RECLAMATION
Managing Water in the West

Proposal for a Revised Method for Calculating Cumulative Salvage Index Values

For Incidental Take of Adult Delta Smelt in the U.S. Fish and Wildlife Service 2008 Biological Opinion

U.S. Department of the Interior
Bureau of Reclamation

August 2014

Mission Statements

The mission of the Department of the Interior is to protect and provide access to our Nation's natural and cultural heritage and honor our trust responsibilities to Indian Tribes and our commitments to island communities.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public

Purpose

The objective of this proposal is to provide a rationale for why the United States Fish and Wildlife Service's (the Service) Incidental Take Statement should include more years in its calculation of anticipated incidental take of adult Delta Smelt. The Incidental Take Statement falls under the 2008 Biological Opinion with Reasonable and Prudent Alternative (RPA) actions to avoid jeopardy to the species, adverse modification of critical habitat and provide a statistical method by which this can be achieved.

Background

In their 2008 Biological Opinion, the Service determined that the coordinated operations of the State Water Project (SWP) and Central Valley Project (CVP) would likely jeopardize the continued existence of Delta Smelt (*Hypomesus transpacificus*) and result in adverse modification of critical habitat. In concordance with a jeopardy determination, the Service developed an RPA to avoid the likelihood of jeopardizing the continued existence of the species and the destruction or adverse modification of critical habitat. Components 1 and 2 of the RPA require reduced exports, as indexed by Old and Middle River flows (OMR), when entrainment risk of Delta Smelt increases. Entrainment risk is assessed on a weekly basis by the Smelt Working Group (SWG). The SWG consists of representatives from the Service, California Department of Fish and Wildlife, California Department of Water Resources (DWR), and the U.S. Bureau of Reclamation (Reclamation). The SWG evaluates multiple real-time metrics such as: physical data, river inflows, exports, and smelt distribution in order to provide an OMR recommendation to the Service for consideration when implementing RPA actions. OMR recommendations can range from

-1250 cfs to -5000 cfs, and OMR cannot go more negative than -5000 cfs once RPA Action 2 is triggered. The Biological Opinion contains an Incidental Take Statement (ITS) which determines the amount of annual adult and juvenile Delta Smelt incidental take anticipated under the operations of the SWP and CVP with the implementation of the RPA. The estimated salvage of Delta Smelt at the fish screening facilities associated with the CVP and SWP intakes is used as a surrogate for actual entrainment of smelt at the intakes, which is presently unmeasured. Take is expressed in terms of salvage[1], and is used to both calculate the incidental take limit and measure take. If take exceeds the incidental take limit (ITL), Reclamation and DWR must reinitiate consultation with the Service to determine appropriate measures for protecting smelt while operating the projects.

[1] Salvage represents the total number of fish collected at the Skinner Fish Facility (SWP) and Tracy Fish Collection Facility (CVP).

The ITS for adult Delta Smelt was developed with the objective of estimating the amount of take expected for the RPA action under Component 1[2]. Through an examination of historical salvage trends, the Service selected a subset of years (2006, 2007, 2008) as the basis for expected take under the RPA using the cumulative salvage index approach (CSI; see below for details). These years were selected because they represented years when OMR flows were similar to the RPA threshold

(-5000 cfs) and the population abundance index was similar to levels observed in the post Pelagic Organism Decline era (Sommer et al. 2007). Since the Biological Opinion was released, new scientific information in the form of investigations and statistical models have improved both the knowledge of factors that affect entrainment and increased predictability of adult Delta Smelt salvage patterns (timing and magnitude) at the SWP and CVP (Grimaldo et al. 2009; Sommer et al. 2011; Murphy and Hamilton 2013). In light of this new information, Reclamation has reviewed the three years used to generate the ITS to determine if they appropriately captured variability in conditions that can generate the highest entrainment risk or salvage. Reclamation has concluded that the three years selected do not adequately capture high entrainment risk conditions and, more specifically, do not represent variability in salvage observed during first flush conditions in which Delta Smelt movement following the first storms of the season often result in high salvage events (Grimaldo et al. 2009). First flush conditions are characterized as periods following the first rainfall that measurably increases Delta outflow[3] (~25,000 to 75,000 cfs) and elevated turbidities throughout the Delta. During and after first flush events, Delta Smelt move upstream and are broadly distributed. Years with first flush conditions typically present high entrainment risk and are years when the RPA conditions for adult Delta Smelt would be triggered and in effect for the duration of RPA actions[4]. Thus, not including the CSIs from these years for inclusion in the ITS could underestimate take expected in these year types, even if the RPA is implemented at more conservative targets (i.e., OMR more positive than -5000 cfs).

The rationale provided in the Biological Opinion[5] for not using CSIs from more historical years, including years that had first flush conditions, indicated that these years had OMR flows that were more negative than -5000 cfs and had high salvage numbers. Thus, CSIs from these years were not considered for inclusion in the ITS calculation because salvage and OMR flows were not representative of levels desired under the RPA. The objective of this proposal is to demonstrate an approach for incorporating CSIs from years with high entrainment risk conditions as a more robust way to estimate adult Delta Smelt take expected under the RPA. Ultimately, this information could be used to revise the adult Delta Smelt ITS to

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[2] Biological Opinion Page 287

[3] Delta outflow is the sum of river flow from the watershed that exits the Delta. See http://www.water.ca.gov/dayflow/documentation/dayflowDoc.cfm

[4] See Actions 1 (page 329) and 2 (page 352) of the Biological Opinion

[5] Biological Opinion Pages 385-386

more accurately reflect take expected under variable hydrodynamic conditions that affect distribution and entrainment. The proposed approach only applies for adult Delta Smelt take, not juvenile take.

How is the ITL Calculated?

To express incidental take with implementation of the RPA actions, the Service scaled cumulative adult salvage (CS) to abundance using the abundance indices provided by the prior year's Fall Mid-Water Trawl

($FMWT_{t-1}$) survey[6]. This scaling was termed the cumulative salvage index (CSI):

$$CSI_t = \frac{CS_t}{FMWT_{t-1}} = \frac{\Sigma_j (SWP_{t,j} + CVP_{t,j})}{FMWT_{t-1}}$$

(a)

$SWP_{t,j}$ and $CVP_{t,j}$ are expanded salvage estimates[7] for day j in the period from December 1 of year $t-1$ through March 31 of year t.

The Service then averaged the three CSI values for 2006-2008 to produce a multiplier (Υ_T) for determining the allowable incidental take (IT) take for the projects each year (IT_t):

$$IT_t = \Upsilon_T \, FMWT_{t-1}$$

(b)

Where Υ_T is multiplied against the FMWT index value for year t, the result yields the Incidental Take Limit for year t+ 1.

The CSI values averaged to generate Υ_T for the Biological Opinion (pgs. 384-5) were 8.3 for the 2005-2006 entrainment season, 0.88 (2006-2007), and 12.6 (2007-2008), which yielded a multiplier of 7.25. Υ_T was subsequently corrected to 8.63 after a math error was found in the original computation[8]. Thus the incidental take calculation is:

$$IT_t = 8.63 * FMWT_{t-1}$$

(c)

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[6] The FMWT is the monitoring survey conducted by Department Fish and Wildlife.The FMWT is used to gauge annual abundance trends.

[7] Salvage counts are made every few hours (typically every 4 hrs) and expanded to a count for the day. See methods section from Grimaldo et al. 2009 for how this is calculated.

[8] http://www.the Service.gov/sfbaydelta/documents/memorandum_ocap_incidental_take_statement_correction_2013-02-22.pdf

Do the three years used for the CSI produce a multiplier representative of the full range of entrainment risk conditions?

Environmental conditions during the onset of winter storms and fish behavior influence the distribution and subsequent entrainment risk of adult Delta Smelt (Grimaldo et al. 2009). Pre-spawn fish that move into the south Delta (Figure 1) will face an elevated entrainment risk which increases exponentially with increased reverse OMR flow. Whether Delta Smelt continue towards the south Delta pumps depends on a number of factors including hydrodynamics and habitat conditions. Under very high Delta outflow (~ 75,000 cfs or above), adult Delta Smelt often remain downstream of the Delta, presumably because they can find suitable freshwater spawning habitat in the Suisun Bay area and Napa River (Figure 1). Under extremely dry conditions, adult Delta Smelt distribution is less variable, either they remain in the lower Sacramento River and/or move into the Cache Slough Complex. A hypothesized mechanism for this response in drier years is that Delta Smelt actively avoid moving into the south Delta during dry years unless there is a gradient of higher turbidities and perhaps other water quality conditions (Burau and Bennett 2014). Thus, during extreme wet and critically dry water types, entrainment risk is very low (see Figure S7 from the Biological Opinion[9]). Entrainment risk is highest in the in-between years where Delta outflow averages between 25,000 and 75,000 cfs, especially during years when there are pronounced first flush (i.e., winter run-off) events (Grimaldo et al. 2009). Note, however, that hydrology and transport is complex and short term events may create a "turbidity bridge" between the north and south Delta even in dry years.

As previously mentioned, the years selected for the basis of the CSI multiplier deserve further attention because two of the years do not represent conditions when entrainment risk is an issue. In fact, these years represent low entrainment risk periods when the RPA actions either would not be triggered or would be off-ramped altogether[10]. In 2006, the Delta Smelt population was largely distributed in Suisun Bay and the west Delta (Figure 1) when Delta outflow was high (Figure 2), which resulted in relatively low salvage. Overall, 2005-2006 was considered a very low entrainment risk season and the RPA actions would have been temporarily suspended due to the high outflows despite negative OMR flows over the four month averaging period (Dec-Mar; Figure 2). In effect, the 2006 CSI (8.3) is what can be expected under a wet year hydrology, which has only occurred in approximately 4 of the 20 historical years (1995, 1997, 1998, 2006, and 2011) for which we have reliable Delta Smelt salvage data[11].

