Proposal for a Revised ITL and Expected Take for Adult Delta Smelt
Metropolitan Water District
July 29, 2014 Draft

Background

The 2008 USFWS Incidental Take Level (ITL) calculation determines the amount of annual delta smelt salvage allowed to be taken by the State Water Project (SWP) and Central Valley Project (CVP) during operating conditions expected under Reasonable and Prudent Alternative (RPA) thresholds. There is an ITL for adult and juvenile delta smelt. Using advances in statistical models, data sources, and overall improved knowledge of entrainment dynamics, we offer a robust approach for calculating a revised ITL and accompanying expected take method under the RPA for the SWP and CVP that remains protective of the species while providing improved flexibility for managing water operations.

Current Adult Smelt Incidental Take Limit Method

The BiOp calculated the multiplier for the adult Delta Smelt ITL using data from three years: 2006-2008. For each year, USFWS calculated the cumulative salvage index by taking the sum of the amount of salvage from December through March, and dividing it by the prior year's Fall Midwater Trawl (FMWT). USFWS then averaged the three cumulative salvage index (CSI) values for 2006-2008 to produce the ITL multiplier. That number (7.25) was incorporated as the multiplier in the yearly ITL formula. The multiplier was subsequently corrected to approximately 8.63 after a math error was found in the original computation. Thus the current Incidental Take Limit is: Incidental Take = 8.63 * Prior Year's FMWT.

Incorporating year to year variability in adult smelt expected take and ITL statements

It is now recognized that year to year variability in adult smelt entrainment is influenced by factors other than OMR flows alone given that has salvage has been documented under a range of positive and negative OMR conditions (Grimaldo et al. 2009; USFWS 2011). Incorporating turbidity or other appropriate surrogates (e.g., Sacramento River inflow, FMWT Secchi depth) with OMR flow can improve the variability explained in salvage patterns (see below).

Although the existing 2008 USFWS ITL method incorporates the CSI metric, which is appropriate for considering population level impacts, using only three years to calculate the ITL severely constrains expected variability in biological and physical conditions that are likely to produce entrainment (Grimaldo et al. 2009, USFWS 2011). Currently the ITL includes a very wet year (2006), and extremely dry year with low turbidity (2007), and in-between water year (2008). During wet years, when outflows exceed 100,000 cfs, entrainment is very low because adult delta smelt remain distributed in Suisun Bay. During extreme dry years with low turbidity, adult delta smelt will tend to avoid the south Delta. Recognizing that combinations of high reverse OMR flows and high turbidity generally lead to high entrainment, the ITL should still include other years (i.e., in-between years) where smelt are likely to move into the south Delta.

Not all years were used to set the 2008 ITL on the basis that ITL should not include years where salvage and salvage ratios were believed to have significant impacts to the population. However, MWD has developed an approach for incorporating all the years using recent advances in the state of knowledge of turbidity dynamics.

Estimating RPA-Compliant Cumulative Salvage Indices 1993 – 2012

MWD developed a regression model that best explained observed salvage ratios and then used this model to determine what salvage ratios 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. That is, 14 day average OMR was capped at -5000 cfs while average OMR over 5 days was capped at -5000*1.25 = -6250 cfs. By applying the RPA to the historical years, the model provides an expectation of salvage ratios under all the combinations of exports and turbidity observed since 1993. Using a regression model approach to predict 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).

To conduct these analyses, MWD obtained data from existing monitoring surveys or in-stream gauges that currently inform Smelt Workgroup discussions. OMR values were obtained from the USGS. The measure of turbidity chosen was Secchi depth in the Sacramento River January – March. December values for Secchi depth were not used because the FMWT is nearly always completed before the first major turbidity increase of the season. 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. Because the SKT has fewer stations than the FMWT, only FMWT stations that are also recorded in the SKT were averaged. Average OMR values greater than zero were set to zero. Secchi depth was also available for the years 1991 and 1992. However, identification of Delta smelt was unreliable before 1993 and so those years were excluded.

