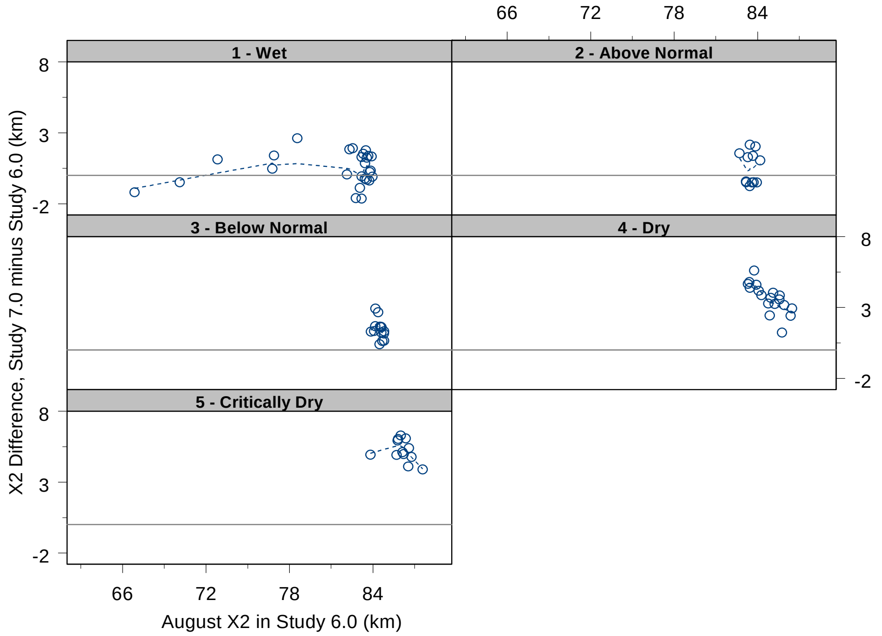


Figure 13-11 Variation in X2 in Study 7.0 with respect to Study 6.1 in August

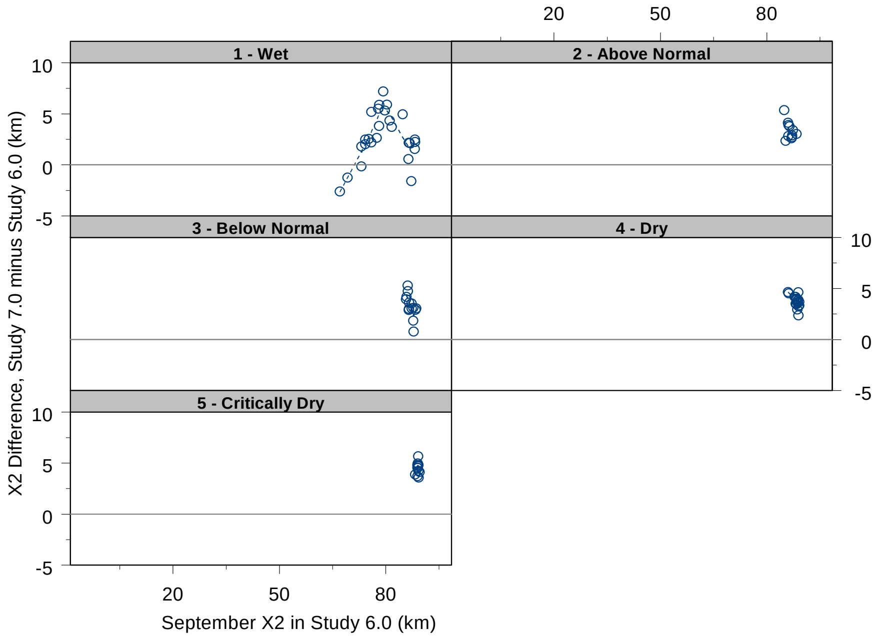


Figure 13-12 Variation in X2 in Study 7.0 with respect to Study 6.1 in September

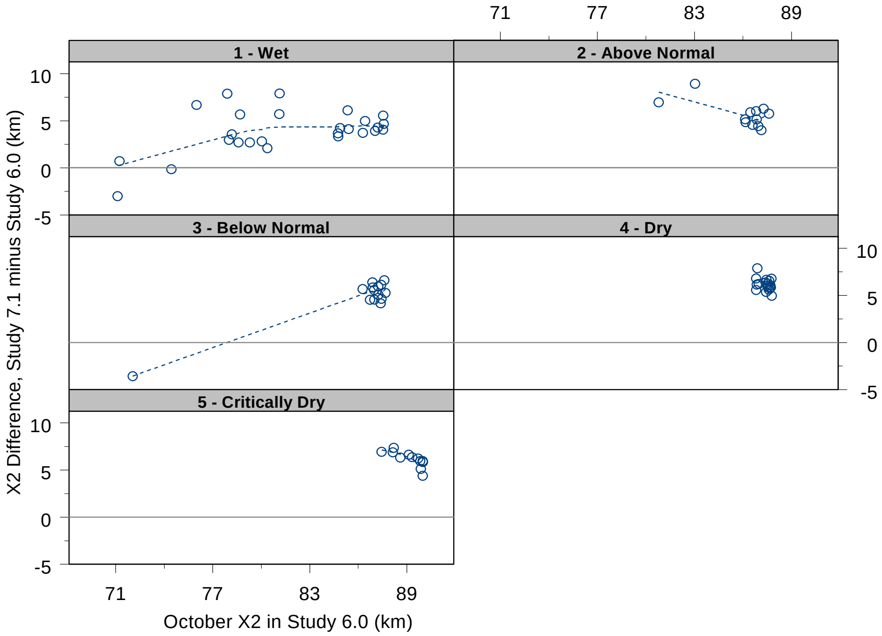


Figure 13-13 Variation in X2 in Study 7.1 with respect to Study 6.1 in October

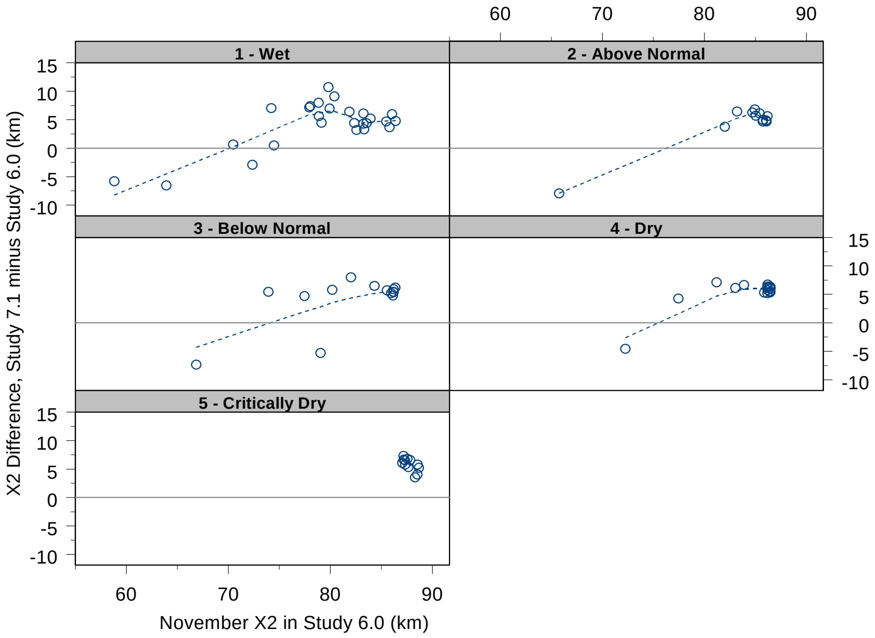


Figure 13-14 Variation in X2 in Study 7.1 with respect to Study 6.1 in November

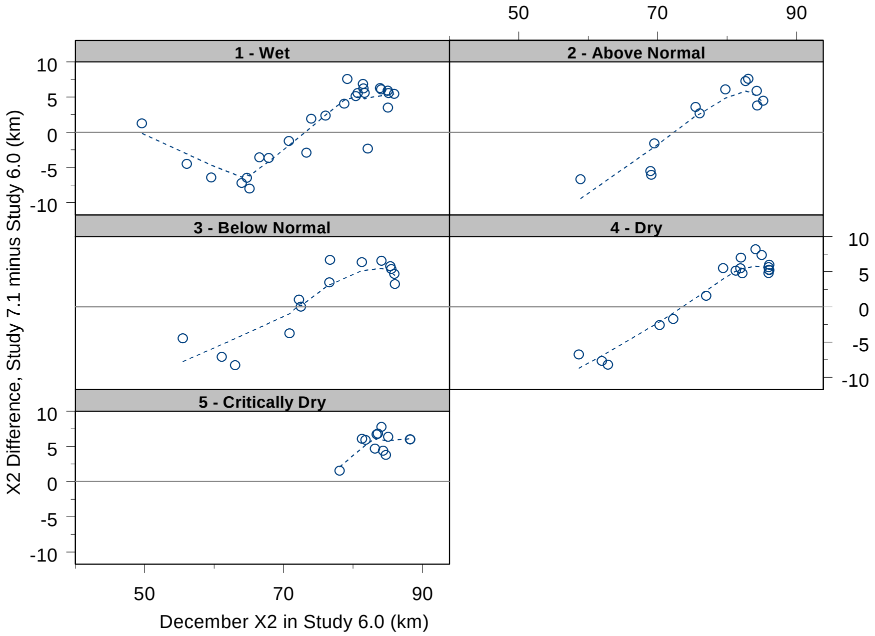


Figure 13-15 Variation in X2 in Study 7.1 with respect to Study 6.1 in December

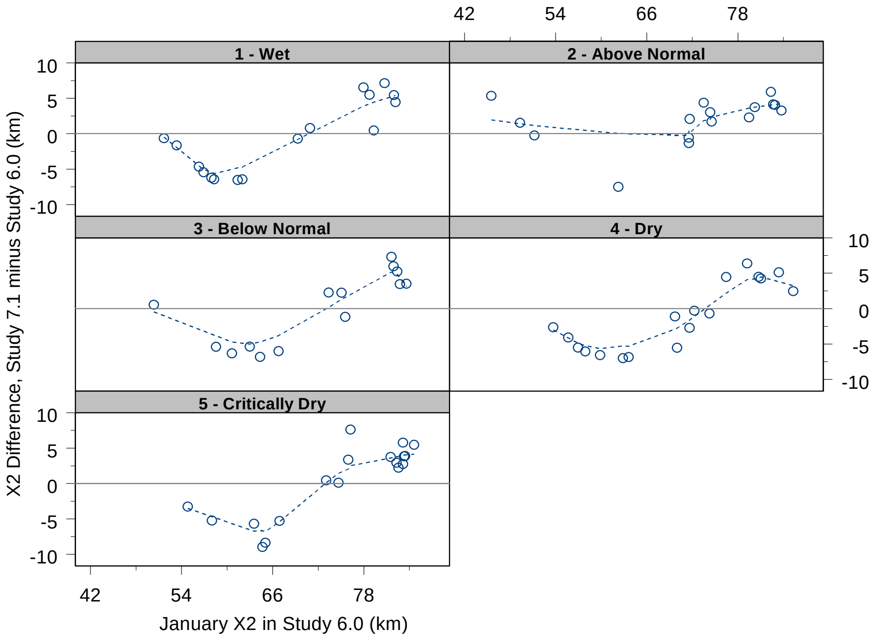


Figure 13-16 Variation in X2 in Study 7.1 with respect to Study 6.1 in January

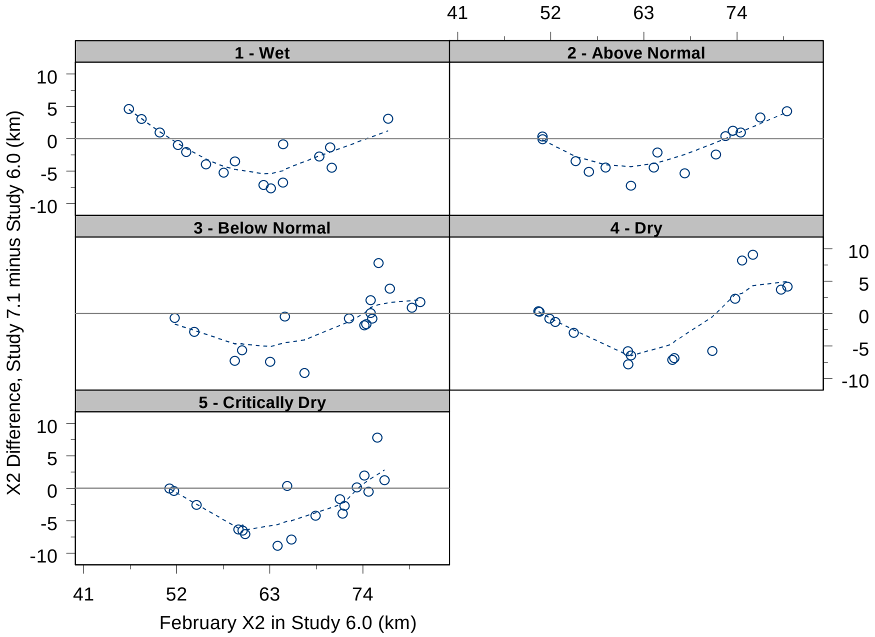


Figure 13-17 Variation in X2 in Study 7.1 with respect to Study 6.1 in February

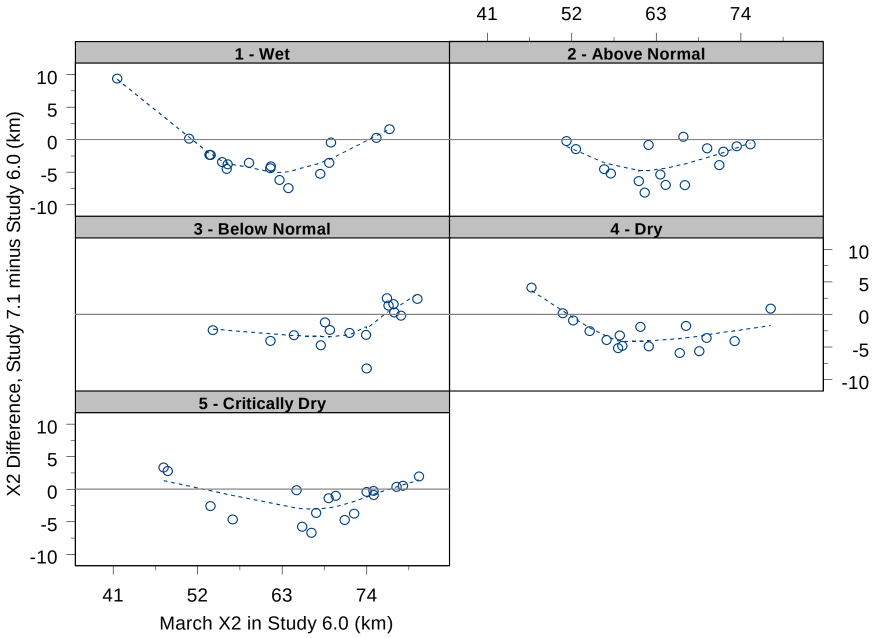


Figure 13-18 Variation in X2 in Study 7.1 with respect to Study 6.1 in March

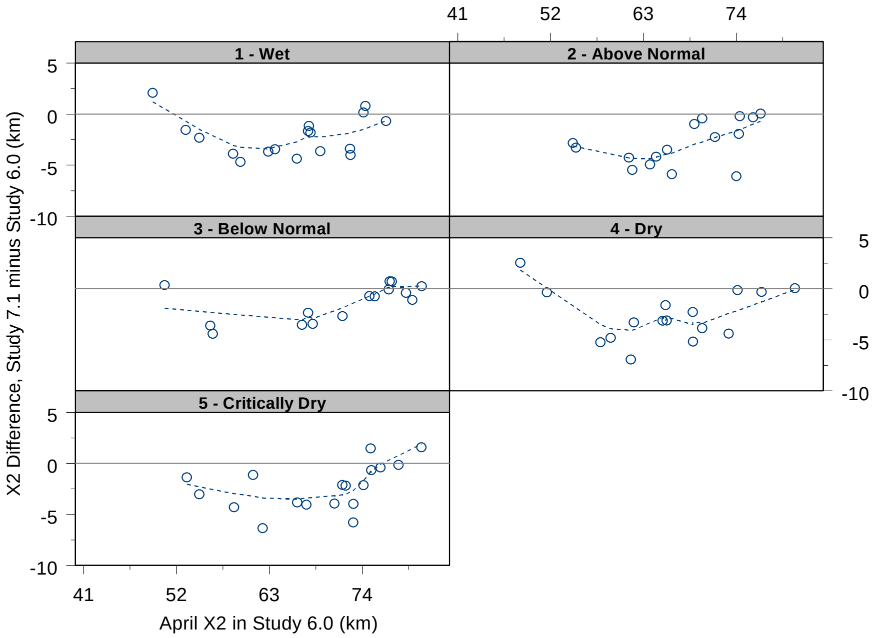


Figure 13-19 Variation in X2 in Study 7.1 with respect to Study 6.1 in April

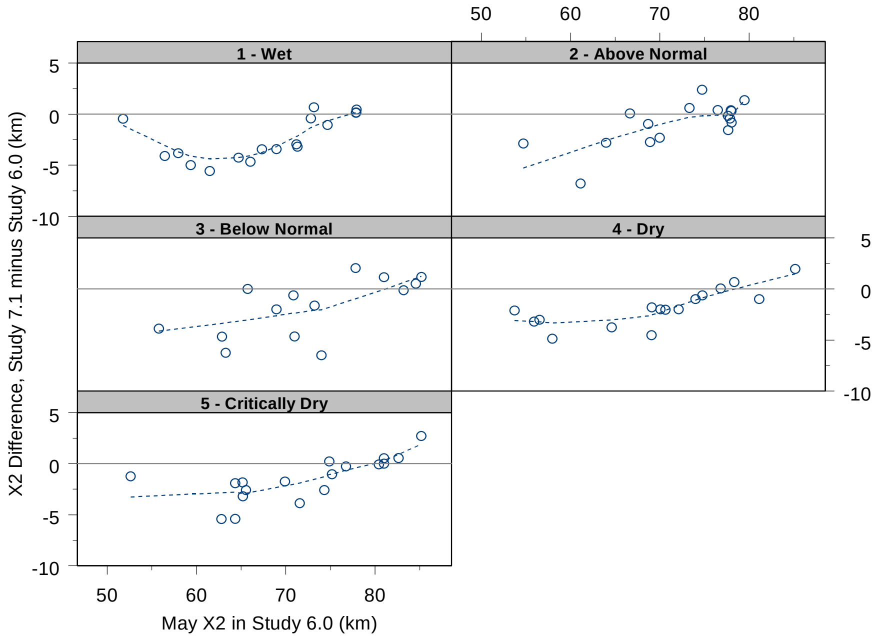


Figure 13-20 Variation in X2 in Study 7.1 with respect to Study 6.1 in May

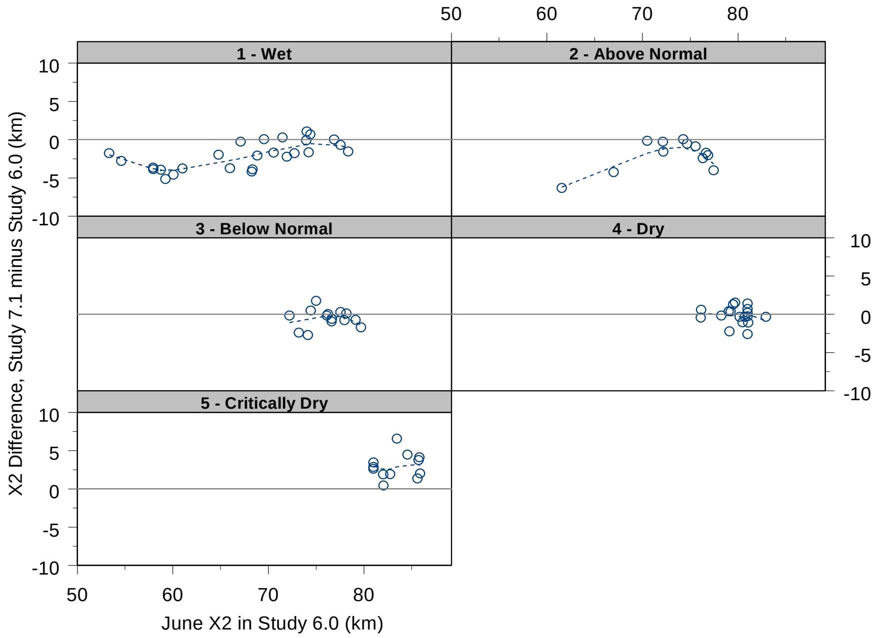


Figure 13-21 Variation in X2 in Study 7.1 with respect to Study 6.1 in June

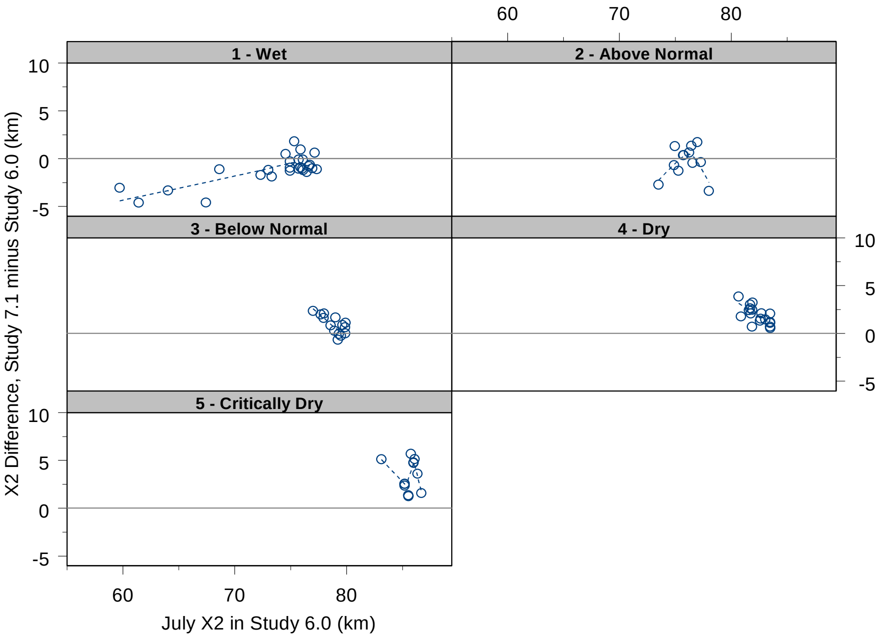


Figure 13-22 Variation in X2 in Study 7.1 with respect to Study 6.1 in July

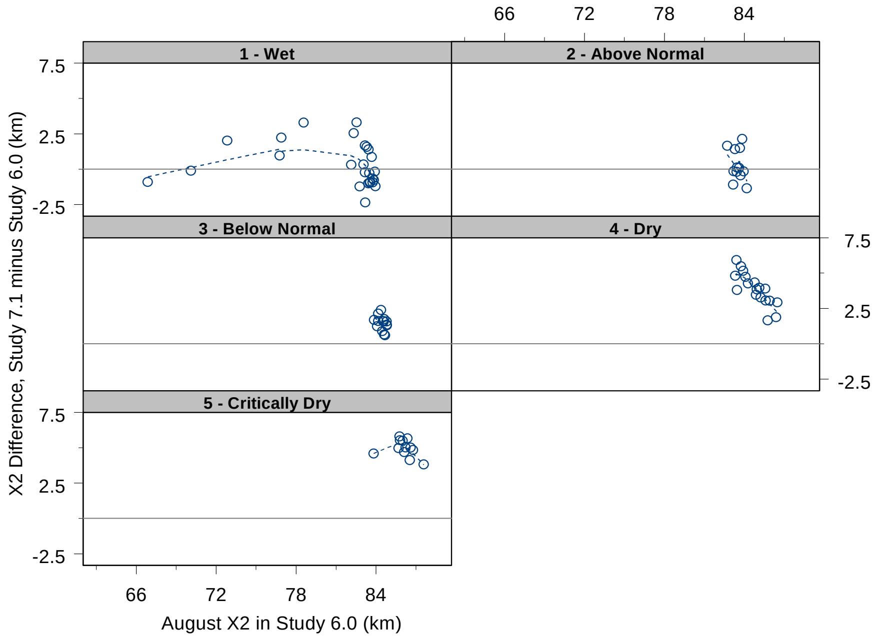


Figure 13-23 Variation in X2 in Study 7.1 with respect to Study 6.1 in August

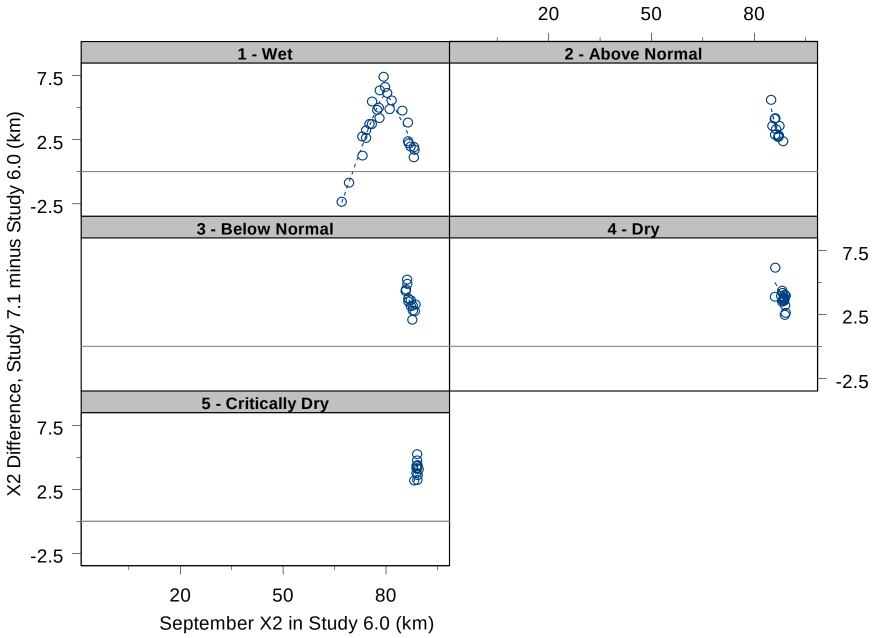


Figure 13-24 Variation in X2 in Study 7.1 with respect to Study 6.1 in September

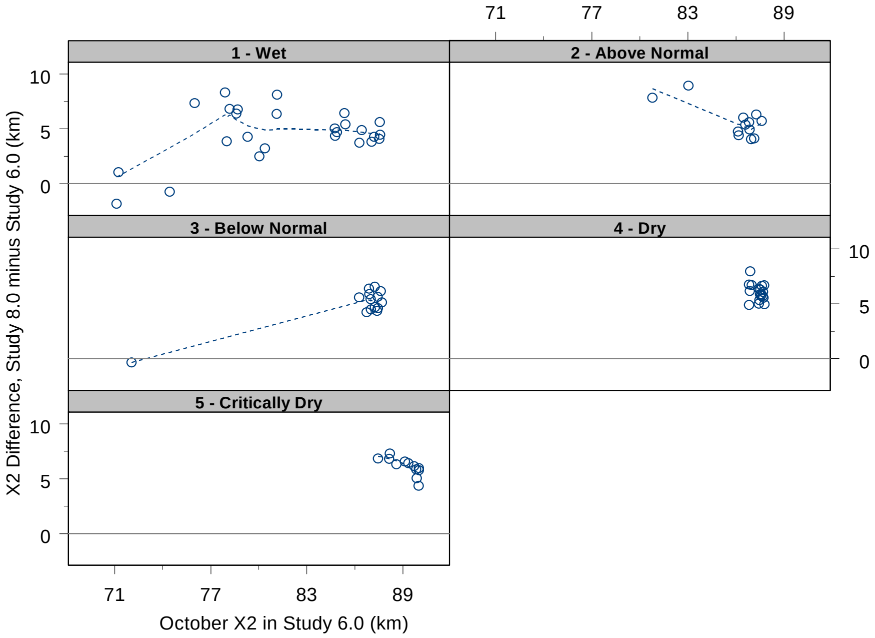


Figure 13-25 Variation in X2 in Study 8.0 with respect to Study 6.1 in October

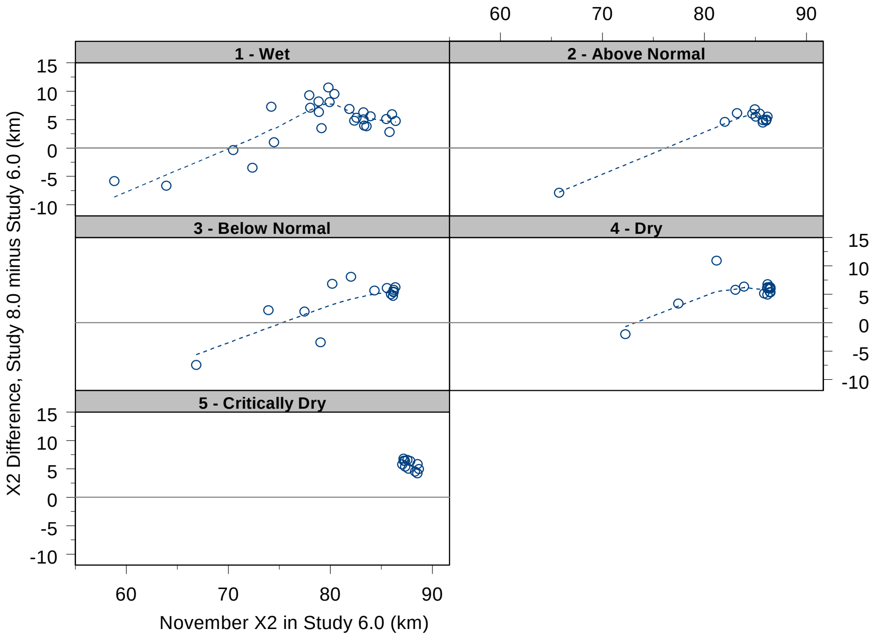


Figure 13-26 Variation in X2 in Study 8.0 with respect to Study 6.1 in November

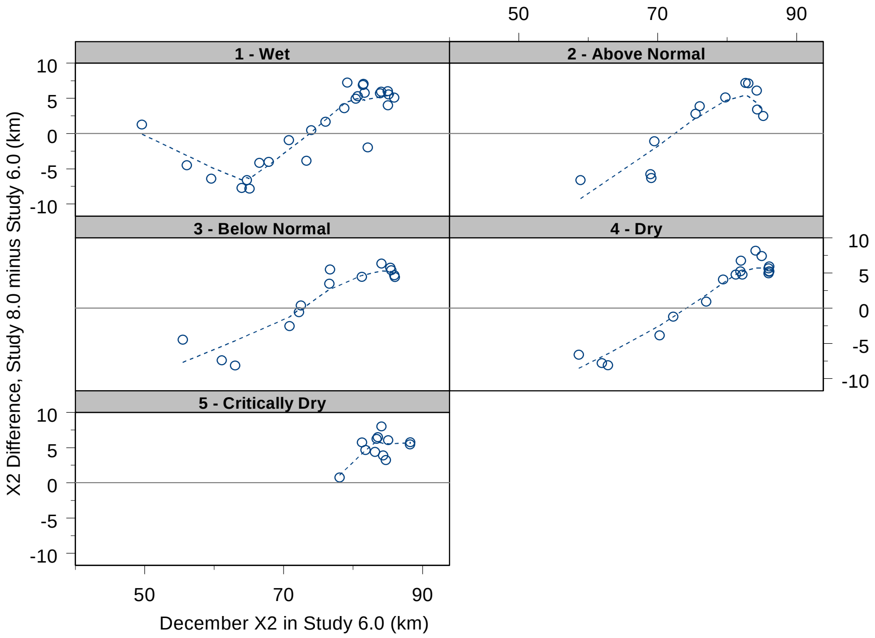


Figure 13-27 Variation in X2 in Study 8.0 with respect to Study 6.1 in December

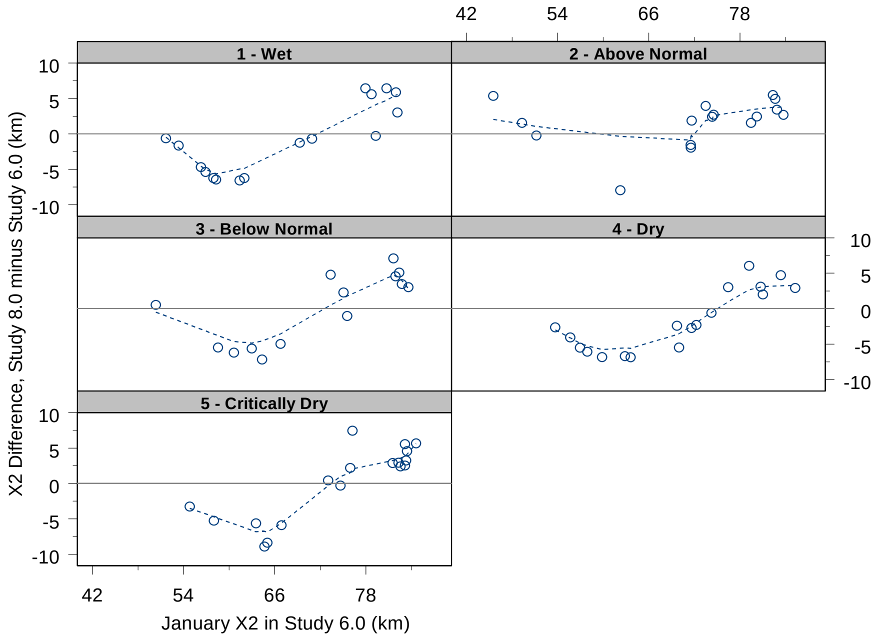


Figure 13-28 Variation in X2 in Study 8.0 with respect to Study 6.1 in January

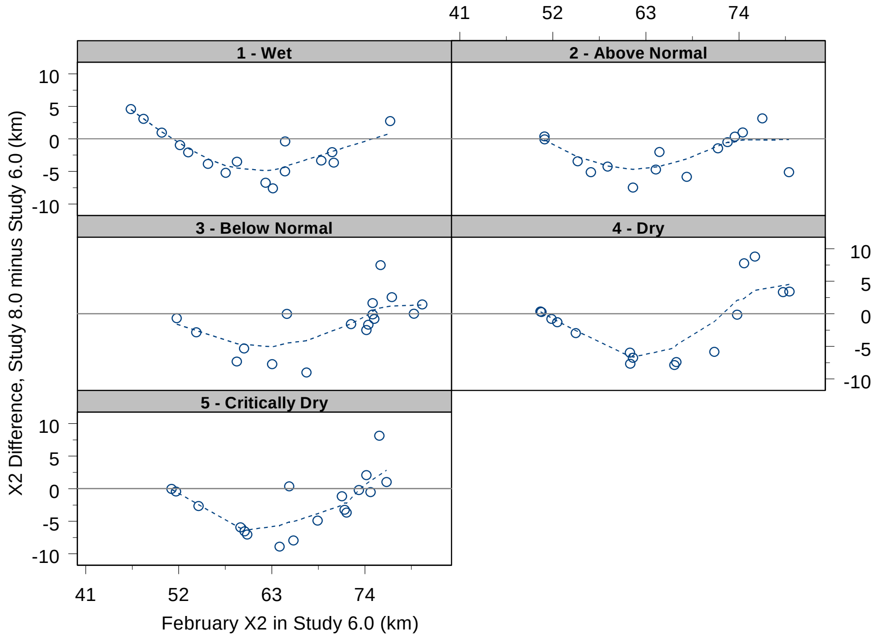


Figure 13-29 Variation in X2 in Study 8.0 with respect to Study 6.1 in February

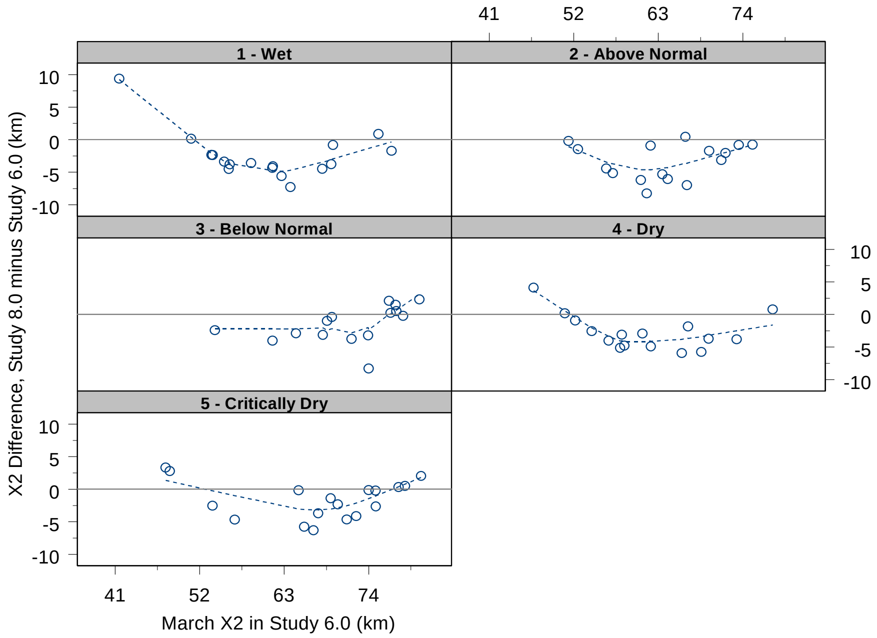


Figure 13-30 Variation in X2 in Study 8.0 with respect to Study 6.1 in March

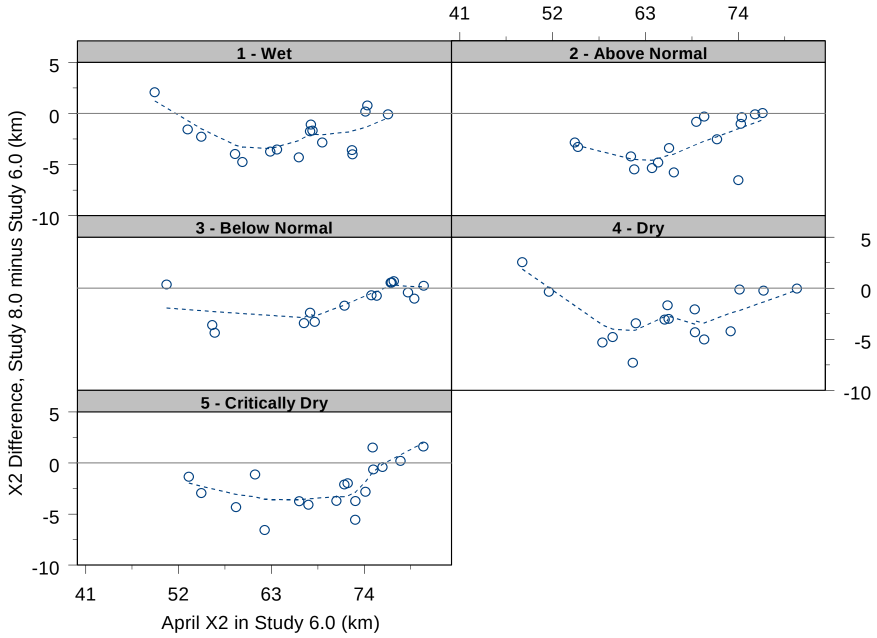


Figure 13-31 Variation in X2 in Study 8.0 with respect to Study 6.1 in April

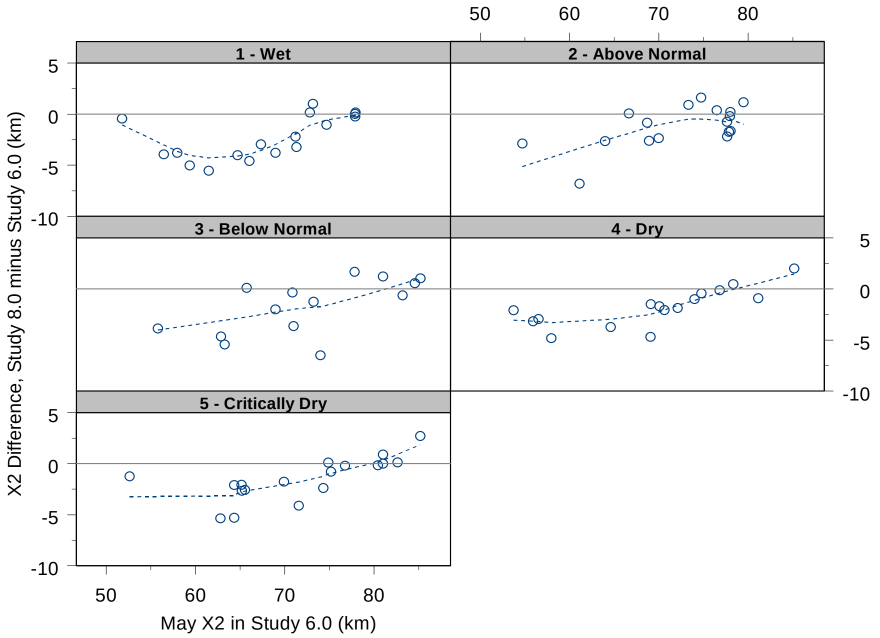


Figure 13-32 Variation in X2 in Study 8.0 with respect to Study 6.1 in May

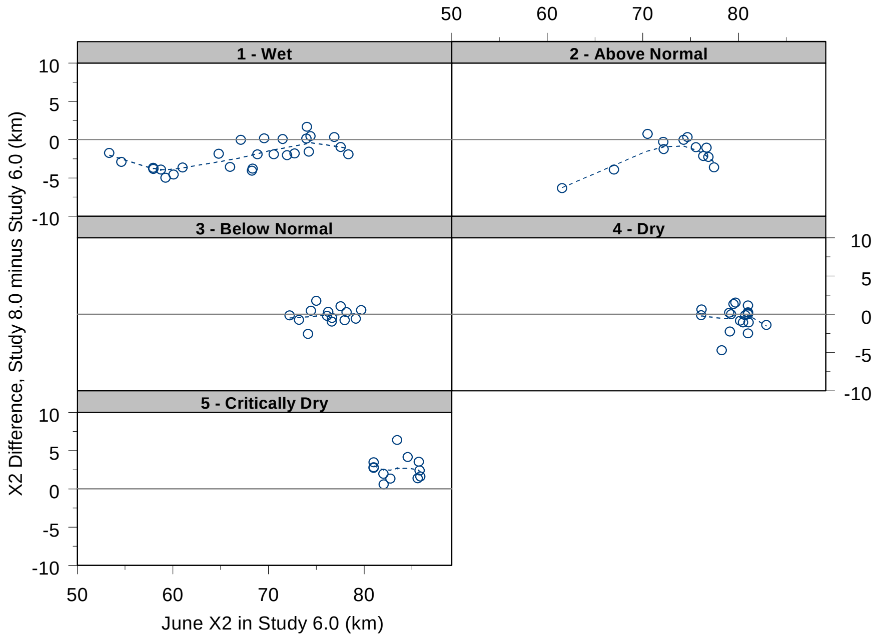


Figure 13-33 Variation in X2 in Study 8.0 with respect to Study 6.1 in June

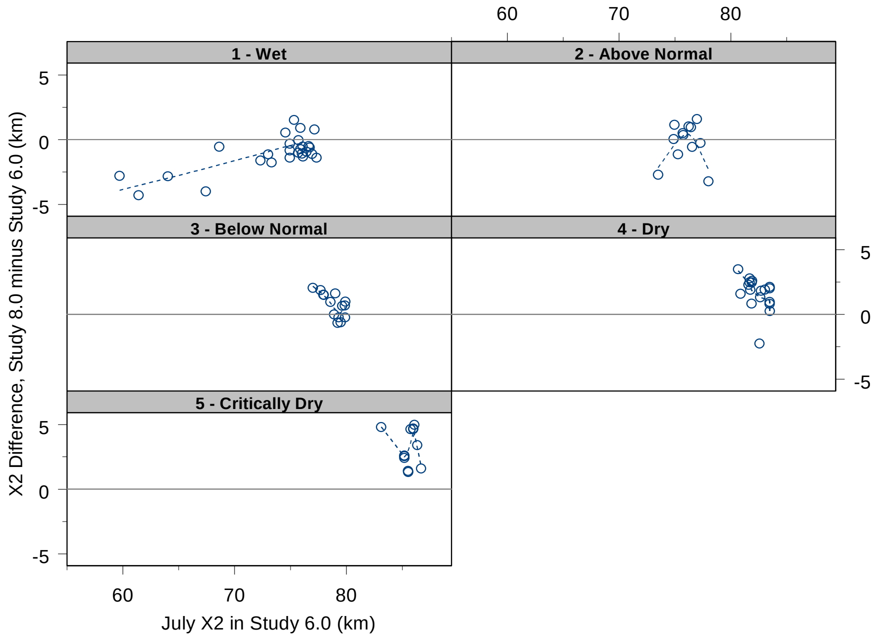


Figure 13-34 Variation in X2 in Study 8.0 with respect to Study 6.1 in July

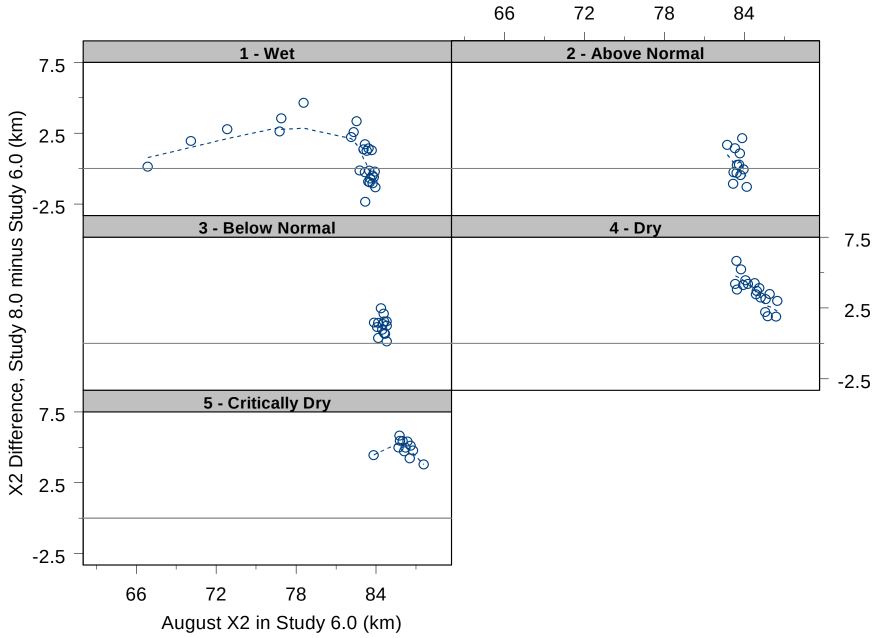


Figure 13-35 Variation in X2 in Study 8.0 with respect to Study 6.1 in August

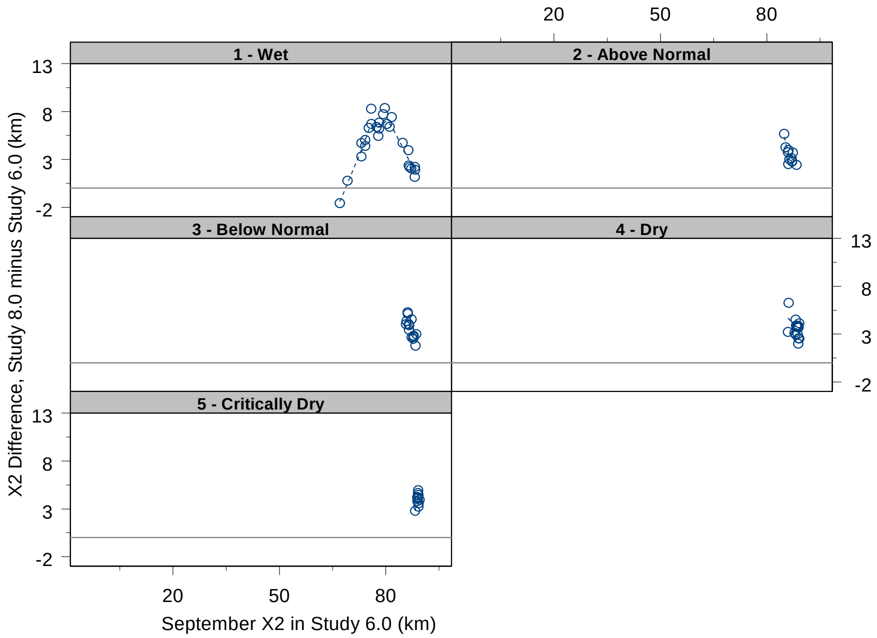


Figure 13-36 Variation in X2 in Study 8.0 with respect to Study 6.1 in September

Climate Change

The evaluation of climate change effects presented here is adapted from Appendix R sections 4.2.2 through 4.3.2. Appendix R reports an analysis of the potential implications of climate change for the CVP and SWP that is intended to examine the sensitivity of of CVP/SWP operations and system conditions to a range of future climate conditions that may evolve over the consultation horizon (2030) of the BA. It develops four climate change scenarios intended to bookend the range of possibilities arising from available climate projection information. The bookends span the range of outcomes developed under the assumptions of CalSim-II Study 8 with respect to two variables: precipitation and temperature. All four scenarios are based on the assumptions, derived from published sources, that sea level will rise approximately 30 cm by 2030, and that the tidal range will increase by 10 percent.

We have considered the possible consequences to delta smelt that arise out of the four scenarios. For delta smelt, the impacts likely to be associated with climate change would be caused by (a) changes in the availability and distribution of habitat, as indexed by X2, and (b) changes in entrainment at the CVP and SWP export facilities in the south delta. To address the possibility that changes in habitat and entrainment rates might affect delta smelt under the four climate change scenarios, this evaluation consists of the following elements:

(1) Consideration of the effects of a 1 ft (30 cm) sea level rise in a comparison with the base case (no change in temperature or precipitation)

(2) Consideration of X2 for each of the four climate change scenarios

(3) Consideration of the DSM2 OMR flows results for each of the four climate change scenarios [with adapted tables 17,18,19]

(4) Consideration of uncertainties associated with the climate change analyses

Effects of Sea Level Rise Alone

This review is limited to the months of February through June, which are the months addressed in Appendix R. However, because sea level is likely to proportionately rise in all seasons, we expect results for the summer and fall to be similar to the modeled months in which the least precipitation occurs (May and June). The assumed 1 ft rise in sea level is likely to move X2 upstream by 1 km to 3 km in the base study, Study 9.1 (Figure 13-37 blue and red-hashed white columns). For the months of February through approximately April, X2 and its variability are similar (Figure 13-37). However, for the months of May and June, the median X2 moves upstream in the presence of sea level rise relative to the base case (loc cit). Moreover, the 95th percentile X2 in those months is much farther upstream (approx. 15 km in May and 20 km in June) than in the base case, indicating circumstances that would be expected to very substantially alter delta smelt habitat availability and location.

These results suggest that sea level rise alone is likely to result in upstream movement of delta smelt habitat during months not modeled and also not subject to X2 control, particularly the fall months. We would expect a 1-3 km upstream movement of X2 during the fall on top of movement expected under Study 8.0 to reduce the availability of high quality habitat available to maturing delta smelt (see X2 section below). Furthermore, increased late spring/summer entrainment risk arising from movement of smelt habitat closer to the export pumps is a possibility that should be considered, at least in the more extreme cases predicted by the model.

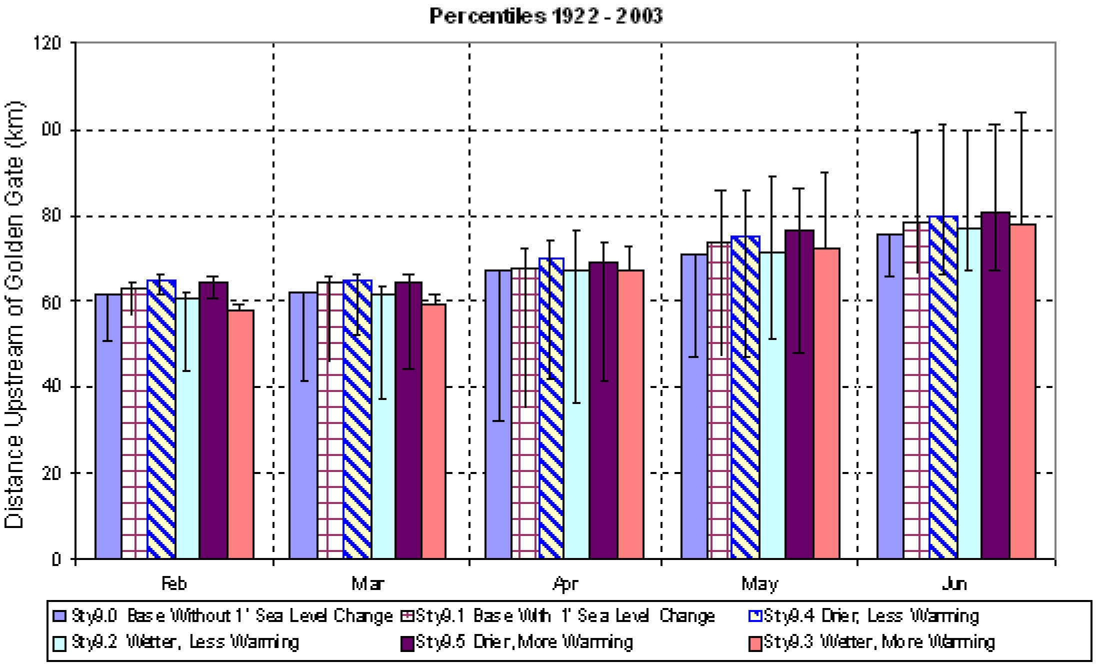


Figure 13-37 X2 in climate change studies. The bars represent 50th percentile with 5th and 95th as the whisker.

Changes in X2 in Climate Change Scenarios

This review is limited to the months of February through June, which are addressed in Appendix R. However, because sea level is likely to proportionately rise in all seasons, we expect expect results for the summer and fall to be similar to the modeled months in which the least precipitation occurs (May and June). The wetter scenarios (wetter/less warming and wetter/more warming) produced similar outcomes (Figure 13-37). In the wetter scenarios, X2 is similar to or lower than the base case for February through May, but both high precipitation scenarios result in a 1-2 km upstream movement of X2 in June. Both wetter scenarios also predict a higher incidence of X2 movement upstream of the median than the base case.

The drier scenarios (drier/less warming and drier/more warming) were also similar to one another (loc cit). Both drier scenarios produced upstream movements of 2-3 km in all months during February through June. As with the wetter scenarios, both produced a higher frequency of substantial upstream X2 movement exceeding 20 km in June.

These results suggest that the drier scenarios would produce more substantial movement of X2 upstream than sea level rise alone, but that the wetter scenarios either conform to the sea level-based prediction or (in February and March) may result in downstream X2 movement. Upstream movement of 1-3 km in several scenarios would likely result in a loss of habitat quality for delta smelt in the fall months (see X2 section below). Extreme upstream movement occurring in a small percentage of years could also substantially increase the risk of entrainment during these months.

Changes in OMR Flow in Climate Change Scenarios

We examined OMR flow rather than export pumping predictions because of the tighter relationship between OMR flow and entrainment. The changes in OMR flow under the various scenarios were more mixed than changes in X2. Fall and winter flows were the most sensitive to climate change, with the polarity of changes depending on precipitation:

(a) Negative winter flows become more extreme during drier years in all scenarios and during wetter years for the drier climate change scenarios
(b) Negative winter flows increase during wetter years for the wetter, less warming scenario
(c) Winter flows changed from negative to positive during wetter years for the wetter, more warming scenario

OMR flow in the base case, changes in OMR flow, and percent change in OMR flow are presented in Appendix R Tables 15, 17, and 19 (pp. 99-103) for “more warming” scenarios and Tables 16, 18, and 20 (pp. 100-104) for “less warming” scenarios.. In these tables, negative values indicate an upstream shift in OMR flow. Increases in upstream OMR flow are likely to cause proportionately higher levels of delta smelt entrainment during the months of December through March (adults) and March through July (larvae and juveniles).

Overall, the pattern of results suggests that OMR flow during January through June becomes more negative during dry years in the drier/less warming and drier/more warming scenarios, but with some substantial changes that are mostly either increases in negative flow or decreases in positive flow in the other scenarios. In other words, in the drier climate change scenarios we would generally expect to see higher entrainment of delta smelt during January through June under the operational assumptions of Study 8 than in the absence of climate change.

Uncertainty about Climate Change

Appendix R cautions that there are several sources of uncertainty in this modeling, and, in fact, has been structured to reflect the absence of a “most likely” or consensus climate trajectory arising from available projections. The uncertainties enumerated in Section 5 of Appendix R include:

(a) uncertainties about climate forcing, including greenhouse gas emission pathways, the role of biogeochemical cycles, and atmospheric contributions to climate forcing
(b) climate simulation, including the physical paradigms underlying climate models and computational methodologies
(c) climate projection bias-correction
(d) climate projection downscaling to local scales
(e) watershed response to changing climatic conditions
(f) social response to changing climate
(g) discretionary operational response to changing climatic conditions and evolving pressures associated with the change

Given these qualifications, the evaluation here should be viewed as conditional upon both the assumptions made in Appendix R and those made here and in Chapter 7, with potentially significant uncertainties neither quantified nor represented.

500 CFS Increased Diversion to Provide Reduced Exports Taken to Benefit Fish Resources

Delta Smelt

Clifton Court Forebay (CCF) is typically operated at or near the rates defined in the USACE Public Notice 5820A, Amended, unless otherwise restricted. Public Notice 5820A, Amended, requires that daily summer diversions into CCF not exceed 13,870 AF and a three-day average not to exceed 13,250 AF. Banks Pumping Plant is operated to the available physical capacity, as constrained by CCF operations. Banks Pumping Plant is also adjusted to assist in maintaining velocity criteria at Skinner Fish facility as exports allow. Maximum average monthly SWP summer exports from Banks Pumping Plant are 6,680 cfs.

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

Water exported under the 500 cfs increased export limit would first be used to recover export reductions taken during the VAMP period (assumed mid-April to mid-May) or applied to the "shoulder" periods preceding or following the VAMP period. Any remaining water could be applied to other export reductions for fish protection during that calendar year or be stored in San Luis Reservoir to be applied to export reductions for the subsequent calendar year. As the SWP share of San Luis Reservoir is filled, there is a risk that this water would be "spilled" from the reservoir. "Spilling" the stored water would result in lower exports from the Delta during the time the reservoir is filling. Normally, this would occur during December – March. The fishery agencies would decide whether to implement an export reduction in the fall or winter time period equivalent to the water stored in the reservoir or assume the risk that the water would be spilled later on. Additional details regarding the implementation of the 500 cfs increased diversion are contained in Chapter 2.

Analyses Contained in the Initial Study

Much of the information in this discussion is taken from the *Initial Study for the 2005 – 2008 State Water Project Delta Facility Increased Diversion to Recover Reduced Exports Taken to Benefit Fish Resources* (DWR 2004). The operation analyzed in the Initial Study and implemented in 2005 – 2008 is slightly different than the operation contained in this project description. The difference is the ability to carry over water exported under the 500 cfs increased diversion limit into the subsequent calendar year. The operation analyzed in the Initial Study and implemented through 2008 does not allow carry over of the exported water. The operation to begin in 2009 allows carry over of the exported water as long as it does not affect the ability to fill the SWP share of San Luis Reservoir. Water exported under the 500 cfs export limit is to be used only for export reductions to benefit fish resources.

The Initial Study uses a comparative analysis to quantify the impacts of the 500 cfs increased diversion (Project) compared to a no-project (Base) condition. The range of potential impacts is defined by modeling two hydrologies: a year of low delta inflow, and a year of high delta inflow. The hydrologies are used as input for the DWRDSM2 HYDRO and QUAL studies, which evaluate changes in flow, stage, velocity, and salinity. Tidally averaged comparisons of water quality, flow, stage, and velocities for all the locations studied are in Appendix II of the Initial Study (DWR 2004). The modeling assumptions for the Project include the following:

- Two 30-day periods to reduce diversions to benefit fish resources are chosen: May 15-June 15, and November 15–December 15. The total reduction in diversions cannot exceed 90 TAF.
- The operations of the SWP and CVP must comply with existing Bay-Delta requirements of the SWRCB Decision 1641. Operations are assumed to comply with the ESA, and other regulatory and contractual requirements related to the Sacramento-San Joaquin River Delta.
- Current SWP operations allow a maximum three-day average diversion rate of 6,680 cfs during July, August, and September. Project diversions during that period must exceed the maximum three-day average diversion rate of 6,680 cfs to constitute a with-Project condition since diversions less than that amount are already permitted in the base condition.

- The increased diversions during July, August, and September of any calendar year equals the amount of reduced diversions during that calendar year.

The historic hydrologies were examined to find a representative period and a high and low inflow year. The representative period is from1987 to 1999 and the low and high inflow years are 1992 and 1997. The reasons for selecting 1992 and 1997 are discussed below.

1992, Low Delta Inflow Year