[9] the Service Biological Opinion Page 162
[10] the Service Biological Opinion Pages 339-340, 352-354
[11] the Service Biological Opinion Page 204

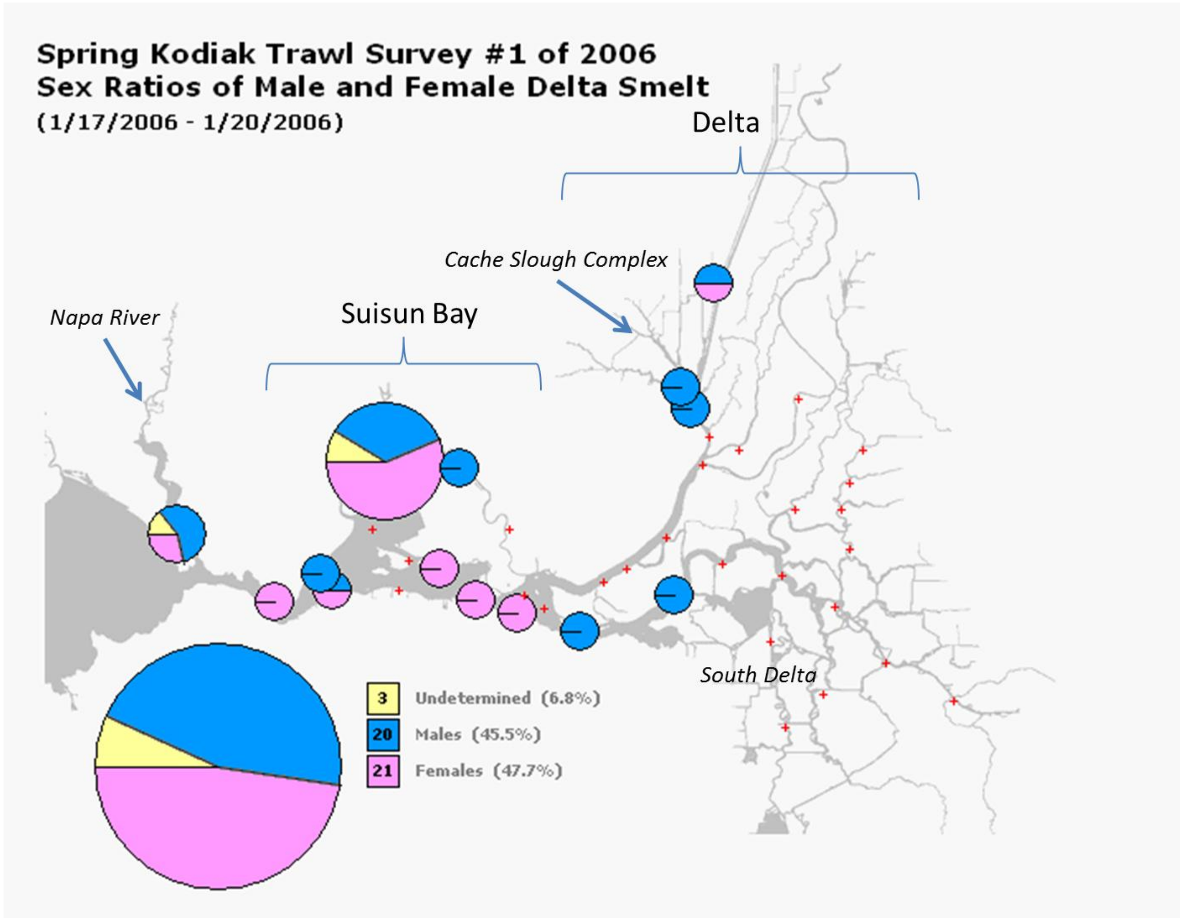

Figure 1. Distribution of adult Delta Smelt (females in pink, males in blue, and unknowns in yellow) over a 4 day period in the Suisun Bay/Delta region from the Spring Kodiak Survey[12] #1 2006.The size of the circles represent relative catch at each site. Sites with no catch are represented by red stars.

12 Spring Kodiak Trawl survey: http://www.dfg.ca.gov/delta/projects.asp?ProjectID=SKT

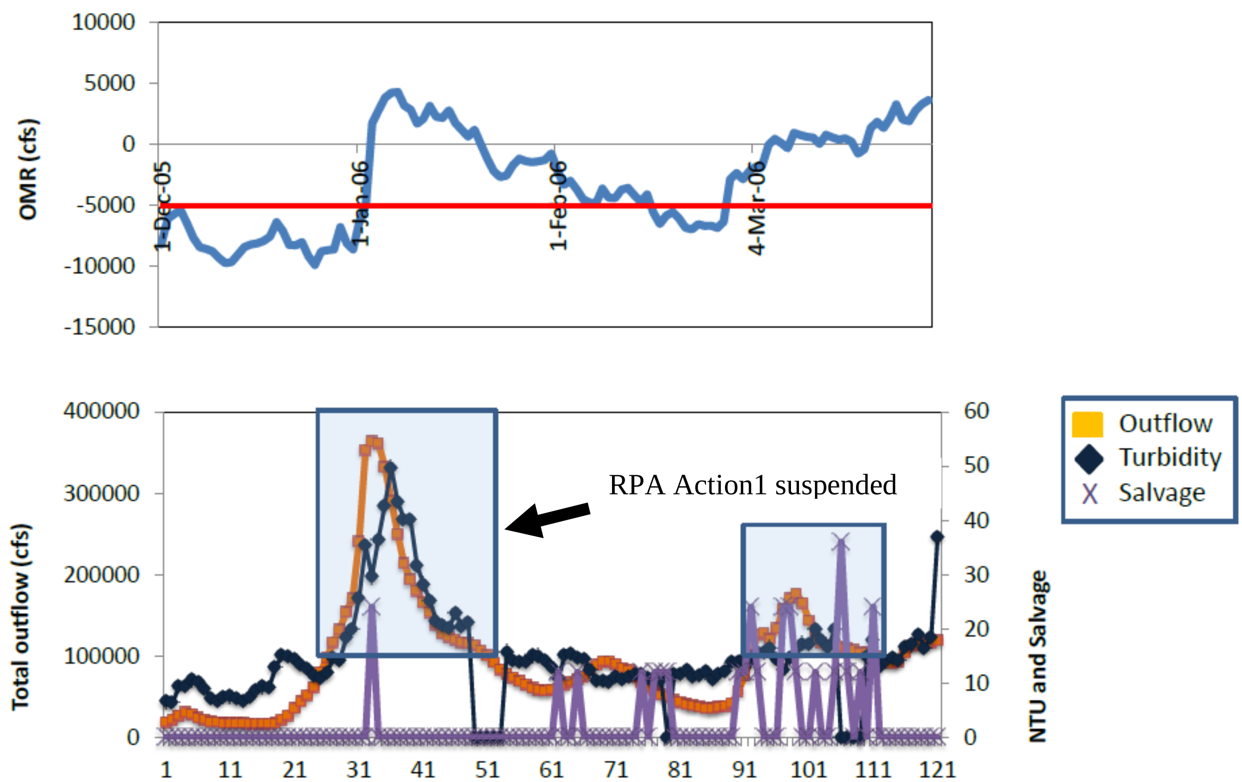

Figure 2. Old and Middle River flows (OMR) for 121 days beginning December 1st 2005. The red line represents the -5000 cfs Reasonable and Prudent Alternative (RPA) action. Total outflow (cfs), Clifton Court Forebay turbidity (NTU) and salvage for both State Water Project and Central Valley Project. The shaded area represents when conditions would have warranted suspension of the RPA action.

In contrast, 2007 was a dry year with low Delta outflow, low turbidity and low salvage (Figure 3). The adult population was mostly distributed in Suisun Bay and Cache Slough Complex, far from the SWP and CVP zone of influence[13] (Figure 4). Turbidity was well below the 12 NTU trigger, which suggests that the RPA actions may not have been triggered until March. The 2007 CSI was representative of conditions under extremely dry conditions. Similar dry years have occurred in approximately 4 out of 20 years in the historical record (1994, 2007, 2013, and 2014).

[13] Zone of influence is the area where exports directly affect net flow (and fish within the water) towards the SWP and CVP facilities.

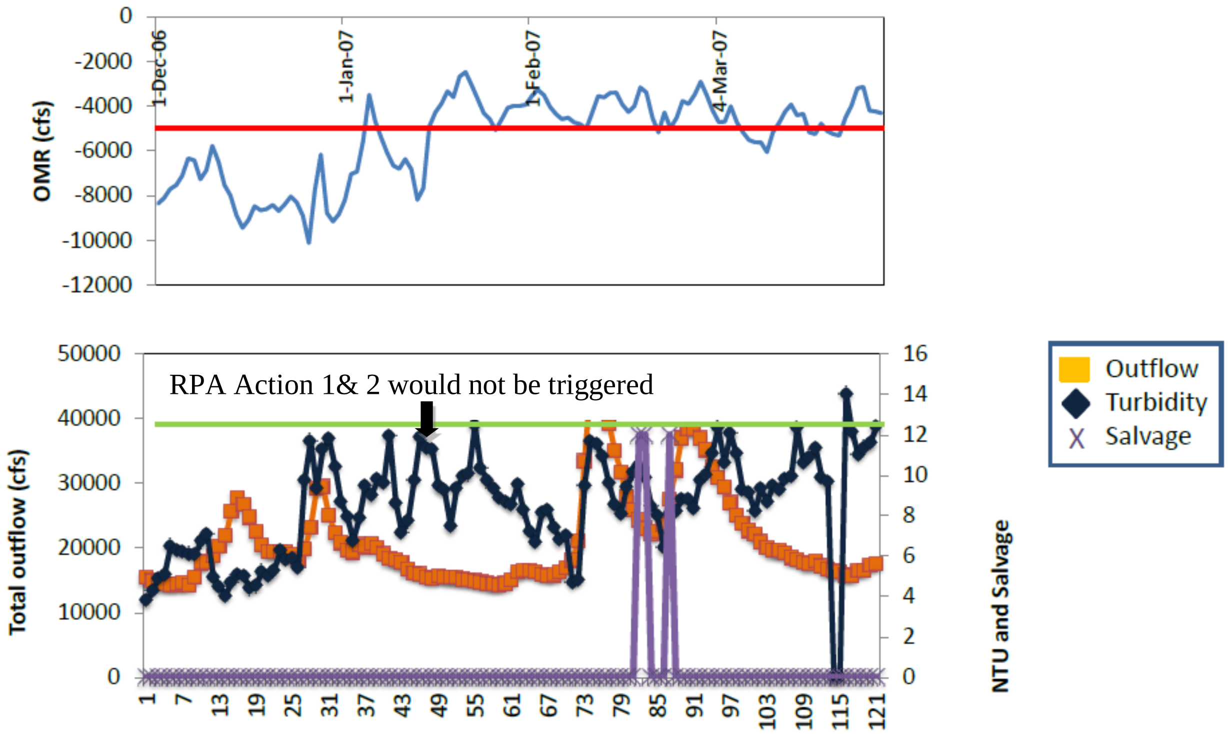

Figure 3. Old and Middle River flows (OMR) for 121 days beginning December 1st 2006. The red line represents the -5000 cfs Reasonable and Prudent Alternative (RPA). Total outflow (cfs), Clifton Court Forebay turbidity (NTU) and salvage for both State Water Project and Central Valley Project. The shaded area represents when conditions would have warranted suspension of the RPA actions.

