United States Department of the Interior

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MEMORANDUM

To: Regional Director
Pacific Southwest Region
U.S. Fish and Wildlife Service

From: David G. Murillo *David G. Murillo*
Regional Director

Subject: Reinitiation of Endangered Species Act Consultation on the Coordinated Long-term Operation of the Central Valley Project and State Water Project to Address Estimated Adult Delta Smelt Take for 2013 Operations

By this memorandum, the Bureau of Reclamation is reinitiating formal consultation on the estimated adult delta smelt incidental take authorized by the 2008 Biological Opinion (BiOp) regarding the effects of the coordinated long-term operation of the Central Valley Project and State Water Project on delta smelt. Endangered Species Act regulations require action agencies to reinitiate consultation when the estimate of incidental take included in the take statement is exceeded. While incidental take for delta smelt has not yet been exceeded, Reclamation is reinitiating consultation at this time as a precautionary measure.

Reclamation and the applicant to the consultation, the California Department of Water Resources, have implemented the Reasonable and Prudent Alternative (RPA) Component 1 for water year 2013 for protection of adult delta smelt in the manner determined by the U.S. Fish and Wildlife Service and consistent with the BiOp. The hydrologic conditions in December 2012 created an unusually pronounced "first flush," which appears to have set up a situation for the early onset of take of adult delta smelt. Reclamation believes that reinitiation on the estimated adult delta smelt incidental take authorization should begin so that the agencies can work together to determine whether there is a need to modify the incidental take estimate or the measures required to minimize take. Based on historical data, Reclamation does not believe that continued project operations consistent with RPA Component 1 will result in an exceedance of incidental take for 2013 (see Attachment). However, this year has presented an unusual occurrence of migration into the South Delta which has created the possibility of exceeding the take level. Reclamation does not believe that this possible exceedance of the estimated level of take for the remainder of the adult delta smelt season should constitute a detrimental effect to the population or critical habitat. Nor does Reclamation believe that it will irretrievably or irreversibly commit any resources which would foreclose the development or implementation of any RPA action during this reinitiated consultation.

Thank you for your time and attention to this important matter. My staff will be available to meet with your staff to continue discussions on how to proceed through the reinitiated consultation.

Attachment

2/12/13

Summary of conditions to date

- In early December, a series of storms created conditions (e.g., turbid water, high river inflows) that are often associated with delta smelt migration from the low salinity zone into freshwater regions of the Delta. Also known as the "first flush" period, this is the time when delta smelt can become vulnerable to entrainment at the SWP and CVP if they migrate in the south and central delta, an area within the "footprint" of Project operations which is indexed by Old and Middle River (OMR) flow for regulatory/management purposes.
- Historically, the highest delta smelt salvage occurred in years with strong first flush conditions similar to what was observed in December 2012.
- The CVP salvaged its first adult delta smelt on December 14th.
- On December 19th, the FWS initiated RPA Component 1 - Action 1 of their Biological Opinion (-2000 OMR cfs for 14 days) after recording three days of consecutive salvage.
- As of February 12th, 228 delta smelt have been salvaged at the SWP and CVP fish facilities. This take number represents 75% of the take limit (305).
- No delta smelt have been salvaged since February 5th.
- On February 8th, FWS made the determination that OMR flows should be no more negative than -1,250 cfs on a 14-day running average.
- It is uncertain how many smelt will be salvaged over the next few weeks. However, it is possible that the take limit can be reached as early as February or March.

What can be expected under present physical conditions in the next few weeks?

- Adult smelt salvage typically ceases around late March or early April.
- Salvage of delta smelt also decreases as turbidity decreases and OMR flows become less negative. Turbidity in the south Delta is dropping to levels (less than 10 ntu) where salvage tapers off significantly.
- Further, an analysis of historical data (see Appendix 1) predicts that salvage of delta smelt under current hydrodynamic conditions (Sacramento Flow ~ 17,000 cfs) would not exceed 1.2 fish per per 14 days if OMR flow was to continue at -1,250 cfs (~ 7 total smelt salvage between now and April 30th). At OMR flows of -3,022 cfs, the model predicts salvage would not exceed 2.35 smelt per 14 days (~13 total smelt salvage between now and April 31st).
- Thus, the take limit, based on model predictionswould not to be reached before April 30th, even if OMR flow ranges between -1250 and -3000 cfs.

How the existing take limit was calculated

- The FWS Biological Opinion determined annual take numbers using a method called the cumulative salvage index (CSI; Page 385 of the FWS Biological Opinion). The CSI is calculated as the total year's adult salvage (the aggregate number for expanded salvage at both the Banks and Jones export facilities for the period December through March) divided by the previous year's FMWT Index

- The FWS used the average CSI (7.5) from water years 2006 (8.3), 2007 (0.88), 2008 (12.6) as the multiplier to set the annual take limit. These years were selected because they represented current population size and because they best represented years within the historic dataset where salvage would be expected under RPA Component 1.

Environmental Variability Allowance

- The FWS Biological Opinion acknowledges that it is challenging to predict take numbers due to variability in where smelt migrate in any given year:

  The specific level of take of adult delta smelt at the CVP/SWP pumping facilities is difficult to definitively project, due to inherent uncertainties. Distribution of adult smelt is highly variable between years, and is driven by factors that are both inherently difficult to predict and also not completely understood. These factors are, at best, imperfectly controlled (Page 383).

- Hydrodynamic and turbidity conditions during water years 2006-2008 are different from conditions observed in the current water year (2013). As mentioned previously, conditions during December 2012 produced strong first flush conditions (i.e., high turbidity and elevated outflow) that cued smelt to migrate into the lower San Joaquin River and interior Delta. This migration upstream was observed by the salvage facilities and the Department of Fish and Wildlife Spring Kodiak Trawl Survey.

- To account for variability in delta smelt distribution, the range of CSI values (2006 = 8.3, 2007 = 0.88, and 2008 = 12.6) could be used to determine the take limit if the Projects need to reinitiate and not just average value (7.5).

Report on Planning and Forecasting Turbidity and Salvage Predictions for the Metropolitan Water District of Southern California Task Order 1 of Agreement 119889

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Summary

! Equation (3.7) in the report by Manly (2011a) can be used to predict 14 day averages of Clifton Court turbidity (CCT) using 14 day averages of the Sacramento River flow at Freeport (SAC) and flows from east side streams in the Sacramento-San Joaquin Delta excluding the San Joaquin River flow (EAST), with the river flow averages starting ten days before the turbidity averages. This equation accounts for 55.6% of the variation in the turbidity values. It was considered that the equation might be improved if the variables SAC and EAST were modified by removing the effects of reservoir releases. This was investigated but it was found that if the variables are modified in this way then the best fitting equation no longer contains these variables and the percentage of the variation accounted for is reduced by about 2.5%. Therefore, modifying the variables SAC and EAST in this way does not give an improved equation for estimating 14 day average turbidity values.

! The report by Manly (2010) included the examination of equations for estimating weekly salvage totals weeks in December to January, February to March, and December to February. One equation was of particular interest, which involved the estimation of weekly salvage totals using weekly averages of the combined Old and Middle River flows and Sacramento River flows to estimate weekly salvage numbers in December to January. This earlier study is extended here to the estimation of 14 day salvage totals with the extra variable EAST considered and also the modified versions of SAC and EAST with the effects of reservoir releases removed. It was found from the new analyses described here that a quadratic equation using 14 day averages of the modified SAC variable starting ten days before a 14 day salvage period can account for 62.2% of the variation in the salvage numbers, a quadratic equation using the combined Old and Middle River flows (COMR) and the modified SAC variable with 14 day averages starting one day before 14 day salvage periods can account for 83.3% of the variation in the salvage numbers, and a quadratic equation using these variables and the San Joaquin River flow at Vernalis can account for 88.2% of the variation in salvage numbers. Initially the salvage equations were estimated using data from four observations in each December to January period for 14 day intervals starting on 1 December, 15 December, 29 December and 12 January to give independent observations on salvage. However, once the form of the best quadratic equations was determined the equations were re-estimated using the data from all possible 14 day periods in December and January. This produced equations that fit the data from all possible 14 day periods slightly better than the original equations in some years.

! A comparison with the total salvage estimates for 14 day salvage periods using an equation provided by Deriso (2010) indicates that the Deriso equation does not give fit the observed salvage numbers as well the equations estimated in this report using the data from all 14 day periods in December and March. However, this may be because the Deriso equation was fitted using data from December to March rather than December to January, and also for the years 1988 to 2006 rather than 1993 to 2009.

1. Equations for Predicting 14 Day Average Clifton Court Turbidity

The first objective of Task Order 1 of Agreement 119889 between Western EcoSystems Technology Inc. and the Metropolitan Water District of Southern California was to refine equation (3.7) in the report by Manly (2011a) by modifying the Sacramento at Freeport and the East Side Stream flows to net out reservoir releases, to see how this improves the equation. The modified flow data for this objective was provided by Paul Hutton on April 11, 2011 in the Excel file Reservoir releases - clean v2.xlsx.

Equations Fitted Earlier

Equation (3.7) in the report by Manly (2011a) was obtained when the five possible predictor variables shown in Table 1.1 were considered. These variables were standardized for use in linear regression models to have means of zero and standard deviations (SD) of one in order to avoid very high or low estimated regression coefficients, so that the variable X was replaced by X = (X - Mean)/SD, where the means and standard deviations are shown in Table 1.2, along with the maximum and minimum observed values.

Table 1.1 The variables considered for predicting CCT (the Clifton Court turbidity) or Ln(CCT). Daily values for each of these variables were available for the period January 1, 1990 to June 30, 2009 (7121 days). These data were provided by David Fullerton on December 27, 2010. All flows are in cubic feet per second (cfs).

COMR	The combined Old and Middle River flow.
SAC	The Sacramento River flow at Freeport.
OUT	The Sacramento-San Joaquin Delta outflow.
SJRV	The San Joaquin River flow at Vernalis.
EAST	The flow from east side streams in the Delta, not including the San Joaquin River.

Table 1.2 Minimums, maximums, means and standard deviations (SD) for daily values of predictor variables from January 1, 1990 to June 30, 2009.

	COMR	SAC	OUT	SJRV	EAST
Minimum	-24297	4340	-29087	390	54
Maximum	30800	113000	567185	54300	60841
Mean	-4447	22934	24520	4063	1360
SD	5016	18377	42367	5696	2401

The standardized variables were used to fit all possible quadratic equations with one, two and three predictor variables of the forms

$$E(CCT) = b_0 + b_1X_1 + b_2X_1^2, \quad (1.1)$$

$$E(CCT) = b_0 + b_1X_1 + b_2X_2 + b_3X_1^2 + b_4X_2^2 + b_5X_1X_2, \quad (1.2)$$

and

$$E(CCT) = b_0 + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_1^2 + b_5X_2^2 + b_6X_3^2 + b_7X_1X_2 + b_8X_1X_3 + b_9X_2X_3, \quad (1.3)$$

where E(CCT) is the expected average turbidity in a 14 day period in the months December to February, X_1, X_2 and X_3 are three of the variables COMR, SAC, OUT, SJRV and EAST with one of nine averaging periods so that X_1, X_2 and X_3 could be averages for the same 14 days as the turbidity average, or averages starting 1, 2, 3, 4, 5, 7, 10 or 14 days before the turbidity period.

Quadratic models as defined by equations (1.1) to (1.3) were also considered but with Ln(CCT), the natural logarithm of the Clifton Court turbidity, as the dependent variable to see whether this produced a better fit to the data.

Equation (3.7) in the earlier report involves the two variables SAC and EAST with averages starting ten days before the turbidity average. As shown in Table 1.3 these two variables give the best quadratic equation involving two variables. It gives the smallest regression residual mean square, and accounts for 55.6% of the variation in the 14 day turbidity averages.

Table 1.3 This was Table 3.2 in Manly (2011a). It shows the 20 best fitting models using two variables in terms of the percentage of the variation in turbidity accounted for (% Expl) and the residual mean square (RMS). The Days Back variable is the number of days that the river flow 14 day average begins before the turbidity average (e.g., a value of 0 means that both averages are for the same 14 days, while a value of 14 means that the river flow averages are for a period that ends the day before the turbidity average period begins). Estimated regression coefficients and their standard errors (SE) are shown for each model.