Two difficulties in selecting a year of low delta inflow occurred. Exports in years of low delta inflow during each of the two 30-day periods, (May 15-June 15, and

November 15–December 15) typically did not exceed 90 TAF. Current constraints on export/inflow ratios were instituted in 1995 under the Bay-Delta Accord. All years since 1995 have been classified as wet years (up to the year 2000). Therefore, historic operations during a year of low delta inflow with current regulatory constraints did not exist at the time of the study.

Three years of low delta inflow were considered: 1987, 1988, and 1992. In 1987 and 1988, exports during the two 30-day periods, (May 15-June 15, and November 15-December 15) could be reduced by 90 TAF. However, operations prior to 1995 were not subject to existing regulatory requirements, and thus the export/inflow ratios during 1987 and 1988 exceeded existing export/inflow requirements of the SWRCB. In 1987, daily exports exceeded present requirements by an average of 2744 cfs, and a maximum of 6146 cfs. Therefore, 1987 and 1988 were eliminated from consideration.

In 1992, exports during the two 30-day periods, May 15-June 15, and November 15-December 15, were approximately 46 TAF and 66 TAF, respectively. Therefore, exports could not be reduced by the full proposed amount of 90 TAF. Although export/inflow ratios exceeded existing requirements, the existing requirements could be met with minor adjustments to the historic inflow. In 1992, present export/inflow ratio requirements could be met by increasing Sacramento River inflow by an average of 11 cfs. For these reasons, 1992 was selected as the year to represent conditions of low Delta inflow.

1997, High Delta Inflow Year

Current constraints on export/inflow ratios were instituted in 1995 and delta inflow during the subsequent years was high. Therefore, several years of historic operations with high delta inflow and current regulatory constraints exist. Thus, 1995-1999 were considered. SWP exports during May 15-June 15 exceeded 90 TAF in 1995, 1996, and 1997. In 1998 and 1999, SWP exports during May 15-June 15 were only 78 TAF and 71 TAF, respectively, which would not allow a reduction for the full proposed amount of 90 TAF. 1995 was not chosen because SWP exports during the November 15 to December 15 period were only 6,210 AF. 1996 was not chosen because SWP exports during May 15-June 15 were 294 TAF, and this was not considered a representative year. In 1997, SWP exports during May 15-June 15 and November 15 to December 15 period were 100 TAF and 644 TAF, respectively.

Historic vs. Base Hydrologies

The historic hydrologies were modified so the base hydrologies would comply with the initial assumptions explained above and repeated below:

- The operations of the SWP and CVP must comply with existing requirements of SWRCB Decision 1641, with the ESA, and other regulatory and contractual requirements related to the Sacramento-San Joaquin River Delta.
- Current SWP operations allow a maximum three-day average diversion rate of 6,680 cfs during July, August, and September. Project diversions during that period must exceed the maximum three-day average diversion rate of 6,680 cfs because diversions less than this base condition are already permitted.

Sacramento River flows were also modified from historic conditions. When export/inflow ratios exceeded existing requirements, Sacramento River flows were increased until existing constraints were met. When exports were modified, Sacramento River flows were modified to maintain the net delta outflow. Thus, the SWP was simply changing the time when storage in Oroville was being moved to San Luis Reservoir.

The potential changes in diversion rate into CCF will affect fish salvage at the SWP. To determine the impact of such export changes, historic salvage data from 1992 and 1997 (representative low and high Delta inflow years used in the modeling) were used to estimate the impact of the Project on fish salvage. Historic salvage density was used to estimate salvage under the different export scenarios through extrapolation as shown in the table below.

Potential Impacts of Water Quality and Flow on Fish

Potential impacts to 10 species, including delta smelt, salmon, steelhead and sturgeon, were examined by two methods. First, the water quality and flow modeling results were examined to determine if they posed potential impacts to fish. Second, historic salvage data was examined to determine if the Project posed potential impacts to delta smelt, salmon, steelhead and sturgeon salvage.

The modeling results predicted minor changes in water quality, which would result in no impacts to delta smelt.

The changes in flow predicted by the modeling suggest that there will be no significant negative impacts to delta smelt distribution. The largest changes in flow occurred during the spring pumping reduction. Flows towards CCF decreased by as much as 2,250 cfs. Decreased flows towards CCF may decrease the potential vulnerability of delta smelt to SWP salvage. The modeling results predicted that flows only slightly increased towards CCF during the increased pumping period, suggesting there will be no impact on delta smelt distribution and subsequent vulnerability to SWP salvage. There are no anticipated changes in total outflow that could impact delta smelt.

Potential Impacts to Fish Salvage

Historic salvage data for ten sensitive fish species or runs, including delta smelt, were analyzed to determine the impact of the proposed project. The fish species may occur in the project area during the project period.

The potential changes in diversion rate into CCF will affect fish salvage at the SWP. To determine the impact of such export changes, historic salvage data from 1992 and 1997 (representative low and high Delta inflow years used in the modeling) were used to estimate the impact of the Project on fish salvage. Historic salvage density was used to estimate salvage under the different export scenarios through extrapolation.

The difference in fish salvage between the base and Project conditions was used as the effect of the Project on fish salvage. Base (No-Project) salvage was calculated as the product of historic salvage density (number of fish salvaged per AF diverted) and modeled base exports. Project salvage was calculated as the product of historic salvage density and modeled Project exports. The effect of the Project on fish salvage was the difference between the Project and base salvage estimates. For example:

historic salvage / historic AF diverted = historic salvage density (HSD)

HSD x base exports = estimated base salvage (BS)

HSD x Project exports = estimated Project salvage (PS)

PS – BS = estimated difference in salvage from the base caused by the Project.

The results of this analysis (Table 13-19) suggest that salvage of delta smelt is likely to substantially decrease under the spring scenarios and not substantially change under the fall scenarios; reduced exports in the months of May and June in the spring scenario are likely to reduce the salvage of delta smelt for the year. The studies can be used to draw conclusions about other potential operations. For example, if the export reduction were taken only in May 1997 (48 taf), 90 taf were exported in July-September, and the remaining 42 taf applied as reduced exports in December, the net reduction in delta smelt salvage for the May-December period would be 10,286 (with a reduction of 10,282 occurring in May).

Table 13-19 Delta smelt

Spring 1992	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Total**
Historic exports	42,376	57,220	25,689	90,836	161,905	378,026
Historic salvage	1,903	2,367	24	0	0	4,294
Historic salvage density	0.0449	0.0414	0.0009	0.0000	0.0000	-
Base exports	15,099	56,040	410,018	410,018	396,792	1,287,968
Base salvage	678	2,318	383	0	0	3379
Project exports	0	25,469	425,732	425,732	411,036	1,287,969
Project salvage	0	1,054	398	0	0	1,451
Percent change	-100%	-55%	4%	0	0	--57%

Fall 1992	Jul	Aug	Sep	Nov	Dec	Total
Historic exports	25,689	90,836	161,905	62,303	168,276	509,009
Historic salvage	24	0	0	0	0	24
Historic salvage density	0.0009	0.0000	0.0000	0.0000	0.0000	-
Base exports	410,018	410,018	396,792	66,651	35,531	1,319,011
Base salvage	383	0	0	0	0	383
Project exports	432,852	432,852	417,390	35,917	0	1,319,011
Project salvage	404	0	0	0	0	404
Percent change	5%	0	0	0	0	5%

Spring 1997	May	Jun	Jul	Aug	Sep	Total
Historic exports	78,236	153,854	321,231	269,918	341,334	1,164,573
Historic salvage	16,760	6,140	216	0	0	23,116
Historic salvage density	0.2142	0.0399	0.0007	0.0000	0.0000	-
Base exports	47,995	153,058	410,018	410,018	396,792	1,417,882
Base salvage	10,282	6,108	276	0	0	16,666
Project exports	0	111,953	440,708	440,708	424,512	1,417,882
Project salvage	0	4,468	296	0	0	4,764
Percent change	-100%	-27%	7%	0	0	-71%

Fall 1997	Jul	Aug	Sep	Nov	Dec	Total
Historic exports	321,231	269,918	341,334	292,036	419,732	1,644,251
Historic salvage	216	0	0	0	257	473
Historic salvage density	0.0007	0.0000	0.0000	0.0000	0.0006	-
Base exports	410,018	410,018	396,792	292,923	196,804	1,706,556
Base salvage	276	0	0	0	121	396
Project exports	440,708	440,708	424,512	245,403	155,224	1,706,556
Project salvage	296	0	0	0	95	391
Percent change	7%	0	0	0	-21%	-1%

Note: Row headers for the above table are as follows:
Historic exports = Actual SWP exports for given month (AF).
Historic salvage = Actual SWP salvage for given month.
Historic salvage density = Historic salvage ÷ historic exports (number of fish/AF).
Base exports = Modeled base exports for given month.
Base salvage = Historic salvage density x modeled base exports.
Project exports = Modeled project exports for given month.
Project salvage = Historic salvage density x modeled project exports.
Percent change = (Project salvage – Base salvage) x 100%/Base salvage

Clifton Court Forebay Aquatic Weed Control Program

Effects on Delta Smelt

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 impacts 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 13-38 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.

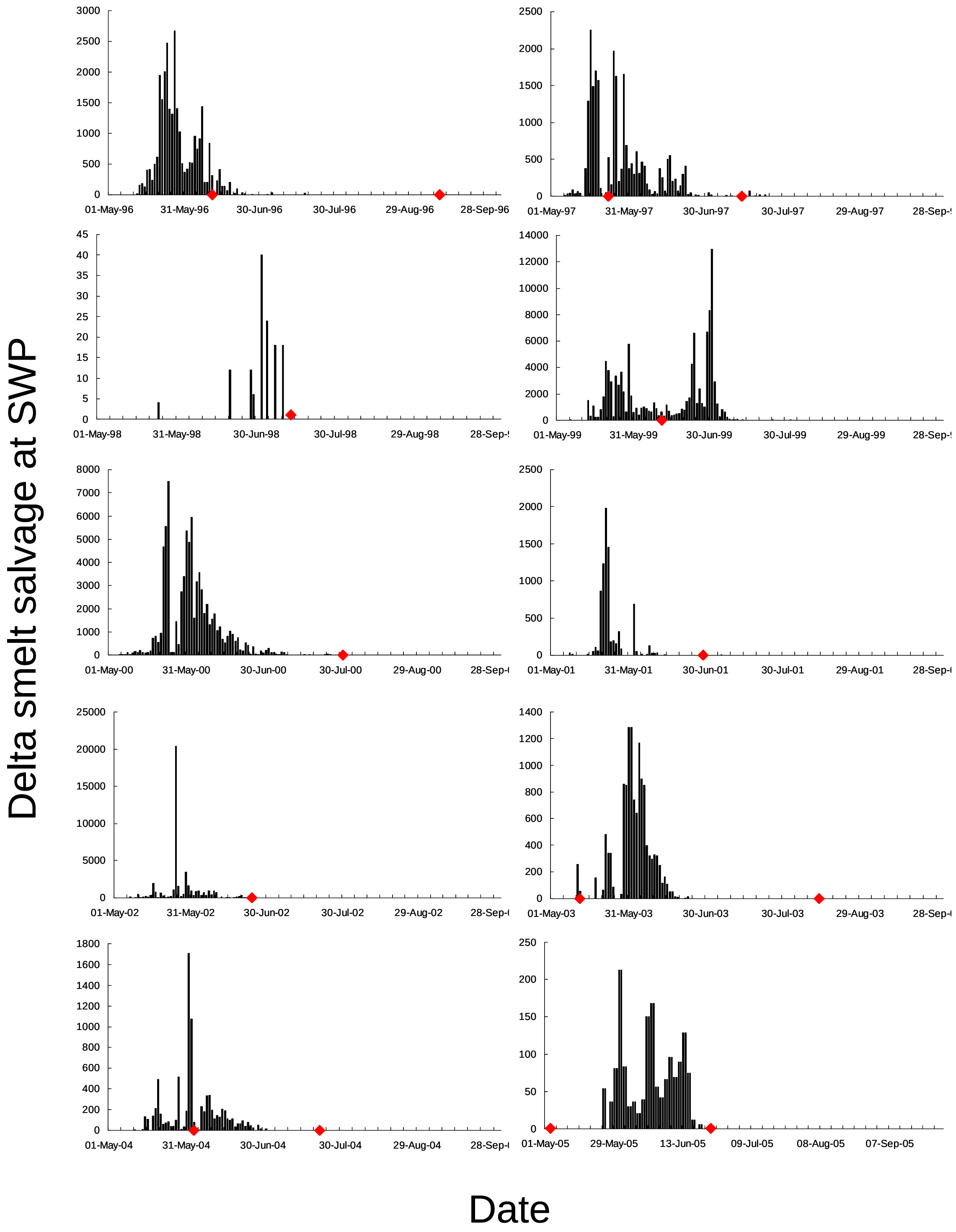


Figure 13-38 May-September delta smelt salvage at the SWP Banks Pumping Plant, 1996-2005, with the start and end dates of Komeen or Nautique aquatic weed treatment indicated by the red diamonds.

North Bay Aqueduct

Summer (Jun-Aug)

The summer pumping rates of NBA diversions were not different between studies 7.0 and 7.1 (average 42 cfs) but both were 12 percent lower than study 8.0 (average 48 cfs) (Chapter 12). 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.

Fall (Sept-Nov)

North Bay aqueduct diversions are lowest in the fall (Chapter 12) only averaging 18 cfs in study 7.0, 17.6 cfs in study 7.1, 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.

Winter (Dec-Feb)

North Bay Aqueduct diversions are highest during the winter months. There were no differences between studies 7.0 and 7.1 during the winter but diversion rates rate for study 8 in December (64 cfs) was higher than diversion rates for studies 7.0 (43 cfs) and 7.1 (41 cfs). The hydrodynamic modeling of NBA diversions indicates that the majority of water diverted origins from Cambell Lake and Calhoun Cut during the winter. As previously mentioned, delta smelt migrate up into the Delta during the winter months. However, since the screens on the intakes meet criteria for protecting 20 mm SL delta smelt, adult entrainment is not a concern.

In some years, delta smelt will begin spawning in February when temperatures reach about 12 ^{o}C (Bennett 2005). Thus in some years, delta smelt larvae may be entrained at the NBA diversions. However since the majority of water diverted origins from Cambell Lake during the winter, these effects are likely to be minimized to the areas of 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 will spawn in the North Delta (Sweetnam 1999).

Spring (Mar-May)

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 studies 7.0 and 7.1 (Chapter 12). NBA diversions ranged between 30 and 54 cfs during the spring, indicating that the majority of water diverted origins from Campbell Lake at these diversions rates. Thus a 20 percent increase in study 8 from studies 7.0 and 7.1 is negligible when you account for the source of water diverted. Overall, spring 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 (http://www.delta.dfg.ca.gov/data/NBA/).

Rock Slough Intake

CCWD diverts water from Old River via Rock Slough into the Contra Costa Canal at the Rock Slough Intake. The diversion is presently unscreened. Reclamation, in collaboration with CCWD, is responsible for constructing a fish screen at the Rock Slough Headworks under the Central Valley Project Improvement Act and under the 1993 USFWS Biological Opinion for the Los Vaqueros Project. Reclamation has received an extension on fish screen construction until December 2008, and is preparing to request a further extension until at least 2013 because the requirements for screen design will change as CCWD proceeds with its project to replace the earth-lined portion of the canal with a pipeline.

Before 1998, the Rock Slough Intake was CCWD's primary diversion point. It has been used less since 1998 when Los Vaqueros Reservoir and the Old River Pumping Plant began operating. The diversion at the headworks structure is currently sampled with a sieve net three times per week from January through June and twice per week from July through December. A plankton net is fished at the headworks structure twice per week during times larval delta smelt could be present in the area (generally March through June). A sieve net is fished at Pumping Plant #1 two times per week from the time the first Sacramento River winter-run Chinook salmon is collected at the CVP and SWP (generally January or February) through June. Numbers of listed fish species captured during monitoring are shown in Table 13-20.

The numbers of delta smelt entrained by the facility since 1998 have been extremely low, with only a single fish taken in February 2005 (Table 13-20).

The Contra Costa Canal Replacement Project will replace the 4-mile unlined section of canal from Rock Slough to Pumping Plant #1 with a pipeline. The project is fully permitted (NMFS issued its concurrence letter on June 11, 2007 and USFWS issued a BO on June 21, 2007) and the first phase of the project is scheduled to begin in the Fall of 2008. When completed, the Canal Replacement project will eliminate tidal flows into the Canal intake section and should significantly reduce entrainment impacts and improve the feasibility of screening Rock Slough.

Because most diversions at the Rock Slough intake now occur during the summer months when delta smelt and salmonids are not present in the vicinity of the diversion and because very few listed fish species (one winter–run Chinook, 14 spring-run sized Chinook, 6 unclipped steelhead, and one delta smelt) have been captured during monitoring from 1998 to 2008, the Rock Slough diversion is not believed to be a significant source of mortality for any of the listed species. No green sturgeon have been captured at the site.

It is expected that entrainment in the future will be reduced with the addition of CCWD's Alternative Intake Project because CCWD diversions in general during the migration period will be reduced, with most of that reduction taking place at the Rock Slough intake. (See the July 3, 2007 NMFS biological opinion on the Alternative Intake Project). Few listed runs have been captured in sampling since 1996 so take of listed runs is expected to be very low, probably fewer than 50 spring–run, 50 winter–run, and 20 steelhead. Estimates of future losses of spring-run Chinook salmon and winter-run Chinook salmon at the Rock Slough Intake with the Alternative Intake Project in service have been made assuming future CCWD demands of 188,000 af/year. Based on average densities of the salmon in channels (from monitoring programs over the past 10 years), losses were estimated at about 5 winter-run and 16 spring-run juveniles per year.

Table 13-20 Summary of listed fish captured at the Rock Slough Headworks and Pumping Plant 1 and amount of water diverted each year, 1998 – 2008.