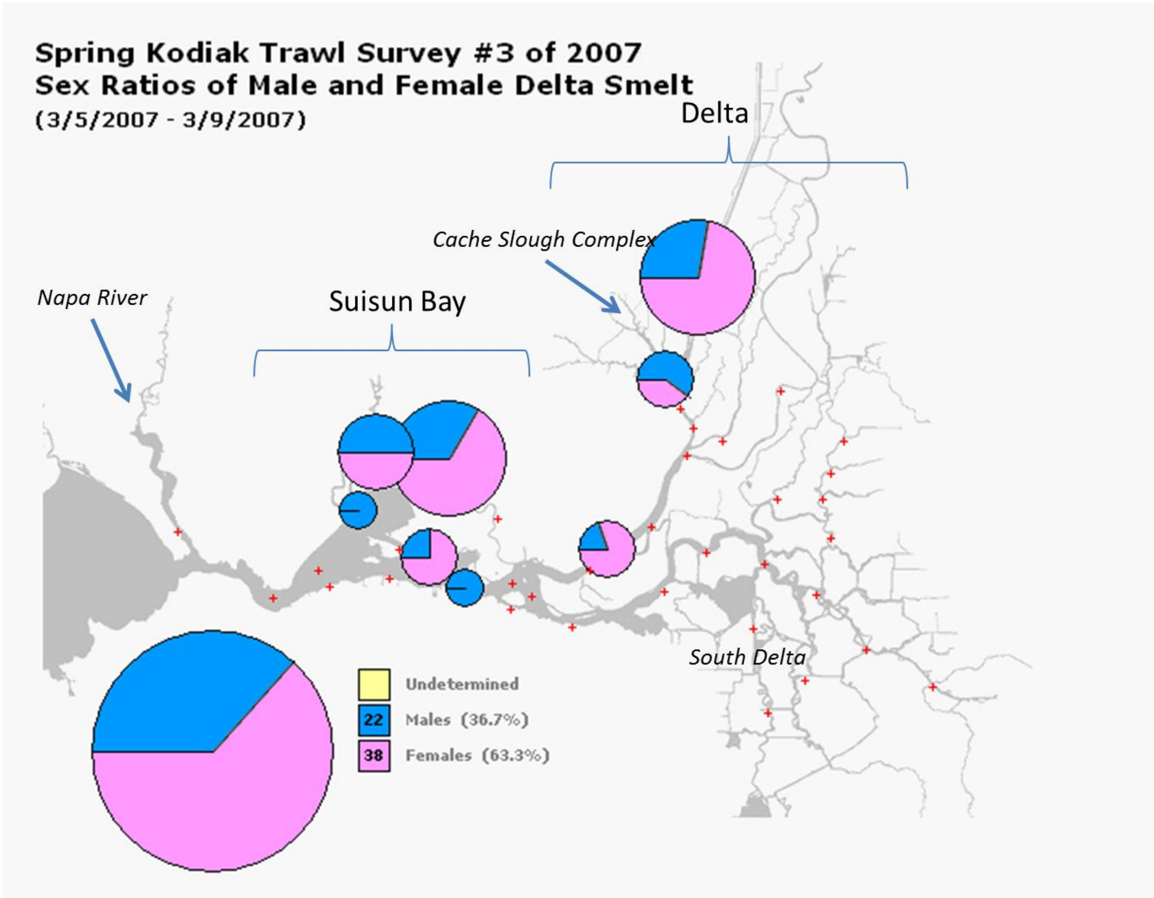

Figure 4. Distribution of adult Delta Smelt (females in pink, males in blue, and unknowns in yellow) over a 4 day period in the Suisun Bay/Delta region from the Spring Kodiak Survey #3 2007.The size of the circles represents relative catch at each site. Sites with no catch are represented by red stars.

2008 is the only year that is representative of conditions likely to trigger the RPA for the entire period (Dec-Mar; Figure 5). First flush conditions, marked by elevated turbidities (> 12 NTU) and outflow (> 25,000 cfs), resulted in adult Delta Smelt distributions that created elevated entrainment risk concerns14. Adult Delta Smelt were widely distributed (i.e, in Suisun Bay and Cache Slough Complex) but many moved into the central Delta within the zone of influence of the SWP and CVP (Figure 6). Although 2008 was a year where entrainment risk was elevated, using it to represent all high entrainment risk year types would not appropriately characterize the combination of outflows and turbidities that generate some of the highest entrainment risk conditions (Figure 7).

[14] See workgroup notes; http://www.the Service.gov/sfbaydelta/documents/smelt_working_group/SWG_recommendation_3-March-08.pdf

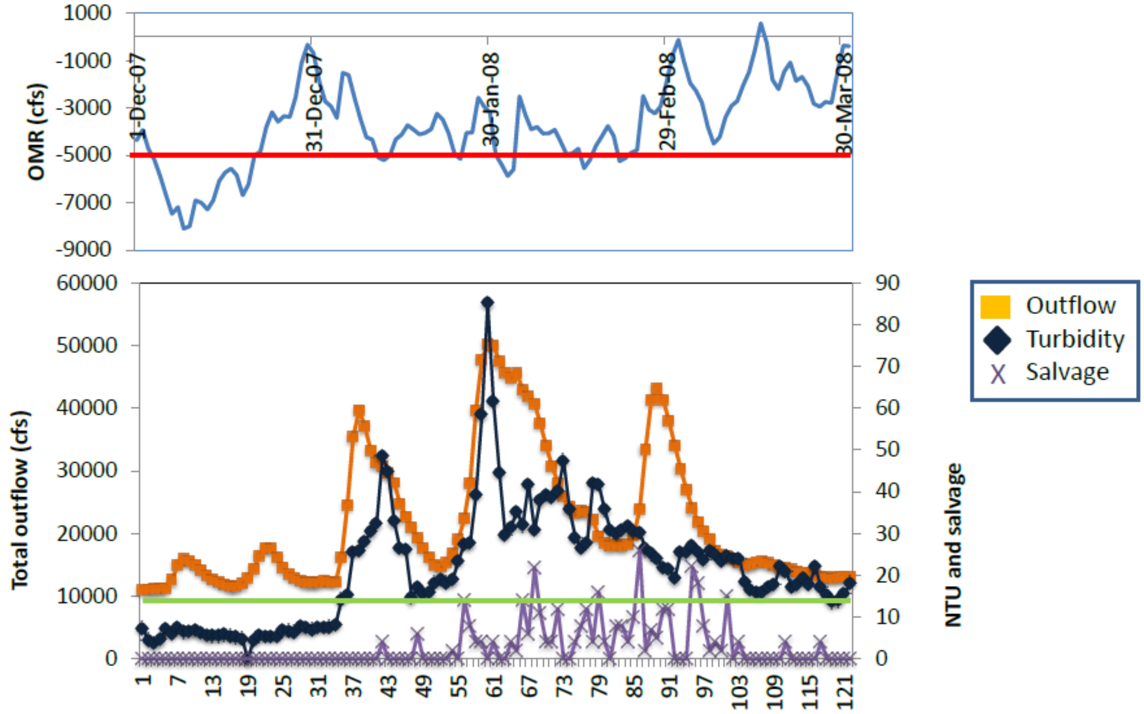

Figure 5. Old and Middle River flows (OMR) for 121 days beginning December 1st 2007. The red line represents the -5000 cfs Reasonable and Prudent Alternative (RPA). Total outflow (cfs), Clifton Court Forbay turbidity (NTU) and salvage for both State Water Project and Central Valley Project. The shaded area represents when conditions would have warranted suspension of the RPA.