	RMS	% Expl	Days Back	X_1	X_2	b_0	SE	b_1	SE	b_2	SE	b_3	SE	b_4	SE	b_5	SE
1	44.9	55.6	10	SAC	EAST	16.17	1.16	10.68	2.63	-0.61	4.40	-5.52	1.45	0.09	0.90	2.59	3.17
2	45.5	55.0	7	SAC	EAST	14.38	1.14	14.28	2.39	-7.51	3.97	-7.76	1.27	-1.99	0.61	9.29	2.40
3	46.2	54.3	5	SAC	EAST	14.17	1.18	14.61	2.58	-7.85	4.34	-8.37	1.44	-2.50	0.71	10.61	2.83
4	46.6	53.9	4	SAC	EAST	14.06	1.16	14.74	2.61	-7.93	4.31	-8.53	1.48	-2.60	0.70	10.86	2.83
5	47.7	52.8	3	SAC	EAST	13.93	1.14	14.67	2.63	-7.87	4.26	-8.46	1.50	-2.58	0.69	10.74	2.80
6	47.9	52.6	10	SAC	SJRV	15.57	1.64	13.30	2.18	-4.01	4.50	-6.62	1.09	-1.67	0.73	7.23	2.09
7	48.3	52.2	7	SAC	SJRV	15.24	1.65	12.63	2.17	-3.02	4.43	-6.09	1.10	-1.29	0.67	6.23	1.90
8	49.4	51.2	7	SAC	OUT	16.01	1.12	11.33	3.77	-1.56	6.19	-8.51	3.22	-0.89	2.58	6.78	6.12
9	49.8	50.8	14	SAC	EAST	17.21	1.16	10.58	2.45	0.56	4.09	-6.45	1.48	-0.56	0.71	3.79	2.73
10	49.8	50.8	2	SAC	EAST	13.98	1.10	13.96	2.62	-6.81	4.08	-8.09	1.52	-2.42	0.68	9.98	2.73
11	50.2	50.3	5	SAC	OUT	16.69	1.16	9.34	3.94	3.33	6.65	-12.29	2.73	-5.18	1.74	14.45	4.86
12	50.8	49.7	5	SAC	SJRV	14.83	1.57	11.21	2.13	-1.81	4.14	-5.04	1.06	-0.79	0.65	4.70	1.65
13	51.0	49.5	7	COMR	SAC	14.15	1.06	-1.95	1.52	8.24	1.44	0.79	0.50	-2.60	0.78	0.94	1.04
14	51.1	49.5	4	SAC	OUT	16.64	1.17	8.70	3.96	4.44	6.71	-12.25	2.66	-5.27	1.54	14.42	4.58
15	51.3	49.2	5	COMR	SAC	13.53	1.03	-1.96	1.51	7.56	1.43	0.89	0.48	-2.09	0.75	0.68	1.01
16	51.4	49.1	4	COMR	SAC	13.31	1.02	-1.87	1.50	7.33	1.42	0.93	0.47	-1.93	0.74	0.57	0.98
17	51.7	48.9	4	SAC	SJRV	14.65	1.51	10.59	2.07	-1.26	3.91	-4.60	1.03	-0.60	0.64	4.08	1.52
18	51.7	48.9	3	COMR	SAC	13.12	1.01	-1.74	1.48	7.12	1.42	0.99	0.47	-1.80	0.73	0.43	0.96
19	52.0	48.6	14	SAC	SJRV	15.70	1.65	12.27	2.37	-3.73	4.84	-6.02	1.15	-1.21	1.09	6.23	2.70
20	52.0	48.5	3	COMR	SJRV	12.90	1.18	-6.65	1.52	10.22	1.75	5.64	2.23	2.91	2.45	-8.41	4.51

This best fitting equation using SAC and EAST is

$$E(CCT) = 16.167 + 10.679(SAC10) - 0.614(EAST10) - 5.520(SAC10^2) + 0.093(EAST10^2) + 2.587(SAC10.EAST10), \quad (1.4)$$

where the use of SAC10 and EAST10 is to indicate that the variables are averages ten days before the turbidity average. In this equation the coefficients of EAST10 ($t = -0.14$ with 105 df, $p = 0.889$), $EAST10^2$ ($t = 0.10$, $p = 0.918$) and SAC10.EAST10 ($t = 0.82$, $p = 0.416$) are not at all significant. Removing the SAC10.EAST10 term changes the equation to

$$E(CCT) = 16.707 + 8.916(SAC10) + 2.577(EAST10) - 4.481(SAC10^2) + 0.793(EAST10^2), \quad (1.5)$$

which accounts for 55.7% of the variation in CCT with highly significant coefficients for SAC10, $SAC10^2$ and $EAST10^2$. The coefficient of EAST10 is not significant ($t = 1.27$ with 106 df, $p = 0.206$) but this term was left in the equation because of the significance of its squared effect.

Table 1.4 This was Table 3.5 in Manly (2011a). It shows the 20 best fitting models using two variables in terms of the percentage of the variation in Ln(Turbidity) accounted for (% Expl) and the residual mean square (RMS). The Days Back variable is the number of days that the river flow 14 day average begins before the turbidity average (e.g., a value of 0 means that both averages are for the same 14 days, while a value of 14 means that the river flow averages are for a period that ends the day before the turbidity average period begins). Estimated regression coefficients and their standard errors (SE) are shown for each model.

	RMS	% Expl	Days Back	X_1	X_2	b_0	SE	b_1	SE	b_2	SE	b_3	SE	b_4	SE	b_5	SE
1	0.20	51.2	10	SAC	EAST	2.61	0.08	0.84	0.18	-0.11	0.29	-0.42	0.10	-0.02	0.06	0.22	0.21
2	0.20	50.4	7	SAC	EAST	2.53	0.08	0.95	0.16	-0.35	0.27	-0.48	0.08	-0.09	0.04	0.45	0.16
3	0.20	50.1	10	SAC	SJRV	2.64	0.11	0.89	0.14	-0.07	0.29	-0.44	0.07	-0.09	0.05	0.35	0.14
4	0.21	49.2	7	SAC	OUT	2.60	0.07	0.90	0.24	-0.21	0.40	-0.62	0.21	-0.10	0.17	0.52	0.4
5	0.21	48.8	14	SAC	EAST	2.68	0.08	0.82	0.16	-0.03	0.27	-0.47	0.10	-0.05	0.05	0.27	0.18
6	0.21	48.6	5	SAC	EAST	2.50	0.08	0.96	0.17	-0.39	0.29	-0.50	0.10	-0.12	0.05	0.51	0.19
7	0.21	47.8	7	SAC	SJRV	2.62	0.11	0.83	0.14	0.00	0.29	-0.40	0.07	-0.08	0.04	0.29	0.13
8	0.21	47.8	4	SAC	EAST	2.49	0.08	0.96	0.18	-0.41	0.29	-0.50	0.10	-0.12	0.05	0.53	0.19
9	0.22	47.2	14	SAC	SJRV	2.63	0.11	0.85	0.15	-0.14	0.31	-0.42	0.07	-0.07	0.07	0.33	0.17
10	0.22	47.2	10	SAC	OUT	2.63	0.07	0.92	0.24	-0.25	0.39	-0.69	0.17	-0.17	0.09	0.67	0.29
11	0.22	47.1	10	COMR	SAC	2.57	0.07	-0.14	0.10	0.70	0.09	0.01	0.03	-0.27	0.05	0.13	0.07
12	0.22	46.9	5	SAC	OUT	2.62	0.08	0.78	0.26	0.02	0.44	-0.71	0.18	-0.23	0.11	0.71	0.32
13	0.22	46.5	3	SAC	EAST	2.47	0.08	0.95	0.18	-0.42	0.29	-0.50	0.10	-0.12	0.05	0.53	0.19
14	0.22	45.6	4	SAC	OUT	2.60	0.08	0.75	0.26	0.06	0.44	-0.70	0.18	-0.23	0.10	0.71	0.30
15	0.22	45.4	7	COMR	SAC	2.50	0.07	-0.16	0.10	0.65	0.10	0.02	0.03	-0.22	0.05	0.09	0.07
16	0.23	44.4	2	SAC	EAST	2.46	0.07	0.91	0.18	-0.38	0.28	-0.47	0.10	-0.11	0.05	0.49	0.18
17	0.23	44.2	5	SAC	SJRV	2.56	0.11	0.76	0.14	0	0.28	-0.33	0.07	-0.05	0.04	0.23	0.11
18	0.23	44.1	14	COMR	SAC	2.58	0.07	-0.17	0.10	0.67	0.09	-0.02	0.03	-0.25	0.05	0.19	0.07
19	0.23	43.5	3	SAC	OUT	2.58	0.08	0.75	0.26	0.02	0.44	-0.67	0.18	-0.23	0.10	0.70	0.30
20	0.23	43.0	5	COMR	SAC	2.45	0.07	-0.16	0.10	0.59	0.10	0.03	0.03	-0.17	0.05	0.07	0.07

Using Ln(CCT) as the dependent variable did not gives results that were as good as those using CCT. Table 1.4 shows the best fitting models with two variables that were found with Ln(CCT) as the dependent variable. The best equation still uses the variables SAC and EAST with averages starting ten days before the turbidity averages, but only accounts for 51.2% of the variation in Ln(CCT), compared to 55.6% for the best equation with CCT as the dependent variable.

The best equation is

$$E\{Ln(CCT)\} = 2.612 + 0.836(SAC10) - 0.113(EAST10) - 0.416(SAC10^2) - 0.024(EAST10^2) + 0.223(SAC10.EAST10). \quad (1.6)$$

In this equation the coefficients of EAST10 ($t = -0.39$ with 105 df, $p = 0.701$), $EAST10^2$ ($t = -0.40$, $p = 0.688$) and SAC10.EAST10 ($t = 1.06$, $p = 0.292$) are not at all significant. Removing the $EAST10^2$ term changes the equation to

$$E\{Ln(CCT)\} = 2.627 + 0.788(SAC10) - 0.028(EAST10) - 0.385(SAC10^2) + 0.143(SAC10.EAST10), \quad (1.7)$$

which accounts for 51.6% of the variation in Ln(CCT) with significant coefficients for SAC10, $SAC10^2$ and SAC10.EAST10. The coefficient of EAST10 is not significant ($t = -0.14$ with 106 df, $p = 0.890$) but this term was left in the equation because of the significance of the product effect.

Equations with Reduced Data

Equation (1.5) above was labeled as equation (3.7) by Manly (2011a), while equation (1.7) was labeled (3.12) by Manly (2011a). The question that is now considered is whether equation (1,5) can be improved by modifying the flow variables SAC and EAST to net out reservoir releases.

There is a complication involved with this question because the modified data for SAC and EAST provided by Paul Hutton starts on October 3, 1993 but the data used to fit equation (1.5) started on January 1, 1990. Hence there are no modified data available for 14 week periods in the months of December to February from January 1990 to February 1993. For fitting the equations in the earlier report there were 111 data points available, but this is reduced to 93 data points for fitting equations with the modified data. To allow for this the calculations that resulted in Tables 1.3 and 1.4 were repeated with the same variables as used by Manly (2011a) but only using the 93 data points available after October 1993, to see how much this changes the results. The standardization of variables was still based on the means and standard deviations shown in Table 1.2.

Table 1.5 shows the results from the 20 best fitting models using two predictor variables and the dependent variable CCT with the variables used by Manly (2001) but without using the results before October 1993. The best model is still the one using the variables SAC and EAST with averages starting ten days before the turbidity average but the percentage of the variation accounted for is now 52.7% which is less than the 55.6% accounted for with equation (1.4).

Table 1.5 This table shows the 20 best fitting models using two variables in terms of the percentage of the variation in turbidity (CCT) accounted for (% Expl) and the residual mean square (RMS) when the analysis of Manly (2011a) was repeated with the same variables but only using data after October 1993. The Days Back variable is the number of days that the river flow 14 day average begins before the turbidity average (e.g., a value of 0 means that both averages are for the same 14 days, while a value of 14 means that the river flow averages are for a period that ends the day before the turbidity average period begins). Estimated regression coefficients and their standard errors (SE) are shown for each model.

	RMS	% Expl	Days Back	X_1	X_2	b_0	SE	b_1	SE	b_2	SE	b_3	SE	b_4	SE	b_5	SE
1	49.9	52.7	10	SAC	EAST	15.80	1.27	11.69	2.99	-2.99	4.87	-6.05	1.62	-0.20	0.98	4.00	3.48
2	50.1	52.5	7	SAC	EAST	14.13	1.25	15.02	2.69	-9.57	4.36	-8.10	1.40	-2.13	0.65	10.28	2.60
3	50.7	51.8	5	SAC	EAST	14.08	1.30	15.37	2.89	-9.62	4.80	-8.81	1.59	-2.68	0.76	11.61	3.09
4	51.1	51.5	4	SAC	EAST	14.04	1.29	15.49	2.92	-9.48	4.77	-9.00	1.62	-2.77	0.75	11.80	3.09
5	52.5	50.2	3	SAC	EAST	14.03	1.27	15.17	2.94	-8.85	4.69	-8.83	1.65	-2.70	0.74	11.37	3.05
6	52.8	49.9	10	SAC	SJRV	15.30	1.73	13.63	2.43	-5.53	4.92	-6.88	1.24	-1.76	0.78	7.97	2.26
7	53.3	49.4	7	SAC	SJRV	14.88	1.76	13.00	2.42	-4.89	4.86	-6.28	1.25	-1.30	0.71	6.93	2.05
8	54.9	47.9	7	SAC	OUT	16.16	1.27	11.58	4.74	-1.83	7.34	-9.24	3.78	-1.28	2.82	7.86	6.97
9	54.9	47.9	5	SAC	OUT	17.06	1.32	9.30	4.87	4.02	7.82	-13.06	3.19	-5.54	1.89	15.29	5.55
10	55.0	47.8	2	SAC	EAST	14.26	1.23	14.09	2.92	-6.99	4.45	-8.30	1.67	-2.46	0.73	10.17	2.95
11	55.5	47.3	4	SAC	OUT	17.08	1.33	8.61	4.88	5.41	7.85	-13.09	3.10	-5.65	1.68	15.28	5.23
12	55.5	47.3	14	SAC	EAST	17.00	1.26	11.15	2.76	-1.04	4.48	-6.71	1.64	-0.73	0.76	4.66	2.97
13	56.2	46.6	5	SAC	SJRV	14.59	1.67	11.49	2.38	-3.44	4.51	-5.17	1.20	-0.74	0.70	5.20	1.77
14	57.2	45.7	4	SAC	SJRV	14.50	1.61	10.77	2.34	-2.60	4.26	-4.70	1.16	-0.53	0.69	4.46	1.63
15	57.7	45.2	7	COMR	SAC	14.41	1.17	-1.69	1.77	7.98	1.73	0.71	0.56	-2.59	0.90	1.01	1.21
16	57.7	45.2	14	SAC	SJRV	15.48	1.76	12.17	2.62	-4.94	5.37	-5.97	1.26	-1.29	1.16	6.70	2.93
17	57.7	45.2	5	COMR	SAC	13.90	1.15	-1.66	1.74	7.30	1.71	0.80	0.53	-2.11	0.86	0.79	1.14
18	57.7	45.2	4	COMR	SAC	13.73	1.13	-1.55	1.71	7.11	1.71	0.82	0.51	-1.97	0.85	0.71	1.10
19	57.8	45.2	3	SAC	OUT	16.80	1.32	8.32	4.88	5.35	7.80	-12.68	3.12	-5.48	1.61	14.90	5.15
20	57.9	45.0	3	COMR	SAC	13.59	1.12	-1.40	1.70	6.90	1.71	0.86	0.50	-1.86	0.83	0.60	1.07