Summary of Sieve Net and Plankton Net Monitoring Conducted at the Rock Slough Headworks and Pumping Plant 1 (PP1) from August 1998 through March 2008.

Year	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	Totals
Months Monitoring Occurred	Aug-Dec	Mar-Dec	Mar-Dec	Jan-Aug	Jan-Dec	Jan-Dec	Jan-Dec	Jan-Dec	Jan-Dec	Jan-Dec	Jan-Mar	
Amount of Water Diverted at Rock Slough Acre Feet	68,683	43,037	51,421	26,749	35,904	27,302	31,283	35,686	43,273	39,366	5,848	408,552
Number of Headworks &PP1 Sieve Net Surveys	Unknown	Unknown	Unknown	Unknown	Unknown	35	102	131	133	107	54	**562**
Number of Headworks Plankton Net Surveys	Unknown	Unknown	Unknown	Unknown	10	0	34	26	15	23	10	**118**
Winter-run Chinook	Dec=1	0	0	0	0	0	0	0	0	0	0	**1**
Spring-run Chinook	0	0	0	0	0	0	Mar=1 Apr=5	May=4	May=4	0	0	**14**
Central Valley steelhead (unclipped)	0	0	0	0	0	0	0	Mar=2 Apr=1	Jan=1 Mar=1	May=1	0	**6**
Central Valley steelhead (clipped)	0	0	0	0	0	0	0	0	0	0	Feb=6 Mar=2	**8**
Central Valley steelhead (unknown)	0	0	0	0	0	0	0	Feb=1	0	0	0	**1**
Fall run/late fall run Chinook (unclipped)	0	0	May=3	0	0	0	Mar=2 Apr=3 May=1	Apr=2 May=6 Jun=1	May=1	0	0	**19**
Fall run/late fall run Chinook (clipped)	0	0	0	0	0	0	May=1	May=1	0	0	0	**2**
Green sturgeon	0	0	0	0	0	0	0	0	0	0	0	**0**
Delta smelt	0	0	0	0	0	0	0	Feb=1*	0	0	0	**1**
Longfin smelt	0	0	0	0	0	0	0	0	0	0	Mar=1**	**1**

South Delta Temporary Barriers (TBP)

The following evaluation is limited to the operational effects of these projects on delta smelt. Section 7 consultation for the construction and operation of the TBP through 2010 has been completed with NMFS. The operation effects of the TBP are being consulted upon with FWS through this OCAP BA. The construction effects requiring ESA consultation with FWS will be evaluated in a separate consultation process.

Simulation modeling completed for this OCAP BA incorporates the effects of the South Delta Temporary Barriers Project and 500 cfs increased export in Studies 6.1 and 7.0. The SDIP Stage 1, the 500 cfs increased export, and the CVP aqueduct intertie are incorporated into Studies 7.1 and 8.0. The Temporary Barriers are not included in Studies 7.1 and 8.0. A full evaluation of the combined effects of these elements on Chinook salmon, steelhead and green sturgeon are presented in Chapter 13. Because the simulation models examined the combination of these elements, it is not possible to separate and examine the effects of any single project element by itself. Therefore, the effects analysis for these individual projects is taken largely from prior Biological Assessments and other related consultations. The specific documents from which material was obtained include: *DWR 2000 Proposed Mitigated Negative Declaration and Initial Study Temporary Barriers Project 2001-2007 and 2007 Supplemental Biological Assessment South Delta Temporary Barriers Project.* Because the modeling for these documents was conducted a few years ago, it naturally differs to some degree from what was conducted for the OCAP Biological Assessment. However, the differences are not such that they would alter any interpretation of the likely general effects of these projects individually. For clarity, provided below are brief descriptions of the projects, details of the modeling approaches for the former documents, and an assessment of likely effects. Additional discussion of the flows in Old and Middle Rivers during the spring and early summer with and without the temporary barriers is included in Appendix Z.

The following information is from the 2007 Supplemental Biological Assessment. This supplement to the 2000 TBP Biological Assessment presents information and results of analyses to assess the impacts of the TBP on special status species in light of recent ESA listings by the NMFS and their subsequent request for re-initiation of consultation. This supplemental biological assessment serves to update permits prior to the installation of the temporary barriers in 2007, as required by NMFS. New permits, permit extensions, and project approval were needed to continue the TBP for a fourth operation interval that began in 2008. DWR has already obtained a DFG Streambed Alteration Agreement and Incidental Take permit extending the TBP through 2010. NMFS has issued a Biological Opinion and Incidental Take permit covering the TBP from 2008 through 2010. The FWS has issued a statement extending their previous Biological Opinion and Incidental Take permit for the TBP through 2008 and will apply the OCAP BA as their basis for extending operations of the TBP beyond 2008. However the FWS will require separate consultation on the installation and removal impacts of the TBP to cover ESA beyond 2008. The US Army Corps of Engineers have issued permits based upon the NFMS and FWS responses extending the TBP through 2010.

Hydrodynamic Effects

The TBP causes changes in the hydraulics of the Delta, which may pose impacts to fish. The TBP does not alter total Delta outflow, thus the position of X2, the linear position where bottom salinity measures two parts per million in the estuary, is not affected by the project. However, the TBP does cause hydrodynamic changes within the interior of the Delta. When the barrier at the head of Old River is in place, most water flow is effectively blocked from entering Old River. This in turn increases the flow in Turner and Columbia Cuts, two major central Delta channels that flow towards the south Delta. The underlying result of this hydrodynamic change is that there is an increase in reverse flow in these and other interior Delta channels. In most instances, net flow is directed towards the CVP and SWP pumps and local agricultural diversions. The directional flow towards the pumping facilities may increase the vulnerability of fish to entrainment by the pumps. Larval and small fishes are especially susceptible to these flows.

Unfortunately, the varying operational configurations of the TBP, natural variations in fish distribution, and a number of other physical and environmental variables prohibit statistical confidence in assessing fish salvage when the TBP is operational versus when it is not. The most effective direct method for examining the effect of the hydrodynamic consequences of the TBP on fish is by examining real-time fish salvage, however statistical results are lacking. Nobriga and others (2000) and Grimaldo (unpublished data) found that under certain conditions, salvage of delta smelt could increase dramatically when the TBP is operational. In 1996, the installation of the spring barrier at the head of Old River 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. This data indicates that short-term salvage, especially that of delta smelt and other small species and juveniles can significantly increase when the TBP is installed in such a manner that causes a sharp change or reversal of positive net daily flow in the interior south and central Delta. Tidally averaged daily flow data for the south Delta was obtained from the U.S. Geological Survey to look for similar phenomena in previous years for a variety of fish species, however nothing was found to be as dramatic as that which occurred in 1996.

The Vernalis Adaptive Management Plan (VAMP), initiated in 2000 as part of the State Water Resources Control Board’s Decision 1641, is a large-scale, 12-year, interdisciplinary experimental program designed to protect juvenile Chinook salmon migrating from the San Joaquin River through the Delta. VAMP is studying how salmon survival rates change in response to alterations in San Joaquin River flows and SWP/CVP exports with the installation of the barrier at the head of Old River. VAMP employs an adaptive management strategy to use current knowledge of hydrology and environmental conditions to protect Chinook salmon smolts, while gathering information to allow more efficient protection in the future. In each year, VAMP schedules and maintains pulse San Joaquin River flows and reduced project exports for a one month period, typically from April 15 - May 15 (May 1-31 in 2006). Tagged salmon smolts released in the San Joaquin River are monitored as they move through the Delta in order to determine their fate. While VAMP studies attempt to limit project impacts to salmonids, the associated reduction in exports reduces the upstream flows that occur in the south and central Delta. This reduction limits the southward draw of water from the central Delta, and thus shortens the Projects’ zone of influence with regard to the passive entrainment of fishes.

Temporary Barriers Fish Monitoring

In 1992, DFG initiated the TBP Fish Monitoring Program in order to examine the impacts of the TBP on resident fish communities in the south Delta. Ten permanent sites within the south Delta were sampled with electrofishing and gill nets to study resident fish community composition and distribution (DWR 1998). Unfortunately, a lack of pre-project monitoring data and gear type made an analysis of overall project impacts impossible. This data could only be used to provide simple descriptive species presence/absence information. Similarly, a number of other fish monitoring and special study program data sets were used to assess potential impacts of the TBP. Because these other programs were not designed to specifically test TBP impacts, analysis from these data are also largely descriptive.

Predation Impacts to Fish

The physical presence of the TBP may attract piscivorous fishes and influence predation on special status fish species. However, past studies by the DFG TBP Fish Monitoring Program has indicated that predation on special status fish species near the Temporary Barriers is negligible (DWR 2000a). The top predatory fish in the Delta, the striped bass, primarily feed on threadfin shad and smaller striped bass, as adults. Having highly opportunistic diets, striped bass are known to consume about anything that is in high abundance (Moyle 2002). Rearing-age green sturgeon and other fish much larger than 10 cm escape predation by most adult striped bass (Nelson et. al. 2006).

Water Quality Impacts to Fish

Monitoring of water quality parameters has been conducted during the DFG TBP Fish Monitoring of the study area and also by DWR as part of the DWR annual TBP Monitoring Reports. These studies have found that water quality is not significantly impacted by the TBP (DWR 2000a). In general, electrical conductivity (EC) is slightly higher upstream of the TBP facilities than downstream. This is mostly due to the fact that Sacramento River water is drawn to the south Delta when the TBP is operational. Sacramento River water has generally lower EC than the San Joaquin River and thus improves water quality within the south Delta, downstream of the TBP facilities. Hydrodynamic and water quality modeling has shown that EC in the south Delta increases when SWP pumping decreases (DWR 2000b). The decreased pumping reduced the draw of Sacramento River water in the south Delta and thus water quality “degraded” in the form of increased EC.

Dissolved oxygen (DO) sags have occurred in the project area during years when the TBP was both operational and when it was not, over the same time period. The DO sags appear to be related to increased water temperatures in the summer and have even occurred in high outflow years such as 1998 (DWR 1999). Data from the 1997 fish monitoring water quality element suggest that the TBP does not promote low DO upstream of the facilities (DWR 1998). At the Old River at Tracy (ORT) barrier from March through August, DO levels above the barrier were lower on the flood tide than they were on the ebb tide. This can occur above the ORT barrier whenever flood tides are not strong enough to push enough water over and through the ORT barrier weir and culverts to increase circulation toward the head of the Grant Line Canal. The ORT barrier height is 2.0 feet MSL, while the other two agricultural barriers are at 1.0 feet MSL, a design meant to force circulation up Old River and down the Grant Line Canal. When flood tides are not strong enough, null zones can occur upstream of the ORT barrier due to a combination of weak tides and agricultural diversions. These null zones are areas of low circulation where EC can increase and DO levels can be lower than on the downstream side of the barrier.

Water impounded upstream of the three agricultural barriers is seasonally warmed into the 70-80+ °F range, depending on location, from May – October. There is a concern that fishes that become trapped upstream of the agricultural barriers and are therefore susceptible to high water temperatures.

Vulnerability to Local Agricultural Diversions

Fish that may become trapped upstream of the TBP agricultural barriers may suffer increased vulnerability to local agricultural diversions. There are numerous local diversions within the southern Delta that are generally most active from April through October (Cook and Buffaloe 1998), the same time period of TBP operation. However, there are many agricultural diversions on the downstream side of the barriers in the central and northern delta as well, consequently, whether there is a difference in vulnerability upstream versus downstream of the TBP agricultural barriers is unknown.

The Interagency Ecological Program (IEP) conducted a Delta Agricultural Diversion Study from 1993 through 1995 in attempt to determine the impacts of in-Delta diversions on resident and anadromous fish (Cook and Buffaloe 1998). No delta smelt were captured in the fyke net. Overall, threadfin shad, catfish and sunfish were the dominant species captured, comprising over 99 percent of the total catch.

Similar sampling of diversions in other regions of the Delta (Cook and Buffaloe 1998) has captured small numbers of delta smelt, Chinook salmon, splittail. These data suggest that fish vulnerability, especially delta smelt, to in-Delta diversions increases when fish density is high in the immediate vicinity of the diversion. The fact that presumably no species considered under this supplemental B.A. were entrained in the diversion within the TBP area is probably due to the fact that their densities were extremely low in this area during the study period. It can be expected that a few of these fishes will be entrained into local diversions however; the overall impact is expected to be minimal based upon the results of the IEP study.

Impacts to Potential Fish Prey Items

The conditions posed by the TBP may not influence the abundance and distribution of food items used by delta smelt.

The extent to which the distribution and abundance of these organisms will be 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 impacted. These data suggest that the TBP probably will not influence prey populations within the Delta.

Past Measures

Under Terms and Conditions 1 (e) of the USFWS Biological Opinion (4/26/96), DWR was required to install at least three fish screens on agricultural diversions per year in the Delta. To date, DWR has installed a total of 14 screens on agricultural diversions and has capped another diversion at Sherman Island, for a total of 15 screens (3 screens per year for the permit period). DWR also contributed to funding a study that examined the entrainment patterns of two side-by-side screened and unscreened diversions at Sherman Island. DWR will continue the operation and maintenance of all 14 fish screens that have been installed at Sherman Island. The previously mentioned DWR study on the entrainment patterns of two side-by-side screened and unscreened diversions at Sherman Island provided evidence that screens can protect fish from entrainment into agricultural diversions (Nobriga and others 2000).

Under Terms and Conditions 3 of the USFWS Biological Opinion (4/26/96), DWR was required to mitigate for the footprint of the Grant Line Canal barrier. DWR fulfilled this requirement by acquiring a 1:1 ratio of 0.064 acres of riparian scrub, 0.011 acres of shaded mudflat, 0.411 acres of shallow water, and 0.250 acres of intertidal vegetation at Kimball Island.

Under Condition 11 of the DFG 1601 Agreement (5/2/96), DWR was required to mitigate for the impact to shallow water habitat. DFG agreed to credit the Kimball Island mentioned above habitat purchase to satisfy this mitigation requirement.

Under Condition 16 of the DFG 1601 Agreement (5/2/96), DWR was required to screen two agricultural diversions in the Bay-Delta Estuary. The fish screen project at Sherman Island fulfilled this requirement.

An additional conservation measure will be to notch each of the agricultural barriers similar to the HORB fall barrier to provide passage for migrating adult salmon that have strayed into Old and Middle Rivers and Grant Line Canal.

South Delta Improvement Program Operable Gates

The following assessment identifies potential effects of operating the gates with the implementation of Stage 1 of the South Delta Improvements Program (SDIP) on delta smelt in the Delta. SDIP Stage 1 consists of the installation and operation of gates at four locations in the south Delta. There is no increase in the export diversion rate in Stage 1. Stage 2 includes the operable gates with the increase in exports up to 8,500 cfs.

ESA consultation for the operation of the SDIP gates in Stage 1 is being done within this OCAP BA. ESA consultation for the potential construction-related, predation and passage effects will be done separately. The operational effects are discussed and the other effects summarized in the subsequent text.

Simulation modeling completed for this OCAP BA incorporates the effects of the South Delta Temporary Barriers Project and 500 cfs increased export in Studies 6.1 and 7.0. The SDIP Stage 1, the 500 cfs increased export, and the CVP aqueduct intertie are incorporated into Studies 7.1 and 8.0. A full evaluation of the combined effects of these elements is presented in Chapter 13. Because the simulation models examined the combination of these elements, it is not possible to separate and examine the effects of any single project element by itself. Therefore, the effects analysis for the SDIP Stage 1 is taken largely from *South Delta Improvements Program Action Specific*

Implementation Plan (DWR and USBR 2006), and the *South Delta Improvements Program EIS/EIR* (DWR and USBR 2006), http://baydeltaoffice.water.ca.gov/sdb/sdip/documents/final_eis_eir.cfm. The effects of operation of the gates are discussed in the following text. Details on the hydrodynamics of the SDIP operable gates are in Appendix Z.

Effects of Gate Operation on Delta Smelt Spawning and Rearing Habitat, and Entrainment

Head of Old River Operations Effects

Operation (closing) of the head of Old River fish control gate is proposed to begin on April 15. Spring operation is generally expected to continue through May 15, to protect outmigrating salmon and steelhead. During this time, the head of Old River gate would be fully closed, unless the San Joaquin River is flowing above 10,000 cfs or the Gate Operations Review Team (GORT) recommends a partial opening for other purposes.

Under constant SWP and CVP pumping, Head of Old River gate closure causes additional net flow to be drawn from the San Joaquin River and south through Old River, Middle River, and Turner Cut. The increased net flow toward the south may increase entrainment of larval and juvenile delta smelt. The effects of the Head of Old River closure are similar for Alternatives 1 (No Action) and 2A (SDIP Stage 1), however the fish control gate constructed under Alternative 2A is fully closed compared to the temporary barrier at the head of Old River which has culverts that allow a portion of the San Joaquin River flow through the south Delta. Use of the permanent operable fish control gate at the Head of Old River is not limited to fully open or fully closed settings. The operable gate can be set at any height within its operable range, thus allowing a variety of flows into the south Delta via Old River.

The most notable effect seen in implementation of the permanent operable gates is in years when the San Joaquin River flow is between 5,000 cfs and 10,000 cfs. In these years, under the temporary barriers project, the Head of Old River barrier would not be constructed because the flows in the San Joaquin River are greater than 5,000 cfs. But the permanent gate is operated because it can be operated when the San Joaquin River is flowing up to 10,000 cfs. Whereas under the temporary barriers project there is little to no additional net flow being drawn from the San Joaquin River through Turner and Columbia Cuts, now, through the operation of the Head of Old River gate there is significant flows being drawn in. Delta smelt presence in the lower reaches of the San Joaquin River, especially in the central Delta, would be affected by this scenario. This hydrodynamic effect is discussed further in Appendix Z.

Operations during the months of October and November (fall operations) to improve flow and water quality conditions (i.e., low dissolved oxygen) in the San Joaquin River for adult migrating Chinook salmon is expected to provide a benefit similar to that achieved with the temporary barrier. Operations would not occur if the San Joaquin River flow at Vernalis is greater than 5,000 cfs because it is expected that this flow would maintain sufficient DO in the San Joaquin River.

Head of Old River gate operations in the fall are confined to the months of October and November. This operation is the same as the existing operation of the temporary Head of Old River barrier use. There is no additional impact associated with the fall operation because Delta smelt are not in the Delta during this period and the operations are the same as existing conditions.

Flow Control Gate Operations Effects

The flow control gates in Middle River, Grant Line Canal, and Old River near the DMC, would be operated (closed during some portion of the tidal cycle) throughout the agricultural season of April 15 through November 30. As with the head of Old River fish control gate, when the gates are not operated, they are fully lowered in the channel.

Spring Operations

During April 15 through May 15 (or until the Spring operation of the head of Old River gate is completed), in most years, water quality in the south Delta is acceptable for the beneficial uses but closure of the head of Old River fish control gate has negative impacts on water levels in the south Delta. Therefore, the flow control gates would be operated to maintain minimum water levels of 0.0 feet msl. In the less frequent year types, dry or critically dry, when water quality in the south Delta is threatened by this static use of the gates, circulation may be induced to improve water quality in the south Delta channels.

Summer and Fall Operations

When the Spring operation of the head of Old River fish control gate is completed and through November 30, the gates would be operated to control minimum water levels and increase water circulation to improve water quality in the south Delta channels. Reclamation and DWR have committed to maintaining water levels during these times at 0.0 foot msl in Old River near the CVP Tracy facility, 0.0 foot msl at the west end of Grant Line Canal, and 0.5 foot msl in Middle River at Mowry Bridge. It is anticipated that the target level in Middle River would be lowered to 0.0 foot msl following extension of some agricultural diversions.

The proposed gate operations will increase the tidal circulation in the south Delta channels. This is accomplished by tidal flushing upstream of the flow-control gates with relatively low-salinity water from Old River and Middle River downstream of the gates (i.e., high fraction of Sacramento River water). The flow-control gates would remain fully open during periods of flood tide (i.e., upstream flow) and then two of the gates would be fully closed (i.e., top elevation of gates above upstream water surface) during periods of ebb tide (i.e., downstream flow). The remaining gate (i.e., Grant Line) would be maintained at a lower elevation (i.e., 0.0 feet msl) to allow the ebb tide flow to exit from the south Delta channels so that the flood-tide flow over the gates can be maximized during each tidal cycle. This is the same operation described as Purpose 5 earlier in the description of the SDIP gates.

Flow control gates in Middle River, Grant Line Canal, and Old River at DMC could affect access to spawning and rearing habitat for delta smelt in the south Delta channels. These gates would be open at tide elevations between 0.0 feet msl and about 3 feet msl, an increase in the tidal range currently allowed by the temporary barriers. Total tidal volume would approach 80 percent of the tidal volume that would occur without gates in place. The flow control gates could have a beneficial effect on movement of delta smelt by enhancing access to Middle River, Grant Line Canal, and Old River. Measurable benefits to delta smelt, however, are likely small considering the assumed high probability that larval and juvenile delta smelt spawned in the south Delta would be entrained in agricultural diversions and operation of these gates is not started until later in the spring.

Operations of the flow control gates to preserve water stage in the south Delta has lower impacts than construction of the existing temporary agricultural flow control barriers. The temporary barriers are constructed at a higher elevation than what is required to maintain water stage. Because of the difference in height, the temporary barriers block more San Joaquin River flow from entering the south Delta, thus directing more water through Turner and Columbia Cuts. Similar in effect to the Head of Old River gate, the increased net flow from the central Delta toward the export facilities may increase entrainment of larval and juvenile delta smelt.

Operations of the flow control gates to induce circulation in south Delta channels will have similar impacts as those experienced with the existing temporary barriers. Flows from the central Delta to the south Delta are not significantly different between the two project scenarios. The fate of larval and juvenile Delta smelt will be very similar once in the south Delta channels. Particle tracking simulations in the south Delta have shown that the fate of particles released in the south Delta is either in agricultural intakes or the export facilities. Other particle tracking analysis is offered in Appendix Z.

Construction-related, Predation and Passage Effects

The potential construction-related, predation and passage effects are summarized below. All the details of the effects of the SDIP actions, including construction, predation and passage effects, are addressed in detail in the *South Delta Improvements Program Action Specific Implementation Plan* (DWR and USBR 2006), and the *South Delta Improvements Program EIS/EIR* (DWR and USBR 2006), http://baydeltaoffice.water.ca.gov/sdb/sdip/documents/final_eis_eir.cfm.

Permanent gates would be constructed at the head of Old River and in Middle River, Grant Line Canal, and Old River at the Delta Mendota Canal (DMC). Construction of the gates includes grading the channel bank, dredging the channel bottom, constructing sheet-pile cofferdams or an in–the-wet construction method, driving foundation piles and placing riprap, concrete, and other materials on the channel bank and bottom.

Dredging for all of the permanent gates would occur between August and November. Cofferdams would also be placed in the channel during the August through November timeframe. Work outside of the channel and within the cofferdams, if used, is assumed to occur during any month.

Dredging of Middle River and portions of Old River would increase the tidal conveyance capacity of the channels. Tidal flow velocity may be slightly reduced in West Canal and, depending on existing channel constrictions, circulation may be increased in Middle River, Old River, and Grant Line Canal.

The operation of the permanent flow control gates on Middle River, Grant Line Canal, and Old River would maintain water surface elevation above 0.0 feet msl during April 15 through November. Under current conditions, tides range from about 1.0 foot below mean sea level to 3.0 feet msl two times each day. The maximum change in SWP pumping (and CCF operations) could reduce the daily higher high tide from about 2.6 to 2.4 feet msl near the CCF gates. The reduction in higher high tide attributable to change in SWP pumping is less with distance from the CCF gates. When closed during tide levels below 0.0 feet msl, the flow control gates block fish passage. When opened during tide levels greater than 0.0 feet msl, fish passage is restored. The volume of water exchanged during each tidal cycle is reduced by about 20 percent for the channels upstream of the gates on Middle River, Grant Line Canal, and Old River.

During the spring, the head of Old River fish control gate would be operated to block flow and movement of juvenile fall-run Chinook salmon and other fishes from the San Joaquin River into Old River from about April 15 through May 15, or other periods as recommended by USFWS, NOAA Fisheries, and DFG. Juvenile Chinook salmon move down the San Joaquin River past Stockton, a pathway believed to enhance survival relative to movement into Old River (Brandes and McLain 2001).

During fall, the head of Old River fish control gate would be operated to increase flow in the San Joaquin River past Stockton from about September 15 through November 30. The increased flow in the San Joaquin River potentially improves water quality, including increased DO, in the San Joaquin River channel near Stockton (Giulianotti et al. 2003). Improved water quality could benefit upstream migrating adult Chinook salmon.

Construction-Related Loss of Spawning Habitat Area for Delta Smelt

Delta smelt spawn in the Delta. As indicated in the methods description, existing information does not indicate that spawning habitat is limiting population abundance and production (U.S. Fish and Wildlife Service 1996).

Shallow areas that may provide spawning habitat for delta smelt could be permanently modified by construction of the gates in the south Delta and subsequent maintenance activities. The area of shallow habitat affected by the gate footprints, riprapped levee, and dredging may total several acres. The permanent gates constructed under Alternative 2A would have minimal effect on habitat within the construction footprint at the head of Old River, Middle River, and Old River at DMC. Construction of the temporary barriers has previously modified shallow water habitat. Three of the four permanent gates would be constructed in the same location as the temporary barriers and would result in little change in habitat quality and quantity relative.

Construction of a new gate on Grant Line Canal and the proposed dredging in West Canal, Middle River, and Old River potentially would remove and modify existing shallow habitat. The loss of spawning habitat in the Delta has not been explicitly identified as a factor contributing to the decline of delta smelt, and the south Delta channels have not been identified as important spawning habitat (U.S. Fish and Wildlife Service 1996). The relative importance of spawning habitat in the south Delta in contributing to population abundance is likely low. Nonnative species currently dominate the fish community in shallow areas of the south Delta (Feyrer 2001), and many of the species prey on delta smelt and their eggs. In addition, entrainment of larvae in diversions, especially CVP and SWP pumping, would minimize the importance of spawning habitat in the south Delta.

Construction-Related Loss of Rearing Habitat Area for Delta Smelt

Delta smelt larvae, juveniles, and adults rear in the Delta and Suisun Bay. The importance of rearing habitat in the south Delta, however, appears to be relatively low. Nonnative species currently dominate the fish community in the south Delta (Feyrer 2001), and many of the species prey on delta smelt larvae and juveniles. In addition, entrainment of larvae and juveniles in diversions, especially CVP and SWP pumping, would minimize the importance of rearing habitat in the south Delta. Rearing habitat loss associated with gate construction, maintenance activities, and dredging is determined to be minimal.

Construction-Related Reduction in Food Availability for Delta Smelt

Many of the same factors affecting rearing habitat area would be expected to affect food production and availability for delta smelt. Construction of the gates in the south Delta and maintenance activities have the potential to permanently modify channel form and remove bottom substrates. Delta smelt, however, feed on zooplankton and effects on benthic invertebrate habitat may not affect food for delta smelt. This potential effect is minimal for the same reasons discussed for effects on rearing habitat.

Construction-Related Loss of Delta Smelt to Accidental Spill of Contaminants

Contaminants associated with construction activities, including gate construction, placement of riprap, dredging, and maintenance dredging, could be introduced into the south Delta channels and could adversely affect delta smelt and their habitat. Environmental commitments, including an erosion and sediment control plan, hazardous materials management plan, spoils disposal plan, and environmental training, will be developed and implemented before and during construction activities. The environmental commitments would substantially reduce the likelihood of any considerable contaminant input. Contaminants would have a minimal effect on delta smelt and their habitat in the south Delta because the potential for increased contaminant input following implementation of environmental commitments is small.

Construction-Related Loss of Delta Smelt to Direct Injury

Construction of the gates would include placement of sheetpiles and riprap and could directly injure fish present during the time of construction. Dredging could entrain and injure delta smelt. Cofferdams, if used, would be installed to isolate gate construction areas from the channel. Placement of cofferdams in the channels could trap larval, juvenile, and adult delta smelt. Fish that become trapped inside the cofferdams could be killed during desiccation of the construction area and construction activities. Direct injury associated with construction and maintenance activities, including dredging, would have a minimal effect on delta smelt because the number of fish injured is likely small given that:

- in-water construction, including the construction of a cofferdam, would occur between August and November;
- the area of construction activity is small relative to the channel area providing similar habitat quality in the south Delta; and
- most juvenile and adult delta smelt would move away from construction activities and into adjacent habitat of similar quality.

Construction-Related Loss of Delta Smelt to Predation.

Construction of gates and extension of agricultural intakes would add permanent structure and cover to the south Delta channels. The addition of structure has the potential to increase the density of predator species and predation on fish moving around and past the structure. Concentrations of disoriented fish increase prey availability and create predator habitat.

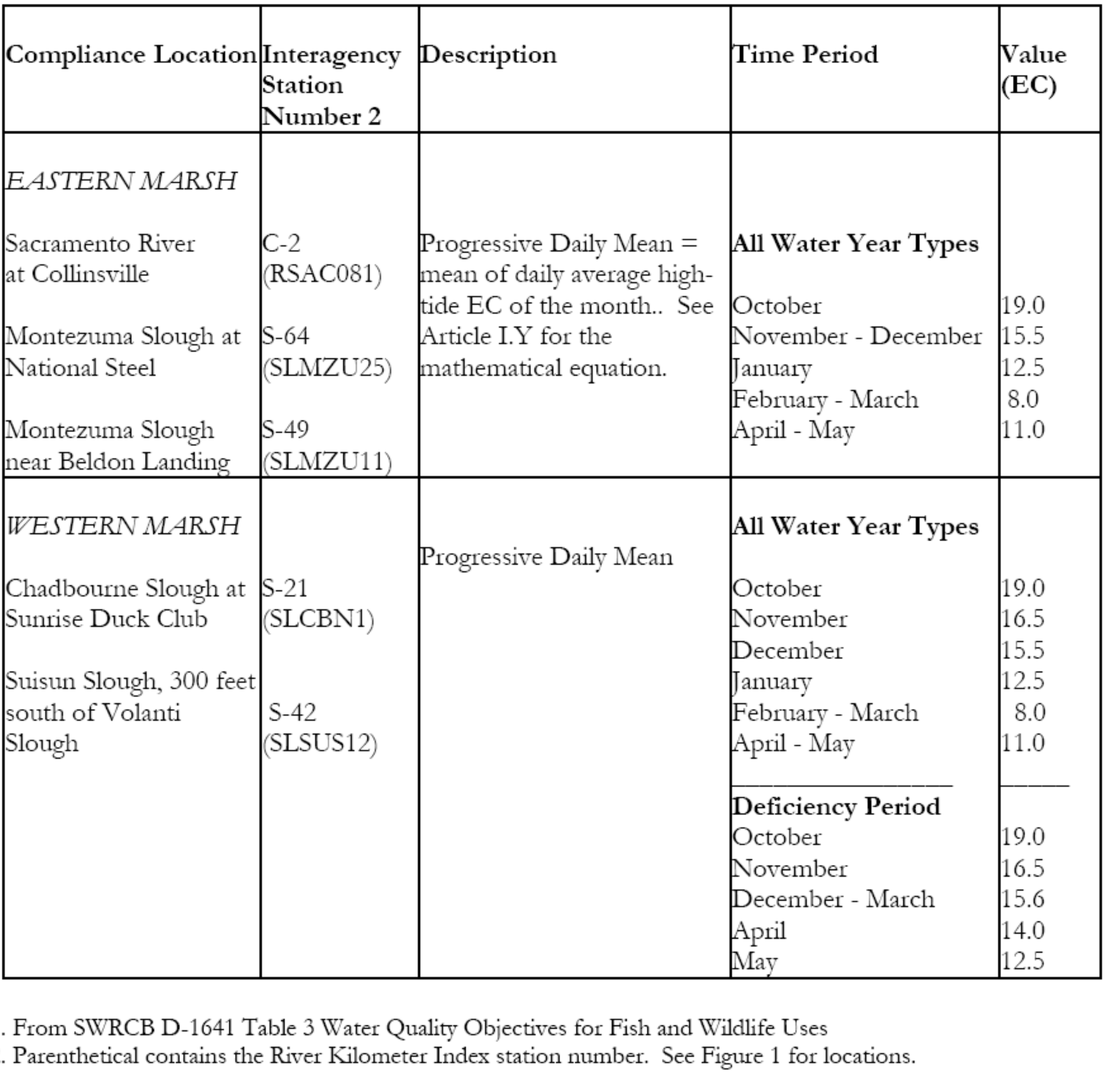
Predation associated with the addition of the operable gates and the agricultural intake extensions to the south Delta channels could cause a small and likely negligible (i.e., minimal effect) increase in mortality of the delta smelt moving past the structures. The determination is based on several factors. Design elements will minimize turbulence that could disorient fish and increase vulnerability to predation. The structures would not create conditions that could concentrate delta smelt. Flow velocity would be similar to velocities within the channel upstream and downstream of the gates and the agricultural intake extensions.

The transition zones between various elements of the gates (e.g., sheetpiles and riprap) could provide low-velocity holding areas for predatory fish. Predatory fish holding near the gates and agricultural intakes could prey on vulnerable species. The additional predator habitat created by the gates and intake extensions would have a minimal effect on delta smelt because the increase in potential predator habitat is small relative to habitat in adjacent areas, including the habitat currently created by the temporary barriers and habitat at the existing agricultural intakes. Disorientation and concentration of juvenile and adult fish would be minimal given the size and design of the gates.

Suisun Marsh Salinity Control Gates

The SMSCG is generally operated as needed September through May to meet State salinity standards in the marsh (Table 13-21). The number of days the SMSCG are operated in any given years varies. Historically, the SMSCG were operated between 60-120 days between October and December (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 operation. In 2006 and 2007, the gates were operated periodically between 10-20 days annually. This level of operational frequency (10-20 days per year) can generally be expected to continue in the future except perhaps during the most critical hydrologic conditions.

Table 13-21 Suisun Marsh Channel Water Standards 1/



Compliance Location	Interagency Station Number 2	Description	Time Period	Value (EC)
EASTERN MARSH Sacramento River at Collinsville Montezuma Slough at National Steel Montezuma Slough near Beldon Landing	C-2 (RSAC081) S-64 (SLMZU25) S-49 (SLMZU11)	Progressive Daily Mean = mean of daily average high-tide EC of the month.. See Article I.Y for the mathematical equation.	**All Water Year Types** October November - December January February - March April - May	 19.0 15.5 12.5 8.0 11.0
WESTERN MARSH Chadbourne Slough at Sunrise Duck Club Suisun Slough, 300 feet south of Volanti Slough	S-21 (SLCBN1) S-42 (SLSUS12)	Progressive Daily Mean	**All Water Year Types** October November December January February - March April - May	 19.0 16.5 15.5 12.5 8.0 11.0
			Deficiency Period October November December - March April May	 19.0 16.5 15.6 14.0 12.5

1. From SWRCB D-1641 Table 3 Water Quality Objectives for Fish and Wildlife Uses
2. Parenthetical contains the River Kilometer Index station number. See Figure 1 for locations.

The SMSCG does not directly affect delta smelt in any measurable way. It is possible, however, for delta smelt and other fishes to be entrained into Montezuma Slough and Suisun Marsh when the SMSCG is fully operational. 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. However, the degree to which movement of delta smelt is constrained is unknown. It is also unknown if there are differences in habitat conditions that may affect delta smelt that are temporarily forced to remain in Suisun Marsh. 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 those of the MIDS. Entrainment into MIDS from the Sacramento River may be unlikely though because particle tracking studies have demonstrated low entrainment vulnerability for particles released at random locations throughout Suisun Marsh (3.7%), and almost no vulnerability (<0.1%) to particles released at Rio Vista (Culberson et al. 2004). Moreover, DWR staff monitored fish entrainment from September 2004 to June 2006 at MIDS to evaluate entrainment losses at the facility.

Monitoring took place over several months under various operational configurations to provide data on the site-specific impact of the MIDS diversion with a focus on delta smelt and salmonids. Over 20 different species were identified during the sampling, yet only two fall-run sized Chinook salmon (south intake, 2006) and no delta smelt from entrained water were caught. 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.

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, thus the impacts of the SMSCG on X2 during this period are mostly negligible. Therefore, SMSCG operations from January to May are not likely to impact entrainment vulnerability. In addition, because delta smelt move upstream between January and March, operations of the SMSCG are unlikely to adversely affect delta smelt habitat suitability during this period.

Morrow Island Distribution System

The 1997 FWS BO issued for dredging of the facility included a requirement for screening the diversion to protect delta smelt. Due to the high cost of fish screens and the lack of certainty surrounding their effectiveness at MIDS, DWR and Reclamation proposed to investigate fish entrainment at the MIDS intake with regard to fishery populations in Goodyear Slough and to evaluate whether screening the diversion would provide substantial benefits to local populations of listed fish species. DWR staff monitored fish entrainment from September 2004 to June 2006 at the MIDS in Suisun Marsh (Figure 1) to evaluate entrainment losses at the facility. Monitoring took place over several months under various operational configurations to provide data on the site-specific impact of the MIDS diversion with a focus on delta smelt and salmonids. Over 20 different species were identified during the sampling, yet only two fall-run sized chinook salmon (south intake, 2006) and no delta smelt from entrained water were caught. Two species that associate with instream structures, threespine stickleback and prickly sculpin, comprised most of the entrained fish. DWR and Reclamation staff will continue coordination with the fishery agencies to address the screening requirement.

Reclamation and DWR continue to coordinate with the FWS, NMFS, and DFG regarding fish entrainment at this facility. The objective remains to provide the greatest benefit for aquatic species in Suisun Marsh. Studies suggest that GYS is a marginal, rarely used habitat for special-status fishes. Therefore, implementation and/or monitoring of a tidal restoration project elsewhere is emerging as the most beneficial and pratical approach (in lieu of installing and maintaining fish screens). Restoration of tidal wetland ecosystems is expected to aid in the recovery of several listed and special status species within the marsh and improve food availability for delta smelt and other pelagic organisms.

Effects on Critical Habitat

The USFWS designated delta smelt critical habitat to include "areas of all water and all submerged lands below ordinary high water and the entire water column bounded by and constrained in Suisun Bay (including the continguous Grizzly and Honker Bays); the length of Goodyear, Suisun, Cutoff, First Mallard (Spring Branch), and Montezuma sloughs; and the existing contiguous waters contained within the Delta." (U.S. Fish and Wildlife Service. 1994. Endangered and threatened wildlife and plants: Critical habitat determination for the delta smelt. December 19, 1994. Federal Register 59(242): 65256-65279 [Rule]). Both direct and indirect effects described here for the CVP and SWP upon delta smelt take place within these geographical boundaries. Present and future operations described in studies 6.1, 7.0, and 7.1 are likely to affect the primary constituent elements of delta smelt critical habitat as follows.

Habitat

As described by the Rule, delta smelt require "shallow, fresh or slightly brackish backwater sloughs and edgewaters for spawning. To ensure egg hatching and larval viability, spawning areas also must provide suitable water quality (i.e., low concentrations of pollutants) and substrates for egg attachment (e.g., submerged tree roots and branches and emergent vegetation)." In recent years the densest spawning aggregations of adult delta smelt have been found in the Cache Slough/Sacramento Deepwater Ship Channel complex in the north Delta, with delta smelt also distributed at lower densities in the central and occasionally the south Delta. Current and future CVP and SWP operations described in studies 7.0, 7.1, and 8.0 are unlikely to affect spawning habitat in the interior and north Delta because the projects do not contribute pollutants or otherwise physically or chemically disturb this habitat. During the spawning months, delta outflow is typically high enough that salinity intrusion into areas where delta smelt spawn is unlikely to occur. Moreover, the need to protect the quality of exported water would likely prevent the water projects from causing salinity intrusion into areas where delta smelt are spawning regardless of hydrologic conditions. Water project operations might adversely affect spawning habitat in the west Delta and Suisun Marsh if persistently elevated salinities in those regions resulted in changes in the quality of edgewater habitat and spawning substrate through changes in the plant and animal assemblages that occur there. The extent to which such changes might reduce the overall availability of good-quality spawning habitat is unknown, but given historical geographical patterns of delta smelt is likely to be small.