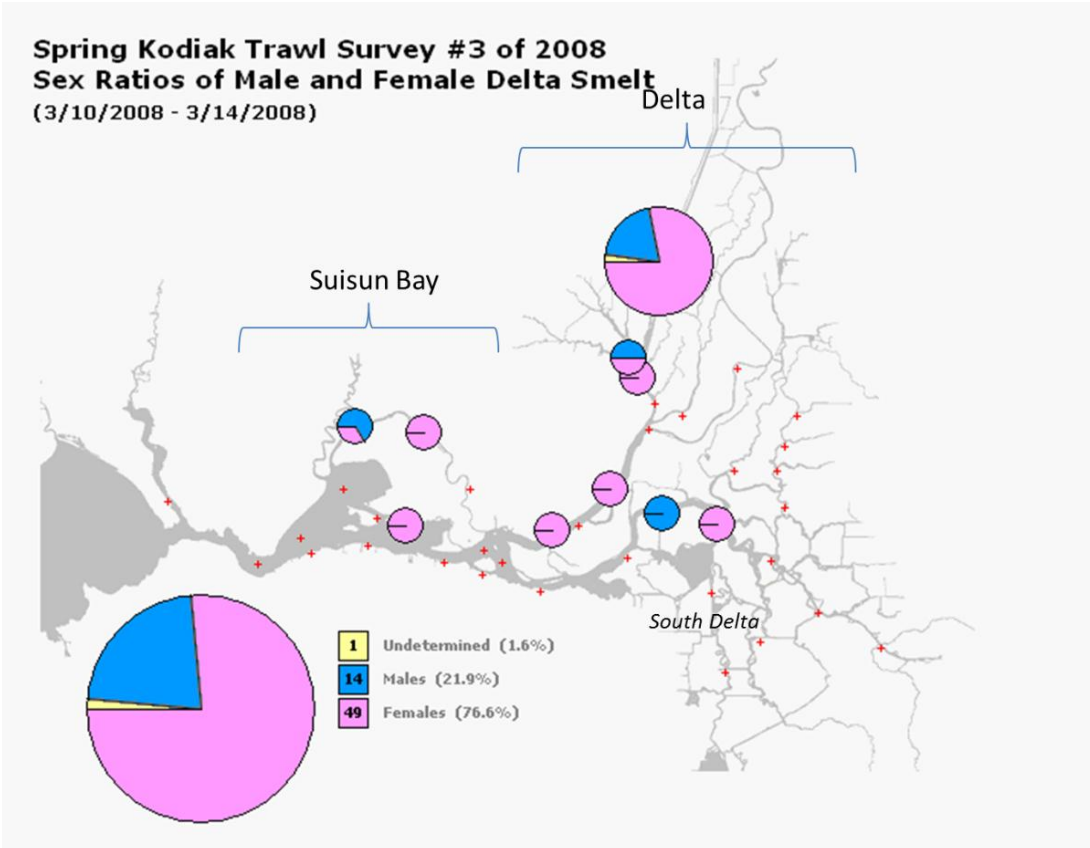

Figure 6. Distribution of adult Delta Smelt (females in pink, males in blue, and unknowns in yellow) over a 4 day period in the Suisun Bay/Delta region from the Spring Kodiak Survey #3 2008.The size of the circles represent relative catch at each site. Sites with no catch are represented by red stars.

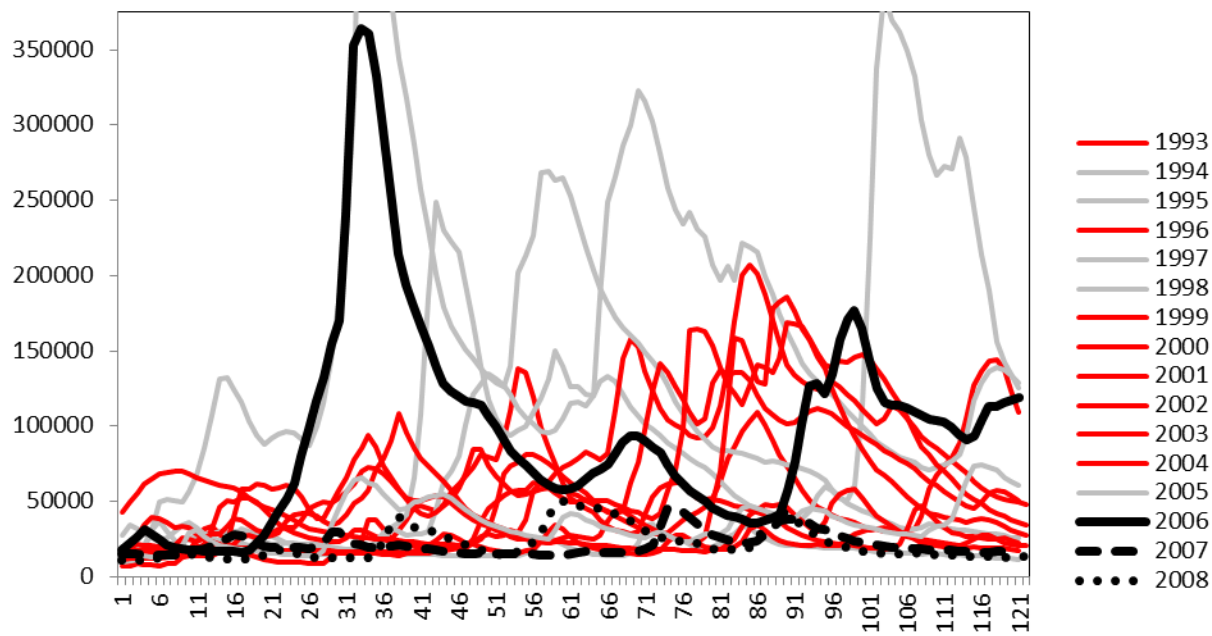

Figure 7. Delta outflow (cfs) for 121 days from December 1st 1993 to 2008. Years in red represent hydrology where salvage observations were highest between 1993 and 2008 (See Grimaldo et al. 2009). Years in black represent values used for the Cumulative Salvage Index average in the 2008 Biological Opinion. Years in grey represent other year types with low to high salvage.

As previously mentioned, the highest entrainment risk conditions occur when both turbidity and outflow dramatically increase following the first storm event in December, as in 1993, 1996, 1999, 2000, 2001, 2002, 2003, and 2004 (see Figure 6 in Grimaldo et al. 2009). Due to a combination of behavior and a greater zone of influence, these years are known for having produced large salvage events. RPA Action 1 was specifically designed to minimize large entrainment in years with a first flush, recognizing that fish behavior and physical conditions can lead to large salvage events. The CSI approach does not currently include years that represent first flush conditions. The Biological Opinion explains that these years were not included because OMR flows were more negative than -5000 OMR cfs and therefore including a CSI from a first flush year where salvage was extremely high may inflate the ITL multiplier beyond the intent of the RPA to reduce extremely high salvage. Another reason why CSI's from other years were not included in the ITL multiplier was because the Service wanted to select later years when the population was at abundance level comparable to recent levels, not historic levels. However, the CSI inherently corrects for that because salvage is divided by the FMWT index, which is a relative measure of population size.

Estimating CSI values for historical years that did not conform to the current RPA actions

It is now recognized that year to year variability in adult Delta Smelt entrainment is influenced by factors other than OMR flows alone because salvage has been documented under a range of positive and negative OMR conditions (Grimaldo et al. 2009). Incorporating turbidity or other appropriate surrogates (e.g., Sacramento River inflow, FMWT Secchi depth) with OMR flow can improve the variability explained in the salvage patterns.

This proposal presents a statistical model that largely explained observed CSI values and then used this model to estimate what CSI's would have been in historical years if OMR had been limited as specified in the adult Delta Smelt RPA from December 20th through the end of March each year. December 20th was selected because that is the normal date upon which the adult Delta Smelt RPA actions can commence (though there are provisions in the RPA for earlier actions if necessary). The steps in the analysis were as follows:

1. Examine primary literature to determine what variables best predict CSIs values

2. Examine differences between predicted and observed CSIs

3. Use the regression generated from this analysis to predict CSIs under RPA threshold

4. Use a bootstrapping technique to assign confidence intervals to the CSI estimates

5. Make a recommendation to the Service to use these CSIs as a more robust and representative way to characterize expected take under the RPA for a range of environmental conditions

1. Background and data sources

Inspection of historical data shows that salvage increases as OMR becomes more negative and as the Delta becomes more turbid, particularly if that source of turbidity is the Sacramento River (Figure 8). The combination of high negative OMR and a continuous turbidity gradient originating in the Sacramento River and extending to the export pumps represents conditions where salvage will probably be highest. By contrast, if south Delta turbidity originates from the Cosumnes or Mokelumne or San Joaquin Rivers and no turbidity gradient is formed, salvage is likely to be lower. Years in which OMR is positive (1997 and 1998, shown in red in Figure 9) also can have significant levels of salvage. However, the mechanisms by which salvage occurs during 1997 and 1998 are probably different than the mechanisms in operation when OMR is negative. Moreover, years with high positive OMR are largely beyond the control of SWP and CVP. For this reason, positive OMR years were excluded from the analysis to focus on periods when OMR was in a range when the RPA would be triggered and implemented. Given the relationships between salvage and (1) OMR and (2) Secchi depth (Figures 5 and 6; data taken from Table 1), the following model was developed:

Log (CSI) = a*OMR + b*Secchi depth + ε
Equation (1)

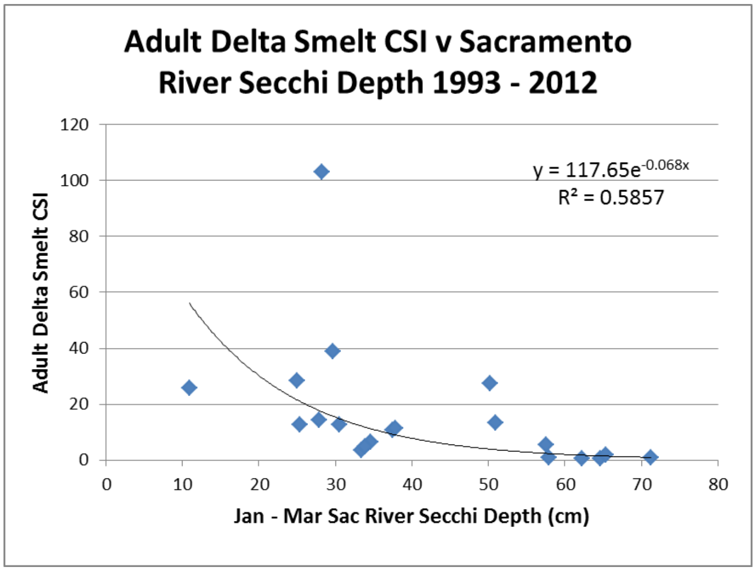

Figure 8. Adult Delta Smelt Cumulative Salvage Index (CSI) and Sacramento (Sac) River Secchi Depth (cm) from January to March 1993-2012.