The best estimated model shown in Table 1.5 is

$$E(CCT) = 15.796 + 11.690(SAC10) - 2.986(EAST10) - 6.055(SAC10^2) - 0.201(EAST10^2) + 3.996(SAC10.EAST10). \quad (1.8)$$

In this equation the coefficients of EAST10 ($t = -0.61$ with 87 df, $p = 0.542$), $EAST10^2$ ($t = -0.21$, $p = 0.838$) and SAC10.EAST10 ($t = 1.15$, $p = 0.253$) are not at all significant. Removing the SAC10.EAST10 term changes the equation to

$$E(CCT) = 16.627 + 8.898(SAC10) + 2.035(EAST10) - 4.439(SAC10^2) + 0.871(EAST10^2), \quad (1.9)$$

which accounts for 52.5% of the variation in CCT with highly significant coefficients for SAC10, $SAC10^2$ and $EAST10^2$. The coefficient of EAST10 is not significant ($t = 0.94$ with 88 df, $p = 0.350$) but this term was left in the equation because of the significance of its squared effect.

Equations (1.5) and (1.9) have similar coefficients, where equation (1.5) is the same as equation (3.7) produced by Manly (2011a). Therefore, the reduced data starting in October 1993 gives about the same equation as the data starting in January 1990, although the percentage of the variation in CCT accounted for is 52.5% based on the reduced data and 55.7% based on the data starting earlier.

Table 1.6 shows the best 20 equations found using the reduced data with Ln(CCT) as the dependent variable in the regressions. The best equation still involves the variables SAC and EAST but with averages starting seven days before the turbidity average rather than ten days before. This accounts for only 46.8% of the variation in Ln(CCT) compared to the 51.2% accounted for by equation (1.6) based on the larger set of data. The second best equation does have SAC and EAST as the variables with averages starting ten days before the turbidity average, and this accounts for 46.6% of the variation in Ln(CCT), which is nearly as much as the best equation. This equation is very similar to equation (1.7).

Table 1.6 This table shows the 20 best fitting models using two variables in terms of the percentage of the variation in Ln(CCT) accounted for (% Expl) and the residual mean square (RMS) when the analysis of Manly (2011a) was repeated with the same variables but only using data after October 1993. The Days Back variable is the number of days that the river flow 14 day average begins before the turbidity average (e.g., a value of 0 means that both averages are for the same 14 days, while a value of 14 means that the river flow averages are for a period that ends the day before the turbidity average period begins). Estimated regression coefficients and their standard errors (SE) are shown for each model.

	RMS	% Expl	Days Back	X_1	X_2	b_0	SE	b_1	SE	b_2	SE	b_3	SE	b_4	SE	b_5	SE
1	0.20	46.8	7	SAC	EAST	2.55	0.08	0.92	0.17	-0.39	0.28	-0.48	0.09	-0.09	0.04	0.46	0.16
2	0.20	46.6	10	SAC	EAST	2.61	0.08	0.84	0.19	-0.22	0.31	-0.42	0.10	-0.04	0.06	0.28	0.22
3	0.20	45.9	5	SAC	EAST	2.53	0.08	0.93	0.18	-0.39	0.30	-0.50	0.10	-0.12	0.05	0.51	0.20
4	0.20	45.8	10	SAC	SJRV	2.62	0.11	0.89	0.15	-0.21	0.30	-0.45	0.08	-0.10	0.05	0.40	0.14
5	0.20	45.4	4	SAC	EAST	2.52	0.08	0.93	0.18	-0.40	0.30	-0.50	0.10	-0.12	0.05	0.53	0.20
6	0.20	45.4	7	SAC	OUT	2.65	0.08	0.72	0.29	0.05	0.45	-0.58	0.23	-0.09	0.17	0.42	0.43
7	0.21	45.0	5	SAC	OUT	2.69	0.08	0.57	0.30	0.38	0.48	-0.68	0.20	-0.22	0.12	0.61	0.34
8	0.21	44.1	4	SAC	OUT	2.68	0.08	0.55	0.30	0.42	0.48	-0.68	0.19	-0.23	0.10	0.63	0.32
9	0.21	44.1	3	SAC	EAST	2.51	0.08	0.92	0.19	-0.39	0.30	-0.49	0.10	-0.12	0.05	0.52	0.19
10	0.21	44.0	7	SAC	SJRV	2.60	0.11	0.84	0.15	-0.15	0.30	-0.40	0.08	-0.08	0.05	0.35	0.13
11	0.21	43.5	14	SAC	EAST	2.68	0.08	0.80	0.17	-0.12	0.28	-0.46	0.10	-0.06	0.05	0.31	0.18
12	0.22	42.2	14	SAC	SJRV	2.61	0.11	0.83	0.16	-0.27	0.33	-0.40	0.08	-0.08	0.07	0.37	0.18
13	0.22	41.8	3	SAC	OUT	2.65	0.08	0.55	0.30	0.37	0.48	-0.66	0.19	-0.23	0.10	0.63	0.32
14	0.22	41.6	2	SAC	EAST	2.51	0.08	0.85	0.18	-0.30	0.28	-0.45	0.11	-0.11	0.05	0.45	0.19
15	0.22	41.0	10	SAC	OUT	2.66	0.08	0.80	0.29	-0.09	0.44	-0.66	0.20	-0.17	0.10	0.62	0.33
16	0.22	40.7	5	SAC	SJRV	2.55	0.11	0.76	0.15	-0.13	0.28	-0.33	0.08	-0.05	0.04	0.26	0.11
17	0.22	40.3	10	COMR	SAC	2.60	0.08	-0.08	0.11	0.67	0.11	0.00	0.04	-0.26	0.06	0.12	0.07
18	0.23	39.5	4	SAC	SJRV	2.54	0.10	0.72	0.15	-0.11	0.27	-0.30	0.07	-0.04	0.04	0.23	0.10
19	0.23	39.1	7	COMR	SAC	2.54	0.07	-0.09	0.11	0.61	0.11	0.02	0.04	-0.21	0.06	0.07	0.08
20	0.23	38.5	2	SAC	OUT	2.62	0.08	0.56	0.30	0.27	0.48	-0.61	0.20	-0.21	0.10	0.60	0.33

Equations using Ln(CCT) as the dependent variable are not considered further here because they do not fit the data as well as equations using CCT as the dependent variable in terms of the percentage of the variation accounted for.

Using the Modified Data

The next stage in the analysis involved redoing the calculations using the data starting in October 1993 but with modified variables replacing SAC and EAST, with reservoir releases netted out. The variable SAC was replaced by the variable SAC1 defined as the Sacramento River flow at Freeport plus the Yolo River flow minus the Keswick, Oroville

Englebright and Folsum flows, while the variable EAST was replaced by EAST1 defined as the flow from Eastside Streams minus the Comanche and New Hogan flows.

Table 1.7 shows the maximums, minimums, means and standard deviations of these and the other predictor variables considered for the period October 3, 1993 to June 30, 2009. The means and standard deviations were used to standardize the daily variable values as X' = (X - Mean)/SD before any other calculations were performed.

Table 1.7 The minimums, maximums, means and standard deviations (SD) for daily values of predictor variables from October 3, 1993 to June 30, 2009 in cubic feet a second (cfs)..

	COMR	SAC1	OUT	SJRV	EAST1
Minimum	-24297	-45574	-29087	741	-813
Maximum	30800	210054	567185	54300	56091
Mean	-4432	8610	27604	4704	525
SD	5429	20767	45737	6147	1684

Table 1.8 This table shows the 20 best fitting models using two variables in terms of the percentage of the variation in turbidity (CCT) accounted for (% Expl) and the residual mean square (RMS) when the analysis of Manly (2011a) was repeated with the modified variables SAC1 and EAST1 using data after October 1993. The Days Back variable is the number of days that the river flow 14 day average begins before the turbidity average (e.g., a value of 0 means that both averages are for the same 14 days, while a value of 14 means that the river flow averages are for a period that ends the day before the turbidity average period begins). Estimated regression coefficients and their standard errors (SE) are shown for each model.

	RMS	% Expl	Days Back	X_1	X_2	b_0	SE	b_1	SE	b_2	SE	b_3	SE	b_4	SE	b_5	SE
1	52.5	50.2	3	COMR	SAC1	11.39	0.93	-1.31	1.49	8.75	1.68	1.35	0.45	-1.46	0.47	-0.45	0.78
2	52.6	50.0	4	COMR	SAC1	11.46	0.93	-1.45	1.52	8.98	1.69	1.26	0.48	-1.55	0.49	-0.28	0.88
3	52.7	49.9	2	COMR	SAC1	11.36	0.94	-1.09	1.48	8.51	1.68	1.44	0.44	-1.39	0.47	-0.67	0.76
4	53.0	49.7	5	COMR	SAC1	11.54	0.93	-1.57	1.56	9.24	1.72	1.23	0.52	-1.69	0.52	-0.20	0.97
5	53.1	49.6	1	COMR	SAC1	11.34	0.95	-0.82	1.48	8.36	1.70	1.49	0.43	-1.34	0.47	-0.85	0.75
6	53.8	49.0	0	COMR	SAC1	11.33	0.96	-0.46	1.48	8.32	1.77	1.45	0.44	-1.34	0.50	-0.90	0.76
7	54.9	47.9	7	COMR	SAC1	11.84	0.94	-1.74	1.64	9.79	1.84	1.13	0.57	-2.08	0.61	0.07	1.08
8	55.9	47.0	10	SAC1	EAST1	12.66	0.92	9.84	2.29	-0.09	2.24	-2.37	0.68	1.26	0.59	-0.37	0.72
9	56.1	46.7	10	SAC1	OUT	12.54	1.04	11.09	2.82	-0.11	2.37	-0.97	1.70	4.05	1.22	-5.70	2.56
10	56.3	46.6	7	SAC1	OUT	9.95	1.24	16.99	3.41	-8.90	3.41	-3.30	1.18	2.65	0.93	-0.02	1.62
11	56.9	45.9	5	SAC1	SJRV	11.18	1.49	10.05	2.25	-2.00	2.89	-1.82	0.62	0.77	0.61	1.06	1.04
12	57.0	45.9	4	SAC1	SJRV	11.19	1.48	9.81	2.22	-1.76	2.82	-1.72	0.59	0.83	0.60	0.87	0.98
13	57.6	45.4	7	SAC1	EAST1	12.64	0.94	10.23	2.42	1.75	2.42	-3.46	1.00	-0.36	0.29	2.38	1.02
14	57.6	45.3	3	SAC1	SJRV	11.38	1.45	9.40	2.21	-1.13	2.73	-1.61	0.58	0.89	0.60	0.50	0.92
15	58.2	44.7	0	SAC1	SJRV	11.96	1.33	8.76	2.10	0.91	2.35	-1.60	0.58	0.81	0.58	-0.13	0.84
16	58.2	44.7	2	SAC1	SJRV	11.62	1.42	8.97	2.18	-0.41	2.64	-1.53	0.57	0.89	0.60	0.21	0.89
17	58.5	44.5	7	SAC1	SJRV	11.91	1.47	10.13	2.33	-0.93	2.87	-2.11	0.71	0.64	0.63	0.86	1.11
18	58.5	44.4	1	SAC1	SJRV	11.83	1.38	8.70	2.13	0.27	2.51	-1.50	0.56	0.87	0.59	-0.04	0.85
19	58.8	44.2	5	COMR	EAST1	12.78	0.94	-3.43	1.59	6.35	1.60	1.47	0.57	-0.45	0.37	-0.26	0.82
20	59.0	44.0	5	SAC1	EAST1	12.47	0.95	9.78	2.32	2.21	2.27	-3.16	1.00	-0.61	0.33	2.33	1.22

Table 1.8 shows the 20 best quadratic equations found of the form of equation (1.2) using two of the five variables with the Clifton Court turbidity as the dependent variable. The best model uses the variables COMR and SAC1 with averages starting three days before the turbidity average, and accounts for 50.2% of the variation in CCT, which is less than the 52.7% accounted for by the unmodified variables SAC and EAST with equation

(1.8). The equation using SAC1 and EAST1 with averages starting ten days before the turbidity average is the eighth best model shown in Table 1.8, with only 47.0% of the variation in CCT accounted for, which is 5.2% less than what is accounted for by equation (1.8).