River Flow

As described in the Rule, to ensure transport of delta smelt larvae from the areas where they hatch to productive rearing or nursery habitat, "the Sacramento and San Joaquin Rivers and their tributary channels must be protected from physical disturbance…and flow disruption (eg. water diversions that result in entrainment and in-channel barriers or tidal gates). Adequate river flow is necessary to transport larvae from upstream spawning areas to rearing habitat in Suisun Bay. Additionally, river flow must be adequate to prevent interception of larval transport by the State and Federal water projects…" Both current and future CVP and SWP operations described in this Biological Assessment are likely to adversely affect larval and juvenile transport by flow disruption and interception (and subsequent entrainment) of fish. The zone of entrainment, in which interception of larval transport occurs, is affected by export rates and especially the degree of upstream flow in Old and Middle Rivers (OMR flow, PE Smith, unpublished analysis, Grimaldo et al. in press, Kimmerer and Nobriga 2008). Disruptive effects associated with negative OMR flow often extend north and east to the San Joaquin River, and sometimes extend far enough north to affect the Sacramento River. While the evidence from the POD investigation principally implicates direct entrainment of adults, larvae, and early juveniles as possible contributing causes of the recent decline of delta smelt, late emerging juvenile delta smelt have historically also been entrained in relatively large numbers during May—July of some years. Increases in the strength of negative OMR flow in June and especially July that are predicted under all model scenarios may have a significant effect in years when the spawning distribution of delta smelt intrudes farther than usual southeast.

The Rule also states that “[a]dult delta smelt must be provided unrestricted access to suitable spawning habitat in a period that may extend from December to July. Adequate flow and suitable water quality may need to be maintained to attract migrating adults in the Sacramento and San Joaquin River channels and their associated tributaries, including Cache and Montezuma sloughs and their tributaries. These areas also should be protected from physical disturbance and flow disruption during migratory periods.” As described above and in Chapter 7, water project operations affect delta hydrodynamics during this period by creating a zone of upstream flows north of the facilities, causing water to move south in OMR under most circumstances. Export pumping levels described in Study 6.1 during the winter and spring may have contributed to the Pelagic Organism Decline. Alterations of those levels in studies 7.0, 7.1, and 8.0 provide more protective flow conditions in general during winter and early spring (with exceptions in March, and June), but OMR flow modeling predicts conditions in most of the winter and spring to cause some entrainment of adults, larvae, and juveniles present in the central Delta and areas north of it in June and July.

Water and Salinity

According to the Rule, “[m]aintenance of the 2 ppt isohaline according to the historical salinity conditions…and suitable water quality (low concentrations of pollutants) within the Estuary is necessary to provide delta smelt larvae and juveniles a shallow, protective, food-rich environment in which to mature to adulthood. This placement of the 2 ppt isohaline also serves to protect larval, juvenile, and adult delta smelt from entrainment in the State and Federal water projects.” As discussed above and in Chapter 7, changes in X2 alter the distribution and availability of pelagic habitat suitable for delta smelt. Upstream X2 movements of several kilometers predicted for the fall months in studies 7.0, 7.1, and 8.0, relative to Study 6.1, are expected to be associated with a reduction in the quality and availability of rearing habitat.

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 impacts 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.

CVP and SWP Delta Effects on Steelhead, Chinook Salmon, and Green Sturgeon

This section addresses the effects associated with Delta pumping on winter-run Chinook, yearling and young-of-the-year (yoy) spring-run Chinook, steelhead and green sturgeon. Fish monitoring programs for CVP and SWP facilities are described, and salvage and loss estimates provided by species and life stage. Instream temperature effects on salmonids resulting from CVP and SWP operations were discussed in Chapter 11, and addressed separately in the effects determination.

CVP and SWP South Delta Pumping Facilities

Winter-run and spring run Chinook losses are seasonal; primarily December through May. The majority of winter-run losses occur December through April (Figure 13-39), yearling spring run surrogate losses December through March, and yoy spring run losses January through May. Distinguishing the four runs of Chinook is difficult; therefore we use a couple of different methods to estimate run losses. Winter run loss is based on length/date criteria (or growth rate criteria) developed by FWS in the upper Sacramento River. Yearling spring run loss is based on using Coleman Hatchery late-fall juveniles as surrogates for yearling spring run. Young-of-the-year spring loss is based on using the entire yoy loss as a relative index of yoy spring run loss. Yoy loss includes both fall-run and spring-run Chinook salmon.

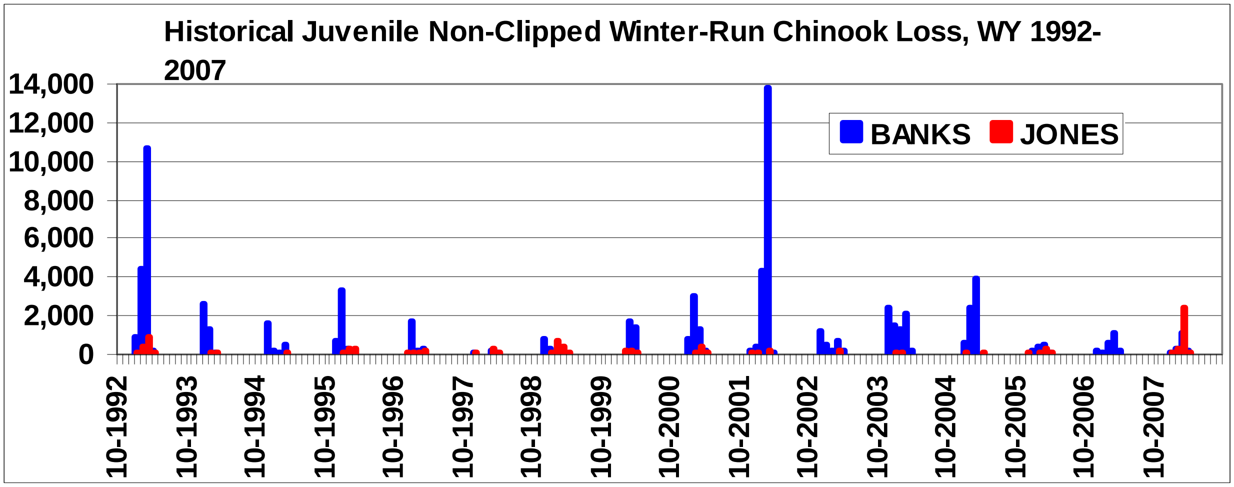


Figure 13-39 Historical juvenile non-clipped winter-run Chinook loss, WY 1992-2007.

Regressions of monthly older juvenile Chinook salmon against exports resulted in significant relationships; more so at the SWP than CVP (Figure 13-40). The months of December through April resulted in most informative relationship based on the historical number of older juvenile

Chinook salvaged each month and the relationship of each month between salvage and exports. Regressions of monthly young-of-the-year (YOY) Chinook salmon against exports did not result in significant relationships at either SWP or CVP (Figure 13-40). Export reductions for VAMP occur during the peak emigration of YOY Chinook which may skew the regression. In all of the graphs, the slope is so small it would necessitate reducing pumping altogether to affect a change in Chinook loss.

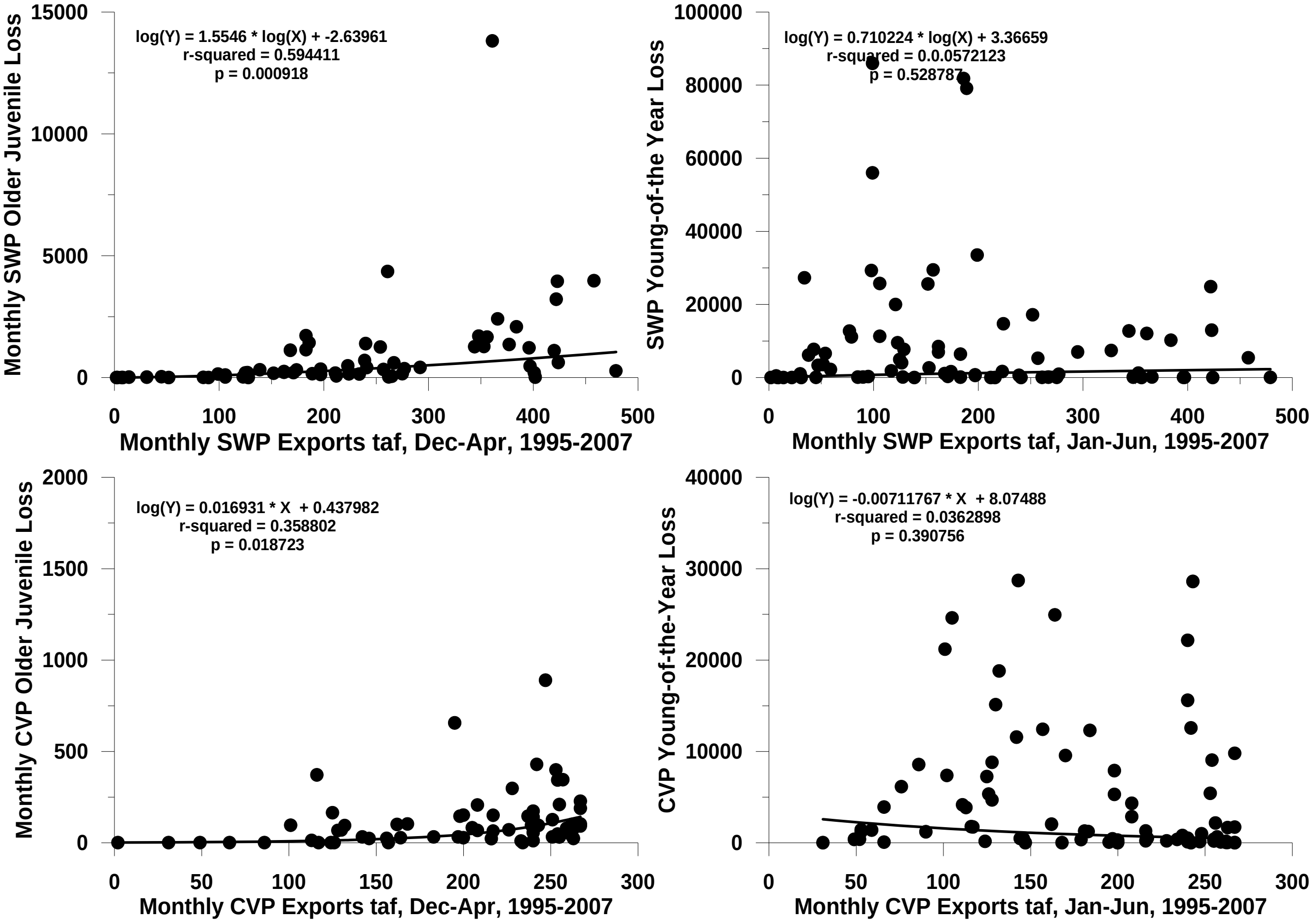


Figure 13-40 Monthly juvenile Chinook loss versus average exports, December through June, 1993 through 2006, at each facility; SWP and CVP.

Regressions of monthly older juvenile Chinook loss against Export/Inflow ratio (EI) between December and April however did not result in significant relationships at the SWP and CVP (Figure 13-40). Regressions of monthly YOY Chinook loss against EI between January and June resulted in a significant relationship for CVP but not SWP (Figure 13-40). In all of the graphs, the slope is so small it would necessitate reducing pumping altogether to affect a change in Chinook loss. There are two regression lines and equations in Figure 13-40, the black lines and equations represent the months of December through April for older juvenile Chinook and January through June for YOY Chinook (similar to the salvage and export graphs in Figure

13-41, and the red lines and equations represent the month of January alone. The regressions of monthly loss against January alone did not result in any significant relationships. Since most of the loss occurs in months other than it would take a large amount of change in EI ratio to affect a small reduction in Chinook loss.

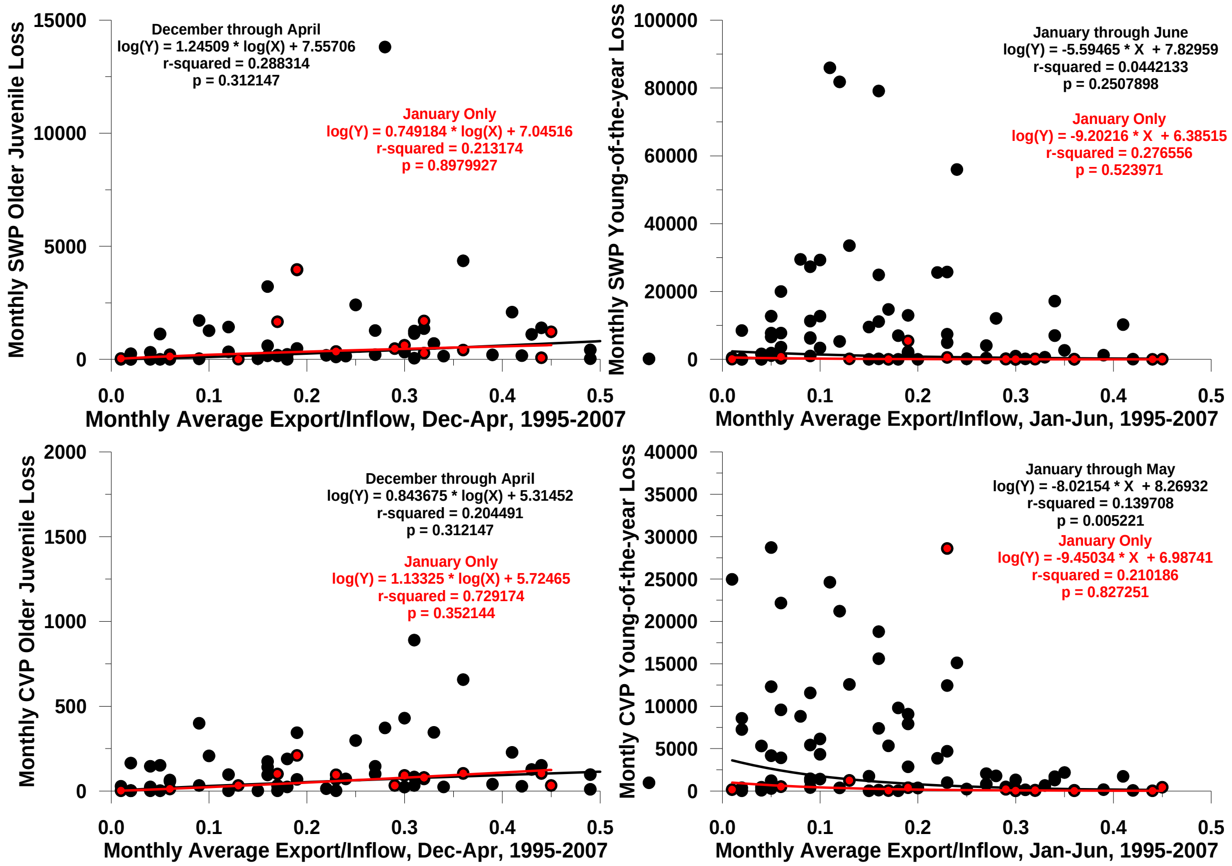


Figure 13-41 Monthly juvenile Chinook loss versus average Export/Inflow ratio, December through June, and January alone, 1993 through 2006, at each facility; SWP and CVP.

Figure 13-42 is an illustration of winter-run Chinook juvenile loss at the SWP and CVP Delta export facilities effect on a winter-run population growth rate parameter, cohort replacement rate (CRR). The CRR is simply the adult escapement one year divided by the adult escapement three years earlier. In Figure 13-42, the regression is a positive relationship between juvenile winter run loss and winter run CRR; meaning as juvenile loss increases, the CRR, or population growth rate, increases. This was not the intuitively expected results. But the regression is driven by one data point, 2003, when the loss and CCR were very high. With just one data point at the high values, there is no way to estimate variation at the high values. For this reason, if we exclude the 2003 data point. Without the 2003 data point, juvenile winter-run loss doesn’t explain the variation in the CCR and the regression is not significant. Based on this analysis, winter-run

Chinook juvenile loss at the SWP and CVP Delta export facilities isn't driving the winter-run Chinook population growth rate.

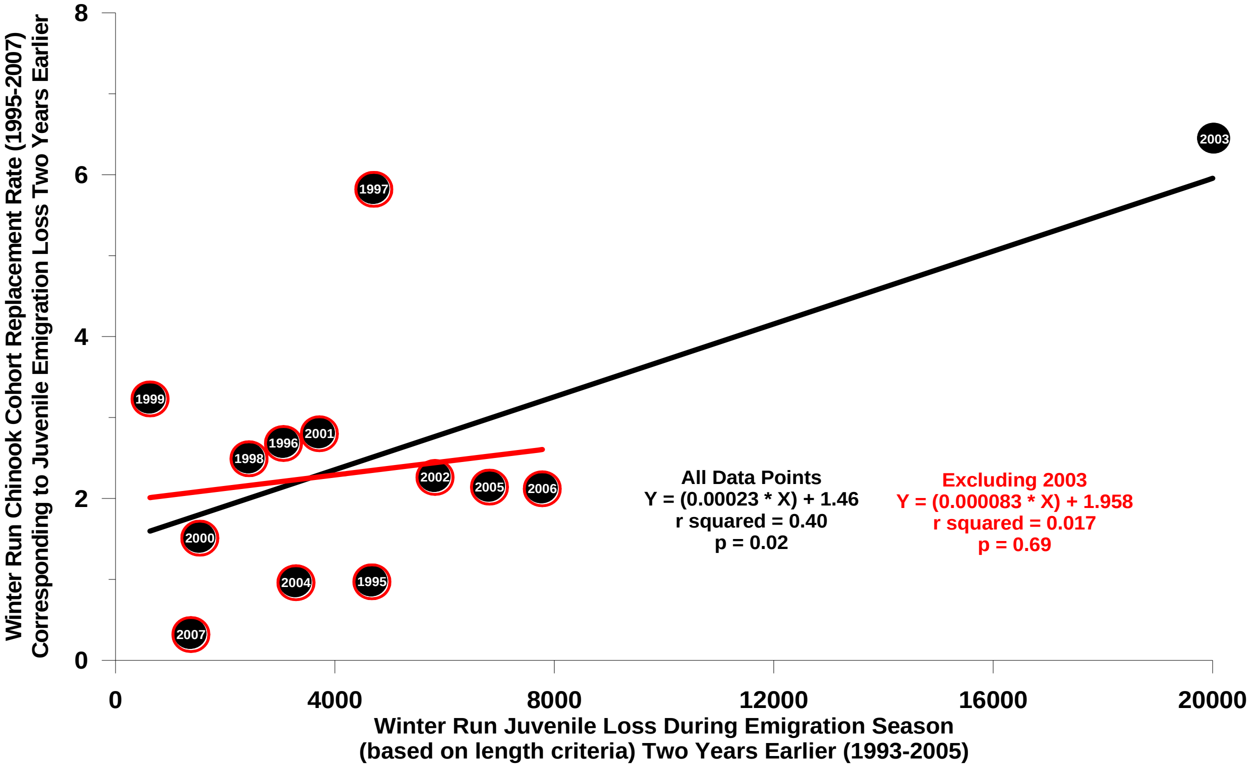


Figure 13-42 Regression of winter-run Chinook cohort replacement rate (population growth rate) to winter-run Chinook juvenile loss at the SWP and CVP Delta exports, 1993-2007.

Similarly, Figure 13-43 is an illustration of spring-run Chinook surrogate loss at the SWP and CVP Delta export facilities effect on a spring-run Chinook population growth rate parameter, cohort replacement rate (CCR). In Figure 13-43, the regression is not significant and spring-run Chinook surrogate loss doesn't explain the variation in the CCR. Based in this analysis, spring-run Chinook surrogate loss at the SWP and CVP Delta export facilities isn't driving the spring-run Chinook population growth rate.

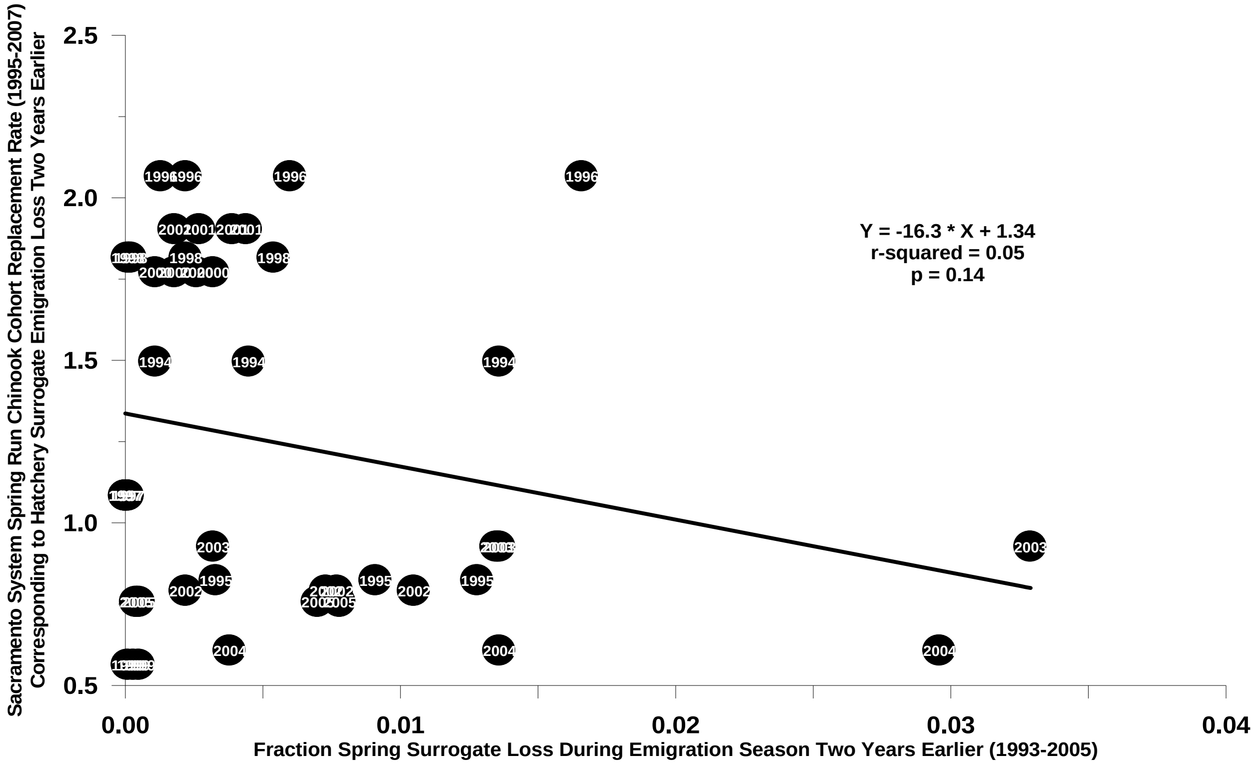


Figure 13-43 Regression of spring-run Chinook cohort replacement rate (population growth rate) to spring-run Chinook surrogate loss at the SWP and CVP Delta exports, 1993-2007.

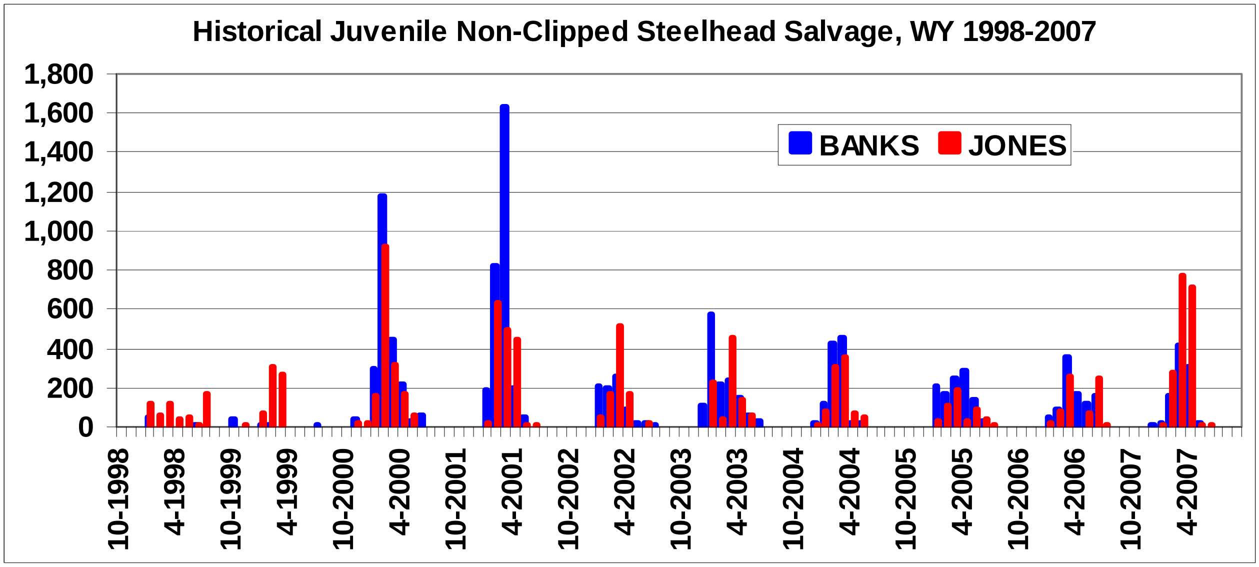


Figure 13-44 Historical Juvenile Non-Clipped Steelhead Salvage, WY 1998-2007.

Regressions of monthly steelhead salvage against exports resulted in significant relationships; more so at the SWP than CVP (Figure 13-45). The months of January through May resulted in most informative relationship based on the historical number of steelhead salvaged each month and the relationship of each month between salvage and exports; December and June both had a very small proportion of the steelhead salvage and very poor and insignificant relationships to exports. Of the four graphs in Figure 13-45, only the SWP clipped steelhead salvage relationship to exports is of interest; the slope actually changes noticeably over the export range; at the high end. In the other three graphs, the slope is so small it would necessitate reducing pumping altogether to affect a change in steelhead salvage.

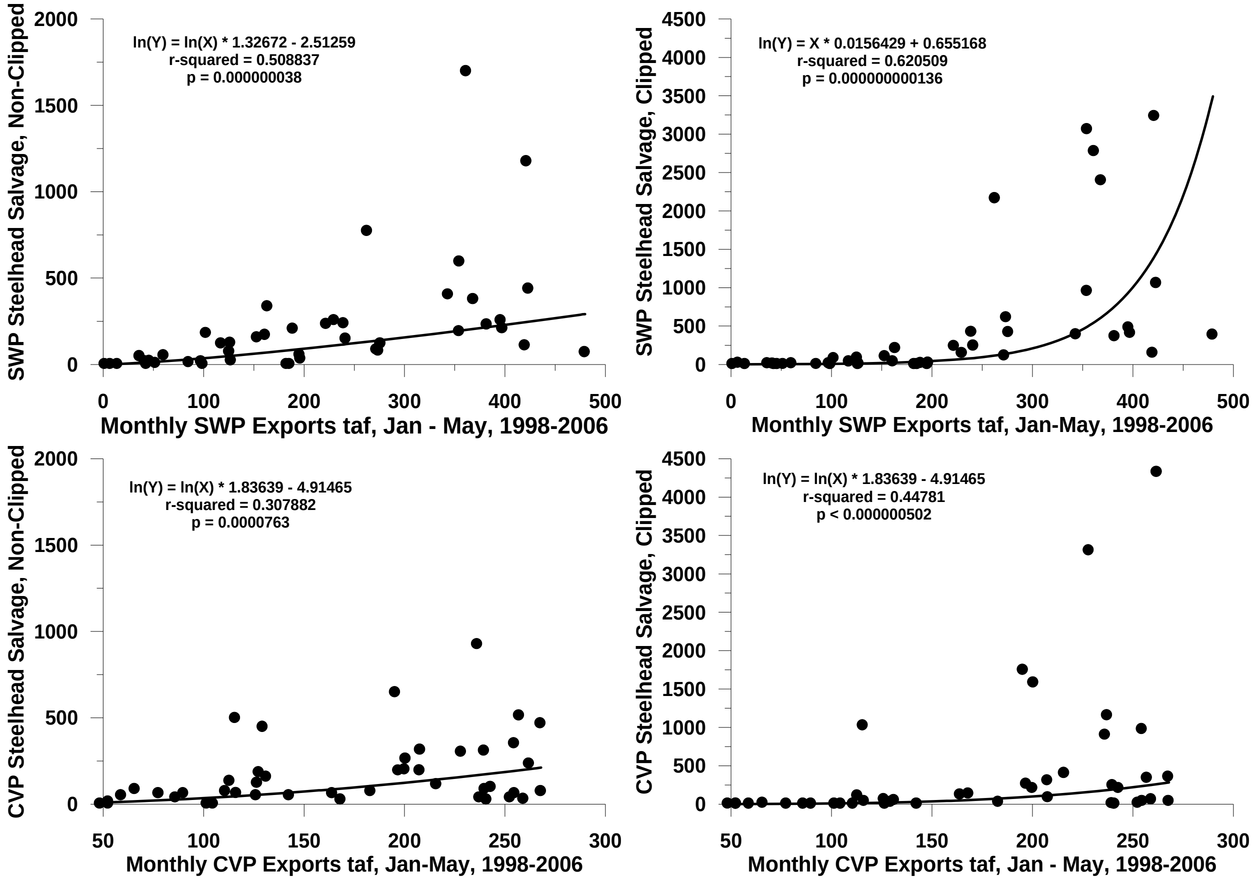


Figure 13-45 Monthly steelhead salvage versus average exports, January through May, 1998 through 2006, at each facility; SWP and CVP.

Regressions of monthly steelhead salvage against Export/Inflow ratio (EI), again, resulted in significant relationships at the SWP and CVP (Figure 13-46). The equations were very similar; not surprising since exports and EI ratio are related. The **r-squared** values were consistently smaller; therefore salvage, not EI ratio, is the better parameter. Of the four graphs in Figure 13-45, only the SWP clipped steelhead salvage relationship to EI ratio is of interest; the slope actually changes noticeably over the EI ratio range; at the high end. In the other three graphs, the slope is so small it would necessitate reducing pumping altogether to affect a change in steelhead salvage. There are two regression lines and equations in Figure 13-46, the black lines and equations represent the months of January through May (similar to the salvage and export graphs in Figure 13-45), and the red lines and equations represent the month of January alone. In three of the graphs in Figure 13-46, the January alone equations had smaller r-squared values and the equations were not significant, which is typical since there were fewer data points. In the remaining graph, SWP clipped steelhead salvage versus EI ratio, the **r-squared** value and was higher for the month of January alone compared to the months of January through May, and the equation was significant. But the slope of the equation is smaller because the most of the higher SWP clipped salvage occurred in months other than January, therefore for the month of January; it would take a large amount of change in EI ratio to affect a small reduction in SWP clipped steelhead salvage.

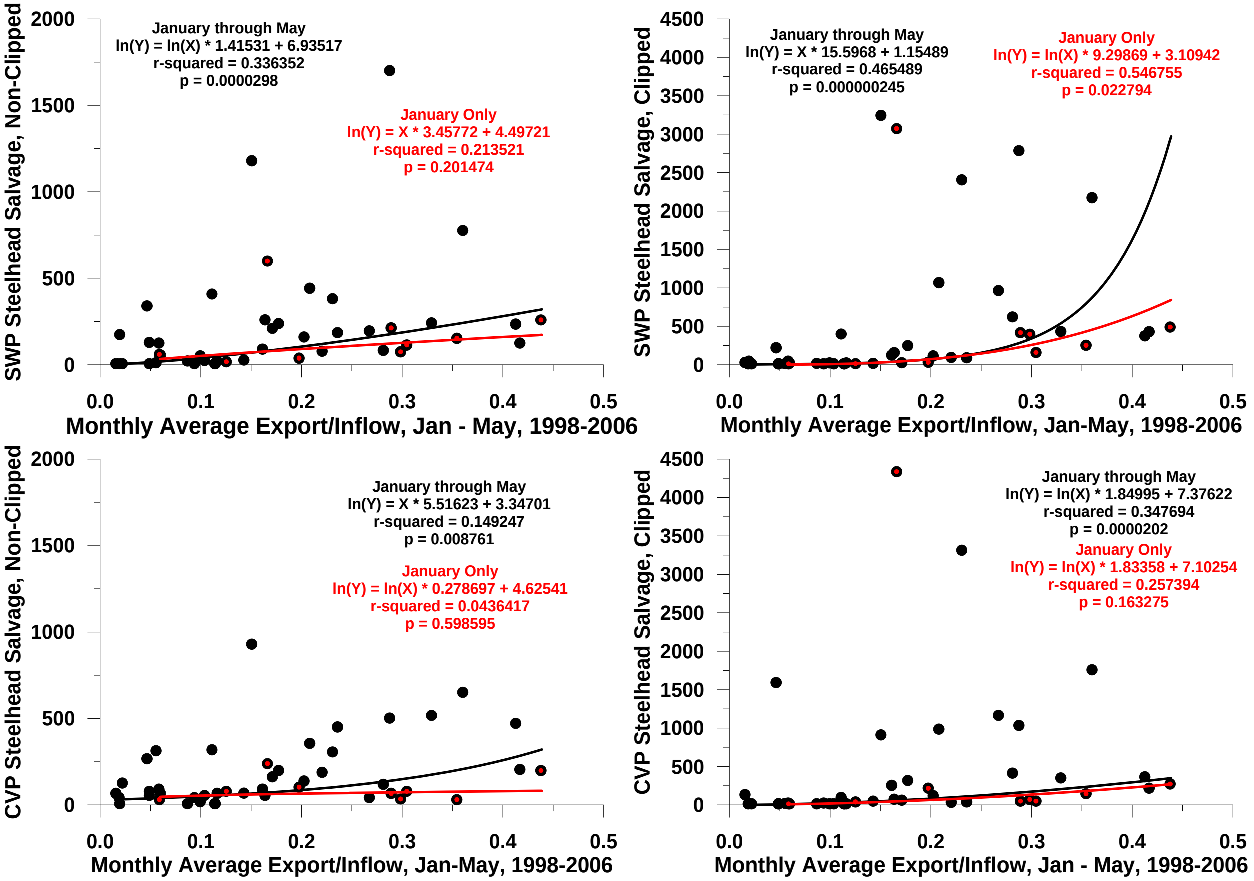


Figure 13-46 Monthly steelhead salvage versus average Export/Inflow ratio in taf, January through May, and January alone, 1998 through 2006, at each facility; SWP and CVP.

Green sturgeon salvage is low; therefore seasonal trends are difficult to determine (Figure 13-47).

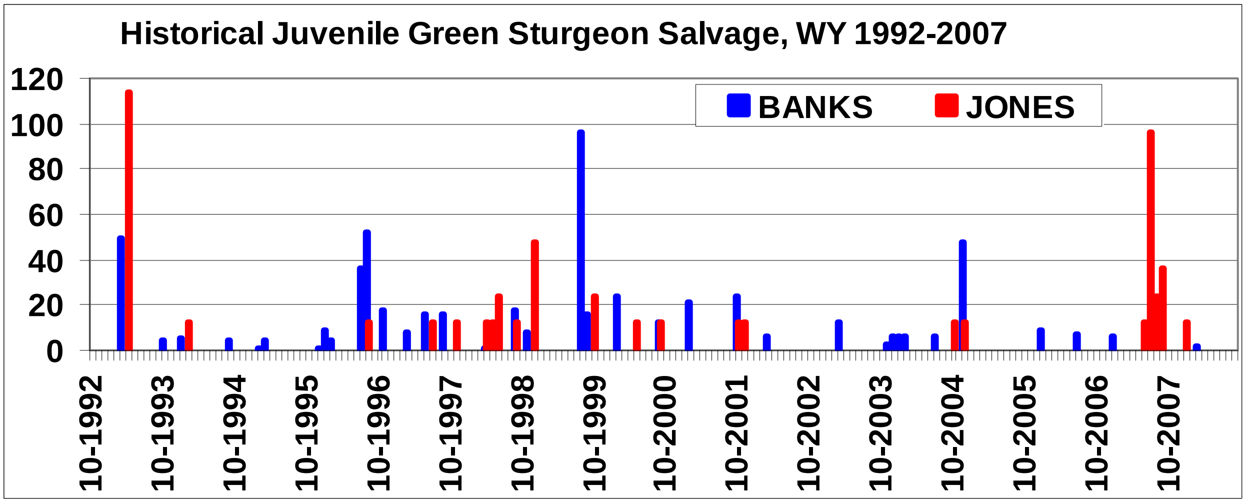


Figure 13-47 Historical juvenile green sturgeon salvage, WY 1992 – 2007.

Figure 13-48 and Figure 13-49 are the green sturgeon salvage grouped by water year type and month at each facility. At Banks, there is a slight trend of higher salvage in wet and critical years, and earlier salvage in wet years than critical years. This trend doesn't occur at Jones.

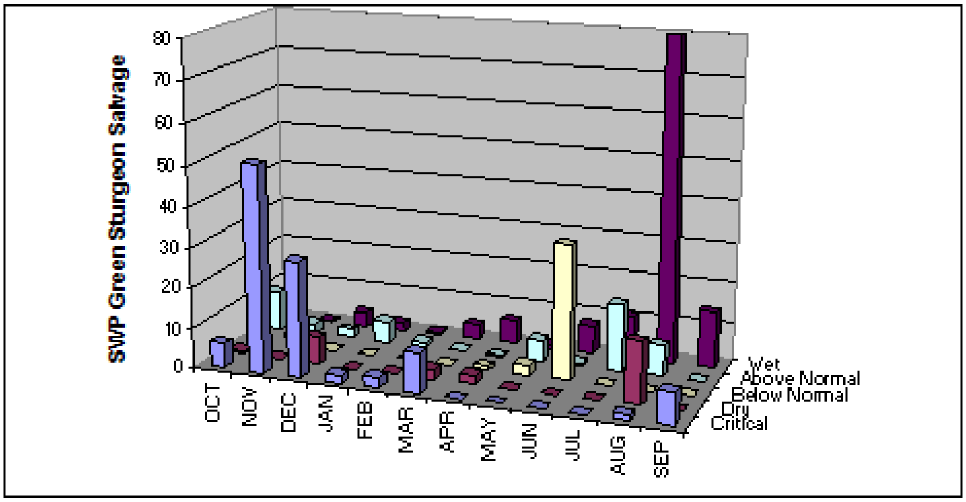


Figure 13-48 Green sturgeon salvage at Banks grouped by water year type and month

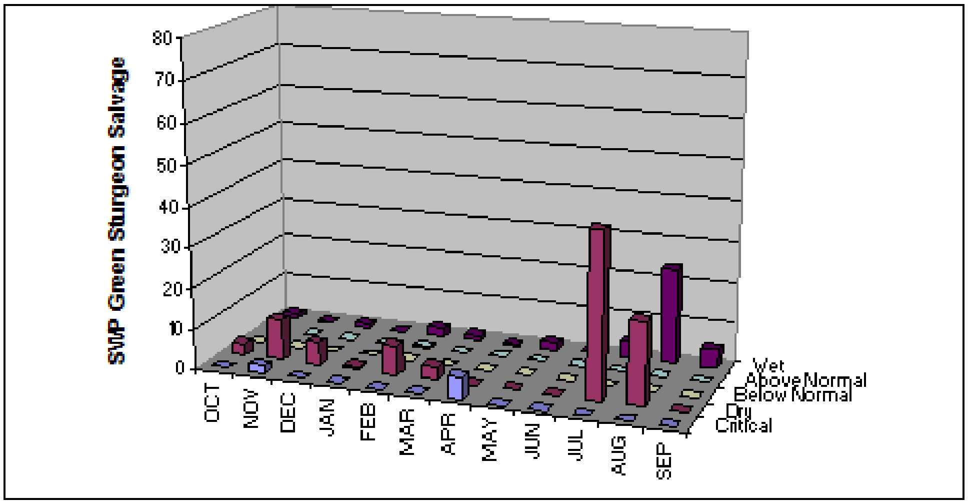


Figure 13-49 Green sturgeon salvage at Jones grouped by water year type and month

Direct Losses to Entrainment by CVP and SWP Export Facilities

Table 13-22 is the average loss of winter-run Chinook, yearling spring-run Chinook, and average salvage of steelhead and green sturgeon used in the effects analysis grouped by water-year type and month. We used Chinook loss data starting from 1993 through 2007 because 1993 was the first year for which adipose fin clip was recorded in the salvage database. Prior to that year, we can not distinguish clipped Chinook from non-clipped Chinook. We used steelhead salvage data starting from1998 because 1998 was the first year for which all hatchery steelhead were clipped. Prior to that year, we can not distinguish clipped from non-clipped steelhead. Loss for winter-run and spring-run was calculated using the Four Pumps Mitigation Agreement method. We used green sturgeon salvage data starting from 1981 because prior to that year green sturgeon were not separated from white sturgeon at Jones. For all species the below normal water year type did not fall into the period of record and was not included in Table 13-22.