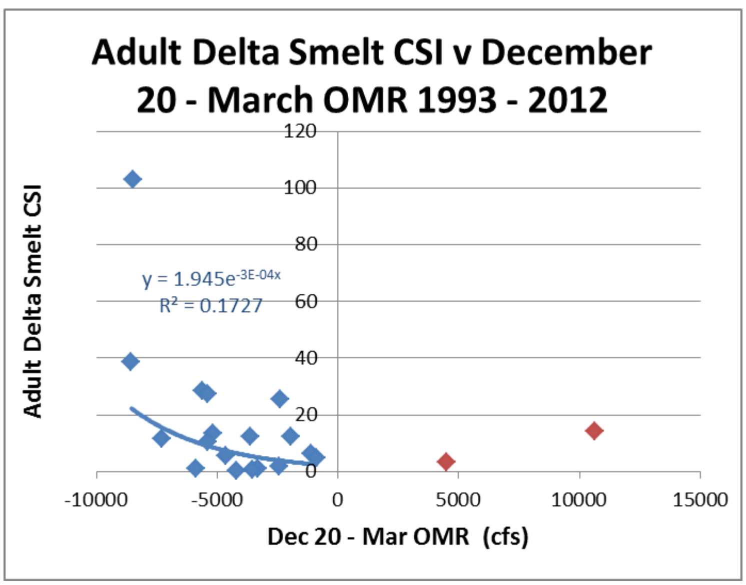

Figure 9. Adult Delta Smelt Cumulative Salvage Index (CSI) and Old and Middle River (OMR) flows (cfs) from December 20th to March 31st 1993-2012. Years with positive OMR flow are included in red, but are not used in the fit line shown on the graph.

Data

Historical CSI values from the years 1993 – 2012 were considered for this analysis. We focused on periods when the RPA would be in effect so that years where offramp targets would have been triggered were handled per the Service's recommendations[15]. Specifically, 1997 and 1998 were excluded for the reasons outlined above. Years prior to 1993 were not analyzed because the Service considered species[16] identification to be unreliable (the Service 2008 page 204). Raw data for the analyses are included in Table 1.

Secchi depth from January to March in the Lower Sacramento River was the variable used to represent turbidity in the analysis. Delta smelt movement behavior changes in response to turbidity (Grimaldo et al. 2009). During the winter period, some Delta Smelt in Suisun Bay and the Sacramento River will move into the San Joaquin side of the Delta in response to heightened turbidity. The source of such turbidity is predominantly the Sacramento River. Also, due to its distance from the water projects turbidity levels in the Sacramento River will be independent of possible changes in South Delta water project operations. By contrast, measures of turbidity from the South Delta are likely to be more problematic because (1) south Delta turbidity will be influenced by turbidity inputs from the San Joaquin River and east side streams which may have little impact on smelt movement and (2) turbidity values measured in the south Delta are more likely to be impacted by the hydraulic changes associated with changed exports and are thus not independent of OMR.

Values for Secchi depth were available for the years 1993 – 2001 from the FMWT dataset and for the years 2002 through 2012 from the Spring Kodiak Trawl (SKT) dataset. FMWT stations that are also recorded in the SKT were averaged together except where there was no SKT. Averaged stations were: 704 – 707, 711 – 713, 715 – 716, and 724. December values for Secchi depth were not used because the FMWT is nearly always completed before the first major turbidity increase of the season.

A complete set of OMR flow values for all years were obtained from a model developed by Paul Hutton (Hutton 2008). These flows will be termed "historical" OMR flows. Flows at Rio Vista and Vernalis were taken from Dayflow.

2. Modeling CSI values

Using the regression approach, Log (CSI) was modeled with Sacramento River Secchi Depth and OMR. Data used can be found in Table 1. The years 1997 and 1998 were excluded since OMR was positive. The regression analysis resulted in the equation:

$$\text{Log (CSI)} = 1.641 - .0298 * \text{Secchi depth (cm)} - 0.00011 * \text{OMR (cfs)} + \varepsilon$$

Equation 2

Turbidity and OMR flow significantly predicted variation in CSI ($r^2 = 0.75$, s.e. = 0.36, $p < 0.01$).

[15] Ken Newman ITL review

[16] the Service Biological Opinion, page 149

Table 1. Measured adult Delta smelt Cumulative Salvage Index (CSI), Secchi Depth (cm) of the Lower Sacramento River from January to March, and Old and Middle River (OMR) flows (cfs) from 1993 to 2012. Log measured CSI, Modeled log CSI from equation 2, and Modeled CSI were calculated. * Years that where not used in the correlation.

Year	Adult Smelt CSI	Log (CSI)	January - March Secchi (cm)	Dec 20 - March 31 OMR (cfs)	Modeled Log (CSI)	Modeled CSI
a	b	c	d	E	f	g
1993	28.4	1.453318	25	-5589.76	1.498762	31.53276
1994	0.4	-0.39794	64.7	-4185.09	0.16423	1.459586
1995	25.6	1.40824	10.9	-2385.09	1.57345	37.44981
1996	6.3	0.799341	34.6	-1085.17	0.727023	5.33363
1997	14.4	1.158362	27.9	10626.84		
1998	3.4	0.531479	33.4	4506.016		
1999	4.9	0.690196	33.9	-898.787	0.72779	5.343054
2000	13.3	1.123852	51	-5151.93	0.676739	4.750494
2001	10.6	1.025306	37.5	-5409.31	1.106798	12.78785
2002	11.4	1.056905	37.8	-7304.4	1.302172	20.05266
2003	103	2.012837	28.2	-8458.51	1.712687	51.60444
2004	38.8	1.588832	29.7	-8557.46	1.678654	47.71491
2005	27.3	1.436163	50.2	-5395.44	0.726832	5.331289
2006	12.5	1.09691	30.5	-1955.2	0.943007	8.770142
2007	0.9	-0.04576	57.9	-5855.62	0.54698	3.523543
2008	12.5	1.09691	25.3	-3643.16	1.279954	19.05258
2009	1	0	71.2	-3291.36	-0.12583	0.748462
2010	5.4	0.732394	57.5	-4646.17	0.428505	2.682288
2011	1.7	0.230449	65.4	-2412.67	-0.04772	0.895944
2012	0.6	-0.22185	62.3	-3538.8	0.166074	1.465798

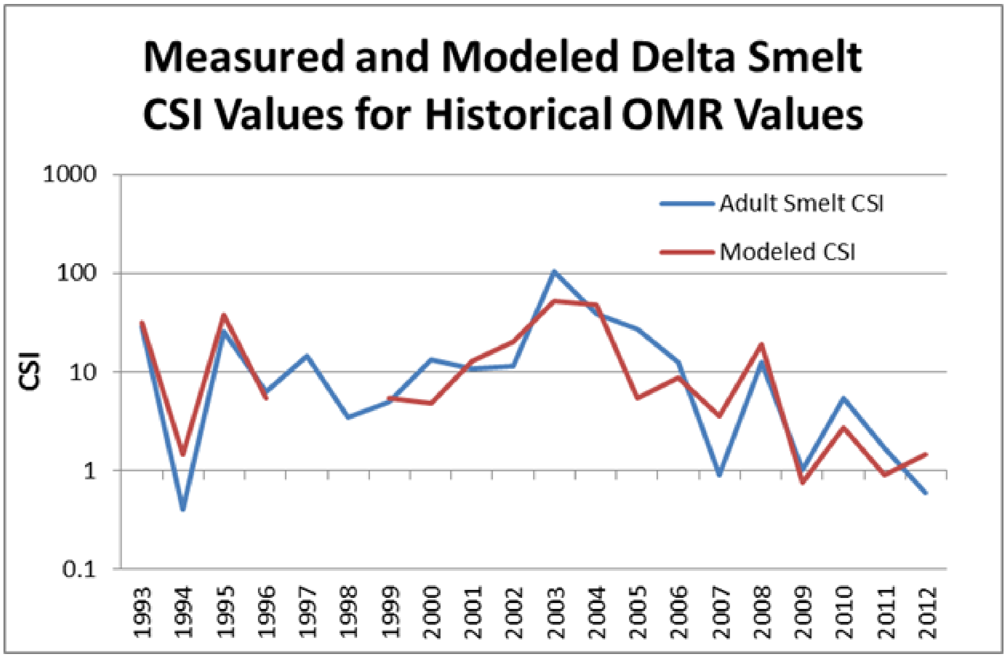

Figure 10. Adult Delta Smelt modeled and measured Cumulative Salvage Index (CSI) for both the historical Old and Middle River flow values (OMR).

Modeling OMR if RPAs had been applied to all years from 1993 – 2012

Modeled CSI values closely track measured Adult Smelt CSI values for historical OMR (Fig. 10) Measured data do not exist that exactly define the operations that would have occurred during 1993 – 2012 if the RPA had been in place. In particular, the turbidity monitoring stations identified in the RPA at Prisoners Point, Holland Cut, and Victoria Canal were not established until the summer of 2007. Clifton Court Forebay turbidity data was available, but that location does not represent turbidity at the three turbidity trigger stations used in the RPA and does not identify whether a turbidity bridge exists in Old and Middle Rivers for Delta Smelt to follow. Therefore, two Scenarios were adopted to model RPA compliant OMR for the period 1993 – 2012.

For Scenario 1, it was assumed that adult Delta Smelt Action 2 was imposed on December 20th every year and applied until March 31. Action 2 limits a 14 day average OMR to -5000 cfs and 5 day OMR to -6250 cfs. For Scenario 2, it was assumed that Action 1 was imposed on December 20th each year, followed by Action 2 as described in the RPA. Action 2 requires OMR to be no more negative than -2000 cfs for a period of 14 days. Scenario 2 is more conservative than Scenario 1 because a limit of -2000 is imposed on December 20th.