Table 1.9 This table shows the 20 best fitting models using two variables in terms of the percentage of the variation in Ln(CCT) accounted for (% Expl) and the residual mean square (RMS) when the analysis of Manly (2011a) was repeated with the modified variables SAC1 and EAST1 using data after October 1993. The Days Back variable is the number of days that the river flow 14 day average begins before the turbidity average (e.g., a value of 0 means that both averages are for the same 14 days, while a value of 14 means that the river flow averages are for a period that ends the day before the turbidity average period begins). Estimated regression coefficients and their standard errors (SE) are shown for each model.

	RMS	% Expl	Days Back	X_1	X_2	b_0	SE	b_1	SE	b_2	SE	b_3	SE	b_4	SE	b_5	SE
1	0.23	39.7	5	COMR	SAC1	2.32	0.06	-0.09	0.10	0.63	0.11	0.07	0.03	-0.12	0.03	-0.04	0.06
2	0.23	39.5	4	COMR	SAC1	2.32	0.06	-0.09	0.10	0.61	0.11	0.06	0.03	-0.11	0.03	-0.04	0.06
3	0.23	39.2	3	COMR	SAC1	2.32	0.06	-0.08	0.10	0.60	0.11	0.06	0.03	-0.10	0.03	-0.04	0.05
4	0.23	39.2	7	SAC1	OUT	2.26	0.08	1.01	0.22	-0.42	0.22	-0.15	0.08	0.15	0.06	-0.09	0.10
5	0.23	39.0	7	COMR	SAC1	2.34	0.06	-0.10	0.11	0.66	0.12	0.07	0.04	-0.15	0.04	-0.03	0.07
6	0.23	38.7	2	COMR	SAC1	2.31	0.06	-0.07	0.10	0.58	0.11	0.07	0.03	-0.10	0.03	-0.04	0.05
7	0.23	38.2	10	SAC1	OUT	2.38	0.07	0.70	0.18	-0.02	0.15	-0.04	0.11	0.22	0.08	-0.35	0.16
8	0.23	38.1	1	COMR	SAC1	2.31	0.06	-0.06	0.10	0.57	0.11	0.07	0.03	-0.09	0.03	-0.05	0.05
9	0.23	37.8	7	SAC1	EAST1	2.39	0.06	0.63	0.15	0.14	0.15	-0.17	0.06	-0.01	0.02	0.05	0.07
10	0.23	37.5	5	SAC1	SJRV	2.33	0.10	0.64	0.14	-0.04	0.19	-0.11	0.04	0.04	0.04	-0.02	0.07
11	0.23	37.5	0	COMR	SAC1	2.31	0.06	-0.04	0.10	0.57	0.12	0.06	0.03	-0.09	0.03	-0.05	0.05
12	0.23	37.4	10	SAC1	EAST1	2.39	0.06	0.67	0.15	-0.01	0.15	-0.14	0.04	0.07	0.04	-0.06	0.05
13	0.23	37.4	4	SAC1	SJRV	2.33	0.10	0.62	0.14	-0.03	0.18	-0.11	0.04	0.04	0.04	-0.02	0.06
14	0.23	37.2	5	SAC1	EAST1	2.38	0.06	0.58	0.15	0.16	0.14	-0.13	0.06	-0.02	0.02	0.03	0.08
15	0.24	37.0	5	SAC1	OUT	2.28	0.08	0.90	0.22	-0.29	0.22	-0.15	0.08	0.07	0.05	-0.00	0.11
16	0.24	37.0	3	SAC1	SJRV	2.33	0.09	0.61	0.14	-0.02	0.17	-0.10	0.04	0.05	0.04	-0.02	0.06
17	0.24	36.9	7	SAC1	SJRV	2.37	0.09	0.66	0.15	0.01	0.18	-0.14	0.05	0.04	0.04	-0.03	0.07
18	0.24	36.6	4	SAC1	EAST1	2.37	0.06	0.56	0.15	0.16	0.14	-0.12	0.06	-0.01	0.02	0.01	0.08
19	0.24	36.5	2	SAC1	SJRV	2.34	0.09	0.58	0.14	0.01	0.17	-0.10	0.04	0.04	0.04	-0.03	0.06
20	0.24	36.3	0	SAC1	SJRV	2.36	0.09	0.56	0.13	0.09	0.15	-0.10	0.04	0.03	0.04	-0.04	0.05

Finally, Table 1.9 shows the 20 best models with the dependent variable Ln(CCT) using the data after October 1993 and two variables selected from COMR, SAC1, OUT, SJRV and EAST1. The best model uses the variables COMR and SAC1 with averages starting five days before the turbidity average, and accounts for 39.7% of the variation in Ln(CCT). This is much worse than the 46.8% accounted for by the unmodified variables SAC and EAST with averages starting seven days before the turbidity average, as shown in Table 1.6.

Discussion

The results in Tables 1.5 and 1.8 show that modifying the variables SAC and EAST by removing reservoir releases results in equations that account for less of the variation in turbidity than equations using the unmodified variables. In particular, Table 1.5 shows that the best equation for predicting the Clifton Court turbidity (CCT) uses the unmodified variables SAC and EAST and accounts for 52.7% of the variation in CCT, while Table 1.8 shows that if the modified variables SAC1 and EAST1 are considered instead then the best fitting model does not use both of these variables, and only accounts for 50.2% of the variation in CCT. Also, Table 1.8 shows that if the modified variables are used in an equation, with averages starting ten days before the turbidity averages, then only 47.0% of the variation is accounted for. That is 5.7% less than the variation accounted for with the unmodified variables, which is a very substantial reduction.

The situation is not improved if Ln(CCT) is used as the dependent variable. Table 1.6 shows that the best equation using the unmodified SAC and EAST variables accounts for 46.8% of the variation in Ln(CCT), with the flow averages starting seven days before the turbidity averages. Table 1.9 shows that if the modified variables SAC1 and EAST1 are used instead then the best model only accounts for 39.7% of the variation, and using SAC1 and EAST1 with averages starting seven days before the turbidity averages only accounts for 37.8% of the variation.

2. Equations for Predicting 14 Day Salvage Numbers at Banks and Jones

The second objective of Task Order 1 of Agreement 119889 between Western EcoSystems Technology Inc. and the Metropolitan Water District of Southern California was to modify the third equation of Table 3.2 in the report by Manly (2010) for predicting salvage numbers at the Banks and Jones Pumping Plants. The modifications involved considering 14 day salvage numbers instead of weekly numbers in December and January, considering possible effects of flows from east side streams other than the San Joaquin River into the Delta, and considering the removal of reservoir releases from the Sacramento River flow.

Equations Fitted Earlier for Weekly Salvage Numbers

The report by Manly (2010) was updated to the report by Manly (2011b) because of some corrections made to salvage numbers in 2006. This only led to minor changes in the equations for predicting salvage numbers, and no changes to the equations for predicting Clifton Court turbidity.

The equation of particular interest in the report by Manly (2010) involved the prediction of weekly salvage numbers in December and January using weekly averages of the combined Old and Middle River flow (COMR) and the Sacramento River flow at Freeport (SAC) with the flow averages starting six days before the salvage week. These two variables were chosen from the initial potential variables shown in Table 2.1, although the variables SandY and X2 were removed from the list of potential variables because of high correlations between these and other variables.

The reduced set of variables COMR, SAC, OUT, SJRV, SJRS, SSFp and SSVn were considered for further analyses, with daily data available January 1, 1991 to June 30, 2006. These variables were standardized using the means and standard deviations for this period, as shown in Table 2.2, where the standardization involved replacing each observed value x by $x' = (x - \bar{x})/s$, where $\bar{x}$ is the mean and s is the standard deviation of x. As shown below, the variable Ln(FMWT) was included in all equations for predicting weekly salvage numbers on the grounds that salvage numbers are expected to be related to the overall abundance of delta smelt, irrespective of the effects of other variables.

For the estimation of the total Banks and Jones salvage in a specific week starting on a Sunday there were eight averaging periods considered for the standardized variables, as follows: (0) the averaging period for the standardized variables corresponded to the salvage week; (1) the averaging period corresponded to the week starting one day before the salvage week; (2) the averaging period corresponding to the week starting two days before the salvage week; and so on up to (7) the averaging period corresponding to the week before the salvage week.

Table 2.1 Variables considered as predictors of weekly salvage numbers at the Banks and Jones Pumping Plants for December to January in the report by Manly (2010) and the revised report by Manly (2011b)..

Ln(FMWT)	The natural logarithm of the Fall Midwater Trawl abundance index provided by the California Department of Fish and Game.
COMR	The combined old and middle river flow (cfs) as supplied by B.J. Miller on March 27, 2007.
SAC	The Sacramento River flow at Freeport (cfs) from the DAYFLOW database.
SandY	The sum of SAC (as defined above) and the variable QYOLO (cfs) from the DAYFLOW database.
OUT	The Delta outflow variable (cfs) from the DAYFLOW database.
SJRV	The flow of the San Joaquin River at Vernalis (cfs) from the DAYFLOW database.
X2	The estimated distance from Golden Gate to 2 ppt salinity (km) from the DAYFLOW database, for October 1, 1996 onwards. Earlier values from January 1, 1991 onwards were calculated using the DAYFLOW equation, starting with 87.63 on January 1, 1991 (the stable value for the OUT variable on that day).
SJRS	The San Joaquin River flow at Stockton (cfs) as provided by Paul Hutton on March 12, 2008.
	New Variables
SSFp	The suspended sediment in the Sacramento River at Freeport (tons/day) as provided by David Fullerton on November 12, 2010.
SSVn	The suspended sediment in the San Joaquin River at Vernalis (tons/day) as provided by David Fullerton on November 12, 2010.

Table 2.2 The number of observations (n), the mean values, the standard deviations (SD), the minimum values (Min) and the maximum values (Max) for the daily values of variables for the period January 1, 1991 to June 30, 2006.

	COMR	SAC	OUT	SJRV	SJRS	SSFp	SSVn
n	5660	5660	5660	5660	5660	5660	5660
Mean	-4086.8	25295.7	28670.3	4650.5	2028.8	5522.3	1000.9
SD	5321.9	19709.4	46465.7	6232.2	2664.7	10418.8	1658.4
Min	-27079	4340	-29087	390	-244	35	16
Max	30146	113000	567185	54300	18812	122000	45600

Having calculated these eight averages the data were reduced to the Banks and Jones salvage numbers for weeks starting in December and January (i.e., with Sundays in those months), with corresponding averages for COMR, SAC, OUT, SJRV, SJRS, SSFp and SSVn for the eight averaging periods stated above. All possible quadratic equations were then considered for the estimation of weekly total salvage numbers of the forms:

$$E(Salvage) = Exp\{b_0 + b_1X_1 + b_2X_1^2 + b_3Ln(FMWT)\}, \quad (2.1)$$

$$E(\text{Salvage}) = \text{Exp}\{b_0 + b_1X_1 + b_2X_2 + b_3X_1^2 + b_4X_2^2 + b_5X_1X_2 + b_6\text{Ln}(\text{FMWT})\}, \quad (2.2)$$

and

$$E(\text{Salvage}) = \text{Exp}\{b_0 + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_1^2 + b_5X_2^2 + b_6X_3^2 + b_7X_1X_2 + b_8X_1X_3 + b_9X_2X_3 + b_{10}\text{Ln}(\text{FMWT})\}, \quad (2.3)$$

where E(Salvage) is the expected weekly salvage, Exp() is the exponential function, X_1, X_2 and X_3 are three of the variables COMR, SAC, OUT, SJRV, SJRS, SSFp and SSVn with the same one of the eight averaging periods, and FMWT is the fall abundance index for the December year. These equations were estimated as generalized linear models for count data with over-dispersed Poisson sampling errors.

The justification for including Ln(FMWT) in all of the linear terms in the equations is that it can be argued that the expected salvage should be proportional to the abundance of delta smelt. This would be the case if the coefficient of Ln(FMWT) is equal to one because Exp{Ln(FMWT)} = FMWT. However, in practice the estimated coefficient of Ln(FMWT) is often quite different from one. Hence the coefficient of Ln(FMWT) is always estimated rather than set equal to one. This allows the fall abundance of delta smelt to have an effect on the expected salvage without the expected salvage necessarily being proportional to the fall abundance.

When all possible equations were fitted with one of the seven predictor variables shown in Table 2.1 and one of the eight averaging periods for the predictor variables the best fitting equation used the variable SAC with averages starting one day before the salvage week. This is equation (3.1) in Manly (2011b), which accounts for 45.3% of the variation in weekly salvage numbers.

When all possible equations were fitted with two of the seven predictor variables and one of the eight averaging periods the best fitting equation used the variables COMR and OUT with averages starting six days before the salvage weeks. This is equation (3.2) in Manly (2011b), which accounts for 73.1% of the variation in weekly salvage numbers. The second best fitting equation also used the variables COMR and OUT but with averages starting five days before the salvage week, and accounts for 71.1% of the variation in weekly salvage numbers, while the third best fitting equation uses the variables COMR and SAC with averages starting six days before the salvage week, and accounts for 71.0% of the variation in the weekly salvage numbers.

The third best equation is of particular interest. As shown in Table 3.2 of Manly (2011b) this equation takes the form

$$E(\text{Salvage}) = \text{Exp}[2.28 - 2.35(\text{COMR6}) + 1.80(\text{SAC6}) - 0.26(\text{COMR}^2) - 0.66(\text{SAC6}^2) - 0.62(\text{COMR6.SAC6}) + 0.31\{\text{Ln}(\text{FMWT})\}], \quad (2.4)$$

where COM6 and SAC6 indicate that the averages for these variables are six days before the salvage week.