Table 13-22 Average loss of winter-run, yearling-spring-run and young-of-the-year spring-run Chinook, and steelhead and green sturgeon salvage by export facility, water-year type and month.

NOTE: Winter run loss was based on non-clipped juveniles in the winter run length range using the Delta Model length criterion from 1993 - 2007. Clipped winter-run loss was based on Livingston Stone Hatchery winter-run from 1999-2007. Yearling spring run loss was based on Coleman Hatchery late-fall hatchery surrogates as described in the Salmon Protection Plan 1995-2007. Young-of-the-year spring run loss was based on total, non-clipped young-of-the-year juvenile loss as a surrogate 1993-2007. Steelhead salvage was based on non-clipped and clipped salvage from 1998 – 2007. Green sturgeon average salvage was calculated from , 1981 – 2007, and categorized into water year types.

BANKS YEARTYPE	SPECIES	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Critical	NC Winter	0	0	1630	168	145	482	16	4	4	0	0	0
Dry	NC Winter	0	0	370	366	1810	4895	140	8	0	0	0	0
Below	NC Winter	*	*	*	*	*	*	*	*	*	*	*	*
Above	NC Winter	0	0	584	1653	1866	1155	125	0	0	0	0	0
Wet	NC Winter	0	0	258	826	247	539	264	4	0	0	0	0
Critical	CL Winter	*	*	*	*	*	*	*	*	*	*	*	*
Dry	CL Winter	*	*	*	*	0.01%	0.07%	0.00%	0	0	0	0	0
Below	CL Winter	*	*	*	*	*	*	*	*	*	*	*	*
Above	CL Winter	*	*	*	*	0.05%	0.09%	0.01%	0	0	0	0	0
Wet	CL Winter	*	*	*	*	0	0.02%	0.02%	0	0	0	0	0
Critical	SR Yearlings	*	*	*	*	*	*	*	*	*	*	*	*
Dry	SR Yearlings	0	0	0.13%	0.09%	0.13%	0.04%	0.00%	0	0	0	0	0
Below	SR Yearlings	*	*	*	*	*	*	*	*	*	*	*	*
Above	SR Yearlings	0	0.01%	0.20%	0.24%	0.12%	0.03%	0	0	0	0	0	0
Wet	SR Yearlings	0	0	0.04%	0.10%	0.03%	0.00%	0	0	0	0	0	0
Critical	F/SR YOY	0	0	0	0	0	0.01	0.12	0.86	0.01	0	0	0
Dry	F/SR YOY	0	0	0	0	0	0.17	0.54	0.28	0.01	0	0	0
Below	F/SR YOY	*	*	*	*	*	*	*	*	*	*	*	*
Above	F/SR YOY	0	0	0	0	0.06	0.11	0.44	0.29	0.10	0	0	0
Wet	F/SR YOY	0	0	0	0.03	0.03	0.05	0.32	0.37	0.20	0.01	0	0
Critical	NC Steelhead	*	*	*	*	*	*	*	*	*	*	*	*
Dry	NC Steelhead	0	0	8	133	400	691	153	27	5	3	0	0
Below	NC Steelhead	*	*	*	*	*	*	*	*	*	*	*	*
Above	NC Steelhead	0	18	57	438	695	342	184	42	41	0	0	0
Wet	NC Steelhead	10	0	0	80	67	151	113	66	49	2	1	0
Critical	CL Steelhead	*	*	*	*	*	*	*	*	*	*	*	*
Dry	CL Steelhead	0	0	0	186	1220	1159	79	3	0	0	0	0
Below	CL Steelhead	*	*	*	*	*	*	*	*	*	*	*	*
Above	CL Steelhead	0	0	28	1753	2079	349	60	2	5	0	0	0
Wet	CL Steelhead	0	0	0	63	156	101	38	3	0	0	0	0
Critical	Grn Sturgeon	0	0	0	6	10	37	0	0	0	0	0	0
Dry	Grn Sturgeon	3	0	20	0	0	7	6	0	0	0	45	0
Below	Grn Sturgeon	*	*	*	*	*	*	*	*	*	*	*	*
Above	Grn Sturgeon	1	1	2	4	9	0	0	0	0	2	0	0
Wet	Grn Sturgeon	0	2	23	2	3	13	35	0	1	7	19	7

JONES YEARTYPE	SPECIES	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Critical	NC Winter	0	0	59	14	85	341	114	0	0	0	0	0
Dry	NC Winter	0	0	39	77	351	486	59	0	0	0	0	0
Below	NC Winter	*	*	*	*	*	*	*	*	*	*	*	*
Above	NC Winter	0	0	23	38	118	159	39	8	3	0	0	0
Wet	NC Winter	0	0	22	43	47	138	39	1	0	0	0	0
Critical	CL Winter	*	*	*	*	*	*	*	*	*	*	*	*
Dry	CL Winter	*	*	*	*	0.003%	0.005%	0.001%	0	0	0	0	0
Below	CL Winter	*	*	*	*	*	*	*	*	*	*	*	*
Above	CL Winter	*	*	*	*	0.003%	0.008%	0	0	0	0	0	0
Wet	CL Winter	*	*	*	*	0.004%	0.006%	0	0	0	0	0	0
Critical	SR Yearlings	*	*	*	*	*	*	*	*	*	*	*	*
Dry	SR Yearlings	0	0	0.01%	0.01%	0.01%	0.00%	0.00%	0	0	0	0	0
Below	SR Yearlings	*	*	*	*	*	*	*	*	*	*	*	*
Above	SR Yearlings	0	0	0.026%	0.022%	0.010%	0.00%	0	0	0	0	0	0
Wet	SR Yearlings	0	0.001%	0.006%	0.007%	0.002%	0	0	0	0	0	0	0
Critical	F/SR YOY	0	0	0	0	0	0.05	0.82	0.12	0.01	0	0	0
Dry	F/SR YOY	0	0	0	0	0.01	0.24	0.60	0.13	0.02	0	0	0
Below	F/SR YOY	*	*	*	*	*	*	*	*	*	*	*	*
Above	F/SR YOY	0	0	0	0	0.15	0.11	0.37	0.33	0.04	0	0	0
Wet	F/SR YOY	0	0	0	0.06	0.09	0.10	0.26	0.37	0.11	0	0	0
Critical	NC Steelhead	*	*	*	*	*	*	*	*	*	*	*	*
Dry	NC Steelhead	0	0	3	41	345	531	349	19	12	0	0	0
Below	NC Steelhead	*	*	*	*	*	*	*	*	*	*	*	*
Above	NC Steelhead	0	12	12	194	484	386	151	60	0	0	0	0
Wet	NC Steelhead	0	3	0	60	138	208	17	52	73	48	0	0
Critical	CL Steelhead	*	*	*	*	*	*	*	*	*	*	*	*
Dry	CL Steelhead	0	0	0	55	1440	914	128	9	0	0	0	0
Below	CL Steelhead	*	*	*	*	*	*	*	*	*	*	*	*
Above	CL Steelhead	0	0	42	2309	1021	220	71	0	0	0	0	0
Wet	CL Steelhead	0	0	0	66	198	505	19	2	0	0	0	0
Critical	Grn Sturgeon	0	7	0	0	0	0	23	0	0	0	0	0
Dry	Grn Sturgeon	9	31	17	2	22	0	9	0	0	108	61	0
Below	Grn Sturgeon	*	*	*	*	*	*	*	*	*	*	*	*
Above	Grn Sturgeon	0	0	0	0	4	0	0	0	0	0	0	0
Wet	Grn Sturgeon	8	1	4	0	12	8	1	12	3	27	147	31

Table 13-23 is the average change in Banks and Jones Pumping grouped by water year type comparing Study 7.1 to Study 7.0, and Study 8.0 to Study 7.0. The relative change in fish loss and salvage will be based on the relative change in pumping.

Table 13-23 Average change in Banks and Jones pumping grouped by water year type.

Facility	WaterYearType	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Study 7.1 compared to 7.0													
Banks	Critical	7.7%	-8.2%	-6.1%	15.5%	18.2%	8.7%	6.4%	8.8%	25.1%	-7.0%	-11.9%	-13.1%
Banks	Dry	0.2%	-5.3%	7.2%	10.5%	0.0%	4.7%	10.3%	12.4%	3.5%	-8.4%	1.1%	-12.8%
Banks	Bl Normal	11.4%	-4.1%	6.6%	6.1%	-2.4%	7.2%	14.0%	34.3%	6.9%	14.4%	0.9%	-8.3%
Banks	Ab Normal	14.5%	-5.5%	8.3%	-0.3%	7.3%	4.3%	13.1%	42.2%	13.4%	32.5%	-8.5%	-10.2%
Banks	Wet	6.1%	-3.1%	6.6%	5.3%	4.9%	-0.2%	19.2%	20.9%	1.2%	4.2%	-7.8%	-2.9%
Jones	Critical	8.5%	6.2%	15.1%	1.0%	7.9%	16.4%	8.2%	28.6%	-1.0%	-16.6%	-1.7%	-4.3%
Jones	Dry	3.8%	4.5%	11.9%	17.2%	5.1%	-4.2%	6.3%	32.3%	3.9%	7.8%	-13.5%	-7.7%
Jones	Bl Normal	7.5%	6.1%	19.7%	15.0%	-3.4%	-15.7%	-4.3%	5.3%	-2.3%	24.3%	6.6%	-7.5%
Jones	Ab Normal	-0.5%	8.3%	20.6%	15.5%	-1.5%	-13.6%	-9.0%	6.9%	1.2%	9.3%	13.6%	3.3%
Jones	Wet	6.2%	9.0%	18.4%	15.1%	-0.1%	-25.9%	-2.3%	-1.1%	-2.5%	4.5%	5.7%	3.3%
Study 8.0 compared to 7.0													
Banks	Critical	4.8%	-17.5%	-8.7%	-2.9%	20.3%	7.4%	6.7%	13.8%	-11.9%	-22.0%	-17.1%	-2.9%
Banks	Dry	0.3%	-7.8%	8.1%	12.4%	-1.8%	5.3%	8.2%	18.5%	-8.3%	-8.8%	-2.4%	-7.0%
Banks	Bl Normal	7.0%	-5.6%	3.4%	9.9%	-3.1%	1.5%	13.9%	31.3%	9.3%	22.3%	12.9%	-0.2%
Banks	Ab Normal	4.8%	-10.1%	4.4%	4.6%	8.1%	4.8%	12.2%	43.1%	16.9%	51.9%	17.3%	-5.3%
Banks	Wet	2.5%	-4.7%	6.8%	6.1%	5.1%	2.7%	19.2%	20.9%	4.0%	16.1%	-3.8%	-2.7%
Jones	Critical	11.6%	-4.6%	17.5%	9.9%	4.8%	23.4%	5.9%	22.0%	-10.1%	-31.4%	-19.8%	-16.5%
Jones	Dry	8.1%	6.1%	11.9%	17.1%	5.9%	-6.6%	4.2%	29.1%	-3.8%	-0.4%	-29.3%	-8.3%
Jones	Bl Normal	13.8%	7.7%	20.2%	15.6%	-1.6%	-12.9%	-7.2%	-2.6%	-4.2%	19.8%	3.8%	-5.1%
Jones	Ab Normal	-1.6%	4.9%	24.2%	11.2%	11.0%	-7.9%	-8.4%	5.3%	1.2%	7.4%	-0.7%	13.4%
Jones	Wet	8.6%	11.5%	17.9%	13.1%	-1.4%	-20.3%	-1.5%	-0.1%	-1.0%	-8.1%	5.5%	5.1%
Study 6.1 compared to 7.0													
Banks	Critical	3.2%	-9.0%	-18.1%	8.0%	5.5%	-1.5%	-13.4%	-5.5%	-17.8%	-13.5%	-16.6%	20.0%
Banks	Dry	-0.7%	-6.2%	-6.1%	4.1%	-8.1%	-5.0%	-20.9%	25.2%	-10.4%	-1.8%	18.5%	5.3%
Banks	Bl Normal	9.5%	-1.0%	-2.6%	-2.8%	-6.6%	-7.7%	1.0%	4.0%	-8.6%	17.6%	11.8%	13.3%
Banks	Ab Normal	3.8%	-3.6%	-6.7%	2.7%	-6.8%	-6.4%	0.3%	1.5%	4.8%	45.6%	12.1%	6.1%
Banks	Wet	1.4%	-5.6%	-6.9%	-10.2%	-9.1%	-15.5%	-2.2%	-2.6%	1.9%	20.2%	2.5%	2.4%
Jones	Critical	7.3%	1.5%	4.1%	-4.1%	-18.5%	-3.5%	-15.3%	0.0%	19.5%	5.8%	27.9%	-8.3%
Jones	Dry	1.8%	-0.4%	0.2%	4.2%	2.7%	4.7%	-13.4%	16.8%	-2.8%	-7.1%	-11.3%	1.5%
Jones	Bl Normal	5.4%	2.9%	1.4%	-0.6%	7.3%	1.0%	1.1%	-3.1%	-4.1%	-2.1%	-0.1%	-2.1%
Jones	Ab Normal	-1.6%	3.0%	5.3%	-0.9%	4.4%	4.3%	-3.8%	10.9%	2.7%	9.7%	-1.1%	4.3%
Jones	Wet	8.3%	4.0%	3.8%	-0.1%	-6.8%	-2.6%	-3.3%	14.5%	-0.5%	-12.4%	1.1%	2.6%

Table 13-24 represents potential loss and salvage changes for both non-clipped and clipped winter-run, yearling and yoy spring run, non-clipped and clipped steelhead and green sturgeon comparing operations today to future operations (Model 7.1 vs 7.0, model 8.0 vs 7.0) if we assumed that salvage is directly proportional to the amount of water exported (i.e. doubling the amount of water exported doubles the number of fish salvaged). Because there is not a direct method to estimate yoy spring run loss, we used the combination of yoy fall- and spring-run losses as a surrogate for you spring run loss and reported just the percentage change for yoy spring run loss. The highlight cells represent just a visual inspection of the months and water year types with the relatively largest changes in loss or salvage. The values in each table are different because they are in terms of the take statement in the current Biological Opinion (BO). Take for non-clipped winter-run is in terms of loss, for hatchery winter-run (clipped) and yearling spring run are in terms of the percentage of released hatchery juveniles subsequently lost at the Delta pumping facilities, steelhead and green sturgeon are in terms of salvage. Take for young of the year spring run isn't defined in the current BO because there is no method to identify spring run available for management use. Since the values or metrics are different for each species, the values from one table (or species) aren't relative to another table or species.

Table 13-24 Average change in winter run, yearling spring run and young-of-the-year spring run loss, and steelhead and green sturgeon salvage by species, model, facility, water-year type and month assuming a direct relationship between monthly exports and monthly salvage.

NOTE: Winter run loss was based on non-clipped juveniles in the winter run length range 1993 - 2007. Clipped winter-run loss was based on Livingston Stone Hatchery winter-run from 1999-2007. Yearling spring run loss was based on Coleman Hatchery late-fall hatchery surrogates as described in the Salmon Protection Plan 1995-2007. Young-of-the-year spring run loss was based on total, non-clipped young-of-the-year juvenile loss as a surrogate 1993-2007. Steelhead salvage was based on water years 1998 – 2007. Green sturgeon average salvage was based on salvage from 1981 -2007, and categorized into all 5 water year types.

Species	Fac	WYType	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Model 7.1 compared to 7.0														
Winter Loss	Banks	Critical	0	0	-100	26	26	42	1	0	1	0	0	0
Winter Loss	Banks	Dry	0	0	27	39	0	230	14	1	0	0	0	0
Winter Loss	Banks	Bl Normal	*	*	*	*	*	*	*	*	*	*	*	*
Winter Loss	Banks	AbNormal	0	0	49	-5	135	50	16	0	0	0	0	0
Winter Loss	Banks	Wet	0	0	17	44	12	-1	51	1	0	0	0	0
Winter Loss	Jones	Critical	0	0	9	0	7	56	9	0	0	0	0	0
Winter Loss	Jones	Dry	0	0	5	13	18	-20	4	0	0	0	0	0
Winter Loss	Jones	Bl Normal	*	*	*	*	*	*	*	*	*	*	*	*
Winter Loss	Jones	AbNormal	0	0	5	6	-2	-22	-4	1	0	0	0	0
Winter Loss	Jones	Wet	0	0	4	7	0	-36	-1	0	0	0	0	0
Model 8.0 compared to 7.0														
Winter Loss	Banks	Critical	0	0	-142	-5	29	36	1	1	-1	0	0	0
Winter Loss	Banks	Dry	0	0	30	45	-33	261	11	1	0	0	0	0
Winter Loss	Banks	Bl Normal	*	*	*	*	*	*	*	*	*	*	*	*
Winter Loss	Banks	AbNormal	0	0	26	76	151	55	15	0	0	0	0	0
Winter Loss	Banks	Wet	0	0	18	50	13	15	51	1	0	0	0	0
Winter Loss	Jones	Critical	0	0	10	1	4	80	7	0	0	0	0	0
Winter Loss	Jones	Dry	0	0	5	13	21	-32	2	0	0	0	0	0
Winter Loss	Jones	Bl Normal	*	*	*	*	*	*	*	*	*	*	*	*
Winter Loss	Jones	AbNormal	0	0	6	4	13	-13	-3	0	0	0	0	0
Winter Loss	Jones	Wet	0	0	4	6	-1	-28	-1	0	0	0	0	0

Species	Fac	WYType	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Model 6.1 compared to 7.0														
Winter Loss	Banks	Critical	0	0	-295	13	8	-7	-2	0	-1	0	0	0
Winter Loss	Banks	Dry	0	0	-22	15	-146	-245	-29	2	0	0	0	0
Winter Loss	Banks	Bl Normal	*	*	*	*	*	*	*	*	*	*	*	*
Winter Loss	Banks	AbNormal	0	0	-39	45	-126	-74	0	0	0	0	0	0
Winter Loss	Banks	Wet	0	0	-18	-84	-22	-84	-6	0	0	0	0	0
Winter Loss	Jones	Critical	0	0	2	-1	-16	-12	-17	0	0	0	0	0
Winter Loss	Jones	Dry	0	0	0	3	9	23	-8	0	0	0	0	0
Winter Loss	Jones	Bl Normal	*	*	*	*	*	*	*	*	*	*	*	*
Winter Loss	Jones	AbNormal	0	0	1	0	5	7	-1	1	0	0	0	0
Winter Loss	Jones	Wet	0	0	1	0	-3	-4	-1	0	0	0	0	0
Model 7.1 compared to 7.0														
CL Winter Loss	Banks	Critical	*	*	*	*	*	*	*	*	*	*	*	*
CL Winter Loss	Banks	Dry	*	*	*	*	0.000%	0.003%	0.001%	0	0	0	0	0
CL Winter Loss	Banks	Bl Normal	*	*	*	*	*	*	*	*	*	*	*	*
CL Winter Loss	Banks	AbNormal	*	*	*	*	0.002%	0.007%	0.003%	0	0	0	0	0
CL Winter Loss	Banks	Wet	*	*	*	*	0.000%	0.000%	0.003%	0	0	0	0	0
CL Winter Loss	Jones	Critical	*	*	*	*	*	*	*	*	*	*	*	*
CL Winter Loss	Jones	Dry	*	*	*	*	0.00%	0.00%	0.00%	0	0	0	0	0
CL Winter Loss	Jones	Bl Normal	*	*	*	*	*	*	*	*	*	*	*	*
CL Winter Loss	Jones	AbNormal	*	*	*	*	0.000%	-0.002%	0.000%	0	0	0	0	0
CL Winter Loss	Jones	Wet	*	*	*	*	0.000%	-0.002%	0.000%	0	0	0	0	0
Model 8.0 compared to 7.0														
CL Winter Loss	Banks	Critical	*	*	*	*	*	*	*	*	*	*	*	*
CL Winter Loss	Banks	Dry	*	*	*	*	0.000%	0.004%	0.000%	0	0	0	0	0
CL Winter Loss	Banks	Bl Normal	*	*	*	*	*	*	*	*	*	*	*	*
CL Winter Loss	Banks	AbNormal	*	*	*	*	0.002%	0.008%	0.003%	0	0	0	0	0
CL Winter Loss	Banks	Wet	*	*	*	*	0.000%	0.001%	0.003%	0	0	0	0	0
CL Winter Loss	Jones	Critical	*	*	*	*	*	*	*	*	*	*	*	*
CL Winter Loss	Jones	Dry	*	*	*	*	0.000%	0.000%	0.000%	0	0	0	0	0
CL Winter Loss	Jones	Bl Normal	*	*	*	*	*	*	*	*	*	*	*	*
CL Winter Loss	Jones	AbNormal	*	*	*	*	0.001%	-0.001%	0.000%	0	0	0	0	0
CL Winter Loss	Jones	Wet	*	*	*	*	0.000%	-0.001%	0.000%	0	0	0	0	0
Model 6.1 compared to 7.0														
CL Winter Loss	Banks	Critical	*	*	*	*	*	*	*	*	*	*	*	*
CL Winter Loss	Banks	Dry	*	*	*	*	0.00%	0.003%	0.00%	0	0	0	0	0
CL Winter Loss	Banks	Bl Normal	*	*	*	*	*	*	*	*	*	*	*	*
CL Winter Loss	Banks	AbNormal	*	*	*	*	-0.002%	-0.02%	0.00%	0	0	0	0	0
CL Winter Loss	Banks	Wet	*	*	*	*	0.00%	-0.001%	0.00%	0	0	0	0	0
CL Winter Loss	Jones	Critical	*	*	*	*	*	*	*	*	*	*	*	*
CL Winter Loss	Jones	Dry	*	*	*	*	0.00%	0.00%	0.00%	0	0	0	0	0
CL Winter Loss	Jones	Bl Normal	*	*	*	*	*	*	*	*	*	*	*	*
CL Winter Loss	Jones	AbNormal	*	*	*	*	0.00%	-0.001%	0.00%	0	0	0	0	0
CL Winter Loss	Jones	Wet	*	*	*	*	-0.001%	-0.001%	0.00%	0	0	0	0	0
Model 7.1 compared to 7.0														
YRL Spring Loss	Banks	Critical	*	*	*	*	*	*	*	*	*	*	*	*
YRL Spring Loss	Banks	Dry	0	0.00%	0.01%	0.01%	0.00%	0.00%	0.00%	0	0	0	0	0
YRL Spring Loss	Banks	Bl Normal	*	*	*	*	*	*	*	*	*	*	*	*
YRL Spring Loss	Banks	AbNormal	0	0.00%	0.02%	0.00%	0.00%	0.00%	0.00%	0	0	0	0	0

Species	Fac	WYType	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
YRL Spring Loss	Banks	Wet	0	0.00%	0.00%	0.01%	0.00%	0.00%	0.00%	0	0	0	0	0
YRL Spring Loss	Jones	Critical	*	*	*	*	*	*	*	*	*	*	*	*
YRL Spring Loss	Jones	Dry	0	0.00%	0.002%	0.002%	0.00%	0.00%	0.00%	0	0	0	0	0
YRL Spring Loss	Jones	Bl Normal	*	*	*	*	*	*	*	*	*	*	*	*
YRL Spring Loss	Jones	AbNormal	0	0.00%	0.01%	0.00%	0.00%	0.00%	0.00%	0	0	0	0	0
YRL Spring Loss	Jones	Wet	0	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0	0	0	0	0
Study 8.0 compared to 7.0														
YRL Spring Loss	Banks	Critical	*	*	*	*	*	*	*	*	*	*	*	*
YRL Spring Loss	Banks	Dry	0	0.00%	0.01%	0.01%	0.00%	0.00%	0.00%	0	0	0	0	0
YRL Spring Loss	Banks	Bl Normal	*	*	*	*	*	*	*	*	*	*	*	*
YRL Spring Loss	Banks	AbNormal	0	0.00%	0.01%	0.01%	0.00%	0.00%	0.00%	0	0	0	0	0
YRL Spring Loss	Banks	Wet	0	0.003%	0.01%	0.001%	0.00%	0.00%	0.00%	0	0	0	0	0
YRL Spring Loss	Jones	Critical	*	*	*	*	*	*	*	*	*	*	*	*
YRL Spring Loss	Jones	Dry	0	0.00%	0.002%	0.002%	0.00%	0.00%	0.00%	0	0	0	0	0
YRL Spring Loss	Jones	Bl Normal	*	*	*	*	*	*	*	*	*	*	*	*
YRL Spring Loss	Jones	AbNormal	0	0.00%	0.001%	0.00%	0.00%	0.00%	0.00%	0	0	0	0	0
YRL Spring Loss	Jones	Wet	0	0.00%	0.001%	0.00%	0.00%	0.00%	0.00%	0	0	0	0	0
Study 6.1 compared to 7.0														
YRL Spring Loss	Banks	Critical	*	*	*	*	*	*	*	*	*	*	*	*
YRL Spring Loss	Banks	Dry	0	0	-0.01%	0.003%	-0.01%	0.00%	0.00%	0	0	0	0	0
YRL Spring Loss	Banks	Bl Normal	*	*	*	*	*	*	*	*	*	*	*	*
YRL Spring Loss	Banks	AbNormal	0	0	-0.01%	0.01%	-0.01%	-0.003%	0.00%	0	0	0	0	0
YRL Spring Loss	Banks	Wet	0	0	-0.003%	-0.01%	-0.002%	-0.001%	0.00%	0	0	0	0	0
YRL Spring Loss	Jones	Critical	*	*	*	*	*	*	*	*	*	*	*	*
YRL Spring Loss	Jones	Dry	0	0	0.00%	0.00%	0.00%	0.00%	0.00%	0	0	0	0	0
YRL Spring Loss	Jones	Bl Normal	*	*	*	*	*	*	*	*	*	*	*	*
YRL Spring Loss	Jones	AbNormal	0	0	0.001%	0.00%	0.00%	0.00%	0.00%	0	0	0	0	0
YRL Spring Loss	Jones	Wet	0	0	0.00%	0.00%	0.00%	0.00%	0.00%	0	0	0	0	0
Model 7.1 compared to 7.0														
F/S YOY Loss	Banks	Critical	0	0	0	15.5%	18.2%	8.7%	6.4%	8.8%	25.1%	0	0	0
F/S YOY Loss	Banks	Dry	0	0	0	10.5%	0.0%	4.7%	10.3%	12.4%	3.5%	0	0	0
F/S YOY Loss	Banks	Bl Normal	*	*	*	*	*	*	*	*	*	*	*	*
F/S YOY Loss	Banks	AbNormal	0	0	0	-0.3%	7.3%	4.3%	13.1%	42.2%	13.4%	0	0	0
F/S YOY Loss	Banks	Wet	0	0	0	5.3%	4.9%	-0.2%	19.2%	20.9%	1.2%	0	0	0
F/S YOY Loss	Jones	Critical	0	0	0	1.0%	7.9%	16.4%	8.2%	28.6%	-1.0%	0	0	0
F/S YOY Loss	Jones	Dry	0	0	0	17.2%	5.1%	-4.2%	6.3%	32.3%	3.9%	0	0	0
F/S YOY Loss	Jones	Bl Normal	*	*	*	*	*	*	*	*	*	*	*	*
F/S YOY Loss	Jones	AbNormal	0	0	0	15.5%	-1.5%	-13.6%	-9.0%	6.9%	1.2%	0	0	0
F/S YOY Loss	Jones	Wet	0	0	0	15.1%	-0.1%	-25.9%	-2.3%	-1.1%	-2.5%	0	0	0
Study 8.0 compared to 7.0														
F/S YOY Loss	Banks	Critical	0	0	0	-2.9%	20.3%	7.4%	6.7%	13.8%	-11.9%	0	0	0
F/S YOY Loss	Banks	Dry	0	0	0	12.4%	-1.8%	5.3%	8.2%	18.5%	-8.3%	0	0	0
F/S YOY Loss	Banks	Bl Normal	*	*	*	*	*	*	*	*	*	*	*	*
F/S YOY Loss	Banks	AbNormal	0	0	0	4.6%	8.1%	4.8%	12.2%	43.1%	16.9%	0	0	0
F/S YOY Loss	Banks	Wet	0	0	0	6.1%	5.1%	2.7%	19.2%	20.9%	4.0%	0	0	0
F/S YOY Loss	Jones	Critical	0	0	0	9.9%	4.8%	23.4%	5.9%	22.0%	-10.1%	0	0	0
F/S YOY Loss	Jones	Dry	0	0	0	17.1%	5.9%	-6.6%	4.2%	29.1%	-3.8%	0	0	0
F/S YOY Loss	Jones	Bl Normal	*	*	*	*	*	*	*	*	*	*	*	*
F/S YOY Loss	Jones	AbNormal	0	0	0	11.2%	11.0%	-7.9%	-8.4%	5.3%	1.2%	0	0	0
F/S YOY Loss	Jones	Wet	0	0	0	13.1%	-1.4%	-20.3%	-1.5%	-0.1%	-1.0%	0	0	0

Species	Fac	WYType	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Study 6.1 compared to 7.0														
F/S YOY Loss	Banks	Critical	0	0	0	8.0%	5.5%	-1.5%	-13.4%	-5.5%	-17.8%	0	0	0
F/S YOY Loss	Banks	Dry	0	0	0	4.1%	-8.1%	-5.0%	-20.9%	25.2%	-10.4%	0	0	0
F/S YOY Loss	Banks	Bl Normal	*	*	*	-2.8%	-6.6%	-7.7%	1.0%	4.0%	-8.6%	*	*	*
F/S YOY Loss	Banks	AbNormal	0	0	0	2.7%	-6.8%	-6.4%	0.3%	1.5%	4.8%	0	0	0
F/S YOY Loss	Banks	Wet	0	0	0	-10.2%	-9.1%	-15.5%	-2.2%	-2.6%	1.9%	0	0	0
F/S YOY Loss	Jones	Critical	0	0	0	-4.1%	-18.5%	-3.5%	-15.3%	0.0%	19.5%	0	0	0
F/S YOY Loss	Jones	Dry	0	0	0	4.2%	2.7%	4.7%	-13.4%	16.8%	-2.8%	0	0	0
F/S YOY Loss	Jones	Bl Normal	*	*	*	-0.6%	7.3%	1.0%	1.1%	-3.1%	-4.1%	*	*	*
F/S YOY Loss	Jones	AbNormal	0	0	0	-0.9%	4.4%	4.3%	-3.8%	10.9%	2.7%	0	0	0
F/S YOY Loss	Jones	Wet	0	0	0	-0.1%	-6.8%	-2.6%	-3.3%	14.5%	-0.5%	0	0	0
Model 7.1 compared to 7.0														
Steelhead Slvg	Banks	Critical	*	*	*	*	*	*	*	*	*	*	*	*
Steelhead Slvg	Banks	Dry	0	0	1	14	0	32	16	3	0	0	0	0
Steelhead Slvg	Banks	Bl Normal	*	*	*	*	*	*	*	*	*	*	*	*
Steelhead Slvg	Banks	AbNormal	0	-1	5	-1	50	15	24	18	6	0	0	0
Steelhead Slvg	Banks	Wet	1	0	0	4	3	0	22	14	1	0	0	0
Steelhead Slvg	Jones	Critical	*	*	*	*	*	*	*	*	*	*	*	*
Steelhead Slvg	Jones	Dry	0	0	0	7	17	-22	22	6	0	0	0	0
Steelhead Slvg	Jones	Bl Normal	*	*	*	*	*	*	*	*	*	*	*	*
Steelhead Slvg	Jones	AbNormal	0	1	2	30	-7	-52	-14	4	0	0	0	0
Steelhead Slvg	Jones	Wet	0	0	0	9	0	-54	0	-1	-2	2	0	0
Model 8.0 compared to 7.0														
Steelhead Slvg	Banks	Critical	*	*	*	*	*	*	*	*	*	*	*	*
Steelhead Slvg	Banks	Dry	0	0	1	17	-7	37	13	5	0	0	0	0
Steelhead Slvg	Banks	Bl Normal	*	*	*	*	*	*	*	*	*	*	*	*
Steelhead Slvg	Banks	AbNormal	0	-2	2	20	56	16	22	18	7	0	0	0
Steelhead Slvg	Banks	Wet	0	0	0	5	3	4	22	14	2	0	0	0
Steelhead Slvg	Jones	Critical	*	*	*	*	*	*	*	*	*	*	*	*
Steelhead Slvg	Jones	Dry	0	0	0	7	21	-35	15	5	0	0	0	0
Steelhead Slvg	Jones	Bl Normal	*	*	*	*	*	*	*	*	*	*	*	*
Steelhead Slvg	Jones	AbNormal	0	1	3	22	53	-30	-13	3	0	0	0	0
Steelhead Slvg	Jones	Wet	0	0	0	8	-2	-42	0	0	-1	-4	0	0
Model 6.1 compared to 7.0														
Steelhead Slvg	Banks	Critical	*	*	*	*	*	*	*	*	*	*	*	*
Steelhead Slvg	Banks	Dry	0	0	0	6	-32	-35	-32	7	0	0	0	0
Steelhead Slvg	Banks	Bl Normal	*	*	*	*	*	*	*	*	*	*	*	*
Steelhead Slvg	Banks	AbNormal	0	-1	-4	12	-47	-22	1	1	2	0	0	0
Steelhead Slvg	Banks	Wet	0	0	0	-8	-6	-23	-2	-2	1	0	0	0
Steelhead Slvg	Jones	Critical	*	*	*	*	*	*	*	*	*	*	*	*
Steelhead Slvg	Jones	Dry	0	0	0	2	9	25	-47	3	0	0	0	0
Steelhead Slvg	Jones	Bl Normal	*	*	*	*	*	*	*	*	*	*	*	*
Steelhead Slvg	Jones	AbNormal	0	0	1	-2	22	17	-6	7	0	0	0	0
Steelhead Slvg	Jones	Wet	0	0	0	0	-9	-5	-1	8	0	-6	0	0
Model 7.1 compared to 7.0														
CL Steelhead Slvg	Banks	Critical	*	*	*	*	*	*	*	*	*	*	*	*
CL Steelhead Slvg	Banks	Dry	0	0	0	20	0	54	8	0	0	0	0	0
CL Steelhead Slvg	Banks	Bl Normal	*	*	*	*	*	*	*	*	*	*	*	*
CL Steelhead Slvg	Banks	AbNormal	0	0	2	-5	151	15	8	1	1	0	0	0
CL Steelhead Slvg	Banks	Wet	0	0	0	3	8	0	7	1	0	0	0	0

Species	Fac	WYType	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
CL Steelhead Slvg	Jones	Critical	*	*	*	*	*	*	*	*	*	*	*	*
CL Steelhead Slvg	Jones	Dry	0	0	0	9	73	-38	8	3	0	0	0	0
CL Steelhead Slvg	Jones	Bl Normal	*	*	*	*	*	*	*	*	*	*	*	*
CL Steelhead Slvg	Jones	AbNormal	0	0	9	358	-16	-30	-6	0	0	0	0	0
CL Steelhead Slvg	Jones	Wet	0	0	0	10	0	-131	0	0	0	0	0	0
Model 8.0 compared to 7.0														
CL Steelhead Slvg	Banks	Critical	*	*	*	*	*	*	*	*	*	*	*	*
CL Steelhead Slvg	Banks	Dry	0	0	0	23	-22	62	6	1	0	0	0	0
CL Steelhead Slvg	Banks	Bl Normal	*	*	*	*	*	*	*	*	*	*	*	*
CL Steelhead Slvg	Banks	AbNormal	0	0	1	81	169	17	7	1	1	0	0	0
CL Steelhead Slvg	Banks	Wet	0	0	0	4	8	3	7	1	0	0	0	0
CL Steelhead Slvg	Jones	Critical	*	*	*	*	*	*	*	*	*	*	*	*
CL Steelhead Slvg	Jones	Dry	0	0	0	9	86	-60	5	2	0	0	0	0
CL Steelhead Slvg	Jones	Bl Normal	*	*	*	*	*	*	*	*	*	*	*	*
CL Steelhead Slvg	Jones	AbNormal	0	0	10	259	112	-17	-6	0	0	0	0	0
CL Steelhead Slvg	Jones	Wet	0	0	0	9	-3	-102	0	0	0	0	0	0
Model 6.1 compared to 7.0														
CL Steelhead Slvg	Banks	Critical	*	*	*	*	*	*	*	*	*	*	*	*
CL Steelhead Slvg	Banks	Dry	0	0	0	8	-99	-58	-16	1	0	0	0	0
CL Steelhead Slvg	Banks	Bl Normal	*	*	*	*	*	*	*	*	*	*	*	*
CL Steelhead Slvg	Banks	AbNormal	0	0	-2	48	-141	-22	0	0	0	0	0	0
CL Steelhead Slvg	Banks	Wet	0	0	0	-6	-14	-16	-1	0	0	0	0	0
CL Steelhead Slvg	Jones	Critical	*	*	*	*	*	*	*	*	*	*	*	*
CL Steelhead Slvg	Jones	Dry	0	0	0	2	39	43	-17	1	0	0	0	0
CL Steelhead Slvg	Jones	Bl Normal	*	*	*	*	*	*	*	*	*	*	*	*
CL Steelhead Slvg	Jones	AbNormal	0	0	2	-21	45	9	-3	0	0	0	0	0
CL Steelhead Slvg	Jones	Wet	0	0	0	0	-13	-13	-1	0	0	0	0	0
Model 7.1 compared to 7.0														
Grn Sturgeon Slvg	Banks	Critical	0	0	0	1	2	3	0	0	0	0	0	0
Grn Sturgeon Slvg	Banks	Dry	0	0	1	0	0	0	1	0	0	0	0	0
Grn Sturgeon Slvg	Banks	Bl Normal	*	*	*	*	*	*	*	*	*	*	*	*
Grn Sturgeon Slvg	Banks	AbNormal	0	0	0	0	1	0	0	0	0	1	0	0
Grn Sturgeon Slvg	Banks	Wet	0	0	2	0	0	0	7	0	0	0	-1	0
Grn Sturgeon	Jones	Critical	0	0	0	0	0	0	2	0	0	0	0	0

Species	Fac	WYType	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Slvg														
Grn Sturgeon Slvg	Jones	Dry	0	1	2	0	1	0	1	0	0	8	-8	0
Grn Sturgeon Slvg	Jones	Bl Normal	*	*	*	*	*	*	*	*	*	*	*	*
Grn Sturgeon Slvg	Jones	AbNormal	0	0	0	0	0	0	0	0	0	0	0	0
Grn Sturgeon Slvg	Jones	Wet	0	0	1	0	0	-2	0	0	0	1	8	1
Model 8.0 compared to 7.0														
Grn Sturgeon Slvg	Banks	Critical	0	0	0	0	2	3	0	0	0	0	0	0
Grn Sturgeon Slvg	Banks	Dry	0	0	2	0	0	0	1	0	0	0	-1	0
Grn Sturgeon Slvg	Banks	Bl Normal	*	*	*	*	*	*	*	*	*	*	*	*
Grn Sturgeon Slvg	Banks	AbNormal	0	0	0	0	1	0	0	0	0	1	0	0
Grn Sturgeon Slvg	Banks	Wet	0	0	2	0	0	0	7	0	0	1	-1	0
Grn Sturgeon Slvg	Jones	Critical	0	0	0	0	0	0	1	0	0	0	0	0
Grn Sturgeon Slvg	Jones	Dry	1	2	2	0	1	0	0	0	0	0	-18	0
Grn Sturgeon Slvg	Jones	Bl Normal	*	*	*	*	*	*	*	*	*	*	*	*
Grn Sturgeon Slvg	Jones	AbNormal	0	0	0	0	0	0	0	0	0	0	0	0
Grn Sturgeon Slvg	Jones	Wet	1	0	1	0	0	-2	0	0	0	-2	8	2
Model 6.1 compared to 7.0														
Grn Sturgeon Slvg	Banks	Critical	0	0	0	0	1	-1	0	0	0	0	0	0
Grn Sturgeon Slvg	Banks	Dry	0	0	-1	0	0	0	-1	0	0	0	8	0
Grn Sturgeon Slvg	Banks	Bl Normal	*	*	*	*	*	*	*	*	*	*	*	*
Grn Sturgeon Slvg	Banks	AbNormal	0	0	0	0	-1	0	0	0	0	1	0	0
Grn Sturgeon Slvg	Banks	Wet	0	0	-2	0	0	-2	-1	0	0	2	0	0
Grn Sturgeon Slvg	Jones	Critical	0	0	0	0	0	0	-3	0	0	0	0	0
Grn Sturgeon Slvg	Jones	Dry	0	0	0	0	1	0	-1	0	0	-8	-7	0
Grn Sturgeon Slvg	Jones	Bl Normal	*	*	*	*	*	*	*	*	*	*	*	*
Grn Sturgeon Slvg	Jones	AbNormal	0	0	0	0	0	0	0	0	0	0	0	0
Grn Sturgeon Slvg	Jones	Wet	1	0	0	0	-1	0	0	2	0	-3	2	1

The months of greatest changes in loss or salvage between the base case (Study 7.0) and the future (Studies 7.1 and 8.0) are December through June for salmonids. Green sturgeon change is too irregular to summarize.