Alternative correlations tested included Secchi depth averages over the entire estuary. These correlations were approximately as good as the correlation using Sacramento River Secchi depth. Interestingly, correlations using San Joaquin River Secchi depths generated a poorer fit. There could be many reasons for this: the source of the delta smelt is probably the Sacramento River and Sacramento Secchi depth may better measure the strength of the turbidity cloud within which smelt move toward the pumps; San Joaquin River Secchi depth is influence by several sources of turbidity (San Joaquin River, Cosumnes River, Mokelumne River) which may be less important to salvage than Sacramento turbidity; turbidity in Old and Middle Rivers is highly influenced by wind during the winter.

The correlation derived is as follows:

$$\text{Log (CSI)} = 1.54 - .029 * \text{Secchi depth (cm)} - 0.00012 * \text{OMR (cfs)} \qquad \text{Equation 1}$$

$N = 20$
$r^2 = .76$
$p_{secchi} < .00001$
$p_{OMR} = .0022$

Figure 1 shows measured CSI and the CSI predicted by the salvage correlation. The fit is quite good with no outliers.

Figure 2 shows how average OMR from December 20 through March would have changed if 14 day average OMR had been limited to -5000 cfs with 5 day average OMR limited to -6250 cfs. There is some reduction in average OMR in most years, but the largest reductions in OMR occur over the period 2001 – 2005.

Figure 3 adds to Figure 1 the annual CSI that the correlation predicts would have occurred if average OMR had been adjusted per the Delta smelt RPA (as shown in Figure 2). Most years change very little because CSI is not very sensitive to OMR until high negative values are reached. The greatest changes are in 2003 and 2004 OMR was very negative. Table 1 shows measured CSI values, the Secchi depth and OMR values used in the correlation, the CSI values generated by the correlation to fit historical values and the values predicted by the correlation assuming RPA-adjusted operations.

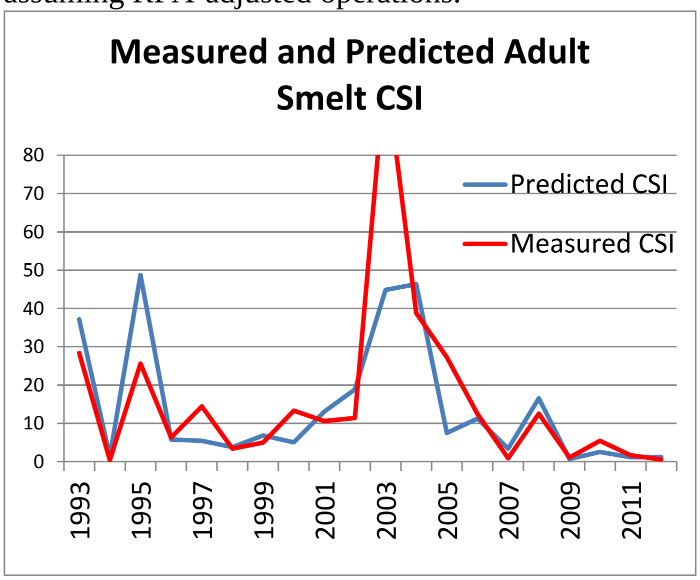

Figure 1. Measured cumulative salvage index (CSI) (red line) and CSI predicted by the correlation (blue line).

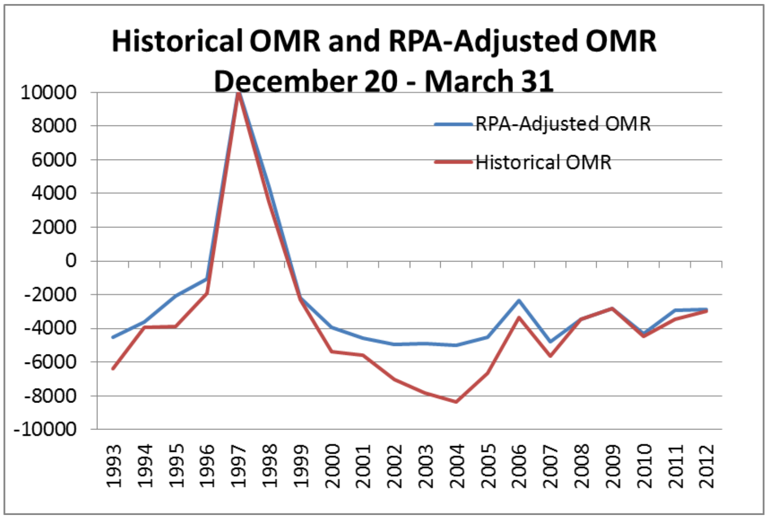

Figure 2. Historical estimated OMR (red line), estimated OMR adjusted for adult smelt RPA (blue line)