When all possible equations were fitted with three of the seven predictor variables the best equation used the variables COMR, OUT and SJRS with averages starting six days before the salvage week. This is equation (3.4) in Manly (2011b), which accounts for 75.6% of the variation in weekly salvage numbers. It is noted by Manly (2011b) that because the best three variable equation only accounts for 2.5% more variation than the best two variable equation, a simpler two variable equation may be preferred for a practical application.

Equations for Predicting 14 Day Salvage Numbers

Table 2.3 shows the ten flow and suspended sediment variables now being considered for the prediction of the total salvage numbers in a 14 day period in December and January. As for earlier analyses, the daily values were coded to have means of zero and standard deviations of one for the periods shown in the table, so that a value x was replaced by $x' = (x - \bar{x})/s$, where $\bar{x}$ is the mean and s is the standard deviation of the variable, as shown in the table.

Using these variables, all possible equations with one, two and three variables of the form of equations (2.1) to (2.3) were fitted for the prediction of the total salvage in 14 day periods starting December 1, December 15, December 29 and January 12. A total of 64 observations were then available starting with December 1, 1993 and ending with January 12, 2009 because this was the period allowed by the available values for SAC1 and EAST1, as shown in Table 2.3.

A total of nine averaging periods were considered for the predictor variables, with these averaging periods being the same as the 14 day period for salvage numbers, or 14 day averaging periods starting 1, 2, 3, 4, 5, 7, 10 or 14 days before the salvage period. For the one variable equations of the form of equation (2.1) there are ten choices for the variable used and nine averaging periods for each variable. Hence 10 x 9 = 90 equations were fitted. For two variable equations like (2.2) there are $^{10}C_2 = 45$ choices of the two variables and hence 45 x 9 = 405 equations were fitted with the nine averaging periods. With three variable equations like (2.3) there are $^{10}C_3 = 120$ choices for the three variables and hence 120 x 9 = 1080 equations were fitted with the nine averaging periods.

Table 2.4 shows the 20 best fitting equations using one of the ten predictor variables. the best equation uses the variable SAC1 with the 14 day average for this variable starting ten days before the salvage period. This equation accounts for 62.2% of the variation in the 14 day salvage totals. The second best equation uses the same variable but with averaging starting 14 days before the salvage period, and accounts for 59.5% of the variation in salvage totals, while the other 18 equations shown in the table only account for from 50.6% to 54.6% of the variation.

Table 2.3 The variables considered for predicting the total salvage in 14 day periods in December and January. Daily values were available for the variables for the time periods shown.

	Start	End	Min	Max	Mean	SD	Description
COMR	Jan 1990	Jun 2009	-24297	30800	-4447	5016	Old & Middle River Flow (cfs)[1]
SAC	Jan 1990	Jun 2009	4340	113000	22934	18377	Sacramento River flow at Freeport (cfs)[1]
OUT	Jan 1990	Jun 2009	-29087	567185	24520	42367	Sacramento-San Joaquin outflow (cfs)[1]
SJRV	Jan 1990	Jun 2009	390	54300	4063	5696	San Joaquin River flow at Vernalis (cfs)[1]
EAST	Jan 1990	Jun 2009	54	60841	1360	2401	Flow from east side streams excluding the San Joaquin River[1]
SJRS	Jan 1991	Jun 2009	-254	18812	1815	2502	San Joaquin River flow at Stockton (cfs)[2]
SSFp	Jan 1990	Jun 2009	35	122000	4716	9511	Suspended sediment at Freeport (tons/day)[3]
SSVn	Jan 1990	Jun 2009	16	45600	852	1515	Suspended sediment at Vernalis (tons/day)[3]
SAC1	Oct 1993	Jun 2009	-45574	210054	8610	20767	SAC with reservoir releases netted out[4]
EAST1	Oct 1993	Jun 2009	-813	56091	525	1685	EAST with reservoir releases netted out[4]

[1]Source: D. Fullerton, December 27, 2010.
[2]Source: P. Hutton, May 5, 2011.
[3]Source: D. Fullerton, November 12, 2010.
[4]Source: P. Hutton, November 4, 2010.

Table 2.5 shows the results for the 20 best fitting equations using two variables. The three best equations use the variables COMR and SAC1 with 14 day averages starting one day before the salvage period, two days before the salvage period, and averages for the salvage period. These three equations account for from 84.1% to 84.9% of the variation in the salvage numbers. The best fitting eight equations all use the variable COMR with either SAC or SAC1, with 82.3% or more of the variation accounted for.

Table 2.6 shows the results for the 20 best fitting equations using three variables, with the restriction that both SAC and SAC1 were not allowed to be in an equation because of the similarity between these variables. Equations with a high percentage of the variation in salvage numbers accounted for were obtained with these two variables and another one but the coefficients of SAC and SAC1 were extremely large with large standard errors, indicating that these equations are unstable.

Table 2.4 The 20 best fitting equations with one variable in terms of the amount of variation accounted for with Banks and Jones 14 day total salvage numbers in December and January. The residual deviance (Res Dev) is a measure of the amount of variation not accounted for by an equation, and the percentage of variation explained (% Expl) is the amount of the total variation accounted for. The Days Back is the number of days for the averaging of the variable before the start of the salvage period (e.g. a value of 0 means that the averaging period for the variable is the same as the 14 day salvage period, a value of 1 means that the variable 14 day averaging period starts one day before the salvage period, etc.). The estimated coefficients and their standard errors shown are as for equation (2.1).

	Res Dev	% Expl	Days Back	X_1	b_0	SE	b_1	SE	b_2	SE	b_3	SE
1	35461	62.2	10	SAC1	3.15	0.95	3.45	0.49	-0.93	0.20	0.34	0.16
2	37972	59.5	14	SAC1	3.58	1.06	3.88	0.67	-1.32	0.34	0.30	0.17
3	42556	54.6	2	SAC	4.43	1.09	3.36	0.56	-1.12	0.23	0.14	0.18
4	42618	54.5	0	SAC1	2.03	1.14	2.84	0.43	-0.57	0.12	0.47	0.18
5	42634	54.5	3	SAC	4.88	1.10	3.29	0.54	-1.12	0.23	0.07	0.19
6	42691	54.5	1	SSFp	1.89	1.21	2.63	0.46	-0.56	0.13	0.52	0.19
7	43007	54.1	1	SAC	3.88	1.10	3.42	0.58	-1.11	0.23	0.22	0.18
8	43101	54.0	4	SAC	5.23	1.11	3.21	0.52	-1.13	0.23	0.03	0.19
9	43545	53.5	0	SAC	3.38	1.13	3.45	0.60	-1.10	0.23	0.30	0.18
10	43679	53.4	2	SSFp	2.11	1.23	2.45	0.42	-0.51	0.12	0.51	0.20
11	43903	53.2	5	SAC	5.43	1.12	3.14	0.51	-1.14	0.24	0.01	0.20
12	44175	52.9	10	SAC	4.90	1.18	3.61	0.64	-1.67	0.37	0.18	0.20
13	44586	52.4	1	SAC1	2.05	1.19	2.66	0.42	-0.51	0.11	0.48	0.19
14	44913	52.1	7	SAC	5.52	1.12	3.15	0.53	-1.25	0.27	0.03	0.20
15	44932	52.1	0	SSFp	2.06	1.20	2.49	0.46	-0.53	0.13	0.49	0.19
16	45358	51.6	2	SAC1	1.98	1.23	2.60	0.41	-0.49	0.11	0.50	0.19
17	45479	51.5	10	SSFp	1.81	1.22	2.04	0.34	-0.36	0.10	0.60	0.19
18	45818	51.1	3	SSFp	2.24	1.29	2.25	0.39	-0.45	0.11	0.51	0.21
19	46188	50.7	7	SAC1	2.83	1.13	2.89	0.47	-0.67	0.15	0.38	0.19
20	46293	50.6	3	SAC1	1.92	1.28	2.54	0.40	-0.47	0.11	0.51	0.20

The best six equations shown in Table 2.6 use the variables COMR and SAC1 with either SJRS or SJRV, with averages either for the same 14 days as the salvage total or averages starting one or two days earlier that the salvage period. These six equations account for 87.9% to 88.6% of the variation in the 14 day salvage totals. However, all of the equations include large or very large positive or negative coefficients, which suggests that although these three variable equations account for a large part of the variation in salvage numbers they may be unstable for future prediction purposes.

Table 2.5 The 20 best fitting equations with two variables in terms of the amount of variation accounted for with Banks and Jones 14 day total salvage numbers in December and January. The residual deviance (Res Dev) is a measure of the amount of variation not accounted for by an equation, and the percentage of variation explained (% Expl) is the amount of the total variation accounted for. The Days Back is the number of days for the averaging of the variable before the start of the salvage period (e.g. a value of 0 means that the averaging period for the variable is the same as the 14 day salvage period, a value of 1 means that the variable 14 day averaging period starts one day before the salvage period, etc.). The estimated coefficients and their standard errors shown are as for equation (2.2).

	Res Dev	% Expl	Days Back	X_1	X_2	b_0	SE	b_1	SE	b_2	SE	b_3	SE	b_4	SE	b_5	SE	b_6	SE
1	14122	84.9	1	COMR	SAC1	1.40	0.98	-3.44	1.62	2.72	0.58	-1.67	1.10	-0.50	0.06	-0.31	0.87	0.34	0.13
2	14397	84.6	2	COMR	SAC1	1.61	1.00	-4.09	1.75	2.81	0.51	-2.25	1.14	-0.49	0.06	-0.04	0.72	0.29	0.12
3	14924	84.1	0	COMR	SAC1	1.09	1.00	-2.90	1.51	2.72	0.59	-1.17	1.05	-0.53	0.06	-0.45	0.88	0.39	0.14
4	15313	83.7	2	COMR	SAC	1.01	1.08	-5.04	1.81	3.42	0.61	-2.94	1.13	-0.77	0.12	0.57	0.79	0.44	0.13
5	15333	83.6	3	COMR	SAC1	1.82	1.05	-4.55	1.90	2.78	0.46	-2.63	1.28	-0.48	0.06	0.05	0.61	0.25	0.12
6	15640	83.3	1	COMR	SAC	0.58	1.06	-4.42	1.72	3.31	0.65	-2.17	1.06	-0.75	0.12	0.34	0.84	0.50	0.13
7	16076	82.9	3	COMR	SAC	1.41	1.13	-5.33	1.96	3.36	0.63	-3.38	1.29	-0.79	0.12	0.55	0.80	0.39	0.13
8	16555	82.3	0	COMR	SAC	0.13	1.09	-3.89	1.70	3.18	0.70	-1.52	1.08	-0.74	0.13	0.06	0.89	0.56	0.14
9	16632	82.3	1	SJRS	SAC1	0.98	1.21	-1.68	1.51	3.10	0.64	0.40	0.41	-0.48	0.10	-0.71	0.99	0.44	0.16
10	16694	82.2	0	SJRS	SAC1	0.60	1.24	-1.63	1.48	3.07	0.63	0.46	0.40	-0.48	0.11	-0.81	0.96	0.50	0.16
11	16837	82.0	4	COMR	SAC1	2.17	1.12	-4.61	2.07	2.57	0.49	-2.58	1.50	-0.47	0.06	-0.11	0.62	0.19	0.14
12	16987	81.9	1	SJRV	SAC1	1.49	1.13	-1.21	1.72	2.92	0.59	0.52	0.51	-0.44	0.11	-1.35	1.18	0.42	0.16
13	17098	81.8	0	SJRV	SAC1	1.13	1.15	-1.21	1.57	2.89	0.56	0.58	0.52	-0.43	0.11	-1.44	1.08	0.48	0.16
14	17222	81.6	2	COMR	OUT	1.78	1.06	-5.46	2.12	4.22	0.93	-2.31	1.45	-1.06	0.13	0.87	1.40	0.32	0.13
15	17284	81.6	3	COMR	OUT	2.22	1.11	-5.62	2.30	4.15	1.00	-2.55	1.63	-1.06	0.13	0.88	1.48	0.26	0.13
16	17417	81.4	2	OUT	SAC1	2.05	1.03	-5.03	2.60	6.50	2.35	-2.89	2.60	-2.26	2.02	4.57	4.53	0.25	0.13
17	17582	81.2	2	SJRS	SAC1	1.30	1.21	-1.71	1.53	3.16	0.65	0.32	0.48	-0.50	0.10	-0.59	1.01	0.39	0.16
18	17642	81.2	1	COMR	OUT	1.26	1.05	-5.02	2.03	4.19	0.92	-1.70	1.37	-1.07	0.13	0.66	1.38	0.39	0.13
19	17664	81.2	4	COMR	OUT	2.63	1.19	-5.60	2.49	3.98	1.08	-2.48	1.84	-1.08	0.13	0.71	1.57	0.19	0.14
20	17751	81.1	4	COMR	SAC	1.89	1.22	-5.33	2.18	3.12	0.70	-3.32	1.55	-0.80	0.14	0.36	0.86	0.32	0.15

Table 2.6 The 20 best fitting equations with three variables in terms of the amount of variation accounted for with Banks and Jones 14 day total salvage numbers in December and January. The residual deviance (Res Dev) is a measure of the amount of variation not accounted for by an equation, and the percentage of variation explained (% Expl) is the amount of the total variation accounted for. The Days Back is the number of days for the averaging of the variable before the start of the salvage period (e.g. a value of 0 means that the averaging period for the variable is the same as the 14 day salvage period, a value of 1 means that the variable 14 day averaging period starts one day before the salvage period, etc.). The estimated coefficients and their standard errors shown are as for equation (2.3).