Indirect Losses to Entrainment by CVP and SWP Export Facilities

The FWS Service has conducted juvenile Chinook survival experiments in the Delta for many years. They have conducted yoy fall-run survival experiments in the spring months on the Sacramento and San Joaquin rivers, and late-fall run survival experiments in the fall and winter months on the Sacramento River using hatchery reared juvenile Chinook. One of the purposes of these experiments has been to try to determine the “indirect” effects of Delta exports on juvenile Chinook survival as they emigrate through the Delta. Ken Newman (2008) published analyses of all these data sets. The results as quoted from the executive summary are:

> **Results**
>
> For the most part, the substantive conclusions from the Bayesian Hierarchical Model (BHM) analyses, summarized below, were consistent with previous USFWS analyses.
>
> > **Delta Cross Channel:** There was modest evidence, 64 to 70% probability, that survival of Courtland [above DCC] releases, relative to the survival of Ryde [below DCC] releases, increased when the gate was closed.
> >
> > **Interior:** Survival for the interior Delta releases was estimated to be about 44% of the survival for the Sacramento River releases.
> >
> > **Delta Action 8:** There was a negative association between export volume and relative [interior Delta] survival, i.e., a 98% chance that as exports increased, relative [interior Delta] survival decreased. Environmental variation in the relative survival was very large, however; e.g., for one paired release the actual relative survival at a low export level could with high probability be lower than relative survival at a high export level for another paired release.
> >
> > **VAMP:** (a) The expected probability of surviving to Jersey Point was consistently larger for fish straying I the San Joaquin River (say passing Dos Reis) than fish entering Old River, but the magnitude of the difference varied between models somewhat; (b) thus if the HORB effectively keeps fish from entering Old River, survival of out-migrants should increase; (c) there was a positive association between flow at Dos Reis and subsequent survival from Dos Reis and Jersey Point, and if data from 2003 and later were eliminated from analysis the strength of the association increased and a positive association between flow in Old River and survival in Old River appeared; (d) associations between water export levels and survival probabilities were weak to negligible. Given complexity and number of potential models for the VAMP data, however, a more thorough model selection procedure using Reversible Jump MCM is recommended.

From Newman's results, we conclude fish emigrating from the Sacramento River through the interior Delta survive about half as well as fish emigrating down the mainstem Sacramento River, but exports affect the change in relative interior survival by about -5 percent per 1,000 cfs increase in exports between 2,000 cfs and 4,000 cfs, and by about -2.75 percent per 1000 cfs increase in exports between 8,000 cfs and 10,000 cfs (Figure 13-50). For fish emigrating from the San Joaquin River through the south Delta, the effect of exports on survival was weak to negligible.

FIGURE 24. DA 8: Posterior means (solid) and medians (dashed line) for θ from the BHM (with log transformed θ and uniform priors on standard deviations of random effects) plotted against export levels. The 2.5% and 97.5% intervals are indicated by vertical lines.

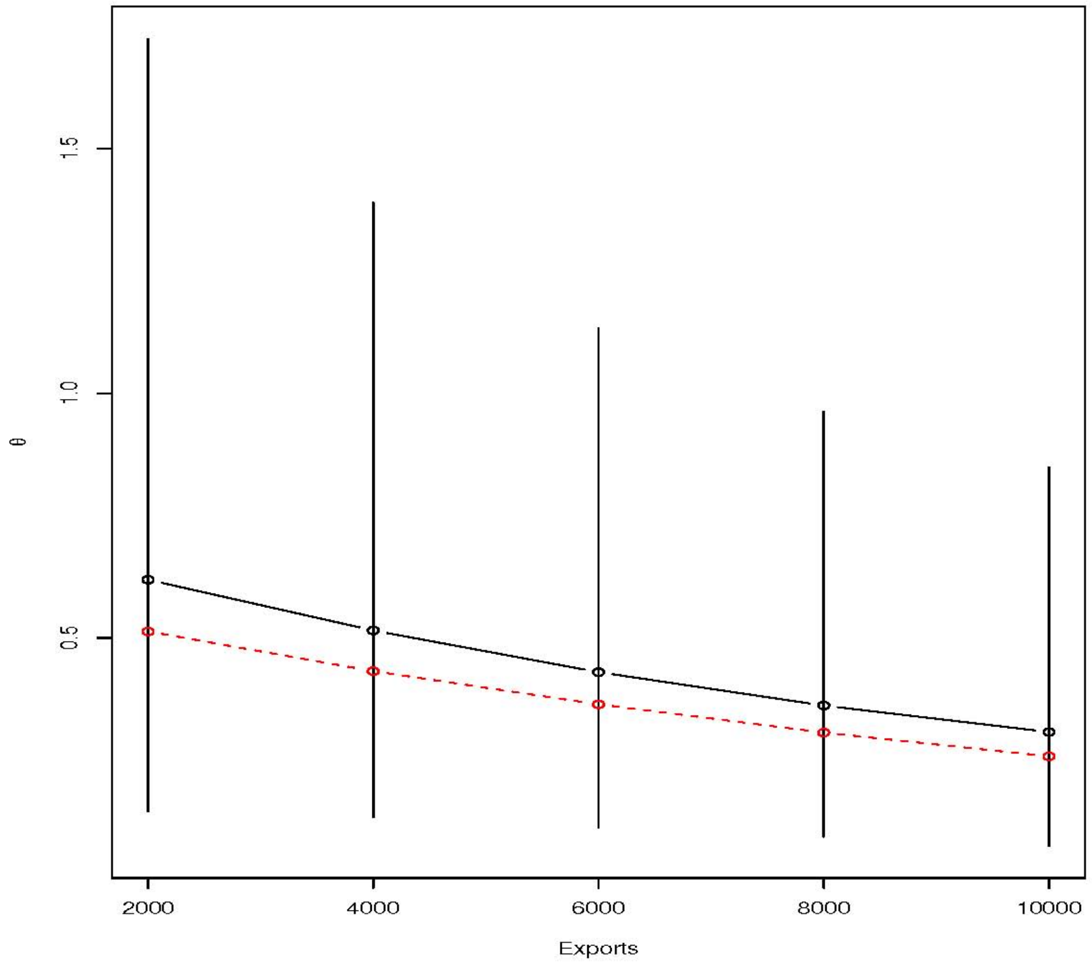


Figure 13-50 Posterior means and medians

Steelhead Predation Study

Steelhead entrained in the Forebay are subject to predation, synonymous with pre-screen loss, as they traverse the Forebay toward the John E. Skinner Fish Protective Facility (SFPF). DWR conducted a study in 2005, 2006, and 2007 to assess and quantify steelhead pre-screen losses within Clifton Court Forebay. The investigation was developed to provide useful information that could serve to reduce the potential vulnerability of steelhead to predation mortality within Clifton Court Forebay. A final report will be available in the fall of 2008.

Preliminary results suggest that the pre-screen loss rate was 82 ±3% (mean ± 95% confidence interval) in 2007. This result is similar to previous pre-screen loss studies of other fish species including Chinook salmon and juvenile striped bass (Schaffter, 1978; Hall, 1980; and Kano, 1985). In contrast, the SFPF loss rate was 26 ±7% (mean ± 95% confidence interval). Statistical analysis showed that pre-screen loss rate did not differ by month of release. However, the time to salvage was greater for PIT tagged steelhead released at the radial gates in February than those released in January or April. Data analysis concluded that there was no correlation between steelhead movement rates and water temperature, export rate, turbidity, radial gate water velocities, or light intensity. However, steelhead movement rates were correlated to the length of time spent within Clifton Court Forebay. The longer steelhead remained within the Forebay the less they moved.

500 CFS Increased Diversion to Provide Reduced Exports Taken to Benefit Fish Resources Effects on Salmonids and Green Sturgeon

Clifton Court Forebay (CCF) is typically operated at or near the rates defined in the USACE Public Notice 5820A, Amended, unless otherwise restricted. Public Notice 5820A, Amended, requires that daily summer diversions into CCF not exceed 13,870 AF and a three-day average not to exceed 13,250 AF. Banks Pumping Plant is operated to the available physical capacity, as constrained by CCF operations. Banks Pumping Plant is also adjusted to assist in maintaining velocity criteria at Skinner Fish facility as exports allow. Maximum average monthly SWP summer exports from Banks Pumping Plant are 6,680 cfs.

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.

Water exported under the 500 cfs increased export limit would first be used to recover export reductions taken during the VAMP period (assumed mid-April to mid-May) or applied to the “shoulder” periods preceding or following the VAMP period. Any remaining water could be applied to other export reductions for fish protection during that calendar year or be stored in San Luis Reservoir to be applied to export reductions for the subsequent calendar year. As the SWP share of San Luis Reservoir is filled, there is a risk that this water would be “spilled” from the reservoir. “Spilling” the stored water would result in lower exports from the Delta during the time the reservoir is filling. Normally, this would occur during December – March. The fishery agencies would decide whether to implement an export reduction in the fall or winter time period equivalent to the water stored in the reservoir or assume the risk that the water would be spilled later on. Additional details regarding the implementation of the 500 cfs increased diversion are contained in Chapter 2.

Analyses Contained in the Initial Study

Much of the information in this discussion is taken from the *Initial Study for the 2005 – 2008 State Water Project Delta Facility Increased Diversion to Recover Reduced Exports Taken to Benefit Fish Resources* (DWR 2004). The operation analyzed in the Initial Study and implemented in 2005 – 2008 is slightly different than the operation contained in this project description. The difference is the ability to carry over water exported under the 500 cfs increased diversion limit into the subsequent calendar year. The operation analyzed in the Initial Study and implemented through 2008 does not allow carry over of the exported water. The operation to begin in 2009 allows carry over of the exported water as long as it does not affect the ability to fill the SWP share of San Luis Reservoir. Water exported under the 500 cfs export limit is to be used only for export reductions to benefit fish resources.

The Initial Study uses a comparative analysis to quantify the impacts of the 500 cfs increased diversion (Project) compared to a no-project (Base) condition. The range of potential impacts is defined by modeling two hydrologies: a year of low delta inflow, and a year of high delta inflow. The hydrologies are used as input for the DWRDSM2 HYDRO and QUAL studies, which evaluate changes in flow, stage, velocity, and salinity. Tidally averaged comparisons of water quality, flow, stage, and velocities for all the locations studied are in Appendix II of the Initial Study (DWR 2004). The modeling assumptions for the Project include the following:

- Two 30-day periods to reduce diversions to benefit fish resources are chosen: May 15-June 15, and November 15–December 15. The total reduction in diversions cannot exceed 90 TAF.
- The operations of the SWP and CVP must comply with existing Bay-Delta requirements of the SWRCB Decision 1641. Operations are assumed to comply with the ESA, and other regulatory and contractual requirements related to the Sacramento-San Joaquin River Delta.
- Current SWP operations allow a maximum three-day average diversion rate of 6,680 cfs during July, August, and September. Project diversions during that period must exceed the maximum three-day average diversion rate of 6,680 cfs to constitute a with-Project condition since diversions less than that amount are already permitted in the base condition.
- The increased diversions during July, August, and September of any calendar year equals the amount of reduced diversions during that calendar year.

The historic hydrologies were examined to find a representative period and a high and low inflow year. The representative period is from1987 to 1999 and the low and high inflow years are 1992 and 1997. The reasons for selecting 1992 and 1997 are discussed below.

1992, Low Delta Inflow Year

Two difficulties in selecting a year of low delta inflow occurred. Exports in years of low delta inflow during each of the two 30-day periods, (May 15-June 15, and November 15-December 15) typically did not exceed 90 TAF. Current constraints on export/inflow ratios were instituted in 1995 under the Bay-Delta Accord. All years since 1995 have been classified as wet years (up to the year 2000). Therefore, historic operations during a year of low delta inflow with current regulatory constraints did not exist at the time of the study.

Three years of low delta inflow were considered: 1987, 1988, and 1992. In 1987 and 1988, exports during the two 30-day periods, (May 15-June 15, and November 15-December 15) could be reduced by 90 TAF. However, operations prior to 1995 were not subject to existing regulatory requirements, and thus the export/inflow ratios during 1987 and 1988 exceeded existing export/inflow requirements of the SWRCB. In 1987, daily exports exceeded present requirements by an average of 2744 cfs, and a maximum of 6146 cfs. Therefore, 1987 and 1988 were eliminated from consideration.

In 1992, exports during the two 30-day periods, May 15-June 15, and November 15-December 15, were approximately 46 TAF and 66 TAF, respectively. Therefore, exports could not be reduced by the full proposed amount of 90 TAF. Although export/inflow ratios exceeded existing requirements, the existing requirements could be met with minor adjustments to the historic inflow. In 1992, present export/inflow ratio requirements could be met by increasing Sacramento River inflow by an average of 11 cfs. For these reasons, 1992 was selected as the year to represent conditions of low Delta inflow.

1997, High Delta Inflow Year

Current constraints on export/inflow ratios were instituted in 1995 and delta inflow during the subsequent years was high. Therefore, several years of historic operations with high delta inflow and current regulatory constraints exist. Thus, 1995-1999 were considered. SWP exports during May 15-June 15 exceeded 90 TAF in 1995, 1996, and 1997. In 1998 and 1999, SWP exports during May 15-June 15 were only 78 TAF and 71 TAF, respectively, which would not allow a reduction for the full proposed amount of 90 TAF. 1995 was not chosen because SWP exports during the November 15 to December 15 period were only 6,210 AF. 1996 was not chosen because SWP exports during May 15-June 15 were 294 TAF, and this was not considered a representative year. In 1997, SWP exports during May 15-June 15 and November 15 to December 15 period were 100 TAF and 644 TAF, respectively.

Historic vs. Base Hydrologies

The historic hydrologies were modified so the base hydrologies would comply with the initial assumptions explained above and repeated below:

- The operations of the SWP and CVP must comply with existing requirements of SWRCB Decision 1641, with the ESA, and other regulatory and contractual requirements related to the Sacramento-San Joaquin River Delta.
- Current SWP operations allow a maximum three-day average diversion rate of 6,680 cfs during July, August, and September. Project diversions during that period must exceed the maximum three-day average diversion rate of 6,680 cfs because diversions less than this base condition are already permitted.

Sacramento River flows were also modified from historic conditions. When export/inflow ratios exceeded existing requirements, Sacramento River flows were increased until existing constraints were met. When exports were modified, Sacramento River flows were modified to maintain the net delta outflow. Thus, the SWP was simply changing the time when storage in Oroville was being moved to San Luis Reservoir.

The potential changes in diversion rate into CCF will affect fish salvage at the SWP. To determine the impact of such export changes, historic salvage data from 1992 and 1997 (representative low and high Delta inflow years used in the modeling) were used to estimate the impact of the Project on fish salvage. Historic salvage density was used to estimate salvage under the different export scenarios through extrapolation as shown in the tables below.

Potential Impacts of Water Quality and Flow on Fish

Potential impacts to 10 species, including delta smelt, salmon, steelhead and sturgeon, were examined by two methods. First, the water quality and flow modeling results were examined to determine if they posed potential impacts to fish. Second, historic salvage data was examined to determine if the Project posed potential impacts to delta smelt, salmon, steelhead and sturgeon salvage.

The modeling results predicted minor changes in water quality, which would result in no impacts to salmon, steelhead and sturgeon.

The changes in flow predicted by the modeling suggest that there will be no significant negative impacts to salmon, steelhead and sturgeon distribution. The largest changes in flow occurred during the spring pumping reduction. Flows towards CCF decreased by as much as 2,250 cfs. Decreased flows towards CCF may decrease the potential vulnerability of salmon, steelhead and sturgeon to SWP salvage. The modeling results predicted that flows only slightly increased towards CCF during the increased pumping period, suggesting there will be no impact on salmon, steelhead and sturgeon distribution and subsequent vulnerability to SWP salvage.

Potential Impacts to Fish Salvage

Historic salvage data for ten sensitive fish species or runs, including salmon, steelhead and sturgeon, were analyzed to determine the impact of the proposed project. The fish species may occur in the project area during the project period.

The potential changes in diversion rate into CCF will affect fish salvage at the SWP. To determine the impact of such export changes, historic salvage data from 1992 and 1997 (representative low and high Delta inflow years used in the modeling) were used to estimate the impact of the Project on fish salvage. Historic salvage density was used to estimate salvage under the different export scenarios through extrapolation.

The difference in fish salvage between the base and Project conditions was used as the effect of the Project on fish salvage. Base (No-Project) salvage was calculated as the product of historic salvage density (number of fish salvaged per AF diverted) and modeled base exports. Project salvage was calculated as the product of historic salvage density and modeled Project exports. The effect of the Project on fish salvage was the difference between the Project and base salvage estimates.

For example:

historic salvage / historic AF diverted = historic salvage density (HSD)

HSD x base exports = estimated base salvage (BS)

HSD x Project exports = estimated Project salvage (PS)

PS – BS = estimated difference in salvage from the base caused by the Project.

The results of this analysis (see following tables) suggest that salvage of Chinook salmon and steelhead is likely to be reduced while there will be no substantial change in salvage of green sturgeon. The studies can be used to draw conclusions about other potential operations. Consider a scenario in which the export reduction is taken only in May 1997 (48 taf), 90 taf were exported in July-September, and the remaining 42 taf applied as reduced exports in December. This scenario results in the following estimates of changes in salvage:

	May	Jul-Sept	Dec	Total
Chinook Salmon	-1817	+4	-46	-1859
Steelhead	-14	0	-3	-17
Sturgeon	0	+1	0	+1

The results of this scenario supports the conclusion above, that salvage of Chinook salmon and steelhead is likely to be reduced while there will be no substantial change in salvage of green sturgeon.

NOTE: Row headers for the following tables are as follows:

Historic exports = Actual SWP exports for given month (AF).
Historic salvage = Actual SWP salvage for given month.
Historic salvage density = Historic salvage ÷ historic exports (number of fish per AF).
Base exports = Modeled SWP base exports for given month.
Base salvage = Historic salvage density x modeled base exports.
Project exports = Modeled SWP exports for given month which includes the 500 cfs increased export limit.
Project salvage = Historic salvage density x modeled project exports.
Percent change = Estimated percent change in salvage caused by the project.
= (Project salvage – Base salvage)x100%/Base salvage

Table 13-25 Chinook Salmon

Spring 1992	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Total**
Historic exports	42,376	57,220	25,689	90,836	161,905	378,026
Historic salvage	2,365	0	0	0	6	2,371
Historic salvage density	0.0558	0.0000	0.0000	0.0000	0.0000	-
Base exports	15,099	56,040	410,018	410,018	396,792	1,287,968
Base salvage	843	0	0	0	15	857
Project exports	0	25,469	425,732	425,732	411,036	1,287,969
Project salvage	0	0	0	0	15	15
Percent change	-100%	0	0	0	0	-98%

Fall 1992	**Jul**	**Aug**	**Sep**	**Nov**	**Dec**	**Total**
Historic exports	25,689	90,836	161,905	62,303	168,276	509,009
Historic salvage	0	0	6	0	160	166
Historic salvage density	0.0000	0.0000	0.0000	0.0000	0.0010	-
Base exports	410,018	410,018	396,792	66,651	35,531	1,319,011
Base salvage	0	0	15	0	34	48
Project exports	432,852	432,852	417,390	35,917	0	1,319,011
Project salvage	0	0	15	0	0	15
Percent change	0	0	0	0	-100%	-69%

Spring 1997	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Total**
Historic exports	78,236	153,854	321,231	269,918	341,334	1,164,573
Historic salvage	2,962	635	30	0	9	3,636
Historic salvage density	0.0379	0.0041	0.0001	0.0000	0.0000	-
Base exports	47,995	153,058	410,018	410,018	396,792	1,417,882
Base salvage	1,817	632	38	0	10	2,498
Project exports	0	111,953	440,708	440,708	424,512	1,417,882
Project salvage	0	462	41	0	11	514
Percent change	-100%	-27%	8%	0	10%	-79%

Fall 1997	**Jul**	**Aug**	**Sep**	**Nov**	**Dec**	**Total**
Historic exports	321,231	269,918	341,334	292,036	419,732	1,644,251
Historic salvage	30	0	9	4	463	506
Historic salvage density	0.0001	0.0000	0.0000	0.0000	0.0011	-
Base exports	410,018	410,018	396,792	292,923	196,804	1,706,556
Base salvage	38	0	10	4	217	270
Project exports	440,708	440,708	424,512	245,403	155,224	1,706,556
Project salvage	41	0	11	3	171	227
Percent change	8%	0	10%	-25%	-21%	-16%

Table 13-26 Steelhead

Spring 1992	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Total**
Historic exports	42,376	57,220	25,689	90,836	161,905	378,026
Historic salvage	33	0	0	0	0	33
Historic salvage density	0.0008	0.0000	0.0000	0.0000	0.0000	-
Base exports	15,099	56,040	410,018	410,018	396,792	1,287,968
Base salvage	12	0	0	0	0	12
Project exports	0	25,469	425,732	425,732	411,036	1,287,969
Project salvage	0	0	0	0	0	0
Percent change	-100%	0	0	0	0	-100%

Fall 1992	**Jul**	**Aug**	**Sep**	**Nov**	**Dec**	**Total**
Historic exports	25,689	90,836	161,905	62,303	168,276	509,009
Historic salvage	0	0	0	0	16	16
Historic salvage density	0.0000	0.0000	0.0000	0.0000	0.0001	-
Base exports	410,018	410,018	396,792	66,651	35,531	1,319,011
Base salvage	0	0	0	0	3	3
Project exports	432,852	432,852	417,390	35,917	0	1,319,011
Project salvage	0	0	0	0	0	0
Percent change	0	0	0	0	-100%	-100%

Spring 1997	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Total**
Historic exports	78,236	153,854	321,231	269,918	341,334	1,164,573
Historic salvage	23	0	0	0	0	23
Historic salvage density	0.0003	0.0000	0.0000	0.0000	0.0000	-
Base exports	47,995	153,058	410,018	410,018	396,792	1,417,882
Base salvage	14	0	0	0	0	14
Project exports	0	111,953	440,708	440,708	424,512	1,417,882
Project salvage	0	0	0	0	0	0
Percent change	-100%	0	0	0	0	-100%

Fall 1997	**Jul**	**Aug**	**Sep**	**Nov**	**Dec**	**Total**
Historic exports	321,231	269,918	341,334	292,036	419,732	1,644,251
Historic salvage	0	0	0	0	30	30
Historic salvage density	0.0000	0.0000	0.0000	0.0000	0.0001	-
Base exports	410,018	410,018	396,792	292,923	196,804	1,706,556
Base salvage	0	0	0	0	14	14
Project exports	440,708	440,708	424,512	245,403	155,224	1,706,556
Project salvage	0	0	0	0	11	11
Percent change	0	0	0	0	-21%	-21%

Table 13-27 Green Sturgeon

Spring 1992	May	Jun	Jul	Aug	Sep	Total
Historic exports	42,376	57,220	25,689	90,836	161,905	378,026
Historic salvage	0	0	0	0	0	0
Historic salvage density	0.0000	0.0000	0.0000	0.0000	0.0000	-
Base exports	15,099	56,040	410,018	410,018	396,792	1,287,968
Base salvage	0	0	0	0	0	0
Project exports	0	25,469	425,732	425,732	411,036	1,287,969
Project salvage	0	0	0	0	0	0
Percent change	0	0	0	0	0	0

Fall 1992	Jul	Aug	Sep	Nov	Dec	Total
Historic exports	25,689	90,836	161,905	62,303	168,276	509,009
Historic salvage	0	0	0	0	1	1
Historic salvage density	0.0000	0.0000	0.0000	0.0000	0.0000	-
Base exports	410,018	410,018	396,792	66,651	35,531	1,319,011
Base salvage	0	0	0	0	0	0
Project exports	432,852	432,852	417,390	35,917	0	1,319,011
Project salvage	0	0	0	0	0	0
Percent change	0	0	0	0	0	0

Spring 1997	May	Jun	Jul	Aug	Sep	Total
Historic exports	78,236	153,854	321,231	269,918	341,334	1,164,573
Historic salvage	0	0	0	0	18	18
Historic salvage density	0.0000	0.0000	0.0000	0.0000	0.0001	-
Base exports	47,995	153,058	410,018	410,018	396,792	1,417,882
Base salvage	0	0	0	0	21	21
Project exports	0	111,953	440,708	440,708	424,512	1,417,882
Project salvage	0	0	0	0	22	22
Percent change	0	0	0	0	1%	1%

Fall 1997	Jul	Aug	Sep	Nov	Dec	Total
Historic exports	321,231	269,918	341,334	292,036	419,732	1,644,251
Historic salvage	0	0	18	0	0	18
Historic salvage density	0.0000	0.0000	0.0001	0.0000	0.0000	-
Base exports	410,018	410,018	396,792	292,923	196,804	1,706,556
Base salvage	0	0	21	0	0	21
Project exports	440,708	440,708	424,512	245,403	155,224	1,706,556
Project salvage	0	0	22	0	0	22
Percent change	0	0	5%	0	0	5%

Clifton Court Forebay Aquatic Weed Control Program

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 impacts 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).

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 winter- and spring-run Chinook salmon, steelhead, and delta smelt in the Forebay at the time of application are taken. There has been only one green sturgeon at the SWP, 6/26/1996, in the salvage record during the April through June period. Figure 13-51 and Figure 13-52 are illustrations of the total (all runs) Chinook salmon loss at the SWP BPP during the period two weeks before and after Komeen or Nautique treatments from 1995 to 2006. The daily loss values vary greatly within treatments, between months and between years.

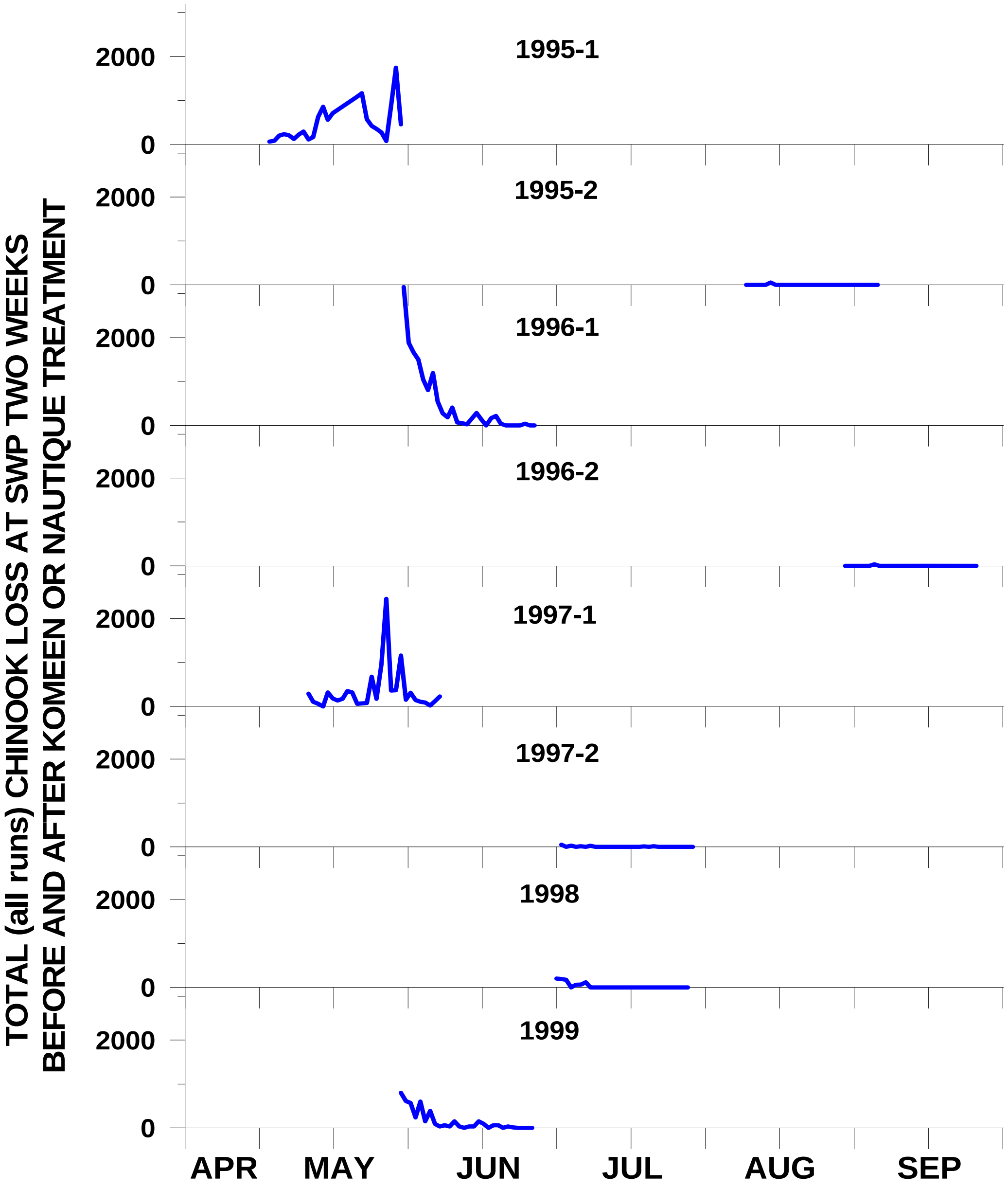


Figure 13-51 Total (all four runs) Chinook loss at the SWP Banks Pumping Plant two weeks before and after Komeen or Nautique aquatic weed treatment, 1995 – 1999.

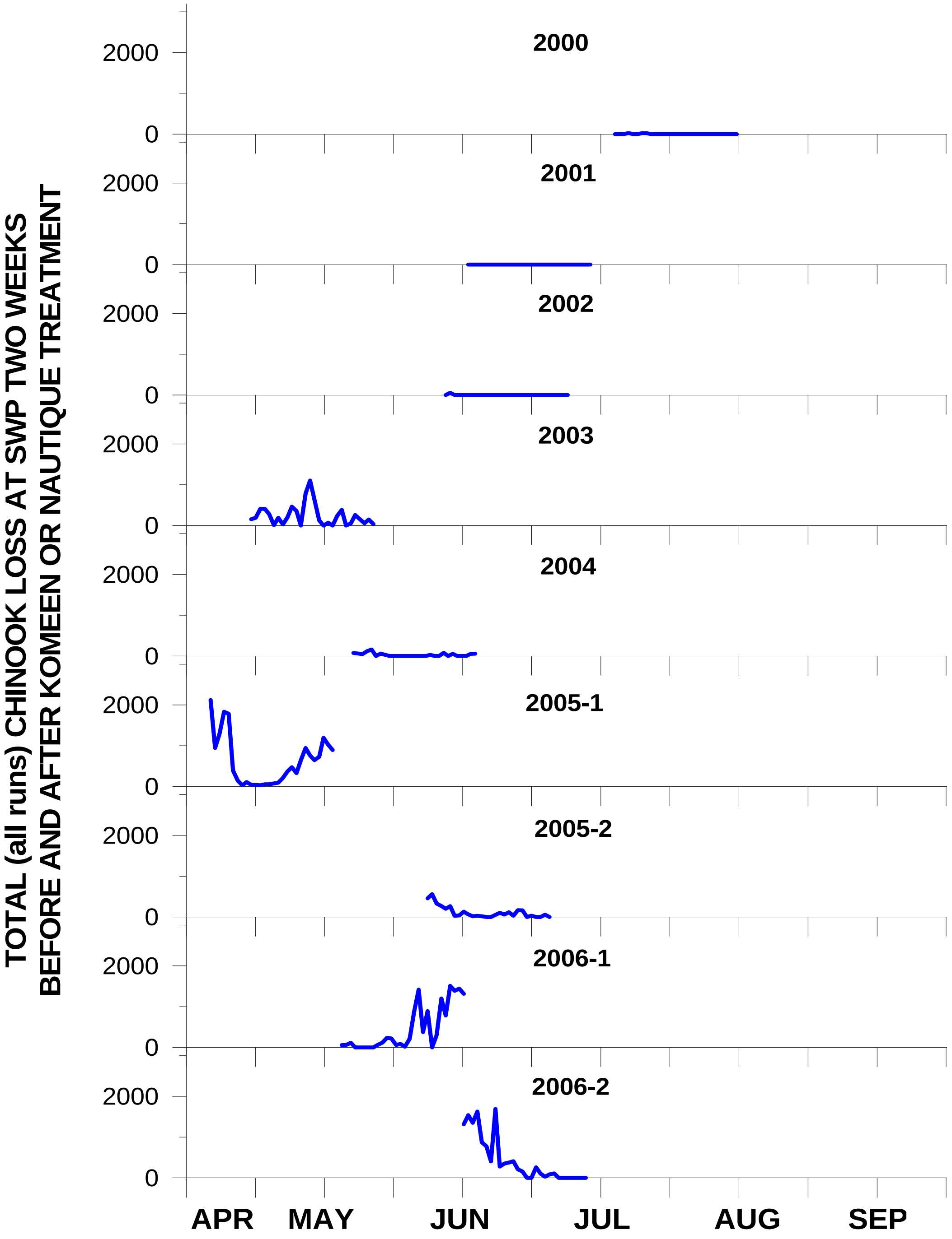


Figure 13-52 Total (all four runs) Chinook loss at the SWP Banks Pumping Plant two weeks before and after Komeen or Nautique aquatic weed treatment, 2000 - 2006.

Figure 13-53 and Figure 13-54 are illustrations of the steelhead salvage at the SWP BPP during the period two weeks before and after Komeen or Nautique treatments from 1995 to 2006. The salvage values vary greatly within treatments, between months and between years.

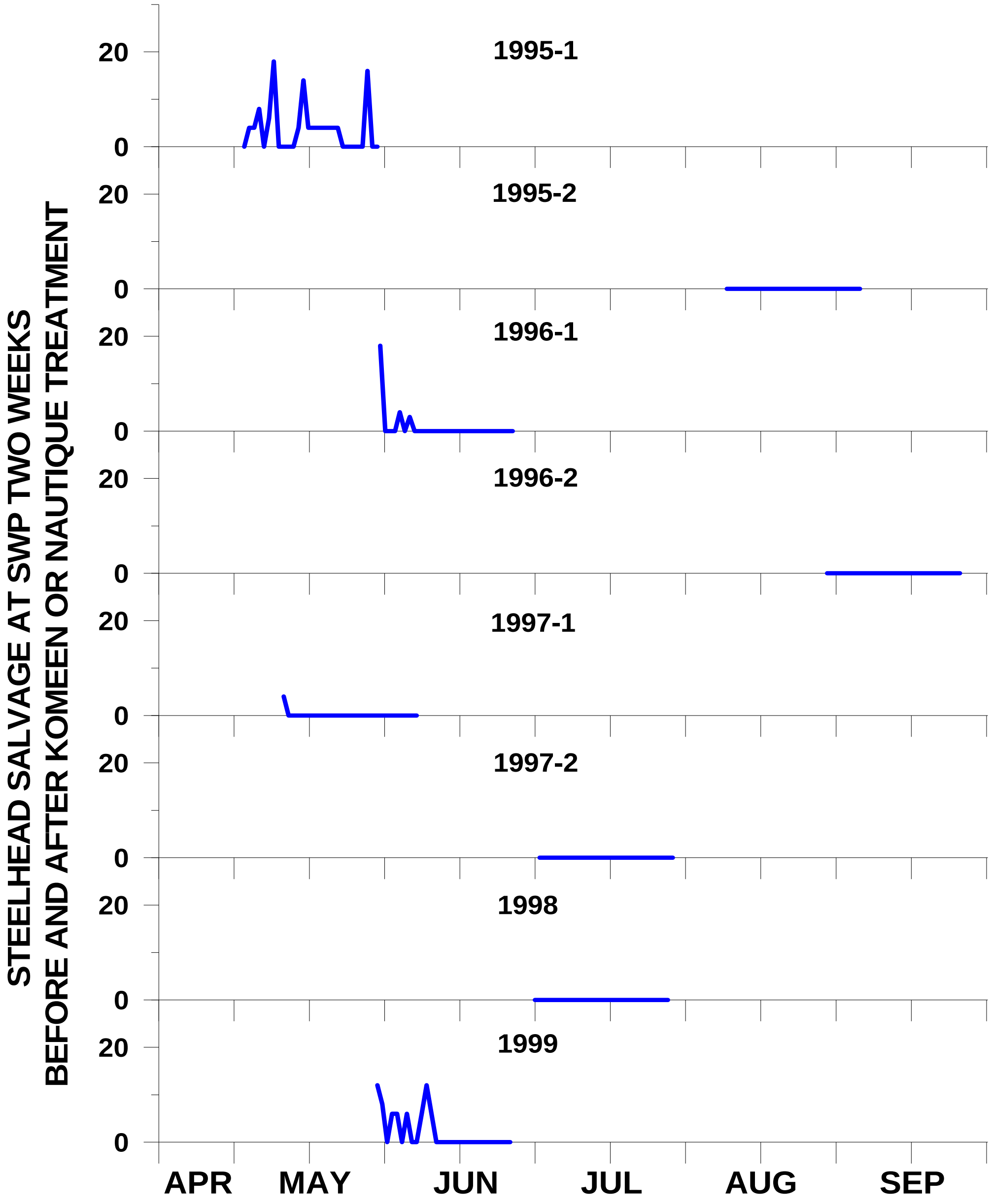


Figure 13-53 Steelhead salvage at the SWP Banks Pumping Plant two weeks before and after Komeen or Nautique aquatic weed treatment, 1995 – 1999.