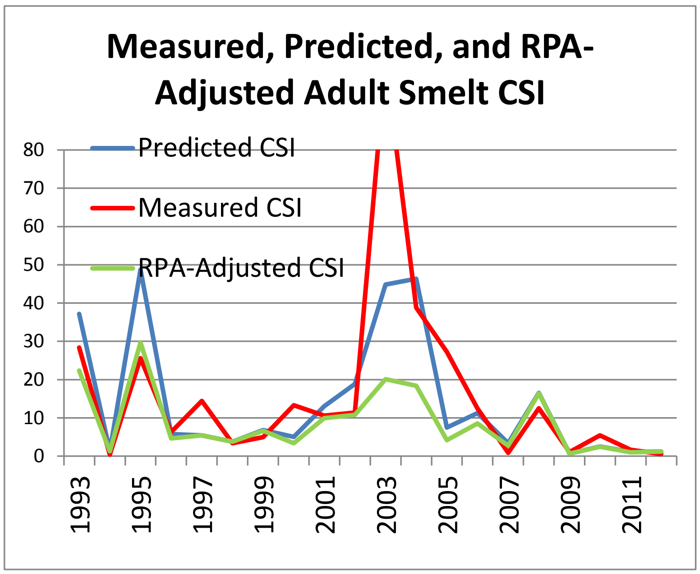

Figure 3. Measured cumulative salvage index (CSI) (red line), Predicted Historical CSI ratios (blue line), predicted RPA-adjusted CSI ratios (green line).

Year	Adult Smelt CSI	January - March Secchi (mm)	Dec 20 - March 31 OMR (cfs)	Modelled CSI	Predicted RPA OMR	Predicted RPA-CSI
1993	28.4	25.0	-6385	43.5	-4512	22.3
1994	0.4	64.7	-3953	1.3	-3603	1.2
1995	25.6	10.9	-3902	33.8	-2074	29.7
1996	6.3	34.6	-1892	4.5	-1085	4.6
1997	14.4	27.9	10096	6.1	10170	5.4
1998	3.4	33.4	3529	4.1	4403	3.8
1999	4.9	33.9	-2306	7.0	-2206	6.6
2000	13.3	51.0	-5405	5.3	-3957	3.4
2001	10.6	37.5	-5591	14.4	-4582	9.9
2002	11.4	37.8	-7032	18.7	-4972	10.8
2003	103.0	28.2	-7851	55.6	-4894	20.1
2004	38.8	29.7	-8338	48.1	-4982	18.6
2005	27.3	50.2	-6668	5.9	-4524	4.2
2006	12.5	30.5	-3344	12.0	-2336	8.6
2007	0.9	57.9	-5641	3.0	-4808	2.7
2008	12.5	25.3	-3481	17.8	-3441	16.4
2009	1.0	71.2	-2797	0.7	-2797	0.6
2010	5.4	57.5	-4485	2.8	-4323	2.4
2011	1.7	65.4	-3486	1.1	-2904	1.0
2012	0.6	62.3	-2982	1.2	-2898	1.2

Table 1 Salvage related data from 2003 to 2012. Measured cumulative salvage index (CSI), January-March Secchi depth (cm), and December 20 – March 31 Old and Middle River (OMR) flows (cfs). The modeled CSI is based on historical Secchi and OMR values. The predicted CSI is based on historical Secchi depth, and modified OMR.

Proposed Method to Revise the ITL

Conceptually, there are three key elements to any CSI approach to setting an ITL:

- Which years to include.
- Whether to use measured or modelled CSI.
- Which statistical output from the set of annual CSI values to select.

As mentioned above, USFWS in its 2008 BiOp made a choice for each of these elements: the years chosen were 2006 – 2008; measured data was used, and the statistical mean was selected.

The proposed method makes different choices in each of these areas:

- The years 1993 – 2012 were selected because reliable identification of Delta smelt is thought to have begun around 1993 and operations were not significantly impacted by the ITL until 2013.
- Modeled CSI data was created as described above to provide estimated annual CSI values under the assumption of RPA-compliant operations.
- The 80% upper prediction interval is proposed as the appropriate statistical output to use in creating the ITL.