	Res Dev	% Expl	Days Back	X_1	X_2	X_3	b_0	SE	b_1	SE	b_2	SE	b_3	SE	b_4	SE	b_5	SE	b_6	SE	b_7	SE	b_8	SE	b_9	SE	b_{10}	SE
1	10722	88.6	1	COMR	SJRS	SAC1	-2.74	1.84	-7.22	1.84	-0.47	1.26	3.95	0.69	-0.87	1.45	6.34	2.34	-0.26	0.11	-7.50	3.42	3.52	1.73	-3.11	1.16	0.66	0.17
2	10863	88.4	1	COMR	SJRV	SAC1	-2.52	1.81	-6.96	1.84	-1.28	1.56	4.03	0.75	-1.18	1.42	8.00	2.99	-0.25	0.11	-7.83	3.66	3.31	1.68	-3.54	1.30	0.62	0.17
3	11057	88.2	2	COMR	SJRS	SAC1	-2.67	1.88	-7.68	1.97	-0.31	1.33	3.98	0.71	-1.57	1.60	6.00	2.35	-0.27	0.10	-7.01	3.59	3.64	1.68	-3.09	1.13	0.67	0.17
4	11186	88.1	0	COMR	SJRS	SAC1	-3.17	1.95	-6.92	1.80	-0.69	1.24	4.14	0.67	0.17	1.36	7.03	2.57	-0.23	0.12	-8.81	3.66	3.97	1.71	-3.50	1.18	0.67	0.18
5	11226	88.0	2	COMR	SJRV	SAC1	-2.37	1.83	-7.37	1.96	-0.93	1.64	4.08	0.77	-1.76	1.53	7.45	3.01	-0.25	0.11	-7.18	3.82	3.55	1.66	-3.59	1.30	0.62	0.17
6	11384	87.9	0	COMR	SJRV	SAC1	-2.84	1.92	-6.56	1.80	-1.58	1.57	4.16	0.71	-0.27	1.34	8.72	3.30	-0.23	0.13	-9.06	3.92	3.55	1.63	-3.85	1.30	0.63	0.18
7	11493	87.7	5	OUT	SSPp	SAC1	-3.43	1.70	-13.44	2.90	-4.89	1.42	18.92	3.44	-12.25	2.89	1.63	0.57	-13.43	2.67	-5.73	1.66	27.60	6.00	2.10	0.77	0.84	0.18
8	11525	87.7	2	OUT	SAC1	EAST1	-2.67	1.65	-18.96	4.46	14.64	3.30	5.30	1.54	-12.91	3.35	-9.97	2.70	2.59	1.08	26.05	6.57	1.15	1.62	-6.25	1.77	0.71	0.18
9	11571	87.7	1	COMR	SSVn	SAC1	-0.01	1.45	-4.44	1.56	-0.33	1.31	3.13	0.88	-1.76	1.34	0.61	0.58	-0.11	0.23	-0.90	1.90	1.32	1.40	-0.95	0.46	0.49	0.16
10	11674	87.6	5	SJRV	EAST	SAC1	-2.06	1.86	-3.49	2.49	-4.93	2.03	4.28	1.43	48.51	9.77	29.53	5.88	-0.55	0.37	-80.78	15.85	11.19	3.36	-11.03	2.04	0.61	0.19
11	11791	87.4	1	COMR	SAC1	EAST1	-0.27	1.28	-4.42	1.70	2.77	0.78	0.16	1.57	-2.24	1.34	-0.07	0.20	0.63	0.78	0.51	1.11	-0.07	2.22	-1.01	0.45	0.57	0.17
12	11807	87.4	0	COMR	SSVn	SAC1	0.75	1.37	-4.20	1.48	0.36	1.30	2.85	0.83	-1.68	1.09	0.02	0.60	-0.05	0.23	0.09	1.78	1.16	1.23	-0.87	0.47	0.40	0.15
13	11843	87.4	3	OUT	SAC1	EAST1	-2.95	1.76	-20.81	4.81	15.94	3.55	5.21	1.54	-14.32	3.43	-11.21	2.84	2.21	1.03	29.17	6.92	0.40	1.59	-5.68	1.69	0.71	0.18
14	11909	87.3	1	COMR	EAST	SAC1	-0.51	1.33	-4.75	1.58	0.19	1.80	3.16	0.92	-2.04	1.45	0.60	1.12	-0.08	0.20	-0.50	2.89	1.41	1.45	-1.20	0.53	0.58	0.16
15	12011	87.2	2	COMR	SSVn	SAC1	-0.14	1.51	-4.95	1.81	-0.71	1.52	3.25	1.06	-2.19	1.71	0.73	0.53	-0.11	0.31	-1.38	2.12	1.50	1.56	-0.93	0.52	0.50	0.16
16	12063	87.1	2	OUT	EAST	SAC1	-1.41	1.45	-15.76	3.95	5.71	1.90	12.12	2.89	-5.22	3.73	4.04	1.57	-7.62	2.56	-6.20	3.87	17.12	6.25	-2.59	2.20	0.72	0.18
17	12070	87.1	2	SAC	SAC1	EAST1	2.67	1.18	-0.76	1.22	2.46	1.32	1.91	1.06	-3.30	2.41	-2.65	2.18	1.64	1.09	6.02	4.42	-9.28	2.42	4.34	2.13	0.45	0.18
18	12101	87.1	2	COMR	SAC1	EAST1	0.20	1.27	-4.74	1.78	2.83	0.93	-0.49	1.62	-2.31	1.49	0.00	0.27	1.11	0.88	0.95	1.39	-1.13	2.66	-1.30	0.58	0.48	0.17
19	12149	87.0	0	COMR	SAC1	EAST1	-0.68	1.29	-4.26	1.66	2.89	0.65	0.32	1.35	-2.06	1.17	-0.11	0.18	0.51	0.69	0.48	0.87	0.34	1.72	-0.93	0.41	0.62	0.17
20	12194	87.0	2	COMR	EAST	SAC1	-0.25	1.36	-5.07	1.69	-0.30	1.90	3.13	1.01	-2.02	1.63	1.00	1.43	-0.02	0.25	-1.73	3.25	1.70	1.58	-1.36	0.64	0.52	0.16

The best fitting single variable equation shown in Table 2.4 is

$$E(Salvage) = Exp\{3.145 + 3.452(SAC1) - 0.934(SAC1^2) + 0.339\ Ln(FMWT)\}, \quad (2.5)$$

where E(Salvage) is the expected salvage in a 14 day period and SAC1 is the average of this flow variable for a 14 day period starting ten days earlier than the salvage period. In this equation the coefficients of SAC1 and $SAC1^2$ are significant at the 0.1% level and the coefficient of Ln(FMWT) is significant at the 5% level. The equation accounts for 62.2% of the variation in the salvage numbers.

The best fitting two variable equation shown in Table 2.5 is

$$E(Salvage) = Exp\{1.404 - 3.439(COMR) + 2.716(SAC1) - 1.673(COMR^2) - 0.496(SAC1^2) - 0.308(COMR.SAC1) + 0.335ln(FMWT)\}, \quad (2.6)$$

where COMR and SAC1 are 14 day averages for these variables starting one day before the salvage period. In this equation the coefficients of SAC1 and $SAC1^2$ are significant at the 0.1% level, the coefficients of COMR and Ln(FMWT) are significant at the 5% level, and the coefficients of $COMR^2$ and COMR.SAC1 are not significant at the 5% level. The equation accounts for 84.9% of the variation in salvage numbers.

If the insignificant effects of $COMR^2$ and COMR.SAC1 are removed from equation (2.6) then it becomes

$$E(Salvage) = Exp\{1.528 - 2.119(COMR) + 3.078(SAC1) - 0.519(SAC1^2) + 0.285Ln(FMWT)\}, \quad (2.7)$$

where the coefficients of COMR, SAC1 and $SAC1^2$ are significant at the 0.1% level and the coefficient of Ln(FMWT) is significant at the 5% level. This equation accounts for 83.3% of the variation in salvage numbers.

The best fitting three variable equation shown in Table 2.6 uses the variables COMR, SJRS and SAC1 with 14 day averages starting one day before the salvage period. This equation accounts for 88.6% of the variation in salvage numbers. However, the second best equation accounts for 88.4% of the variation in salvage numbers using COMR, SJRV and SAC1, and is preferred here because observed values of SJRV are in the Dayflow database on the website www.water.ca.gov/dayflow while some of the historic values of SJRS are calculated rather than observed.

The equation using the variables COMR, SJRV and SAC1 is

$$
\begin{aligned}
E(\text{Salvage}) = \text{Exp}\{&-2.522 - 6.963(\text{COMR}) - 1.276(\text{SJRV}) + 4.025(\text{SAC1}) \\
&- 1.175(\text{COMR}^2) + 7.988(\text{SJRV}^2) - 0.254(\text{SAC1}^2) \\
&- 7.826(\text{COMR.SJRV}) + 3.303(\text{COMR.SAC1}) \\
&- 3.539(\text{SJRV.SAC1}) + 0.618\text{Ln}(\text{FMWT})\}, \qquad (2.8)
\end{aligned}
$$

where COMR, SJRV and SAC1 are the 14 day averages for these variables starting one day before the salvage period. The coefficients in this equation are significant at the 5% level or a higher level except for the coefficients of SJRV and COMR^2 which are not at all significant. However, if the effect of COMR^2 is removed from the equation then it becomes

$$
\begin{aligned}
E(\text{Salvage}) = \text{Exp}\{&-2.512 - 6.438(\text{COMR}) - 1.613(\text{SJRV}) + 4.388(\text{SAC1}) \\
&+ 8.320(\text{SJRV}^2) - 0.230(\text{SAC1}^2) - 9.178(\text{COMR.SJRV}) \\
&+ 4.037(\text{COMR.SAC1}) - 3.998(\text{SJRV.SAC1}) \\
&+ 0.595\text{Ln}(\text{FMWT})\}, \qquad (2.9)
\end{aligned}
$$

which accounts for 88.2% of the variation in the data. In this equation the coefficients of COMR, SAC1, SJRV.SAC1 and Ln(FMWT) are significant at the 0.1% level, the coefficients of SJRV^2, COMR.SJRV and COMR.SAC1 are significant at the 1% level, and the coefficient of SAC1^2 is significant at the 5% level. The coefficient of SJRV is not significant at the 5% level ($p = 0.258$) but is retained in the equation because of the significance of SJRV^2 and COMR.SJRV. The large positive and negative coefficients in equation (2.9) are of concern because this may result in extremely large expected salvage numbers for combinations of river flows not seen in the data used to fit the equation.

Figure 2.1 shows how the predictions from the equations (2.5), (2.7) and (2.9) compare with the observed 14 day salvage numbers for the 64 data points used to estimate the equations. Overall equations (2.7) and (2.9) give slightly better predictions than equation (2.5) while the predictions from equations (2.7) and (2.9) are very similar except that equation (2.9) gives slightly better predictions of the very high salvage numbers in 2003.

Further Examination of the Fitted Equations (2.6) and (2.7)

Equation (2.7) only involves two flow variables and does not have large positive and negative coefficients like equation (2.9). Also, equations (2.7) and (2.9) give similar results for the data used for estimation of the equations . For these reasons the use of equations (2.6) and (2.7) to predict salvage numbers has been investigated further.

One question of interest is how these equations performs if they are applied to predict the salvage numbers for every possible 14 day period in December and January from 1 December 1993 to 31 January 2009. For example, consider the period from 1 December 1993 to 31 January 1994. To estimate equations (2.6) and (2.7) four data points were used from this period, namely 1 to 14 December, 15 to 28 December, 29 December to 11 January, and 12 to 25 January, with the observed Banks and Jones salvage numbers for these four 14 day periods being 34, 43, 27 and 0, respectively. Only four data points were used so that these four data points are for periods that do not overlap and are independent in that sense.