We consider that both Scenario 1 and 2 are conservative because the hydrological/ turbidity conditions that trigger Actions 1 and 2 will not occur by December 20th in many years. Also, high salvage events in the past have frequently been associated with operations that pushed OMR far more negative than

-5000 cfs prior to the onset of salvage. If operations were limited to -5000 cfs for the entire period from December 20 – March 31, it is unclear whether reductions in OMR less negative than -5000 would ever have been needed. For the years 2009 -2012 when the RPA was being applied, Scenarios 1 and 2 produce OMR values that are less negative than those observed in actual operations (Fig. 11).

The RPA envisions restrictions during periods of heightened salvage risk that would make OMR less negative than -5000 cfs for limited periods of time. However, it should be noted that in some cases, restrictions on OMR were motivated by concern that the ITL would be exceeded. It would therefore be circular to assume that annually modeled RPA Compliant CSI estimates should be dependent upon the need to avoid hitting the existing ITL. It was for this reason that water year 2013 was excluded from the model (operations in 2013 were determined largely by a desire to avoid exceeding the ITL).

To provide a sensitivity analysis, Scenario 3 was created similarly to Scenario 2 with a 14 day averaged period of -2000 cfs starting on December 20, but in which Action 2 assumes a 14 day limit of -4000 cfs instead of -5000 cfs. The RPA suspend Actions 1 and 2 at very high flow levels (90,000 Rio Vista and 10,000 San Joaquin on three day running averages). For this reason, historical OMR values were allowed for any day in which (1); three day Rio Vista flows exceeded 90,000 cfs and (2); three day San Joaquin River flows at Vernalis exceeded 10,000 cfs. There were few days over the period for which this condition applied. Historical OMR values and projected OMR values under Scenarios 1, 2 and 3 are shown in Table 2 and Figure 11. Note, OMR scenarios more positive than -4000 CFS were not modeled as a scenario because review of SWG notes (http://www.fws.gov/sfbaydelta/cvp-swp/smelt_working_group.cfm) shows that Action 2 Determinations were no more positive than -5000 cfs in 5 of the 6 years observed since the 2008 Biological Opinion has been in effect. In 2013, the FWS made determinations to SWP and CVP to manage OMR flows to values less than -5000 cfs, as noted above, because of concern over eclipsing the ITL, not that entrainment risk had increased to the Delta-wide population overall. In fact, in 2013, the center of the population was located in the north Delta after the first flush period of that year.

Table 2. Historical Old and Middle River (OMR) flows (cfs), Scenario 1 OMR, Scenario 2, and Scenario 3 OMR for the years 1993-2012. Flows represent averages for December 20th through March. 1997 and 1998 were where not used in the correlation therefore there their values were not modeled.

Year	Estimated Historical OMR	OMR Scenario 1	OMR Scenario 2	OMR Scenario 3
1993	-5590	-4371	-4005	-3426
1994	-4185	-3687	-3281	-3191
1995	-2385	-1281	-933	-456
1996	-1085	-337	-247	25
1997	10627			
1998	4506			

Year	Estimated Historical OMR	OMR Scenario 1	OMR Scenario 2	OMR Scenario 3
1999	-899	-899	-899	-899
2000	-5152	-3858	-3528	-3102
2001	-5409	-4478	-4154	-3486
2002	-7304	-4953	-4541	-3759
2003	-8459	-4976	-4582	-3758
2004	-8557	-4988	-4653	-3777
2005	-5395	-3983	-3610	-3158
2006	-1955	-1490	-1145	-951
2007	-5856	-4762	-4439	-3733
2008	-3643	-3558	-3343	-2967
2009	-3291	-3175	-3079	-2937
2010	-4646	-4415	-4102	-3547
2011	-2413	-2362	-2048	-1794
2012	-3539	-3330	-2964	-2773

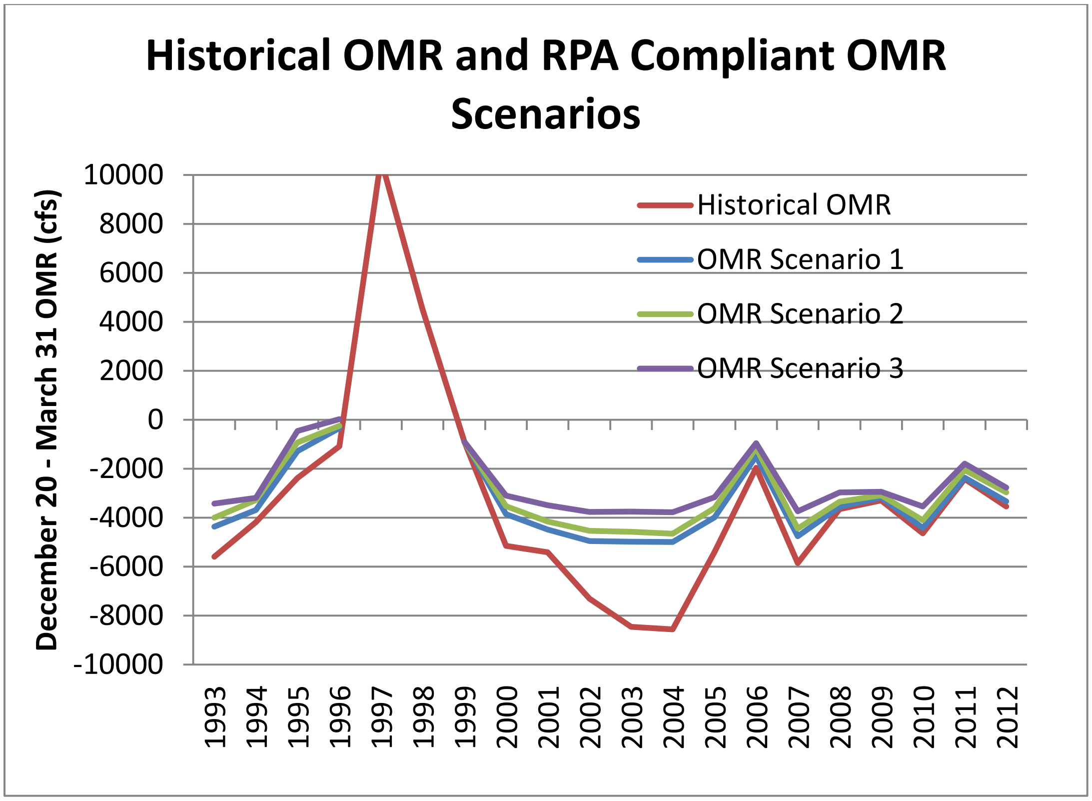

Figure 11. Historical and RPA-compliant Scenarios 1 -3 Old and Middle River (OMR) flows (cfs) from December 20th to march 31st for the years 1993-2012.

In Figure 11, despite the automatic application of Actions 1 and 2 on December 20th, deviations from historical OMR values were small except during the years 2002 to 2005. In most years, historical operations were largely in compliance with RPA Actions 1 and 2 either because of limited water availability, positive OMR flows or limited demand. It was only during years 2002 – 2005 where consistent deviations between historical OMR and RPA-Compliant OMR were evident.

3. Prediction of CSI Values

Using Equation 2, we predicted what CSI would be under each of the three scenarios. This regression model approach to predicting effects of project operations is consistent with methods applied in the 2008 Biological Opinion (e.g., Pages 271-277 and 2011 Draft (see Pages 246-248). Historical CSI values from 1997 and 1998 are not included because these years were not modeled (Table 3; Figs. 13,14).

4. Bootstrapping Analysis

In order the get a better estimate of the 95% confidence limits estimated by the CSI model, a statistician (Bryan Manly, Western EcoSystems Technology, Inc) was contracted to run a bootstrap analysis of the data (Table 3). A description of his analysis is attached (Bootstrapping Appendix). The CSI estimates with 95% confidence limits derived using bootstrapping are shown below for Scenario 2. The confidence intervals are much smaller after bootstrapping. On average, the limits have shrunk by about a factor of 4 on both sides of the expected value.

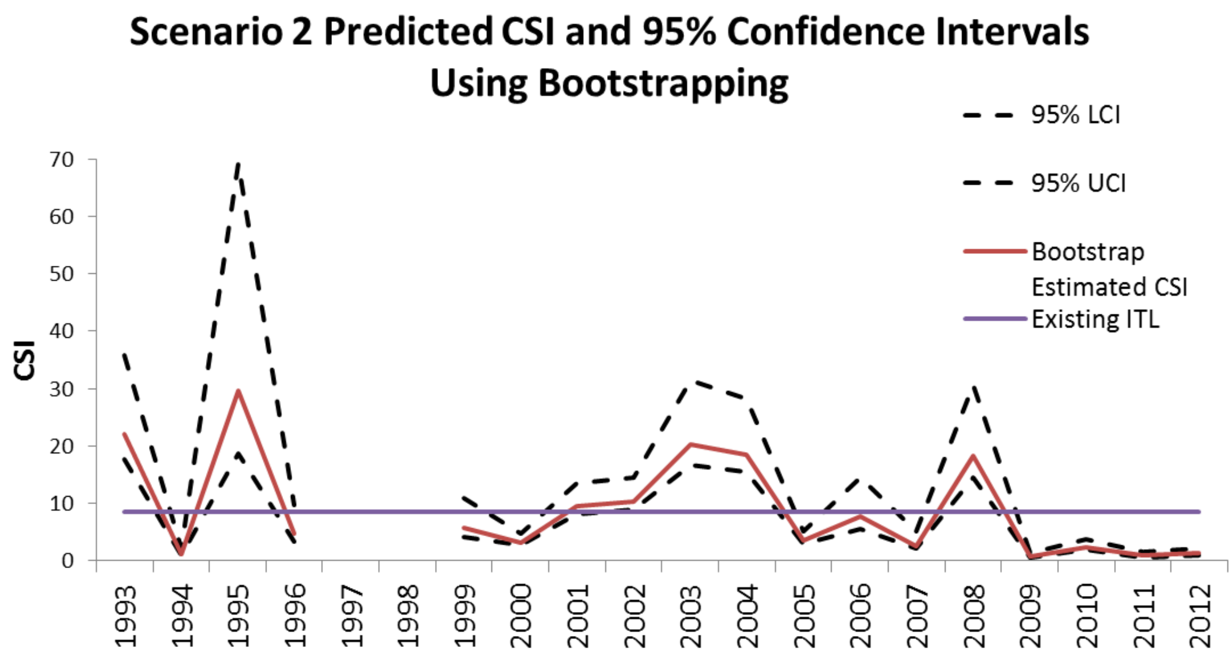

Figure 12. The predicted Cumulative Salvage Index (CSI) from Scenario 2 (red line) with 95% confidence intervals for the Lower (LCL) and the Upper (UCL) and the existing Incidental Take Level (ITL, purple line) from 1993-2012.