The use of the average cumulative salvage index to set the ITL multiplier in the BiOp caused a significant problem: the CSI values for 2006 and 2008 were approximately 12 while the CSI value for 2007 was approximately 0. The average CSI was approximately 8, but the median CSI was approximately 12. Thus, assuming that the years selected represented the statistics of salvage, we would expect the ITL to be exceeded in a majority of years, even assuming compliance with the RPAs.

A better method is to use the 80% Upper Prediction Interval to calculate the ITL. The 80% Upper Prediction Interval is a statistical analysis that tells us when a number occurs only 20% of the time at the upper end of the data set. It analyzes the distribution of numbers within a set and groups them according to their likelihood of occurring within the set. Thus, for example, in the diagram below, the upper 20% of the numbers in the set occur within the shaded area:

Table entry for p and C is the critical value t^* with probability p lying to its right and probability C lying between $-t^*$ and t^*.

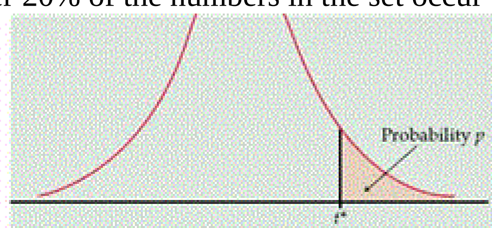

TABLE D t distribution critical values

	Upper tail probability p											
df	.25	.20	.15	.10	.05	.025	.02	.01	.005	.0025	.001	.0005
1	1.000	1.376	1.963	3.078	6.314	12.71	15.89	31.82	63.66	127.3	318.3	636.6
2	0.816	1.061	1.386	1.886	2.920	4.303	4.849	6.965	9.925	14.09	22.33	31.60
3	0.765	0.978	1.250	1.638	2.353	3.182	3.482	4.541	5.841	7.453	10.21	12.92
4	0.741	0.941	1.190	1.533	2.132	2.776	2.999	3.747	4.604	5.598	7.173	8.610
5	0.727	0.920	1.156	1.476	2.015	2.571	2.757	3.365	4.032	4.773	5.893	6.869
6	0.718	0.906	1.134	1.440	1.943	2.447	2.612	3.143	3.707	4.317	5.208	5.959
7	0.711	0.896	1.119	1.415	1.895	2.365	2.517	2.998	3.499	4.029	4.785	5.408
8	0.706	0.889	1.108	1.397	1.860	2.306	2.449	2.896	3.355	3.833	4.501	5.041
9	0.703	0.883	1.100	1.383	1.833	2.262	2.398	2.821	3.250	3.690	4.297	4.781
10	0.700	0.879	1.093	1.372	1.812	2.228	2.359	2.764	3.169	3.581	4.144	4.587

Figure 1

In the context of the ITL, the use of the 80% Upper Prediction Interval is helpful because it provides a point at which salvage has become higher than what we would normally expect, rather than merely higher than average.

The 80% Upper Prediction Interval is still highly conservative and falls within the expected range of salvage ratios under the RPA. Based on historic conditions, the approach predicts that the ITL will still be exceeded roughly every five years. Indeed, NMFS endorses and routinely uses a one-sided 80% Prediction Interval when assessing population stock levels. For example, in the 2005 Revisions to Guidelines for Assessing Marine Mammal Stocks, a panel of NMFS scientists commended use of "the 20th percentile of a log-normal distribution" as a properly protective method for estimating marine mammal minimum abundance. *Id.* at 6. This approach uses the bottom 20th percentile of the available population estimates to set a minimum estimate of population, which is then used as a multiplier to calculate the "Potential Biological Removal" level—a number roughly analogous to the ITL. *See, e.g.,* False Killer Whale: Hawaiian Islands Stock Complex (Draft, 2012) at 65 (using the "log-normal 20th percentile" to estimate abundance); Long-Beaked Common Dolphin: California Stock (2011) at 117 (using the "log-normal 20th percentile" to estimate abundance). An assessment by Roman et al 2013, says that the use of the log-normal 20th percentile criteria, was protective with 8 out of 12 stocks having showed improvement in abundance. Here, where the concern is identifying when losses are anomalously large, the 80% Upper Prediction Interval is similarly appropriate.