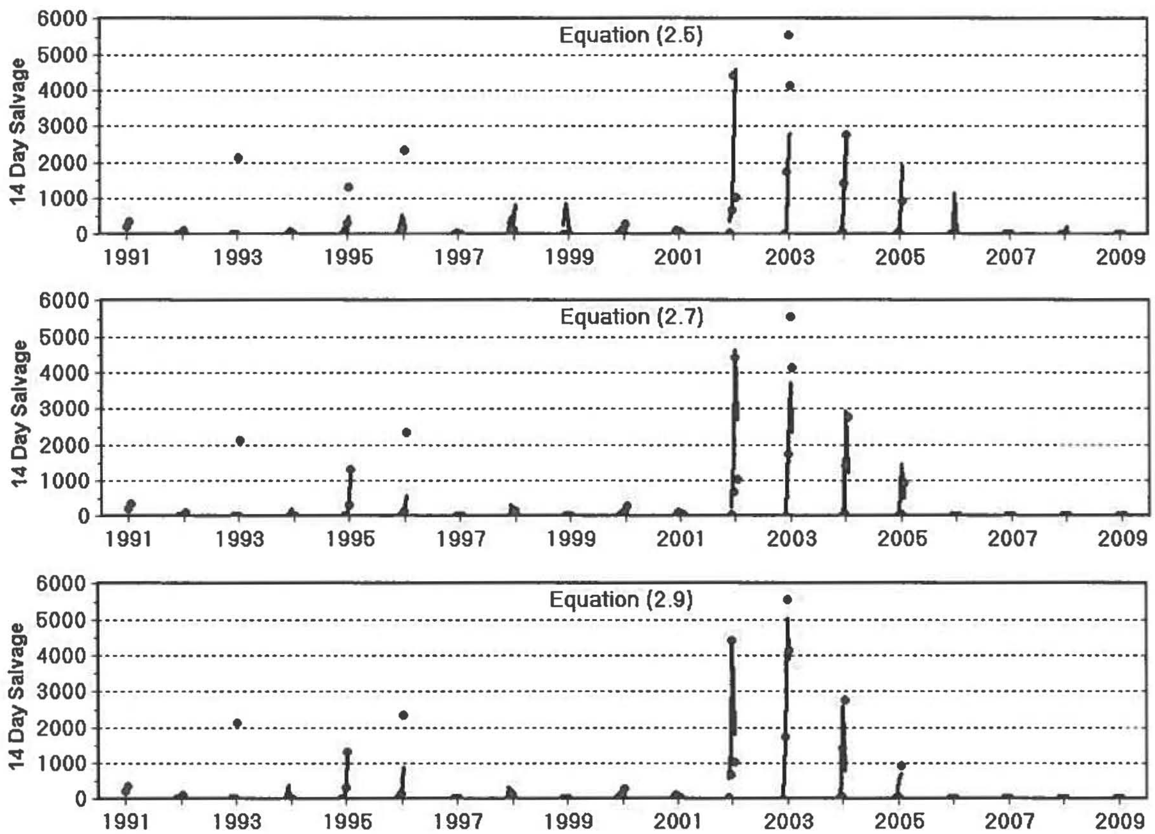

Figure 2.1 The predicted (—) and observed (!) 14 day salvage numbers from the one variable equation (2.5), the two variable equation (2.7) and the three variable equation (2.7) for the 64 14 day periods used to fit the equations. Salvage numbers are available from January 1991 until January 2009, while predicted values from the equations are available from December 1993 until January 2009. The horizontal axis shows the time for the start of 14 day periods. For example the observed salvage for the 14 day period from 1 to 14 January 1991 is plotted at the horizontal value 1991.

Although only four data points from December 1993 and January 1994 were used to estimate equations (2.6) and (2.7) the fitted equation can be applied for any of the 14 day periods in these two months, as indicated in Table 2.7. Estimates were therefore calculated in this way for all 14 day periods in December and January from December 1993 to January 2009.

It is also possible to estimate equations of the form of equations (2.6) and (2.7) using the data from all possible 14 day periods in December and January. There are 784 such periods. Obviously they do not provide independent data for estimation because the observed salvage data from two successive 14 day periods includes 13 days with the same salvage. This means that the usual assumption that each data point provides independent data is not valid, which means, for example, that the estimated standard errors for the coefficients of variables will be unrealistically small, but nevertheless, the fitted equations will still give the best fit to the data.

Table 2.7 The 14 day periods in December 1993 and January 1994, with the values of the variables COMR, SAC1 and Ln(FMWT) used to estimate the total salvage numbers in these periods using equation (2.7), the observed salvage in the periods, and the predicted salvage from equation (2.7). Similar data are available for the other December and January periods. The 14 day averages for COMR and SAC1 start one day before the salvage period.

					14 Day Salvage	
Start	End	COMR	SAC1	Ln(FMWT)	Observed	Predicted
01-Dec-93	14-Dec-93	-0.745	-0.257	6.983	34	71.8
02-Dec-93	15-Dec-93	-0.793	-0.226	6.983	22	88.1
03-Dec-93	16-Dec-93	-0.806	-0.189	6.983	28	102.3
04-Dec-93	17-Dec-93	-0.798	-0.142	6.983	31	117.2
05-Dec-93	18-Dec-93	-0.793	-0.094	6.983	37	135.4
06-Dec-93	19-Dec-93	-0.805	-0.055	6.983	37	157.4
07-Dec-93	20-Dec-93	-0.815	-0.024	6.983	37	176.6
08-Dec-93	21-Dec-93	-0.828	-0.001	6.983	37	195.3
09-Dec-93	22-Dec-93	-0.840	0.015	6.983	49	210.2
10-Dec-93	23-Dec-93	-0.839	0.030	6.983	49	219.4
.						
.						
.						
14-Jan-94	27-Jan-94	0.165	-0.184	6.983	0	13.3
15-Jan-94	28-Jan-94	0.148	-0.139	6.983	0	16.0
16-Jan-94	29-Jan-94	0.132	-0.101	6.983	0	18.6
17-Jan-94	30-Jan-94	0.096	-0.072	6.983	0	22.1
18-Jan-94	31-Jan-94	0.048	-0.052	6.983	0	26.0

The equivalent to equation (2.6) estimated using the data from all the 784 possible 14 day periods is

$$E(\text{Salvage}) = \text{Exp}\{1.412 - 3.284(\text{COMR}) + 2.437(\text{SAC1}) - 1.299(\text{COMR}^2) - 0.523(\text{SAC1}^2) - 0.473(\text{COMR.SAC1}) + 0.343\text{Ln}(\text{FMWT})\} \quad (2.6a)$$

and the equivalent to equation (2.7) using all possible 14 day periods is

$$E(\text{Salvage}) = \text{Exp}\{1.508 - 2.281(\text{COMR}) + 2.842(\text{SAC1}) - 0.538(\text{SAC1}^2) + 0.311\text{Ln}(\text{FMWT})\}. \quad (2.7a)$$

The coefficients in these equations are quite similar to those in equations (2.6) and (2.7).

Figure 2.2 shows how the 784 possible observed 14 day salvage numbers compare with the predicted values from equations (2.6), (2.7), (2.6a) and (2.7a). It is seen from Figure 2.2 that the relatively high average daily salvage numbers in 1993 and 1996 were not predicted, that the observed average salvage numbers were much lower than the predicted numbers in 1995 and 2006, but that in other years the predicted average values were close to the observed values, particularly for the years 2002 to 2006. Equations (2.6a) and (2.7a) predict the observed salvage numbers somewhat better than equations (2.6) and (2.7) for December 1994 to January 1995, December 2001 to January 2002 and December 2005 to January 2006, but overall the predictions from the four equations are rather similar.

Figure 2.3 is also relevant to the use of the four equations. It shows the predicted levels of salvage for the 64 observations used to estimate equations (2.6) and (2.7) plotted against the unstandardized values of COMR and SAC1 in cubic feet per second. For the predictions the value of Ln(FMWT) was always set at 6.983, corresponding to the FMWT value of 1078 for November 1993. The value of Ln(FMWT) was kept constant for the predictions so that the effect of the abundance of delta smelt is removed from the plots.

For all four equations the high 14 day salvage numbers (1000 to less than 5000) or very high salvage numbers (5000 or more) are predicted when the values of COMR are more negative than about -7,500 cfs and SAC1 is above 20,000 cfs. More generally, all four equations give similar patterns for very low, low, medium, high and very high salvage numbers. However, one difference between the equations is for the two observations with values of SAC1 of about 105,000 and COMR about -7,000 or -1,500. For the observation with SAC1 of about -7,000 equations (2.6) and (2.7) predict high salvage numbers, but equations (2.6a) and (2.7a) predict medium salvage numbers. For the observation with SAC1 of about -1,500 equations (2.6) and (2.6a) predict very low salvage, equation (2.7) predicts medium salvage, and equation (2.7a) predicts low salvage.

Comparison of Equations (2.6a) and (2.7a) With Deriso's Equation

A report by Deriso (2010) provides an alternative equation for estimating 14 day salvage totals based on the combined Old and Middle River flow and the Clifton Court turbidity. The model used can be written as

$$S = a + (1 - p)\, b\, (COMR - COMR^*) \qquad (2.10)$$

where S is the average 14 day salvage rate which is the salvage number divided by the previous Fall Midwater Trawl abundance index, COMR is the average daily combined Old and Middle River flow (cfs) for the same period as the salvage, p = 1 if COMR is greater than COMR* or otherwise p = 0 and

$$COMR^* = a' + (1 - p')\, b'\, (TUR - TUR^*)$$

where TUR is the average 14 day Clifton Court turbidity (NTU) for the same 14 day period as the salvage, and p' = 1 if TUR is greater than TUR* or otherwise p' = 0.

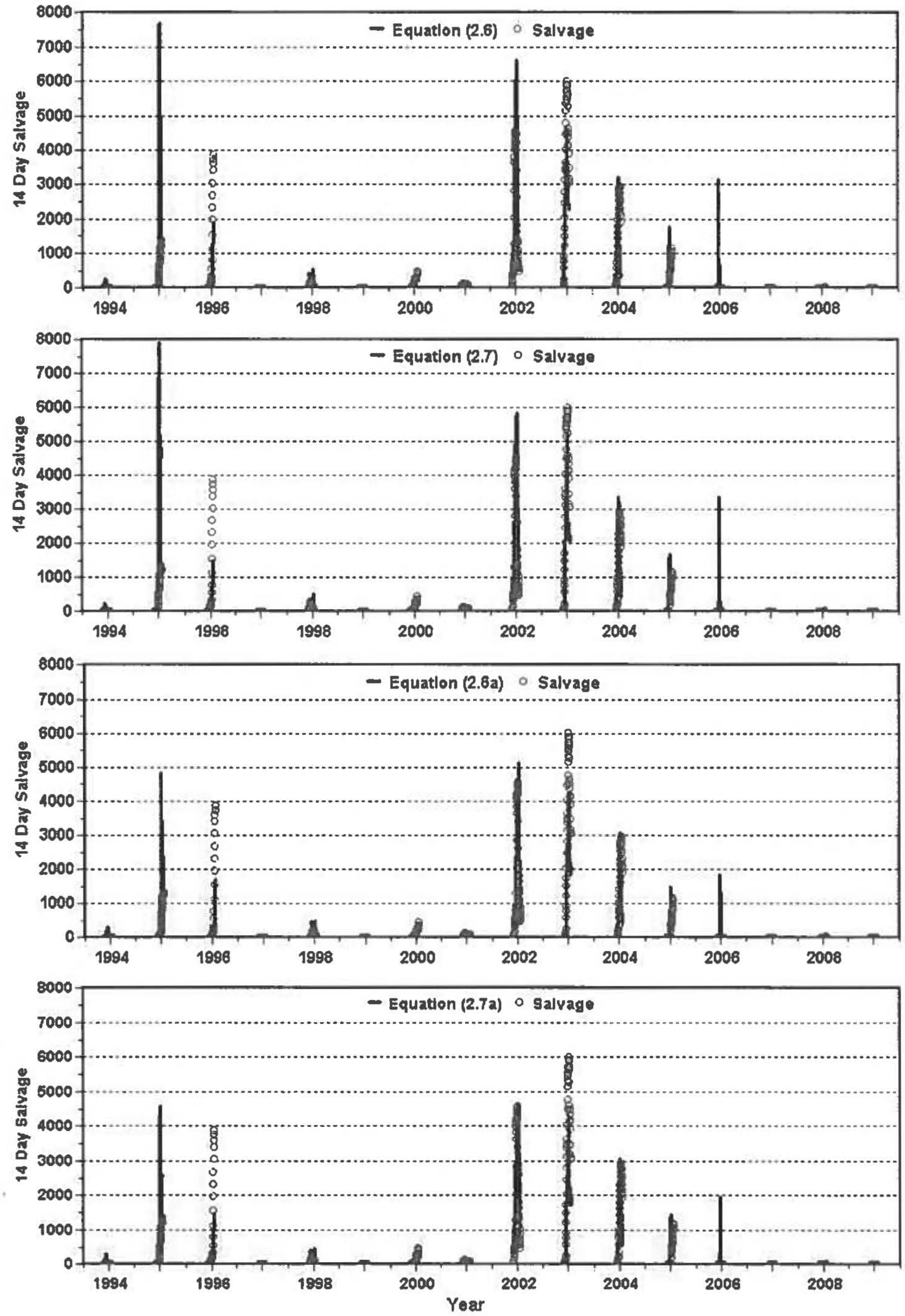

Figure 2.2 Salvage numbers for 14 day periods in December and January as predicted by equations (2.6), (2.7), (2.6a) and (2.7a), and as observed. Observed 14 day salvage numbers are available from January 1991 until January 2009 but predictions from the fitted equations do not start until December 1993. The horizontal axis is as for Figure 2.1 so that the observed and predicted values for the salvage from 1 to 14 January 1994 are plotted against 1994.