Thus, while the confidence limits derived from the simple CSI model tended to include the existing ITL value of 8.63 in most years, the confidence limits based on bootstrapping generally do not include the existing ITL value. In fact, 8.63 lies within the confidence limits in only four of the 18 years in this graph.

As discussed above in the earlier section, there is a disconnect between (1) setting the ITL multiplier to be a constant value (e.g., ITL = 8.63) and the results of the CSI model, which suggest that CSI values – even when compliant with the RPA -- will vary in the future between approximately 0 and 25 in the future. Lower ITL values will be frequently exceeded. Higher ITL values will not be frequently exceeded, but will be less protective to the species. Thus a balance must be struck between protectiveness and frequency of exceedance. As noted above, CSI values that are predicted to be exceeded in approximately 20% of years may be reasonable. For the bootstrapping example provided above, this would imply that the ITL multiplier would be approximately 18.

Table 3. Historical and predicted Cumulative Salvage Index (CSI) for Delta Smelt during the years 1993 to 2012. Bootstrapped predictions (see appendix) for the first two scenarios were added for comparison.

Year	Historical CSI	Model Predicted CSI: OMR Scenario 1	Model Predicted CSI: OMR Scenario 2	Model Predicted CSI: OMR Scenario 3	Bootstrap Predicted CSI: OMR Scenario 1	Boostrap Predicted CSI: OMR Scenario 2
1993	28.4	23.24	21.23	18.38	22.03	21.27
1994	0.4	1.29	1.16	1.14	1.22	1.17
1995	25.6	28.56	26.20	23.28	29.56	26.12
1996	6.3	4.42	4.32	4.04	4.7	4.33
1997	14.4					
1998	3.4					
1999	4.9	5.36	5.36	5.36	5.7	5.34
2000	13.3	3.45	3.18	2.86	3.24	3.17
2001	10.6	10.15	9.36	7.93	9.53	9.36
2002	11.4	11.16	10.08	8.30	10.27	10.10
2003	103	21.76	19.73	16.08	20.26	19.71
2004	38.8	19.70	18.13	14.58	18.56	18.10
2005	27.3	3.74	3.41	3.05	3.49	3.42
2006	12.5	7.80	7.16	6.82	7.65	7.17
2007	0.9	2.69	2.48	2.08	2.55	2.48
2008	12.5	18.61	17.65	16.07	18.38	17.68
2009	1	0.73	0.71	0.69	0.76	0.71
2010	5.4	2.54	2.35	2.05	2.41	2.34
2011	1.7	0.88	0.82	0.77	0.87	0.82
2012	0.6	1.40	1.27	1.22	1.33	1.27

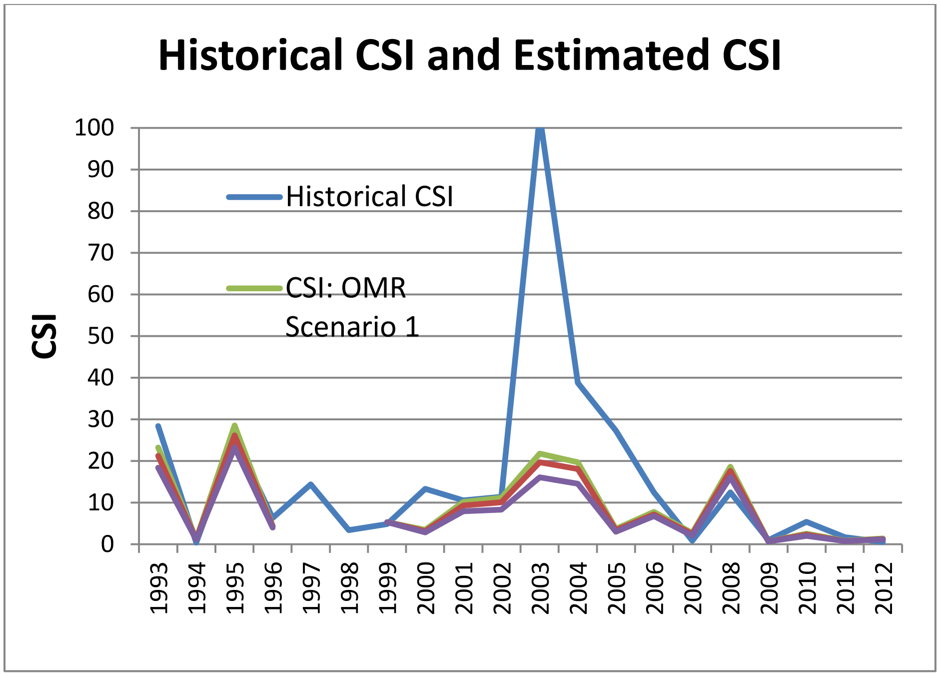

Figure 13. Historical, Scenario 1, Scenario 2, and Scenario 3 Cumulative Salvage Index (CSI) for Delta Smelt during the years 1993 to 2012

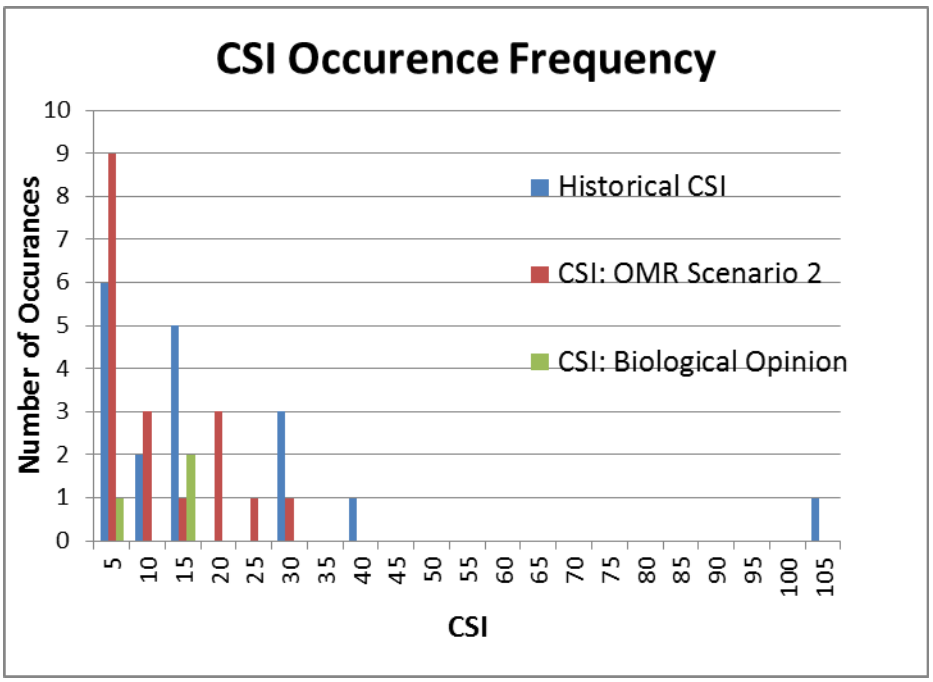

Figure 14. Frequency distribution of the number of occurrences of Cumulative Salvage Index (CSI) including Historical values, the values used in the Biological Opinion, and the values projected using OMR Scenario 2. Each column represents the number of years in which the CSI was between the numerical value in the graph and the preceding value. Thus, counts for CSI= 5 represent the number of counts from 0 to 5.

5. Possible application of the predicted CSIs to the ITS

The approach provided in this proposal to estimate CSIs during years when conditions historically produced high entrainment risk could be used by the Service to develop a more robust ITS. Specifically, this approach allows for a better estimation of expected take under high entrainment risk conditions when the RPA would likely be applied. A frequency of exceedance can be determined from Table 3. From a total of 18 data points that represent each of the modeled years, each point represents a ~ 5.6% probability of exceedance, assuming that future hydrological and turbidity patterns are reflected by the variation of the past 18 years. Thus, CSI values that would be exceeded approximately 20% of the time could be approximated by selecting the 4th highest CSI value in each OMR Scenario. For Scenario 1, the fourth highest CSI value is 19.7. For Scenario 2, the fourth highest CSI value is 18.13. For Scenario 3, the fourth highest CSI value is 16.08. Exceedance rates of 25% would be reflected by the 5th highest CSI values or 18.61, 17.65, and 14.58 for the three Scenarios.

Summary

In summary, the current ITL is based on a few years that are not fully representative of years where conditions present high entrainment risk periods. We provide a statistical approach for estimating likely future distributions of CSI under both high and low entrainment risk conditions and encourage the Service to incorporate this variation into the ITS calculation for estimating incidental take levels expected under the RPA.