Overall expected salvage ratios under the RPA

The 80% Upper Prediction Interval for the "Predicted RPA-Compliant CSI" values in Table 1 is 13.97. This is the value that USFWS should consider establishing as a new ITL value according to the proposed method.

In addition, the model applied above indicates salvage ratios between 0.6 and 29.7 in any given RPA-compliant year might reasonably be expected. This range of expected salvage ratios can be used as additional guidance for the USFWS, DWR, and USBR for managing OMR flows in circumstances when salvage is approaching the ITL. For example, if salvage rates are approaching the ITL, the USFWS can use the expected take calculation to determine if existing operations need to be modified based on the trajectory to exceed the upper limit of expected salvage ratios before next RPA is triggered. This guidance could be particularly critical in late February or early March when entrainment risk has been shown to taper off significantly.

A multivariate examination of entrainment risk

Equation 1 can also be used to better understand the risks associated with various levels of OMR and Secchi depth. Equation 1 is an equation for the log of CSI. CSI itself is therefore exponentially related to Secchi depth and OMR. Specifically,

$$CSI = 34.8 * 10^{(\text{-Secchi depth}/34.5)} * 10^{(\text{-OMR}/8476)} \qquad \text{Equation 2}$$

Thus, as average Secchi depth in the Sacramento River declines toward 40 cm, we expect the CSI to start spiking upward. Similarly, as OMR approaches -8000 CSI should spike. If both circumstances occur simultaneously, then the spike will be even more powerful because the effects are multiplied. This effect is shown graphically in Figure 4. It explains why 2003 and 2004 had such high CSI – Secchi depth was well below 40 cm and OMR was more negative than -8000 cfs. This equation can be used to generate a rough gauge of risk as each winter develops.