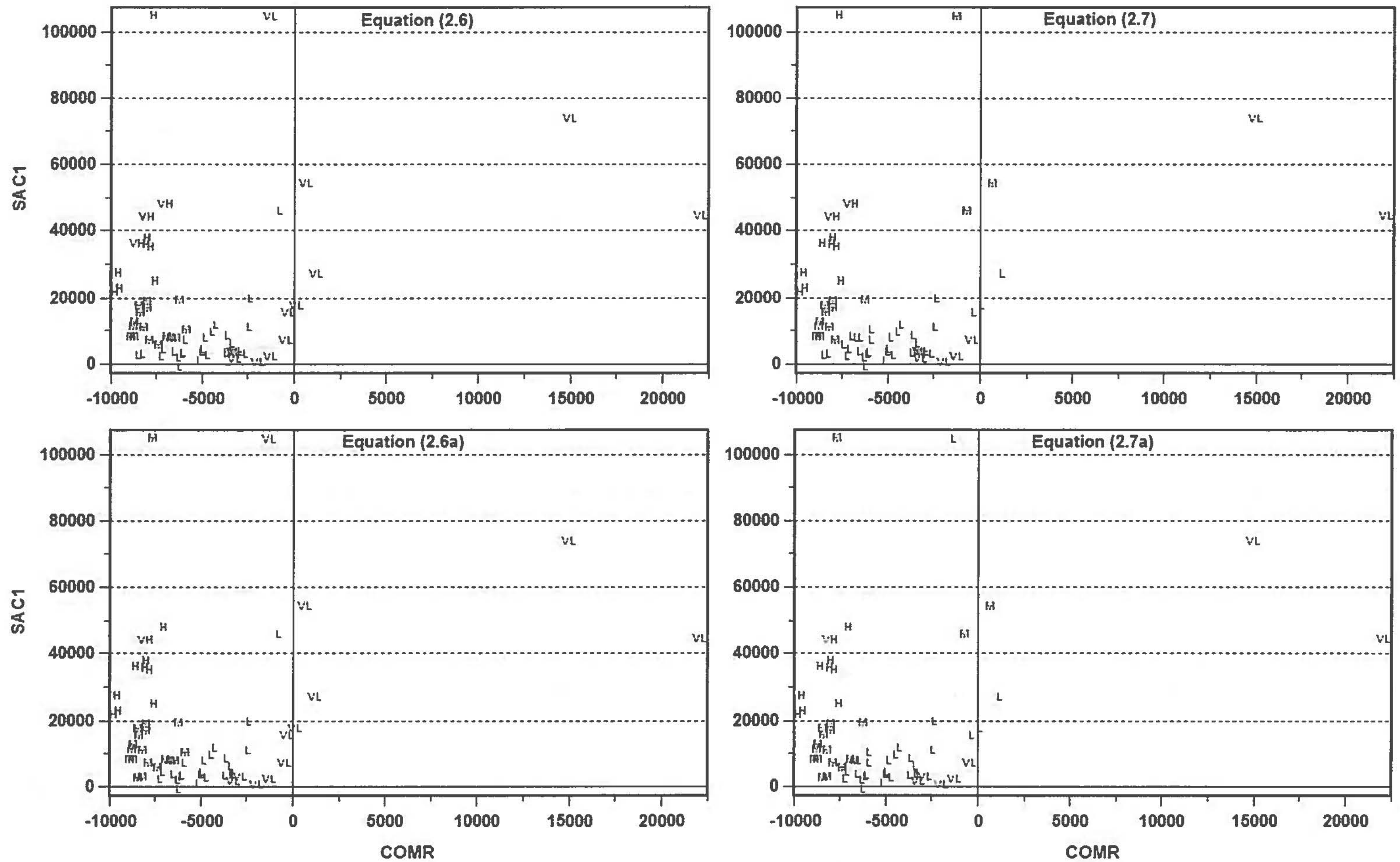

Figure 2.3 Predicted 14 day salvage numbers from equations (2.6), (2.7), (2.6a) and (2.7a). The predictions are shown as very low (VL) if less than 10, low (L) if from 10 to less than 100, medium (M) if from 100 to less than 1000, high (H) if from 1000 to less than 5000, and very high (VH) if 5000 or more. For all predictions the value of Ln(FMWT) was set at 6.983 which is the value that applied for December 1993 and January 1994.

There are five parameters in equation (2.10) that have to be estimated from the available data. In Table 3 of the Deriso (2010) report the values for these are provided for 14 day salvage periods as a = 0.072, b = -0.00023, a' = -3563, b' = 411.34 and TUR* = 27.73. Using these parameters the average daily salvage rates can be estimated for all of the 14 day periods in December and January starting with 1 - 14 December 1993 and ending with 18 - 31 January 2009. There are 784 of these 14 day periods and Figure 2.2 already shows the observed total salvage numbers in these periods and the predicted totals from equations (2.6), (2.7), (2.6a) and (2.7a).

The average daily salvage rates from equation (2.10) are turned into estimates of the total 14 day salvage by multiplying by the number of days averaged (14) and also multiplying by the previous Fall Midwater Fall abundance index. Figure 2.4 shows how the estimated total 14 day salvage numbers obtained in this way compare with the estimates from equations (2.6a) and (2.7a). As before, the predictions from equations (2.6a) and (2.7a) are rather similar. They are somewhat better than the predictions from Deriso's equation (2.10) but this may be because Deriso's equation was estimated using data from December to March from 1988 to 2006. The equation may therefore fit better if it is only estimated using December and January data and including the available data up to the present time.

Discussion

The best fitting quadratic equation of the form of equation (2.2) using two variables and the logarithm of the Fall Midwater Trawl abundance was found to be equation (2.6), which reduces to equation (2.7) when coefficients that are not significant at the 5% level are removed. These equations were estimated using 64 non-overlapping 14 day periods for salvage numbers and account for 84.9% and 83.3%, respectively in the variation in salvage numbers. The equations can also be estimated using all the possible 784 overlapping 14 day periods in December and January. The regression assumption of independent data values then no longer applies, but in practice the estimated equations obtained using the 784 periods are similar to equations (2.6) and (2.7). Any one of the equations (2.6), (2.7), (2.6a) and (2.7a) can be used to predict 14 day salvage numbers, but there is some suggestion that equations (2.6a) and (2.7a) may give slightly better results. Deriso's equation (2.10) does not fit the December and January salvage data from December 1993 to January 2009 as well as equations (2.6a) and (2.7a), possibly because it was estimated using December to March data from December 1988 to March 2006.

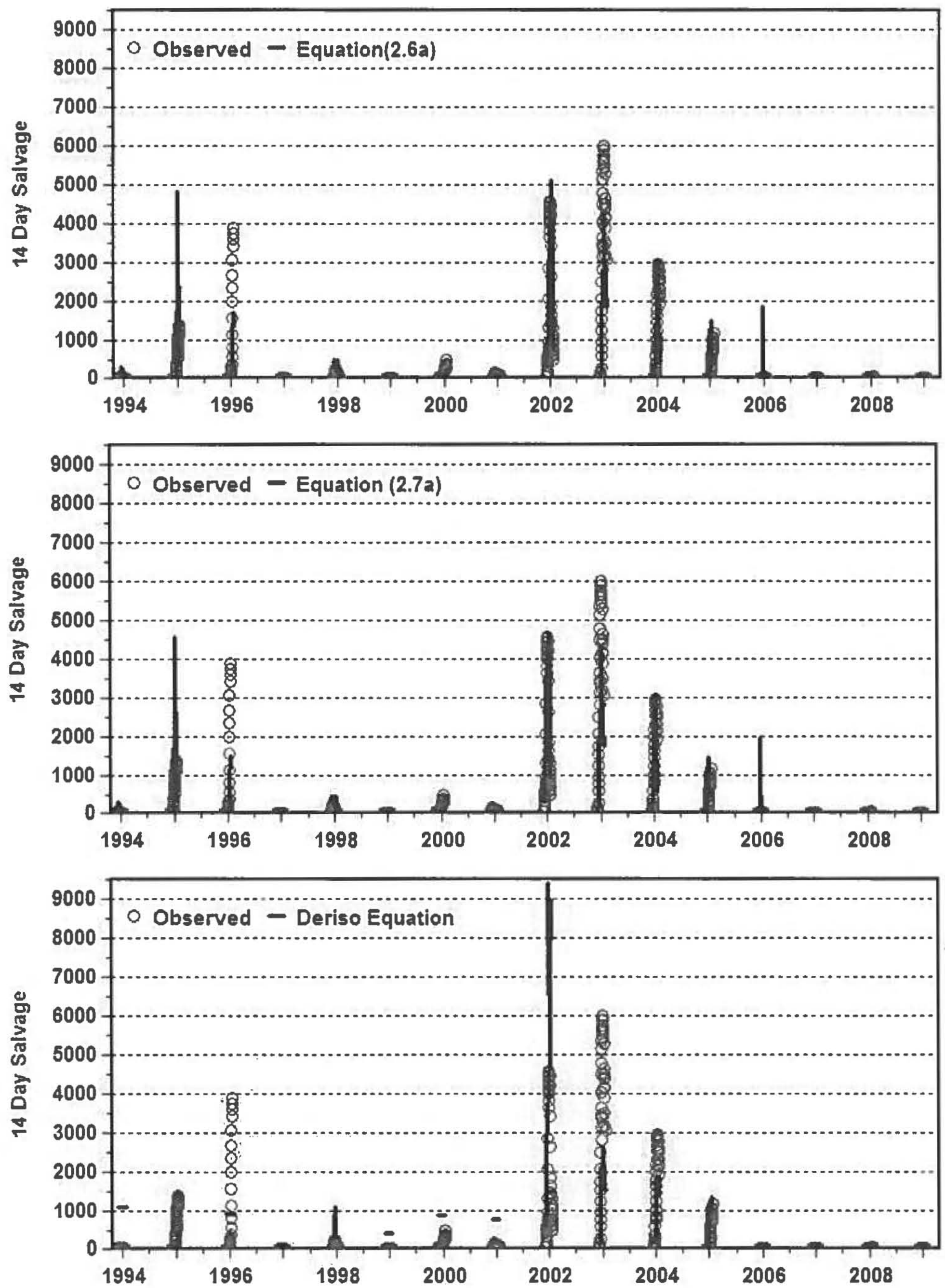

Figure 2.4 Observed 14 day total salvage numbers and the predicted numbers from equations (2.6a) and (2.7a) and from the Deriso equation (2.10).

Equations for Predicting Daily Clifton Court Turbidity

Coming later.

Equations for Predicting Daily Salvage Numbers

Coming later.

References

Deriso, R. (2010). *Adult Smelt Salvage as a Function of Turbidity and Salvage.* Report revised in July 2010.

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Appendix

Data Used to Fit Equations (2.5) to (2.9)

The following table shows the values for the variables SAC1, COMR and SJRV used to fit equations (2.5) to (2.9), with these variables being defined in Table 2.3. The Start and End dates give the 14 day period for which the total Banks and Jones salvage (B&J) is recorded. For example, the total Banks and Jones salvage recorded for the period from 1 to 14 December 1993 was 14. The values for Ln(FMWT) are the natural logarithms of the Fall Midwater Trawl abundance for the period considered, $SAC1_{10}$ is the average value of the variable SAC1 for a 14 day period starting ten days before the salvage period, $COMR_1$ is the average value of the variable COMR for a 14 day period starting one day before the salvage period, $SJRV_1$ is the average value of the variable SJRV for the same period as $COMR_1$, and $SAC1_1$ is the average value for the variable SAC1, again for the same averaging period as $COMR_1$.

The values of the variables SAC1, COMR and SJRV are standardized to have means of zero and standard deviations of one for the periods shown in Table 2.3 before averaging. The standardized values are therefore SAC1' = (SAC1 - 8610.3)/20767.2, COMR' = (COMR + 4447.2)/5015.9, SJRV' = (SJRV - 4062.7)/5695.5 where SAC1, COMR and SJRV are the original flow values in cubic feet per second and SAC1', COMR' and SJRV' are the standardized values. This standardization was done to avoid getting extremely large of small coefficients for variables in fitted equations.

As an example, of the standardization and averaging of variables, consider the variable $SAC1_{10}$ in the following table. The first value is -0.325. This was obtained by first standardizing the daily flow values in cfs by subtracting 8610.3 and dividing by 20767.2. The value of -0.325 was then found by averaging the daily standardized values for the 14 day period from 21 November to 4 December 1993, i.e for the 14 day period starting ten days before the salvage period of 1 to 14 December.

Start	End	B&J	Ln(FMWT)	$SAC1_{10}$	$COMR_1$	$SJRV_1$	$SAC1_1$
01-Dec-93	14-Dec-93	34	6.983	-0.325	-0.745	-0.429	-0.257
15-Dec-93	28-Dec-93	43	6.983	-0.055	-0.881	-0.420	-0.006
29-Dec-93	11-Jan-94	27	6.983	-0.150	-0.096	-0.407	-0.205
12-Jan-94	25-Jan-94	0	6.983	-0.231	0.231	-0.412	-0.235
01-Dec-94	14-Dec-94	4	4.625	-0.320	0.010	-0.488	0.058
15-Dec-94	28-Dec-94	30	4.625	0.199	-0.497	-0.485	-0.013
29-Dec-94	11-Jan-95	328	4.625	-0.088	-0.803	-0.423	0.449
12-Jan-95	25-Jan-95	1333	4.625	3.178	-0.644	0.035	4.703
01-Dec-95	14-Dec-95	0	6.801	-0.312	0.319	-0.334	-0.264
15-Dec-95	28-Dec-95	0	6.801	0.146	0.416	-0.302	0.543
29-Dec-95	11-Jan-96	168	6.801	0.269	-0.282	-0.346	0.089
12-Jan-96	25-Jan-96	2334	6.801	0.010	-0.712	-0.336	0.502
01-Dec-96	14-Dec-96	12	4.844	-0.177	-0.340	0.388	-0.556
15-Dec-96	28-Dec-96	6	4.844	0.000	1.129	2.001	0.902
29-Dec-96	11-Jan-97	0	4.844	0.036	3.866	4.567	3.149