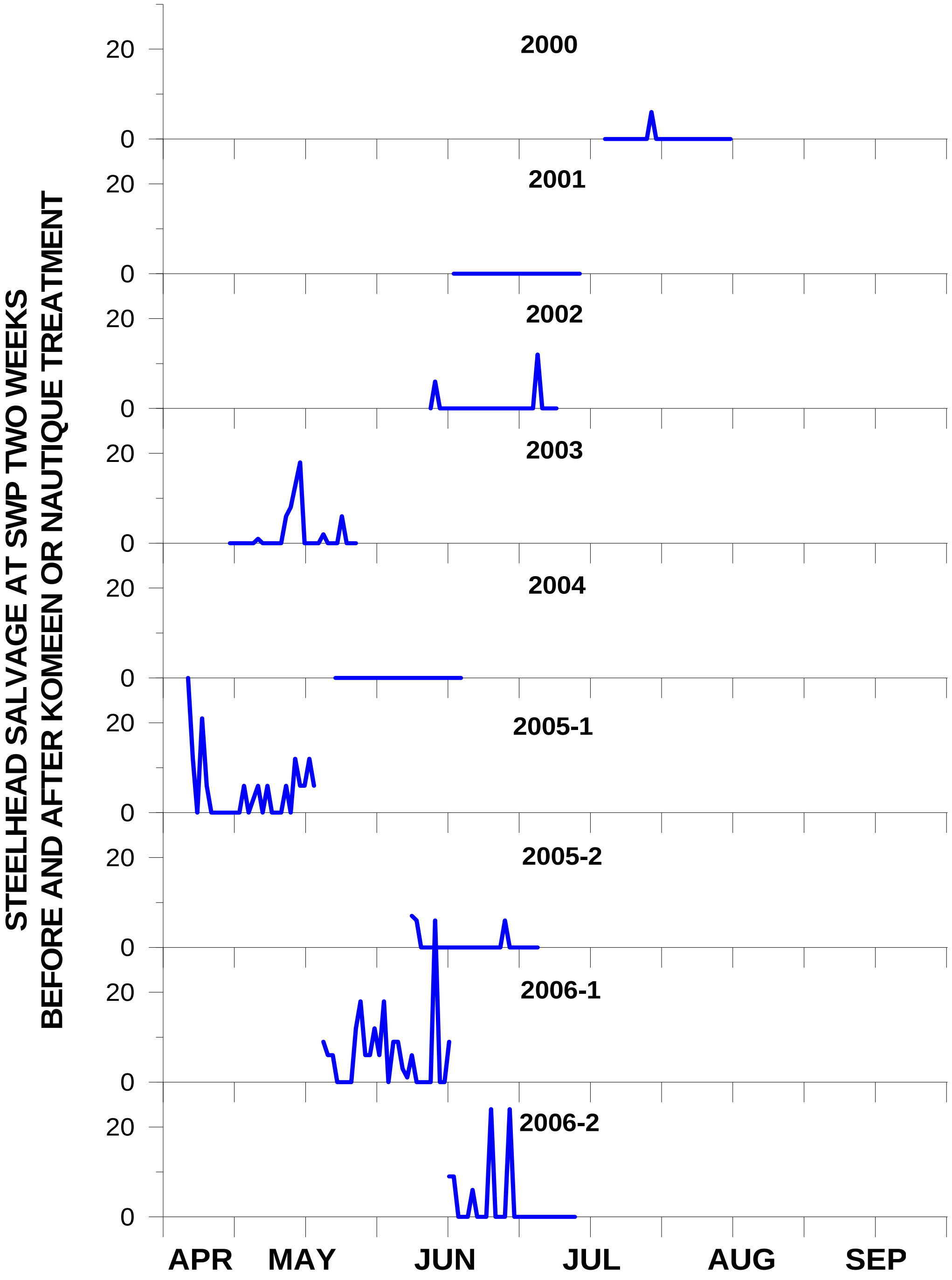


Figure 13-54 Steelhead salvage at the SWP Banks Pumping Plant two weeks before and after Komeen or Nautique aquatic weed treatment, 2000 – 2006.

To estimate the loss of listed Chinook salmon, winter and spring run, at the salvage facilities during Komeen or Nautique treatments, we used genetic characterization. The four Chinook runs look alike at the juvenile lifestage; therefore we used the average fraction of genetically identified winter- and spring-run Chinook lost at the SWP Salvage Facilities, during the historical treatment periods to extrapolate to the actual treatment times. The averages for winter run were 0 percent from the last half of April through July, and for spring run: last half of April – 1 percent, May – 5 percent, June – 1 percent, and July 0 percent. Table 13-28 is the fraction of genetically identified winter and spring-run Chinook lost at the SWP salvage facilities during the historical Komeen or Nautique treatment periods.

Table 13-28 Fraction of salvage sampled, fraction winter run of total Chinook loss based on genetic characterization, and fraction spring run of total Chinook loss based on genetic characterization. Time intervals are two weeks starting Mid-April and ending July.

		later April					
Year	Facility	Fraction Sampled	Fraction WinterRun	Fraction SpringRun			
1997	SWP	0.21	0.00	*			
1999	SWP	0.04	0.00	*			
2000	SWP	0.05	0.00	*			
2006	SWP	0.99	0.00	0.00			
2007	SWP	0.99	0.00	0.02			
Average			0.00	0.01			
		earlier May			later May		
Year	Facility	Fraction Sampled	Fraction WinterRun	Fraction SpringRun	Fraction Sampled	Fraction WinterRun	Fraction SpringRun
1997	SWP	0.19	0.00	*	0.21	0.00	*
1999	SWP	0.08	0.00	*	0.10	0.00	*
2000	SWP	0.07	0.00	*	0.05	0.00	*
2006	SWP	0.98	0.00	0.00	1.00	0.00	0.06
2007	SWP	0.97	0.00	0.06	0.87	0.00	0.00
Average			0.00	0.03		0.00	0.03
		earlier June			later June		
Year	Facility	Fraction Sampled	Fraction WinterRun	Fraction SpringRun	Fraction Sampled	Fraction WinterRun	Fraction SpringRun
1997	SWP	0.33	0.00	*	0.30	0.00	*
1999	SWP	0.17	0.00	*	0.37	0.00	*
2000	SWP	0.00	*	*	0.00	*	*
2006	SWP	1.00	0.00	0.01	0.97	0.00	0.01
2007	SWP	1.00	0.00	0.00	*	*	*
Average			0.00	0.01		0.00	0.01
		earlier July			later July		
Year	Facility	Fraction Sampled	Fraction WinterRun	Fraction SpringRun	Fraction Sampled	Fraction WinterRun	Fraction SpringRun
1997	SWP	0.00	*	*	0.00	*	*
1999	SWP	0.00	*	*	*	*	*
2000	SWP	0.00	*	*	0.00	*	*
2006	SWP	0.91	0.00	0.00	*	*	*
2007	SWP	*	*	*	*	*	*
Average			0.00	0.00		*	*

To estimate the take of listed Chinook salmon and steelhead associated with Komeen or Nautique treatments, we estimated the total (all runs) Chinook salmon and steelhead in the Forebay from 1995 to 2006 during treatment times. We averaged the loss and salvage densities over the week prior to treatment, adjusted the total Chinook loss by the fractions of winter and spring run based on genetic identification, and extrapolated the loss and salvage densities to the approximate volume of water in the Forebay at treatment time. Table 13-29 is the estimated take of listed Chinook salmon and steelhead in the Forebay during Komeen or Nautique treatments.

Table 13-29 Estimated take of listed Chinook (winter and spring run), and steelhead in the Forebay during Komeen or Nautique aquatic weed treatments, 1995 – 2006.

Date	Total Chinook Take In Forebay	Winter Chinook Take In Forebay	Spring Chinook Take In Forebay	Steelhead Take In Forebay
5/15/1995	2084.46	0.00	0.00	12.54
8/21/1995	0.00	0.00	0.00	0.00
6/11/1996	264.43	0.00	0.00	0.00
9/10/1996	1.59	0.00	0.00	0.00
5/23/1997	2010.80	0.00	0.00	0.00
7/14/1997	0.00	0.00	0.00	0.00
7/13/1998	0.00	0.00	0.00	0.00
6/11/1999	520.77	0.00	0.01	32.39
7/31/2000	5.88	0.00	0.00	1.24
6/29/2001	0.00	0.00	0.00	0.00
6/24/2002	0.00	0.00	0.10	0.00
5/12/2003	2923.82	0.00	0.00	9.59
6/3/2004	24.63	0.00	0.53	0.00
5/3/2005	846.09	0.00	0.00	17.64
6/20/2005	71.94	0.00	0.53	0.00
6/1/2006	554.64	0.00	0.40	53.44
6/28/2006	1089.62	0.00	0.00	13.21

Delta Cross Channel

Juvenile salmon survival is higher when the fish remain in the Sacramento River, than when they migrate through the interior (Newman 2008), but the effect of the Delta Cross Channel (DCC) gate position is only modest. Newman's results are quoted below:

> **Results.**
>
> For the most part, the substantive conclusions from the Bayesian Hierarchical Model (BHM) analyses, summarized below, were consistent with previous USFWS analyses.
>
> **Delta Cross Channel:** There was modest evidence, 64 to 70% probability, that survival of Courtland releases, relative to the survival of Ryde releases, increased when the gate was closed.
>
> **Interior:** Survival for the interior Delta releases was estimated to be about 44% of the survival for the Sacramento River releases.

This has not been studied for steelhead, but they are likely affected in a similar manner, although to a lesser extent because steelhead emigrants are larger than Chinook. SWRCB D-1641 provides for closure of the DCC gates from February 1 through May 20. During November through January, the gates may be closed for up to 45 days for the protection of fish. The gates may also be closed for 14 days during the period May 21 through June 15. Reclamation shall determine the timing and duration of the closures after consultation with FWS, DFG, and NMFS. Consultation with the CALFED Operations Group will also satisfy the consultation requirement. The CALFED Ops Group has developed and implemented the Salmon Protection Decision Process. The Salmon Protection Decision Process depends on identifying the time when young salmon are likely entering the Delta and taking actions to avoid or minimize the effects of DCC and other Project operations on their survival in the Delta. The decision process identifies "Indicators of sensitive periods for salmon" such as hydrologic changes, detection of spring–run or spring–run surrogates at monitoring sites or the salvage facilities, and turbidity increases at monitoring sites. These actions should provide protection to both steelhead and Chinook salmon for much of their peak emigration period. Figure 13-55 and Figure 13-56 show the percent of the Sacramento River flow passing through the DCC and through Georgiana Slough during critically dry years. Figure 13-57 shows the percent continuing on down the main Sacramento River channel. During the other water year types a lower percentage of flow passes through the DCC with the lowest percentage occurring in wet years. The percentage passing through the DCC increases in the future in July through December. The increased flow through the DCC occurs when few juvenile salmon or steelhead are present in the Delta. The cross channel gate closure in February through May and low percentage passing through the channel in December and January avoids the majority of salmon and steelhead emigrating from the Sacramento system.

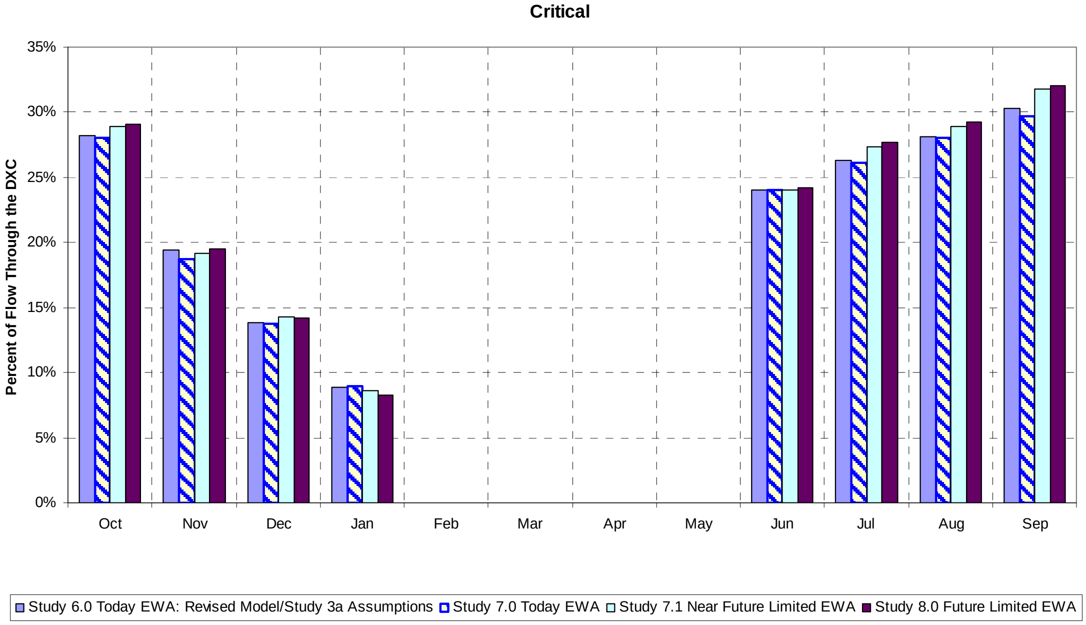


Figure 13-55 Percent of Sacramento River flow passing through the DCC during critically dry years under the three scenarios.

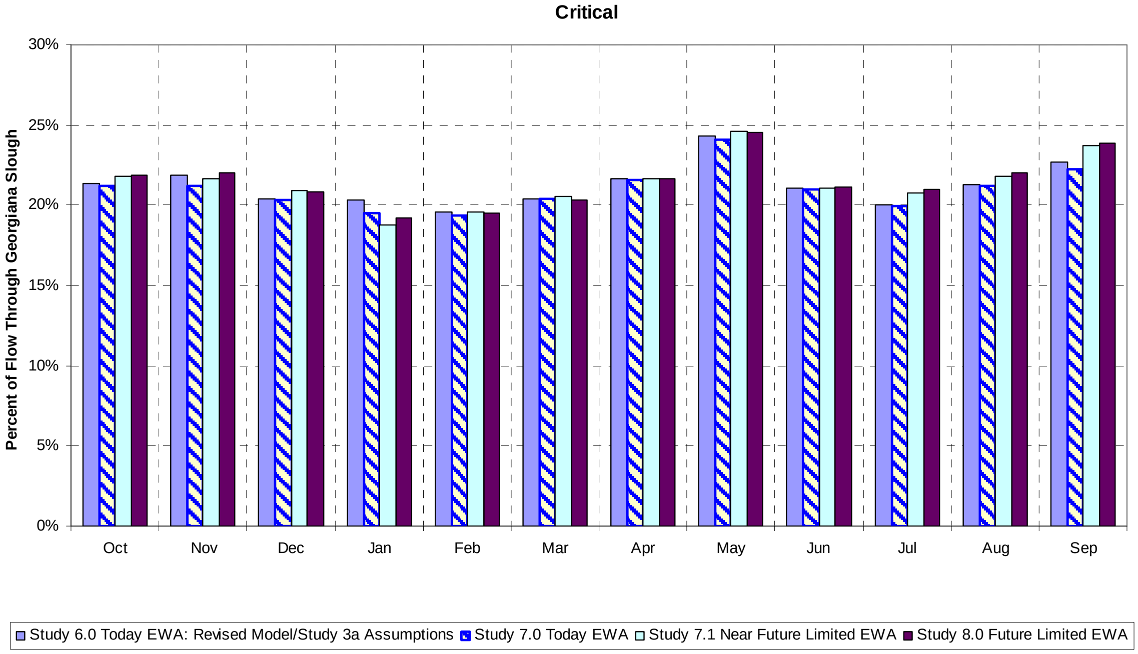


Figure 13-56 Percent of Sacramento River flow passing through Georgiana Slough during critically dry years under the three scenarios.

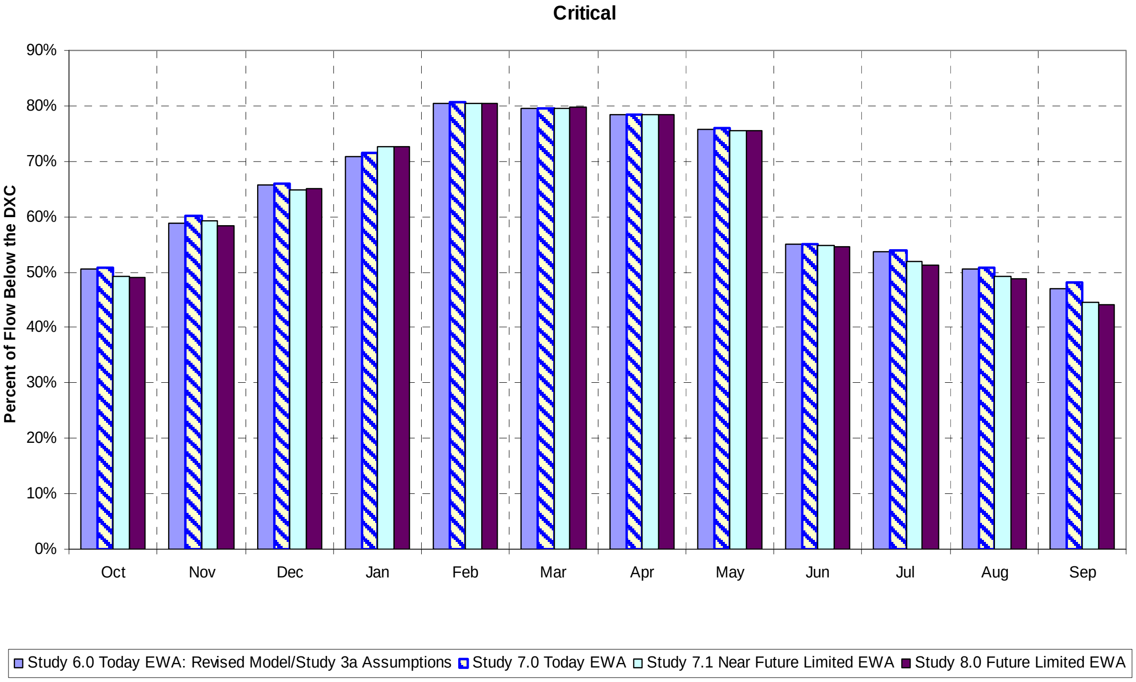


Figure 13-57 Percent of Sacramento River flow continuing down the main Sacramento River channel past the DCC and Georgiana Slough during critically dry years under the three scenarios.

North Bay Aqueduct

The maximum pumping capacity of the NBA facility is 175 cfs, but the mean is typically lower. The NBA facility has positive barrier fish screens built to DFG specifications to exclude juvenile salmon. The screens have approach velocities ranging between 0.2 and 0.4 feet per second. DFG has determined this is sufficient to prevent entrainment of juvenile salmonids. The facility is located at the end of Barker Slough, more than 10 miles from the mainstem Sacramento River. There is no information on salmonids migrating up Barker Slough.

Sommer et al. (2001b) reported the 1998 and 1999 Chipps Island survival indices were comparable to or higher for CWT Chinook released into Yolo Bypass than for fish released simultaneously in the Sacramento River. Similarly, Brandes and McLain (2001) found survival indices were higher for CWT Chinook that passed through the Steamboat-Sutter slough complex than for fish that traveled down the mainstem Sacramento River. Both Yolo Bypass and Steamboat Slough empty into Cache Slough placing fish closer to the NBA pumping plant than they would have been had they remained in the main river channel. This suggests the NBA facility does not significantly adversely impact juvenile salmonids traveling in the river or Cache Slough. The higher survival of Steamboat-Sutter smolts does not affect the conclusions of the Newman and Rice analyses.

Rock Slough Intake

CCWD diverts water from Old River via Rock Slough into the Contra Costa Canal at the Rock Slough Intake. The diversion is presently unscreened. Reclamation, in collaboration with CCWD, is responsible for constructing a fish screen at the Rock Slough Headworks under the Central Valley Project Improvement Act and under the 1993 USFWS Biological Opinion for the Los Vaqueros Project. Reclamation has received an extension on fish screen construction until December 2008, and is preparing to request a further extension until at least 2013 because the requirements for screen design will change as CCWD proceeds with its project to replace the earth-lined portion of the canal with a pipeline.

Before 1998, the Rock Slough Intake was CCWD's primary diversion point. It has been used less since 1998 when Los Vaqueros Reservoir and the Old River Pumping Plant began operating. The diversion at the headworks structure is currently sampled with a sieve net three times per week from January through June and twice per week from July through December. A plankton net is fished at the headworks structure twice per week during times larval delta smelt could be present in the area (generally March through June). A sieve net is fished at Pumping Plant #1 two times per week from the time the first Sacramento River winter-run Chinook salmon is collected at the CVP and SWP (generally January or February) through June. Numbers of listed fish species captured during monitoring are shown in Table 13-30.

The extrapolated numbers of steelhead entrained by the facility between 1994 and 1996 were low, ranging from 52 to 96 per year (Morinaka 1998). The extrapolated numbers of juvenile Chinook salmon (all races) entrained by the facility between 1994 and 1996 ranged from 262 to 642 per year (Morinaka 1998). Entrainment has decreased since Los Vaqueros Reservoir and the Old River Intake came on line in 1998 and Rock Slough Intake diversion decreased significantly. CCWD estimated entrainment levels based on salvaged fish numbers per amount of water pumped at the CVP and SWP from 1998 to 2008. They estimated entrainment within the Contra Costa Canal assuming diversions within Rock Slough of 37,700 acre feet per year for juvenile winter-run salmon are 8 per year and for juvenile spring-run salmon are 25 per year.

The Contra Costa Canal Replacement Project will replace the 4-mile unlined section of canal from Rock Slough to Pumping Plant #1 with a pipeline. ESA consultations have been completed for construction (NMFS issued its concurrence letter on June 11, 2007 and USFWS issued a BO on June 21, 2007) and the first phase of the project is scheduled to begin in the Fall of 2008. When completed, the Canal Replacement project will eliminate tidal flows into the Canal intake section and should significantly reduce entrainment impacts and improve the feasibility of screening Rock Slough.

Because most diversions at the Rock Slough intake now occur during the summer months when salmon and steelhead are not present in the vicinity of the diversion and because very few listed fish species (one winter–run Chinook, 14 spring-run sized Chinook, 6 unclipped steelhead, and one delta smelt) have been captured during monitoring from 1998 to 2008, the Rock Slough diversion is not believed to be a significant source of mortality for any of the listed species. No green sturgeon have been captured at the site.

It is expected that entrainment in the future will be reduced with the addition of CCWD's Alternative Intake Project because CCWD diversions in general during the migration period will be reduced, with most of that reduction taking place at the Rock Slough intake. (See the July 3, 2007 NMFS biological opinion on the Alternative Intake Project). Few listed runs have been captured in sampling since 1996 so take of listed runs is expected to be very low, probably fewer than 50 spring–run, 50 winter–run, and 20 steelhead. Estimates of future losses of spring-run Chinook salmon and winter-run Chinook salmon at the Rock Slough Intake with the Alternative Intake Project in service have been made assuming future CCWD demands of 188,000 af/year. Based on average densities of the salmon in channels (from monitoring programs over the past 10 years), losses were estimated at about 5 winter-run and 16 spring-run juveniles per year.

Table 13-30 Sumary of listed fish captured at the Rock Slough Headworks and Pumping Plant 1 and amount of water diverted each year, 1998 – 2008.

Summary of Sieve Net and Plankton Net Monitoring Conducted at the Rock Slough Headworks and Pumping Plant 1 (PP1) from August 1998 through March 2008.

Year	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	Totals
Months Monitoring Occurred	**Aug-Dec**	**Mar-Dec**	**Mar-Dec**	**Jan-Aug**	**Jan-Dec**	**Jan-Dec**	**Jan-Dec**	**Jan-Dec**	**Jan-Dec**	**Jan-Dec**	**Jan-Mar**	
Amount of Water Diverted at Rock Slough Acre Feet	68,683	43,037	51,421	26,749	35,904	27,302	31,283	35,686	43,273	39,366	5,848	408,552
Number of Headworks &PP1 Sieve Net Surveys	Unknown	Unknown	Unknown	Unknown	Unknown	35	102	131	133	107	54	**562**
Number of Headworks Plankton Net Surveys	Unknown	Unknown	Unknown	Unknown	10	0	34	26	15	23	10	**118**
Winter-run Chinook	Dec=1	0	0	0	0	0	0	0	0	0	0	**1**
Spring-run Chinook	0	0	0	0	0	0	Mar=1 Apr=5	May=4	May=4	0	0	**14**
Central Valley steelhead (unclipped)	0	0	0	0	0	0	0	Mar=2 Apr=1	Jan=1 Mar=1	May=1	0	**6**
Central Valley steelhead (clipped)	0	0	0	0	0	0	0	0	0	0	Feb=6 Mar=2	**8**
Central Valley steelhead (unknown)	0	0	0	0	0	0	0	Feb=1	0	0	0	**1**
Fall run/late fall run Chinook (unclipped)	0	0	May=3	0	0	0	Mar=2 Apr=3 May=1	Apr=2 May=6 Jun=1	May=1	0	0	**19**
Fall run/late fall run Chinook (clipped)	0	0	0	0	0	0	May=1	May=1	0	0	0	**2**
Green sturgeon	0	0	0	0	0	0	0	0	0	0	0	**0**
Delta smelt	0	0	0	0	0	0	0	Feb=1*	0	0	0	**1**
Longfin smelt	0	0	0	0	0	0	0	0	0	0	Mar=1**	**1**

South Delta Temporary Barriers Project (TBP)

The following evaluation is limited to the operational effects of these projects on Chinook salmon, steelhead and green sturgeon. Section 7 consultation for the construction and operation of the TBP through 2010 has been completed with NMFS. The operation effects of the TBP are being consulted upon with FWS through this OCAP BA. The construction effects requiring ESA consultation with FWS will be evaluated in a separate consultation process.

Simulation modeling completed for this OCAP Biological Assessment incorporates the effects of the South Delta Temporary Barriers Project and the 500 cfs increased export in Studies 6.1 and 7.0. The SDIP Stage 1, the 500 cfs increased export, and the CVP aqueduct intertie are incorporated into Studies 7.1 and 8.0. The Temporary Barriers are not included in Studies 7.1 and 8.0. Full evaluation of the combined effects of these elements on Chinook salmon, steelhead and green sturgeon are presented in Chapter 13. Because the simulation models examined the combination of these elements, it is not possible to separate and examine the effects of any single project element by itself. Therefore, the effects analysis for these individual projects is taken largely from prior Biological Assessments and other related consultations. These documents include: *DWR 2000 Proposed Mitigated Negative Declaration and Initial Study Temporary Barriers Project 2001-2007 and 2007 Supplemental Biological Assessment South Delta Temporary Barriers Project*. Because the modeling for these documents was conducted a few years ago, it naturally differs to some degree from what was conducted for the current OCAP Biological Assessment. However, the differences are not such that would alter any interpretation of the likely general effects of these projects individually. For clarity, provided below are brief descriptions of the projects, details of the modeling approaches for the former documents, and an assessment of likely effects.

The following information is from the 2007 Supplemental Biological Assessment. This supplement to the 2000 TBP Biological Assessment presents information and results of analyses to assess the impacts of the TBP on special status species in light of recent ESA listings by the NMFS and their subsequent request for re-initiation of consultation. This supplemental biological assessment serves to update permits prior to the installation of the temporary barriers in 2007, as required by NMFS. New permits, permit extensions and project approval were needed to continue the TBP for a fourth operation interval that began in 2008. DWR has already obtained a DFG Streambed Alteration Agreement and Incidental Take permit extending the TBP through 2010. NMFS has issued a Biological Opinion and Incidental Take permit covering the TBP from 2008 through 2010. The FWS has issued a statement extending their previous Biological Opinion and Incidental Take permit for the TBP through 2008 and will apply the OCAP BA as their basis for extending operations of the TBP beyond 2008. However the FWS will require separate consultation on the installation and removal impacts of the TBP to cover ESA beyond 2008. The US Army Corps of Engineers have issued permits based upon the NFMS and FWS responses extending the TBP through 2010.

Hydrodynamic Effects

The TBP causes changes in the hydraulics of the Delta, which may pose impacts to fish. The TBP does not alter total Delta outflow, thus the position of X2, the linear position where bottom salinity measures two parts per million in the estuary, is not affected by the project. However, the TBP does cause hydrodynamic changes within the interior of the Delta. When the barrier at the head of Old River is in place, most water flow is effectively blocked from entering Old River. This in turn increases the flow in Turner and Columbia Cuts, two major central Delta channels that flow towards the south Delta. The underlying result of this hydrodynamic change is that there is an increase in reverse flow in these and other interior Delta channels. In most instances, net flow is directed towards the CVP and SWP pumps. The directional flow towards the pumping facilities may increase the vulnerability of fish to entrainment by the pumps and local agricultural diversions. Larval and small fishes are especially susceptible to these flows.

Unfortunately, the varying operational configurations of the TBP, natural variations in fish distribution, and a number of other physical and environmental variables prohibit statistical confidence in assessing fish salvage when the TBP is operational versus when it is not. The most effective direct method for examining the effect of the hydrodynamic consequences of the TBP on fish is by examining real-time fish salvage, however statistical results are lacking.

Nobriga and others (2000) and Grimaldo (unpublished data) found that under certain conditions, salvage of delta smelt could increase dramatically when the TBP is operational. In 1996, the installation of the spring barrier at the head of Old River 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. This data indicates that short-term salvage, especially that of delta smelt and other small species and juveniles can significantly increase when the TBP is installed in such a manner that causes a sharp change or reversal of positive net daily flow in the interior south and central Delta. Tidally averaged daily flow data for the south Delta was obtained from the U.S. Geological Survey to look for similar phenomena in previous years for a variety of fish species, however nothing was found to be as dramatic as that which occurred in 1996.

The Vernalis Adaptive Management Plan (VAMP), initiated in 2000 as part of the State Water Resources Control Board’s Decision 1641, is a large-scale, 12-year, interdisciplinary experimental program designed to protect juvenile Chinook salmon migrating from the San Joaquin River through the Delta. VAMP is studying how salmon survival rates change in response to alterations in San Joaquin River flows and SWP/CVP exports with the installation of the barrier at the head of Old River. VAMP employs an adaptive management strategy to use current knowledge of hydrology and environmental conditions to protect Chinook salmon smolts, while gathering information to allow more efficient protection in the future (USFWS 2007). In each year, VAMP schedules and maintains pulse San Joaquin River flows and reduced project exports for a one month period, typically from April 15 - May 15 (May 1-31 in 2005/06). Tagged salmon smolts released in the San Joaquin River are monitored as they move through the Delta in order to determine their fate. While VAMP studies attempt to limit project impacts to salmonids, the associated reduction in exports reduces the upstream flows that occur in the south and central Delta. This reduction limits the southward draw of water from the central Delta, and thus shortens the Projects’ zone of influence with regard to the passive entrainment of fishes.

Impacts to Fish

The assessment of potential impacts to fishes is based upon the current understanding of the biology of those species that may be affected. However, as will become apparent, there are gaps in this knowledge that raise the level of uncertainty when attempting to determine project impacts. In some instances, the degree of a potential impact can not be positively determined because quantification is impossible due to the lack of critical data. The potential impacts to green sturgeon, steelhead and spring-run Chinook salmon are discussed below.

Temporary Barriers Fish Monitoring

In 1992, DFG initiated the TBP Fish Monitoring Program in order to examine the impacts of the TBP on resident fish communities in the south Delta. Ten permanent sites within the south Delta have been sampled with electrofishing and gill nets to study resident fish community composition and distribution (DWR 1998). Unfortunately, a lack of pre-project monitoring data and gear type makes an analysis of overall project impacts impossible. In addition, the gear types used are very inefficient for sampling juvenile salmonids, two of the three species of concern for this BA. This data can only be used to provide simple descriptive species presence/absence information. Similarly, a number of other fish monitoring and special study program data sets were used to assess potential impacts of the TBP. Because these other programs were not designed to specifically test TBP impacts, analysis from these data are also largely descriptive.

Since data concerning the occurrence of green sturgeon in the south Delta is greatly lacking, DWR will add a monitoring section to the annual report beginning in 2009 that would serve to help quantify the presence of salmonids and green sturgeon in the immediate vicinity of the TBP barriers. More specifically, the degree to which juvenile salmonids and green sturgeon are entrapped between the spring HOR BARRIER and the three agricultural barriers would serve to better examine potential project impacts to these fishes. The NMFS has also required a study be developed and implemented to collect this information as part of their Biological Opinion. DWR is working with NMFS on a study plan to be implemented in 2009.

Passage Impacts to Fish

Green Sturgeon. There are no data indicating which areas are used by adult and juvenile green sturgeon but salvage data does indicate they are found in the South Delta year-round and are therefore expected to be exposed to the effects of the temporary barriers over their entire eight-month installation period. Although the effects of the TBP operations on green sturgeon are not understood or predictable, it is likely that green sturgeon may become redirected by these operations, though the effect of this on their behavior, success at foraging, and susceptibility to predation is unknown. Operation of the TBP could impact on green sturgeon by restricting or altering flows which may be used as cues for spawning adults and emigrating or rearing juveniles. While the barriers could constrain movement, they do not preclude juvenile and adult green sturgeon migration into the Sacramento River and out to the Pacific Ocean. Assessing the impacts of flows resulting from the barriers requires a better understanding of sturgeon responses to flows. However, any green sturgeon caught in the interior of the south Delta during the installation of the barriers has the potential to be exposed to lowered water quality until they found their way out of the south Delta or the barriers are removed in the fall. No estimates of the number of individuals rearing in the South Delta are available so the population level impact is unknown.

Spring-run Chinook Salmon. Adult spring-run Chinook salmon migrate through the estuary and into the Sacramento River Basin to spawn from March-September (Moyle 2002). Although their timing overlaps the TBP operating period of April-November, they are unlikely to use the interior Delta as a migration corridor, and therefore are not expected to be impacted by the project. In 2001 and 2003 the DFG tracked tagged fall-run Chinook salmon as they migrated out of the estuary. While most stayed within the Sacramento River, a few were observed to stray into the central and north Delta before continuing up the Sacramento River. Eight tagged individuals were observed exiting the Delta via the San Joaquin River (DFG 2007). It appears that even San Joaquin River basin fall-run Chinook salmon migrate upstream mainly through the mainstem of the San Joaquin River rather than through Delta sloughs. This may be a result of reverse flow conditions in south Delta channels, including Old River, Middle River, and others that occurs during the TBP operating season (DFG 2007). Hallock and others (1970) found that the majority of San Joaquin River basin Chinook salmon migrated through the mainstem river and not through other Delta channels. Additionally, DFG Fish Monitoring data suggests that adult salmon are rare in the south Delta. Large mesh drift nets were used to monitor the presence of fall- and late fall-run adult Chinook salmon during September 1997 and 1998 at Grant Line Canal, Middle River, and Old River at Tracy. In over 74 hours of sampling, only a single adult Chinook salmon was captured.

Juvenile spring-run Chinook salmon are also unlikely to experience a migration impact caused by the TBP. Although some show up in annual salvage at the south Delta fish facilities, juvenile spring-run originate in the Sacramento River basin and are not likely to occur in the south Delta in numbers significant to their population size. The Delta Cross Channel Gates are currently operated in a manner to greatly minimize the potential for spring-run smolts to enter the central Delta. Thus, direct passage impacts are unlikely for juvenile spring-run Chinook salmon. The section on hydraulic impacts below will further discuss potential impacts to juvenile salmonids out-migrating from the Sacramento River.

Steelhead. The TBP may pose a significant passage problem for steelhead. Several monitoring programs indicate that both adult and juveniles might be present in the south Delta during times when the TBP is operational. However, the degree of impact is difficult to quantify. As aforementioned, San Joaquin basin Chinook salmon are known to migrate predominately through the San Joaquin River rather than other peripheral Delta channels. Although similar information is not available for steelhead, it is likely that they also travel primarily through the San Joaquin River because the DFG TBP Fish Monitoring Program never observed a single steelhead outside of the San Joaquin River in over eight years of sampling. A potential passage problem cannot be ruled out, due to the lack of information on adult steelhead migration routes and timing. However, notches constructed into the barriers for fall-run Chinook salmon passage provide an equal benefit to any adult steelhead that might occur downstream of the barriers during TBP operations in the fall.

The best indicator of juvenile steelhead presence in the south Delta is SWP salvage. Annual steelhead salvage increases slightly in the fall, peaks in January through May, and then declines significantly into the summer (DWR 2000a). Some juvenile steelhead migrating downstream in the San Joaquin River may become temporarily trapped upstream of the agricultural barriers following removal of the spring HOR barrier by June 1 of each year, and in years when the spring HOR barrier is not installed. This blockage is temporal in nature, since the three agricultural barriers are regularly overtopped by higher tide stages, during which time downstream passage is possible. In addition to maintaining adequate upstream water levels, overtopping of the agricultural barriers will also benefit fishes temporarily held upstream by slightly lowering water temperatures and replenishing dissolved oxygen levels until passage is achieved. An inherent risk exists for any outmigrating juvenile salmonids that pass from the San

Joaquin River into Old River and the south Delta due to Delta pumping, regardless of TBP operations. Although the number of juveniles that become temporarily trapped in this area is expected to be insignificant to their numbers in the San Joaquin River, those that pass downstream of the agricultural barriers face additional risks of entrainment by the Projects.

Predation Impacts to Fish

The physical presence of the TBP may attract piscivorous fishes and influence predation on special status fish species. However, past studies by the DFG TBP Fish Monitoring Program has indicated that predation on special status fish species near the Temporary Barriers is negligible (DWR 2000a). The top predatory fish in the Delta, the striped bass, primarily feed on threadfin shad and smaller striped bass, as adults. Having highly opportunistic diets, striped bass are known to consume about anything that is in high abundance (Moyle 2002). Rearing-age green sturgeon and other fish much larger than 10 cm escape predation by most adult striped bass (Nelson et. al. 2006).