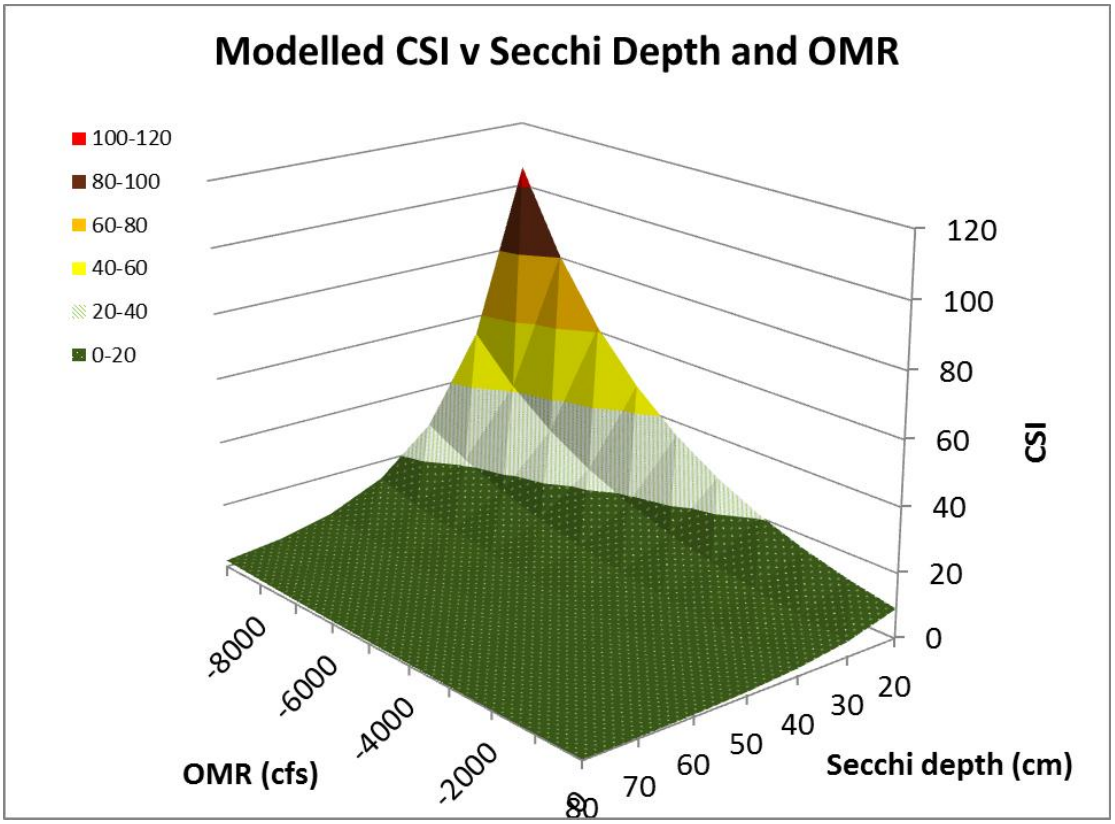

Figure 4

What to expect in 2014

As noted previously, salvage is expected to be extremely low during dry years with Delta turbidity levels less than 10 NTU (Grimaldo et al. 2009). Figure 4 shows the relationship between Secchi depth and turbidity in the Sacramento River in December (data taken from FMWT dataset 2009 – 2012). Rio Vista turbidity levels in January 2014 have been running around 6 NTU which translates into Secchi depths of greater than 100 cm. The multivariate model discussed above and the GAM model produced in the USFWS draft biological opinion (2011) predict low salvage ratios consistent with what was observed in 1994 (0.33) and 2007 (0.88). Unless there is a significant first flush event that raises turbidity levels in south and central Delta, entrainment risk should remain low. Additionally, concerns about the low 2013 FMWT and effects of salvage or reaching the ITL in 2014 should remain low if turbidity conditions remain low.

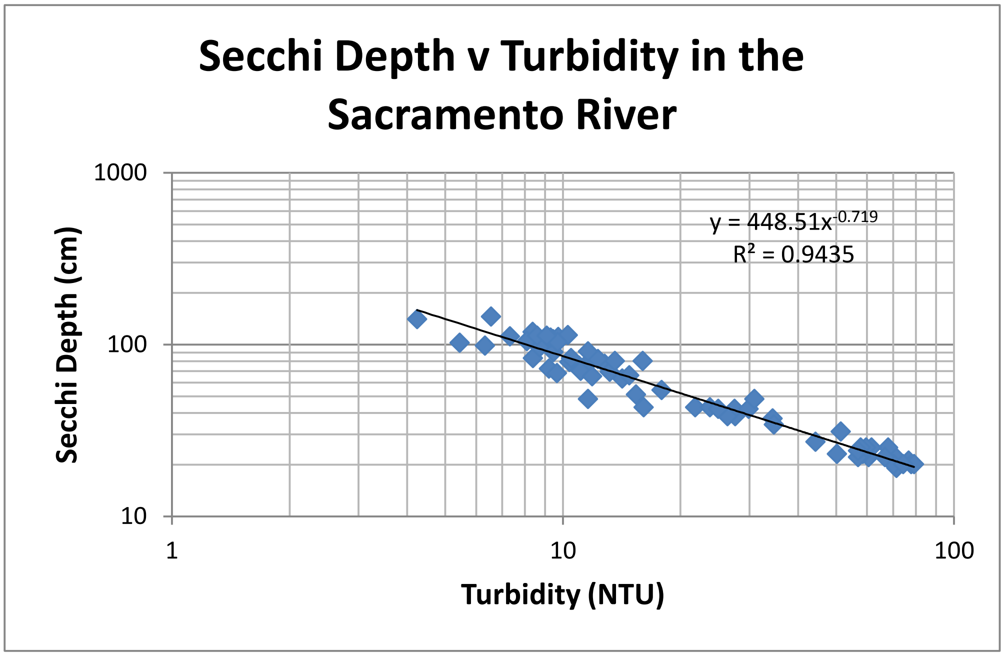

Figure 4. Secchi depth v turbidity in the Sacramento River in December (data taken from FMWT dataset 2009 – 2012).

Summary

- Currently the ITL calculated by USFWS may only represent a small portion of the overall variance in entrainment.
- A new approach incorporating all the recorded years using recent advances in the state of knowledge of turbidity dynamics is being proposed.
- The modeled approach utilizes the relationship between Secchi depth and OMR with the cumulative salvage index.
- The modeled CSI accurately predicted measured CSI.
- The modeled output is characterized by a one-sided 80% Prediction Interval based on previous guidelines produced by NMFS as a properly protective method for estimating abundance.

Roman J, Altman I, Dunphy-Daly MM, Campbell C, Jasny M, Read AJ. 2013. The Marine Mammal Proection Act at 40: Status, recovery, and future of U.S. marine mammals. Annals of the New York Academy of Sciences. p 1-21.