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Appendix

Bootstrap Analysis of CSI Data

Bryan Manly

November 18, 2014

Step 1: Fit the regression model to the real data using the Excel Linest function and find the regression residuals, as shown below

		J-M	D-M		Fit		Fit
Year	lgCSI	Secchi	OMR		LgCSI	Resid	CSI
1993	1.453318	25.0	-5589.76		1.49876	-0.04544	31.53
1994	-0.397940	64.7	-4185.09		0.16423	-0.56217	1.46
1995	1.408240	10.9	-2385.09		1.57345	-0.16521	37.45
1996	0.799341	34.6	-1085.17		0.72702	0.07232	5.33
1999	0.690196	33.9	-898.79		0.72779	-0.03759	5.34
2000	1.123852	51.0	-5151.93		0.67674	0.44711	4.75
2001	1.025306	37.5	-5409.31		1.10680	-0.08149	12.79
2002	1.056905	37.8	-7304.40		1.30217	-0.24527	20.05
2003	2.012837	28.2	-8458.51		1.71269	0.30015	51.60
2004	1.588832	29.7	-8557.46		1.67865	-0.08982	47.71
2005	1.436163	50.2	-5395.44		0.72683	0.70933	5.33
2006	1.096910	30.5	-1955.20		0.94301	0.15390	8.77
2007	-0.045757	57.9	-5855.62		0.54698	-0.59274	3.52
2008	1.096910	25.3	-3643.16		1.27995	-0.18304	19.05
2009	0.000000	71.2	-3291.36		-0.12583	0.12583	0.75
2010	0.732394	57.5	-4646.17		0.42851	0.30389	2.68
2011	0.230449	65.4	-2412.67		-0.04772	0.27817	0.90
2012	-0.221849	62.3	-3538.80		0.16607	-0.38792	1.47
	Excel Regression with Linest						
	-0.000108	-0.0298	1.641				
	0.000039	0.0051	0.299				
	0.749	0.362	#N/A				
	22.44	15	#N/A				
	5.88	1.965	#N/A				

Step 2: Find predicted CSI values for Scenarios 1 and 2 for the same years as before.

	OMR Scenario		Predicted CSI Scenario	
Year	1	2	1	2
1993	-4371	-4005	23.30	21.28
1994	-3687	-3281	1.29	1.17
1995	-1281	-933	28.47	26.12
1996	-337	-247	4.43	4.33
1999	-899	-899	5.34	5.34
2000	-3858	-3528	3.45	3.17
2001	-4478	-4154	10.15	9.36
2002	-4953	-4541	11.19	10.10
2003	-4976	-4582	21.74	19.71
2004	-4988	-4653	19.67	18.10
2005	-3983	-3610	3.75	3.42
2006	-1490	-1145	7.81	7.17
2007	-4762	-4439	2.69	2.48
2008	-3558	-3343	18.65	17.68
2009	-3175	-3079	0.73	0.71
2010	-4415	-4102	2.53	2.34
2011	-2362	-2048	0.88	0.82
2012	-3330	-2964	1.39	1.27

Step 3: Resample the residuals from the original data fit with replacement and add them to the fitted values from the original fit. For example for year 1 (1993) the original Log(CSI) fit is 1.49876. A random residual is then -0.38792 (from 2012) and the bootstrap Log(CSI) value for 1993 is 1.49876-0.38792 = 1.110840. The regression equation is fitted to this bootstrap data using Linest and the fitted values for Log(CSI) and CSI are shown in the last two columns below.

	Bootstrap Data							
	Fit	B/S	Fit+Resid	J-M	D-M		Fit	Fit
Year	LgCSI	Resid	LgCSI	Secchi	OMR		LgCSI	CSI
1993	1.49876	-0.38792	1.110840	25.0	-5589.76		1.42986	26.91
1994	0.16423	-0.18304	-0.018814	64.7	-4185.09		0.14595	1.40
1995	1.57345	0.27817	1.851618	10.9	-2385.09		1.59264	39.14
1996	0.72702	-0.18304	0.543979	34.6	-1085.17		0.78965	6.16
1999	0.72779	0.07232	0.800107	33.9	-898.79		0.79557	6.25
2000	0.67674	0.44711	1.123852	51.0	-5151.93		0.62718	4.24
2001	1.10680	0.30015	1.406948	37.5	-5409.31		1.04633	11.13
2002	1.30217	-0.24527	1.056905	37.8	-7304.40		1.18751	15.40
2003	1.71269	-0.03759	1.675093	28.2	-8458.51		1.56246	36.51
2004	1.67865	-0.16521	1.513444	29.7	-8557.46		1.52598	33.57
2005	0.72683	-0.04544	0.681389	50.2	-5395.44		0.67009	4.68
2006	0.94301	-0.04544	0.897563	30.5	-1955.20		0.97964	9.54
2007	0.54698	-0.16521	0.381770	57.9	-5855.62		0.47907	3.01
2008	1.27995	-0.08149	1.198462	25.3	-3643.16		1.26688	18.49
2009	-0.12583	0.12583	0.000000	71.2	-3291.36		-0.11681	0.76
2010	0.42851	-0.59274	-0.164231	57.5	-4646.17		0.39513	2.48
2011	-0.04772	0.27817	0.230449	65.4	-2412.67		-0.01505	0.97
2012	0.16607	0.07232	0.238391	62.3	-3538.80		0.16567	1.46
			-0.000079	-0.0295	1.726			
			0.000029	0.0038	0.221			
			0.830	0.268	#N/A			
			36.54	15	#N/A			
			5.24	1.076	#N/A			

Step 4: Calculated the predicted values of Log(CSI) and CSI from the model fitted to the bootstrap data, as shown below.

				Predicted Log(CSI)		Predicted CSI	
		OMR Scenario		Scenario		Scenario	
Year	Secchi	1	2	1	2	1	2
1993	25.0	-4371	-4005	1.33335	1.30439	21.55	20.16
1994	64.7	-3687	-3281	0.10649	0.07437	1.28	1.19
1995	10.9	-1281	-933	1.50520	1.47768	32.00	30.04
1996	34.6	-337	-247	0.73039	0.72329	5.38	5.29
1999	33.9	-899	-899	0.79557	0.79559	6.25	6.25
2000	51.0	-3858	-3528	0.52474	0.49861	3.35	3.15
2001	37.5	-4478	-4154	0.97260	0.94695	9.39	8.85
2002	37.8	-4953	-4541	1.00136	0.96873	10.03	9.31
2003	28.2	-4976	-4582	1.28676	1.25555	19.35	18.01
2004	29.7	-4988	-4653	1.24340	1.21686	17.51	16.48
2005	50.2	-3983	-3610	0.55828	0.52873	3.62	3.38
2006	30.5	-1490	-1145	0.94281	0.91550	8.77	8.23
2007	57.9	-4762	-4439	0.39251	0.36692	2.47	2.33
2008	25.3	-3558	-3343	1.26014	1.24312	18.20	17.50
2009	71.2	-3175	-3079	-0.12604	-0.13363	0.75	0.74
2010	57.5	-4415	-4102	0.37681	0.35205	2.38	2.25
2011	65.4	-2362	-2048	-0.01905	-0.04393	0.96	0.90
2012	62.3	-3330	-2964	0.14915	0.12017	1.41	1.32

Steps 3 and 4 were repeated 10,000 times and the 10,000 values for each year of each scenario were used to calculate the mean and standard error of these estimates and the bootstrap 95% confidence limits (the value exceeded by 2.5% of the estimates and the value exceeded by 97.5% of the estimates) as shown below. Also shown for each year is the estimated probability of getting a predicted CSI value of 8.63 or more. Overall for Scenario 1 a value of 8.63 or more occurred 40.2% of the time while for Scenario 2 this occurred 38.2% of the time.

Original = prediction from equation (2) with real data
Avg = average from 10000 bootstrap samples
SE = standard error from 10000 bootstrap samples
LCL = lower 95% confidence limit for the year
UCL = upper 95% confidence limit for the year
Prob = estimated probability that the predicted CSI will be 8.63 or more
All = proportion of CSI values of 8.63 or more for all years

	Scenario 1						Scenario 2					
Year	Original	Avg	SE	LCL	UCL	Prob	Original	Avg	SE	LCL	UCL	Prob
1993	23.30	24.14	6.56	19.44	39.22	1.000	21.28	22.07	6.09	17.68	35.96	1.000
1994	1.29	1.35	0.41	1.05	2.32	0.000	1.17	1.22	0.38	0.95	2.13	0.000
1995	28.47	32.04	16.46	20.70	73.78	0.995	26.12	29.65	15.85	18.78	69.80	0.989
1996	4.43	4.81	2.00	3.39	9.77	0.046	4.33	4.71	2.00	3.30	9.66	0.043
1999	5.34	5.72	2.15	4.20	10.95	0.094	5.34	5.72	2.15	4.20	10.95	0.094
2000	3.45	3.52	0.73	3.00	5.13	0.000	3.17	3.25	0.70	2.75	4.79	0.000
2001	10.15	10.33	1.99	8.90	14.82	0.801	9.36	9.54	1.86	8.21	13.72	0.661
2002	11.19	11.39	2.23	9.80	16.48	0.911	10.10	10.28	1.97	8.86	14.74	0.794
2003	21.74	22.39	5.55	18.43	34.95	1.000	19.71	20.29	4.99	16.71	31.57	1.000
2004	19.67	20.21	4.80	16.77	31.12	1.000	18.10	18.59	4.37	15.46	28.46	0.999
2005	3.75	3.83	0.77	3.29	5.54	0.000	3.42	3.50	0.73	2.98	5.11	0.000
2006	7.81	8.29	2.90	6.21	15.23	0.383	7.17	7.67	2.86	5.63	14.61	0.301
2007	2.69	2.77	0.69	2.27	4.34	0.000	2.48	2.55	0.63	2.10	4.34	0.000
2008	18.65	19.39	5.49	15.42	32.03	0.998	17.68	18.42	5.33	14.57	30.67	0.996
2009	0.73	0.78	0.29	0.57	1.49	0.000	0.71	0.76	0.29	0.55	1.46	0.000
2010	2.53	2.60	0.63	2.15	4.06	0.000	2.34	2.41	0.59	1.99	3.76	0.000
2011	0.88	0.94	0.33	0.70	1.74	0.000	0.82	0.87	0.32	0.64	1.64	0.000
2012	1.39	1.45	0.42	1.14	2.45	0.000	1.27	1.33	0.40	1.04	2.29	0.000
					All	0.402					All	0.382

Note: I tried resampling the original 18 observations with replacement to get bootstrap data. That occasionally gave very extreme predictions for the scenarios. I think this was probably because the bootstrap data only contained high or low Secchi depths but the scenario data has the full range of Secchi depths.