Water Quality Impacts to Fish

Monitoring of water quality parameters have been conducted during the DFG TBP Fish Monitoring of the study area and also by DWR as part of the DWR annual TBP Monitoring Reports. These studies have found that water quality is not significantly impacted by the TBP (DWR 2000a). In general, electrical conductivity (EC) is slightly higher upstream of the TBP facilities than downstream. This is mostly due to the fact that Sacramento River water is drawn to the south Delta when the TBP is operational. Sacramento River water has generally lower EC than the San Joaquin River and thus improves water quality within the south Delta, downstream of the TBP facilities. Hydrodynamic and water quality modeling has shown that EC in the south Delta increases when SWP pumping decreases (DWR 2000b). The decreased pumping reduced the draw of Sacramento River water in the south Delta and thus water quality “degraded” in the form of increased EC.

Dissolved oxygen (DO) sags have occurred in the project area during years when the TBP was both operational and when it was not, over the same time period. The DO sags appear to be related to increased water temperatures in the summer and have even occurred in high outflow years such as 1998 (DWR 1999). Data from the 1997 fish monitoring water quality element suggest that the TBP does not promote low DO upstream of the facilities (DWR 1998). At the Old River at Tracy (ORT) barrier from March through August, DO levels above the barrier were lower on the flood tide than they were on the ebb tide. This can occur above the ORT barrier whenever flood tides are not strong enough to push enough water over and through the ORT barrier weir and culverts to increase circulation toward the head of the Grant Line Canal. The ORT barrier height is 2.0 feet MSL, while the other two agricultural barriers are at 1.0 feet MSL, a design meant to force circulation up Old River and down the Grant Line Canal. When flood tides are not strong enough, null zones can occur upstream of the ORT barrier due to a combination of weak tides and agricultural diversions. These null zones are areas of low circulation where EC can increase and DO levels can be lower than on the downstream side of the barrier.

Water impounded upstream of the three agricultural barriers is seasonally warmed into the 70-80+ °F range, depending on location, from May – October. There is a concern that fishes that become trapped upstream of the agricultural barriers and are therefore susceptible to high water temperatures.

According to Mayfield and Cech (2004) 1-3 year old rearing juvenile green sturgeon prefer water at 59-61 ºF, tolerate temperatures up to 65 ºF, and likely perish in water that is 72 ºF or higher. Since green sturgeon occurrence is expected to be rare in the south Delta, they are not expected to be greatly impacted by increased temperatures. Although the HOR BARRIER installation is timed to prevent salmonid smolts from emigrating from the San Joaquin River into the south Delta at Old River, a small limited number are expected to be impacted.

Vulnerability to Local Agricultural Diversions

Fish that may become trapped upstream of the TBP agricultural barriers may suffer increased vulnerability to local agricultural diversions. There are numerous local diversions within the southern Delta that are generally most active from April through October (Cook and Buffaloe 1998), the same time period of TBP operation. However, there are many agricultural diversions on the downstream side of the barriers in the central and northern delta as well, consequently, whether there is a difference in vulnerability upstream versus downstream of the TBP agricultural barriers is unknown.

The Interagency Ecological Program (IEP) conducted a Delta Agricultural Diversion Study from 1993 through 1995 in attempt to determine the impacts of in-Delta diversions on resident and anadromous fish (Cook and Buffaloe 1998). No delta smelt, green sturgeon, or salmonids were captured in the fyke net. Overall, threadfin shad, catfish and sunfish were the dominant species captured, comprising over 99 percent of the total catch.

Similar sampling of diversions in other regions of the Delta (Cook and Buffaloe 1998) has captured small numbers of delta smelt, Chinook salmon, splittail. These data suggest that fish vulnerability, especially delta smelt, to in-Delta diversions increases when fish density is high in the immediate vicinity of the diversion. The fact that presumably no species considered under this supplemental B.A. were entrained in the diversion within the TBP area is probably due to the fact that their densities were extremely low in this area during the study period. It can be expected that a few of these fishes will be entrained into local diversions however; the overall impact is expected to be minimal based upon the results of the IEP study.

Impacts to Potential Fish Prey Items

The conditions posed by the TBP may influence the abundance and distribution of food items used by green sturgeon, steelhead, and juvenile spring- and winter-run Chinook salmon. Although their diet in the Delta has not been extensively studied (Sasaki 1966), steelhead and juvenile Chinook salmon likely feed on a variety of aquatic insects and crustaceans as well as small fish. Green sturgeon feed primarily on benthic crustaceans (i.e. amphipods), shrimp, clams, annelid worms and miscellaneous crabs and fishes (Moyle 2002, Kelly et. al. 2006).

The extent to which the distribution and abundance of these organisms will be influenced by the conditions posed by the TBP is difficult to determine. Orsi and Mecum (1986) found that copepod and cladoceran abundance was correlated with chlorophyll a concentration and temperature, but not with net flow or velocity. Such impacts are expected upstream of operating barriers, where occurrence of green sturgeon and salmonids is not expected. Mysid shrimp abundance is strongly related to temperature, salinity, and food supply (Orsi and Mecum 1986, Obrebski and others 1992, Kimmerer and Orsi 1996). 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 impacted. These data suggest that the TBP probably will not influence prey populations within the Delta.

Past Measures

Under Terms and Conditions 1 (e) of the USFWS Biological Opinion (4/26/96), DWR was required to install at least three fish screens on agricultural diversions per year in the Delta. To date, DWR has installed a total of 14 screens on agricultural diversions and has capped another diversion at Sherman Island, for a total of 15 screens (3 screens per year for the permit period). DWR also contributed to funding a study that examined the entrainment patterns of two side-by-side screened and unscreened diversions at Sherman Island. DWR will continue the operation and maintenance of all 14 fish screens that have been installed at Sherman Island. The previously mentioned DWR study on the entrainment patterns of two side-by-side screened and unscreened diversions at Sherman Island provided evidence that screens can protect fish from entrainment into agricultural diversions (Nobriga and others 2000).

Under Terms and Conditions 3 of the USFWS Biological Opinion (4/26/96), DWR was required to mitigate for the footprint of the Grant Line Canal barrier. DWR fulfilled this requirement by acquiring a 1:1 ratio of 0.064 acres of riparian scrub, 0.011 acres of shaded mudflat, 0.411 acres of shallow water, and 0.250 acres of intertidal vegetation at Kimball Island.

Under Condition 11 of the DFG 1601 Agreement (5/2/96), DWR was required to mitigate for the impact to shallow water habitat. DFG agreed to credit the Kimball Island mentioned above habitat purchase to satisfy this mitigation requirement.

Under Condition 16 of the DFG 1601 Agreement (5/2/96), DWR was required to screen two agricultural diversions in the Bay-Delta Estuary. The fish screen project at Sherman Island fulfilled this requirement.

An additional conservation measure will be to notch each of the agricultural barriers similar to the HORB fall barrier to provide passage for migrating adult salmon that have strayed into Old and Middle Rivers and Grant Line Canal.

South Delta Improvement Program Operable

The following assessment identifies potential effects of operating the gates with the implementation of Stage 1 of the South Delta Improvements Program (SDIP) on Chinook Salmon, Steelhead and Sturgeon in the Delta. SDIP Stage 1 consists of the installation and operation of gates at four locations in the south Delta. There is no increase in the export diversion rate in Stage 1. Stage 2 includes the operable gates with the increase in exports up to 8,500 cfs.

ESA consultation for the operation of the SDIP gates in Stage 1 is being done within this OCAP BA. ESA consultation for the potential construction-related, predation and passage effects will be done separately. The operational effects are discussed and the other effects summarized in the subsequent text.

Simulation modeling completed for this OCAP BA incorporates the effects of the South Delta Temporary Barriers Project and 500 cfs increased export in Studies 6.1 and 7.0. The SDIP Stage

1, the 500 cfs increased export, and the CVP aqueduct intertie are incorporated into Studies 7.1 and 8.0. A full evaluation of the combined effects of these elements on Chinook salmon, steelhead and green sturgeon are presented in Chapter 13. Because the simulation models examined the combination of these elements, it is not possible to separate and examine the effects of any single project element by itself. Therefore, the effects analysis for the SDIP Stage 1 is taken largely from *South Delta Improvements Program Action Specific Implementation Plan* (DWR and USBR 2006), and the *South Delta Improvements Program EIS/EIR* (DWR and USBR 2006), http://baydeltaoffice.water.ca.gov/sdb/sdip/documents/final_eis_eir.cfm. The effects of operation of the gates are discussed in the following text. Details on the hydrodynamics of the SDIP operable gates are in Appendix Z.

South Delta Improvements Project (SDIP) – Stage 1

Permanent gates would be constructed at the head of Old River and in Middle River, Grant Line Canal, and Old River at the Delta Mendota Canal (DMC). Construction of the gates includes grading the channel bank, dredging the channel bottom, constructing sheet-pile cofferdams or an in–the-wet construction method, driving foundation piles, and placing riprap, concrete, and other materials on the channel bank and bottom.

Dredging for all of the permanent gates would occur between August and November. Cofferdams would also be placed in the channel during the August through November timeframe. Work outside of the channel and within the cofferdams, if used, is assumed to occur during any month.

Dredging of Middle River and portions of Old River would increase the tidal conveyance capacity of the channels. Tidal flow velocity may be slightly reduced in West Canal and, depending on existing channel constrictions, circulation may be increased in Middle River, Old River, and Grant Line Canal.

The operation of the permanent flow control gates on Middle River, Grant Line Canal, and Old River would maintain water surface elevation above 0.0 feet msl during April 15 through November. Under current conditions, tides range from about 1.0 foot below mean sea level to 3.0 feet msl two times each day. The maximum change in SWP pumping (and CCF operations) could reduce the daily higher high tide from about 2.6 to 2.4 feet msl near the CCF gates. The reduction in higher high tide attributable to change in SWP pumping is less with distance from the CCF gates. When closed during tide levels below 0.0 feet msl, the flow control gates block fish passage. When opened during tide levels greater than 0.0 feet msl, fish passage is restored. The volume of water exchanged during each tidal cycle is reduced by about 20% for the channels upstream of the gates on Middle River, Grant Line Canal, and Old River.

During the spring, the head of Old River fish control gate would be operated to block flow and movement of juvenile fall-run Chinook salmon and other fishes from the San Joaquin River into Old River from April 15 through May 15, or other periods as recommended by USFWS, NOAA Fisheries, and DFG. Juvenile Chinook salmon move down the San Joaquin River past Stockton, a pathway believed to enhance survival relative to movement into Old River (Brandes and McLain 2001).

During fall, the head of Old River fish control gate would be operated to increase flow in the San Joaquin River past Stockton from about September 15 through November 30. The increased flow in the San Joaquin River potentially improves water quality, including increased dissolved oxygen (DO), in the San Joaquin River channel near Stockton (Giulianotti et al. 2003). Improved water quality could benefit upstream migrating adult Chinook salmon.

Central Valley Chinook Salmon - Operational and Passage Effects

Effects of Gate Operation on Juvenile and Adult Chinook Salmon Migration

The head of Old River fish control gate would be closed from April 15 to May 15 under both Alternative 1 (No Action) when flow in the San Joaquin River is less than 5,000 cfs and in SDIP Stage 1 (Alternative 2A within the SDIP EIR/EIS) when San Joaquin River flow is less than 10,000 cfs. Under Alternative 1, a temporary fixed barrier is constructed and removed each year. Under SDIP Stage 1, a gate structure would be constructed with operable gates that would allow a range of operations. Gate closure would minimize the movement of juvenile Chinook salmon into Old River. Although the effects of gate closure are similar for both Alternative 1 and SDIP Stage 1, the operable gate constructed under SDIP Stage 1 would provide increased opportunities (i.e., longer closure) for fish protection. The increased flexibility to operate the fish control gate is also considered a beneficial effect.

The head of Old River fish control gate may also provide benefits to adult Chinook salmon during upstream migration in September, October, and November. Hallock (1970) observed that adult Chinook salmon avoided water temperatures greater than 66°F if DO was less than 5 mg/l. Low DO in the San Joaquin River channel near Stockton may delay migration of fall-run Chinook salmon. High San Joaquin River flows past Stockton maintain higher DO levels (Hayes and Lee 2000). Closure of the head of Old River fish control gate increases the San Joaquin River flow past Stockton, but the increase in flow during years with low-to-average flow (less than 1,000 cfs) appears to have minimal effect on DO levels. Available data indicate that the operation of flow control gates could reduce DO in the San Joaquin River near Stockton during the summer, but closure of the head of Old River fish control gate September 15 through November 30 would result in DO levels that are the same for Alternative 1 and SDIP Stage 1. Migration of adult Chinook salmon would be protected. Although the benefit of closing the head of Old River fish control gate to upstream movement of adult fall-run Chinook salmon is uncertain for all flow conditions, an operable gate constructed under SDIP Stage 1 would provide increased opportunities to evaluate the potential effects of increased flow under a wide range of San Joaquin River flow conditions. The increased flexibility of an operable gate is a beneficial effect.

Gates in Middle River, Grant Line Canal, and Old River at the DMC could affect access to rearing habitat in the south Delta channels and passage through the channels by adult and juvenile Chinook salmon during operation from April 15 through November. Operation of the gates, however, generally avoids the period of adult and juvenile Chinook salmon movement through the Delta, except during May and June when juvenile Chinook salmon could be affected. During May, the proposed closure of the head of Old River Gate would transcend the effects of the gates on Middle River, Grant Line Canal, and Old River at the DMC. In addition, the gate operations would have a beneficial effect relative to the existing temporary barriers. The existing temporary barriers are in place from mid-May through September and may also be in place in April to mid-May and in October and November, although the culverts on the Grant Line Canal barrier are tied open. Tidal flow overtops the barriers twice each day during the portion of tide that exceeds 1 foot msl. High tide approaches 3 feet msl, and total tidal volume in the channels upstream of the barriers is reduced by about 50 percent. The gates constructed under SDIP Stage 1 would operate from May through September. The gates would be open at tide elevations between 0.0 feet msl and about 3 feet msl, an increase in the tidal period currently allowed by the temporary barriers. Total tidal volume would approach 80% of the tidal volume without gates in place. Operable gates would have a beneficial effect on movement of adult and juvenile Chinook salmon because of the potential management flexibility and increased period of access to Middle River, Grant Line Canal, and Old River (i.e., passage conditions are provided at water surface elevations exceeding 0 feet msl under SDIP Stage 1 versus passage provided at elevations exceeding 1 foot msl under Alternative 1). The increased flexibility of an operable gate is a beneficial effect.

Effects of Head of Old River Gate Operation on Juvenile Chinook Salmon Entrainment

Closure of the head of Old River fish control gate during April 15th – May15th under SDIP Stage 1 would direct juvenile Chinook salmon down the San Joaquin River during most of the peak out-migration period. Installation of the temporary barrier reduces the number of juvenile Chinook salmon salvaged compared to years when the temporary barrier was not installed (San Joaquin River Group Authority 2003). Although the difference in the estimated survival with and without the gate is not statistically significant, relative survival for juvenile Chinook salmon migrating down the San Joaquin River has been about twice the survival for Chinook salmon migrating down Old River (Brandes and McLain 2001; Baker and Morhardt 2001).

Whether or not the gate alone would substantially minimize entrainment-related losses of juvenile fall-run Chinook salmon from the San Joaquin River, however, is currently not well supported. The gate closure results in additional flow from the San Joaquin River channel into Turner Cut, Middle River, and Old River channels to supply the CVP and SWP pumps. There is currently no clear correlation between SWP and CVP pumping and survival of juvenile Chinook salmon moving through the Delta in the lower San Joaquin River (Baker and Morhardt 2001).

Construction-Related Effects on Chinook Salmon

Chinook salmon rear in the Delta. Construction of the gates in the south Delta and maintenance activities have the potential to permanently modify shallow vegetated areas that may provide rearing habitat for Chinook salmon. The permanent gates constructed under SDIP Stage 1 would have minimal effect on habitat within the construction footprint at the head of Old River, Middle River, and Old River at DMC. Construction of the temporary barriers has previously modified shallow water habitat. Three of the four permanent gates would be constructed in the same location as the temporary barriers and would result in little change in habitat quality and quantity relative to Alternative 1.

Construction of a new gate on Grant Line Canal, which would be located in a different location than the temporary barrier, and the proposed dredging in West Canal, Middle River, and Old River potentially would remove and modify existing shallow vegetated habitat. Relative to historical extent, existing availability of shallow vegetated areas is limited. Therefore loss of additional shallow vegetated area that may represent rearing habitat for Chinook salmon could contribute to the historical loss and to an ongoing adverse effect. The site currently used for the temporary Grant Line Canal barrier will be abandoned which would eventually offset some of the shallow vegetated habitat losses associated with the placement of the permanent operable gate.

Predation Effects on Chinook Salmon

Predation associated with the addition of the operable gates and the agricultural intake extensions to the south Delta channels could cause a small and likely negligible increase in mortality of the juvenile Chinook salmon moving past the structures. The determination is based on several factors. Design elements will minimize turbulence that could disorient fish and increase vulnerability to predation. The structures would not create conditions that could concentrate juvenile Chinook salmon. Flow velocity would be similar to velocities within the channel upstream and downstream of the gates and agricultural intake extensions.

The transition zones between various elements of the gates (e.g., sheetpiles and riprap) could provide low-velocity holding areas for predatory fish. Predatory fish holding near the gates and agricultural intakes could prey on vulnerable species. The additional predator habitat created by the gates and intake extensions would have a minimal effect on juvenile Chinook salmon because the increase in potential predator habitat is small relative to habitat in adjacent areas, including the habitat currently created by the temporary barriers and habitat at the existing agricultural intakes. Disorientation and concentration of juvenile fish would be minimal given the size and design of the gates.

Effects of Head of Old River Gate Operation on Juvenile Central Valley Steelhead Migration

Closure of the head of Old River fish control gate would minimize the movement of juvenile steelhead into Old River. Although the effects of gate closure are similar for both Alternatives 1 and 2A, an operable gate constructed under SDIP Stage 1 would provide increased opportunities for fish protection in response to new information on fish survival for variable flows and migration pathways. The increased flexibility is a beneficial effect.

The head of Old River fish control gate may also provide benefits to adult steelhead during upstream migration in September through November. The head of Old River gate structure is designed with vertical-slot fishway. The fishway would be approximately 40 feet long and 10 feet wide and constructed with reinforced concrete. The ladder would be closed during the spring and opened during the fall, through November. Stoplogs would be used to close the fishway.

The benefits would be similar to those described above for adult Chinook salmon relative to movement in the San Joaquin River past Stockton. An operable gate constructed under SDIP Stage 1 would provide increased opportunities to evaluate the potential effects of increased flow and effects on DO levels under a wide range of San Joaquin River flow conditions. The increased flexibility of an operable gate is a beneficial effect.

Construction Effects on Steelhead

Steelhead rear primarily in natal reaches upstream of the Delta and are not expected to rear for substantial periods in the Delta. Therefore, construction activities in the Delta would not affect steelhead rearing or food resources for steelhead. Contaminants associated with construction activities, including gate construction, placement of riprap, dredging, and maintenance dredging, could be introduced into the south Delta channels and could adversely affect steelhead during migration. However, environmental commitments, including an erosion and sediment control plan, Stormwater Pollution Prevention Plan, hazardous materials management plan, spoils disposal plan, and environmental training, will be developed and implemented before and during construction activities. These environmental commitments would substantially reduce the likelihood of any considerable contaminant input. Construction of the gates would also include placement of sheetpiles and riprap and could directly injure fish present during the time of construction. Dredging could entrain and injure juvenile steelhead. Cofferdams, if used, could trap juvenile steelhead. Steelhead that become trapped inside the cofferdams could be killed during desiccation of the construction area and other construction activities. Direct injury associated with construction and maintenance activities, including dredging, would have a minimal effect on steelhead. This determination is based on the fact that 1) in-water construction, including the construction of a cofferdam, would occur between August and November, 2) the area of construction activity is small relative to the channel area providing passage through the south Delta, 3) in-water construction and dredging would occur over a relatively short period (i.e., about 3 years), and 4) most juvenile and adult steelhead would move away from construction activities and into adjacent habitat of similar quality.

Predation Effects on Steelhead

Construction of gates and extension of agricultural intakes would add permanent structure and cover to the south Delta channels. The addition of structure has the potential to increase the density of predator species and predation on steelhead moving around and past the structure. Predation associated with the addition of the operable gates and the agricultural intake extensions to the south Delta channels could cause a small and likely negligible increase in mortality of the juvenile steelhead moving past the structures. The determination is based on the fact that 1) design elements will minimize turbulence that could disorient fish and increase vulnerability to predation, 2) the structures would not create conditions that could concentrate juvenile steelhead, and 3) flow velocity would be similar to velocities within the channel upstream and downstream of the gates and agricultural intake extensions. The increase in potential predator habitat is small relative to habitat in adjacent areas, including the habitat currently created by the temporary barriers and habitat at the existing agricultural diversion intakes.

Passage Effects on Steelhead

Closure of the head of Old River fish control gate would minimize the movement of juvenile steelhead into Old River. In comparison to the existing temporary barriers, an operable gate would provide increased opportunities for fish protection in response to new information on fish survival for variable flows and migration pathways. The increased flexibility is a beneficial effect. The head of Old River fish control gate may also be available to provide benefits to adult steelhead during upstream migration in September through November. The benefits would be similar to those described for adult Chinook salmon relative to movement in the San Joaquin River past Stockton. Hallock (1970) observed that adult Chinook salmon avoided water temperatures greater than 66°F if DO was less than 5 mg/l. Low DO in the San Joaquin River channel near Stockton may delay migration of fall-run Chinook salmon. High San Joaquin River flows past Stockton maintain higher DO levels (Hayes and Lee 2000). Closure of the head of Old River fish control gate increases the San Joaquin River flow past Stockton, but the increase in flow during years with low-to-average flow (less than 1,000 cfs) appears to have minimal effect on DO levels. The operation of flow control gates could reduce DO in the San Joaquin River near Stockton during the summer, but closure of the head of Old River fish control gate September 15 through November 30 would result in DO levels that are the same for the existing temporary barriers and for the operable gates. Migration of adult Chinook salmon and steelhead would be protected. An operable gate would provide increased opportunities to evaluate the potential effects of increased flow and effects on DO levels under a wide range of San Joaquin River flow conditions. The increased flexibility of an operable gate is a beneficial effect.

Operational Effects on Green Sturgeon

Operational effects on adults that migrate in February or March would be avoided because gate closure would not occur until April 15th. Furthermore, adults that use the San Joaquin River channel as a migration corridor would be unaffected by gate operation during all months because the gates would not affect fish passage in the San Joaquin River. The following assessment, therefore, focuses on the potential effects of the design and operation of the gates on adult and juvenile movement.

The flexible operation of the permanent flow control gates in Middle River, Grant Line Canal, and Old River at DMC will have a beneficial effect on green sturgeon movement relative to the existing temporary barriers. The existing temporary agricultural barriers are in place from mid-May, mid-April if the barrier at the head of Old River is in place, possibly through November. They must be removed by November 30th. They are constructed of rock and include culverts with flap-gates that are pushed open and close under tidal influences. The barriers operate as raised weirs at a fixed elevation that likely block the movement of green sturgeon. Under current operations of the temporary barriers, green sturgeon entrainment upstream of the barriers would only be possible when tidal flows overtop the barriers or if they pass through the culverts. Currently there is no information as to whether or not green sturgeon are capable of migrating over or through the temporary barriers during flood tides.

The permanent gates constructed under the SDIP would be open at tide elevations between 0.0 foot msl and about +3 foot msl, an increase in the tidal period currently allowed by the temporary barriers. Operable gates would have beneficial effects on the movement of adult and juvenile green sturgeon because the period of access to Middle River, Grant Line Canal, and Old River would increase relative to the period of access provided by the existing temporary barriers. Passage of green sturgeon would be expected when the Obermeyer gates are down because the gate panels would sit flat on the channel bottom and sturgeon would have access via articulated concrete mats over the riprap on the upstream and downstream sides of the gate.

The head of Old River gate will be operated from mid-April to mid-May and during June through November. The HOR gate would be operated in the spring as a fish barrier to keep juvenile San Joaquin River fish from entering Old River where they presumably are more vulnerable to entrainment by diversions, including the SWP and CVP pumps. Operation during June through November would be to improve flow in the San Joaquin River to avoid time of low DO. Under baseline conditions, a temporary fixed barrier is constructed each spring and/or fall. Under the SDIP, a gate would be constructed with operable bottom-hinged gates that would allow a range of operations.

Construction Effects on Green Sturgeon

The area of green sturgeon habitat affected by the gate footprints, rip-rapped levee, and dredging may total several acres. However, construction of the permanent gates would have minimal effect on green sturgeon habitat and prey availability within the construction footprint at the head of Old River, Middle River, and Old River near the DMC because construction of the temporary barriers has previously modified channel habitat. Three of the four permanent gates would be constructed in the same location as the temporary barriers and would result in little change in habitat and prey quality and quantity relative to existing conditions. Construction of a new gate on Grant Line Canal and the proposed dredging in West Canal, Middle River, and Old River potentially would remove and modify existing shallow vegetated areas and channel bottom substrate, however the area affected by gate construction and riprap placement is small relative to availability of similar vegetated areas and bottom substrates in adjacent channel reaches. Contaminants associated with construction activities, including gate construction, placement of riprap, dredging, and maintenance dredging, could be introduced into the south Delta channels and could adversely affect adult green sturgeon during migration and juveniles rearing in the Delta. However, Environmental commitments, including an erosion and sediment control plan, Stormwater Pollution Prevention Plan, hazardous materials management plan, spoils disposal plan, and environmental training, will be developed and implemented before and during construction activities. These environmental commitments would substantially reduce the likelihood of any considerable contaminant input. Construction of the gates would also include placement of sheet-piles and riprap and could directly injure fish present during the time of construction. Dredging could entrain and injure green sturgeon. Cofferdams, if used, could trap juvenile and adult green sturgeon. Direct injury associated with construction and maintenance activities, including dredging, would have a minimal effect on green sturgeon. This determination is based on the fact that 1) the area of construction activity is small relative to the channel area in-water construction, 2) dredging would occur over a relatively short period (i.e., about 3 years) and be limited to the August to November timeframe, and 3) most juvenile and adult green sturgeon would move away from construction activities and into adjacent habitat of similar quality.

Predation Effects on Green Sturgeon

Increased predation could be associated with the addition of the operable gates and the agricultural intake extensions to the south Delta channels. Design elements, however, will minimize turbulence that could disorient fish and increase vulnerability to predation. The structures would not create conditions that could concentrate green sturgeon. The increase in potential predator habitat is small relative to habitat in adjacent areas, including the habitat currently created by the temporary barriers and habitat at the existing agricultural diversion intakes. Disorientation and concentration of juvenile fish would be minimal given the size and design of the gates.

Passage Effects on Green Sturgeon

The Sacramento River provides a migration pathway between freshwater and estuarine habitats for green sturgeon, however; there is currently no available data about the migratory paths of adult or juvenile green sturgeon through the Sacramento-San Joaquin Delta. If green sturgeon migrate through the South Delta, the gate closures could restrict the movement of green sturgeon into the Sacramento River and out to the Pacific Ocean. However, closure of the Old River fish control gate would not preclude juvenile and adult sturgeon movement between the San Joaquin River upstream and downstream of Old River and the Sacramento River or Pacific Ocean. Boat locks that are regularly opened at the Head of Old River gate may also provide some passage for sturgeon.

Suisun Marsh Salinity Control Gates

The Suisun Marsh Salinity Control Gates could potentially be operated September through May, overlapping with an expected November through May spring–run Chinook salmon emigration. However, juvenile Chinook salmon of all races are rare in Suisun Marsh and are therefore unlikely to be substantially affected by gate operations. Examination of the UC Davis Suisun Marsh Monitoring databases showed only 257 juvenile Chinook salmon were captured from 1979 through 1997.

The infrequent occurrence of young Chinook in the marsh suggests that predation associated with migration delays is unlikely to significantly affect the spring–run or winter–run population. As support for this hypothesis, only three Chinook salmon were found in the stomachs of striped bass and pikeminnow captured near this facility between 1987 and 1993 (DWR 1997).

Although young Chinook salmon will probably not be significantly affected by gate operations, it is possible upstream passage of adults could be influenced. Adult winter–run and spring–run may pass through the marsh channels from December through May when their migration could potentially be delayed. The SMSCG Steering Group decided based on preliminary results from the modified SMSCG tests that the slots resulted in less adult passage than the original flashboards. The modification made for the 2001-02 control season was to leave the boat lock at the SMSCG open at all times.

SMSCG Fish Passage Study

The SMSCG were constructed and operate under Permit 16223E58 issued by the US Army Corps of Engineers which includes a special condition to evaluate the nature of delays to migrating fish. Ultrasonic telemetry studies in 1993 and 1994 showed that the physical configuration and operation of the gates during the Control Season have a negative effect on adult salmonid passage (Tillman et al 1996: Edwards et al 1996).

The Department coordinated additional studies in 1998 - 1999, and 2001- 2004 to assess potential measures to increase the salmon passage rate and decrease salmon passage time through the gates. Monitoring results from the 1998 and 1999 studies indicate that the flashboards modified with horizontal slots did not improve salmon passage at the SMSCG (Vincik et al., 2003). Results in 2001, 2003, and 2004 indicated that leaving the boat-lock open during the Control Season when the flashboards are in place at the SMSCG and the radial gates are tidally operated provided nearly equivalent fish passage to the Non-Control Season configuration when the flashboards are out and the radial gates are open (Vincik et al., 2005). This approach minimized delay and blockage of adult Sacramento River winter-run Chinook salmon, Central Valley spring-run Chinook salmon, and Central Valley steelhead migrating upstream during the Control Season while the SMSCG is operating. However, the boat-lock gates would be closed temporarily to stabilize flows to facilitate safe passage of watercraft through the facility.

USBR and DWR are continuing to coordinate with the SMSCG Steering Committee in identifying water quality criteria, operational rules, and potential measures to facilitate removal of the flashboards during the Control Season that would provide the most benefit to migrating fish. However, the flashboards would not be removed during the Control Season unless it was certain that standards would be met for the remainder of the Control Season without the flashboards installed.

The SMSCG could be operated as needed to meet State salinity standards in the marsh September through May, overlapping with an expected January through May peak emigration of steelhead through the Delta. However, young steelhead are rare in Suisun Marsh and are therefore unlikely to be substantially affected by gate operations. Examination of the UC Davis Suisun Marsh Monitoring databases revealed six steelhead were captured from 1979 through 1997. Only two of the six were sub-adult sized fish. The very low number of steelhead in the samples is partly due to poor capture efficiencies of the beach seines and otter trawl used in the UC Davis survey. However, 1,505 splittail greater than 200 mm, were collected by UC Davis sampling during the same period. Both adult splittail and yearling steelhead are excellent swimmers and are inefficiently sampled by the gear types used in this program. The much higher incidence of adult splittail in the samples suggests steelhead are relatively rare in the marsh. Furthermore, the marsh sampling collected more adult steelhead (4) than yearlings (2). The adults are larger and faster and therefore sampled less efficiently, providing additional evidence that yearling steelhead seldom occur in Suisun Marsh. The very infrequent occurrence of steelhead in the marsh suggests predation associated with migration delays is unlikely to significantly affect the steelhead population. As support for this hypothesis, steelhead were not listed as a prey item of striped bass or Sacramento pikeminnow captured near this facility between 1987 and 1993 (DWR 1997).

Morrow Island Distribution System

The 1997 FWS BO issued for dredging of the facility included a requirement for screening the diversion to protect delta smelt. Due to the high cost of fish screens and the lack of certainty surrounding their effectiveness at MIDS, DWR and Reclamation proposed to investigate fish entrainment at the MIDS intake with regard to fishery populations in Goodyear Slough and to evaluate whether screening the diversion would provide substantial benefits to local populations of listed fish species. DWR staff monitored fish entrainment from September 2004 to June 2006 at the MIDS in Suisun Marsh to evaluate entrainment losses at the facility.

Monitoring took place over several months under various operational configurations to provide data on the site-specific impact of the MIDS diversion with a focus on delta smelt and salmonids. Over 20 different species were identified during the sampling, yet only two fall-run sized Chinook salmon (south intake, 2006) from entrained water were caught. Two species that are associated with instream structures, threespine stickleback and prickly sculpin, comprised most of the entrained fish. DWR and Reclamation staff will continue coordination with the fishery agencies to address the screening requirement.

Reclamation and DWR continue to coordinate with the FWS, NMFS, and DFG regarding fish entrainment at this facility. The objective remains to provide the greatest benefit for aquatic species in Suisun Marsh.

Goodyear Slough

Studies suggest that Goodyear Slough is a marginal, rarely used habitat for special-status fishes. Therefore, implementation and/or monitoring of a tidal restoration project elsewhere is emerging as the most beneficial and pratical approach (in lieu of installing and maintaining fish screens). Restoration of tidal wetland ecosystems is expected to aid in the recovery of several listed and special status species within the marsh and improve food availability for other pelagic organisms.

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 (CVP) 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. Juvenile salmonids are rarely present in the Delta in these months, so no increase in salvage due to water transfers during these months is anticipated. Water transfers could be beneficial if they shift the time of year that water is pumped from the Delta from the winter and spring period to the summer, avoiding periods of higher salmonid abundance in the vicinity of the pumps. Some adult salmon and steelhead are immigrating upstream through the Delta during July through September. Increased pumping is not likely to affect immigrating adults because they are moving in a general upstream direction against the current. For transfers that occur outside of the July through September period, all current water quality and pumping restrictions would still be in place to limit effects that could occur.

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 13-58 and Figure 13-59 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.

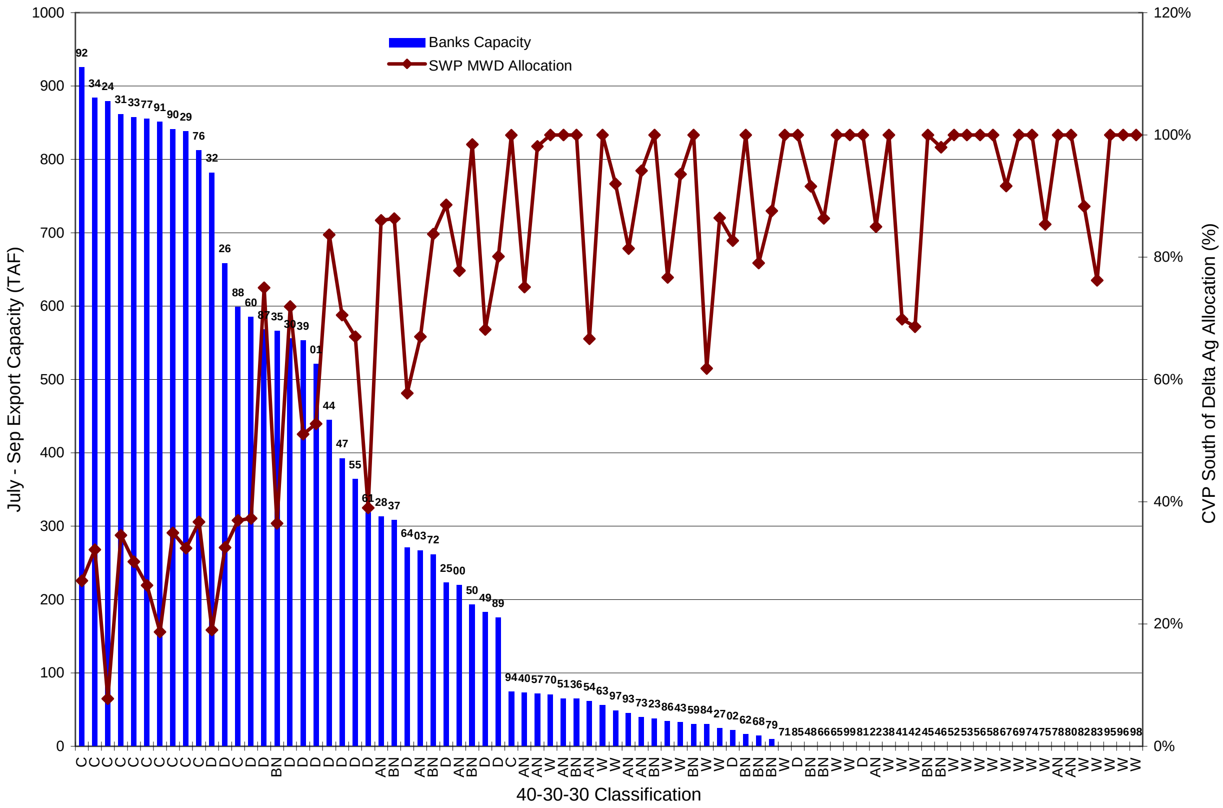


Figure 13-58 Available Export Capacity at Banks Pumping Plant

From Figure 13-58, the most capacity at Banks will be available 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 13-59) 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.

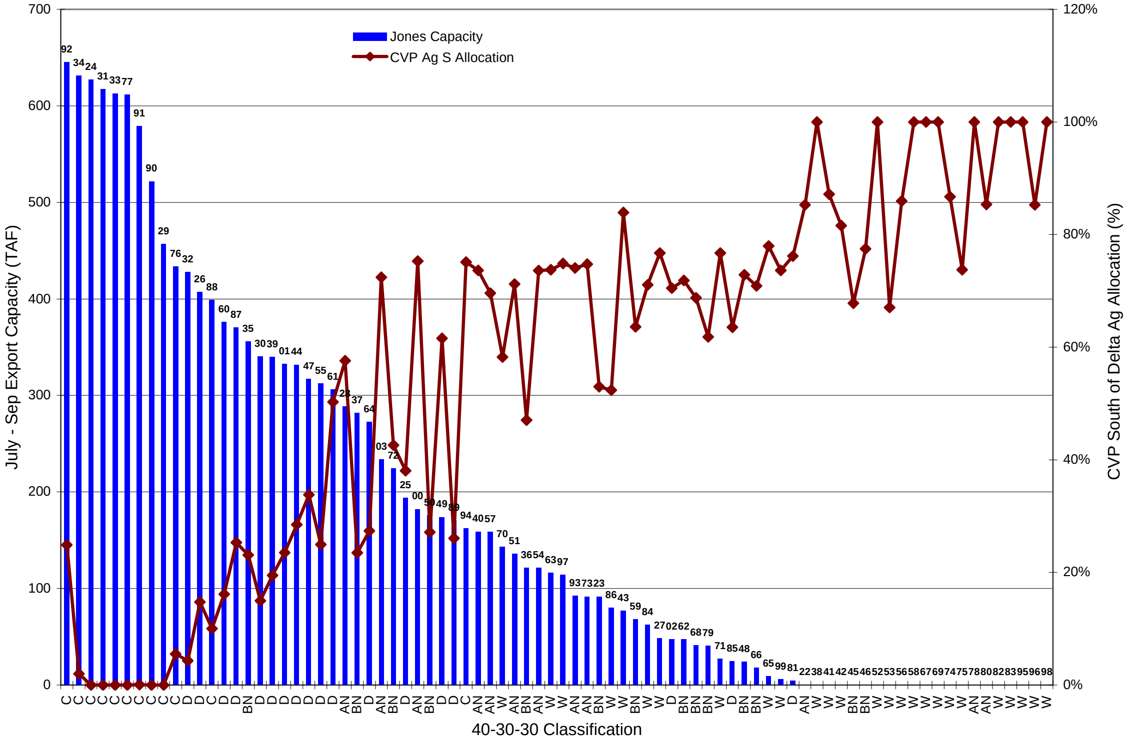


Figure 13-59 Available Export Capacity at Jones Pumping Plant

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 theestimated 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 taf
Consecutive Dry	up to 600 taf
Dry after Critical	up to 600 taf
All other Years	up to 360 taf